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Dipartimento di Fisica
UNIVERSITÀ DEGLI STUDI DI PARMA

JEMS 2012

Joint European Magnetic Symposia

PARMA

Niccolò Paganini Auditorium and Congress Centre

September 9th-14th 2012

BOOK OF ABSTRACTS

Monday, 10 September 2012

Oral Communications

Monday, 10 September 2012
Aida Room

PLENARY
Chair: D. Givord

09.00 – 09.45
Ferroelectric and multiferroic tunnel junctions
A. Chanthbouala [1], A. Crassous [1], V. Garcia [1], K. Bouzehouane [1], S. Fusil [1], L. Bocher [2], A. Gloter [2], C. Deranlot [1], S. Xavier [3], N. Mathur [4], M. Bibes [1], *A. Barthélémy* [1]
(1) Unité Mixte de Physique CNRS/Thales, Campus de l'école polytechnique, 1 av. A. Fresnel, 91767 Palaiseau, and Université Paris Sud, 91405 Orsay, France, (2) Laboratoire de Physique des Solides, Université Paris Sud, 91405 Orsay, France, (3) Thales Research and Technology, 1 Av. Augustin Fresnel, 9167 Palaiseau, France, (4) University of Cambridge, Cambridge CB2 3EQ, United Kingdom

The phenomenon of electron tunneling has been known since the advent of quantum mechanics. Its interplay with magnetism, i.e., spin-dependent tunneling observed in magnetic tunnel junctions has aroused considerable interest and led to important advances in the field of magnetic random access memories. In 1971, Esaki *et al.* proposed to couple another ferroic order, ferroelectricity, with quantum-mechanical tunnelling in ferroelectric tunnel junctions composed of metallic electrodes with a ferroelectric tunnel barrier. The recent advances in the growth of ferroelectric thin films and the possibility to achieve stable and switchable ferroelectric polarization in nanometer-thick films have now allowed achieving this goal.
In these ferroelectric tunnel junctions, large changes in the resistance are observed and correlated with the direction of the ferroelectric polarisation of the barrier [1]. This give rise to large electroresistance phenomena (TER) that amounts to 75000% for a 3nm $BaTiO_3$ tunnel barrier as revealed by scanning probe microscopy. This resistance switching in solid-state ferroelectric tunnel junctions is large, fast, stable, reproducible and reliable electroresistance offering new opportunities for ferroelectrics in future data storage [2].
When a ferromagnetic counter electrode of Fe is added to obtain a ferroelectric magnetic tunnel junction, a modulation of tunnel magnetoresistance reflecting changes in the spin polarisation of the electrode when the ferroelectric polarisation is switched have been observed [3]. These junctions provide an interesting opportunity to obtain a robust room temperature magnetoelectric effect and to achieve an electric control of the spin polarisation. We will review recent advances in this field.

[1] Nature 460, 81 (2009) ; Appl. Phys. Lett. **96**, 042901 (2010)
[2] Nature Nanotechnology 7, 101 (2012)
[3] Science 327, 1106 (2010) ; Nature Materials 10, 753 (2011)
We acknowledge financial support from the European Research Council (ERC Advanced Grant FEMMES, No. 267579)
e-mail: agnes.barthelemy@thalesgroup.com

Monday, 10 September 2012
Aida Room

SEMIPLENARY
Chair: B. Hillebrands

09.45 - 10.30
Ultrafast emergence of nanoscale ferromagnetism far from equilibrium
H. Dürr [1]
(1) SLAC National Accelerator Laboratory, Menlo Park, 94025, CA, USA

Long-range magnetic order in solids is usually ascribed to the exchange interaction between electron spins. Close to equilibrium this leads to spontaneous magnetization when the system cools below the magnetic ordering temperature. We show that the far from equilibrium flow of angular momentum via spin currents can also achieve long-range ferromagnetic order even above the ordering temperature. To reveal this process, we use ultrafast x-ray diffraction at SLAC's Linac Coherent Light Source to probe the nucleation, growth and transient existence of ferromagnetic order on the nm length and fs timescale after fs optical laser excitation has brought a metallic 3d - 4f alloy system into a highly non-equilibrium chaotic spin state. This offers a novel view at the microscopic mechanism behind all-optical switching of ferrimagnets.

Monday, 10 September 2012
Nabucco Room

SEMIPLENARY
Chair: L. Schultz

09.45 – 10.30
Exploiting magnetostructural transitions
M. Acet [1]
(1) Physics Dept., Duisburg-Essen University, 47048 Duisburg, Germany

Magnetic transitions accompanied by structural transitions are commonly referred to as magnetostructural transitions. Such transitions occur in a broad class of alloys and compounds, in which strong interplay takes place between magnetic and structural degrees of freedom. Many magnetic-field-induced effects such as magnetic shape memory, magnetocaloric, exchange-bias, kinetic arrest, etc. are either observed around the transition or caused by its presence when an external field is applied. To understand the cause of these effects, it is necessary to understand the nature of the magnetic coupling in the temperature-vicinity of the magnetostructural transition. Furthermore, to be able to exploit these effects in applications such as actuation, magnetic refrigeration, etc., it also important to understand and master the thermal hysteresis associated with such transitions. We provide here a broad outline of the research conducted and the research methods employed to understand the fundamental properties related to magnetostructural transitions and how the knowledge of fundamental properties have affected the exploitation of magnetostructural phenomena for applications.

Monday, 10 September 2012
Aida Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

MAGNONICS AND SPIN DYNAMICS

Chair: M. Bibes

11.00 – 11.30

Spin waves in magnonic crystals from nanopatterned permalloy *(invited)*

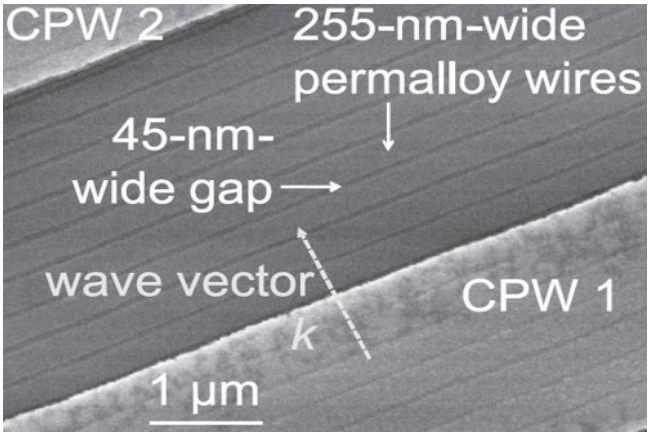
R. Huber [1], G. Duerr [1], T. Schwarze [1], F. Brandl [1], S. Neusser [1], *D. Grundler* [1]

(1) Physik Department E10, Technische Universitaet Muenchen, James-Franck-Str. 1, 85747 Garching, Germany

Collective spin excitations in nanopatterned ferromagnets have regained great interest recently. In particular, magnonic crystals (MCs), i.e. the magnetic counterpart of photonic crystals, open intriguing perspectives for the controlled transmission and manipulation of spin waves on the nanoscale [1]. Formed by periodically patterned ferromagnets they offer an artificially tailored band structure for magnons with allowed minibands and forbidden frequency gaps. Going beyond photonics, one-dimensional (1D) MCs have been found to form a novel class of artificial crystals in that their band structure is reprogrammed by different remanent magnetic states [2]. We have prepared permalloy thin film devices being periodically patterned in, both, one and two dimensions [2,3]. Typical lattice constants range from about 300 to 1000 nm. Minimum feature sizes such as edge-to-edge separations in periodic nanowire lattices and hole diameters in antidot lattices are 100 nm and below. We perform all-electrical spin-wave spectroscopy using two collinear coplanar wave guides (CPWs) which are integrated (see figure) and excite spin waves with wave vectors on the order of 10^{4} rad/cm. By this, we explore spin-wave transmission and damping in 1D and 2D MCs. We report our recent results obtained on nanostructured magnonic devices.

We thank C.H. Back, H. Bauer, G. Carlotti, G. Gubbiotti, D. Heitmann, M. Kostylev, M. Krawczyk, V.V. Kruglyak, M. Madami, M.L. Sokolovsky, S. Tacchi, J. Topp, G. Woltersdorf, H. Yu, and R. Zivieri for cooperations. The research leading to the results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement no. 228673 and the German Excellence Cluster 'Nanosystems Initiative Munich'.

[1] V.V. Kruglyak, S.O. Demokritov, and D. Grundler, J. Phys. D: Applied Physics 43, 264001 (2010)
[2] J. Topp, D. Heitmann, M.P. Kostylev, and D. Grundler, Phys. Rev. Lett. 104, 207205 (2010)
[3] S. Neusser et al., Phys. Rev. Lett. 105, 067208 (2010)



Nanowire array forming a 1D MC with integrated CPWs

11.30 – 11.45

Linewidth broadening and related noise characteristics in vortex based spin transfer oscillators

E. Grimaldi [1], P. Bortolotti [1], J. Grollier [1], B. Marcilhac [2], J. Mage [2], A. Fukushima [3], H. Kubota [3], K. Yakushiji [3], S. Yuasa [3], V. Cros [1], A. Fert [1]

(1) Unité Mixte de Physique CNRS/Thales, 1 Av Fresnel, Campus de l'Ecole Polytechnique, 91767 Palaiseau, and Université Paris-Sud, 91405 Orsay, France., (2) Unité Mixte de Physique CNRS/Thales, TRT Thales, 1 Av Fresnel, Campus de l'Ecole Polytechnique, 91767 Palaiseau., (3) National Institute of Advanced Industrial Science and Technology (AIST), Spintronics Research Center, Tsukuba, Japan

Linewidth broadening of spin transfer torque nano-oscillators (STNOs) that remain very large compared to existing VCO devices, is a critical issue for the targeted applications. Indeed for uniform magnetization STNOs, several studies allowed to highlight the main role played by the rather large coupling between amplitude and phase due to the nonlinearities of the spin transfer oscillators [1,2].
Her we focus on spin transfer induced gyrotropic vortex motion in a MTJ. Recently we demonstrated that such vortex based oscillators (STVOs) displays excellent performances for emitted power and spectral linewidth [3]. Our objective is to investigate linewidth broadening with dc current and external field. In parallel, we perform measurements in time domain in order to analyze the respective weight of amplitude and phase noise. Similarly to the case of uniform STNOs, we find that phase noise is the dominant contribution to the linewidth broadening, however with a reduction of 20 dBc/Hz on the whole frequency range. For the best peak in frequency domain ($P \approx 50$ nW and $LWP \approx 50$ nW500 kHz), we report a $1/f^2$ dependence of phase noise up to 2 MHz for the carrier frequency and then close to $1/f^3$ above. Moreover we find that amplitude noise strongly depends on the injected dc current. Finally, we show that the improvement of linewidth for vortex oscillators is related to a weaker values of nonlinear parameters, making these STVOs to be good candidates for the development of spintronic rf devices.

Acknowledgements : CANON ANELVA for preparing the MTJ films, ANR VOICE and SPINNOVA grant and EU MASTER grant for funding. E.G. acknowledges financial support from CNES and DGA.

[1] M. Quinsat et al., Appl. Phys. Lett. 97, 182507 (2010)
[2] L. Bianchini et al, Appl. Phys. Lett. 97, 032502 (2010)
[3] A. Dussaux, et al., Nature Comm., 1, 8 (2010)

Monday, 10 September 2012
Aida Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

MAGNONICS AND SPIN DYNAMICS

Chair: M. Bibes

11.45 – 12.00

Magnon Band Structure of a Two-dimensional Bicomponent Magnonic Crystal

S. Tacchi [1], G. Duerr [2], J.W. Klos [3], M. Madami [1], S. Neusser [2], G. Gubbiotti [4], G. Carlotti [5], M. Krawczyk [3], D. Grundler [2]

(1) CNISM, Unità di Perugia and Dipartimento di Fisica, Via A. Pascoli, I-06123 Perugia, Italy, (2) Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department,James-Franck-Str. 1, D-85747 Garching b. München, Germany, (3) Faculty of Physics, Adam Mickiewicz University, Umultowska 85, Poznan 61-614, Poland, (4) Istituto Officina dei Materiali del Consiglio Nazionale delle Ricerche (IOM-CNR), Sede di Perugia and CNISM, Unità di Perugia, Dipartimento di Fisica, Via A. Pascoli, I-06123 Perugia, Italy, (5) CNISM, Unità di Perugia and Dipartimento di Fisica, Via A. Pascoli, I-06123 Perugia, Italy and Centro S3, CNR-Instituto di Nanoscienze, Via Campi 213A, I-41125 Modena, Italy

Bicomponent magnonic crystals, represent a new class of metamaterials where periodic alternation of the constituent magnetic materials allows to manipulate spin wave propagation and band structure, similarly to light in photonic crystals. In this work we have employed Brillouin light scattering (BLS) to measure the spin wave band diagram of a bicomponent lattice consisting of Co nanodisks, 15 nm thick, partially embedded in a 24 nm thick $Ni_{80}Fe_{20}$ (Py) film. Co nanodisks have a diameter of 310 nm and are arranged into a square lattice having period of 600 nm. The frequency dispersion of spin waves has been measured applying a magnetic field H = 200 Oe along the side of the square lattice and sweeping the spin-wave wave vector along the perpendicular direction. We investigated the reciprocal space up the fourth Brillouin Zone (BZ) of the artificial crystal. In the first BZ we detect several discrete peaks showing a clear dispersive character. These modes merge into one branch in the second BZ. A magnonic band gap, having a width of 0.7 GHz, is observed at the boundary of the first BZ. The measured dispersion has been compared with calculations performed by the Plane Wave Method obtaining a very good agreement. We found extended modes which propagate in the stripes going through both the Py and Co or in the Py stripes comprised between the Co nanodisks. The band gap at the boundary of the first BZ is explained in terms of Bragg diffraction of propagating modes, due to the periodicity of the magnetic structure.

Authors acknowledge the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°228673 (MAGNONICS) and the German Excellence Cluster "Nanosystems Initiative Munich".

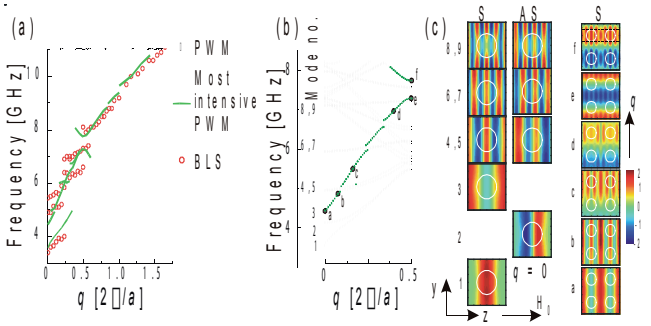


Fig.1 Comparison between the measured (open circles) and calculated spin-wave frequencies (lines). Bold curves indicate modes with the largest calculated BLS cross-section.

12.00 – 12.15

Inverse spin Hall effect detection of travelling magnons

A.V. Chumak [1], A.A. Serga [1], B. Jungfleisch [1], R. Neb [1], D. Bozhko [2], V.S. Tiberkevich [3], B. Hillebrands [1]

(1) Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany, (2) Faculty of Radiophysics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine, (3) Department of Physics, Oakland University, Rochester, Michigan 48309, USA

The combination of the spin pumping effect with the inverse spin Hall effect (ISHE) allows the use of spin waves (or magnons) for the carrying of signals in spintronic devices. In spite of sufficient progress in these studies, no magnon-carried spin transfer has yet been shown directly. We use a spatially separated inductive spin-wave source and an ISHE detector to demonstrate the signal transport by travelling magnons in a time resolved experiment [1]. The setup comprises a 2.1 μm thick YIG waveguide with a 10 nm thick (200 μm x 3 mm) Pt strip deposited on the top. The YIG waveguide is magnetized along its long axis by applying an external bias magnetic field of 175.4 mT. In order to excite short spin-wave packets the 50 μm wide Cu microstrip antenna is placed at a distance of 3 mm from the Pt strip. While propagating under the Pt layer, the spin-wave packet generates a spin current in it due to spin pumping, and the delayed ISHE DC pulse is detected. The delay appears due to the finite spin-wave group velocity and proves the magnon nature of the spin transport. In addition, the contribution of the secondary excited magnons [2] leading to delay and shape distortion of the ISHE voltage pulse has been observed. The field dependent measurements have shown that the spin pumping efficiency in YIG-Pt bi-layers does not depend on the spin-wave wavelength. The study suggests to utilize spin waves for the transfer of spin information over macroscopic distances in spintronic devices and circuits.

[1] A. V. Chumak, et al., Appl. Phys. Lett. **100**, 082405 (2012).
[2] M. B. Jungfleisch, et al., Appl. Phys. Lett. **99**, 182512 (2011).

Monday, 10 September 2012
Aida Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

MAGNONICS AND SPIN DYNAMICS

Chair: M. Bibes

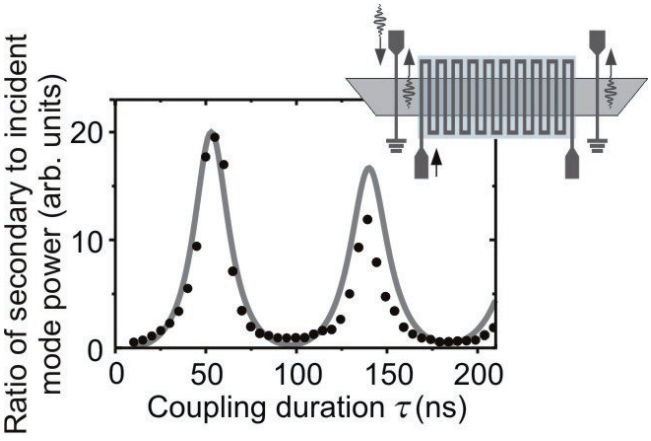
12.15 – 12.30

Oscillatory energy exchange between spin wave modes coupled by a dynamic magnonic crystal

A.D. Karenowska [1], A.V. Chumak [2], V.S. Tiberkevich [3], A.A. Serga [2], J.F. Gregg [1], A.N. Slavin [3], B. Hillebrands [2]
(1) Department of Physics, Clarendon Laboratory, University of Oxford, OX1 3PU Oxford, United Kingdom, (2) Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany, (3) Department of Physics, Oakland University, Rochester, Michigan 48309, USA

In common with other artificial crystals (for example photonic and phononic crystals) the transmission spectra of magnonic crystals include band gaps; frequency intervals over which wave propagation is prohibited. In this paper, we present the results of a series of investigations into spin-wave propagation in a *dynamic* magnonic crystal (DMC) [1, 2]. The DMC can be switched from a spatially uniform state with a gapless transmission spectrum ('off'), to a spatially modulated state featuring a well-defined band gap ('on'). We show that this dynamic functionality—unique in the wider context of artificial crystal systems—allows us to observe interesting new physical phenomena.
In particular, we demonstrate that if the DMC undergoes a rapid transition from 'off' to 'on' whilst an incident spin wave having a frequency lying within the band gap is excited inside it, a coupling between this wave and a secondary counter-propagating mode is produced. The incident and secondary waves, which generally have different frequencies, are found to periodically exchange energy (see figure). We explore the features of this oscillatory energy exchange phenomenon experimentally and theoretically and establish that its underlying physics reveals a fundamental result of general wave dynamics. We further offer experimental confirmation that the coupling effect can be used to perform frequency conversion and time reversal of signals; functionalities which potentially find significant application in the context of ultra-low-power magnetic and spintronic information processing [1, 3].

[1] A. D. Karenowska et al., Phys. Rev. Lett. 108, 015505 (2012).
[2] A. V. Chumak et al., J. Phys. D 42, 205005 (2009).
[3] A. V. Chumak, V. S. Tiberkevich, A. D. Karenowska et al., Nature Commun. 1, 141 (2010).



Oscillatory energy exchange in the DMC (inset), circles are experiment, line is theory.

12.30 – 12.45

Spin-current generation from rotational motions of rigid and elastic bodies

M. Matsuo [1], J. Ieda [1], E. Saitoh [2], S. Maekawa [1]
(1) Japan Atomic Energy Agency/ASRC/319-1195 Tokai,Japan, (2) Tohoku University/IMR/980-8577 Sendai, Japan

In 1915, Einstein, de Haas and Barnett discovered experimentally the coupling of magnetism and rotational motion before the dawn of modern quantum physics. Recent experimental developments of spintronics have allowed us to exchange the angular momentum among conduction electron spin, magnetization, and photon polarization. In this stream, a remaining form of angular momentum carried by condensed matter systems is a mechanical torque due to rotational motion.
Recently, we constructed the fundamental Hamiltonian directly coupling the spin current with mechanical rotation from the general relativistic Dirac equation, and predicted the generation of spin current from a rigid rotation in a ballistic system[1]. Those results are extended to the diffusive regime introducing the effects of impurity scattering on the rotation-induced spin currents[2,3]. The spin accumulation in a Pt film attached to the rigidly rotating disk with an external magnetic field is calculated by solving the spin diffusion equation along the radial direction with a spin source term.
We *also* study a spin current generation due to surface acoustic wave (SAW) in a non-magnetic metal. Electron spins are coupled to the rotational deformation caused by SAW. The coupling is responsible for the mechanically induced spin current in elastic bodies. The spin accumulation is evaluated from the spin diffusion equation with the spin source term from the SAW-induced spin current. Dependence of the spin diffusion length, amplitude and frequency of the mechanical resonator on the spin accumulation will be discussed.

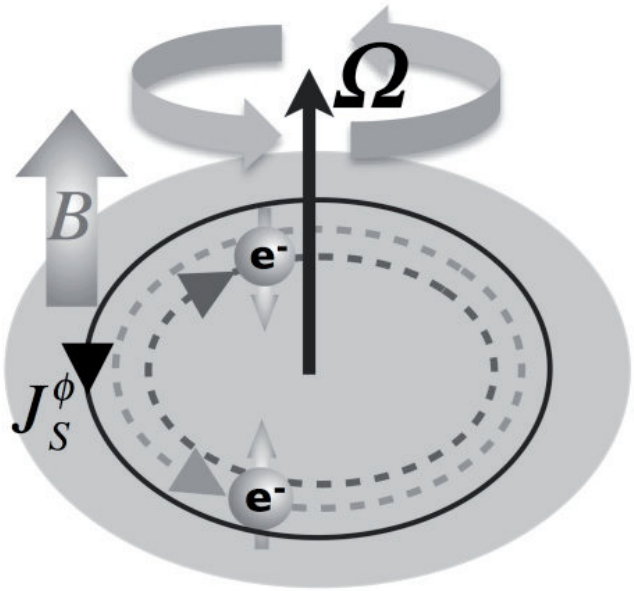
[1] M. Matsuo, J. Ieda, E. Saitoh, and S. Maekawa, Phys. Rev. Lett. 106, 076601 (2011).
[2] M. Matsuo, J. Ieda, E. Saitoh, and S. Maekawa, Appl. Phys. Lett. 98, 242501 (2011).
[3] M. Matsuo, J. Ieda, E. Saitoh, and S. Maekawa, Phys. Rev. B84, 104410 (2011).

Monday, 10 September 2012
Aida Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

MAGNONICS AND SPIN DYNAMICS

Chair: M. Bibes



Spin current can be created from rigid rotation under the external magnetic field.

12.45-13.00

Investigations of interactions in Fe dot-antidot lattice

S. Sakshath [1], K. Vijaysankar [1], K.S. Bhagyashree [1], S.V. Bhat [1], P.S.A. Kumar [1]

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Over the last decade advances in fabrication techniques have been utilized to create interesting magnonic materials with spatially varying magnetic properties by tuning dipolar fields or by modification of the substrate/interfaces of thin magnetic films [1, 2]. Fe/GaAs(001) films exhibit a plethora of magnetic anisotropies depending on the thickness [3]. Using this property, we demonstrate a way of achieving a controlled spatial modulation of local magnetic anisotropy while maintaining chemical and structural uniformity in epitaxially grown Fe films.

Rectangular and square lattices of antidots are prepared using epitaxial 10 ML MgO/25 ML Fe/GaAs(001) deposited by pulsed laser ablation in an ultrahigh vacuum chamber with base pressure ~1exp(-10) Torr. Using low energy ion beam etching, the thickness of Fe is reduced within lithographically defined regions to 15 ML and capped with 10 ML MgO before lift-off. Thus square antidot regions of size 200 nm containing Fe of thickness lower than the surrounding matrix were created. These antidot regions have a dominant uniaxial anisotropy whereas the surrounding film has a dominant cubic anisotropy. The spacing between the antidots is varied between 120 and 400 nm.

Magnetic properties were studied by ferromagnetic resonance (FMR) and Magneto-Optical Kerr effect. Micromagnetic simulations are used to explain some of the features seen in hysteresis loops. Magnetic anisotropy constants are extracted and the nature of the resultant anisotropies is discussed in terms of the coupling between the antidot region and surrounding matrix. Multiple peaks, seen along some directions in the in-plane FMR spectra, are correlated with dipolar interactions due to the particular arrangement of the antidot regions in the lattice.

[1] S. P. Li et al, Phys. Rev. Lett. 88, 087202 (2002)
[2] J. Ding et al, Phys. Rev. Lett. 107, 047205 (2011)
[3] S. Sakshath et al, J. Appl. Phys. 109, 07C114 (2011)

Monday, 10 September 2012
Nabucco Room

SENSORS, MEMS AND MAGNETIC DEVICES
Chair: R. Bertacco

11.00 – 11.30

Spintronic Plaforms for Biological and Biomedical applications *(invited)*

P.P. Freitas [1], F.A. Cardoso [1], V. Martins [2], J. Amaral [1], S. Cardoso [1], A. Sebastião [3], L. Fonseca [4], C. Da Silva [4], J.M. Cabral [4], M. Piedade [5], J. Germano [5], T. Costa [5]

(1) INESC-MN, IN, and Instituto Superior Tecnico, 1000-029, Lisbon, Portugal, (2) INL, 4715-31 Braga, Portugal, (3) Lab. of Neurosciences, Faculty of Medicine, University of Lisbon, Portugal, (4) Instituto Superior Tecnico and IBB-CEBQ, 1000-029, Lisbon, Portugal, (5) INESC ID, 1000-029, Lisbon, Portugal

This work reviews recent work on integrated spintronic platforms for biological and biomedical applications [1]. Integrated spintronic biochip platforms are being developed for portable, point-of-care, diagnostic and cytometric applications. Hybrid systems incorporating magnetoresistive sensors are applied to neuroelectronic studies and biomedical imaging, namely magnetoencephalography and magnetocardiography. Also lab-on-a-chip MR-based platforms are under development to perform biological studies at the single molecule level.

Applications to the detection of DNA hybridization events (DNA-chips) and antibody-antigen recognition at immunoassays (immune or protein chips) are discussed. These platforms allow multiplexed, portable, highly sensitive analyte detection for diagnostics and treatment follow up. Both static and dynamic biochips for analyte detection are reviewed as well as lateral flow immunoassay geometries. Particular examples for cell free DNA detection as a cancer biomarker and flow cytometry (extraction and counting) of CD34+ magnetically labeled cells coming from bone marrow or cord blood samples are given.

For biomedical imaging applications, field sensitivity is being pushed below 1pT/sqrt(Hz) in hybrid devices incorporating flux guides, magnetoresistive elements, and a MEMS dc to ac flux transformer. Incorporation of magnetoresistive sensors in micro-needles is also reviewed. Applications in magnetocardiography and in neural signal detection are discussed.

[1]-P.P.Freitas et al., Lab on Chip, in press (2012)

11.30 – 11.45

Magnetic Microfluidic Microsystem (Bio-Mag-MEMS) combining magnetophoresis and dielectrophoresis for biological applications

G. Blaire [1], A. Masse [2], L.F. Zanini [3], V. Gaude [4], T. Honegger [5], F. Bruckert [6], D. Peyrade [5], M. Weidenhaupt [7], N.M. Dempsey [8], F. Dumas-Bouchiat [9], G. Reyne [10], O. Cugat [10]

(1) G2Elab/LMGP, MINATEC, Grenoble University, 38016, France, (2) G2Elab, MINATEC, Grenoble University, 38016, France, (3) Néel Institute/G2Elab, MINATEC, Grenoble University, 38016, France, (4) G2Elab/CIME Nanotec, MINATEC, Grenoble University, 38016, France, (5) LTM/CNRS/CEA, MINATEC, Grenoble University, 38054, France, (6) LMGP/MINATEC, Grenoble University, 38016, France, (7) LMGP, MINATEC, Grenoble University, 38016, France, (8) Néel Institute/CNRS, Grenoble University, 38042, France, (9) Néel Institute/UJF/CNRS, Grenoble University, 38042, France, (10) G2Elab/CNRS, MINATEC, Grenoble University, 38016, France

This work reports on the fabrication of magnetic MEMS for biology (Bio-Mag-MEMS), combining magnetophoresis, dielectrophoresis and microfluidics:

- chessboards-like micro-patterns have been created by Thermo-Magnetic-Patterning (TMP) and were used to capture superparamagnetic (SPM) beads. The recently developed TMP [1] is used to produce micro-magnets with comparable characteristics to commercially available macro-magnets. Due to the scale reduction laws [2], these integrated magnets produce magnetic gradients up to several Mega T/m at the interface between oppositely oriented magnets.
- indium tin oxide electrodes have been produced using lithography process and e-beam etching [3]. Micro-electrodes can be used to attract beads by dielectrophoresis (DEP).

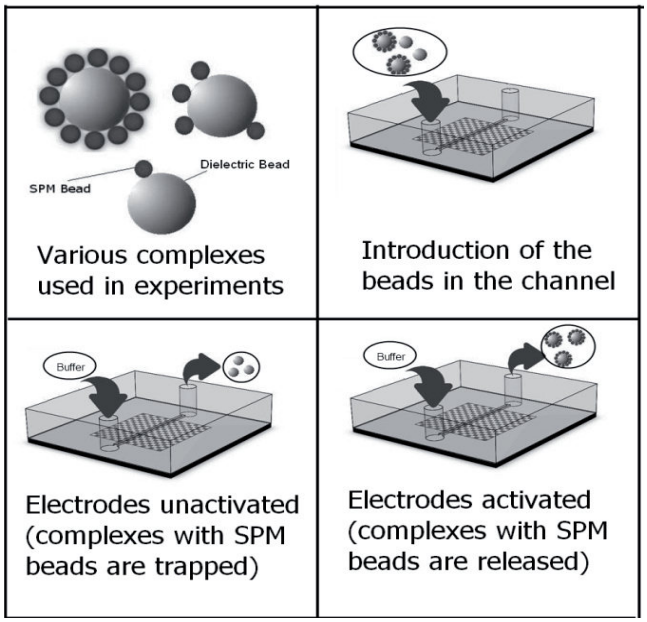
Using two different kinds of functionalized beads (1 µm dielectric beads and 100 nm SPM beads) it is possible to combine the magnetic and dielectrophoretic effects. To perform this, SPM beads are bound with dielectric beads to create complexes which contain one dielectric bead and a determinate number of SPM beads. Complexes containing various numbers of SPM are passed through a microfluidic channel fixed between the magnets and the electrodes. Due to the SPM beads, the complexes are trapped by the magnetic gradients. A buffer is then passed through the channel and finally DEP is perfomed. By changing the voltage, the dielectrophoretic strength can be modulated in order to overcome the magnetic trapping and release complexes with the desired number of SPM beads [FIG]. The magnetic and dielectrophoretic strenghts are predicted with Finite Element Method simulations and compared to experimental results.

This protocol allows new possibilities for biology applications. As an example magnetic labeled cell sorting is performed.

[1] F. Dumas-Bouchiat, L. F. Zanini et al. Appl. Phys. Lett. (2010)
[2] O. Cugat, J. Delamare, G. Reyne. IEEE Transactions on Magnetics. (2003)
[3] T. Honegger, K. Berton et al. Microelectronic Engineering. (2009)

Monday, 10 September 2012
Nabucco Room

SENSORS, MEMS AND MAGNETIC DEVICES
Chair: R. Bertacco



Principle of the Bio-Mag-MEMS

11.45 – 12.00
Selective bio-functionalization of magnetic biosensors
E. Albisetti [1], D. Petti [1], F. Damin [2], M. Cretich [2], M. Bagnati [2], L. Sola [2], M. Chiari [2], R. Bertacco [1]
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Early stage diagnostics is one of the major goals of medicine. This relies on the development of highly sensitive, low cost and portable diagnostic tools allowing for a wide screening of patients. Magnetic labels in combination with spintronic biosensors offer the opportunity to combine sensitivities in the zeptomolar range [1] with fast performances, integrability and portability.
In such devices, magnetic tags are attached to the target molecules and their magnetic stray field is picked up by embedded magnetoresistive sensors as a change of electrical resistance. As in the most common array technologies, functionalization of the sensor active area with micrometer precision is a major issue, in order to achieve higher sensitivities, quantification capability, lower essay time and less biological material requirement.
Here we present a new, straightforward procedure to create patterns of bio-reactive polymer regions on the sensors' surface. Arrays of MgO based magnetic tunnelling junctions are grown by magnetron sputtering microfabricated by optical lithography [2]. For the selective bio-functionalization, 4x150 μm^2 rectangles have been patterned by optical lithography on the sensors surface. The chip was coated with a functional copolymer and then spotted with biomolecules. After the lift-off procedure, only the patterned areas of the chip result bio-functionalized. The chips then undergo DNA-DNA hybridization while magnetic nanoparticles are used to label complementary oligonucleotides (Fig. 1). As a result of the selective funtionalization process, the magnetic nanoparticles bind to the surface only in the bio-patterned areas. The effectiveness of the procedure in achieving high specificity, enhancing the sensor performance and allowing a quantitative interpretation of the measurements is demonstrated by simulations and assays.

[1] R. S. Gaster et al. Nat. Nanotechnology **6**, 314–320 (2011).
[2] M. Donolato et al. Appl. Phys. Lett., **98**, 073702 (2011).

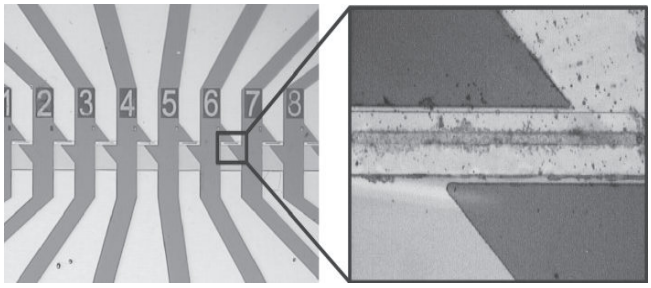

Figure 1: Selectively functionalized area of the sensor covered by magnetic beads

12.00 – 12.15
Noise measurements of $La_{0.7}Sr_{0.3}MnO_3$ based magnetic tunnel junctions
R. Guerrero [1], A. Solignac [1], C. Fermon [1], *M. Pannetier-Lecoeur* [1], P. Lecoeur [2]
(1) DSM/IRAMIS/SPEC- CNRS URA 2464, CEA Saclay, 91191 Gif sur Yvette Cedex France, (2) Institut d'Electronique Fondamentale, Université Paris-Sud, CNRS, 91405 Orsay, France

To be used as magnetic sensor, magnetic tunnel junctions (MTJ) should exhibit high tunnel magnetoresistance (TMR), spin-valve behaviour with a well-defined hard layer and low level of noise. Noise in metallic MTJ, in particular with MgO barrier, has been widely studied since they operate at room temperature.
The highest magnetoresistance ratios are however observed at lower temperature in oxide materials such as the manganite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), which is a half metal with a high spin polarisation (measured up to 92% [1]). This material can be used as an electrode for an MTJ, with TMR ratio up to 2000% [2]. The performances of the overall system are then defined by several parameters, including not only the TMR ratio, but also the pinning of the reference layer and the noise floor.
Here we have fabricated MTJ where the pinned layer is a bilayer of $La_{0.7}Sr_{0.3}Mn_{0.995}Ru_{0.005}O_3$(LSMRO)/LSMO with increased coercive field and preserved interface properties. Indeed, the LSMRO has an increased coercive field due to the Ru doping [3]. Nevertheless the density of state at the interface of the barrier is changed if the LSMRO is directly in contact with the $SrTiO_3$ insulating barrier. But, keeping a thin LSMO layer at the barrier interface could partially avoid this effect. The junctions have been tested in magnetotransport, and for the first time in oxide MTJ, noise at low frequency has been measured. We can link the noise level to the magnetization state of the junction and we compared it with the noise in the state of the art metallic MTJ.

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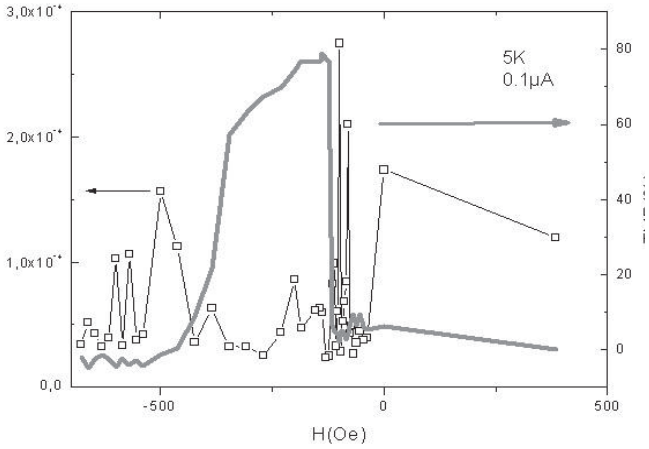
[1] B. Nadgorny et al., Phys. Rev. B **63,**184433 (2001)
[2] R. Werner et al., Appl. Phys. Letters, **98**, 162505 (2011)
[3] S. Sundar Manoharan et al., J. Appl. Phys. **83,** 7183 (1998)



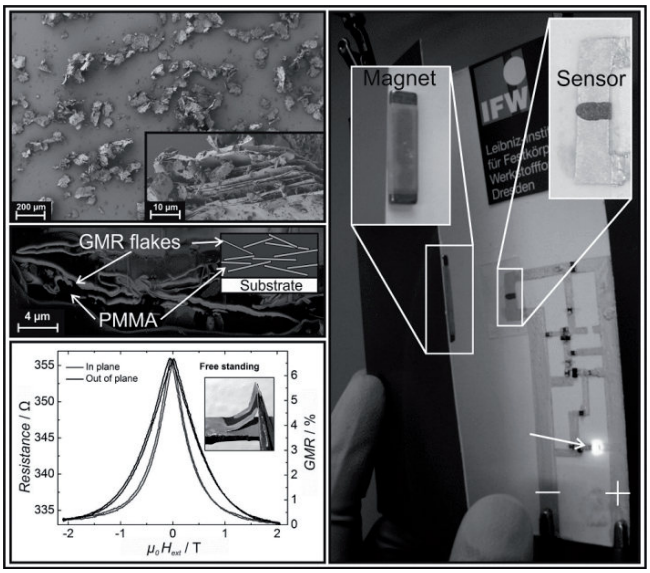
Low frequency noise (α parameter) and magnetoresistance vs applied field

12.15 – 12.30
Printable Magnetoelectronics

D. Karnaushenko [1], D. Makarov [1], C. Yan [1], R. Streubel [1], O.G. Schmidt [1]
(1) Institute for Integrative Nanosciences, IFW Dresden, Dresden 01069, Germany

Over the last years, printable electronics has emerged as a key research field in modern electronics. The rise of this field is mainly indebted to huge efforts in materials science to fabricate cost-efficient versatile electronic building blocks, such as transistors, diodes and resistors [1]. However, the fabrication of printable electronic sensors and contactless switches operating in combination with magnetic fields remains challenging, mainly due to the lack of appropriate sensing compounds at ambient conditions [2].
Here, we demonstrate the first printable magnetic sensor that relies on the giant magnetoresistance (GMR) effect. The preparation process uses standard sputter deposition of [Co/Cu] GMR multilayers, milling and mixing machines for high yield production of GMR powder. A multicomponent magnetic ink is prepared by mixing GMR powder with an acrylic rubber-based binder solution. The transfer of the magnetic sensor to different substrates was demonstrated by painting on various substrates, such as paper, polymer and ceramic. The fabricated sensor exhibits a room-temperature GMR of up to 8%.
By adding a magnetic sensor to printable electronic circuitry, active intelligent packaging, post cards, books or promotional materials that communicate with the environment could be envisioned. We integrated the sensor in a hybrid electronic circuit (amplification cascade with a light emitting diode (LED)) fabricated on the paper of a postcard. The LED ON/OFF state is triggered by a permanent magnet that modifies the resistance of the printable magnetic sensor. This change of resistance, in turn, alters the open/close state of the transistors in the amplification cascades regulating the current flow through the LED.

[1] A. C. Arias et al., Chem. Rev. 110, 3 (2010)
[2] L. Torsi et al., Nat. Mater. 7, 412 (2008)



(Left) Magnetic ink and its magnetoelectrical response. (Right) Demonstrator.

12.30 – 12.45
Material Parameters and Thermal Stability of Synthetic Ferrimagnet Free Layers in Magnetic Tunnel Junction Nanopillars

D. Markó [1], T. Devolder [1], K. Ito [2], K. Miura [2], J. Kim [1], C. Chappert [1], S. Ikeda [3], H. Ohno [3]
(1) Institut d'Electronique Fondamentale, UMR CNRS 8622, 91405 Orsay, France, (2) Hitachi, Ltd., Advanced Research Laboratory, 1-280 Higashi-koigakubo, Kokubunji-shi, Tokyo 185-8601, Japan, (3) Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

Synthetic ferrimagnets (SyFs) consisting of two thin ferromagnetic layers with different magnetic moment, that are antiferromagnetically coupled by RKKY interaction through a nonmagnetic metallic spacer, have a variety of unique properties making them interesting for applications in magnetic data storage or sensor technology. For instance, the weak net moment and small stray field of SyFs minimize magnetostatic interactions between adjacent magnetic elements such as magnetic tunnel junctions (MTJs) or spin-valves. Moreover, compared to isolated ferromagnetic layers, SyFs have a higher coercivity and a lower ratio of switching current density to thermal stability factor [1].
In order to optimize SyFs for a specific application, the exact knowledge of their materials parameters and the corresponding influence on the critical fields (spin-flop field, direct-write field, and saturation field) is indispensable. Here, we present both an

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experimental and theoretical study of in-plane magnetized SyFs, that are used as free and reference layers in MgO-based MTJs. Combining R-H loops measurements as well as microwave noise spectroscopy (see Fig. 1), and using a 2-macrospin model of the free SyF, we have extracted its material parameters such as saturation magnetization or interlayer exchange coupling constant. In order to determine these parameters with a greater accuracy, additional experiments by means of vector network analyzer ferromagnetic resonance have been conducted on SyF full films. Moreover, from waiting time experiments of field-induced switching, the energy barrier and the attempt frequency relevant for the thermally activated switching have been experimentally evaluated and will be compared to an existing model [2].

[1] J. Hayakawa et al., Jpn. J. Appl. Phys. 45, L1057 (2006).
[2] D. C. Worledge, Appl. Phys. Lett. 84, 4559 (2004).

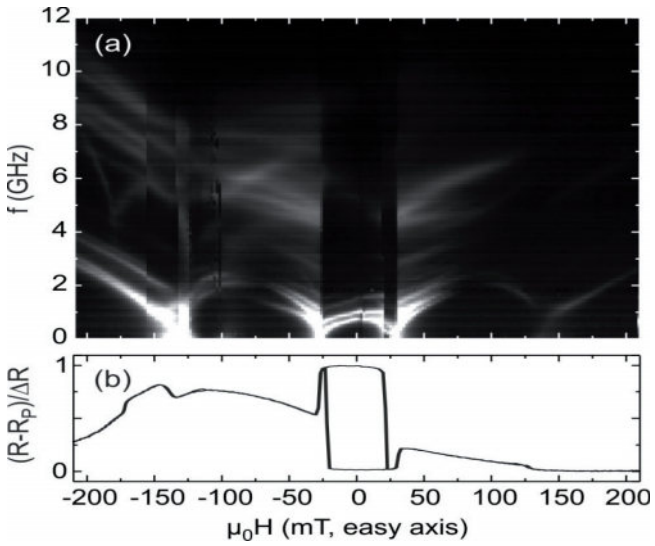
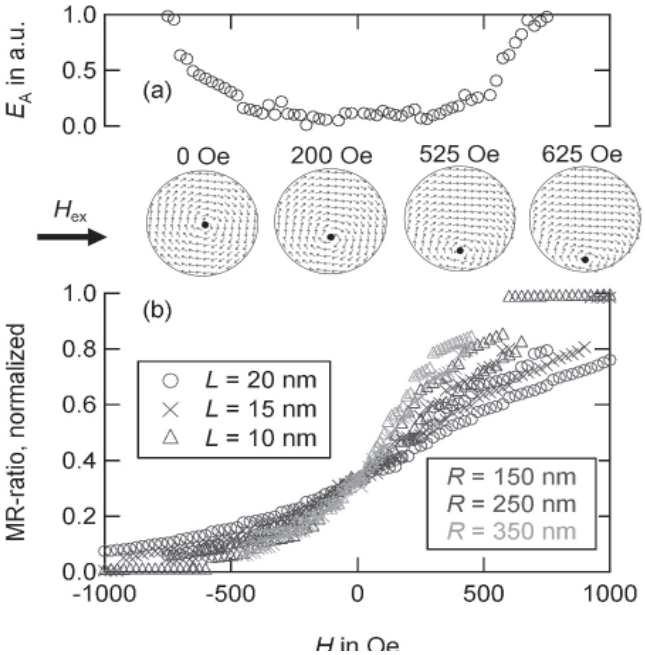


Fig. 1: Power spectrum density (a) and resistance (b) of a MTJ with SyF free and reference layers for a magnetic field applied along its easy axis.

12.45 – 13.00
TMR sensors with a vortex state free layer
R. Lehndorff [1], A. Weddemann [2], A. Auge [3], K. Rott [3], A. Hütten [3], G. Reiss [3]
(1) Sensitec GmbH, 55131 Mainz, Germany, (2) Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, USA, (3) Thin Films & Physics of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany

Magnetic field sensors based on the tunneling magnetoresistance effect of CoFeB/MgO/CoFeB are of great interest for industrial applications due to their high output signal and energy saving capability. To produce a functional field sensor a linearization of sensor output has to be achieved while at the same time hysteresis has to be minimized.
In this work we investigate one route to the linearization of the sensor output by shaping the free layer of the spin valve type layer stack such that it holds a vortex state. This state is known to show a very linear and nonhysteretic magnetization curve at low fields [1, 2]. We show in experiments, as well as in simulations, that the linear range and the sensitivity of the sensors can be widely adjusted by changing the free layer dimensions.
We discuss advantages of this design over conventional means for linearization like shape anisotropy or hard magnetic bias layers.
This work was part of the industrial collaboration project "MultiMag" funded by the BMBF (German Federal Ministry of Education and Research).



Micromagnetic simulations of the free layer magnetization and resulting sensor signals for varying dimensions of the free layer

[1] K. Yu. Guslienko, V. Novosad, Y. Otani, H. Shima, K. Fukamichi, Appl. Phys. Lett. 78, 3848 (2001).
[2] R. P. Cowburn, J. Phys. D: Appl. Phys. 33, R1 (2000).

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MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS
Chair: P.A. Algarabel Lafuente

11.00 – 11.30

Neutron scattering and μSR studies of spin gap formation in the caged compounds CeT_2Al_{10} (T = Fe, Ru, Os) *(invited)*

D. Adroja [1], A. Hillier [1], T. Takabatake [2], Y. Muro [3], K. Yutanai [4], J. Kajino [2], P. Deen [5], A. Strydom [6], D. Khalyavin [1], J. Stewart [1], J. Taylor [1], F. Demmel [1], E. Goremychkin [1], A.T. Boothroyd [7]

(1) ISIS Facility, Rutherford Appleton Laboratory, Chilton, OX11 0QX, UK, (2) Dept. Quantum Matter, AdSM, Hiroshima University, Higashi-Hiroshima 739-8530, Japan, (3) Liberal Arts and Sciences, Toyama Prefectural University, Imizu 939-0391, Japan, (4) 2Dept. Quantum Matter, AdSM, Hiroshima University, Higashi-Hiroshima 739-8530, Japan, (5) European Spallation Source, St Algatan 4, Box 176 Lund Sweden 221 00, (6) Physics Department, University of Johannesburg, PO Box 524, Auckland Park 2006, South Africa, (7) Department of Physics, Oxford University, Oxford, OX1 3PU, UK

According to conventional theories of strongly correlated electron systems, the natural consequence of strong hybridization between f-electrons and conduction electrons is the opening of a gap in both charge and spin channels. Despite their importance, there are few experimental observations of such gaps in real materials. Recently, the opening of a spin gap has been reported in the intermetallic compounds CeT_2Al_{10} (T = Ru and Os) below T_N = 27-29 K through heat capacity and magnetic susceptibility measurements as well as in the paramagnetic state of $CeFe_2Al_{10}$ through resistivity and NMR measurements. Various theoretical models have been proposed to explain the spin gap formation, for example a spin-Peierls model of Hanzawa for $CeRu_2Al_{10}$. To understand the nature of the spin gap formation in these compounds, we have carried out neutron diffraction, inelastic neutron scattering, and μSR studies of these three compounds. Our neutron diffraction and μSR studies reveal a clear sign of long-range magnetic ordering in $CeRu_2Al_{10}$ and $CeOs_2Al_{10}$, while $CeFe_2Al_{10}$ does not order magnetically down to 50mK. We have found a clear evidence of spin gap formation in the inelastic response of the Ru and Os compounds below their magnetic ordering temperatures as well as in the paramagnetic state of $CeFe_2Al_{10}$. We will present the inelastic neutron scattering measurements on CeT_2Al_{10} (T=Ru and Os) single crystals that unravel the true nature of the spin gap formation in these compounds. We will compare the spin gap formation in CeT_2Al_{10} with that observed in the dimerised ground state of $YbAl_3C_3$ and mixed valence compounds CeRhAs and $CeRu_4Sb_{12}$.

11.30 – 11.45

Magnetic and structural properties of Ni-Mn-In Heusler alloys thin films

A. Grunin [1], A. Goikhman [1], V. Rodionova [2]

(1) Innovation Park of Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russia, (2) Innovation Park, I.Kant Baltic Federal University, 236041 Kaliningrad, Russia; Dpto. Fisica de Materiales, UPV/EHU 20009 San Sebastian, Spain; Faculty of Physics, Lomonosov MSU, 119991 Moscow, Russia

We report on the results of the investigation of magnetic and structure properties of Ni-Mn-In Heusler alloy thin films formed by pulsed laser deposition technique. The influence of stoichiometric composition and valence electron concentration *e/a* was studied.

Ni-Mn-In thin films were grown under high vacuum conditions using pure targets of Ni, Mn and In by co-deposition technique with two Nd:YAG lasers at different harmonics.

Chemical composition was investigated by Auger electron spectroscopy (AES), Rutherford backscattering spectrometry (RBS) and Energy-dispersive X-ray spectroscopy (EDX); magnetic properties – by vibrating sample magnetometery (VSM) and Physical properties measurement system (PPMS); structural properties - by X-ray Diffraction (XRD) and Raman scattering.

Several series of the thin films with different ratios of elements were created: $Ni_{50+x}Mn_{25}In_{25-x}$ and $Ni_{50}Mn_{25+y}In_{25-y}$, where x = 0÷8 and y = 0÷16.

$Ni_{50+x}Mn_{25}In_{25-x}$ samples with thickness about 40 nm are superparamagnetic at room temperature (RT) as well as a number of samples with Mn concentration from 19 to 27%. It can be related to the granular nanostructure of the films [1]. At the same time all these samples are in austenitic state at RT, as shown by XRD.

It was shown, that increasing of Mn and Ni concentrations increases the saturation magnetization, while increasing of In content significantly decreases it at room temperature.

The degradation of magnetic properties was confirmed for the samples: after nine months since deposition samples become non-magnetic at RT, while up to three months after deposition they were ferromagnetic at RT and showed martensitic transition at low temperatures.

[1] M. Kurfiβ, F. Schultz, R. Anton, G. Meier, L. von Sawilski, J. Kötzler, JMMM, 290–291 (2005) 591–594.

11.45 – 12.00

Influence of strain on the AFM-FM phase transition in epitaxial FeRh films

J. Juraszek [1], C. Bordel [2], D. Cooke [2], C. Baldasseroni [2], S. Moyerman [3], E. Fullerton [3], F. Hellman [2]

(1) Groupe de Physique des Matériaux, UMR CNRS 6634, Université de Rouen, 76801 St Etienne du Rouvray, France, (2) Department of Physics, University of California, Berkeley, Berkeley, California 94720, USA, (3) Center for Magnetic Recording Research, University of California, San Diego, La Jolla, California 92093, USA

The equiatomic FeRh alloy is known to undergo a metamagnetic antiferromagnetic (AFM) to ferromagnetic (FM) phase transition slightly above room temperature, which makes it very attractive for thermally-assisted storage applications. The driving force of this transition is still under debate, but it seems that the dominant contribution to the entropy change at the transition is due to magnetic fluctuations of the Rh moment [1].

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In this study, we have performed magnetometry and conversion electron Mössbauer spectrometry (CEMS) experiments from 300 K to 500 K on epitaxial FeRh thin films. The samples were sputter-deposited on both MgO and ion-bombard-assist-deposited (IBAD)-MgO. The latter substrate enables the growth of epitaxial thin films on amorphous transparent membranes, but its lattice parameter is slightly different from that of single-crystalline MgO [2], which offers the opportunity to study the effect of strain on epitaxial FeRh films.
It was found by CEMS that the samples are chemically ordered in the CsCl crystal structure. Besides that, both exhibit a jump in the magnetization and hyperfine field at the transition, the Fe magnetic moment being higher in the FM phase than in the AFM phase [3]. The magnetic domain nucleation/expansion is however clearly affected by strain.
More globally, we have shown that the magnetic properties, including the temperature of the transition itself, can be tuned by strain, as well as by composition, increasing the possibility of utilizing this material for future applications in magnetic data storage.

[1] L. M. Sandratskii *et al.*, Phys. Rev. B 83, 174408 (2011)
[2] David W. Cooke *et al.*, Rev. of Sci. Instr. 82, 023908 (2011)
[3] G. Shirane *et al.*, Phys. Rev. 131, 183 (1963)

12.00 – 12.15
Transport and magnetic properties of $CeNi_{5-x}Ge_x$
M. Zapotokova [1], I. Curlik [1], M. Reiffers [2], M. Giovannini [3]
(1) Institute of Experimental physics, Watsonova 47, SK 043 53 Kosice, Slovakia, (2) Institute of Experimental physics, Watsonova 47, SK 043 53 Kosice, Slovakia, Department of Physics, Mathematics and Technics, FHNS, Presov University, ul. 17. novembra 1, SK 08116 Presov, Slovakia, (3) CNR-SPIN and Department of Chemistry, CNR-SPIN and Department of Chemistry, University of Genova I-16146 Genova, Italy, Italy

Metallic Ce compounds are of great interest for the intriguing physical properties associated with the 4f electrons. One notable example of compound intensively studied for many years is $CeNi_5$ crystallizing in the hexagonal $CaCu_5$ type, which results to be a Stoner enhanced paramagnet characterized by a spin fluctuation contribution.
Here the effect of the Ni/Ge substitution on the ground state of $CeNi_5$ is presented. Several ternary germanides $CeNi_{5-x}Ge_x$ (x=0, 0.1, 0.2, 0.5, 0.8) were prepared by arc melting techniques. All the alloys crystallize in the $CaCu_5$ structure. Single phase of the polycrystalline samples was confirmed by X-ray diffraction and by electron microscope analysis. The measurements of resistivity between 2 and 300 K, heat capacity between 0.4 and 300 K and magnetic susceptibility up to 800 K are provided and the results are presented. The resistivity measurements show a typical metallic behaviour. No phase transition was observed in resistivity and heat capacity measurements.

12.15 – 12.30
Engineering the magnitude and the sign of the hysteresis loop shift for in-plane-CoFeB / perpendicular-$SmCo_5$ bilayers
A. Bollero [1], V. Neu [2], V. Baltz [3], C. Rodrigo [4], M. Seifert [2], R. P. Del Real [5], M. Vázquez [5], L. Schultz [2], J. Camarero [4], R. Miranda [4]
(1) IMDEA Nanoscience, Instituto Madrileño de Estudios Avanzados en Nanociencia, Campus Universidad Autónoma de Madrid, 28049 Madrid, Spain, (2) IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany, (3) SPINTEC, UMR-8191 CNRS/CEA-INAC/UJF-Grenoble 1/ Grenoble-INP, 17 rue des Martyrs, 38054 Grenoble cedex 9, France, (4) Dep. de Física de la Materia Condensada, Instituto "Nicolás Cabrera" and IMDEA Nanoscience, Universidad Autónoma de Madrid, 28049 Madrid, Spain, (5) ICMM, Instituto de Ciencia de Materiales CSIC, Campus de Cantoblanco, 28049 Madrid, Spain

Exceptional exchange bias (EB)-like effects have been observed in a system consisting of a hard magnet epitaxial $SmCo_5$ film with perpendicular anisotropy in interaction with a soft magnetic amorphous CoFeB film with in-plane anisotropy. Interestingly the loop shift induced in the CoFeB can be tuned both in magnitude and in sign by simple variation of the orientation of the external in-plane magnetic field. The 30nm thick $SmCo_5$ film was prepared by pulsed laser deposition (PLD) on a Al_2O_3(0001) substrate using a Ru buffer layer [1]. The c-axis is perpendicular to the film plane. A large uniaxial magnetocrystalline anisotropy constant of about K_u=7.5MJ/m^3 was determined for $SmCo_5$ at room temperature. The film structure was completed with the deposition of a Cr layer (11nm). Sputtering of an amorphous CoFeB (3nm) film was done with oblique incidence of the atomic flux in order to induce a uniaxial anisotropy. The Cr spacer plays a twofold role: i) it protects the $SmCo_5$ against oxidation during ex-situ transfers from PLD to sputtering chambers and ii) it diminishes the effective coupling between the soft and hard magnetic layers. This allowed application of relatively low in-plane fields to study systematically the angular dependence of the magnetization reversal in CoFeB by magneto-optical Kerr effect. By contrast with conventional EB films, this bilayer shows a loop shift with no need of any post-depositional treatment. In addition to other EB-like stacks, this bilayer also offers the unprecedented possibility to switch from positive to negative loop shift without changing the magnetic history of the system. The observed effect is of interest for applications in spintronics and magnetic sensors as allows for modulation of the EB field strength and sign by proper choice of the orientation of the applied field.

[1] M. Seifert, V. Neu, L. Schultz, Appl. Phys. Lett. 94, 022501 (2009)

12.30 – 12.45
Alloying as a possible mechanism in annealing induced perpendicular magnetic anisotropy in alumina/Co/M (where M=Pd,Pt or Au)
P. Warin [1], *A. Marty* [1], A. Brenac [1], L. Notin [1], S. Pouget [1], C. Vergnaud [1], C. Beigné [1], M. Jamet [1]
(1) SP2M/INAC, CEA-UJF, F-38054 Grenoble, France

Since the work of Carcia[1], perpendicular magnetic anisotropy (PMA) in ferromagnetic/non-magnetic trilayers or multilayers has attracted much attention. Spin-orbit interaction is the main cause for PMA. Recently it has been shown that in MgO/CoFeB/

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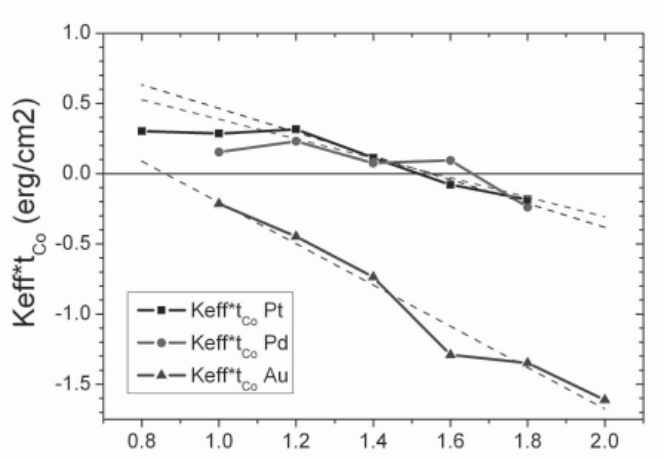
Pt and Oxide/Co/Pt[2], PMA can be induced by annealing. In particular, it has been argued in [3] that the origin of this PMA is the hybridization between Co and O orbitals enhanced by annealing. We demonstrate in this work that another explanation is alloying between cobalt and the capping layer. We have grown and annealed at different temperatures trilayers of alumina(3nm)/Co(t nm)/M(3nm) where t varies from 1 to 2 nm and M= Pd, Pt and Au. For annealing temperature, Ta=300°C, PMA is observed in Co/Pd and Co/Pt for t<1.6 nm and 1.4 nm respectively. However no PMA is observed for any thickness in Co/Au(see figure). At Ta= 400 °C Co/Pd and Co/Pt show PMA for all thicknesses whereas for Co/Au no PMA is observed. It seems that the influence of Co-O bonds is not enough to drive the magnetization out-of-plane in Co/Au. X-Ray diffraction shows that the (111) peak of the Pd and Pt capping layer changes position with annealing whereas in the case of Au no changes is seen. This is an indication of alloying due to annealing. We propose that the appearance of PMA is due to alloying between Co and Pt or Pd, as Co and Au are immiscible no effect is observed in Co/Au.

[1] Carcia et al, Appl. Phys. Lett. 47, 178 (1985).
[2] Nistor et al, Appl. Phys. Lett. 94, 012512 (2009).
[3] Rodmacq et al, Phys. Rev. B 79, 024423 (2009)



Keff*t Co extracted from magnetometry measurement for the three capping layers

12.45 – 13.00
Magnetic ordering in the nanoparticles with the Ruderman-Kittel-Kasuya-Yosida interaction
V.I. Belokon [1], K.V. Nefedev [1], *O.I. Dyachenko* [1]
(1) The School of Natural Sciences/Department of theoretical and experimental physics/Far Eastern Federal University/8, Sukhanova str., 690950, Vladivostok, Russian Federation

In this paper, using the approximation of the molecular field theory and taking into account the Ruderman- Kittel- Kasuya-Yosida (RKKI) interaction we consider possible types of the magnetic ordering of the magnetic spherical nanoparticles embedded in a non-ferromagnetic matrix. Assessment of the possibility of establishing the ferromagnetic or the antiferromagnetic ordering, as well as the spin-glass state is based on the relationship between the parameters of the distribution function of random exchange fields [1]. Type of ordering depends on the ratio H_0 / B, where $H_0 = n\int_V \varphi_k \, \mathrm{d}V$ is the expectation, $B^2 = 2\sigma^2 = 2n\int_V \varphi_k^2 \mathrm{d}V$, σ is the variance, $\varphi_k = \varphi_k\left(\overrightarrow{m_k}, \overrightarrow{r_k}\right)$ is the field created at the origin by particles with magnetic moment $\overrightarrow{m_k}$ located at the point with coordinates $\overrightarrow{m_k}$, n is the number of the particles per unit volume. The law of interaction of the magnetic moments of the spherical particles iterates the law of interaction of the spins [2]. Thus, the possible types of ordering are defined as follows:

1. $H_0 / B > 1, H_0 > 0$ is the ferromagnetic;
2. $|H_0| / B > 1, H_0 < 0$ is the antiferromagnetism;
3. $|H_0| / B < 1$ is the spin-glass state.

Dependence H_0 / B for a given concentration of ferromagnetic atoms $p = n / \left(\frac{4}{3}\pi R_0^3\right)$ is a alternating function with a decreasing amplitude at increasing R_0 / a, where a - the lattice parameter. The maximum value H_0 / B for the largest possible concentration of the nanoparticles is less than unity. Thus, only the ordering of the type of the ferromagnetic or the antiferromagnetic spin-glass state may occur.

[1] V. I. Belokon, K. V. Nefedev, Journal of Experimental and Theoretical Physics, 120(1), 1, (2001)
[2] R. Skomski, Europhys. Lett., 48(4), 455, (1999)

Monday, 10 September 2012
Macbeth Room

DILUTED MAGNETICS SEMICONDUCTORS
Chair: M. Sawicki

11.00 – 11.30

Electronic and magnetic properties in (Ga,Mn)As films and magnetic coupling in (Ga,Mn)As based heterostructures *(invited)*

P. Torelli [1], J. Fujii [1], B. Rache Salles [1], M. Medici [2], M. Sperl [3], C.H. Back [3], G. Panaccione [1]

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(Ga,Mn)As has attracted the interest of the scientific community due to his perfect structural compatibility with III-V semiconductor and high spin polarization at the interface, which make (Ga,Mn)As an ideal candidate for semiconductor spintronics applications [1]. Despite these promising features the applications are still limited due to the persisting of the Tc well below room temperature. Even though, the interest in the (Ga,Mn)As has not diminished due to the extremely rich physics displayed by this material; the reason coming essentially from the indirect exchange interaction between Mn ions which makes the magnetism of (Ga,Mn)As extremely sensitive to the details of the electronic structure. Thus, the properties of (Ga,Mn)As film can be tuned by an appropriate engineering of heterostructures. We have carried out photoemission experiment on the simplest nanostructure (the surface) of a (Ga,Mn)As film in which, taking advantage of the increased probing depth of the hard x-ray photoemission spectroscopy (HAXPES) over the standard XPS, we compared the surface and the bulk electronic structures [2]. The observed difference in the hybridization of the external shells at the surface is then responsible for a different magnetic behaviour as observed in a combined XMCD/Mott scattering experiment (i.e. a reduced hybridization of the external shell at surface decrease the measured Tc). Moreover the magnetic behaviour of (Ga,Mn)As is strongly influenced by the presence of an interface with a ferromagnetic layer; (Ga,Mn)As films have shown ferromagnetic response at room temperature in Fe/(Ga,Mn)As system [3]. This induced polarization by proximity effect with a ferromagnet has been investigated as a function of the film thickness and also in more complex spin valves like heterostructures.

[1] Ohno et al. Appl. Phys. Lett. 69, 363 (1996)
[2] J. Fujii et al. Phys. Rev. Lett. 107, 187203 (2011)
[3] F. Maccherozzi et al. Phys. Rev. Lett. 101, 267201 (2008)

11.30 – 11.45

Mechanisms of exchange interactions in dilute $Ga_{1-x}Mn_xN$, experiment and modelling

A. Grois [1], T. Devillers [1], J. Suffczyński [2], A. Navarro-Quezada [1], B. Faina [1], W. Stefanowicz [3], S. Dobkowska [3], D. Sztenkiel [3], M. Rovezzi [4], T. Li [1], M. Sawicki [3], J.A. Majewski [5], T. Dietl [3], A. Bonanni [1]

(1) Institut für Halbleiter- und Festkörperphysik, Johannes Kepler University, 4040 Linz, Austria, (2) Institute of Experimental Physics, University of Warsaw, 00-681 Warszawa, Poland, (3) Institute of Physics, Polish Academy of Sciences, 02-668 Warszawa, Poland, (4) European Synchrotron Radiation Facility, 38043 Grenoble, France, (5) Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, 00-681 Warszawa, Poland

The nature of exchange interactions and magnetism in the model dilute magnetic insulator $Ga_{1x}Mn_xN$ has represented a matter of fervent debate over the recent years. It is increasingly clear that further progress in the understanding of this challenging system requires both an experimental precise analysis of the material and a revision of the theoretical approaches.

Here we report on our studies of $Ga_{1x}Mn_xN$ layers with x up to 3.5%, grown by MOVPE. High crystallinity, lack of compensation by residual donors, and random distribution of Mn over cation sites are confirmed by HRTEM, HR- and synchrotron XRD, synchrotron XAS, EPR and optical absorption [1].

For $x < 1\%$, the results of our optical studies point to the presence of a strong *pd* coupling between valence band and Mn states, leading to the appearance of a bound hole state at the Mn ions. In particular, as expected within the strong coupling scenario, we establish by photoluminescence that the band gap increases with x. Furthermore, the value and sign of the *apparent* exchange coupling obtained from reflectivity measurements of the excitonic giant Zeeman splitting, are non-standard, but expected in the case of strong coupling [2].

In samples with $x < 3.5\%$, we confirm experimentally the presence of a strong ferromagnetic coupling between neighbouring Mn spins, providing a much wanted verification of a remarkable number of *ab initio* studies [1]. The substantial agreement between our experimental values of $T_C(x)$ from millikelvin SQUID magnetometry and our tight binding and Monte Carlo simulations, makes it possible to identify ferromagnetic superexchange as the microscopic mechanism accounting for the interaction between localized spins in $Ga_{1x}Mn_xN$ [3].

[1] A. Bonanni et al., Phys. Rev. B 84, 35206 (2011), and references therein.
[2] J. Suffczyński et al., Phys. Rev. B 83, 94421 (2011).
[3] M.Sawicki et al. arXiv:1202.6233.

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Macbeth Room

DILUTED MAGNETICS SEMICONDUCTORS
Chair: M. Sawicki

11.45 – 12.00

Theoretical study of bulk in-plane uniaxial anisotropy in (Ga,Mn)As

C. Śliwa [1], M. Birowska [2], J.A. Majewski [2], T. Dietl [1]
(1) Institute of Physics, Polish Academy of Sciences, 02-668 Warszawa, Poland, (2) Institute of Theoretical Physics, University of Warsaw, 00-681 Warszawa, Poland

The in-plane uniaxial anisotropy in (Ga,Mn)As is the basis of a number of schemes employing this material to demonstrate novel functionalities. In this contribution we aim at a microscopic quantitative understanding of this anisotropy, whose presence appears to contradict expectations of the group theory for the crystal symmetry in question.
We show [1] by means of ab initio calculations within the density functional theory that the breaking of the symmetry implied by such an anisotropy can be attributed to energetic non-equivalence of the two orientations of a nearest neighbour pair of Mn atoms on the surface of GaAs during molecular beam epitaxy growth, leading to an excess of [-110]-oriented over [110]-oriented pairs in bulk.
Following the Luttinger's method of invariants, we include in the k.p Hamiltonian a spin-independent term of C_{2v} symmetry to model the resulting magnetic anisotropy. Such a term can be parameterized by effective strains e_{xy}, e_{xx}, the former introduced already in Ref. [2]. These parameters can be obtained ab initio from band structure calculations for a pair of nearest neighbour Mn dopants. Alternatively, we can treat the acceptor effective-mass potential as a perturbation to the k.p Hamiltonian and evaluate the effective strains as a second-order correction. Both procedures lead to satisfactorily similar results.
The calculated magnitude of e_{xy} is 15 to 40 times larger than determined from experiment. This is expected as in real samples the excess of [-110]-oriented Mn pairs is only a fraction of the total Mn content. Assuming such a reduced value of e_{xy} we can reproduce experimental results. The other component, e_{xx}, explains an out-of-plane anisotropy even in the absence of any epitaxial strain.

[1] M. Birowska, C. Śliwa, J. A. Majewski, and T. Dietl, arXiv:12023295.
[2] M. Sawicki et al., Phys. Rev. B 71, 121302 (2005).

12.00 – 12.15

High Quality (Ga,Mn)N Epitaxial Films with Mn Concentrations up to 10%

G. Kunert [1], *S. Dobkowska* [2], T. Li [3], J. Von Borany [4], C. Kruse [1], A. Bonanni [3], J. Grenzer [4], W. Stefanowicz [2], M. Sawicki [2], T. Dietl [5], D. Hommel [1]
(1) Institute of Solid State Physics, University of Bremen, 28359 Bremen, Germany, (2) Institute of Physics, Polish Academy of Sciences, PL-02-668 Warsaw, Poland, (3) Institute of Solid State Physics, Johannes Kepler University Linz, A-4040 Linz, Austria, (4) Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany, (5) Institute of Physics, Polish Academy of Sciences, PL-02-668 Warsaw, Poland; Institute of Theoretical Physics, University of Warsaw, PL-00-681 Warszawa, Poland

Owing to the lack of band carriers, and to the highly localized nature of electrons residing on Mn, (Ga,Mn)N has been classified as dilute magnetic insulator, where spin-spin inter-actions proceed *via* short ranged superexchange coupling [1]. In the case of compensated samples, in which Mn^{2+} prevails, this interaction is antiferromagnetic, like in Mn-based II-VI dilute magnetic semiconductors (DMSs). However, in high quality weakly compensated epilayers that contain merely Mn^{3+} ions, the superexchange acquires a ferromagnetic character [1,2], as predicted a time ago for Cr doped II-VI DMSs and widely studied by first principle methods [3].
In this work we report on the growth by MBE and extensive characterization of (Ga,Mn)N films which show to our knowledge the highest field-induced magnetization $M(H)$ - reaching 150 emu/cm^3- ever reported for any DMS. HRXRD points to a linear dependence of the c-lattice parameter on the amount of Mn incorporated. Reciprocal space maps reveal that the layers are fully strained. Furthermore, according to HRTEM measurements there are no crystallographic secondary phases in these samples. The magnitudes of the Mn concentrations x_{eff} provided by SQUID measurements have been cross-checked by energy-dispersive x-ray spectroscopy and SIMS. A detailed analysis of the crystalline structure of the layers has been performed also by Rutherford backscattering along the (0001)-direction. It has been found that the signal in the channeling mode drops to 3% of its magnitude in the random mode, which is among the lowest values reported for GaN, thus confirming the high structural quality of the (Ga,Mn)N layers.

[1] A. Bonanni *et al*., *Phys. Rev. B* **84**, 3 (2011); M. Sawicki *et al.*, arXiv: 1202.6233.
[2] E. Sarigiannidou *et al*., *Phys. Rev. B* **71**, 041306 (2006).
[3] J. Blinowski *et al.*, *Phys. Rev. B* **53**, 9524 (1996); K. Sato *et al.*, *Rev. Mod. Phys.* **82**, 1633 (2010).

12.15 – 12.30

Tomographic investigation of self-organized nanocolumns in Ge-Mn thin films

I. Mouton [1], R. Lardé [1], E. Talbot [1], C. Genevois [1], D. Blavette [1], V. Baltz [2], A. Barski [3], P. Bayle-Guillemaud [3], M. Jamet [3]
(1) Groupe de Physique des Matériaux, UMR CNRS 6634, Université et INSA de Rouen, Avenue de l'Université, BP 12, 76801 St Etienne du Rouvray, France, (2) SPINTEC, UMR CEA / CNRS / UJF-Grenoble 1 / Grenoble-INP, INAC, 38054 Grenoble, France, (3) INAC/SP2M CEA-Grenoble et Université Joseph Fourier, 38054, Grenoble, France

Future spintronic devices compatible with silicon technology require to design magnetic semiconductors (MS) exhibiting

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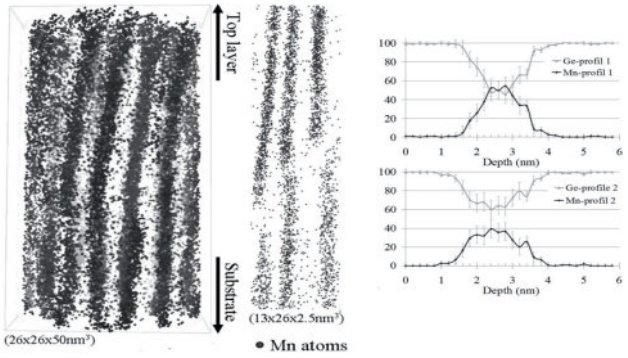
simultaneously semiconducting and magnetic properties at operating temperature. The elaboration of such materials consists in doping semiconductor materials with magnetic atoms. Initially, researches were focused on Diluted Magnetic Semiconductors (DMS) where magnetic transition metal (MT) atoms are randomly dispersed into a semiconductor host matrix. Among the studied systems, Mn doped Ge have focused a particular attention. In 2006 Jamet *et al.* observed self organized Mn-rich nanocolumns (NCls) dispersed in a Ge matrix [1]. In this system many questions remain unanswered. In our study, Atom Probe Tomography (APT) and HRTEM were used to characterize Ge-Mn thin films containing ~10% Mn. Thanks to 3D imaging capability of APT and its high spatial resolution, a new and more precise characterization of Mn-rich NCls was provided. The morphology and the local chemical compositions of NCls were characterised. It was shown that NCls are regularly dispersed and contained about 30% Mn. This concentration is well below the Mn concentration in equilibrium phases present in the Ge-Mn phase diagram. Moreover, the APT technique allowed us to observe that the NCls exhibit chemical fluctuations along the growth direction. Consistently, thanks to the better accuracy of APT, it was also found that, contrary to previous experiments, the remaining matrix is composed of pure Ge. Theses results raise the important question of the Ncls growth mechanism. Kinetic Monte Carlo simulations are in progress to determine whether spinodal or non-classical nucleation and growth occurs in these Ge-Mn thin films under the present composition and temperature conditions [2].

[1] M. Jamet et al,Nat Mater **5**, 653 (2006).
[2] I. Mouton et al, submitted (2012).

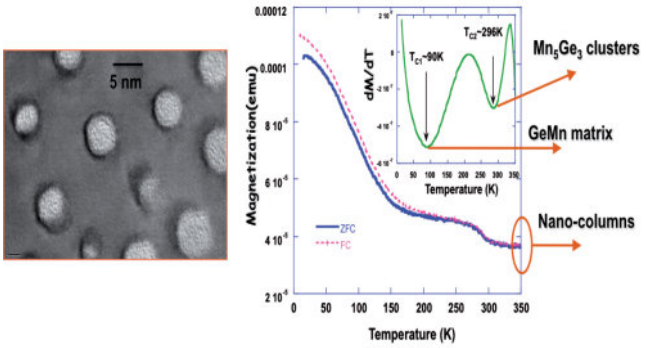


3D image and concentration profiles of Mn-rich nanocolumns embedded in Ge matrix.

12.30 – 12.45
New insight into the kinetic formation of high-T_C GeMn nanocolumns
T.G. Le [1], *M.T. Dau* [1], A. Portavoce [2], M. Petit [1], D. Mangelinck [2], L. Michez [1], V. Le Thanh [1]
(1) CINaM-CNRS, Aix-Marseille University, (2) IM2NP-CNRS,Aix-Marseille University

In recent years, diluted magnetic semiconductors (DMS), obtained by doping magnetic metals into a host semiconducting matrix, have attracted great attention for their potential in combining ferromagnetic and semiconducting properties in a single material. Among various materials, $Ge_{1-x}Mn_x$ DMS appears to be a promising candidate due to its compatibility with mainstream silicon technology. However, in standard growth conditions the Curie temperature (Tc) of most DMSs studied up to now remains relatively low, probably due to a very low solubility of the magnetic elements in semiconductors.
In this work, we report on the formation kinetics and the compositions of high-T_C $Ge_{1-x}Mn_x$ nanocolumns grown on Ge(001) by MBE. We have successfully set up adequate growth conditions to produce $Ge_{1-x}Mn_x$ nanocolumns exhibiting a T_C well above 350 K. We have made in use Atom Probe Tomography (APT) to investigate the Mn composition along a nanocolumn and also in the $Ge_{1-x}Mn_x$ matrix. We provide evidence that the nanocolumns are not a compound with a constant Mn concentration as being currently believed [1] but a solid solution with Mn concentration varying from 5% at the interface to ~40% near the surface. When the Mn concentration reaches a value of ~40%, nanocolumns become no longer stable, transforming into Mn_5Ge_3 clusters. The kinetics of the nanocolumn formation will be discussed with respect to the Mn segregation process and be corrected with the magnetic properties of three components present in the film: nanocolumns, matrix and Mn_5Ge_3 clusters [2, 3].

[1] M. Jamet *et al*., Nat. Mater. **5**, 653 (2006).
[2] A. Spiesser *et al*., Phys. Rev. B **84**, 165203 (2011)
[3] A. Spiesser *et al*., Appl. Phys. Lett. **99** 121904 (2011)



(Left): Plane-view TEM image exhibiting nanocolumns of an average diameter of 5-6 nm (Right): Temperature dependent magnetization displaying the co-existence of three magnetic contributions.

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12.45 – 13.00
Magnetic Properties of Ce^{3+} in PbCeA (A= Te, Se, S) Diluted agnetic Semiconductor
S. Isber [1], X. Gratens [2], S. Charar [3], Z. Golacki [4]
(1) American University of Beirut, Department of Physics, Bliss Street, PO Box 11-0236 Beirut 1107-2020, Lebanon, (2) Instituto de Física, Universidade de São Paulo, 05315-970, São Paulo, Brazil, (3) Group d'Etudes des Semiconducteurs (GES), Université Montpellier II, CC074, 34095 Montpellier Cedex 5, France, (4) Institute of Physics, Polish Academy of Sciences, Pl.02-668 Warsaw, Poland

The magnetic properties of $Pb_{1-x}Ce_xA$ (A = S, Se and Te) crystals with Ce^{3+} concentrations $0.006 \leq x \leq 0.036$ were investigated in the temperature range from 2 K to 300 K. The effective Landé factors were determined by X-band (~9.5 GHz) Electron Paramagnetic Measurements (EPR) to be g = 1.333, 1.364, and 1.402 for Ce ions in PbA, A = S, Se, and Te, respectively. The small difference with the predicted Landé factor g of 10/7 for the Γ_7 (J=5/2) ground state was attributed to crystal-field admixture. The magnetic susceptibility data were found to be consistent with a $^2F_{5/2}$ lowest manifold for Ce^{3+} ions with a crystal-field splitting $\Delta = E(\Gamma_8) - E(\Gamma_7)$ of about 340 K, 440 K and 540 K for $Pb_{1-x}Ce_xTe$, $Pb_{1-x}Ce_xSe$, and $Pb_{1-x}Ce_xS$, respectively. For all the three compounds the doublet Γ_7 lies below the Γ_8 quadruplet which confirms the substitution of Pb^{2+} by Ce^{3+} ions in the host crystals. The observed values for the crystal-field splitting were found to be in agreement with the calculated ones based on the point charge model. Moreover, we will present the de-Haas van-Alphen magnetic oscillations and electric properties of $Pb_{1-x}Ce_xTe$ (x~ 0.05 and 0.07) SMSC. The investigation will be based on a variety of techniques among which are the ultra-low temperature (20 mK) magnetic susceptibility oscillations as shown in Figure 1; A preliminary analysis of the results showed an oscillatory period of 1.12E-6 $Gauss^{-1}$ in the (001) direction. The effective electronic mass (m^*) and its relaxation time (τ) due to scattering were determined for various crystallographic direcions.

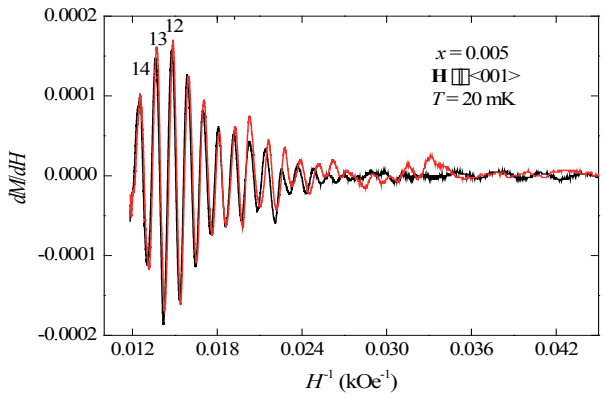

Figure 1: Field dependence of the oscillatory part of the magnetic susceptibility at 20 mK for H || [001].

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ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS
Chair: H. Olhldag

11.00 – 11.30
Neutron Scattering as tool for exploring emerging quantum states in novel materials *(invited)*
H.M. Rønnow [1]
(1) Laboratory for Quantum Magnetism, EPFL, Switzerland

Novel electronic materials simultaneously reveal new electronic states of matter challenging our fundamental understanding of emerging collective phenomena, and offer prospects of future correlated electron technology. Neutron scattering being able to probe order, instantaneous correlations and dynamic fluctuations provides the ideal tool to probe emerging quantum states. I shall present examples ranging from fundamental magnetism to the mechanism of high-temperature superconductivity, and report recent and future advances in neutron scattering and the complimentary high-resolution inelastic X-ray scattering.

[1] http://lqm.epfl.ch

11.30 – 11.45
First principles investigation of μSR experiments
P. Bonfà [1], F. Bernardini [2], R. De Renzi [3]
(1) Department of Physics, University of Parma, I-43124 Parma, Italy, (2) Department of Physics, University of Cagliari, I-09042 Monserrato, Italy, (3) Department of Physics, University of Parma-CNISM, I-43124 Parma, Italy

Muon Spin Rotation Spectroscopy (μSR) is one of the leading experimental probe for the microscopic investigation of magnetism. The success of this technique may be understood by considering the extreme sensitivity of the muon to small internal magnetic fields (down to fraction of Gauss) and the wide time window offered by muons to probe magnetic fluctuations which is also bridging the gap between NMR and neutron scattering experiments [1].
Nonetheless, two issue are usually faced while planning a μSR experiment aimed at assessing quantitative information on the magnetic ground state of a sample. The first problem arises from the determination of the muon stopping site in the crystal. A precise knowledge of the muon position in the crystal is essential in order to independently estimate the magnetic moments of the atoms in the sample. A good guess may be obtained by single crystal experiments, but for polycrystalline samples only heuristic assignments may be provided. The second concern is related to the perturbation produced by the muon implantation: there are well know cases in which μSR results may only be understood by considering the muon local modifications of the crystalline environment [2,3].
To assay these central topics of the μSR technique, we recently started a systematic investigation of the muon/sample interaction by first principles density functional (DFT) calculations. A first

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selection of well known experimental cases allowed us to verify the correctness of the DFT approach in providing the interstitial localization sites of the muon and the relaxation of the crystal around it.
The results of this study will be discussed and the whole knowledge will be collected in a toolbox to become a fundamental companion to μSR experiments.

[1] S. Cox, J. Phys.: Condens.Matter, ***20***, 3187 (1987)
[2] R. Kadono ***et al.***, Phys. Rev. B **39**, 23 (1989)
[3] J. H. Brewer ***et al.***, Phys. Rev. B **33**, 7813 (1986)

11.45 – 12.00

Magnetostriction Measurement of GMR Films on the practical substrates by using inverse-magnetostriction effect

K. Okita [1]
(1) Industrial Instrumentation Division, Tohoku Steel Co., Ltd.,989-1393 Miyagi,Japan

Magnetostriction constant of a magnetic thin film is usually measured on a coupon sample with films deposited on thin glass substrate ("cover glass") by detecting the mechanical distortion as a function of applied field using a laser beam. This method cannot be applied to films deposited on stiffer and large size substrates, such Si or AlTiC, used in real-world applications because the distortion would be too small. Also, the magnetostriction behavior of coupon sample may not reflect the actual behavior on the substrates used in practical substrates.
In the previous paper, we showed the usefulness of a new method of measurement by mechanically bending the substrate and by detecting the changes in magnetic anisotropy field H_K[1].In this paper, I present another new method by mechanically bending the substrate and by detecting the changes in coercive force, Hc. This method also uses the inverse-magnetostriction effect and the magnetostriction constant can be calculated from the gradient of the applied stress vs. Hc curves. With this method, we have successfully measured the magnetostriction constant of the GMR films fabricated on the practical substrate with a high sensitivity over 10^{-7}.

[1] K. Okita, K. Ishiyama and H. Miura, Journal of Physics, Conference Series **200** (2010) 112008

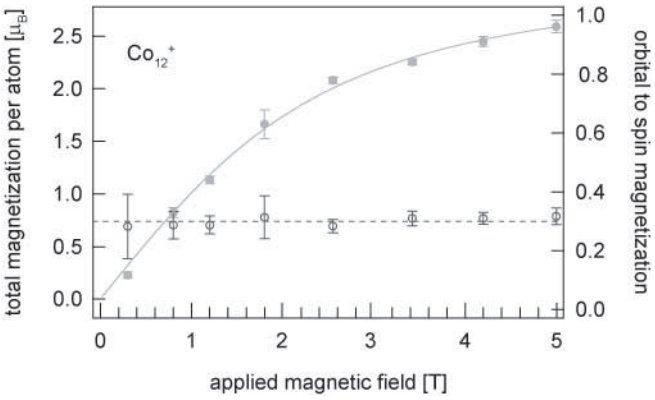
12.00 – 12.15

X-ray magnetic circular dichroism spectroscopy of size-selected molecules, clusters, and complexes in a cryogenic linear ion trap

J.T. Lau [1], K. Hirsch [2], *V. Zamudio-Bayer* [1], A. Langenberg [1], A. Lawicki [1], M. Niemeyer [1], M. Kossick [1], B. Langbehn [1], A. Terasaki [3], T. Möller [2], B. Von Issendorff [4]
(1) Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany, (2) Institut für Optik und Atomare Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany, (3) Department of Chemistry, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan, (4) Fakultät für Physik, Universität Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg, Germany

Because of its local and element-specific nature combined with high sensitivity, x-ray magnetic circular dichroism (XMCD) spectroscopy is perfectly suited to study spin and orbit contributions to the magnetic moment. At the fundamental level, these contributions are ideally studied in unperturbed systems which are controlled with atomic precision in size and composition. We have therefore set up a cryogenic linear ion trap to perform XMCD on well-defined molecular and cluster ions in a magnetic field of up to 5 T and temperatures down to 10 K. This ion trap allows us to investigate magnetic properties of ultra-dilute samples equivalent to 10^{-6} monolayers.
The experimental technique will be introduced and recent results on magnetic order in chromium, iron [1], and cobalt clusters as well as on on local magnetic moments of chromium in gold clusters and manganese in silicon clusters will be presented.

[1] M. Niemeyer et al., Phys. Rev. Lett. 108, 057201 (2012)



Magnetization curve of free Co_{12}^+ clusters at 26 K and ratio of orbital-to-spin magnetization.

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ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS
Chair: H. Olhldag

12.15 – 12.30
X-ray detected ferromagnetic resonance in exchange coupled magnetic multilayers
L. Shelford [1], G. Stenning [2], S. Gregory [2], S. Cavill [1], G. Van Der Laan [1], T. Hesjedal [3], R. Ward [3], P. De Groot [2]
(1) Diamond Light Source Ltd, Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0DE, UK, (2) School of Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ, UK, (3) Oxford Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK

Understanding the dynamical coupling in magnetic multilayers is critical to advancing their design and performance. Ferromagnetic resonance (FMR) is an indispensible tool in the study of magnetic materials, allowing the essential magnetic parameters to be measured [1]. When applied to multilayer thin films information on the interlayer coupling strength can be extracted [2]. Standard FMR techniques, including resonant cavity FMR and magneto-optical Kerr effect (MOKE), can only detect the average response of the system.
X-ray detected ferromagnetic resonance (XFMR) is a new technique [3] that uses the chemical specificity of X-ray magnetic circular dichroism (XMCD). In multilayer systems where the layers are chemically distinct, XMCD enables probing the response of each layer independently. Furthermore, by exploiting the pulsed time structure of storage ring synchrotron radiation the relative phase of precession in the individual layers can be determined.
We have applied XMFR to an exchange-coupled NiFe/CoFe bilayer. Figure 1 shows phase-resolved XFMR data at 8 GHz driving frequency. The amplitude, Fig. 1(a), reveals an FMR mode in the NiFe layers to which the CoFe moments are coupled. Fig. 1(b) shows the phase of the precessing NiFe moments changing through 180° when crossing the resonance, while the CoFe moments show a phase dip over the same field range.

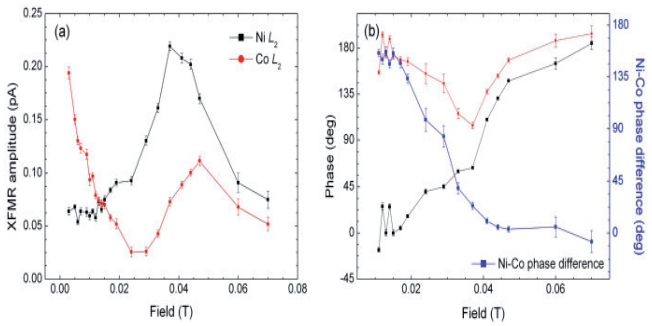

Figure 1 - Phase-resolved XFMR at 8 GHz.

[1] M Farle, Rep. Progr. Phys. **61**, 755 (1998).
[2] M Belmeguenai *et al.*, J. Phys. Cond. Matt. **20**, 345206 (2006); J B Youssef *et al.*, J. Appl. Phys. **108**, 053913 (2010).
[3] M. K. Marcham *et al.*, J. Appl. Phys. **109**, 07D353 (2011); T. Martin *et al.*, J. Appl. Phys. **103**, 07B112 (2008); J. Goulon *et al.*, J. Synchrotron Rad. **14**, 257 (2007); G. Boero *et al.*, Appl. Phys. Lett. **87**, 152503 (2005); D. A. Arena *et al.*, Phys. Rev. B **74**, 064409 (2006).

12.30 – 12.45
Generalized Magneto-optical Ellipsometry for Magnetic Materials Characterization
A. Berger [1], J.B. Gonzalez-Diaz [1], J.A. Arregi [1], O. Idigoras [1]
(1) CIC nanoGUNE Consolider, E-20018 Donostia - San Sebastian, Spain

For the past several decades, ellipsometry has proven itself as an advanced measurement and characterization technique for optical materials properties as well as a crucial metrology tool for multilayer and film growth. A more recently developed implementation and extension of this technique, named Generalized Magneto-optical Ellipsometry (GME), has emerged during the last decade as a methodology to characterize magnetic materials with a high degree of precision by means of utilizing the magneto-optical Kerr effect [1]. Compared to other magneto-optical characterization methods based on the same effect, GME has two key advantages: it can measure both the optical and magneto-optical constants simultaneously and it allows full vector magnetometry, all with only one experimental set-up and measurement configuration. The GME method has been successfully utilized in the study of diverse magnetization reversal processes, the investigation of magneto-optical coupling in ferromagnetic films, for the purpose of identifying spin-polarized electronic states in multiferroic materials [2], as well as for the measurement of the magnetization orientation using two- and three-dimensional vector magnetometry. Our recent developments of this technique include investigations of data set reliability [3] and the detection and methodological incorporation of optical anisotropy, which up to now is generally ignored in the realm of most magneto-optical measurements. These recent developments have the potential to achieve far-reaching improvements in magnetic materials characterization.

[1] A. Berger and M. R. Pufall, Appl. Phys. Lett. **71**, 965 (1997)
[2] M. Bastjan, S.G. Singer, G. Neuber et al., Phys. Rev. **B 77**, 193105 (2008)
[3] J.A. Arregi, J.B. Gonzalez-Diaz, E. Bergaretxe, O. Idigoras, T. Unsal, and A. Berger, accepted for publication in J. Appl. Phys.

12.45 – 13.00
Anisotropy field distribution in thin films by magneto-optic Kerr effect from second harmonic Kerr signal
E. Fernández Martín [1], A. García-Arribas [1], I. Orue [2], J.M. Barandiarán [1], J.M. Barandiarán [1],
(1) Department of Electricity and Electronics, University of Basque Country UPV/EHU, Box 644, 48080 Bilbao, Spain, (2) SGIker, University of Basque Country UPV/EHU, Box 644, 48080 Bilbao, Spain

We present a novel procedure to measure the magnetic anisotropy distribution in thin films by magneto-optic Kerr effect (MOKE). The method is based on the existence of second-order harmonics in the differential magnetization around the anisotropy field [1,2]. This new procedure is very useful on

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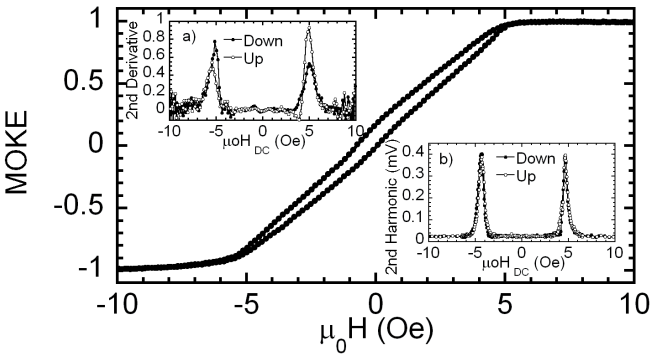
very small size magnetic thin films whose total magnetic signal prevents the use inductive methods. The experimental setup is a conventional MOKE in longitudinal geometry where the dc magnetic field is applied with a pair of Helmholtz coils. An additional pair of Helmholtz coils collinear to the previous ones produces an ac magnetic field of 20 A/m at a frequency of 1.8 kHz. A fast Fourier transform (FFT) of the voltage collected by the light sensor is performed by a signal analyzer to obtain the component at twice the frequency of excitation.
The results obtained in a multilayer thin film FeNi(170nm)/ $Ti(6nm)]_5$/FeNi are shown in the figure. Together with the MOKE hysteresis loop, the anisotropy distribution obtained both using the second derivative of the hysteresis loop method [1] and from the second-order harmonic signal are presented. The second harmonic method is much more precise. This particular test sample is large enough to be measured by inductive methods so we have been able to compare the results obtained by MOKE with those from inductive measurements [2]. They were made with an ac magnetic field of 3 A/m at a frequency of 60 kHz, which are the optimum parameters to obtain a good signal-to-noise ratio for the sample. The results of both methods show good agreement.

[1] J. M. Barandiarán, M. Vázquez, A. Hernando, J. González, and G. Rivero, IEEE Trans. Magn. MAG-25, (1989) 3330.
[2] A. García and J. M. Barandiarán, J. Appl. Phys. 71 (1992) 3047



MOKE hysteresis loop: a) second derivative and b) second harmonic signal.

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MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

NANOSTRUCTURES 1

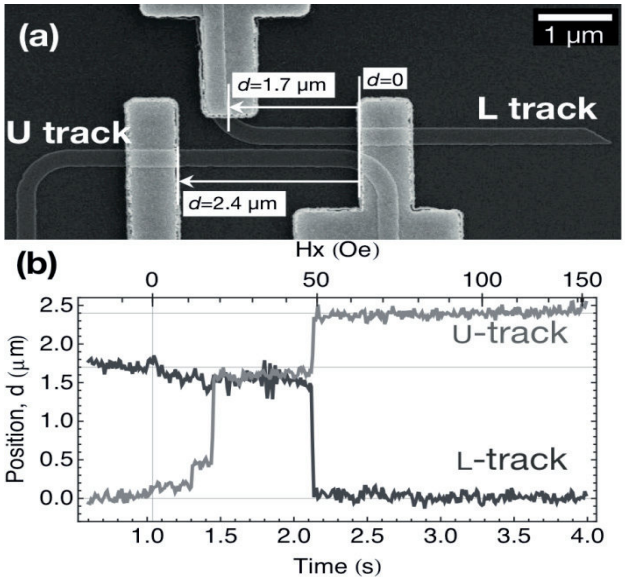
Chair: P. Allia

14.45 - 15.00
Remote coupling and mutually induced depinning of domain walls in adjacent spin valve nanotracks

J. Sampaio [1], L. O'Brien [2], D. Petit [3], D. Read [4], E. Lewis [4], H. Zeng [4], L. Thevenard [5], S. Cardoso [6], R. Cowburn [3]
(1) Unite Mixte de Recherche CNRS/Thales, (2) Dep. of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN 55455, USA, (3) Thin Film Magnetism Group, Cavendish Laboratory, University of Cambridge, UK, (4) Physics department, Imperial College London, UK, (5) Institut des Nanosciences de Paris, UMR 7588, France, (6) INESC-MN/ Institute for Nanosciences and Nanotechnologies, Lisbon, Portugal

Interactions between domain walls (DWs) in closely packed nanotracks are of critical importance to proposed DW logic and data storage devices [1,2], and have been shown to induce significant inter-DW pinning [3]. Here, we present position-resolved transport measurements of the magnetostatic interaction between DWs in adjacent spin valve nanotracks. These measurements reveal the inter-DW induced pinning and formation of coupled DW pairs, as well as dynamic effects such as the DW depinning induced by a near-by travelling DW. We also show how these effects can be used in DW logic devices.

[1] S. S. P. Parkin et al., *Science* **320**, 5873 (2008)
[2] D.A. Allwood et al., *Science* **309**, 1688 (2005)
[3] L. O'Brien et al., *Phys. Rev. Lett.* 103, 7 (2009)



Adjacent spin-valve tracks for interaction measurements: SEM image **(a)**. Simultaneous position determination of DW positions in both tracks from resistance measurements revealing inter-DW pinning and simultaneous depinning **(b)**.

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15.00 – 15.30
Atomically Assembled Quantum Spin Lattices *(invited)*
A.F. Otte [1]
(1) Kavli Institute of Nanoscience, TU Delft, The Netherlands

In this talk I will review recent progress towards controlling the spins of individual atoms on a surface through local access with an STM probe tip. Magnetic d-metal atoms, separated from a metal substrate by a thin decoupling layer, are studied through inelastic electron tunneling spectroscopy (IETS): a tool by which transition energies of spin states can be accurately followed. Combined with the possibility to rearrange the atoms at will, this intriguing technique enables the investigation of the interplay between magneto-crystalline anisotropy, spin coupling and the Kondo effect [1,2]. By addressing atomic spins with a spin-filtered probe tip, controlled excitations or de-excitations can be made, effectively pumping the spin into a magnetization direction of choice [3]. I will discuss avenues to further develop these techniques, leading up to the study of complex phases in extended atomically assembled lattices of magnetic atoms.

[1] C.F. Hirjibehedin et al., Science 317, 1199 (2007)
[2] A.F. Otte et al., Phys. Rev. Lett. 103, 107203 (2009)
[3] S. Loth et al., Nature Physics 6, 340 (2010)

15.30 – 15.45
Chirality selection in the vortex state of magnetic nanodisks with a screw dislocation
A.B. Butenko [1], U.K. Rößler [1], A.N. Bogdanov [1]
(1) IFW Dresden, 01069 Dresden, Germany

Structural defects in magnetic crystalline materials may locally change magnetic properties and can significantly influence the behavior of magnetic nanostructures. E.g., surface-induced Dzyaloshinskii-Moriya interactions can strongly affect vortex structures in magnetic nanodisks causing a chirality selection [1]. Near lattice defects, the spin-orbit interactions induce local antisymmetric Dzyaloshinskii-Moriya exchange and cause effective anisotropies, which can result in spin canting. Broken inversion symmetry near a defect leads to locally chiral exchange. Hence, effects induced by screw dislocations can explain experimentally observed chirality selection in torsionally deformed helimagnets. We present a phenomenological approach for dislocation-induced Dzyaloshinskii-Moriya couplings. As an example we investigate effects of a screw dislocation at the center of a magnetic nanodisk with a vortex state. By numerical calculations on vortex profiles we analyze equilibrium parameters (the size, shape, and stability) of the vortex as functions of applied magnetic field and the material and geometrical parameters. It is proposed that magnetic nanodisks with defects provide a suitable experimental setting to study induced chirality by spin-orbit effects.

[1] A.B. Butenko et al., Phys. Rev. B 80**,** 134410 (2009).

15.45 – 16.00
Magnetoplasmonic Kerr effect
V. Bonanni [1], N. Maccaferri [2], M. Kataja [3], S. Bonetti [4], Z. Pirzadeh[1], J. Nogués [5], P. Vavassori [2], J. Akerman [4], A. Dmitriev [1]
(1) Department of Applied Physics, Chalmers University of Technology, 41296 Göteborg, Sweden, (2) CIC nanoGUNE Consolider, 20018 Donostia-San Sebastián, Spain, (3) NanoSpin, Aalto University School of Science, FI-00076 Aalto, Finland, (4) Material Physics, Royal Institute of Technology, 16440 Kista, Sweden, (5) CIN2 and Univ. Autònoma de Barcelona, Catalan Institute of Nanotechnology (ICN), Campus UAB, 08193 Bellaterra, Spain

Magnetoplasmonics is becoming a very active area of research where magnetic materials are combined with nanometer-scale systems supporting surface or localized surface plasmon resonances (LSPR). The cooperation between the plasma resonance and magneto optical (MO) effects can lead to new physical phenomena as the control of plasmons by an external magnetic field [1]. Interestingly, the direct excitation of LSPRs can take place even in purely ferromagnetic nanostructures [2] despite the high ohmic losses of these materials. In particular, a strong and tunable correlation between the localized plasmons and MO, i.e., the polarizability and the sign of Kerr rotation has been recently reported [3]. The pure plasmonic and the MO responses show sizably different wavelength dependence (anisotropic polarizability) allowing to address them separately by choosing appropriate excitation wavelength and light polarization direction.
Here we show how the anisotropic polarizability is reflected in the 'magnetoplasmonic Kerr effect' for shape-anisotropic ferromagnetic nanostructures as nanoelliptical disks and circular nanopillars where the optical response critically depends on both the incident light and polarization directions.

[1] V. V. Temnov et al., Nat. Photonics 4, 107 (2010)
[2] J. Chen et al., Small 7, 2341 (2011)
[3] V. Bonanni et al., Nano Lett. 11, 5333 (2011)

16.00 – 16.15
Perpendicularly magnetized Co/Ni(111) multilayers: spin waves in presence of magnetic domains
G. Gubbiotti [1], G. Carlotti [2], S. Tacchi [2], M. Madami [2], T. Ono [3], T. Koyama [3], D. Chiba [3], F. Casoli [4], *M.G. Pini* [5]
(1) Istituto Officina dei Materiali del CNR (CNR-IOM), Unità di Perugia, c/o Dipartimento di Fisica, Università di Perugia, I-06123 Perugia, Italy, (2) CNISM, Unità di Perugia and Dipartimento di Fisica, Università di Perugia, I-06123 Perugia, Italy, (3) Laboratory of Nano Spintronics, Division of Materials Chemistry, Istitute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan, (4) Istituto Materiali per Elettronica e Magnetismo del CNR (CNR-IMEM), I-43124 Parma, Italy, (5) Istituto dei Sistemi Complessi del CNR (CNR-ISC), Unità di Firenze, I-50019 Sesto Fiorentino (FI), Italy

Co/Ni(111) multilayers with variable cobalt thickness t_{Co} between

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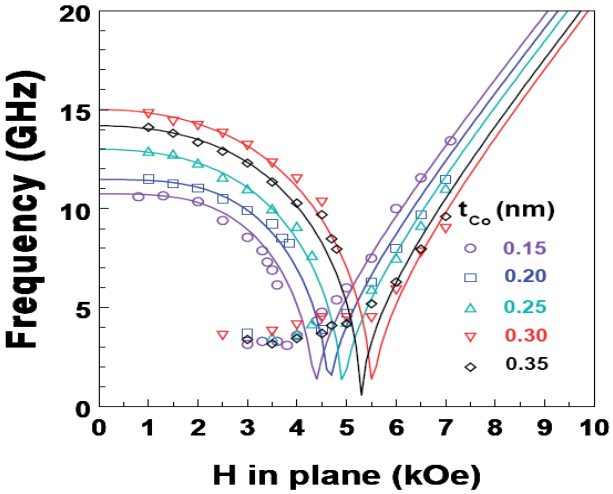
0.15 and 0.35 nm, and fixed nickel thickness t_{Ni}=0.6 nm, were grown on a Pt(1.6 nm)/Ta(3 nm) substrate by dc magnetron sputtering[1]. A strong perpendicular magnetic anisotropy was found both using vibrating sample magnetometry and Brillouin light scattering from thermally excited spin waves. The simultaneous presence of two spin-wave modes, for a range of magnetic fields *H* applied in plane between 2 and 5 kOe, was connected with the presence of bubble domains, revealed by polar Kerr microscopy.
The lower frequency mode ($\nu \approx 3$ GHz), which exhibits a smooth dependence on the strength of *H*, was attributed to harmonic oscillations of the domain walls. The higher frequency mode, which displayed the typical field behavior of a film with a perpendicular anisotropy, was interpreted as the superposition of two nearly degenerate modes, associated respectively with the in-phase and out-of-phase precession of the spins in the bubble array[2]. The higher frequency mode also displayed an unprecedented, non monotonic dependence *on cobalt thickness*, reflecting the non monotonic t_{Co}-dependence of the effective anisotropy field of the multilayer. Both the observed *H*- and t_{Co}-dependence of the higher frequency mode were well reproduced by a model of two strongly coupled layers of Co and Ni with very different magnetic anisotropies [3], including a second-order contribution to the uniaxial perpendicular magnetic anisotropy of Co.

[1] S. Fukami et al., Appl. Phys. Express **3**, 113002 (2010)
[2] J. O. Artman and S. H. Charap, J. Appl. Phys. **49**, 1587 (1978)
[3] A. Layadi, J. Appl. Phys. **83**, 3738 (1998)



Measured and calculated spin wave frequency of Co/Ni multilayers

16.15 – 16.30
Spin polarization in Au-Fe oxide magneto-plasmonic heterostructures

C. De Julián Fernández [1], F. Pineider [2], G. Campo [3], V. Videtta [4], P.D. Cozzoli [5], P. Massala [6], M. Scavini [6], A. Al Hourani [7], A. Caneschi [3], C. Sangregorio [1], P. Ghigna [7]
(1) ISTM- Milano & INSTM R.U. Florence, CNR, 20133, Italy, (2) ISTM- Padova & INSTM R.U. Florence, CNR, 35131, Italy, (3) INSTM R.U. Florence and Department of Chemistry, University of Florence, 50019, Italy, (4) NNL-Istituto Nanoscienze, CNR, 73100, Italy, (5) NNL- CNR & INSTM & Department of Mathematics and Physics, University of Salento, 73100, Italy, (6) Department of Physical Chemistry, University of Milan, 20133, Italy, (7) Department of Chemistry & INSTM, University of Pavia, 27100, Italy

The transfer of magnetic moment on Au in Au@Fe oxide Magneto-Plasmonic (MPs) heterostructures exhibiting core-shell and heterodimer morphologies has been investigated. MPs are multifunctional nanomaterials composed by two different moieties having plasmonic and magnetic properties, respectively. New properties in addition arise from the interplay between the two materials [1,2] such as: enhancement of the magneto-optical response, modification of the plasmonic dynamics and changes in the reversal of magnetisation. The mechanisms determining these new effects are at the moment poorly understood.
In this work we present a detailed study of the magnetic and chemical properties of colloidal Au@iron oxide nano-heterostructures having both a range of core@shell morphologies, and dumbbell-like heterodimers with different dimensions. Our investigation was carried out by combining XMCD and XANES spectroscopies, X-Ray Diffraction and SQUID magnetometry for investigating structural, magnetic properties and possible spin and charge transfer between the two components of the heterostructure. We demonstrate for the first time that spin transfer is possible in these metal/oxide heterostructures: a magnetic moment on gold was observed in Au @Fe oxide nanoparticles with lateral sizes of *ca.* 10 nm and composed by a mixture of Fe_{3}O_{4} and FeO. In other heterostructures with different composition, size and morphology a spin polarization on Au was not detected, excluding that the outcome is simply due to proximity effects. Our results indicate that the spin polarization is driven by the chemical nature of the iron oxide interfacing the Au core domain. This constitutes a new mechanism of spin polarization transfer, which is in addition compatible with plasmonic nanostructures. This research was supported by Cariplo project 2010–0612 and by NANOMAGMA (NMP3 FP7-214107-2).

[1] M. B. Cortie, A. M. McDonagh, Chem. Rev. 111, 3713 (2011)
[2] G. Armelles et al., J. Opt. A: Pure Appl. Opt. 11, 114023 (2009)

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MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

NANOSTRUCTURES 1

Chair: P. Allia

16.30 – 16.45

Magnetic states of individual ferromagnetic nanotube probed by anisotropic magnetoresistance

D. Rüffer [1], R. Huber [2], P. Berberich [2], E. Russo-Averchi [1], M. Heiss [1], J. Arbiol [3], A. Fontcuberta I Morral [1], D. Grundler [4]

(1) Laboratoire des Matériaux Semiconducteurs, Institut des Matériaux, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland, (2) Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, D-85747 Garching bei München, Germany, (3) Institució Catalana de Recerca i Estudis Avançats (ICREA) and Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), 08193 Bellaterra, Spain, (4) Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, D-85747 Garching bei München, Germany & STI, Ecole Polytechnique Fédérale de Lausanne,1015 Lausanne, Switzerland

Future high-density memory elements and spintronic devices are expected to employ nanoscale ferromagnets as basic building blocks. Recently, a novel type of magnetic structure, the ferromagnetic nanotube, has been fabricated. The tubular geometry is interesting as it offers, compared to solid wires, an additional geometrical parameter for tuning the magnetic properties. Furthermore, because such a tube is free of magnetic matter along the axis, Vortex states without magnetic singularity in the core are possible. Hybrid structures consisting of a semiconductor nanowire surrounded by a ferromagnetic nanotube offer novel perspectives for spin injection and spin transport in a one-dimensional electron system. Although theoretical predictions for the magnetizations states exist [1], up to now only large ensembles of nanotubes have been studied experimentally [2].

We report on magnetotransport studies performed on individual ferromagnetic nanotubes deposited on GaAs nanowires with a diameter of 150 nm, grown by molecular beam epitaxy (MBE). The 40 nm thick shell of metallic ferromagnet Ni was deposited by atomic layer deposition (ALD). Single tubes were electrically contacted to perform magnetoresistance measurements under varying field orientation in cryogenic environment. We found hysteretic magnetoresistance behavior. Analyzing the peculiar behavior in terms of the anisotropic magnetoresistance in thin films we develop for the first time a classification of relevant magnetization states in the nanotube [3]. We identify and distinguish different characteristic states during the reversal of the magnetization in magnetic field parallel and perpendicular to the external field. Depending on the magnetic history, our data suggest the tube to be in a vortex- or onion-like state at remanence.

The work has been supported by the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement No. 228673 MAGNONICS.

[1] Landeros et al.. Phys. Rev. B 79, (2009)
[2] Albrecht et al., J. Appl. Phys 109, (2011)
[3] Rüffer et al., submitted.

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS -

COMPUTATIONAL MAGNETISM

Chair: T. Schreft

14.45 – 15.15

Extended Time and Length Scale Micromagnetics *(invited)*

D. Süss [1], C. Vogler [1], F. Bruckner [1], J. Fidler [1], T. Schrefl [2], C. Dellago [3]

(1) Institute of Solid State Physics, Vienna University of Technology, 1040, Vienna, Austria, (2) University of Applied Science, 3100, St Poelten, Austria, (3) Faculty of Physics, University of Vienna, 1090 Vienna, Austria

Various applications ranging from spintronic devices, giant magnetoresistance (GMR) sensors, and magnetic storage devices, include magnetic parts on very different length scales. The involved time scales ranges from the picosecond regime (internal precessional frequency) to years in order to predict the thermal stability of magnetic structures. Within this work we present state of the art methods to bridge the length scales of standard micromagnetic simulations to macroscopic feature size (mm) and extend the time scales to years.

Using the Landau-Lifshitz-Gilbert equation (LLG) constrains the maximum element size to the exchange length. Hence, it is not possible to simulate macroscopic parts with a pure micromagnetic approach. To bridge the length scale we will present a hybrid solver, where micromagnetic parts are coupled to macroscopic magnets which are described by Maxwell's equations using the experimentally obtained material law. Results of magnetic recording heads, where macroscopic shields are simulated using Maxwell equations and the media is simulated using LLG will be presented.

To bridge the time scale gap we developed a technique consisting of a combination of a nudged elastic band (NEB) method, which is part of our finite element micromagnetic package FEMME, and a statistical method to simulate rare events called "Forward Flux Sampling" (FFS). Forward flux sampling uses a series of interfaces between the initial and final states to calculate the average lifetime of a magnetic state and to generate transition paths for rare events in equilibrium or nonequilibrium systems with stochastic dynamics. In between the interfaces Langevin micromagnetic simulations are performed. Using this technique we present calculations of the lifetime of magnetic structures of various shapes which are thermally stable and not directly accessible by standard Langevin simulations. The developed method successfully predicts the rare event switching periods.

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15.15 – 15.45
Eddy current effects in micro magnetic systems *(invited)*
R. Chang [1], M. Escobar [1], S. Li [1], S. Fu [1], M. Lubarda [1], *V. Lomakin* [1]
(1) Center for Magnetic Recording Research / University of California, San Diego / La Jolla, CA 92037, USA

Eddy currents play a significant role in many physical systems. In micromagnetics, Eddy currents may substantially affect the magnetization dynamics and therefore they are important to account for when modelling a number of magnetic devices.
The goal of this work is two-fold. First, we present an efficient method of incorporating the Eddy currents in the Landau-Lifshitz-Gilbert (LLG) equations. In this method, the fields due to the Eddy currents are computed via double integral operators, the LLG equation is cast in an implicit form, and efficient time stepping techniques are used for the time integration. The benefits of the method are that no additional unknowns are introduced, the time step can be large, and highly efficient parallel implementations can be developed.
Next, we present the micromagnetic study of the Eddy current effects on the magnetization dynamics in several complex magnetic systems. In particular, Eddy currents can affect precessional mechanisms, effectively resulting in increased damping. These effects have implications in terms of the device performance. For example, for magnetic recording heads, the increased damping can improve the performance in terms of the switching time and switching robustness. Understanding Eddy currents is also important for understanding heating mechanisms induced by the magnetization dynamics.
Figure 1 demonstrates a simple example of dynamics in a permalloy cube of 27 nm size. The dynamics depends on the conductivity (the z-component of the magnetization is shown). The switching is faster when accounting for the conductivity, which is associated with the presense of Eddy currents. Eddy current also suppress the precessional magnetization motion

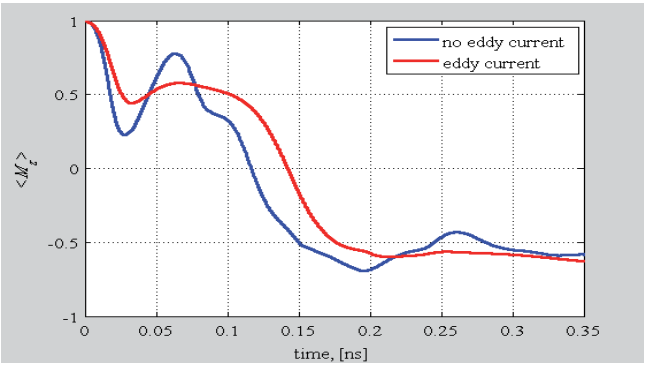

Figure 1.

15.45 – 16.00
Metastability and quantum phenomena in arrays of micron-size permalloy disks
R. Zarzuela [1], S. Velez [1], J.M. Hernandez [1], J. Tejada [1], V. Novosad [2]
(1) Grup de Magnetisme, Departament de Física Fonamental, Facultat de Física, Universitat de Barcelona, 08028 Barcelona, Spain, (2) Materials Sciences Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

The vortex state being characterised by an in-plane closed flux domain structure and an out-of- plane magnetization at its centre (known as the vortex core) is one of the magnetic equilibria of thin soft ferromagnetic micron-size dots. The vortex core is a mesoscopic object and so it is a suitable candidate to observe quantum tunneling of its magnetic moment between classically stable magnetic configurations. For the first time, we report experimental evidence of quantum dynamics of the vortex core of micron-size Permalloy ($Fe_{81}Ni_{19}$) disks induced by the application of an in-plane magnetic field. It is attributed to the quantum tunneling of the vortex core through pinning barriers, which are associated to structural defects in the dots, towards its equilibrium position.
Under the application of a perpendicular magnetic field, the ground state of an array of soft ferromagnetic micron-size dots is determined by the competition between the coupling of the external magnetic field with the magnetic moment of the dots (which tend to align with the field direction) and the dipolar interaction among these magnetic moments (both in and out-of-plane components). At moderate perpendicular fields, dipolar ordering leads to the appearance of metastable states in these ensembles of dots. For the first time, we report experimental evidence of a 'spin-glass' like behaviour of the magnetization in arrays of micron-size Permalloy ($Fe_{81}Ni_{19}$) disks.

16.00 – 16.15
Injection locking at zero field in hybrid spin-valves
G. Finocchio [1], M. Carpentieri [2], B. Azzerboni [1]
(1) Department of Fisica della Materia e Ingegneria Elettronica, University of Messina, C.da di Dio, I-98100, Messina, Italy., (2) Department of Elettronica, Informatica e Sistemistica, University of Calabria, Via P. Bucci 42C, I-87036, Rende (CS), Italy

Recent experiments point out the possibility of achieving microwave oscillations (oscillation frequency around 6GHz) with zero external field in spin valves composed of two in-plane free layers and two out-of-plane polarizers e.g. the structure is $[Co\ 0.5/Pt\ 2]_4/Co\ 0.6/Cu\ 2/Co\ 4/Cu\ 4/Co\ 4/Cu\ 2/[Co\ 0.2/Ni\ 0.8]_8$ where the number after each element is the film thickness in nm.[1] Micromagnetic simulations show that the origin of the dynamical behavior is due to nucleations and rotation of an edge vortex [2] coupled with a propagating domain wall in each free layer. The dynamics of the two free layers are phase locked each other giving rise to a frequency doubling. In other words, the oscillation frequency of the giant-magnetoresistive (GMR) signal is two times the oscillation of the magnetization. Here we present a micromagnetic study[3] of the complex spin-valves with different shape anisotropy in a symmetric case (both polarizers are Co/Ni) or in an asymmetric case (polarizers are Co/Ni and Co/Pt). We also study the injection locking response to a microwave current. Our results indicate around 20% smaller critical current in the symmetric configuration. We also

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found a fractional locking (1/2) for both configurations, while larger locking region is observed in the case of asymmetric perpendicular polarizer. At 300K, the fractional locking gives rise to a reducing of the linewidth of the GMR oscillation frequency of one order of magnitude.

[1] T. Moriyama, G. Finocchio, M. Carpentieri, B. Azzerboni, D. C. Ralph, R. A. Buhrman, submitted for publication.
[2] Ki-S. Lee, M-W. Yoo, Y.-S. Choi, and S.-K. Kim, Phys. Rev. Lett. 106, 147201 (2011).
[3] G. Finocchio, V. S. Pribiag, L. Torres, R. A. Buhrman, B. Azzerboni. Appl. Phys. Lett. 96, 102508, (2010).

16.15 – 16.30
Field dependence of microwave frequency absorption in antiferromagnet/ferromagnet exchange coupled multilayers
F. Gonçalves [1], S. O'Reilly [2], R. Bowman [2], T. Drysdale [1], D. Schmool [3], *R.L. Stamps* [1]
(1) SUPA-School of Physics and Astronomy, University of Glasgow, Glasgow G61 8QQ UK, (2) Centre for Nanostructured Media, School of Maths and Physics, Queen's University of Belfast, Belfast BT7 1NN UK, (3) IN-IFIMUP and Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Rua Campo Alegre 687, 4169 – 007 Porto, Portugal

Control of ferromagnetic resonance frequencies can be achieved through exchange coupling anisotropies across a ferromagnet/antiferromagnet interface. The magnitude of the shifts depends upon film thickness, quality of the interface, magnitude of the coupling, and the type of anisotropy. [1] An advantage of exchange coupled multilayers for microwave applications is the high saturation magnetisation, large filling factor, and soft coercivity of the ferromagnet component. [2,3] We report magnetisation and broadband VNA ferromagnetic resonance studies of FeNi/FeMn multilayers. Analysis of fine structure in the resonance spectra allow us to determine the magnitude of variations in the exchange anisotropy field at interfaces buried in the structure. In some cases, it is possible to associate exchange field values with specific layers in the stack by correlating soft modes with structure observed in magnetisation loops.

[1] R. L. Stamps, R. E. Camley, R. J. Hicken, Phys. Rev. B 54, 4159 (1996).
[2] Y. Lamy, B. Viala, IEEE Trans. Magn. 42, 3332 (2006).
[3] N. N. Phuoc, F. Xu, C. K. Ong, Appl. Phys. Lett. 94, 092505 (2009).

16.30 – 16.45
Competition between surface effects and dipolar interactions in an assembly of nanomagnets
O. Iglesias [1], Z. Sabsabi [2], F. Vernay [2], H. Kachkachi [2]
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From a fundamental point of view, it remains crucial to have an experimental access to single particle intrinsic properties of nanomagnets. Such a characterization provides information on intra-particle quantities like exchange, anisotropy but also on surface effects that become predominant at the nanoscale. Yet, most of the current experimental data are not relevant to individual particles but rather to assemblies of nanomagnets. In this case, collective effects can no longer be neglected as the magnetic properties of the assembly are a result of the interplay between intrinsic properties of the individual entities and inter-particle interactions, which must be taken into account in any theoretical interpretation of experimental data. Taking into account solely dipole-dipole interactions (DDI), we investigate the competition between intrinsic and collective effects in monodisperse assemblies of nanomagnets with oriented anisotropy in the low-density limit. We show that surface anisotropy can be incorporated in the established perturbative approach to DDI [1] within the scope of the effective one-spin problem [2], establishing a new theoretical framework to study the competition between both. In particular, we derive approximate formulas for the thermal and field dependence of the assembly magnetization. In order to in order to establish the range of validity of the analytics results are compared to those obtained from Heisenberg Monte Carlo simulations of two models: a) macrospin ensemble with DDI and uniaxial and cubic anisotropies; b) interacting ferromagnetic particles atomistic spins. The results allow to clarify the distinct influence of surface and interaction effects on measured magnetization curves in real samples with different degrees of concentrations and particle sizes.

[1] M. Azeggagh and H. Kachkachi, Phys. Rev. B **75**, 174410 (2007); Eur. Phys. J. B 44, 299 (2005).
[2] R. Yanes, O. Fesenko-Chubykalo, H. Kachkachi, D.A. Garanin, R. Evans, R. W. Chantrell, Phys. Rev. B 76, 064416 (2007).

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PEROVSKITES AND MULTIFERROICS
Chair: C. Ederer

14.45 – 15.15
Tuning the structure and properties of $BiFeO_3$ and related materials from first-principles *(invited)*
O. Dieguez [1]
(1) ICMAB-CSIC, Campus de la UAB, Bellaterra 08193 Spain

Bismuth ferrite (BiFeO3 or BFO) is the most studied multiferroic material. It has been found that when it is grown as a film on particular substrates it shows a supertetragonal structure that is very different from its rhombohedral ground state, and that using an electric field it is possible to switch between these two phases. In this talk I will review our recent first-principles studies on the structure and properties of BFO and related materials. First, we have shown that those film supertetragonal structures exist also as metastable minima of the *bulk* material [Diéguez, González-Vázquez, Wojdeł, and Íñiguez, PRB 83, 094105 (2011)]. Second, we propose to use chemical substitution as a complement to epitaxial strain in order to take BFO to a region of its phase diagram where a field can be used to switch between rhombohedral and supertetragonal phases; we illustrate this by characterizing the strong responses that appear at the right composition of a solid solution of BFO and bismuth cobaltite [Diéguez and Íñiguez, PRL 107, 057601 (2011)]. Third, we consider extending these mechanisms to other related materials that might have particular properties of interest. And fourth, we study the formation of domain walls in rhombohedral BFO, that have been shown to have properties very different from the bulk such as being conducting.
This work has been done in collaboration with Otto González-Vázquez, Jacek C. Wojdeł, and Jorge Íñiguez, (ICMAB-CSIC).

15.15 – 15.30
Multiferroicity in Vanadium doped $La_2Ti_2O_7$: Insights from first-principles
M. Scarrozza [1], *A. Filippetti* [1], V. Fiorentini [1]
(1) CNR-IOM, UOS Cagliari, and Physics Department, University of Cagliari, I-09042 Monserrato (CA), Italy

La2Ti2O7 (LTO) is a wide-gap layered perovskite ferroelectric (Tc=1770 K, Ps=0.05 C/m2), where polarization (P) is produced by antiferrodistortive octahedra rotations failing to compensate due to the layered structure [1]. To turn on multiferroicity, i.e. a magnetization (M) in addition to the electrical one, we investigated magnetic doping from first-principles within density-functional theory.
Heterovalent substitution of Ti with Sc, Cr and V does yield ferromagnetism. Sc doping induces resonant electronic states at the top valence band (TVB) causing metallicity, it is ferromagnetically coupled, but oxygen vacancies form very easily, spoiling the effect entirely. Cr doping produces deep gap states (~1.8 eV from the TVB). V is the most promising, inducing states in proximity of the conduction band, resulting in a small gap insulating material (0.2 eV).
The V dopants align along a direction orthogonal to P, with strong ferromagnetic order (a stabilization energy of ~78 meV/atom), forming magnetic chains in the ferroelectric host. Supercell calculations at lower doping concentration indicate a tendency of V to clustering along chains, preserving both the insulating nature and the ferromagnetic unidirectional order.
The analysis of the electronic properties of the V-doped LTO shows that the origin of the robust ferromagnetic order lies in the peculiar layered structure of the host, whose structural anisotropy favors directional orbital overlap, resulting in degeneracy removal of the t2g levels and the opening of a small gap. Even more intriguingly, it turns out that the V-based magnetic chains exhibit both spin ordering (ferro) and orbital ordering (antiferro). Our results indicate that V-doped LTO is properly multiferroic. Moreover, we showed that the layered structure of this material, which is at the origin of its ferroelectricity, is also a key to enhance ferromagnetic order when doped with vanadium.

[1] J. Lopez-Perez and J. Iniguez, Phys. Rev. B 84, 075121 (2011).

15.30 – 15.45
Properties of strongly coupled multi-ferroic $Sr_{1-x}Ba_xMnO_3$ perovskites
B. Dabrowski [1], J. Mais [1], S. Kolesnik [1], O. Chmaissem [1]
(1) Department of Physics, Northern Illinois University, DeKalb, IL, USA

Search for multi-ferroic materials, where magnetism and ferroelectricity are strongly coupled, is of fundamental technological and theoretical importance. Weak-coupling between post-transition metal's ferroelectricity of s/p-electrons and transition metal's d-electrons magnetism is known above room temperature (for example, $Bi^{3+}Fe^{3+}O_3$). Improper ferroelectrics, where the same d-electrons are responsible for both ferroelectricity and magnetism are also known (for example, $HoMnO_3$) but their spontaneous polarizations are small and appear at low temperatures. As a result of over 20 years of research on transition metal perovskites AMO_3 we have developed empirical "tolerance factor synthesis-properties design rules" for predicting and obtaining perovskite compounds exhibiting unique properties [1,2]. We have applied these rules [3] to obtain the first strongly coupled multi-ferroic $Sr_{1-x}Ba_xMnO_3$ perovskites for which ferroelectricity (T_F~400 K) and antiferromagnetism (T_N~240 K) originate exclusively from Mn d^3-electrons. Similar to $Ba^{2+}Ti^{4+}O_3$, the classical ferroelectric effects occurs in $Sr_{1-x}Ba_xMnO_3$ (x>0.4) when the Mn ions move out of the center of the MnO_6 octahedral units as a result of deliberately introduced enormous tension exerted on the Mn-O bonds by chemical substitutions. Because of development of the d^3-electrons magnetism these materials exhibit the largest known magneto-electric coupling at T_N. I will describe structural, magnetic and ferroelectric properties of these materials and our recent attempts to obtain similar ferromagnetic manganites with elongated Mn-O bonds.

[1] B. Dabrowski, O. Chmaissem, J. Mais, S. Kolesnik, J.D. Jorgensen, and S. Short, J. Solid State Chem. 170, 154-164 (2003)
[2] B. Dabrowski, O. Chmaissem, J. Mais, and S. Kolesnik, Acta Physica Polonica A 105, 45-56 (2004)
[3] O. Chmaissem, B. Dabrowski, S. Kolesnik, J. Mais, D.E. Brown, R. Kruk, P. Prior, B. Pyles, J.D. Jorgensen, Phys. Rev. B 64, 134412 (2001)

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PEROVSKITES AND MULTIFERROICS
Chair: C. Ederer

15.45 – 16.00

Electronic structure and optical properties of hexagonal multiferroic orthoferrites $RFeO_3$ (R=Ho, Er, Lu)

V. Pavlov [1], A. Akbashev [2], A.M. Kalashnikova [1], V. Rusakov [1], A. Kaul [2], M. Bayer [3], *R. Pisarev* [1]

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Thin films of hexagonal (P.G. 6*mm*) rare-earth orthoferrites $RFeO_3$ (*R*=Ho, Er, Lu) with a thickness of 50-70 nm are grown epitaxially on a (111)-surface of ZrO_2 (Y_2O_3) substrate [1]. The optical study in the range of 0.5-5.6 eV shows that the films are transparent below 1.9 eV; above this energy several broad intense absorption bands are distinguished. Absorption spectra of hexagonal orthoferrites (see Figure) with the fivefold coordinated iron ions noticeably differ from those of perovskite orthoferrites with the octahedral oxygen coordination which are transparent below 2.4 eV. Observed optical features are assigned to particular transitions based on electronic structure calculations using the crystal field theory. Temperature dependencies of the optical absorption and the linear optical birefringence show anomalous behavior at 120-130 K, which we attribute to magnetic ordering of iron sublattices. Below 20 K the birefringence shows another anomaly which we attribute to the rare-earth sublattices. We may conclude that the films of hexagonal (P.G. 6*mm*) rare-earth orthoferrites $RFeO_3$ must show multiferroic properties which were demonstrated recently in Refs. [2].

The work is supported by RFBR, Projects 12-02-00130, 10-02-01008.

[1] V. V. Pavlov, A. R. Akbashev, A.M. Kalashnikova et al., J. Appl. Phys. **111**, 056105 (2012)

[2] Y. K. Jeong, J.-H. Lee, S.-J. Ahn, et al., J. Am. Chem. Soc. **134**, 1450 (2012)

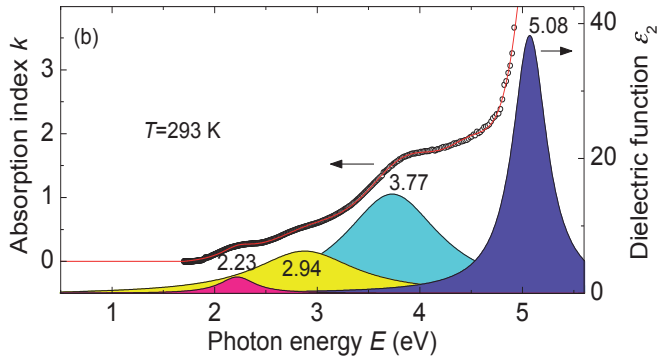

Figure. Optical spectrum of the mean value of the absorption indices of $HoFeO_3$ and $ErFeO_3$ at T=293 K (symbols) and its fit (line).

16.00 – 16.15

Phase transitions in $LiNiPO_4$ olivine – specific heat and torque studies

A. Szewczyk [1], M.U. Gutowska [1], S. Lewińska [1], J. Wieckowski [1], Y. Kharchenko [2], M.F. Kharchenko [2], M. Kowalczyk [3], N. Nedelko [1], A. Ślawska-Waniewska [1], A. Kulka [4], J. Molenda [4]

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On the contrary to Li*M*PO_4 olivines with *M* = Mn, Fe, Co, in $LiNiPO_4$ two step transformation between the paramagnetic and a uniform in space antiferromagnetic phase occurs. At first, a long-range magnetic order develops in the form of an incommensurate antiferromagnetic phase (via the second-order transition at 21.8 K). Then, the first-order transition to the antiferromagnetic phase occurs at 20.9 K. To investigate thermal effects related to these transitions, as well as an influence of magnetic field, *B*, on them, specific heat studies of a $LiNiPO_4$ single crystal were performed. The specific heat was measured from 3 K to 60 K, in zero magnetic field and in the fields up to 9 T, applied along three main crystallographic directions. It was found that *B* applied along the *a* and *b* directions has no effect on the transitions and on the specific heat anomalies accompanying them, whereas *B* directed along the *c* axis shifts both transitions towards lower temperatures (with the transition temperatures depending parabolically on the *B* value). The field of 9 T shifts both transitions by ~1 K. To elucidate these effects and peculiarities of magnetic structure in all phases, supplementary studies of magnetic torque were performed for *B* rotating within *a*-*c* and *b*-*c* planes, for several *B* values, for a series of fixed temperatures. The studies revealed that: (i) the low temperature first-order transition is split into two transformations, (ii) within the region of existence of the incommensurate magnetic phase, transformations of the magnetic structure and a change of magnetic anisotropy occur within the *b*-*c* plane, and (iii) the magnetic moments remain strongly confined to the *b*-*c* plane for all temperatures.

This work was partly supported by the European Union, within the European Regional Development Fund, through the Innovative Economy Grants POIG.01.01.02-00-108/09 and POIG.02.02.00-00-025/09.

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PEROVSKITES AND MULTIFERROICS
Chair: C. Ederer

16.15 – 16.30
Magnetic and Mössbauer characterization of the multiferroic fluoride $K_3Fe_5F_{15}$
F. Mezzadri [1], G. Calestani [2], C. Pernechele [3], M. Solzi [3], G. Spina [4], L. Cianchi [5], F. Del Giallo [5], M. Lantieri [5], M. Buzzi [3], E. Gilioli [1]
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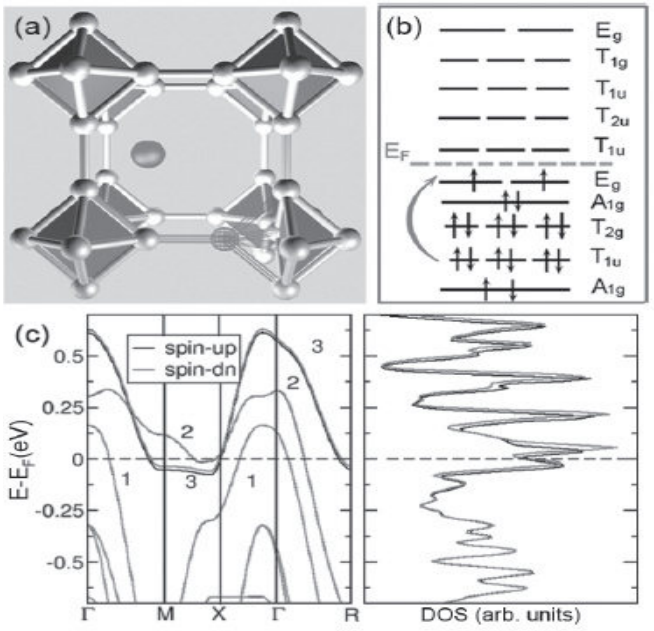
The iron potassium fluoride $K_3Fe_5F_{15}$ is an interesting multiferroic material, for which the coexistence of all the three ferroic orders (elastic, electric, magnetic) is observed below the magnetic ordering transition [1]. The cooperative use of diffraction techniques and physical characterizations allowed the study of the ferroic features separately, while the possibility of coupling is suggested by several observations reported in literature [2]. Ferroelectricity is ascribed in this system to the shift of the iron ions off the center of the coordination octahedra, while two different ferroelastic components are observed, being produced by a slight orthorhombic distortion of the fundamental cell and by a large superstructure related to the cooperative tilting of the corner-sharing FeF_6 octahedra. The complex magnetic behavior was recently explained by the use of magnetization measurements carried out on oriented single crystals, combined with Mössbauer spectroscopy and powder neutron diffraction data [3]. The ferrimagnetic behavior of $K_3Fe_5F_{15}$ results to be related to an antiferromagnetic triangular spin system, frustrated by the difference in the magnetic contributions of adjacent structural layers, originated by Fe(II)/Fe(III) charge ordering. This feature, together with the pseudotetragonal character of the structure, accounts also for the complexity of the M(H) measurements, showing hard behavior and coercive field H_C = 1.4T.

[1] F. Mezzadri, S. Fabbrici, E. Montanari, L. Righi, G. Calestani, E. Gilioli, F. Bolzoni, and A. Migliori, Phys. Rev. B, 78, 064111 (2008)
[2] R. Blinc, G. Tavcar, B. Žemva, D. Hanžel, P. Cevc, C. Filipič, A. Levstik, Z. Jagličić, Z. Trontelj, N. Dadal, V. Ramachandran, S. Nellutla, and J.F. Scott, J. Appl. Phys. 103, 074114 (2008)
[3] Mezzadri F, Calestani G, Pernechele C, Solzi M, Spina G, Cianchi L, Del Giallo F, Lantieri M, Buzzi M, Gilioli E, Phys. Rev. B, 84, 104418 (2011)

16.30 – 16.45
Magnetism and anti-ferroelectricity in MgB_6
I. Popov [1], N. Baadji [1], S. Sanvito [1]
(1) School of Physics and CRANN, Trinity College, Dublin 4, Ireland

The formation of a magnetic moment and its long-range order in materials with no elements having partially filled *d* or *f* shells has been a controversial topic for long time. The coexistence of long-range magnetic and electric order even in compounds containing those elements is rather rare. We will present our *ab initio* study predicting the coexistence of weak ferromagnetism and antiferroelectricity in boron-deficient MgB_6. A boron vacancy causes a molecular orbital extended in one direction, which is responsible for the magnetic moment formation. The long-range magnetic order can emerge from the overlap of such orbitals above percolation threshold. Although there is a finite density of states at the Fermi level, the localized nature of the charge density causes an inefficient electron screening of point charges at Mg and B_6 sites. We find that the Mg^{2+} ions can displace from the center of their cubic cage, effectively breaking the central symmetry of the crystal and generating electrical dipoles. In the ground state these order in an antiferroelectric configuration. If proved experimentally, this will be the first material without *d* or *f* electrons displaying the coexistence of magnetic and electric order.

[1] I. Popov, N. Baadji and S. Sanvito, Phys. Rev. Lett. 108, 107205 (2012)



Atomic and electronic structure of MgB_6 with one vacancy.

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ELECTRONIC STRUCTURE AND CORRELATION EFFECTS IN MAGNETIC SYSTEMS
Chair: E. Pavarini

14.45 – 15.15
Electronic correlations and lattice dynamical properties of elemental iron near the alpha-gamma phase transition *(invited)*
I. Leonov [1]
(1) Theoretical Physics III, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

We present results of a theoretical investigation of the electronic and lattice dynamical properties of elemental iron at finite temperatures obtained within dynamical mean-field theory implemented with the frozen-phonon method [1]. This approach allows us to compute correlation induced lattice transformations and their temperature evolution. We find that electronic correlations are important to explain the lattice stability of iron at the bcc-fcc phase transition. We notice a weak anomaly in the transverse T_1 acoustic mode in the Γ-N direction of the bcc phase. This behavior can be ascribed to a dynamical precursor effect of the bcc-to-fcc phase transition and is found to occur above the Curie temperature. Upon further heating, the bcc phase becomes dynamically unstable due to the T_1 mode near the N point. By contrast, the fcc lattice is found to be dynamically stable in a broad temperature range, including temperatures above and below the bcc-fcc phase transition temperature. Our results for the structural phase stability and lattice dynamical properties of iron are in good agreement with experiment.

[1] I. Leonov, A. I. Poteryaev, V. I. Anisimov, and D. Vollhardt, Phys. Rev. Lett. **106**, 106405 (2011); *idem*, Phys. Rev. B **85**, 020401 (2012).

15.15 – 15.30
On the origin of short-range correlations in paramagnetic RCo_2
C.M. Bonilla [1], J. Herrero-Albillos [2], D. Paudyal [3], K.A. Gschneidner Jr. [3], V.K. Pecharsky [3], L.M. Garcia [1], F. Bartolomé [1]
(1) Instituto de Ciencia de Materiales de Aragón. CSIC-Universidad de Zaragoza, Departamento de Física de la Materia Condensada, Pedro Cerbuna 12, 50009 Zaragoza, Spain, (2) Instituto de Ciencia de Materiales de Aragón. CSIC-UnCentro Universitario de la Defensa, Academia General Militar-Uni. Zaragoza, 50090 Zaragoza, Spain, (3) Ames Laboratory, U.S. Department of Energy, Iowa State University, Ames, Iowa 50011-3020, USA

Short-range correlations, which are found within the paramagnetic phase of lanthanide RCo_2 compounds well above the ordering temperature by different experimental techniques,[1-4] are central to the occurrence of peculiar magnetic configurations, i.e. parimagnetism above the critical temperature of $ErCo_2$. Parimagnetism (an antiparallel configuration of the net magnetizations of two sublattices within a paramagnet under magnetic field) has been explained through the occurrence of a Griffiths-like phase in this system.[5] In order to obtain insights on the onset of the magnetic short range correlations we have performed first principle calculations in RCo_2 systems by using the local spin density approximation including the Hubbard U parameter (LSDA+U) implemented in the tight-binding linear muffin-tin orbital (TB-LMTO) method. In the theoretical model, we have considered a P1 unit cell with eight inequivalent positions for *R* atoms and 16 inequivalent positions for Co atoms. The inclusion of an impurity located at an interstitial position of the cell is needed to nucleate ferromagnetically coupled cobalt clusters. The imbalance of electron charge density between different Co sites due to the impurity within the unit cell could give rise the formation of magnetic short range magnetic correlations among Co atoms. Our work gives a plausible origin for the occurrence of Co ferromagnetic clustering, and therefore parimagnetism.

Work at Ames Laboratory is supported by US DOE under contract No.DE-AC02-07-CH11358. The authors acknowledge the support of IMANA and FEDER funds. C.M. Bonilla acknowledges Spanish Ministry of Economy and Competitivity.

[1] J. Herrero-Albillos, et al. Physical Review B 76, 094409 (2007).
[2] M. R. Soares, et al, J. of Magn. Magnetic Materials 202, 473 (1999).
[3] Y. Öner and O. Kamer, J. Appl. Phys. 103, 07E137 (2008).
[4] A. I. Figueroa, et al. J. Appl. Phys. 109, 07E118, 2011.
[5] J. Herrero-Albillos, et al. J. Phys.: Condens. Matter 21, 216004 (2009).

15.30 – 15.45
Rubidium superoxide: a p-electron Mott insulator
R. Kovacik [1], P. Werner [2], *C. Ederer* [3]
(1) Forschungszentrum Juelich, 52423 Juelich, Germany, (2) Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland, (3) Materials Theory, ETH Zurich, 8093 Zurich, Switzerland

Recently, *p*-electron magnetism has received great attention as alternative option for spintronic applications. The "*p*-magnetism" is often defect-induced and systematic studies are hampered by poor reproducibility and wide spread in experimental data. It is therefore desirable to study intrinsic *p*-magnetism in pure bulk materials. We present results of a combined density functional theory + dynamical mean field theory (DFT+DMFT) study for RbO_2, an insulating antiferromagnet where magnetic properties arise from partially filled oxygen *p* orbitals. For the high-symmetry tetragonal structure, we calculate the Hamiltonian in the basis of maximally localized Wannier functions [1] with antibonding π^* character, which is then solved within DMFT using a continuous-time quantum Monte Carlo solver [2]. We construct a metal-insulator phase diagram as function of temperature and Hubbard interaction parameters *U* and *J*. For realistic values of *U* and *J*, we find that RbO_2 is a paramagnetic insulator at room temperature. We also find indications for orbital order at low temperatures ($T \approx 30$ K) in

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agreement with our previous DFT study [3]. Furthermore, we discuss differences between the realistic Hamiltonian and the one based on the semicircle density of states.

[1] I. Souza, N. Marzari, D. Vanderbilt, Phys. Rev. B 65, 035109 (2001).
[2] E. Gull, *et al.*, Rev. Mod. Phys. 83, 349 (2011).
[3] R. Kováčik and C. Ederer, Phys. Rev. B 80, 140411(R) (2009).

15.45 – 16.00
Numerical study of coupled electron and spin systems on the Shastry-Sutherland lattice: Application to the rare-earth tetraborides
H. Cencarikova [1], P. Farkasovsky [1], N. Tomasovicova [1]
(1) Institute of Experimental Physics, Slovak Academy of Sciences, 040 01 Kosice, Slovakia

We present a simple model for a description of magnetization processes in rare-earth tetraborides. The model is based on the coexistence of two subsystems, and namely, the spin subsystem described by the Ising model and the electronic subsystem described by the Falicov-Kimball model on the Shastry-Sutherland lattice. Moreover, both subsystems are coupled by the anisotropic spin-dependent interaction of the Ising type. At $T=0$ the system exhibits magnetization plateaus at m/m_s=1/2, 1/3, 1/5, 1/7, 1/9 and 1/11 of the saturated spin magnetization m_s. The ground-states corresponding to magnetization plateaus have the same spin structure consisting of parallel antiferromagnetic bands (of the width w=1, 2, 4, 6, 8 and 10) separated by ferromagnetic stripes. For the largest plateaus corresponding to m/m_s =1/2 and 1/3 we have also examined the nature of the phase transitions from the low-temperature ordered phase to the high-temperature disordered phase. It is shown that both phases persist also at finite temperature (up to the critical temperature T_c) and that the phase transition at the critical point is of the second order for the m/m_s =1/2 phase and of the first order for the m/m_s =1/3 phase. The results obtained are used for a description of thermodynamic properties (the specific heat and magnetization curves) of rare-earth tetraborides.

16.00 – 16.15
Electron Spin Resonance in Antiferro-Quadrupolar Ordered CeB_6
P. Schlottmann [1]
(1) Department of Physics, Florida State University, Tallahassee, FL 32306, USA

CeB_6 is the first heavy fermion compound without ferromagnetic short-range correlations for which an ESR signal was observed [1]. The role of the ferromagnetic correlations among Ce or Yb spins in all other compounds displaying an ESR signal is to narrow the resonance width rendering it observable [2,3]. CeB_6 is a cubic compound with a Γ_8 ground-quartet. The orbital content of the quartet gives rise to an antiferro-quadrupolar ordered phase below 4 K. Single ions with a Γ_8 ground-multiplet are expected to display four transitions, however, only one has been observed. Two fundamental questions arise: (1) why is only one transition seen, and (2) why was this transition observed if the Kondo temperature is larger than the linewidth and there are no ferromagnetic correlations between the ions? While for other Ce and Yb compounds with ESR-signal it is not possible to distinguish if the resonance is due to localized spins or conducting heavy electron spins, an itinerant picture within the antiferro-quadrupolar state is necessary for the present case.
Work supported by the Department of Energy under grant No. DE-FG02-98ER45707.

[1] S.V. Demishev *et al*, Phys. Rev. B **80**, 245106 (2009)
[2] E. Abrahams and P. Wölfle, Phys. Rev. B **78**, 104423 (2008); P. Wölfle and E. Abrahams, Phys. Rev. B **80**, 235112 (2009)
[3] P. Schlottmann, Phys. Rev. B **79**, 045104 (2009)

16.15 – 16.30
Spin-spin correlations in magnetic nanosystems at finite observation times
E.Y. Vedmedenko [1], R. Wieser [1], T. Stapelfeldt [1], R. Wiesendanger [1]
(1) IAP, University of Hamburg,20355, Hamburg

Using exact diagonalization, Monte-Carlo, and mean-field techniques, characteristic temperature scales for ferro and antiferromagnetic order are discussed for the Ising and the classical anisotropic Heisenberg model on finite lattices in one and two dimensions. The interplay between nearest-neighbor exchange, anisotropy and the presence of surfaces leads, as a function of temperature, to a complex behavior of the distance dependent spin-spin correlation function, which is very different from what is commonly expected. A finite experimental observation time is considered in addition, which is simulated within the Monte-Carlo approach by an incomplete statistical average. We find strong surface effects for small nanoparticles, which cannot be explained within a simple Landau or mean-field concept and which give rise to characteristic trends of the spin-correlation function in different temperature regimes. Unambiguous definitions of crossover temperatures for finite systems and new, effective method to estimate the critical temperature of corresponding infinite systems are given [1,2].

[1] E. Y. Vedmedenko et al. Eur. Phys. J. B 80, 331–336 (2011)
[2] M. Menzel et al. Phys. Rev. Lett., accepted (2012)

16.30 – 16.45
Spectroscopic study of the spin-chain nickelates R_2BaNiO_5
S. Klimin [1]
(1) Institute of Spectroscopy RAS, 142190, Troitsk, Russia

Y_2BaNiO_5 is a well known Haldane system which does not order magnetically at least down to 100 mK. Presence of magnetic rare-earth (RE) ion R^{3+} in R_2BaNiO_5 leads to an

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ELECTRONIC STRUCTURE AND CORRELATION EFFECTS IN MAGNETIC SYSTEMS

Chair: E. Pavarini

interchain interaction and results in a 3D magnetic ordering at low temperatures (Neél temperatures T_N ~ 12-60 K depending on R). The interest to the R_2BaNiO_5 compounds is kept as 3D magnetic properties coexist with Haldane gap. In this study we present our recent results on the spectroscopic study of R_2BaNiO_5 compounds. We will consider the crystal field effects [1,2] and their impact on magnetic properties of the chain nickelates. The comprehensive study of phonon spectrum of Gd_2BaNiO_5 and first experimental study of phonon-assisted magnetic absorption for Haldane-chains [3] will be present. The experimental results on quantum critically behaviour in magnetically diluted mixed nickelates $(Nd_xY_{1-x})_2BaNiO_5$ will be discussed.

[1] M.N. Popova, S.A. Klimin, E.P. Chukalina, et.al., Phys. Rev B 68, 115103 (2003).
[2] M.N. Popova, S.A. Klimin, E.P. Chukalina, et.al., Phys. Rev. B, 71, 024414 (2005)
[3] S. A. Klimin, A. B. Kuzmenko, M. N. Popova, et.al., Phys. Rev. B **82**, 174425 (2010)

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Rigoletto Room

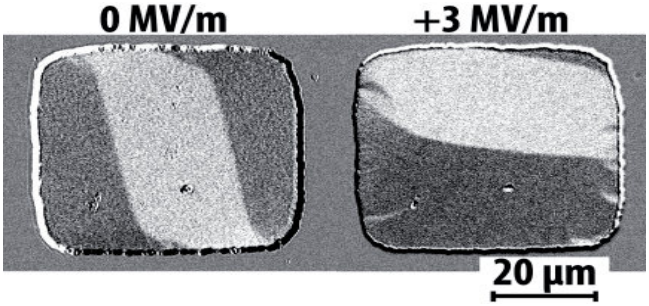
MAGNETIC SHAPE MEMORY, MAGNETOELASTIC AND MULTIFUNCTIONAL MATERIALS

Chair: L. Lanotte

14.45 – 15.15
Direct observation of magnetic easy-axis rotation in integrated magnetoelectric composites by Kerr microscopy *(invited)*
G. Lebedev [1], B. Viala [1], J. Delamare [2], O. Cugat [2]
(1) CEA, LETI, MINATEC Campus, Grenoble 38054, France, (2) G2Elab, Grenoble Electrical Engineering Lab, CNRS-UJF-INPG, St. Martin d'Hères 38402, France

Nowadays, the performances of magnetoelectric composites are getting closer to the requirements necessary to realize new challenging devices such as small and sensitive magnetic sensors, variable inductors, magnetic memories, energy harvesters etc. [1]. Laminated ferromagnetic (FM) / piezoelectric (PE) composites taking advantage of strain-mediated magnetoelectric effect are among the most promising candidates. Recently, we proposed to use push-pull type piezoelectric composites as PE layer, including PZT-based Macro Fiber Composites (MFC); this permits to exploit the large d_{33} piezoelectric coefficient and to generate a uniaxial stress. CoFeB / MFC magnetoelectric composites were fabricated, and the dependence of the giant converse magnetoelectric effect on the CoFeB FM layer's composition was reported [3]. In the present article, we make the next step towards the integration of such composites by patterning the magnetic layer. In this case the behavior of magnetic domains under magnetoelastic interaction becomes of crucial importance for applications.
In this work we performed the direct visualization of magnetic domains in MFC/glass/CoFeB patterned magnetoelectric composite by the mean of Kerr effect microscopy. The patterned objects have typical dimensions of several tens of microns, with thickness in the range of 70-150 nm. A typical example of magnetic domains structure modification under applied electrical field is presented in the figure below. The images are taken in the remanent state (H_{ex}=0). Near-complete 90° swing of the initial magnetic axis is observed. The dependence of the rotation behavior on the external magnetic field and the shape of the pattern is also studied.

[1] J. Ma, J. M. Hu, Z. Li, and C. W. Nan, Adv. Mater. 23, 1062 (2011).
[3] G. A. Lebedev et al., J. Appl. Phys. 111, 07C725 (2012)



Magnetic domains structure of square-patterned CoFeB magnetic layer, for zero-electric field (initial) state and after applying electric field of +3MV/m.

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MAGNETIC SHAPE MEMORY, MAGNETOELASTIC AND MULTIFUNCTIONAL MATERIALS
Chair: L. Lanotte

15.15 – 15.30
The simulation of isotropic and anisotropic magnetoactive elastomers
P. Andrushchenko [1], K.V. Nefedev [1]
(1) School of Natural Sciences, Far Eastern Federal University, 690091, Russian Federation

At present time there is a need for new magnetic materials which properties are substantially depended on the internal structure (distribution of particle magnetic moments, volumes, coordinates, critical fields of magnetization reversal, the properties of the medium in which particles are placed) and the external conditions (magnetic field, pressure, temperature, etc.). These materials are magnetoactive elastomers (MAE).
MAE is a composite material consisting of a flexible polymer medium and filler - magnetically dispersed powder. Today they have found a wide application in areas such as car industry, medicine, advertising, household appliances, construction, etc.
The main aim of developed mathematical model and created software product is the calculation of the properties and reactions of the MAE to changes of the external magnetic field and pressure. Each magnetic particle is in the external magnetic field and in the long-range dipole-dipole interaction field. Instantaneous value of the modulus of the sum of these fields essentially depends on the distribution of structural units of the sample at a given time. A long-range means that the number of interactions in the system grows as N*(N-1), depending on the number of particles N. This fact determines the using of high performance supercomputing technology to calculate the distribution of interaction fields and the tensor of elastic forces in a nonmagnetic medium.
In distinction from the work[1], we have used the model of a finite number of dipoles (up to 10^5 particles), which allows an precise calculation of the matrix interaction fields and module of elastic forces of the external magnetic fields and the forces acting on the samples with anisotropic and isotropic distribution of particles. It is planned to investigate the properties of MAE, depending on the different internal structure of the samples.

[1] L.C. Davis, Model of magnetorheological elastomers, Journal of Applied Physics, 85(6) (1999) 3348–3351.

15.30 - 15.45
Geometric factors on magnetically driven actuation behaviour of polycrystalline Ni-Mn-Ga and its composites
S. Roth [1], J. Romberg [2], U. Gaitzsch [1], P. Müllner [3], L. Schultz [2], *C. Güth [2]*
(1) IFW-Dresden, Institute for Metallic Materials, Dresden, D-01069, Germany, (2) IFW-Dresden, Institute for Metallic Materials, Dresden, D-01069, Germany, and Dresden University of Technology, Dresden, D-01069, Germany, (3) Boise State University, Boise, Idaho, USA

Ni-Mn-Ga ferromagnetic shape memory alloys (FSMAs) show up to 10% strain in magnetic field due to the motion of twin boundaries. But the large strain is only observed for single crystals. For technical application, polycrystals are of great interest because they are easier to produce und cheaper. But in polycrystals the grain boundaries can hinder twin boundary motion. It is known that in textured polycrystals magnetically induced reorientation is possible.
The alloy has a composition of $Ni_{50}Mn_{29}Ga_{21}$ and was produced by induction melting. It has a 10 M modulated structure at room temperature and a martensite transition temperature of about 60 °C. It was found that in thinner plates the MFIS and the mechanical stability are reduced. Furthermore, larger grains do not result in higher MFIS in every case because the elastically stored energy is distributed on less grain boundaries. Thus, the instability of grain boundaries against cracks is grater than in the case of fine grained samples.
The thermo-mechanical behaviour of polycrystalline Ni-Mn-Ga depends on microstructure and several geometric sample properties. The interdependence of microstructure and shape is more pronounced in plate-shaped specimens and therefore a significantly increase of the magnetic field induced strain may be expected.
One approach to reduce the inhibiting influence of the grain boundaries is a polymer filling of provoked cracks. This allows neighbouring grains to deform with less elastic interaction between the grains. The filling acts like glue between two grains providing enough elasticity for the grains to deform without further crack formation. These samples show up to 1 % MFIS and are stable over one million cycles of strain.
This work is supported by DFG within SPP 1239.

15.45 – 16.00
Correlation among piezoresistivity and magnetoelasticity in composites of Ni micro-particles in a silicone matrix
G. Ausanio [1], V. Iannotti [1], L. Lanotte Jr. [2], L. Lanotte [1]
(1) CNR-SPIN, Department of Physical Sciences, "Federico II" University of Naples, V. Tecchio 80, I-80125 Naples, Italy, (2) Department of Chemical Engineering, "Federico II" University of Naples, V. Tecchio 80, I-80125 Naples, Italy

In the recent past, the investigation on composite elastomagnetic samples, made of magnetic and conductive microparticles in an elastic matrix, demonstrates that this type of materials can exhibit innovative coupling between magnetoelastic, piezoelectric and magnetoresistive properties [1-2] with intriguing new theoretical connections and interesting experimental application perspectives.
In the case of the present investigation the composite samples were produced by homogeneous dispersion of nickel particles (4-6 μm in average diameter; with protrusions of 0.1 μm) into a silicone matrix. The particle volume fraction is a little

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above the percolation threshold; so that the particles should be in contact, but the presence of a silicone layer trapped at the interface inhibits it. This configuration is optimal in order to produce a large change of resistivity (from non conductive to conductive conditions) by means of a little strain, that, using the elastomagnetic nature of these composite, can be produced by a magnetization status change.
The previous studies were devoted to the effects of a static gradient of the magnetizing field in sample with no preferential orientation of the particles. The present investigation deals with the influence of the preferential orientation of the particle easy magnetization axis: the magnetic force application induces a strain by means of the elastomagnetic coupling, depending on the particle orientation, and gives different changes of proximity among the microparticles inside the composite, so inducing consequent resistivity changes. Several experimental evidences are reported supporting the presence of this new kind magnetoresistivity effect with a relative change of sample resistance above 50%. A theoretical model and a coherent interpretation of the experimental results are proposed.

[1] G. Ausanio et al**.,** Sensors and Actuators A 127, 56 (2006)
[2] G. Ausanio et al., J. Appl. Phys. 110, 063903 (2011).

16.00 – 16.15
Magnetostrictive Galfenol thin films epitaxied on GaAs(001)
M. Barturen [1], M. Marangolo [2], J. Milano [1], M. Eddrief [2], V.H. Etgens [3], Y. Zheng [2], M. Sacchi [2]
(1) Comision Nacional de Energia Atomica, Centro Atomico Bariloche. (R8402AGP) San Carlos de Bariloche, Rio Negro, Argentina., (2) Institut des NanoSciences de Paris, INSP, UPMC-Paris 6, CNRS UMR 7588, 4 place Jussieu, 75252 Paris Cedex 05, France., (3) VeDeCom- Université de Versailles Saint-Quentin en Yvelines - 55, Av. de Paris - Versailles 78035 Versailles Cedex - France.

An option for reaching smaller size nanodevices is to control magnetism by methods alternative to the use of magnetic fields. One possibility is to make use of magnetoelastic coupling in magnetostrictive systems, i.e., to manipulate magnetic properties by mechanical deformation [1]. We investigated by x-ray diffraction the Ga concentration dependence of the structural properties of Fe1-xGax (Galfenol) thin films grown on a ZnSe/GaAs(001) substrate, a material known for its high magnetostriction. By molecular beam epitaxy (MBE) we grew a series of (001)-oriented layers without in-plane misorientation, with x ranging from 0 up to 0.29 [2]. We find a strong and unexpected Ga-induced tetragonal distortion that conserves the pristine Fe in-plane lattice parameter for all Ga compositions. Supported by theoretical predictions [3], we attribute this unusual tetragonal distortion to short-range ordering of Ga-Ga pairs along the [001]-growth direction. The low-temperature and out-of-equilibrium MBE growth regime tends to stabilize a strong deformed tetragonal phase (up to c/a=1.05 for x=0.29). This tetragonal structure is fully released by post-growth annealing.
Here we show that the tetragonal distortion, combined with strong magnetostriction, induces an out-of-plane component of the Galfenol magnetization and peculiar features in hysteresis loops. MFM measurements indicate a self-organized striped pattern (period ~150 nm) with rotatable anisotropy. Self-organization is affected by the film thickness and by the Ga content.

[1] Lou, M. Liu, D. Reed, Y. H. Ren, and N. X. Sun, Adv. Mater. 21, 4711 (2009).
[2] M. Eddrief, Y. Zheng, S. Hidki, B. Rache Salles, J. Milano, V. H. Etgens and M. Marangolo Phys. Rev.B 84 161410(R) (2011).
[3] R. Wu J. Appl. Phys. 91 7358 (2002).

16.15 – 16.30
Voltage control domain wall pinning through hybrid piezoelectric-magneto-resistive nanodevices
N. Lei [1], T. Devolder [1], G. Agnus [1], P. Aubert [1], L. Daniel [2], J. Kim [1], W. Zhao [1], E. Fohtung [3], O. Shpyrko [3], E. Fullerton [4], C. Chappert [1], D. Ravelosona [1], *P. Lecoeur* [1]
(1) Institut d'Electronique Fondamentale, UMR CNRS, and Universite Paris-Sud, 91405 Orsay, France, (2) Laboratoire de Génie Electrique de Paris, CNRS, UMR8507/SUPELEC/ UPMC/Univ Paris-Sud, 91192 Gif-sur-Yvette, France, (3) Department of Physics, University of California, San Diego, La Jolla, CA 92093-0401, USA, (4) Center for Magnetic Recording Research, University of California, San Diego, La Jolla, CA 92093-0401, USA

Presently, domain wall motion driven by applying a current or magnetic field has launched new concepts for memory and logic devices [1], while pre-patterned multi-notches are used as pinning sites [2]. Here we show that electric field effect can be used to control domain wall pinning acting as a domain wall gate for low power consumption.
We have developed hybrid nanodevices, which consists of a laterally polarized PZT bar inducing a giant in-plane strain that acts on a ferromagnetic in plane magnetized spin valve. By increasing the amplitude of the applied voltage on PZT, we observe a significant increase of the coercive field in the free layer. Particularly, we observe the pinning of a single DW at the corner of PZT electrodes (see plateau on figure 1), which is related to a strain gradient as observed by coherent X-ray diffraction (CXD). CXD measurements further demonstrate that this highly non-uniform strain gradient locally breaks the inversion symmetry of the PZT unit cell resulting in an induced dipole moment.
By combining strain simulations with micromagnetics simulation, we show that these results are consistent with a much higher energy barrier for domain wall motion.
In summary, domain wall pinning controlled by an electric field is demonstrated. These results open a new route for future logic devices, for which domain wall gate can be used as an elementary element.

[1] D. A. Allwood *et al.,* Science 309, 1688 (2005); S. S. P. Parkin *et al.*, Science 320, 190 (2008).
[2] M. Hayashi *et al.*, Phys. Rev. Lett. 97, 207205 (2006).

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MAGNETIC SHAPE MEMORY, MAGNETOELASTIC AND MULTIFUNCTIONAL MATERIALS

Chair: L. Lanotte

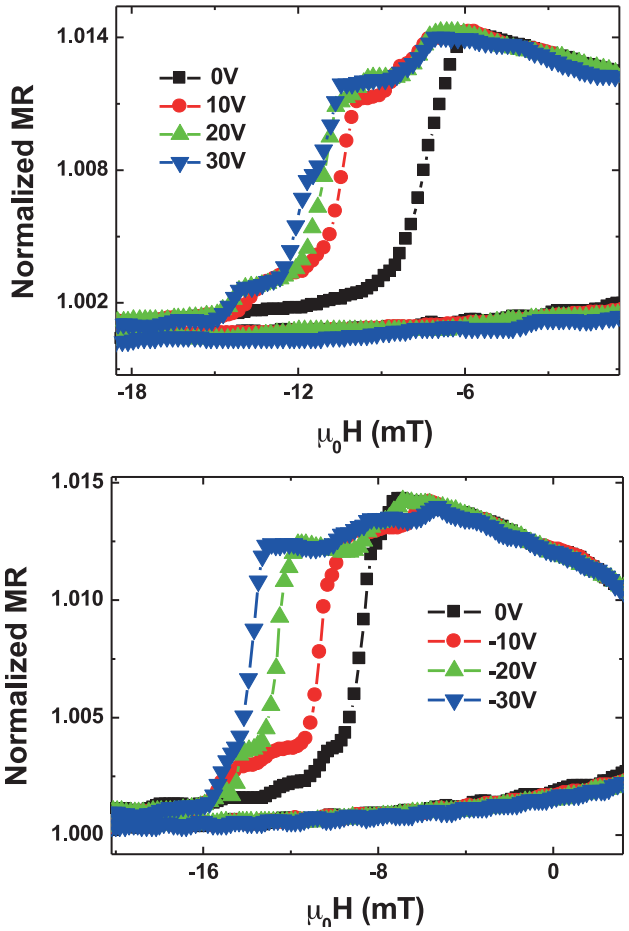

Figure 1: Normalized magnetoresistance curves showing magnetization reversal in the samples with permalloy /CoFeB free layer. (a), (b) shows the effects of negative and positive applied voltages. The presence of a large plateau under voltage corresponds to DW pinning due to strain.

16.30 – 16.45

Design scheme for new tetragonal multifunctional Heusler compounds for spin transfer torque applications

C. Felser [1]
(1) Max Planck Institute Chemical Physics for Solids

Heusler compounds are a remarkable class of materials with more than 1,000 members and a wide range of extraordinary multifunctionalities including half-metallic high-temperature ferri- and ferromagnets, multiferroic shape memory alloys, and tunable topological insulators with a high potential for spintronics, energy technologies and magnetocaloric applications. Recent development of efficient spintronic devices is based on the spin transfer torque (STT) phenomenon. We demonstrate that tetragonal Heusler compounds Mn_2YZ as potential materials for STT applications can be easily designed by positioning the Fermi energy at the van Hove singularity in one of the spin channels (a). The Mn^{3+} ions in Mn_2YZ causes a Jahn Teller distortion (b). A high calculated magnetic anisotropy energy (MAE) is the sufficient condition for a material with perpendicular magnetocrystalline anisotropy (PMA). Materials with saturation magnetizations (M_S) of 0.2 – 4.0 μ_B, high Curie temperatures (T_C) of 380 – 800 K, high spin polarizations, PMA, and required lattice constant matching with MgO can be realized with ferri- or ferromagnetic Heusler-related compounds. Such materials are strongly recommended for the spin transfer torque magnetic random access memory (STT-MRAM) data storage and the spin torque oscillators (STO) for telecommunication.

Acknowledgement: J. Winterlik, S. Chadov, V. Alijani, T. Gasi, K. Filsinger, B. Balke, G. H. Fecher, C.A. Jenkins, J. Kübler, G. D. Liu, S. S. P. Parkin

Monday, 10 September 2012

Posters

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

BIOMAGNETISM
Chair: F. Dumas-Bouchiat

MO-1

Polymer-coated magnetic nanoparticles: first steps towards magnetically assisted neural guidance

M.P. Calatayud [1], C. Riggio [2], V. Raffa [2], A. Cuscheri [2], B. Sanz [1], T.E. Torres [3], M.R. Ibarra [3], *G.F. Goya [3]*

(1) Instituto de Nanociencia de Aragón, Universidad de Zaragoza, Zaragoza, Spain., (2) Scuola Superiore Sant'Anna, Piazza Martiri della Libertà, 33 56127 Pisa (Italy), (3) Instituto de Nanociencia de Aragón and Departamento de Física de la Materia COndensada. Universidad de Zaragoza, Zaragoza, Spain.

Noninvasive therapies based on single-cell actuation can be achieved by new protocols that use magnetic nanoparticles (MNPs) guided by an external magnetic field. MNPs can be used as functional nano-objects to enhance the nerve regeneration and provide guidance to regenerate axons by mechanical forces under the influence of a static magnetic field. We report on a novel synthesis method for obtaining in situ polyethylenimine-coated Fe_3O_4 nanoparticles (PEI-MNPs) with controlled sizes between 25 and 43 nm, using a modified oxidative hydrolysis method. Octahedral morphology and high degree of crystallinity of the magnetic cores were observed from transmission electron microscopy images. The uncoated MNPs showed bulk-like saturation magnetization M_S = 86-92 Am^2/kg, while PEI-MNPs exhibited values of Ms = 58 and 89 Am^2/kg for core sizes of 25 and 43 nm, respectively. The presence of a thin polymer coating (about 0.7-0.9 nm thickness) observed from TEM images were confirmed by Z-potential, attenuated infrared and XPS spectroscopy. In vitro cell toxicity experiments with these MNPs performed on a SH-SY5Y cell line demonstrated a negligible decrease of cell viability for incubation times up to 72 h and 50 mg/ml MNPs concentration. The fate of the PEI-MNPs within the cytoplasm was studied at the single-cell level by SEM-EDX and dual-beam (FIB/SEM) analysis. The results showed large clusters of the PEI-MNPs a strongly attached to the cell membrane, with partial internalization crossing the membrane. The amount of MNPs uploaded obtained from magnetic measurements showed a proportional dependence with concentration. These results suggest that these polymer-coated particles have great potential to be used for neuroscience applications.

MO-2

Silica coated Fe_3O_4 nanoparticles for magnetic hyperthermia

V. Chiesi [1], F. Bigi [2], A. Mega [2], M. Campanini [1], L. Nasi [1], G. Salviati [1], F. Casoli [1], A. Deriu [3], G.F. Goya [4], C. Marquina [5], M.R. Ibarra [4], F. Albertini [1]

(1) IMEM, CNR, 43124 Parma, Italy, (2) Dipartimento di Chimica Organica, University of Parma,43124 Parma, Italy, (3) Dipartimento di Fisica, University of Parma, 43124 Parma, Italy, (4) INA, University of Zaragoza, 50009 Zaragoza, Spain, (5) ICMA, Universy of Zaragoza-CSIC, 50009-Zaragoza, Spain

The specific properties of magnetic nanostructures have generated in the last decades considerable interest due to their possible applications in many different fields. Magnetic nanoparticles have been studied for a new theranostic approach in biomedicine, in which the nanoparticles can be both used as MRI (magnetic resonance imaging) contrast agents and for drug nanovectors or as hyperthermia mediators [1,2].

The most suitable material for magnetic hyperthermia is the well known magnetite. In fact, it is a biocompatible material and has a very good chemical stability.

We have obtained spherical magnetite nanoparticles with an average size of 8 nm through coprecipitation, and functionalised them with APTES (aminopropyltriethoxysilane) shell (1-3 nm) through different processes for improving their dispersibility in polar solvents.

The size, morphology and phase have been investigated by analytical Transmission Electron Microscopy (TEM) in both diffraction and imaging mode. Their behavior in water colloidal suspension, has been characterized by Dynamic Light Scattering measurements and a complete magnetic study has been carried out through a Vibrating Sample Magnetometer.

In Figure 1 a High Resolution TEM (HRTEM) image of magnetite nanoparticles functionalised with APTES is shown.

Their behavior as hyperthermia mediators has been characterized and we obtained remarkable Specific Absorption Rate (SAR) values (up to 50 W/g). We will discuss the dependence of SAR on nanoparticles interactions and their dispersibility in polar solvents.

[1] Q.A. Pankhurst et al. *J. Phys. D: Appl. Phys*. **42** (2009) 224001

[2] I. Sharifi et al. *J. Magn. Magn. Mater.* **324** (2012) 903

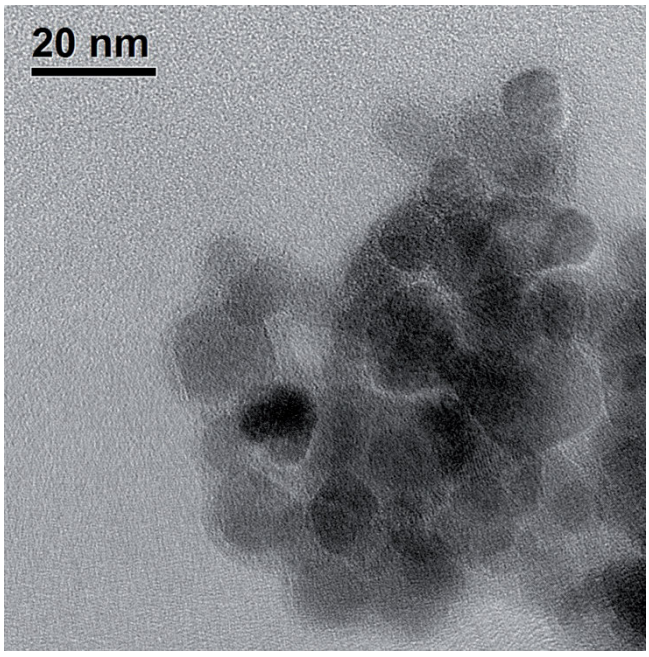

Figure 1 HRTEM image of magnetic nanoparticles with APTES functionalization.

MO-3

Magnetic behavior of functional surface coated maghemite nanoparticles

P. Demchenko [1], N. Mitina [2], A. Zaichenko [2], N. Nedelko [1], *S. Lewińska [1]*, A. Ślawska-Waniewska [1], P. Dłużewski [1], M. Bilska [1], S. Ubizskii [2]

(1) Institute of Physics, Polish Academy of Sciences, Al. Lotnikow 32/46, 02-668 Warsaw, Poland, (2) Lviv Polytechnic National University, 12 Bandera, Lviv, 79013, Ukraine

Surface modified iron oxide particles are considered as very promising materials for biotechnology and medical applications. In this work we report on a template synthesis of functional maghemite nanoparticles performed in the presence of oligoperoxide surfactants that results in narrowed particle size distribution, tailored functionality and reactivity. The nanoparticles obtained consist of magnetic γ-Fe_2O_3 core and organic shell containing peroxide and other reactive functional fragments. Their microstructure, studied with a transmission electron microscopy (JEOL JEM 2000-EX), reveals aggregates of spherical-like grains with a mean diameter of around 10 nm and a log-normal size distribution with standard deviation of 2.3 nm. Static and dynamic magnetic investigations were performed with PPMS (VSM magnetometer and ac susceptometer) over the temperature range 2-300 K in the applied field ±9 T. At room temperature the thermal fluctuations dominate the effective anisotropy energy barrier and the particles exhibit a predominantly superparamagnetic behavior. However, on cooling, the development of the moment dynamics cannot be attributed to a blocking process of individual particles and polydispersity but it can be ascribed as the freezing process to a spin-glass-like state. This glassy state results from strong dipolar interactions combined with randomness in the particle positions and orientations of anisotropy axes in the aggregated structure of maghemite particles separated by an organic interfacial layer.

This work was partially performed in the laboratory founded by POIG.02.02.00-00-025/09, POIG.01.01.02-00-108/09 and POIG.02.01-00-14-032/08

MO-4

Magnetism and spin dynamics of novel encapsulated iron oxide nanoparticles for theranostics applications

P. Arosio [1], F. Orsini [1], M. Corti [2], A. Lascialfari [3], C. Ravagli [4], G. Lorenzi [4], G. Baldi [4], C. Innocenti [5], C. Sangregorio [6], A.M. Piras [7], M. Gazzarri [7], A. Dessy [7], F. Chiellini [7], E. Chiellini [7]

(1) Dipartimento di Scienze Molecolari Applicate ai Biosistemi, Università degli Studi di Milano, I-20134 Milano, and Consorzio INSTM, Milano Unit, ITALY, (2) Università degli Studi di Pavia, Dipartimento di Fisica A. Volta, I-27100, Pavia, and Consorzio INSTM, Pavia Unit, ITALY, (3) Dip. di Scienze Molecolari Applicate ai Biosistemi, Università degli Studi di Milano, I-20134 Milano, and Consorzio INSTM, Milano Unit, ITALY; Università degli Studi di Pavia, Dip. di Fisica, Pavia, (4) CERICOL, Colorobbia, via Pietramarina 123, 50053 Sovigliana – Vinci, Firenze – ITALY, (5) Dipartimento di Chimica "Ugo Shiff", Università degli Studi di Firenze, via della Lastruccia 3-13, 50019 Sesto Fiorentino (Firenze), and INSTM, Firenze Unit – ITALY, (6) CNR-ISTM, via Camillo Golgi, 20123 Milano, ITALY, (7) BIOlab, Laboratorio di Materiali Polimerici Bioattivi per Applicazioni Biomediche ed Ambientali, Dipartimento di Chimica e Chimica Industriale, Università di Pisa, UdR INSTM, ITALY

In this work, magnetite nanoparticles with an average diameters of 12 nm were encapsulated by co-precipitation technique in presence of human serum albumin and a highly water soluble modified b-cyclodextrin into bioerodible nanoparticles (VP-MAG NPs, average diameter 160nm), based on 2–methoxyethanol hemiester of poly(maleic anhydride–*alt*–butyl vinyl ether) 5% grafted with poly(ethylene glycol). VP-MAG NPs exhibit, at room temperature, a superparamagnetic behavior and when compared to the commercial compound ENDOREM®, they present nuclear relaxivities that make them promising as magnetic resonance imaging (MRI) contrast agents (CAs). In particular, ^{1}H-NMR relaxivity measurements showed values of the nuclear transverse relaxivity r_2, 3 ÷ 4 times higher than actually available commercial CAs over the whole frequency range.

The MRI efficiency of our samples was related to their micro-structural and magnetic properties. The NMR relaxometry profile confirmed the nature of the physical mechanisms inducing the increase of the nuclear relaxation rates at low (magnetic anisotropy) and high (Curie relaxation) fields.

Since these nano-objects are synthesized by the co-encapsulation of both magnetite and albumin (used as model protein drug but available also as natural carrier for hydrophobic active agents), the developed VP-MAG NPs trace the way for the preparation of a novel class of efficient MRI contrast agents, where the combination of therapeutic and diagnostic properties on a single nanodevice could be pursued [1].

[1] S.M. Janib, A.S. Moses, J.A. MacKay, Advanced Drug Delivery Reviews 62, 1052 (2010)

This work was supported by NANOTHER project (Seventh Framework Programme: Theme NMP-2007, Large Scale Integrating Collaborative Project; n°: CP-IP 213631-2) and by INSTM-Consorzio Interuniversitario per la Scienza e Tecnologia dei Materiali.

MO-5

Characterization of organically coated gold-magnetite hybridnanoparticles for potential use in biomedical applications

E. Umut [1], T. Orlando [2], F. Pineider [3], P. Arosio [4], C. Sangregorio [3], M. Corti [2], F. Tabak [1], A. Lascialfari [4], P. Ghigna [5]

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Recently, multifunctional hybrid magnetic nanoparticles (HNP) attracted much attention, since they offer unique advantages with respect to mono-functional NPs. For instance the HNPs comprise a magnetic part like magnetite (Fe_3O_4) or maghemite (γ-Fe_2O_3), whose magnetic properties are well known, and a metal component like Au which is non-magnetic but shows surface plasmon phenomena and optical activity. As a whole the HNPs have relevant magnetic and optical properties, and thus behave as multifunctional materials. This multifunctionality is at the origin of possible simultaneous use of HNPs in different biomedical applications, such as biosensing, optical imaging, magnetic resonance imaging (MRI), magnetic fluid hyperthermia, etc.

In this work we present the magnetic, optical and relaxometric

properties of multifunctional Au-Fe_3O_4 HNPs, as possible novel contrast agents (CAs) for MRI. The HNPs have been synthesized by wet chemical methods in heterodimer and core-shell geometries and capped with oleylamine. Structural characterization of the samples have been made by X-ray diffraction and transmission electron microscopy, while magnetic properties have been investigated by means of SQUID magnetometry experiments. As required for MRI applications using negative CAs, the samples resulted superparamagnetic at room temperature. Optical properties have been investigated by analyzing the optical absorbtion spectra collected in UV-visible region. Relaxometric measurements have been performed on organic suspensions of HNPs and Nuclear Magnetic Resonance (NMR) dispersion curves have been obtained by measuring the longitudinal $1/T_1$ and transverse $1/T_2$ relaxation rates of solvent protons in the range 10 kHz¸300 MHz at room temperature. NMR relaxivities r_1 and r_2 have been compared with ENDOREM®, one of the commercial superparamagnetic iron oxide based MRI CAs. MRI contrast enhancement efficiencies have been investigated also by examining T_2-weighted MR images of suspensions. Cariplo Foundation (Project no. 2010-0612) is thanked for funding the research.

MO-6

Fe_3O_4 Hollow Spheres: Magnetic and dye adsorption properties for biomedical applications

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We have prepared magnetite (Fe_3O_4) hollow spheres of two different diameters using solvothermal method. Average diameters of the hollow spheres are 185 nm and 350 nm with a very narrow size distribution. X-ray diffraction analysis confirms that the spheres are made of pure phase Fe_3O_4 crystals. From the SEM and TEM images it is clear that the spheres have large void space in them with shell thickness of 35 nm and 65 nm for 185 nm and 350 nm diameter hollow spheres, respectively. The hollow spheres show ferromagnetic behavior with high saturation magnetization. We have done frequency dependent ac hysteresis loop measurements of the hollow spheres that show increase in coercivity with increasing frequency. This frequency dependent measurement is necessary for their possible biomedical applications because heat generated during the alternating magnetization-demagnetization of these materials can be easily calculated from the ac hysteresis loop area multiplied by frequency. AC measurements reveal that these hollow spheres can produce enough power loss which is very useful for their possible application in hyperthermia treatment. DC hysteresis loops of these spheres have considerable coercive field (H_C) but have large saturation magnetization close to the bulk value of Fe_3O_4. Day plots reveal that the domain structures of the hollow spheres shifts from pseudo single domain (PSD) state to multi domain (MD) state with the increase of hollow sphere diameter. These spheres are found to be very good absorber of dye with nearly 90% dye removal efficiency. From the Langmuir isotherm model it is found that dye adsorption process by these hollow spheres is spontaneous and thermodynamically stable. The growth mechanism of the Fe_3O_4 hollow spheres is attributed due to the oriented aggregation of the nanoparticles and Ostwald ripening.

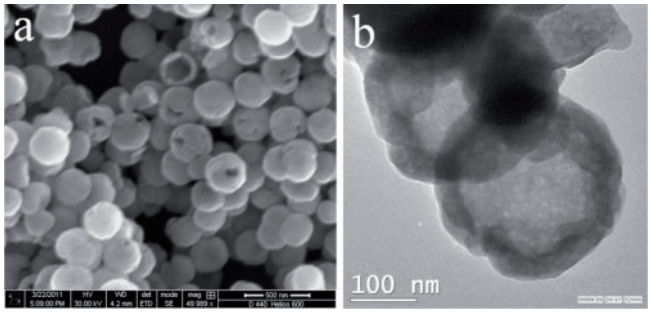

Figure. (a) SEM image; (b) TEM image of Fe_3O_4 hollow spheres of 185 nm diameter.

MO-7

Synthesis and Characterisation of Magnetite Nanoparticles for Biomedical Applications

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Among nanostructured magnetic materials, magnetite nanoparticles (NPs) are very promising in nanomedicine applications, particularly in the field of hyperthermia, drug delivery and biological separation.

NPs have been prepared by coprecipitation of Fe^{2+} and Fe^{3+} in NH_4OH [1] and by thermal decomposition of $Fe(acac)_2$ [2]. NPs obtained by coprecipitation have been coated with a silica shell in order to obtain a stable suspension, while NPs obtained by thermal decomposition have been stabilized by oleic acid and oleylamine.

We have performed a complete characterisation of the samples by Transmission Electron Microscopy (TEM), Vibrating Sample Magnetometer (VSM), Alternating Gradient Force Magnetometer (AGFM) and Dynamic Light Scattering (DLS).

Conventional TEM and High Angle Annular Dark Field techniques have provided information about size, morphology and aggregation state. Selected Area Electron Diffraction analysis has given information about crystal phase, confirmed by Electron Energy-Loss Spectrometry. Spherical *NPs* of *narrow size distribution* and mean diameter of 8 nm have been obtained by coprecipitation. They show a strong tendency to aggregate (Fig. 1a). By simply changing the reaction parameters, we have been able to cover the surface of the aggregates with a silica shell of variable thickness (Fig. 1b). Thermal decomposition synthesis method has been successful in producing highly stabilized spherical NPs with very small diameter (about 4 nm) and a narrow size distribution (Fig. 1c).

The obtained NPs show a superparamagnetic behaviour at room temperature (Fig. 1d) and a saturation magnetization in agreement with bulk value.

The magnetite NPs are currently being optimised for their use *in* hybrid multifunctional nanodevices for cancer therapy, which combine Hypertermia and Photo Dynamic Therapy treatments.

[1] J. P. Jolivet et al., *E.* Chem. Commun. 5 (2004), 481

[2] F. Cattaruzza et al., Chem. Mater. 17 (2005), 3311-3316

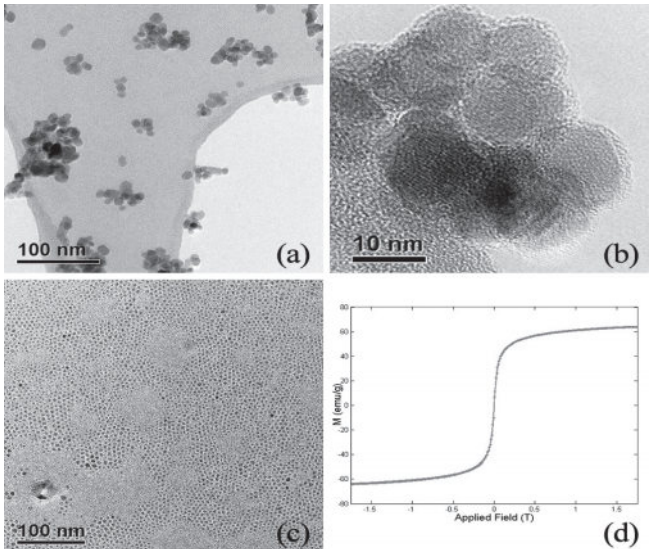

Fig. 1 (a, b, c) TEM images of magnetite NPs; (d) typical magnetization measurement @RT.

MO-8

Control of the thermal response in magnetic hydrogels

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In the last years the research on sub-micrometric drug-curriers focussed on thermo switchable magnetic hydrogels, such as the one formed by the polymer Poly(N-isopropylacrylamide) (PNIPAM) and magnetic nanoparticles (MNPs)[1-3]. Indeed, these hydrogels can behave as smart carriers for drugs whose release is controlled by external magnetic fields via a magneto-thermal stimulus

We propose methods for a fine control of the LCST parameter of the PNIPAM hydrogel. A wide range of LCST values, ranging between 32°C and 52°C, was achieved promoting these material as highly tuneable thermosensitive composite.

It is demonstrated that the most important application parameter of the hydrogel, the lower critical solution temperature (LCST), can be controlled by varying the concentration of adsorbed nanoparticles. This is clearly shown by Photon correlation spectroscopy and Magneto-calorimetric investigations.

The sigmoidal trend in the adsorption of MNP on the PNIPAM hydrogel supports the model that considers the PNIPAM hydrogel as a template for the deposition of magnetic nanoparticles. This indicates that there is a maximum amount of MNP that can be adsorbed on PNIPAM beyond which no further absorption can occur.

We show that PNIPAM/MNP ratio is fully responsible of the thermal response and magnetic values of these hydrogels and that there exists a linear trend of LCST with respect to MNP concentration in the hydrogels.

[1] B. Luo, X.-J. Song, F. Zhang, A. Xia, W.-L. Yang, J.-H. Hu, C.-C.Wang, Langmuir, 26,1674–1679 (2010).

[2] R. Regmi, S. R. Bhattarai, C. Sudakar, A.S.Wani, R. Cunningham, P.P.Vaishnava, R. Naik, D. Oupickyb, G. Lawes, J Mater Chem, 20**,** 6158–6163(2010).

[3] J. Rubio-Retama, N. E. Zafeiropoulos, C. Serafinelli, R. Rojas-Reyna, B.Voit, E. Lopez Cabarcos, M. Stamm, Langmuir, 23, 10280-10285 (2007).

MO-9

Towards optimization of the thermal response of iron oxide nanoparticles

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Superparamagnetic iron oxide nanoparticles (SPION) are of large interest in biomedicine as they may result in minimally invasive and selective cancer diagnostic and therapeutic agents. This is due to the success in synthesis preparation of SPION in size range between 4 and 20 nm, with a narrow size distribution, high magnetization values and biocompatible features rendered through adequate coating.

Here, we report on the study of thermal and magnetic properties of SPION in dynamical regime. SPION with sizes ranging from 7 to 18 nm, narrow size distribution and highly uniform shape, were synthesized by thermal decomposition of an iron precursor in organic media. SPION surface was modified by a dimercaptosuccinic acid (DMSA) coating leading to highly stable colloidal suspensions with hydrodynamic diameters of about 60 nm for all particle sizes. The thermal response of the SPION was studied in aqueous and agar solutions at different alternative magnetic field conditions (different frequencies and field strength) and Fe concentrations. The specific absorption rate (SAR) values were accurately determined under non-adiabatic conditions by modeling the temperature variation with time. Our results show that SAR values increase with particle size, magnetic field frequency and strength. Surprisingly, SAR values are similar in the Fe concentration range from 1 till 12 g/l. Moreover, SAR values of DMSA coated SPION dispersed in agar solutions were slightly smaller (15%) than those obtained in aqueous solutions. This may reflect that Néel relaxation mechanism mainly dominates the heat dissipation process in DMSA coated SPION. SAR values around 100 W/g can be easily obtained under mild condition of frequency and field and moderate Fe concentration for the DMSA coated SPION with larger diameter. The 18nm particles are promising candidates for applying intracellular hyperthermia.

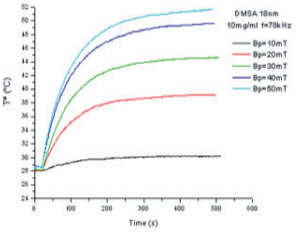

Figure 1: Time variation of temperature in an aqueous 10 g/l sample of 18 nm diameter DMSA coated nanoparticles subjected to AC magnetic fields at different magnetic field strength and given frequency (78 kHz).

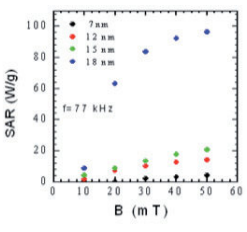

Figure 2: mass-normalized SAR values for different NP diameters at 10 g Fe/l as a function of AC magnetic field strength and 77 kHz.

MO-10

Tuning the Hyperthermia Output of Ferromagnetic Nanoparticles by means of Maximum Applied Field and Sample Concentration

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Magnetic-fluid hyperthermia, a cancer therapy that makes use of the heating power of magnetic nanoparticles (MNPs) under an AC magnetic field, has attracted much attention in the last decades. For an efficient clinical use it is necessary to identify the more adequate working conditions (frequency f, maximum value of the applied magnetic field H_{max} and sample concentration c) as a function of the characteristic parameters of the MNPs (magnetic anisotropy K, saturation magnetization M_s, and volume V) [1].

In this work, we present a general description of the hyperthermia output depending on H_{max} and c. Our results are presented in terms of the particles' characteristic K and M_s values, which provides an insightful tool for designing the best hyperthermia protocols. In order to attain these results we have used a Monte Carlo technique [2] to simulate the hysteresis loops. The hysteresis loss (HL) obtained from these curves is proportional to the heating power of the MNPs, and its dependence on the H_{max} has been studied as function of the sample concentration. We show how the *HL vs. H_{max}* curve varies with c. Two well-differentiated scenarios are observed: for fields $H_{max}<0.5H_A$ (where $H_A=2K/M_s$ is the anisotropy field of the particles), HL is essentially zero for all concentrations; on the contrary, for $H_{max}>0.5H_A$ the maximum HL value occurs for low concentrations, whereas a more complex behavior is observed for high interacting conditions.

[1] B. Mehdaoui, A. Meffre, J. Carrey, S. Lachaize, L. M. Lacroix, M. Gougeon, B. Chaudret, M. Respaud, Adv. Funct. Mater. 21, 4573 (2011)

[2] D. Serantes, D. Baldomir, C. Martinez-Boubeta, K. Simeonidis, M. Angelakeris, E. Natividad, M. Castro, A. Mediano, D.-X. Chen, A. Sanchez, L. I. Balcells, and B. Martinez, J. Apply. Phys. 108, 073918 (2010)

MO-11

Magnetic nanoparticles for in-planta studies (nanoparticles penetration and transport)

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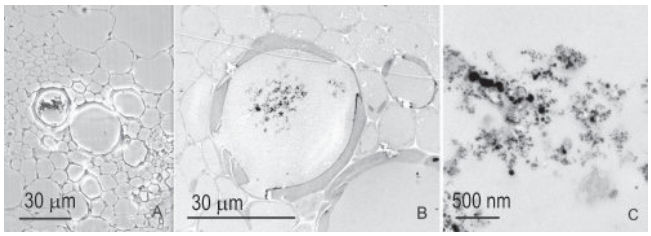
The ongoing research and results obtained up to now concerning the use of magnetic nanoparticles in bio-medicine open a wide range of possibilities for their use in disciplines as, for example, general plant research and agronomy. At this respect, the first stage is to work out the nanoparticles penetration and transport into living plants and plant cells. We have used iron/iron-oxides carbon-coated nanoparticles to produce biocompatible suspensions, which have been injected into pumpkin (*Cucurbita pepo*) living plants[1,2]. The graphitic coating makes possible the nanoparticles visualization into plant cells and tissues, using different microscopy techniques (fluorescence, confocal, light and electron microscopy). Moreover, their magnetic character allows positioning the nanoparticles in the desired plant tissue by applying magnetic field gradients (produced by small magnets). We have also observed that in the absence of magnetic fields, the nanoparticles can travel as well along the vascular systems, reaching different cells and tissues. Nanoparticles have been found both in the cytoplasm and in the extracellular space between cells. A size-based selection mechanism seems to be operating, probably involving cell walls and waxes acting as a barrier. With respect to cytotoxicity, we observed different cytoplasmic density depending on the amount of nanoparticles in the cytoplasm. Damage at plant level was not macroscopically evident. However, further detailed studies are needed to evaluate the cytotoxicity and phytotoxicity of more intense treatments.

We have also studied the absorption and translocation of our nanoparticles into plants of different families, after their administration through the roots and by spraying the nanoparticles suspension on the leaves[3].

[1] P. González-Melendi et al., Annals of Botany **101** (2008) 187

[2] E. Corredor et al., BMC Plant Biology **9** (2009) 45

[3] Z. Cifuentes et al., Journal of Nanobiotechnology (2010) **8**:26 doi: 10.1186/1477-3155-8-26



Light (A) and TEM (B,C) images of magnetic nanoparticles inside xylem vessels

MO-12

Protein-based multifunctional magnetic nanoparticles for cancer therapy

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Magnetic nanoparticles, MNP, are the building-blocks for developing innovative nanodevices with multi-fold therapeutic and diagnostic activities, which include magnetic fluid hyperthermia, MFH, contrast agents for Magnetic Resonance Imaging, CA-MRI, targeting of tumour cells for addressing *in situ* functionalities, such us drug delivery and heat-controlled release. Iron oxide MNPs mineralized within a human H chain ferritin, HFt, protein can represent a viable platform to achieve this goal as they offer multiple advantages: i) they are biocompatible and can freely circulate in the body; ii) they are natively tailored for NP incorporation, which may preclude the occasional release of toxic Fe(III); iii) chemical or genetic conjugation of amino acid side-chains present on the HFt surface with specific molecules can be rationally designed.

However, the main constraint of HFt-based MNP is that their size cannot exceed the protein shell inner diameter, d=8 nm in average. This size can be large enough for MRI application, but too small for MFH, as theoretical and experimental studies demonstrated that the maximum MFH efficiency is reached for magnetite NP of d=16-18 nm, while very poor effects are expected for d<10 nm. In this contribution, we report on the development of protein-based multifunctional nanoparticles comprising small, c.a. 7 nm magnetite/maghemite cores, mineralized inside natural HFt shells, and on their structural, magnetic and hyperthermic characterization. Large enhancement of the hyperthermic efficiency was obtained by finely modifying the chemical composition of the inorganic core through controlled doping with divalent ions other than Fe(II) which allowed for increasing the magnetic anisotropy and the particle magnetic moment.

The surface of the doped magnetite NP-enclosing HFt was further conjugated to polyethylene glycol (PEG) molecules to increase the stability of the constructs and to a targeting moiety able to favour selective NP accumulation on melanoma cells.

MO-13

Surface modified magnetic carriers with native beta-cyclodextrin designed for hydrophobic drug inclusion and targeting

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The present investigation is focused on the synthesis and characterization of magnetic nanoparticles (NPs) with modified surface for drug targeting. Native beta cyclodextrin was chosen for capping magnetic NPs of magnetite and cobalt ferrite synthesized by wet chemistry procedures, taking into account its interaction capacity with cations such as iron and cobalt. The chlortetracycline inclusion in the host cyclodextrin rings was accomplished during the next experimental step. The magnetic NPs functionalized with beta-cyclodextrin/chlortetracycline inclusion complexes in aqueous suspensions were investigated by rheological measurements (density, viscosity, surface tension), as well as by microstructural techniques: X-ray diffraction, transmission electron microscopy and Fourier transform infrared spectrometry. The results showed that both types of synthesized colloidal NPs (mean diameter of about 7–15 nm) with beta-cyclodextrin modified surface were able to develop host-guest interactions with antibiotic molecules.

The vibrating sample magnetometry measurements confirmed the superparamagnetism of the functionalized NPs with saturation magnetization values over 120.00 kA/m. It was shown that the obtained nanosystems were able to sense and respond to an externally applied magnetic field so that they can be artificially manipulated; this could be of help in improving medical treatment by localized delivery of hydrophobic drugs by entrapping them in the hydrophobic cavity of cyclodextrins attached to magnetic nanoparticles.

[1] X. Sun et al., *J. Phys. Chem. C*, 112, 17148 (2008)

[2] L. Slavov et al., J. Magn. Magn. Mat., (2010) doi :10.1016/j.jmmm.2010.01.005

[3] L.A. Cobos Cruz et al., MRS Proceedings, 1243, 11 (2009)

MO-14

Enhancement of the magnetic order in assemblies of iron storage proteins in intact tissues

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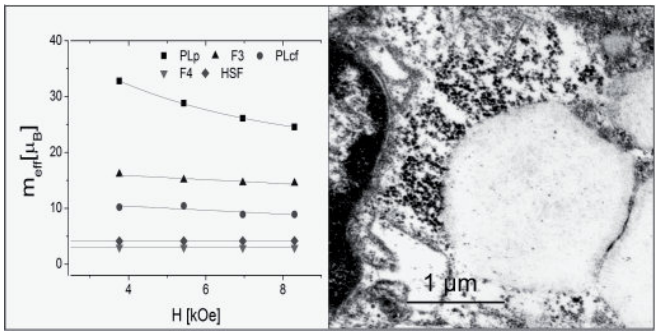
We have performed magnetic susceptibility measurements for the human placenta tissue from periphery (*PLp)* and central part of the placenta close to the umbical cord from the foetal side (*PLcf)*, "crude" (*F3)* and purified (*F4)* placental ferritin extracts. Horse spleen ferritin (*HSF*) was used as a reference. The non-heme iron concentration ranged from 48 to 55 µg Fe/g tissue. Specific magnetisation of the *PLp* sample was more than order of magnitude higher compared to that of the purified placental ferritin and the *HSF*, and higher than that of the crude ferritin extract giving an evidence for the presence of maghemite/magnetite-like phases in the tissue. The figure below shows the effective magnetic moment per iron atom m_{eff} in terms of the Bohr magneton (m_B) calculated from the susceptibility data using the Langevin formular for the data taken at 310K. These findings are in agreement with our previous ESR data on complex susceptibility and dependence of the shape and position of the ferritin ESR spectra in intact tissues on sample orientation [1-3]. We have performed SANS measurement on tissues what confirms the magnetic measurement data and gave an evidence for linear aggregates of the ferritin in placenta tissue. Chain aggregates of the ferritin in the placenta tissue are shown in the electron microscopy image. The data suggest that the enhancement of the magnetic order is an intrinsic feature of the endogenous iron storage proteins in intact tissues, especially at high storaged iron levels.

[1] O. Mykhaylyk et al. in: Scientific and Clinical Applications of Magnetic Carriers, eds. U. Hafeli et al. (Plenum Press, New York, 1997) 177.

[2] O. Mykhaylyk et al., J. Magn. Magn. Mater. 2422, 272 (2004)
[3] O. Mykhaylyk et al., Med. Princ. Pract. 14, 221 (2005)



Specific magnetisation data and ferritin aggregates in the cytoplasm of placenta macrophage

MO-15

Synthesis and magnetic characterization of polymer coated rhenium-iron oxide hybrid nanoparticles for potential use in biomedical

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In this work we have synthesized and characterized nano-composites constituted by a magnetic iron oxide core and a polymeric surfactant to which the "fac-Re(CO)3" moiety has been tightly bound. ^{186}Re and ^{188}Re isotopes are both g and b emitters and can be usefully exploited as diagnostic and therapeutic tools. The polymeric surfactant, nicknamed ISA23SH, is a linear polyamidoamine copolymer, biodegradable, biocompatible and "stealth" (not recognizable by the reticulo endotelial system) containing cysteamine pendants in the minority part that react with the precursor rhenium aquo-complex [1].
The magnetic core has been obtained by a classic coprecipitation method [2] and the aggregated nanoparticles have been directly peptized by ISA23SH, sonicating and moderately heating to enhance the interaction between the nanoparticle surface and the carboxylate groups of the polymer backbone, adjusting the pH to acidic values. The nanoparticles remain well and stably resuspended for months.
The hybrid nanoparticles (HNPs) have been fully characterized by TEM, SQUID, DLS, and termogravimetric analyses. HNPs show a superparamagnetic behavior and nuclear relaxivities that make them promising as magnetic resonance imaging (MRI) contrast agents (CAs). In particular, the nanostructures work like "negative" contrast agents increasing the transverse relaxation rate (r2) of the solution protons. In particular, HNPs exhibit r2 relaxivity values higher than Endoremâ (a commercial CA), over the whole frequency range. Compared to Endoremâ, the biocompatible polymer, offering the possibility to encapsulate ^{186}Re and ^{188}Re, permits to HNPs to behave as bifunctional nanostructures.

[1] D. Donghi, D. Maggioni, G. D'Alfonso, F. Amigoni, E. Ranucci, P. Ferruti, A. Manfredi, F. Fenili, A. Bisazza, R. Cavalli, Biomacromolecules, 10(12), 3273 (2009)
[2] R. Massart, IEEE Transactions of magnetics, 17, 2 (1981)

MO-16

Multifunctional nanovectors based on polyamidoamine polymers for MRI, drug delivery and molecular targeting

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We present multifunctional, biocompatible and biodegradable nanovectors based on different polyamidoamine polymers with diagnostic and therapeutic properties. Using organic radicals with N-oxyl functional group or magnetite nanoparticles with average size 10.1±2.0 nm and 15.5±2.8 nm, paramagnetic and superparamagnetic nanovectors, respectively, were obtained.
The material design bases on synthetic polymers of polyamidoamine (PAA) structure. Two different families of PAAs were proposed. The first derives from the functionalization of a linear amphoteric PAA bearing a carboxyl group per repeating unit, characterized by "stealth" properties and by the ability to concentrate in tumors by the enhanced permeation and retention effect [1]. This PAA was further functionalized by the introduction of varying amounts of TEMPO residues [2].
The second family was designed for the surface modification of iron oxide nanoparticles. These have a segmented copolymer structure, and bear PAA segments containing different amount of carboxyl groups per repeating units together with PEG segments. These copolymers are thought to combine the binding properties of the carboxylated PAA segments to inorganic nanoparticles, with the stealth properties of the PEG ones.
Magnetic measurements revealed all the samples are superparamagnetic at room temperature. The saturation magnetizations were found slightly lower than the bulk value pointing out the good cristallinity of the nanoparticles and, as the overall magnetic behavior, are not affected by the functionalization process. Calorimetric measurements provided, for the largest particles, satisfying heating efficiency at alternating field parameters beyond the human tolerability threshold (SAR of ca. 70 W/g at 200 Hz and 10 kA/m). 1H-NMR relaxivities were not far from the values of the available commercial contrast agents over the whole frequency range.

[1] S. Richarson, P. Ferruti, R. Duncan, J. Drug Targeting l6, 291 (1999)
[2] M. Gussoni, F. Greco, P. Ferruti, E. Ranucci, A. Ponti, L. Zetta, New Journal of Chemistry 32, 323 (2008)

MO-17

Magnetic active polymers for biomedical applications

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We propose to use a compound of magnetic nanoparticles (ferroxide with typical crystallite size of 10-50nm) embedded in a flexible polymer (Polydimethylsiloxane PDMS) to filter circulating tumor cells (CTCs). The analysis of CTCs is an emerging tool for cancer biology research and clinical cancer management including the detection, diagnosis and monitoring of cancer [1]. The combination of experiments [2] and simulations lead to a tunable and flexible microfluidic chip device.

Simulations are essential to understand the influence of the embedded nanoparticles in the elastic PDMS when applying a magnetic field. They combine finite element calculations of the polymer, magnetic simulations of the embedded nanoparticles and the fluid dynamics of blood plasma and blood cells [3].

The magnetic force from an external gradient field acts as a body force (force per volume) on the compound. It can be estimated from the known concentration of nanoparticles and the calculated gradient force an a single particle.

Adjustment and validation of the simulated polymeric model and the real compound were done by cantilever beam experiments (Fig. 1 left). A microfluidic channel was cut into this polymer. These simulations show that the channel can be tuned with an applied magnetic gradient field (Fig. 1 right) which offers a wide range of new opportunities in lab-on-chip designs.

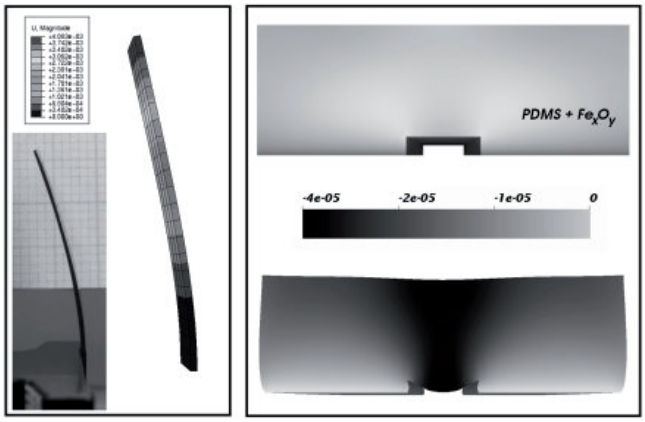

Fig.1: Cantilever beam (left), magnetically tunable microfluidic channel (right)

[1] B. Mostert et al. “Circulating tumor cells (CTCs): Detection methods
and their clinical relevance in breast cancer”, Cancer Treatment Reviews, 2009

[2] N. Kataeva et al. “Magnetically Active Polymeric Filter for Circulating Tumor Cell Separation”, AIT Austrian Institute of Technology, Nano Systems, Vienna, to be published

[3] I. Cimrák et al. “Modelling and Simulation of Processes in Microfluidic Devices for Biomedical Applications.” Computers & Mathematics with Applications, 2012

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS…)

Chair: N. Dempsey

MO-18

PLD-fabricated Nd-Fe-B thick film nanocomposite magnets with dispersion structure

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In order to upgrade the torque of the small motor further, increase in the remenence value of the isotropic films is indispensable. In this study, we prepared nano-composite Nd-Fe-B/Alpha-Fe thick-films with dispersion structure by using a PLD method. Deposition of the thick-films with the Nd-poor compositions compared to stoichiometeric one was carried out by using two methods of Method’s A and B. Although the power of 5 W was constant at the front of a condensing lens in the both methods, the values of energy density on the surface of each target were less than 50 mJ/mm^2 (Method A) and higher than 200 mJ/mm^2 (Method B), respectively, because of the different spot size for the two methods. In Method A, the defocus of laser beam on the surface of an Nd-Fe-B target enabled us to obtain good transfer from a target composition to a film one together with a high deposition rate of about 40 μm/h. The deposited films with the Nd contents range between 9.0 and 9.6 at % could be obtained by using an $Nd_{1.4}Fe_{14}B$ target. On the other hand, the laser beam was just focused on the surface of an $Nd_{2.4}Fe_{14}B$ target, and the samples with the Nd contents range from 8.4 to 9.7 at % could be obtained. Although the Nd-rich target was used, Method B enabled us to reduce the Nd contents of films by several atomic % compared with that of the target. We confirmed that Fe atoms tend to move straightly to a substrate and that Nd atoms are widely emitted under the high energy density of laser beam due to the just focus. Resultantly, we succeeded in obtaining a Nd-Fe-B nano-composite film magnet with remanence, coercivity and (BH) max values of 0.99 T, 386 kA/m and 91 kJ/m^3, respectively, by using Method B.

MO-19

Decomposition and diffusion of DyF_3 in hot-compacted NdFeB magnets

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In order to transfer the recently introduced grain boundary diffusion process (GBDP) from sintered magnets [1,2] to nanocrystalline hot-pressed magnets [3] DyF_3 was coated on commercially available NdFeB powder made of melt spun

ribbons and subsequently hot-compacted. A strong dependency of coercivity as a function of the Dy fraction has been observed in Permagraph measurements in fields up to 2.3 T. This can be explained by a partial decomposition of the introduced DyF_3 and the release of elemental Dy during the compaction process. The formation of Dy-Oxide and Nd-Floride takes also place as Energy dispersive X-ray (EDX) and wavelength dispersive X-ray (WDX) maps reveal. In order to successfully apply a diffusion process to nanocrystalline material we investigated the effect of annealing on the microstructure and the magnetic properties. A low temperature heat treatment at 600°C leads to a significant fluorine diffusion along the flake boundaries upon prolonged annealing times. As a result the maximum in coercivity for low Dysprosium fraction is more pronounced whereas for high Dysprosium fractions the coercive field is drastically reduced. Furthermore it is found that above a critical temperature of 600°C a strong grain growth leads to a strong reduction in coercivity which compensates the positive effect of Dysprosium at all. Hot-compacted magnets with an optimal composition of 1.2 wt% Dy have been hot-deformed by means of die-upsetting to produce textured magnets with energy densities above 300 kJ/m³.

[1] Park et al. Proc. 16th Int. Workshop on RE Magnets and their Applications (Sendai, Japan), p.257 (2000)
[2] Hirota et al. IEEE Trans. Magn. 42, 2909 (2006)
[3] Marinescu et al., J. Appl. Phys. 105, 07A711 (2009)

MO-20

Investigation of Dy Diffusion Pathways in high performance Nd-Fe-B permanent magnets

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Lately, the demand for high coercivity Nd–Fe–B based permanent magnets for hybrid electric vehicles has increased and with it the interest in methods of coercivity enhancement of these magnets. In 2000 Park et al. discovered the so-called grain boundary diffusion process (GBDP), in which the coercivity of Nd-Fe-B magnets is enhanced by coating with Dy and a subsequent heat treatment. During the process, the Dy diffuses into the magnet, leading to improved magnetic hardness without a substantial loss of magnetization [1]. Since then, although intensive research has been carried out to understand the physical principles of the coercivity enhancement [2], studies concerning the diffusion pathways of Dy with their respective distribution of coercivity and magnetisation are still scarce [3].
In the present study, commercial sintered Nd-Fe-B magnets with an energy density exceeding 385 kJ/m³ have been coated with different amounts of Dy powder and were subsequently heat treated at temperatures from 700°C to 1000°C. With SEM/EDX the appearance of Dy-enriched shells along the grain boundaries at temperatures above 900°C is shown, which are believed to cause the coercivity enhancement (figure 1). Additionally, the findings are correlated with MFM line scans over grain boundaries as a function of diffusion depth. This way, a direct visualisation of the Dy diffusion pathways was achieved. Financial support from the BMBF via the PerEMot project (No. 03X4621A) is gratefully acknowledged.

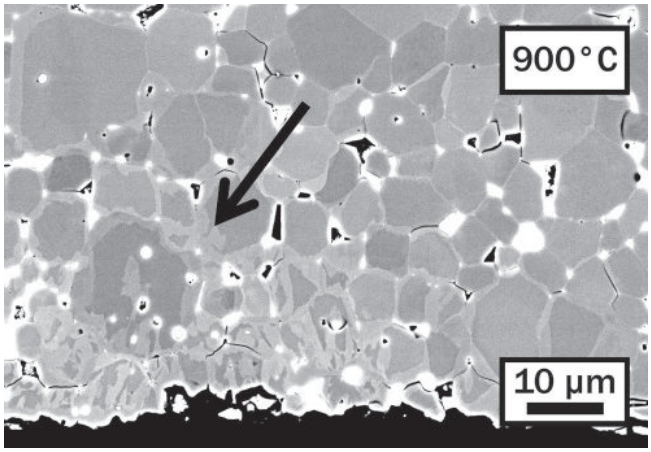

Figure 1: Back scattered electron image of Nd-Fe-B sintered magnet after Dy diffusion process at 900°C. The black arrow indicates a Dy enriched shell along the grain boundaries.

[1] K. T. Park, K. Hiraga, and M. Sagawa, JIM (2000) 257.
[2] H. Sepehri-Amin, T. Ohkubo, and K. Hono, J. Appl. Phys. 107 (2010) 09A745.
[3] H. Nakamura, K. Hirota, T. Ohashi, and T. Minowa, J. Phys. D: Appl. Phys. 44 (2011) 064003

MO-21

Structural and magnetic studies of the nanocrystalline Nd-Fe-B-Nb alloy ribbons

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A detailed study is reported of the phase constitution, microstructure and magnetic properties of the nanocrystalline $Nd_{9.2}Fe_{61.64}B_{21.16}Nb_8$ alloy ribbons. The microstructure consisting of mixture of hard ($Nd_2Fe_{14}B$) and soft ($Nd_2Fe_{23}B_3$) magnetic phases was observed with transmission electron microscopy (TEM). The base alloy was fabricated by arc-melting under an Ar atmosphere the high purity elements. The ribbon samples were obtained by controlled atmosphere melt-spinning technique. The nanocrystalline microstructures were produced by annealing the melt-spun ribbons at temperature range from 923 K to 1063 K. It was shown that the rapidly solidified $Nd_{9.2}Fe_{61.64}B_{21.16}Nb_8$ alloy ribbons have partially amorphous structure and soft magnetic properties in the as-cast state. The heat treatment of these ribbons at temperatures higher than 923 K leads to the growth of the $Nd_2Fe_{14}B$ hard magnetic phase and the $Nd_2Fe_{23}B_3$ metastable phase. The XRD study confirmed that during annealing of the samples at temperature higher than 923 K the $Nd_{1+\varepsilon}Fe_4B_4$ paramagnetic phase was also formed. Furthermore, the magnetic studies have shown that with increasing annealing temperature the decrease of the saturation polarization J_s was observed. The maximum values of coercivity ${}_JH_c$ = 1175 kA/m was obtained for a sample annealed at 1003K. However, the sample heated at temperature of 1023 K exhibited the maximum values of remanence polarization J_r = 0.35 T and the maximum energy product $(BH)_{max}$ = 21 kJ/m³. The increase of annealing temperature significantly affected the values of magnetic parameters of the tested materials. The

main aim of this study was to investigate the effect of annealing conditions on the microstructure and magnetic properties of the $Nd_{9.2}Fe_{61.64}B_{21.16}Nb_8$ alloy ribbons.
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MO-22

Effect of microstructure changes on magnetic properties of spark plasma sintered high coercivity Nd-Fe-B powders

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In this study the SPS method was applied for low RE content (8,5% at.) and high RE content (13,5 % at.) MQ powders. The powders were sintered in a wide range of temperature, for 5 min., under pressure of 35 MPa. The low RE content grade, densified reluctantly and gained the density close to the theoretical value only for 850 oC. The coercivity decreased gradually with increasing sintering temperature. On the other hand, the densification of the higher RE content grade powder occurred much easier and the coercivity, close to the theoretical value, was achieved already at 650 oC. The coercivity of this material also decreased with increasing sintering temperature. Microstructural studies revealed that the SPS sintering process leads to partial decomposition of the Nd2Fe14B phase. In the flakes boundaries one can see small, bright precipitates of RE-rich phase, surrounded by darker, dendritic crystallites of iron. The latter observation evidences that, in the course of sintering, local melting of the material, followed by primary crystallization, occurs. The local character of these phenomena, in the flakes' boundaries and rapid crystallization in microregions, undergoing decomposition, does not enable further crystallization and formation of the Nd2Fe14B phase. The proportion of the RE-rich and iron phases increases parallel to the increasing sintering temperature. On the basis of the current results one can conclude that fabrication of high density MQ powders based magnets by the SPS method is possible, however the powders having higher RE content should be used for this purpose and the sintering temperature as low as possible, related to density, should be kept.

MO-23

Thermal analysis and magnetic properties of Pr-(Fe,Co)-B alloys ribbons with Nb and Zr addition

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In the present work the influence of Fe to B ratio on the phase constitution and magnetic properties of $Fe_{50+x}Co_{13}Pr_9B_{23-x}Zr_1Nb_4$ (where x=0, 2, 5, 8) alloys were investigated. The samples were produced in the form of melt spun ribbons. DTA analysis allowed to determine the range of heat treatment temperatures for obtaining optimal hard magnetic properties. Subsequently samples were subjected to annealing for 5 min at various temperatures from 923 K to 1033 K. The phase constitution of as-cast and annealed ribbons was studied by X-ray diffractometry. The as-cast samples were fully amorphous for all alloy compositions, while those annealed at various temperatures shown variation of phase constitution. The XRD analysis revealed presence of hard magnetic $Pr_2(Fe,Co)_{14}B$ and paramagnetic $Pr_{1+x}Fe_4B_4$ phases. Additionally, the Mössbauer spectroscopy shown existence of soft magnetic disordered phase, which composition changes with the annealing temperature. Dependences of magnetic parameters on the annealing temperature were examined for all alloy compositions. It was shown by DTA analysis and magnetic measurements that with increase of B content a decrease of the optimum temperature for obtaining best hard magnetic properties occurs.
Work supported by the research project N N507 240840 financed by Polish National Science Centre in years 2011–2014

MO-24

Magnetic interactions and microstructure of RE-(Fe,Co)-B alloys doped with Zr, Ti, Ni and Mn

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The microstructure and interactions between grains in $Pr_8Dy_1Fe_{60}Co_7Ni_{6-x}Mn_xB_{14}Zr_1Ti_3$ (where x=0, 3, 6) alloys in a form of ribbons were investigated. The fully amorphous melt spun ribbons (of the thickness of ~ 25 μm) were annealed at various temperatures from 923 K to 1023 K for 5 min.
The X-ray diffraction and Mössbauer spectroscopy shown that annealing leads to formation of hard magnetic $Pr_2(Fe,Co)_{14}B$ and soft magnetic α-Fe phases diluted within the amorphous matrix. Furthermore, square hysteresis loops and the remanence enhancement was observed for all annealed samples. It was shown that presence of Ni in the amorphous phase improves its saturation magnetization and eventually the remanence of the alloy samples. On the other hand presence of Mn atoms in the alloy composition has an effect in the increase of the coercivity field. In order to reveal the origin of differences in magnetic properties of samples of various composition the studies of microstructure and magnetic interaction between the constituent phases present in the samples were performed. The microstructural studies were carried out using TEM, while magnetic properties were measured at room temperature in magnetic field up to 2T using vibration sample magnetometry. The series of recoil curves were obtained for the initially saturated samples and for demagnetized specimens. These allowed to calculate the rates of irreversible magnetization changes upon the change of external magnetic field H. In order to characterize interactions between grains of crystalline phases the ΔM plots were also constructed from recoil data.

MO-25

Crystal structure and magnetic properties of nanostructured $Pr_{2-x}Dy_xFe_{17}$

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The Pr_{2}Fe_{17} compound is a potential candidate for

low cost magnetocaloric materials with a significant relative cooling power (RCP) around room temperature (~280K). In order to increase the Curie temperature (T_{C}), we propose the substitution of Dy for Pr. The polycrystalline $Pr_{2-x}Dy_xFe_{17}$ (x = 0 - 0.5) alloys were prepared using the arc melting technique. The bulk samples were annealed one weak at 1373K in order to homogenize the Th_{2}Zn _{17}-type phase. The nanostructured samples were synthesized by ball-milling technique using a high-energy planetary ball mill and subsequent thermal annealing at 1373K for 30 min. The crystal structure was characterized by X-ray diffraction and analyzed using the Rietveld refinement with Fullprof program. All samples are crystallized in the R-3m rhombohedral Th_2Zn_{17} type structure. The lattice parameters decrease with increasing Dy content (from a = 8.5802Å and c = 12.4592Å, for x = 0, to a = 8.5624Å and c = 12.4402Å, for x = 0.5). This behavior can be explained by the smaller covalent radius of Dy (1.92Å) compared to Pr (2.03 Å). On the contrary, T_{C} of compounds, determined by thermomagnetic analyses, increases with Dy content from 281K, for x = 0 to ~340K, for x = 0.5. The Dy substitution of Pr increases the electronic density in 4f band and therefore strengthens the 3d-5s-4f indirect exchange interaction between the rare earth and Fe sub-lattices. So, we consider that the T_{C} increasing with Dy content is mainly determined by the electronic effects rather than magnetovolumic effect. The magnetocaloric effect is evaluated around T_{C} from magnetization isotherms measured up to 5 T.

MO-26

Microstructure and magnetic properties of hard magnetic $Pr_9Fe_{52}Co_{13}Zr_1Ti_3B_{22}$ alloy ribbons

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In the present work the phase constitution, microstructure and magnetic properties of the $Pr_9Fe_{52}Co_{13}Zr_1Ti_3B_{22}$ alloy in the forms of rapidly solidified ribbons in the as-cast state and subjected to short time annealing were investigated. The ribbons were obtained by melt-spinning technique (with the velocity of the copper roll surface of 25 m/s). Subsequently, the samples were annealed for 5 min at temperatures ranging from 923 to 1013K. The ribbon samples in as-cast state were fully amorphous and exhibited soft magnetic properties. Annealing at 923K resulted in partial devitrification of the samples that have not changed considerably their magnetic properties.

Heat treatment of specimens at higher temperatures resulted in the increase of volume fractions of hard magnetic phase, which is accompanied by significant changes of their hysteresis loops. The evolution of microstructure was studied by transmission electron microscopy TEM. The influence of the annealing conditions on the magnetic parameters such as: coercive field $_JH_c$, polarization remanence J_r, saturation polarization J_s and maximum magnetic energy product $(BH)_{max}$ were also presented. Additionally, magnetic interactions between the grains of crystalline phases of two selected samples were investigated by measurement of two sets of recoil curves. These measurements were performed for specimens initially saturated and for those in demagnetized state. From recoil data the deltaM plots and the field H dependences of reduced irreversible magnetization M_{irr}^D/M_s for saturated samples and those in demagnetized state M_{irr}^R/M_s, were constructed. Furthermore, the remanent susceptibilities dM_{irr}^D/dH and dM_{irr}^R/dH were calculated in order to depict rates of irreversible magnetization changes upon the increase of external magnetic field H.

Work supported by the research project N N507 240840 financed by Polish National Science Centre in years 2011–2014

MO-27

Structural and Magnetic Behaviour of $SmCo_5$/(Fe or $Fe_{65}Co_{35}$) Hard/Soft Magnetic Nanocomposite Obtained by Mechanical Milling

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A ball milling process was employed for the obtaining of $SmCo_5$/(α-Fe or $Fe_{65}Co_{35}$) exchange coupled nanocomposite powders. Both dry and wet milling processes, in shock and friction mode, (ball to powder mass ratio – 10, milling times up to 24 hours, planetary mill) were used. Milling mode, time and medium (dry or wet) greatly influence the size-distribution, structural and microstructure of crystallites. Therefore, different strength of the interphase magnetic coupling and magnetic properties of the resultant milled nanocomposite powders are observed. We present a systematic investigation of the influence of milling and annealing conditions on the structural and magnetic properties of hard/soft $SmCo_5$/(α-Fe or $Fe_{65}Co_{35}$) magnetic powders. The structural modifications of the samples were investigated by X-ray diffraction (XRD). The microstructure was checked by XRD and electron microscopy. The width of the diffraction peaks of the hard and soft magnetic phases was found to increase with the milling time and the peaks of hard magnetic phase almost disappeared after six hours of milling. A heat treatment restored the characteristic diffraction peaks of the $SmCo_5$-type and improves the Fe and $Fe_{65}Co_{35}$ peaks. The stiffness of the soft/hard interphase exchange coupling, the remanent magnetisation and the coercive field are deduced from hysteresis curves, performed in magnetic fields up to 10 Tesla at 300 K. Coercivity was found to increase during friction mode milling and to decrease during shock mode milling. Remanent magnetization was found to increase with increasing milling time in shock mode and also in friction mode after longer milling times.

MO-28

Metastable $SmFe_5$ Ordered Alloy Thin Films Formed on Cu(111) Underlayers

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$SmCo_5$ is a typical high K_u magnetic material and the thin films have been studied for applications to thin film magnets and high-density perpendicular recording media. The Co site in $SmCo_5$ structure can be replaced with other transition metal element, Ni or Fe. $SmNi_5$(0001) [1] and $SmCo_5$(0001) [2] thin films were successfully prepared on Cu(111) underlayers. $SmFe_5$ is, however, metastable and does not appear in the bulk

Sm-Fe phase diagram. In the present study, Sm-Fe films were deposited on Cu(111) underlayers trying to prepare $SmFe_5$(0001) thin films. The film growth behaviour and the crystal structure were investigated. Figs. 1(a)–(c) show the RHEED patterns observed during Sm-Fe film deposition on Cu(111) underlayers at different temperatures by using an UHV-MBE system. The Fe/Sm ratio was carefully controlled to be within Fe – 16.7±0.5 at.% Sm which was confirmed by EDX. With increasing the substrate temperature, a diffuse pattern typical for amorphous structure varies to a regular one which reflects the crystal structure of $SmFe_5$(0001). The sharpness of RHEED pattern increases beyond 350 °C, indicating that the crystallographic quality of $SmFe_5$ ordered alloy is improved. Fig. 1(d) shows the out-of-plane XRD spectrum of Sm-Fe film prepared at 450 °C. $SmFe_5$(0001) superlattice reflection is clearly observed in addition to the $SmFe_5$(0002) fundamental reflection. The present study has shown that Cu(111) underlayer stabilizes the formation of metastable $SmFe_5$ phase. The magnetic property of $SmFe_5$ thin film will be presented at the conference.

[1] M. Ohtake *et al.*, *J. Appl. Phys.*, **107**, 09A708 (2010).
[2] Y. Nukaga *et al.*, *IEEE Trans. Magn.*, **44**, 2891 (2008).

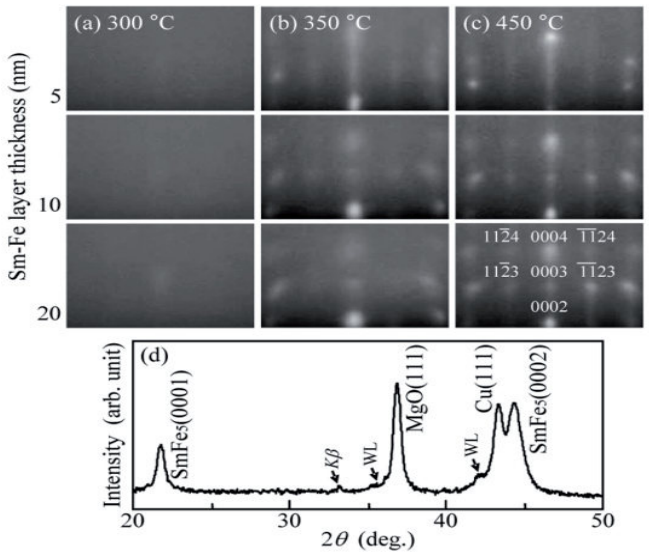

Fig. 1 (a)–(c) RHEED patterns and (d) out-of-plane XRD spectrum.

MO-29

Hard magnetic properties of melt-spun Mn-Al-C alloys

A. Pasko [1], M. Lobue [1], E. Fazakas [2], L.K. Varga [2], F. Mazaleyrat [1]
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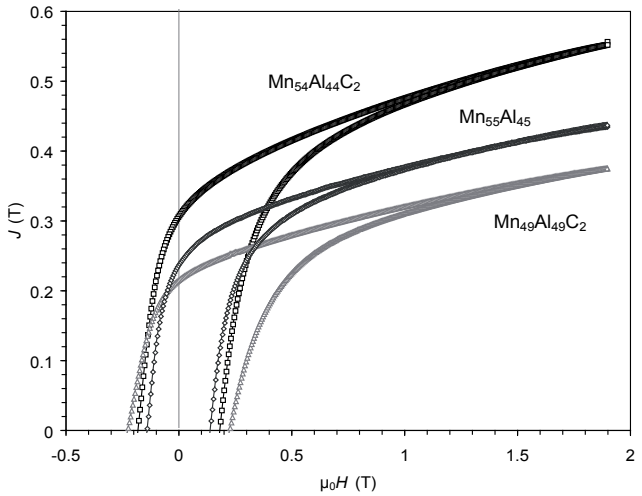
Mn-Al alloys are attractive candidates for permanent magnet applications due to good magnetic properties (superior to conventional ferrites), high technological properties (strength, machinability, corrosion resistance) and low cost (no rare earth elements). The metastable ferromagnetic tetragonal τ-phase with strong uniaxial magnetocrystalline anisotropy [1] forms from the equilibrium non-magnetic hexagonal ε-phase by annealing an alloy with 50-60 % of Mn at approximately 550 °C. Carbon addition stabilizes τ-phase and facilitates production of anisotropic materials. Magnetic hysteresis of Mn-Al-C alloys is sensitive to the microstructure developed during phase formation (comprising martensitic or massive transformation mechanisms) and is therefore influenced by the production route.
Various rapid solidification techniques have been employed for preparation of homogeneous Mn-Al-C alloys with fine grain size [2, 3]. In this paper we report on the structural and magnetic characterization of Mn-Al-C melt-spun ribbons. The phase composition, lattice parameters and mean grain size of the phases involved were determined by X-ray diffraction (XRD). Magnetization curves were recorded after different regimes of annealing at typical τ-phase formation temperatures as well as on heating directly in a vibrating sample magnetometer (VSM). Room temperature magnetic properties of selected compositions are illustrated in the figure below. The presence of carbon results in better magnetization and coercivity (0.19 T) of $Mn_{54}Al_{44}C_2$ alloy compared to $Mn_{55}Al_{45}$ alloy due to greater proportion of τ-phase and domain wall pinning by fine carbide precipitates. The equiatomic $Mn_{49}Al_{49}C_2$ composition is near the limit of τ-phase existence range and displays lower magnetization, but higher coercivity (0.23 T).

[1] H. Kono, J. Phys. Soc. Jpn. 13, 1444 (1958).
[2] E. Fazakas, L.K. Varga, F. Mazaleyrat, J. Alloys Compd. 434-435, 611 (2007).
[3] Z.W. Liu *et al.*, J. Mater. Sci. 47, 2333 (2012).



Magnetization curves of Mn-Al-C melt-spun ribbons annealed at 550 °C for 10 min.

MO-31

Hard/Soft nanocomposites produced by SPS of Hexaferrite/ Permalloy nanopowders

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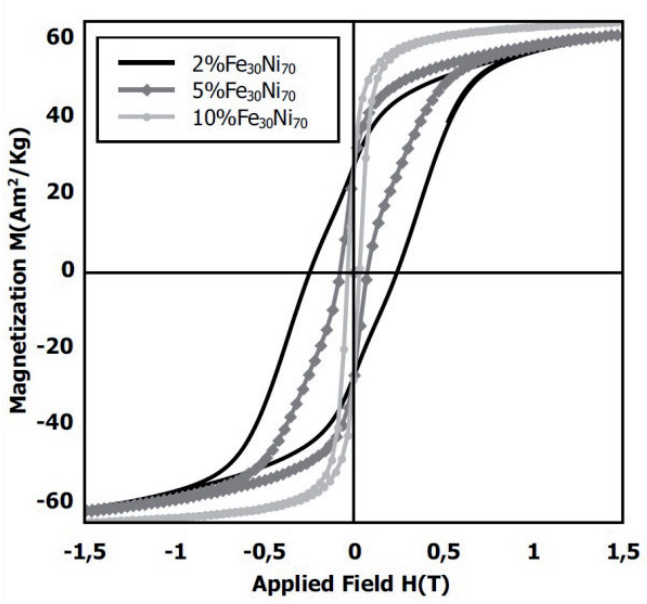
(1) SATIE,ENS Cachan,CNRS,94235 Cachan,France, (2) School of Physics,Devi Ahilya University,452001-Indore,India, (3) Inter University Consortium,Devi Ahilya University,452001-Indore,India, (4) ICMPE,CNRS,94320 Thiais,France

Recently, bulk exchange coupled magnets (i.e. spring-magnets) received a renewed interest due to the introduction of new techniques of mixing and compaction. In nanocomposite hard-soft magnets, the soft phase plays the role of increasing the maximum energy product of the magnet by increasing the remanence of the system while keeping the coercivity of the hard phase. Most of the work done in this field concentrates on the coupling between metal-metal or hard-soft ferrites.
The present study explores the idea of exchange coupling in metal-oxide composites. This paper presents a novel process of

synthesis for the system of metal-ferrite bulk nanocomposites. Fine powders of hexaferrite and iron-nickel were prepared and mixed by mechanical milling for a given volume fractions of Iron-nickel by varying the time of milling. The mixture was then sintered in a one step process at 800°C for 10 minutes using spark plasma sintering method (SPS). The structural characteristics of the system have been studied by X-Ray diffraction (XRD), Scanning Electron Microscopy(SEM) and Mossbauer spectrometry. Vibrating Sample Magnetometer(VSM) has been used for the magnetic characterization of the sample. The soft phase content has been varied and the variation in the properties as a function of the fraction of soft phase content and milling time has been studied.
The measured magnetization curves do not show the shape of two phase uncoupled materials. This confirms the presence of a ferrite metal-oxide coupling mechanism in the prepared composite system.

[1] F.Mazaleyrat, A.Pasko et al., (2010)
[2] G.Asti et.al., Phy. Rev. B, 69, 174401 (2004)



Magnetization curves for Nanocomposites

MO-32
Effect of Ca^{2+} substitution on structural and magnetic properties of M-type Barium hexa-ferrites
M. Athair [1]
(1) Bahauddin Zakryia University Multan Pakistan

M-type Barium hexa ferrites $Ba_{(1-X)}Ca_{(X)}Fe_{12}O_{19}$ (x = 0.1,0.3,0.5,0.7,0.9) were synthesized by solid state reaction technique. Samples were characterized by x-ray powder diffraction technique and vibrating sample magnetometery. The XRD reveals that the samples were single phase M-type hexagonal ferrites. The lattice parameters were calculated from XRD as a = 5.8321Å and c = 23.24 Å. The saturation magnetization (M_s) and remanance (M_r) decreases with the increase of Ca^{2+} content due to segregation of ca ions at the grain boundaries where as coercivity (H_c) shows increasing behavior due to the same reason. The squareness ratio ~0.7 is in good agreement to the reported results.

MO-33
Synthesis, Structural and Magnetic properties of $SrCo_2$-W-type hexaferrite powders
M. Rashad [1], I. Ahmed [1], *M. Rasly Khoudary* [1]
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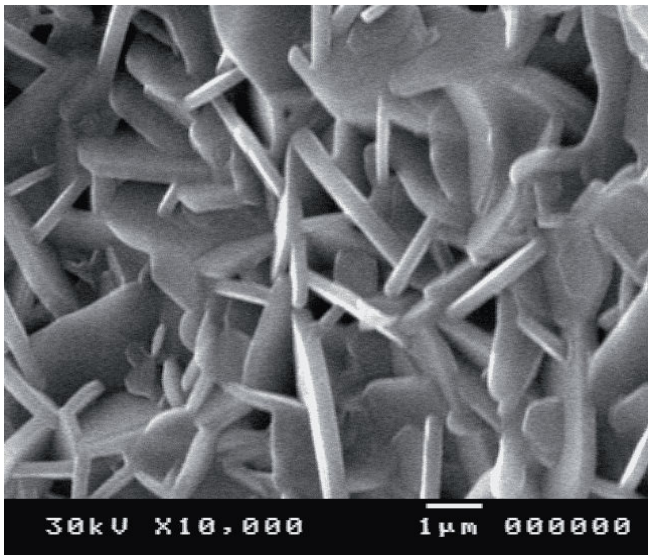
Single phase of $SrCo_2$W-type ($SrCo_2Fe_{16}O_{27}$) ferrite powders have been successfully synthesized using organic acid precursor method. The optimum conditions for the formation of Sr W-type phase were annealing temperature 1200°C, annealing time 6h and $Fe^{3+}/Sr^{2+}/Co^{2+}$ molar ratio 16:1:2 using different type of organic acid namely; oxalic, citric or malic acids, respectively. The crystallite size of the formed powders was temperature and type of organic acid dependent. The lower crystallite size (79.1 nm) can be achieved using malic acid as organic precursor. The microstructure of the obtained powders depicted that mono-dispersed hexagonal platelet like structure was appeared using malic acid as the organic precursor and the fuel as shown in Fig.1. Good saturation magnetization (*Ms*=75.6 emu/g) can be achieved using malic acid annealed at 1200°C for 6h using $Fe^{3+}/Sr^{2+}/Co^{2+}$ molar ratio 16:1: 2.

1- M. M. Rashad, I. A. Ibrahim, J. Mag. Mag. Mater. 323(2011)2158.
2- M. Ahmad, I. Ali, F. Aen, M.U. Islam, M. N. Ashiq, S. Atiq, W. Ahmad, M.U. Rana, Ceram. Inter. 38, (2012)1267.
3- I. Khan, I. Sadiq, M. N. Ashiq, M.-U.-D. Rana, J. Alloys Compd. 509(2011) 8042



MO-34
The effect of nanosized silica on magnetic properties of Sr hexaferrite
M. Mozaffari [1], B. Behdadfar [2]
(1) Department of Physics, Faculty of Science, University of Isfhan, Isfahan, Iran., (2) Department of Materials Engineering, Isfahan University of Technology, Isfahan, Iran

In this work nanosized silica has been prepared by mechanical milling and then its effect on magnetic properties of Sr hexaferrite has been investigated. Mechanical milling of silica (Hickok Science, USA) was carried out in different media, such as stainless steel, alumina and zirconia and the results show that minimum contamination is produced in the zirconia

medium. Sr hexaferrite particles were prepared by conventional ceramic method, using hematite and strontium carbonate as raw materials. Hematite was a Ruthner by product of Mobarakeh steel complex, Iran that modified for reduction of impurities. XRF analysis shows maximum total impurities is less than 0.15 %. Strontium carbonate was a homemade product with 98 % purity. The raw materials were mixed in a ball mill wetly, dried, calcined at 1200 degrees C for 2 h and then cooled to room temperature freely. Calcined samples were then dry milled, using a vibrating mill. Different amounts of nanosized silica (0.0, 0.1, 0.2, 0.5 and 1.0 wt %) were added to the milled Sr hexaferrtie and mixed in the course of wet milling process to achieve submicron hexaferrite powders, using an attrition mill. The slurries were then formed in an external magnetic field of 1 T and dried freely for 48 h. Finally dried compacts were sintered at 1175 degrees C for 4 h, 5 °C/min as heating rate and free cooling to room temperature. The results show that silica can improve coercivity from 2070 Oe for silica free sample to 3185 Oe for the sample with addition of 1 wt %.

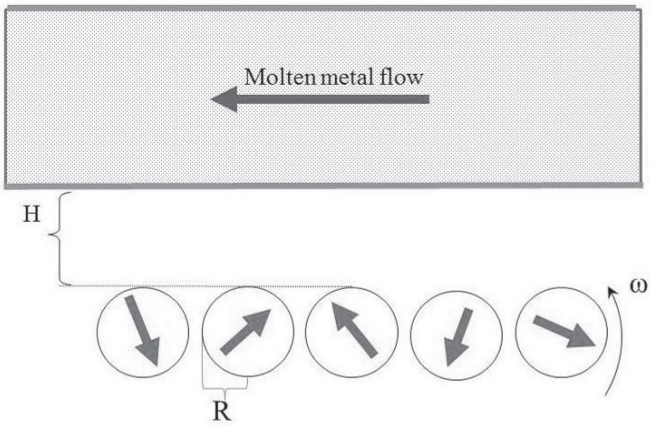
MO-35

Investigation of multiple rotating permanent magnet cylinders system for use in metallurgical applications

T. Beinerts [1], A. Bojarevics [1], J. Gelfgats [1], I. Bucenieks [1]
(1) Institute of Physics of University of Latvia, LV-2169, Latvia

Advances in of Rare-Earth permanent magnet technology also unlock more applications. Current study has been done to investigate possibilities to replace 3-phase AC traveling magnetic field inductors made for driving liquid metal flow in Aluminium recycling industry in order to decrease energy consumption.
A system of multiple synchronously rotating permanent magnet cylinders, which are magnetized orthogonal to the axes, has been proposed. Principal scheme can be seen in figure below. This study resulted from previous experience with permanent magnet pumps for low-melting temperature metals. While performing parameter optimization it was concluded that two pole cylindrical rotor yields higher magnetic field at larger distances using same amount or magnetic materials compared to traditionally used multipole and rectangular shape dipole magnets [1].
System has been extended further introducing multiple simultaneously rotating magnets. The system was estimated analytically and tested experimentally in model experiments with InGaSn eutectic. It was observed that at optimum phase shift between magnets, total efficiently in terms of total liquid metal flow produced increases up to 6 times comparing to a system without a phase shift. This lets build systems that consume up to 5 times less electrical power compared to traditional 3-phase inductors. Introduction of phase shift also opens new possibilities to optimize use of materials for other systems, what becomes increasingly urgent due to constant increase of Rare-Earth material prices. Seeing perspective wide range applications of proposed system, also patent has been obtained [2].

[1] A.Bojarevics, I. Bucenieks, Yu. Gelfgat. Flow at the Liquid Metal Surface Subject to Rotating Magnetic Field. In: 7th PAMIR International Conference on Fundamental and Applied MHD. France, September 8 - 12, 2008.
[2] A.Bojarevics, I. Bucenieks, Yu. Gelfgat., T.Beinerts. Patent No. LV 14404, 20.10.2011



Principal scheme of investigated setup.

MO-36

Magnetic flux concentration methods for magnetic energy harvesting module

K. Tashiro [1], H. Wakiwaka [1], *G. Hattori* [1]
(1) Spin Device Technology Center, Shinshu University, 380-8553 Nagano, Japan

This paper presents magnetic flux concentration methods for magnetic energy harvesting module. Energy harvesting is a key technology for small self-sufficient devices, which use environmental energy as a source. Because power lines are a life-line for our modern life, we are placed in undesirable magnetic power-line field. From the view point of the effect on humans, an acceptable level in a public space is 200 μT at power-line frequency (50 Hz or 60 Hz) [1]. We focus on this magnetic field as an energy harvesting source [2]. Because the harvesting energy is proportional to square of the magnetic flux density, we consider the use of a magnetic core and a magnetic flux concentration coil. The diameter of the coil for magnetic energy harvesting module is as small as 2 cm. The core has dumbbell shape which makes effective permeability more than three times. Compared with the air-core coil, our designed magnetic core makes the harvested energy ten-fold. The magnetic flux concentration coil consists of an air-core Brooks coil and a resonant capacitor. When a uniform magnetic field crossed the coil, the magnetic flux distribution around the coil is changed. It is found that the magnetic field in an area is concentrated larger than 20 times compared with the uniform magnetic field. Employing both methods, the enhancement ratio of the harvested energy is proportional the square of both the effective permeability and the magnetic concentration ratio. Without both methods, the required magnetic field for harvesting 1 mW is larger than 7.2 mT. In contrast, this value becomes less than 100 μT with both methods.

[1] ICNIRP, Health phys, 99(6), pp. 818-836, 2010.
[2] K. Tashiro, H. Wakiwaka, S. Inoue, and Y. Uchiyama, IEEE Trans. Magn., 47 , pp. 4441-4444, 2011.

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES
Chair: M.G. Pini

MO-37

Structural and magnetic characterization of FePt nanoparticles generated with a gas aggregation source

V. Grillo [1], S. D'Addato [2], A. Di Bona [3], P. Luches [3], S. Frabboni [2], S. Valeri [2], P. Lupo [4], F. Casoli [4], P. Ranzieri [4], F. Albertini [4]
(1) Centro S3, Istituto Nanoscienze-CNR, 41125 Modena, Italy and IMEM-CNR, 43124 Parma, Italy, (2) Centro S3, Istituto Nanoscienze-CNR, and Dept. of Physics, UNIMORE, 41125 Modena, Italy, (3) Centro S3, Istituto Nanoscienze-CNR, 41125 Modena, Italy, (4) IMEM-CNR, 43124 Parma, Italy

Fabrication of nanoparticles (NP) with desired shape, structure and size is an important research area, as it presents different possibilities, like, shell-driven magnetisation stability, and realisation of high density memory. In this work it is reported a detailed investigation of the structure, morphology and magnetic properties on FePt NP with linear size between 3 and 10 nm. An experimental set-up was realised for the preparation and the study of pre-formed NP films [1]. The experimental system allows assembly of NP with a gas aggregation source, that can be mass selected with a gas-aggregation source, and co-deposition with other metals, in order to embed them in solid matrix. We could produce in this way FePt NP films in MgO and Ni matrix, to prevent them from NP coalescence during successive thermal treatment and to investigate soft/hard ferromagnetic coupling. The samples were investigated with XPS, SEM, AFM and HR-TEM to study the chemical state of the different atomic species and to determine their morphology and structure. The HR-TEM analysis was performed by exit wave reconstruction method, and advanced simulation [2]. Magnetic properties were studied with AGFM and MFM. It was found that the as-deposited NP, have an icosahedral structure, determined by multitwinning during their assembly, similar to the results from Ni [3] and other metals NP. The films showed a soft ferromagnetic behaviour characteristic of FePt A1 phase. Annealing to T=550 ºC gives rise to hardening of the hysteresis cycles for FePt NP embedded in MgO, while HR-TEM on "naked" NP presented dramatic changes in their structure, revealing a transition to the hard L10 phase, albeit with residual presence of some crystal twinning.

[1] S. D'Addato et al. J. Phys.: Condens. Matter 23 (2011) 175003.
[2] V. Grillo, http://tem-s3.nano.cnr.it/stemcell.htm.
[3] S. D'Addato et al. J. Phys. Chem. C 115 (2011) 14044.

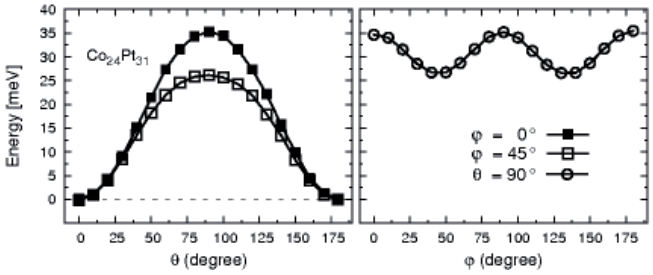
MO-39

Magnetic anisotropy of $L1_0$ cuboctahedral nanoparticles by means of relativistic density functional calculations

R. Cuadrado [1], R. Chantrell [1]
(1) The Department of Physics, University of York, Heslington YO10 5DD, United Kingdom

An important physical quantity in magnetic recording is the magnetic anisotropy energy (MAE). It determines the tendency to align the magnetization along some specific axis in solids and clusters. New recording media would require high MAE values. Good candidates are the binary transition metal nanoparticles (NPs) based on Fe or Co alloyed with a noble metal, especially those chemically L1_{0} ordered[1] showing high values of MAE. To calculate the MAE using the framework of density functional theory (DFT) requires a huge computational resource since a fully relativistic (FR) and a full potential (FP) treatment becomes necessary. We have carried out a FR calculations of the magnetic moments (MMs), density of states and the MAEs within the generalized gradient approximation of L1_{0} cuboctahedral FePt, CoPt, FeAu and FePd based NPs using a recent implementation[2] in SIESTA code[3] under the pseudopotential approximation. We have restricted the total number of atoms to the magic numbers: 13, 55, 147 and 309, ranging the diameters of the NPs from 0.6 nm for N_{tot}=13 up to 2.2 nm for N_{tot}=309.
Although the original stacking is retained after a conjugate gradient relaxation, the atoms feel slight displacements from their original bulk positions providing high values of the MAE in comparison to the undisplaced ones. Also, the anisotropy is size and orientation dependent (see figure1). Further, as the size of the NPs increase the value of the net MM/at range from 1.1\mu_{B} for Fe_{5}Au_{8} up to 1.66\mu_{B} Fe_{67}Pt_{80}.

[1] Markus E. Gruner, et al., Phys. Rev. Lett. 100, 087203 (2008).
[2] R. Cuadrado and J. I. Cerdá J. Phys.: Condens. Matter 24, 086005 (2012).
[3] J.M. Soler, et al., J. Phys.: Condens. Matter, 14, 2745, (2002).



Evolution of the total energy as a function of the magnetization angles for one CoPt NP.

MO-40

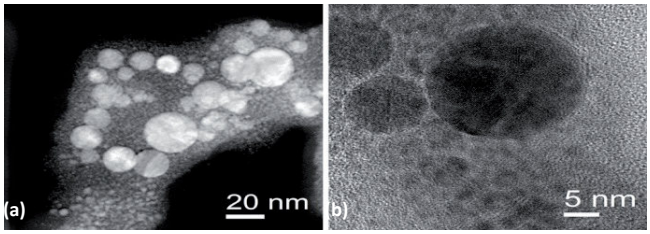
Colloidal solutions of FePt nanoparticles by Pulsed Laser Ablation in liquid medium

L. Nasi [1], F. Casoli [1], G. Cristoforetti [2], E. Tognoni [2], F. Albertini [1], V. Chiesi [1], R. Cabassi [1], S. Fabbrici [1], M. Campanini [1], G. Bertoni [1]
(1) CNR-IMEM, Parco Area delle Scienze 37/A, 43124 Parma-Italy, (2) CNR-INO, Area della Ricerca di Pisa, Via G. Moruzzi 1, 56124 Pisa-Italy

Pulsed Laser Ablation in Liquid medium (PLAL) has been recently proposed for the production of nanoparticles (NPs), due to the excellent experimental flexibility of the technique and its "green" character. Different attempts have been realised to grow various kind of nanoparticles, showing that NP properties critically depend on experimental conditions [1-3]. Because of the complexity of physical processes involved in the synthesis, in-depth studies are required to allow a full control on NPs shape, size, composition and crystallinity. This capability could be reached in principle through an accurate choice of experimental parameters, which appears particularly appealing for FePt NPs, since colloidal solutions of $L1_0$-FePt NPs with

size of a few nanometers can be hardly prepared by chemical synthesis methods.
We have produced colloidal solutions of FePt nanoparticles by PLAL and performed a complete characterisation of the NPs samples by X-Ray Diffraction, Transmission Electron Microscopy (TEM), Alternating Gradient Force Magnetometry and SQUID Magnetometry. We have tested different laser parameters (wavelength, fluence, laser repetition rate, spot size) and solvents (water, ethanol and acetone), with the aim of correlating the experimental parameters with NP characteristics. NPs with spherical shape, variable size (in the range 1-100 nm) and composition (Fe_3Pt, FePt and $FePt_3$) have been obtained. We have demonstrated the possibility to obtain core-shell NPs by a suitable choice of the experimental conditions and evidenced that the PLAL technique determines a prevalence of the Pt-rich composition ($FePt_3$) in the larger nanoparticles and a more balanced ratio in the smaller ones. Coherently with TEM analysis, NPs show a superparamagnetic or ferromagnetic behaviour depending on NP size.

[1] V. Amendola et al., Phys. Chem. Chem. Phys. 11, 3805 (2009).
[2] G.W. Yang, Prog. Mater. Sci 52, 648 (2007).
[3] G. Cristoforetti et al., Appl. Surf. Sci. 258, 3289 (2012).



High Angle Annular Dark Field (a) and High Resolution TEM (b) images of FePt NPs.

MO-42

Ferromagnetic Hard L10 FePt nanoparticles in a carbon matrix: an example of nano-compass behaviour

M. Solzi [1], C. Pernechele [1], M. Villani [2], G. Calestani [3], A. Migliori [4]
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Stoichiometric FePt nanoparticles in the tetragonal $L1_0$ phase, for which a very high uniaxial magnetocrystalline anisotropy (K_u= 6.6×10^7 erg/cm^3) is associated to a theoretical thermal stability of magnetization for grains with size as small as 3 nm, represent one of the leading candidates for the next generation high-density recording media [1]. In the present work, monodispersed ferromagnetic FePt nanoparticles, partially ordered in $L1_0$ phase, were directly prepared without further annealing by high temperatures synthesis (≈ 300°C) involving poly(N-vinyl-2-pyrrolidone) and Triton X-100 as protective agent and reaction solvent respectively. Nanoparticles with average size ranging from 5 to 7 nm and coercive fields reaching 0.1 T at 300K were obtained, but they invariably aggregate by magnetic dipolar interaction. By increasing the solvent viscosity, 5nm superparamagnetic nanoparticles are embedded in an amorphous matrix deriving from solvent condensation/ decomposition, thus avoiding aggregation. Nanoparticles are then completely converted in the hard tetragonal $L1_0$ phase, preserving the original size, by annealing in vacuum at higher temperatures that, at the same time, transform the matrix into amorphous carbon. Annealing at 650°C for 3h leads to coercive fields of about 0.25 T at RT and 1.3 T at 5K (without reaching the saturation of magnetization) and to peculiar squeezing of the hysteresis loops. Subsequent treatments at higher temperature, induce a further shrinking of the loop and a reduction of the coercive field. The possible explanation takes into account that, by raising the annealing temperature, an increasing number of nanoparticles becomes free to rotate inside the matrix, aligning like "nano-compasses" [2] with the applied magnetic field. On the other side a significant (but decreasing) fraction of nanoparticles remains locked to the matrix, generating the superimposed magnetically hard contribution.

[1] S. Sun et al., Science 287 1989 (2000).
[2] Tejada, et al, Phys Rev Lett 104 027202 (2010).

MO-43

Spin Dynamics in Magneto-plasmonic Hybrid Nanostructures

E. Umut [1], A. Capozzi [2], T. Orlando [3], M. Mariani [4], F. Pineider[5], C. Sangregorio [5], M. Corti [3], F. Tabak [1], A. Lascialfari [6], P. Ghigna [7]
(1) Physics Engineering Department, Hacettepe University, 06800, Ankara, Turkey, (2) EPFL SB IPSB GR-CO CH F0 632 (Bâtiment CH) Station 6, 1015 Lausanne, Switzerland, (3) Dipartimento di Fisica "A.Volta", Univ. di Pavia, I-27100, Pavia, Italy, (4) Dipartimento di Fisica, Univ. di Bologna, I-40127, Bologna, Italy, (5) Dept of Chemistry, Università degli Studi di Firenze, 50019, Florence, Italy, (6) Dept. of Molecular Sciences Applied to Biosystems (DISMAB, Università degli Studi di Milano, I-20134, Milano, Italy, (7) Dipartimento di Chimica, Univ. di Pavia, I-27100, Pavia, Italy

The aim of the present work is to study the spin dynamics in Au-Fe_3O_4 hybrid magnetic nanoparticles by means of ^{1}H NMR. Nuclear Magnetic Relaxation rates, $1/T_1$ and $1/T_2$, and spectra have been measured on nanoparticle powders as a function of temperature, covering the range 1.5÷300 K, at two different magnetic fields H=0.65 T and H=1.65 T. In the spin-lattice relaxation rate (SLRR) $1/T_1$ vs T behaviour, three maxima at T~250±20K, T~120±20K and T~10±5K, have been observed; these anomalies are damped and shifted to higher temperatures with magnetic field increasing. We tentatively explain this behaviour with three contributions, each one following the Bloemberger-Purcell-Pound (BPP) equation[1]. In our heuristic model for $1/T_1(T)$, the spectral density of spin fluctuations J(ω) is multiplied by the effective magnetic moment of the nanoparticle χT, which represent the static contribution to the SLRR. ω_L and τ_C being the Larmor frequency and the correlation time corresponding to J(ω), respectively, at temperature where the condition $\omega_L\tau_C \approx 1$ is satisfied an anomaly in $1/T_1$ is observed, so that for each contribution to the SLRR one can finally write $1/T_1 \mu\chi T\, J(\omega)$. Regarding the origin of the anomalies, we hypothesize that: the peak at high temperatures is associated with the re-orientational motion of methyl(CH_3) and ethyl(CH_2) groups in the oleylamine coating, similarly to previous results in literature[2]; the peak observed at intermediate temperatures is related to the blocking temperature T_B, i.e. to the Néel reversal of the magnetization[3]**.** The peak observed at low temperatures, whilst of still unclear origin, could be related to the surface's spins dynamics. Cariplo Foundation (Project no. 2010-0612) is thanked for funding the research.

[1] N. Bloembergen et al., PR. 73, 679-712, (1948)
[2] K.G. Conn et al. J. Chem. Phys. 87, 20-27, (1987)
[3] L. Néel et al., J. Appl. Phys. 31, 27, (1960)

MO-44

Structure and Magnetism of FeRh Nanoparticles

A. Hillion [1], A. Tamion [1], F. Tournus [1], A. Cavallin [2], S. Vlaic [2], J. Dreiser [3], F. Nolting [3], C. Piamonteze [3], S. Rusponi [2], H. Brune [2], *V. Dupuis [1]*

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Magnetic nanoalloys are particularly interesting because they offer large opportunities in tuning the magnetic moment and magnetic anisotropy energy by controlling the composition and structure of the nanoparticle. The FeRh system is particularly promising for the field of optics and magnetic recording. In the bulk, and for equiatomic composition, this alloy presents a metamagnetic transition from an antiferromagnetic to a ferromagnetic state [1]. This transition occurs at room temperature and it is associated with an important increase in magnetic moment. Our goal is to study this effect in particles with sizes of only a few nanometres, where finite size effects could result in a different behaviour with respect to bulk. We have studied the crystallographic structure (HRTEM) and the magnetic properties (SQUID) of 2 to 3 nm diameter FeRh nanoparticles (NPs) encapsulated in a C matrix as a function of their annealing temperature. The NPs have been produced by Low Energy Cluster Beam Deposition [4] and co-deposited with C to avoid coalescence and protect them from oxidation. HRTEM images reveal a transition from the chemically disordered fcc A1 phase to the chemically ordered B2 phase upon annealing to $T \geq 770$ K. Associated with this structural transition, an increase of the magnetic anisotropy energy by a factor of three was observed from SQUID measurements by applying the « triple fit » method [3]. Recent X-ray absorption spectroscopy measurements (EXAFS and XMCD) under synchrotron radiation at both (Fe and Rh) edges will be presented.

[1] J. Balun et al., "Phase equilibria in the Fe–Rh–Ti system I. Experimental results," *Intermetallics* **15**, 1237 (2007)
[2] A. Perez et al.,"Functionalized Cluster-Assembled Magnetic Nanostructures for Applications to high Integration-Density Devices," *Advanced Engineering Materials* **7**, 475 (2005).
[3] A. Tamion et al., "Accurate determination of the magnetic anisotropy in cluster-assembled nanostructures," *Applied Physics Letters* **95**, 062503 (2009).

MO-47

Magnetic properties of Co-Gd nanoparticles in carbon matrix

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Magnetic nanoparticles attract much attention both for their fundamental interest as well as for their potential applications. In order to increase the nanomagnet thermal stability, great efforts have been directed towards an enhancement of the nanoparticles magnetic anisotropy. It is well known that the structure and properties of materials are influenced by preparation conditions and precursor composition. As previously shown in [1], the usage of different metal compounds in precursors leads to metal phase formation by different ways. In the present work we investigated the effect of the precursor and preparation conditions on magnetic properties of metal nanoparticles in the carbon matrix. Metal nanoparticles in the carbon matrix were obtained by method described in [2]. Two different series of samples based on polyacrylonitrile (PAN) and $Co(C_2H_5O_7)_2/Gd(C_2H_5O_7)_3$ or $CoCl_2/GdCl_3$ were prepared by IR-pyrolysis at T = 500 – 900°C. The structure and morphology of obtained materials were studied by X-ray analysis and TEM. Magnetic properties of the samples were investigated with VSM Lakeshore 7404 in the temperature range from 80 to 400 K.

All samples have hysteresis behavior in magnetic field up to 5 kOe at room temperature. The saturation magnetization was stable in all temperature range. But its value strongly changed with synthesis conditions. The coercivity was also different (its value was in the range from 100 to 600 Oe at room temperature) and its thermal dependences were both increasing and decreasing with temperature increase. The structure parameter change was also defined by X-ray analysis.

The magnetic properties correlation with phase content, structure parameters and preparation conditions is discussed.

[1] G. P. Karpacheva, K. A. Bagdasarova, G. N. Bondarenko at al. //Polymer Science, A, Vol. 51, Nos.11–12, (2009), p.1297.
[2] Zemtsov L.M., Karpacheva G.P., Efimov M.N. at al.// Polymer Science A, V. 48, (2006), p.633.

MO-48

Irreversible Magnetic Properties of Carbon Nanoparticles

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Carbon-based materials are interesting due to unusual magnetic properties, such as a high-temperature ferromagnetic behaviour, and a broad area of possible utilization ranging from spintronics to biological and medical applications [1]. We investigate here magnetic properties of the powder and glassy samples, containing carbon nanoparticles, at temperatures $T \sim 3 – 300$ K in magnetic fields B up to 5 T. The purpose is to obtain information on the macroscopic and microscopic magnetic properties of the nanocarbon system.

According to atomic-force microscopy measurements, the assembly of carbon particles has a broad size distribution, characterized by the average and the maximum radii of ~ 60 and 110 nm, respectively. Magnetization $M(T)$ in low fields of 1 – 50 mT exhibits strong irreversibility or deviation of zero-field cooled and field-cooled data, with is suppressed with increasing B above ~ 1 T. The dependence of $M(B)$ demonstrates a saturation above 2 T at high temperatures, but deviates from such behaviour below ~ 150 K. Magnetic hysteresis is observed already at 300 K and is characterized by a power-law temperature dependence of the coercive field, $B_c(T)$.

The distribution of the blocking temperatures is obtained, which suggests a concentration of the magnetization close to the surface to the carbon nanoparticles. This is supported by a detailed

analysis of the macroscopic magnetic properties above, yielding a thickness of the near-surface magnetic layer ~ 1 nm, to be close to the average distance between localized magnetic moments. The results of our work are consistent with the origin of magnetism in nanocarbon presumably with intrinsic surface defects.

[1] T. Makarova and F. Palacio (editors), Carbon-Based Magnetism, Elsevior, North-Holland, 2006.

MO-49

Magnetic response of graphene@MNPs nanostructures

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Interaction of particular electronic states of graphene (GN) monolayers with those of transition metal oxide nanoparticles opens enormous possibilities to engineer new generation of the hybrid GN-based nanostructure, as demonstrated recently for few-layer GN composites. We report on preparation, structure characterization and magnetic response of graphene (GN) monolayers under interaction with magnetic nanoparticles (MNPs). The magnetic response of the MNPs can be effectively controlled by variation of their size and strength of the inter-particle interactions, determined by their separation distance, d_{int}. The investigated GN@MNPs structures constitute of a CVD-grown GN sheet(s) and uniform $CoFe_2O_4$ hydrophobic nanoparticles (d = 6 with a size distribution below 1 nm), prepared by modification of the hydrothermal method. The MNPs were either dispersed directly on the graphene layer, or on the substrate, and subsequently the graphene monolayer has been transferred over the fixed MNPs, and finally a sandwich-like structure has been obtained by combining the two particular steps. In order to control the inter-particle (dipolar) interaction, the d_{int} between the MNPs was varied by changing the initial concentration of the ferrofluid. Morphology of the samples, with focus on dispersion of the individual MNPs, was investigated by AFM. The GN@MNPs nanostructures were further inspected by Raman spectroscopy and MFM, and additional experiments including magnetization, a.c. susceptibility, electrical resistivity, and magnetoresistance were performed (T = 2 – 400 K, B = 0 - 14 T).

MO-50

Magnetic and structural characterization of $Co_{1-x}TM_x$ (Fe, Cr and Mn) nanoalloys

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In the last years metal nanoparticles have drawn much attention because of their potential for development in building ultrahigh density hard drives, devices for biomedical applications and chemical sensing [1,2]. Therefore, for that materials can to have applications is necessary a good control of well-defined size, geometry and surface chemistry effects for minimize coalescence between the particles. In this sense several synthesis process (chemistry and physics) have been extensively investigated. In this work we have studied the structural and magnetic properties of $Co_{1-x}TM_x$ (Fe, Mn and Cr) nanocrystalline alloys using X-ray diffraction and magnetic measurements. The nanocrystalline alloys were obtained chemical route via co-thermolysis of metallic acetylacetonate precursor in oleylamine surfactant/ phenylether at low temperature ($T_S \approx$ 250°C). X-ray diffraction results and Rietveld refinement analysis show for samples with concentrations lower than 20% of TM, the crystalline structure is similar to the cubic structure of the Co with average size of 5 nm. Magnetizations measurements as function of field show that the particles present to be soft magnetically. Figure 1 shows Zero-Field-Cooling and Field-Cooling magnetization curves suggest that the surface anisotropy prevail at low temperature and the systems are strongly interacting and same for samples disperse on the polymeric matrix. Transmission Electronic images would be shown to verify the morphology and size distribution of the nanoparticles. (CNPq).

[1] Q. A. Pankhurst et al., J. Phys. D 36, R167 (2003).
[2] S. Sun et al., Science 287, 1989 (2000).

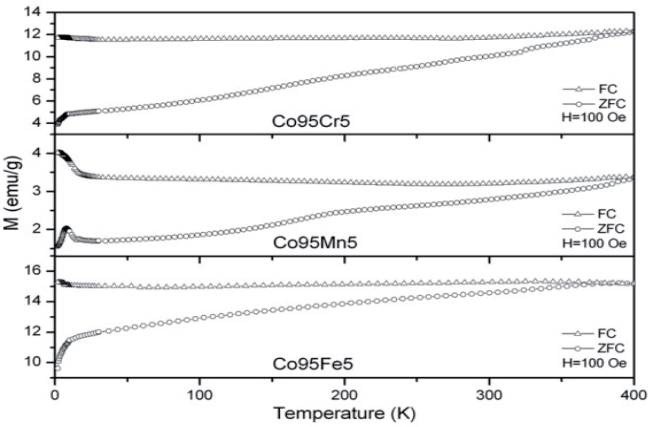

Figure 1: ZFC-FC magnetization curves for samples of cobalt doped with 5% of the TM

MO-51

Magnetic Properties of Cobalt Chromite Nanoparticles

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The multiferroic CoCr2O4 with no orbital degrees of freedom shows tiny deviations from cubic structure, even in its ground state. It orders ferrimagnetically below the Curie temperature, T_c = 94 K, and an additional order-to-order magnetic phase transition to spiral magnetic phase occurs at T_s = 27 K. Magnetocapacitive measurements show that the dielectric constant of $CoCr_2O_4$ couples to the spiral magnetic order parameter, but is insensitive

to the ferrimagnetic spin component. In our work, we address size effect magnetic properties of CoCr2O4 nanoparticles.
The nanoparticles (NPs) of cobalt chromite ($CoCr_2O_4$) were synthesized by hydrothermal method, and subsequently annealed from 300 °C to 500°C.
The crystal structure and particle size distribution of the NPs were investigated by powder Xray diffraction (XRD), dynamic light scattering (DLS) and transmission electron microscopy (TEM).
The particle size was found to be about 5-20 nm for the samples annealed from 300°C to 500°C according to the TEM image. The TEM image also showed the particles were synthesized nearly spherical crystal shape. Magnetization vs. temperature measurements revealed a transition from paramagnetic to superparamagnetic (SPM) state in contrast with the transition from paramagnetic to long-range ferrimagnetic state reported in bulk samples. The zero-field cooled (ZFC) and field-cooled (FC) curves show glassy-like behavior with furcation temperature, T_f = 38 K. The hysteresis loops exhibit a moderate hysteresis ($\mu_0 H_c$~0.4T) and no trend to saturation up to 7T, in contrast to the bulk sample. The typical features of the $CoCr_2O_4$ magnetic order are suppressed in the nanoparticles, resulting in a (super)spin-glass like state.

MO-52
Magnetic properties of Fe/Fe_xO_y core-shell nanoparticles with modified surface
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As the size of the nanoparticles (NPs) decreases, the surface effects become more significant due to the increased surface/volume ratio [1]. We report here our results on the effect of ligands on the surface chemistry and magnetic properties of Fe/Fe_2O_3 and Fe/Fe_3O_4 core-shell NPs functionalized with 3-aminopropyltriethoxysilane (APTS).
Core-shell NPs have been prepared by high-energy ball milling. In the presence of air or Ar, the Fe core is progressively covered with a Fe_2O_3 shell, and the obtained Fe/Fe_2O_3 particles have diameters of 200-300 nm after 68 h of milling. Fe/Fe_3O_4 NPs of 20-60 nm are obtained by wet milling of Fe microparticles for 42 h. For milling times over 42 h the whole amount of Fe is transformed into Fe_3O_4, and the resulting magnetite NPs have diameters ranging from 15 to 50 nm.
The magnetic properties of Fe/Fe_xO_y core-shell NPs can be tailored from ferromagnetic Fe/Fe_2O_3 to weak ferromagnetic Fe/Fe_3O_4 and superparamagnetic Fe_3O_4. The main advantage of such core-shell NPs in biomedical applications, compared with simple Fe_xO_y NPs, resides in their easier use and manipulation for specific applications. To understand the surface chemistry and its influence on the magnetic properties of Fe/Fe_xO_y core-shell NPs, their surface was systematically modified with APTS, by increasing progressively the concentration of the ligand. The low temperature measurements indicate a strong influence of the ligand on the magnetic properties. The change of the magnetic properties also correlates with the specific coordinating functional group bound on the NPs surface. The correlation suggests the decrease in spin-orbital coupling and surface anisotropy of magnetic NPs due to the surface coordination.
Financial support from the UEFISCDI Contract PCCE-ID_76 is highly acknowledged.

[1] S.B. Kim, C. Cai, J. Kim, S. Sun, and D.A. Sweigart, Organometallics 28, 5341 (2009).

MO-53
Microscopic modelling of magnetic nanoparticles: from core/shell to hollow structures
O. Iglesias [1], A. Labarta [1], A. Cabot [2], A.P. Alivisatos [3], V.F. Puntes [4], L. Balcells [5], *K. Simeonidis* [6], C. Martinez-Boubeta [7], M. Angelakeris [6], S. Mourdikoudis [6], I. Tsiaoussis [6], A. Delimitis [8], C. Dendrinou-Samara [9], O. Kalogirou [6]
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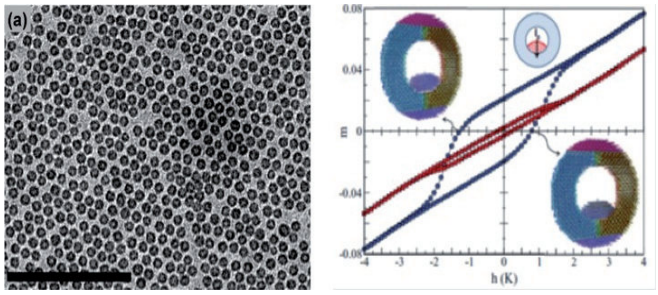
The properties of magnetic particles show interesting peculiar behavior when going to the nanometric and low temperature regimes. Nanoparticles (NP) with non-homogeneous compositions or peculiar morphologies, which can be tuned by proper control of the conditions of the synthesis method, have been shown to be useful for technological and biomedical applications. Here, we will present our recent work on theoretical modeling of some of these NP systems. In particular, we will shoe results of the experimental characterization of two sets of NP synthesized with the help by Kirkendall effect: 1) Fe2O3 hollow NP with peculiar magnetic properties [1], and 2) Co based NPs that show appearance of hysteresis above 300 K due to an enhancement of the surface anisotropy resulting from the additional spin-disordered surfaces when passing from core/shell to hollow structures and shift of field-cooled hysteresis loops that is proportional to the CoO shell thickness [2]. Next, we will show that the microscopic origin of the peculiar magnetic phenomenology can be understood by means of Monte Carlo simulations at the atomistic level [3] which take into account the specific compositions and morphologies of the real samples.

[1] A. Cabot, A. P. Alivisatos, V. F. Puntes, Ll. Balcells, O. Iglesias and A. Labarta, Phys. Rev. B 79, 094419 (2009).
[2] K. Simeonidis, C. Martinez-Boubeta, Òscar Iglesias, et al., Phys. Rev. B, Phys. Rev. B 84 144430 (2011).[3] Ò. Iglesias, et al., J. Nanosc. Nanotech. 8, 2761 (2008).



TEM image of hollow maghemite NPs and simulated hysteresis loop for a yolk/shell (Co/CoO) NP.

MO-54

Tuning the Surface Anisotropy in (Cr,Fe)-doped NiO Nanoparticles

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In the last decades the nanoscience have been an exciting area of research as much of application point of view as of fundamental research. In particular, there are many studies concentrated on physical properties of fine particles with dimensions in the nanometer range [1-2]. In this scenario, magnetic nanoparticles (NP's) have been extensively studied mainly owing to their unique physical properties as compared to their bulk counterparts. In this work, Ni1-x(Cr,Fe)xO nanoparticles have been obtained by the co-precipitation chemical route. X-ray diffraction analyses using Rietveld refinement have shown a slightly decreasing in the microstrain and mean particle size as function of the doping. Transmission electronic microscopy images show that particles change the morphology from a shape faceted to nanorod-like with increasing of doping. The Zero-Field-Cooling and Field-Cooling (ZFC-FC) magnetization curves show a superparamagnetic behavior at high temperature and low temperature peak (at T = 10 K) which is enhanced with increasing of the doping concentration (the ZFC-FC results for Fe-doped samples can be observed in figure 1). An unusual behavior of the coercive field at low temperature region was also observed. We argue that these behaviors can be linked with the strengthening of surface anisotropy caused by the incorporation of doping ions.

[1] L. Néel, Comp. Hebdom. *Séances del'Acad. Sciences* (Paris), Série B, 228, pp 664–666.
[2] R. H. Kodama, A. E. Berkowitz, E. J. McNiff Jr., and S. Foner, *Phys. Rev. Lett*. **77**, 394 (1996).

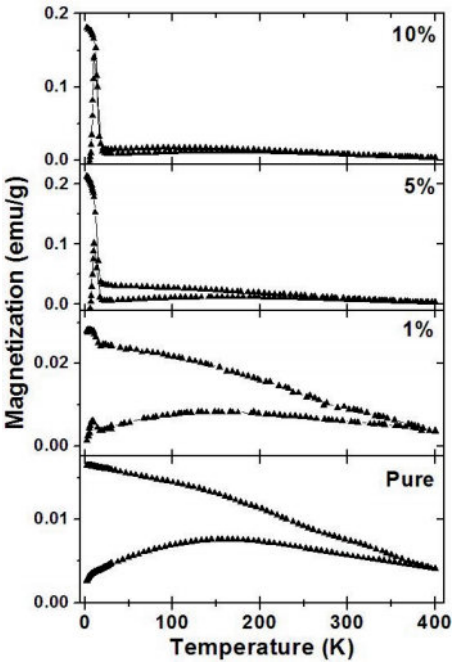

Figure 1: ZFC-FC magnetization curves at $H = 100$ Oe to $Ni_{1-x}Fe_xO$ (x = 0, 0.01, 0.05 and 0.10) nanoparticles synthesized at 350^{0}C.

MO-55

Exchange bias effect in core-shell nanoparticles with non-spherical shape and rough interfaces

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The exchange bias effect in composite magnetic nanoparticles with core-shell morphology and various sizes and shapes is studied in order to understand the interplay between exchange coupling, responsible for exchange biasing, and magnetostatic interactions, responsible for shape anisotropy. We use a classical Heisenberg Hamiltonian including (core, shell, surface) anisotropy terms to describe the magnetic structure of the nanoparticles and the Metropolis Monte Carlo method to simulate the field cooling (FC) process and the isothermal hysteresis loop. The coercive and exchange bias fields for spherical and cubical nanoparticles with similar nominal sizes are compared. The scaling relation between the exchange bias field and the net magnetic moment due to uncompensated spins is modified due to shape anisotropy. The effect of interface roughness is also considered and it is demonstrated that the influence of particle shape diminishes as the degree of interface roughness increases.

MO-56

Non-linear susceptibility and influence of the applied magnetic field on ZFC/FC curves

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ZFC/FC curves are widely used to characterize assemblies of magnetic nanoparticles. They reflect the crossover between the blocked and superparamagnetic (SP) regime with increasing temperature [1,2]. With a low applied field a linear response can be assumed, the shape of the curves is then independent of the applied field H, and a simple theoretical modeling is possible: this allows efficient theoretical fits of experimental curves. We have studied the influence of the applied field magnitude on the ZFC/FC curves shape, both theoretically and experimentally. While the effect of H on the energy barriers has already been discussed, its effect on the response of SP particles has not been considered. However, this non-linearity manifests itself much before the modification of the switching energy distribution. In addition to experimental measurements on a diluted Co nanoparticle assembly, we have simulated ZFC/FC curves for different applied fields, including the third-order susceptibility in the SP response. The later depends on the anisotropy and does not at all correspond to a Langevin function around the blocking temperature. We find that the curves can be significantly affected (in particular the low temperature limit of the FC) for quite low applied fields, which are usually used in experiments.

[1] F. Tournus and E. Bonet, J. Mag. Mag. Mater. 323, 1109 (2011).
[2] F. Tournus and A. Tamion, J. Mag. Mag. Mater. 323, 1118 (2011).

MO-57

What can we learn from isothermal remanent magnetization curves on diluted nanoparticle assemblies?

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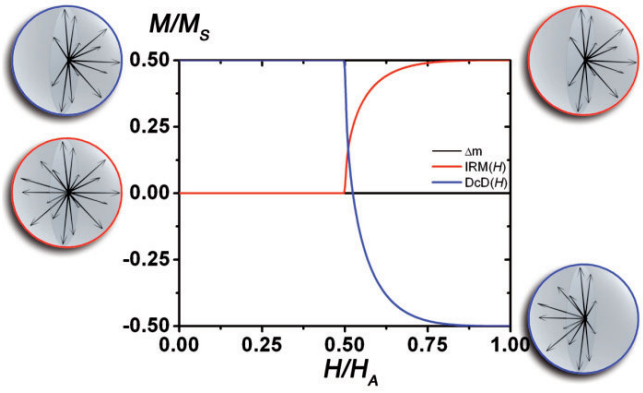
Isothermal remanent magnetization (IRM) and direct-current demagnetization (DcD) curves are mainly used to characterize interactions in a granular magnetic media and to determine the switching field distribution. These curves are only sensitive to irreversible changes, i.e. to the particle magnetization switching for samples made of clusters embedded in a matrix. Moreover, at remanence there is no unsuitable contribution (superparamagnetic, diamagnetic or paramagnetic) to the signal. This makes IRM/DcD curves of great interest in the investigation of the intrinsic properties of nanoparticles. The underlying process, i.e. macrospin switching by applying a field, is complementary to the thermal switching observed with ZFC/FC curves where the particle size distribution has a critical influence [1]. Interestingly, IRM curves have a high sensitivity to other characteristics such as an anisotropy constant distribution, non-uniaxial terms of the anisotropy, and of course inter-particle interactions.
We show how IRM/DcD curves can be modelled for an assembly of randomly oriented and non-interacting macrospins, thus allowing efficient and realistic simulations of experimental curves (taking into account the size distribution, temperature, etc). This modelling is then confronted to a series of measurements on diluted Co nanoparticle samples prepared by low-energy cluster-beam deposition [1]. Experiment/theory comparison can provide new insights on their magnetic properties.



IRM and DcD at 0 K calculated for an assembly of randomly oriented uniaxial macrospins.

[1] A. Tamion, M. Hillenkamp, F. Tournus, E. Bonet, and V. Dupuis, Appl. Phys. Lett. 95, 062503 (2009).
[2] A. Perez, V. Dupuis, J. Tuaillon-Combes, L. Bardotti, B. Prevel, E. Bernstein, P. Mélinon, L. Favre, A. Hannour, and M. Jamet, Advanced Engineering Materials 7, 475-485 (2005).

MO-58

Efficient hysteresis loop simulations of nanoparticle assemblies beyond the uniaxial anisotropy

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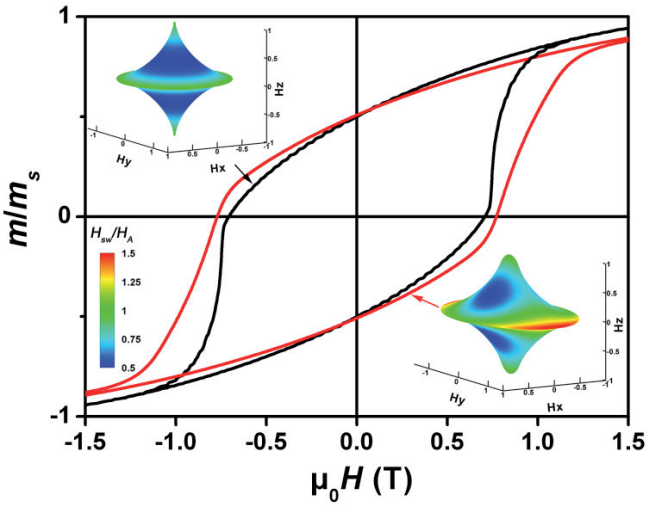
In ferromagnetic nanoclusters, the coherent switching of the magnetization is one of the basic processes by which the cluster responds to the magnetic field. The first systematic study of the coherent rotation of magnetization at 0 K in small particles was performed by Stoner and Wohlfarth (SW) for the case where the anisotropy is uniaxial and of second degree. Therefore, the problem is reduced to a 2D problem. However, in standard magnetometery the lowest accessible temperature is close to 2 K. Moreover, most magnetic clusters do not have a perfect uniaxial anisotropy of second degree but are characterized by the presence of higher degree magnetic anisotropies.
We present a deterministic approach which can be used to fit the experimental low temperature hysteresis loops of nanoparticle assemblies with a random distribution of the anisotropy axes. Within this model, the thermal effects are taken into account using the model presented in [1]. To deal with more complex clusters anisotropies, the geometrical approach is used [2], also know as the "astroid method".
The applicability of the introduced model for fitting the experimental data is tested on non-interacting Co clusters embedded in carbon and germanium matrices, respectively [3]. Moreover, we also provide a comparison of the fits of high temperature $m(H)$ and Zero-Field Cooled (ZFC) /Field Cooled (FC) susceptibility measurements. We show that the deduced magnetic properties are not necessarily the same for these two approaches.



Theoretical hysteresis loops at 0 K for an uniaxial ($K_2 = 0$) and a biaxial anisotropy ($K_2/K_1 = 0.5$). The corresponding astroids are in insert.

[1] J. Garcia-Otero, A. J. Garcia-Bastida, and J. Rivas, J. Magn. Magn. Mater. 189, 377 (1998).
[2] A. Thiaville, Phys. Rev. B 61, 12221 (2000).
[3] A. Tamion, E. Bonet, F. Tournus, C. Raufast, A. Hillion, O. Gaier and V. Dupuis, accepted in Phys. Rev. B.

MO-59

Magnetic Properties of $Sm_{0.1}Ca_{0.9}MnO_3$ Nanoparticles

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Size dependent magnetic properties of $Sm_{0.1}Ca_{0.9}MnO_3$ (SCMO) with average size 25 (SCMO25) and 60 nm (SCMO60) have been investigated. Bulk SCMO exhibits *G*-type antiferromagnetic (AFM) structure with ferromagnetic (FM) component and $T_C \approx T_N \approx 110$ K [1,2]. Temperature dependences of magnetization show that T_C decreases with decreasing particle size from 107 K for SCMO60 to 94 K for SCMO25. Deviations of from Curie-Weiss law point to possible existence of Griffith phase. The spontaneous magnetization M_0 at 10 K was found to be $M_0 \approx 0.075$ and 0.31 μ_B/f.u. for SCMO25 and SCMO60, respectively, what is equivalent to the relative volume of FM phase of 2.4% and 10%. Paramagnetic Curie temperature $\Theta \approx 5$, 68, 79 K for SCMO25, SCMO60, and bulk, respectively also indicate weakening of FM interactions with decreasing particle size. On the other hand, high filed susceptibility taken as a slope of $M(H)$ curve in the range 50-90 kOe is almost the same for SCMO25 and SCMO60 indicating the stability of AFM matrix in the core. Pronounced exchange bias (EB) effect was observed in SCMO25 (Fig. 1), while in SCMO60 the effect is small. EB field, remanence asymmetry, and magnetic coercivity H_C, strongly depend on the cooling field H_{cool}. In contrast to a typical monotonic decrease of coercivity with increasing temperature, H_C of SCMO25 and SCMO60 exhibit complex behavior (see inset in Fig. 1). Monte Carlo simulations [3] for non-interacting AFM particles with an AFM core and disordered shell predict qualitatively similar behavior of $H_C(T)$.

1. C. Martin et al., Phys. Rev. B. 60, 12191 (1999)
2. V. Markovich et al. J. Phys.: Condens. Matter 18, 9201 (2006)
3. E. Winkler et al. Nanotechnology 19, 185702 (2008)

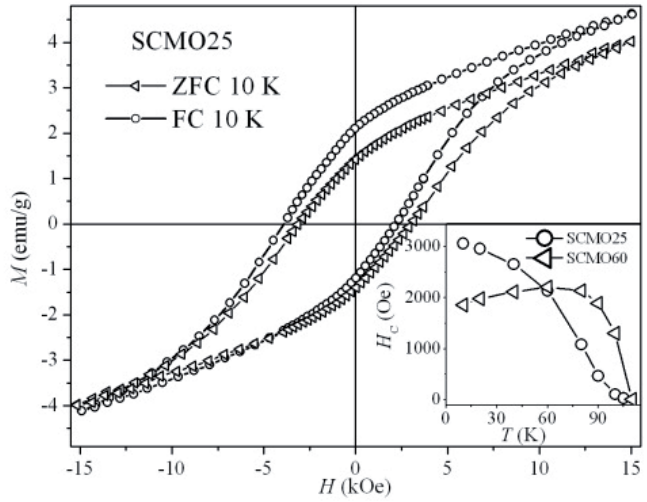

Fig. 1 Hysteresis loops SCMO25 at 10 K after ZFC and FC. Inset: H_C vs. T.

MO-60

Size dependent magnetic state of $La_{0.23}Ca_{0.77}MnO_3$ nanoparticles

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Size dependent magnetic properties of $La_{0.23}Ca_{0.77}MnO_3$ nanoparticles with average size ranging from 12 to 60 nm have been investigated. At low temperatures thermoremanent (TRM) and isothermoremanent magnetization (IRM) decay following the power while at $T \geq 100$ K both TRM/IRM monotonously increase with time. Smallest 12 nm particles show clear ageing and memory effects, indicating together with pronounced frequency dependence of ac susceptibility the existence of a spin glass-like state. Nevertheless, in particles of 20 nm, and larger, these effects completely disappear. The temperature of ZFC magnetization peak decreases with increasing magnetic field as $H_0[1 - T/T_f(H)]^p$. Fitting procedures for 20 nm particles data at $H < 2$ kOe give a critical line with $p=1.71\pm0.36$, which is very close to de Almeida–Thouless (AT) exponent $p=3/2$. For small 12 nm particles the AT exponent of 3/2 is unexpectedly seen only at $H \geq 700$ K, while for $0 < H < 2000$ Oe the obtained $p=2.59$. Such deviation from AT value is attributed to the formation of cluster glass state and unidirectional anisotropy [1]. The anisotropy arises from interparticle interactions, as confirmed by the exchange bias phenomenon observed in 12 nm particles. Field dependencies of TRM /IRM at 10 K provided fingerprints of irreversible magnetization [2] in nanoparticles shells, see Fig. 1. We conclude that saturation of TRM in strong fields and substantial increase of TRM/IRM in 12 nm particles reflect enhanced contribution, with respect to particles with larger sizes, of disordered shells to the magnetic state of particle ensembles.

[1] X.H. Huang et al., J. Appl. Phys 106, 083904 (2009)
[2] M. J. Benitez et al., Phys. Rev. B 83, 134424 (2011)

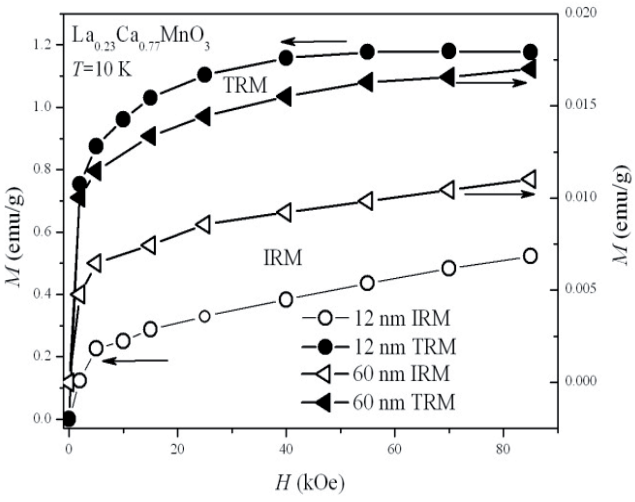

Fig.1 TRM/IRM versus field for 12 and 60 nm $La_{0.23}Ca_{0.77}MnO_3$ particles at 10 K

MO-61

Looking for quantum effects in magnetic nanoparticles using the molecular nanomagnet approach

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In an effort to build a unitary view of the properties of Magnetic NanoParticles (MNPs) and Molecular NanoMagnets (MNMs),[1] we investigated with different techniques MNPs of spinel type iron oxide of approximately 3.5 and 8 nm mineralized in the internal cavity of ferritin type proteins.[2] In particular, we used Electron Magnetic Resonance, EMR, and static and dynamic magnetic measurements and took advantage of the capacity of the protein shells to control the size of the MNP. A signal at half-field in the EMR spectrum is observed for the first time for MNPs as big as 8 nm mineralized in protein cavities. This feature has been interpreted as the signature of the discrete structure of the energy levels and, therefore, of the quantum nature of the system. The EMR behavior of the MNPs is compared with that of two large MNMs: one containing 19 Fe(III) and a second containing 19 Mn(II) centers.[3] The ideal structure of the latter is used as a model to show the structuring of the energy levels. In particular, the analysis of MNPs behavior based on the MNM approach helps to shed light on the role of the different energy terms which govern the MNP properties.

[1] D. Gatteschi, et al., accepted for publication by Angew. Chem. Int. Ed.
[2] M. Fittipaldi, et al., Phys. Rev. B 83, 104409, (2011)
[3] L. Castelli, et al., Dalton Trans., 40, 8145–8155 (2011)

MO-62

The role of magnetic interactions in Exchange Bias properties of $MnFe_2O_4$ Ferrofluid Nanoparticles

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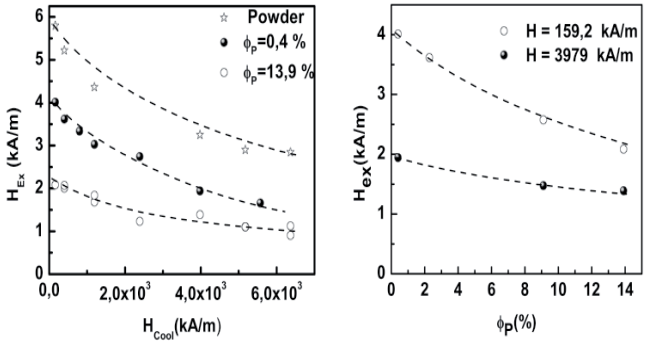
We investigate hysteresis loop properties of magnetic nanoparticles (NPs) obtained by a chemical core/shell strategy developed for ferrofluid synthesis [1], focusing on the role of magnetic interactions on Exchange Bias (EB) phenomena. Previous studies evidenced in such NPs a well-ordered ferrimagnetic core surrounded by a disordered surface layer [2]. Mössbauer spectroscopy has shown, that in the presence of an external field the surface spins progressively align with those of the ferrite core [3]. We compare here magnetization measurements carried out on two systems based on 3.3 nm diameter NP with a $MnFe_2O_4$ core protected by a maghemite shell: (1) powders and (2) frozen magnetic colloids, i.e., non-aggregated particles; in the colloids the NP volume fraction ϕ_P ranges between 0.4% and 13.9%.

After cooling the samples under a field H_{cool}, we observe that the hysteresis loops shift both along H and M axes, which indicates a coupling between the ordered cores and other spins in NPs. In the powder sample and in the frozen ferrocolloids (whatever ϕ_P), the dependence of the EB field H_{EB} on H_{cool} is always similar. As H_{cool} increases, the spin misalignment is reduced, which decreases H_{EB} as illustrated below. In powder samples, H_{EB} is larger, most probably due to exchange interaction between spins of neighboring particles. In frozen diluted ferrocolloids, the coupling between the spin-ordered core and the disordered surface layer only subsists. However in concentrated ferrocolloids H_{EB} decreases with NP volume fraction, because interparticle dipolar interaction enters in play at large ϕ_P.

Acknowledgments: CAPES-COFECUB, CNPq, CNRS, FAPDF



H_{cool} and ϕ_P dependences of EB field H_{EB} at T = 5K; lines are guides for the eyes.

[1] J. A. Gomes et al., J.Phys.Chem. C 112, (2008) 6220
[2] R. Aquino et al., Phys.Rev. B 72, (2005) 184435
[3] E. C. Sousa et al., J.Appl.Phys. 106, (2009) 093901

MO-63

Memory effects and slow dynamic behavior of ferromagnetic-$MnCo_2O_4$ ultrafine particles

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A detailed study of magnetization *(M)* and its relaxation dynamics in ferromagnetic spinel-$MnCo_2O_4$ ultrafine particles has been reported. Memory and time dependent (aging) effects are observed by means of various protocols like frequency (f_m), wait-time (t) and magnetic field (H) during the dc- and ac-magnetization measurements. The Curie temperature T_C is centered around 184 K as observed from both dc- and ac-magnetic susceptibility data recorded under different cooling fields and frequencies, respectively. The blocking temperature ($T_B \sim$ 165 K) as obtained from the temperature dependent ac susceptibility [$\chi'(f_m,T)$ and $\chi''(f_m,T)$] curves essentially follows the Vogel–Fulcher law $T_B=T_0+T_a/ln(f_0/f_m)$. The attempt frequency (f_0) and the activation temperature (T_a) are determined for both T_B and T_C. The frequency (f_m) and bias field (H_b) dependent studies reveal that $MnCo_2O_4$ system essentially exhibits spin glass-like behavior below T_C. The contribution of inter-particle interactions (T_0) on the magnetic relaxation process has been discussed.

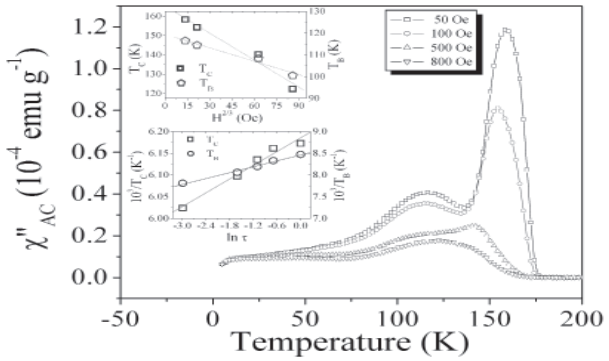
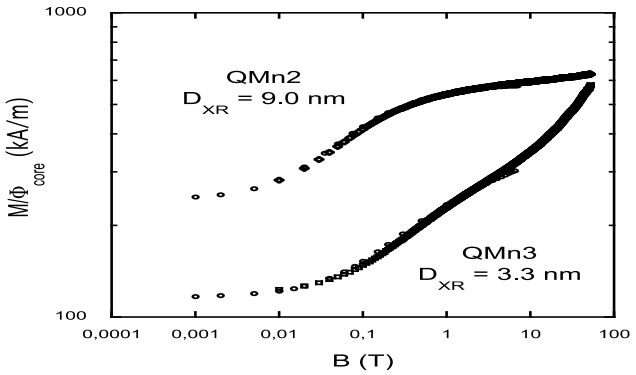


Figure: Imaginary part of the ac-magnetic susceptibility χ''_{AC} vs temperature under different dc-bias fields H_b superimposed with an ac-probing field H_{AC} of amplitude 1 Oe and frequency 2Hz.



ZFC magnetization divided by the core volume fraction versus magnetic field.

MO-64

High field-dependence of the surface spin magnetization in core-shell manganese ferrite nanoparticles

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We present magnetization measurements performed on powder samples of $MnFe_2O_4$ nanoparticles, protected by a maghemite shell with X-ray diameter 3,3 nm and 9 nm, at T=1.5K, under pulsed magnetic field up to 52 T at LNCMI. Previous studies, performed at lower fields have shown that these NPs have a core-shell magnetic structure [1]. This structure consists of a well ordered ferrimagnetic core, whose contribution dominates at high temperatures, surrounded by a surface layer of spins, fluctuating at high temperatures and freezing in a disordered manner at low temperatures. For each sample, a chemical titration allows to determine the respective volume fractions Φ_{Shell} and Φ_{core} [2]. Here, we compare the behavior of the highest branch of hysteresis loop for the two samples. A strong surface contribution is observed in high fields as illustrated below, where LNCMI determinations are normalized to SQUID measurements. The magnetization M/Φ_{core} in high field does not saturate, this effect being stronger for the smallest particles. If M is written as the sum of two terms M_{core} and M_{shell}, it is possible to extract M_{shell} in high field as then M_{core}/Φ_{core} saturates to a given value m^s_{core} . In [1] m^s_{core} was determined from the extrapolation at low T's of the Bloch law for the core (determined at high T's where surface spins do not contribute). Here we obtain at B = 52 T, M_{shell}/Φ_{Shell} of the order of 300 kA/m for both samples, which is a reasonable order of magnitude. However for the smallest nanoparticles no sign of M_{shell} saturation is seen in the experiment at 52 T.

Acknowledgments: CAPES-COFECUB, CNPq, CNRS, FAPDF

[1] R. Aquino R et al, Phys.Rev. B 72 (2005) 184435
[2] J. de A. Gomes et al, J.Phys.Chem. C 112 (2008) 6220

MO-65

Study of structural and magnetic properties of polymeric membranes containing Cobalt Ferrite nanoparticles

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Membrane separation technologies have been widely used in pharmaceutical, chemical, food, biological engineering, environmental protection, metallurgy, electronics and other fields. With the development of nanomaterials and nanotechnology, the use of inorganic nanomaterials for the preparation of inorganic-organic composite ultrafiltration membranes with enhanced functionalities was proposed.

Homogeneous polymeric dispersions of $CoFe_2O_4$ magnetic nanoparticles (MNPs) [1] were obtained by dispersing at room temperature 20 nm size MNPs in a solution of polyetheretherketone with cardo group (PEEK-WC) at 15% wt. with respect to the solvent tetrahydrofuran (THF). Samples with MNPs to polymer wt % ratio of 4.5, 7.5 and 10.2 were also prepared. Preliminary magnetic characterization performed by VSM magnetometer indicated that all the samples show a ferromagnetic behaviour at room temperature with approximately constant values of M_r/M_s =0.62 and H_c = 2.8 kOe. By the analysis of the IRM and DCD curves and of ΔM-plots the presence of dipolar interparticle interactions was inferred. However, since the coercivities remain approximately constant despite the coupling effects and independently on the MNPs concentrations in the membrane, we confirmed the good quality of the dispersion, even in the most concentrated sample. These samples constitute a good starting point for ultrafiltration membranes with the additional functionalities of the ferromagnetic material.

[1] C. Cannas et al. J. Nanop. Reaserch, 8, 2, 255-257, (2006)

MO-66

Magnetic behaviour of dextrine coated ferrite nanoparticles

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Magnetic nanoparticles are of large interest in state-of-the-art research as they exhibit interesting magnetic behaviour, from magnetic irreversibility and slow dynamics of magnetization, to complex magnetic order due to the finite size effects. Considerable efforts are made in different syntheses in order to tune this behaviour, and especially interesting are the coatings ranging from different non-metal-oxides to some biologically relevant large molecules, which has big relevance in applications.

We synthesized ferrite nanoparticles with composition MFe_2O_4, where M = Fe, Co, Mn, Ni, and their surface was coated with dextrine at the end of the precipitation in solution.

X-ray diffraction revealed the amorphous structure of particles, and SEM imaging showed relatively narrow size distribution of rather spherical nanoparticles with average size less than 10 nm.

Temperature dependence of magnetization points to the blocking of magnetic moment of nanoparticles at low temperatures caused with anisotropy barriers. This is consistent with observed hysteresis loops behaviour below the blocking temperature.

The characteristics of nanoparticles obtained from both the structure and magnetic properties are generally consistent with the data known for the same materials in different forms. However, they also show some specific features associated with their amorphous structure, reduced dimensions and capping. It is shown here that dextrine successfully prevented the overgrowth of magnetic nanoparticles, as well as their agglomeration. This manifests also in magnetic behaviour, in a manner characteristic for the independent several nanometer sized magnetic particles.

MO-67

Interparticle Interactions and Magnetic Anisotropy in Cobalt Ferrite nanoparticles: influence of molecular coating

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Molecular coating of nanoparticles represents probably the most important and, at the same time, critical step in order to design new nanostructured magnetic materials. The interaction between molecules and surface atoms leads to a strong modification of surface magnetic properties, that are one of the key point in the physics of magnetic nanoparticles. In this paper the magnetic properties of $CoFe_2O_4$ nanoparticles ($\langle D \rangle \cong 4$ - 8 nm) coated by oleic acid have been investigated in order to clarify the role of the surfactant on the interparticle interactions and surface anisotropy. In coated nanoparticles an increase of magnetic anisotropy (i.e. coercive field and anisotropy constant) with particle size is observed, indicating that the magnetic anisotropy is governed mainly by its magneto-crystalline component. Thermal treatments in suitable conditions allow to remove the surfactant without significant modifications in morpho-structural features of the particles. The removal of molecular coating induces a strong increase of anisotropy, due to the increase of its surface component, as indicated by the increase of exchange bias field.

[1] D. Peddis et al., Chem. Mater., 26, (6), 1062-1071, (**2012**)

MO-68

Surface and doping effects in SiO_2 coated Cobalt ferrite nanoparticles

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Magnetic studies of SiO_2 coated cobalt ferrite ($CoFe_2O_4$) nanoparticles have been investigated in detail [1]. We have synthesized SiO_2 coated cobalt ferrite nanoparticles by sol-gel method. Structural characterization has been done by using X-ray diffraction, Transmission Electron Microscopy (TEM) and Fourier Transform Infrared (FTIR) spectroscopy. We have studied the surface spins effects, SiO_2 matrix concentration effects and effect of Zn-doping on magnetic properties of SiO_2 coated cobalt ferrite nanoparticles. Increase of SiO_2 concentration restrict the average particle to smaller diameters and also helps to prevent nanoparticle agglomeration. The effect of doping non-magnetic zinc in cobalt ferrite nanoparticles reveals an anomalous magnetic behavior. Saturation magnetization shows a non-monotonic behavior on increasing Zn- concentration. However coercivity shows a monotonic behavior with increasing Zn- concentration. We have also studied the temperature dependent magnetic properties which signify the presence of enhanced surface anisotropy at low temperatures in these nanoparticles [2]. The study will bring knowledge about the cation distribution, effect of non-magnetic SiO_2 matrix and contribution of enhanced surface anisotropy in coated cobalt ferrite nanoparticles.

[1] K. Nadeem, H. Krenn, T. Traussing, and I. Letofsky-Papst, *J. Appl. Phys.* ***109****, 013912 (2011).*

[3] R.H. Kodama and A.E. Berkowitz, Physical Review B, 59, 6321-6336 (1999)

MO-69

Surface effects in cobalt ferrite ($CoFe_2O_4$) nanoparticles as a function of size

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We have systematically studied the magnetic properties of cobalt ferrite, $CoFe_2O_4$, nanoparticles in the size range 2–7 nm of diameter with very narrow grain size distributions. Samples were prepared by the thermal decomposition of $Fe(acac)_3$ and $Co(acac)_2$ in the presence of surfactants giving nanoparticles covered by oleic acid. TEM images and XRD diffraction patterns confirms that all samples are composed by crystalline nanoparticles with the spinel structure expected for the cobalt ferrite.

Magnetic properties have been determined from the temperature dependence of magnetization and magnetization isotherms measurements. The samples exhibit characteristic of a superparamagnetic system showing an increase in the blocking temperatures with the particle size, and evidence small size

distribution confirming the TEM measurements. It is observed a size dependence of the ferrimagnetic order of the ferrite. Larger particles have a bulk-type magnetic ordering while the smaller ones have broken the ferrimagnetic order behaving as paramagnetic and / or superparamagnetic of small clusters, depending on temperature. The nanoparticles of 4.5 nm show a mixed behavior indicating that this particle size is the crossover between the system perfectly ordered and magnetically ordered. In this case the competition between exchange energy (which tends to magnetically ordered magnetic moments) and the surface anisotropy (which tends to cause magnetic disorder) are of the same order. For smaller sizes preponderance making the surface anisotropy (magnetically disordered system) and larger sizes of energy exchange is the dominant (ferrimagnéticamente ordered system).

MO-70

Spin-glass freezing induced by structural disorder in Co-ferrite nanoparticles

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Magnetic nanoparticles show a variety of unusual magnetic phenomenology when compared to the bulk materials, such as superparamagnetism and glassy behaviour due to the influence of the surface on magnetic interactions and charge rearrangement, and to the closeness of the particle size to critical magnetic length scales [1]. In the case of spinel ferrites such as Co-ferrite, further complexity arises due to the likely size-dependent cation distribution of the tetrahedral and octahedral sites in the close-packed oxygen structure, which strongly affect the magnetic properties of the particles such as saturation magnetization and magnetic anisotropy.

Here we study a system of weakly interacting Co-ferrite nanoparticles, with narrow size distributions, synthesized by a high-temperature decomposition method of Fe and Co organic precursors in an organic solvent [2]. We find that 8-nm nanoparticles show spin glass-like behaviour at low temperature with strong magnetic frustration associated with highly defective crystallographic structure. Our high-resolution TEM measurements exclude the formation of a core-shell structure, and indicate the presence of crystallographic defects and/or domain boundaries inside the nanoparticles, giving rise to a strong magnetic frustration which is responsible of the formation of spin-glass-like regions between ferrimagnetically ordered spins (core of the crystallographic domains). Above the freezing temperature, the nanoparticles undergo an unblocking process towards a typical SPM regime where the magnetization curves at different temperatures can be scaled in a conventional H/T plot. For 12-nm particles, the ferrimagnetic contribution to the hysteresis loop becomes increasingly more predominant, even at low temperatures. This could be related to the presence of fewer defects and cation vacancies, or to an enhanced structural relaxation compared to the smaller particles.

[1] X. Batlle and A. Labarta *J. Phys. D: Appl. Phys.* **35** R15 (2002).

[2] N. Pérez, F. López-Calahorra, A. Labarta, and X. Batlle, *Physical Chemistry Chemical Physics* **3** 19485 (2011).

MO-71

Influence of the cationic disorder on the magnetic properties of bulk and nanocrystalline $ZnFe_2O_4$ and Co_3O_4 samples

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We report structural and magnetic measurements on nanocrystalline and bulk $ZnFe_2O_4$ and Co_3O_4 samples obtained through co-precipitation chemical method and solid state reaction. Both systems presents the well-known spinel structure where two different crystallographic sites are occupied for 2+ and 3+ metallic ions. In their bulk forms $ZnFe_2O_4$ and Co_3O_4 display an antiferromagnetic order at 10 and 30 K, respectively. The Rietveld analysis of X-ray patterns reveal that *i*) our samples are single phase, *ii*) the average particle size increase with synthesis temperature and *iii*) cationic disorder increase with decreasing of the mean particle size. The latter means the deviation of the normal spinel structure. In spite of the antiferromagnetic character the Zero-Field-Cooled (ZFC) and Field-Cooled (FC) magnetization measurements show an increase in the magnetic moment which is related with the cationic disorder. Besides, we have verified that the average blocking temperature increase with increasing mean particle size. Finally, Co_3O_4 shows a structural and magnetic dependence with the concentration of chelating agents sucrose, glycerine and triton.

MO-72

Preparation of zinc ferrite nanoparticles via a modified wet-milling process

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In this work, single phase $ZnFe_2O_4$ nanoparticles with a mean crystallite size of 12 nm were successfully prepared by a modified wet-milling method from metallic Zn and Fe powders and water without any subsequent heat treatment. The as milled sample has an s shape magnetization curve, which shows it is a ferrimagnet. This is due to a different cation distribution in comparison with the bulk zinc ferrite. To investigate the effect of annealing treatment on crystallite size and magnetic properties of the as milled sample, it was annealed at different temperatures from 150 to 800 degrees C and the annealed samples were characterized by both XRD and magnetometery methods. The results show that as annealing temperature increases, magnetization decreases and finally the sample annealed at the highest temperature shows a paramagnetic behavior at room temperature. This is due to relaxation of the strains introducing in the course of mechanical millin

MO-73

Magnetic properties of $Znfe_2O_4$ nanostructured compound

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We present in this work a study on the magnetic properties of the nanocrystals of $ZnFe_2O_4$ obtained by sol-gel process calcinated at 400 °C. The average size of the particles as determined by X-ray diffraction gives an average size of about 20nm. Afterwards the structural and magnetic properties of the samples had been investigated by XRD and Squid. The experimental results on these samples indicate the presence of single phase cubic-spinel structure. From magnetic measurements, zero field cooling and field cooling, we observed that the as synthesized nanocrystals of $ZnFe_2O_4$ are superparamagnetic at room temperature with blocking temperature T_B~30 K and from magnetic hysteresis data taking at different temperatures was possible to obtain a coercive field of H_c = 528 Oe at 5K and a maximum magnetization M_S ~ 40 emu/g at T = 5K The hysteresis loops are not fully saturated, even at a high magnetic field of 30 kOe. AC susceptibility measurements have been performed in the temperature range of---- K at four frequencies. Frequency dependent cusp was observed suggesting an spin.glass behavior.

[1] M.Perovic et al. Acta Physica Polonica A, 118(2010) 813

MO-74

Dependence of the structure, optical and magnetic properties in Zn ferrite from size and layout of nanoparticles

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Difference in structure and physical properties between pressed pellets and thin films of ZnFe2O4 is investigated. The role of geometry and size on electronic and magnetic states in spinel ferrite nanoparticles is one of the most challenging research areas today because of applications in the field of magnetic memory, micro-generation and recording media. ZnFe2O4 nanopowders and thin films were obtained using sol-gel auto-ignition and spray-pyrolysis methods. Pellets were prepared from nanopowders and annealed in air/vacuum at different temperatures. Thin films were grown in spray-pyrolysis method on substrates at different temperatures in nitrogen environment. As raw materials the nitrates of the corresponding metal cations were used, which were dissolved in distilled water at respective molar ratio. Structure and composition of synthesized materials were measured with X-ray diffractometer and X-ray fluorescence (XRF) spectrometer with micro-focused X-ray excitation. The morphology of nano-size powders and thin film is examined with SEM. It is found that electrical, optical and magnetic properties depend as from layout (bulk pellet – thin film) as from temperature of annealing – synthesis.

MO-75

Effect of Reduced Particle Size on Spin-Phonon and Magnetoelectric Coupling of Chemically Synthesized BiFeO3 Nanocrystals

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There is a recent surge in the development of new synthesis methods and to understand the physical properties of multifunctional materials. Among these materials, $BiFeO_3$ (BFO) is one of the most widely studied because of coexistence of FE and AFM ordering at room temperature. In BFO below the particle size ~62 nm there is an enhancement in both ferroelectric and magnetic polarization because of the combined action of exchange and spin-orbit interactions which produces spin canting. Here, we report the effect of reduction in particle size on the temperature dependent magnetization, Raman and dielectric spectroscopy of chemically synthesized BFO nanocrystals with average grain size of 55 nm. Our results show the evidence of existence of a low temperature anomaly due to spin-glass transition in the range from 40-44 K in the field cooled magnetization curves. In bulk single crystals, this transition is reported to be situated at around 50 K, however, this transition remained so far undiscovered in the recent studies. The Raman spectra (90-700 K) show two sets of transitions in the lowest Raman E mode, associated with Bi-O bond motion situated in close proximity to the spin reorientation transitions reported for BFO, thereby indicating the existence of possible coupling between magnons and phonons for particle size below the helical order parameter (62 nm). We also observe a step-like behavior in Raman peak position around the Ne`el temperature, suggesting that the phonons are influenced by the magnetic ordering in nanosized BFO. Our results clearly present new information on the size dependent properties of BFO nanoparticles.

[1] A. Jaiswal, R. Das, K. Vivekanand, P. M. Abraham, S. Adyanthaya, P. Poddar, J Phys. Chem. C **114**, 2108 (2010).
[2] A. Jaiswal, R. Das, T. Maity, K. Vivekanand, S. Adyanthaya, P. Poddar, J Phys. Chem. C **114**, 12432 (2010).

MO-76

Tuning the magnetic properties of CeO_2-Fe_2O_3/SiO_2 nanocomposites

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CeO_2-containing materials have received a lot of attention mainly due to their useful application in catalysis. Additional enhancement of their physical properties could be done by introduction of other metal ions into the ceria structure or creation of the CeO_2-based mixed oxides – for instance, the CeO_2-α-Fe_2O_3 binary oxide composite have much higher catalytic activity than the individual pure oxides. Creation of the nanocomposite system comprising the CeO_2 and magnetic

phases of Fe_2O_3 could extend possible applications of such material due to the rising of the magnetic response. Depending on the phase composition of the Fe_2O_3, we could create different multifunction nanocomposites combining catalytic properties with different magnetic properties and resulting to different potencial applications.
We have focused on tuning the magnetic properties of CeO_2-Fe_2O_3/SiO_2 nanocomposites via changing the preparation conditions. The samples with two different concentrations of Fe (Ce/Fe/Si molar ratio equal to 1/1/20 – L samples and 1/2/9 – H samples, respectively) were obtained by sol-gel method, subsequently annealed at different temperatures, T_{an} up to 1100°C and characterized by the Mö
ssbauer spectroscopy, Transmission Electron Microscopy (TEM), Powder X-ray Diffraction (PXRD) and Energy Dispersive X-ray analysis (EDX). Detailed measurements of magnetization and magnetization isotherms, respectively, performed by commercial SQUID magnetometer up to 7T, demonstrated significant change of magnetic properties with respect to the change of the Fe/Ce/Si ratio and to the T_{an} from pure superparamagnetic behavior for the L sample annealed at 950°C to magnetic behavior characteristic for the high-coercivity ε-Fe_2O_3 phase for the H sample annealed at 1100°C. The most dramatic effect is a sharp increase of the room-temperature coercivity from 0.2 mT for the L sample annealed at 950°C to ~ 1.8 T for the H sample annealed at 1100°C. These significant changes of the magnetic properties are interpreted by change of the phase compositions of the samples.

MO-77

Zn K-edge XAS and XMCD study of the ferromagnetic behaviour in ZnO nanoparticles capped with organic molecules

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Zn K-edge XAS and XMCD study of the ferromagnetic behaviour in ZnO nanoparticles capped with organic molecules. We present a combined study of the local structure and of the magnetic properties of ZnO nanoparticles capped with organic molecules performed by using X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) at the Zn K-edge. ZnO nanoparticles (NPs) have been capped with three different organic molecules: tryoctylphosphine (TOPO), dodecylamine (AMINE), and dodecanethiol (THIOL), which bond to the particle surface through an O, N, and S atom respectively. In all the cases the magnetization is characterized by the existence of remanence, coercivity and saturation up to room temperature.
The analysis of the XAS spectra of ZnO NPs capped with dodecanethiol points out the formation of a ZnO-ZnS core-shell structure and of a highly disordered ZnO-ZnS interface. Zn K-edge XMCD measurements reveal the coexistence of two different magnetic contributions: a paramagnetic response from the core(ZnO)-shell(ZnS) components of the NP, and a ferromagnetic contribution stemming from the interface.
These results demonstrate, on the one hand, that the observed magnetism in these materials is intrinsic and relays in the conduction band. On the other hand they indicate that ferromagnetism originates at the disordered interface formed between the ZnS shell and the ZnO core. Moreover, our results indicate that within this disordered interfaceferromagnetism is favoured in those regions of the interface where the local order is closer to wurtzite-like ZnO (w-ZnO) than to w-ZnS.

[1] Straumal, P. B.; Schütz, G.; van Aken, P. A.; Goering, E.; Baretzky, B. Phys. Rev. B 2009, 79, 205206
[2] Coey, J. M. D. Curr. Opin. Solid State Mater. Sci. 2006, 10, 83.
[3]Guglieri, C.; Chaboy, J. J. Phys. Chem. C 2010, 114, 19629

MO-78

Magnetic and photocatalytic properties of TiO_2 coated $NiFe_2O_4$ nanoparticles

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Titanium dioxide (TiO_2) nanostructures have been extensively studied in recent years due to its interesting applications in several fields. Regarding its photocatalytic activity, TiO_2 offers a great capability of removing organic pollutants from waste water by the irradiation of ultraviolet UV light. Core–shell structures composed of a ferromagnetic core and a TiO_2 shell represent promising photocatalysts due to the possibility to disperse them in aqueous media, recover the nanoparticles using an external magnetic field and recycle them for several uses [1].
This work is focused on the preparation of a magnetic removable photocatalyst and the evaluation of its photocatalytic activity through the decolourization of an organic colorant (methyl orange) [2]. Core-shell $NiFe_2O_4$-SiO_2 nanoparticles were initially synthesized using *sol-gel* procedure. Subsequently, a TiO_2 shell was deposited on the $NiFe_2O_4$-SiO_2 nanoparticles. DSC and Thermogravimetry analysis were employed to characterize the optimum calcination temperatures of the initial gels. The crystallographic structure of the calcined nanostructures was analyzed by X-ray diffraction, showing the characteristic diffraction peaks of the $NiFe_2O_4$ spinel and TiO_2 anatase phases. SQUID magnetometry was employed to characterize the magnetic response of the $NiFe_2O_4$-SiO_2 core-shell structures before and after the TiO_2 coating. The initial $NiFe_2O_4$-SiO_2 nanoparticles display at 300 K the characteristic superparamagnetic behaviour of $NiFe_2O_4$ nanometric systems. In spite of the introduction of the SiO_2 intermediate shell, noticeable changes in the magnetic properties of the $NiFe_2O_4$ nucleus (i.e. reduction in the saturation magnetization) are detected after the TiO_2 coating procedure. Nevertheless, the synthesised TiO_2 coated nanostructures display in dissolution the required characteristics, that is, external magnetic field guidance and decomposition of organic substances (i.e. methyl orange) under UV radiation.

[1] D. Beydoun, R. Amal, G. K-c Low, S. McEvoy, J.Phys. Chem B 104, 4387 (2000)
[3] Y. Ahang, J. Wan, Y. Ke, J. Hard. Mat 177, 750 (2010)

MO-79
Superferromagnetic response
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Superferromagnets (SFMs), e.g., magnetic nano-particle self-assemblies and/or arrays, have a variety of promising applications, like, nano-scale electronic devices, sensors, high-density data storage media, etc. Such soft magnetic systems provide an opportunity to develop new materials with characteristics far beyond traditional solids. Resently developed randomly jumping interacting moments (RJIM) model, see [1] and refs. therein, represents useful framewok for studies of SFMs. In particular, it gives a basis for developing analytical tools employed in order to specify, quantify and analyse respective magnetic structures. Such tools explore correlations of magnetic noise amplitudes and allow for quantitative definition, description and study the SFM origin, as well as self-organized criticality in the response properties.
In this contribution we briefly overview some results for SFM reactivity in external fields on various examples, e.g., (i) spatially uniform field changing slowly in time and (ii) magnetic moment of single particle, i.e., a mode of sensor for detection of magnetic particles. The Monte Carlo simulation technique, cf., [1], was used to describe the system dynamics. Arrays of nano-particles with multiple magnetic response anomalies are demonstrated to display strong dependence on system disorder. Possible implications of peculiarities in superferromagnetic response as sensors are considered. The surface and boundary effects are analyzed.

[1] V. N. Kondratyev. J. Phys.: CS, **248**, 012027 (2010)

MO-80
Investigation of magnetic nanoparticles and nanomaterials by means of NMR technique
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A short introduction to pulse NMR in magnetics – also known as “NMR-in-magnetics” or “spin echo” technique – is presented. The technique is very effective in control, testing and certification of magnetic (nano)materials of various kinds, e.g. bulk materials, thin films, multilayers and other nanostructures, molecular magnets, etc. Therefore, the technique is the useful addition to well known diagnostic methods and allows one to get unique information which cannot be reached by other methods. The usefulness of NMR is illustrated by ^{59}Co spectra in cobalt-containing magnetic nanostructures [1], ^{55}Mn and ^{139}La spectra in intrinsically inhomogeneous perovskite-like CMR manganites, ^{57}Fe and ^{61}Ni NMR in submicron- and/or nanostructured iron and nickel etc. All the examples demonstrate convincingly that NMR experiments reveal the highly informative and reliable data on the local magnetic structure and properties of the investigated systems: hyperfine fields, temperature behavior of magnetization, etc. For iron-containing nanostructures there is especially useful to combine NMR and Mössbauer techniques for characterization of the material structure and properties in more detail. An example of such kind was a description of core-shell structure of bimetallic FeCo nanoparticles.
As a separate part we present experimental observation of the effect of an increasing of magnetic moments for cobalt atoms at the surface of a cobalt nanoparticle. The effect was earlier predicted theoretically and partly confirmed by some indirect experiments. NMR technique – a clear advantage in this case – allows one to detect such atoms/such effect directly as the enhanced magnetic moment leads to a separate spectral line at higher frequency. Such lines have been detected for cobalt clusters (nanoparticles) in some SiO_{2} matrices [2,3].

[1] V.V. Matveev et al, Chem. Phys. Lett. 422, 402 (2006)
[2] G.A. Nikolaychuk et al., Lect. Notes Phys., 593, 203 (2002)
[3] V.V. Matveev et al, *to be submitted*.

MO-81
Magnetic nitride nanoparticles
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Magnetic nitrides of transition metals are electrical conductors characterized by high saturation magnetization values at room temperature, and superior chemical stability when compared with the metal base materials. Although iron nitrides have been extensively studied, Ni and Co nitrides have not, and most of the reported information concerns films where properties are strongly dependent on the growth conditions.
In this work, iron, nickel and cobalt nitride nanoparticles were produced from the corresponding oxide nanoparticles by nitridization under ammonia atmosphere at low pressures. The oxide nanoparticles, with average diameter between 20 nm and 60 nm, were obtained by chemical synthesis. To achieve the required nitride phases, with composition X_3N and/or X_4N (X=Fe, Ni or Co), systematic optimization of the conditions for the nitridization process were carefully selected using XRD diffraction as to follow the formed phases. After nitridization, annealing treatments in vacuum were used to change the nitrides stoichiometry and achieve phases with lower N content.
The obtained magnetic nitride particles were studied combining X-ray diffraction and TEM images to characterize structure and size distribution, with SQUID magnetization measurements as a function of the applied magnetic field and temperature, ac susceptibility measurements and ^{57}Fe Mössbauer in the case of the iron compounds, to access magnetic properties.
This work was supported by Portuguese funds through FCT-*Fundação para a Ciência e a Tecnologia* project PTDC/FIS/102270/2008.

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS
Chair: D. Adroja

MO-82

Neutron scattering and μSR investigations of the antiferromagnetic heavy-fermion compounds: $CeTGe_3$ (T=Ni, Co and Ir)

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Recently a number of Ce based compounds with general formula $CeTX_3$ (T = transition metals and X = Si and Ge) having the tetragonal non-centrosymmetric space group I4mm, have been reported to exhibit heavy-fermion superconductivity (HFSC) under applied pressure. For example, at ambient pressure $CeCoGe_3$ and $CeIrGe_3$ show antiferromagnetic (AFM) ordering below 21 K and 8.5 K, respectively, but reveal SC under an applied pressure of 5.5 GPa (T_{sc} = 0.7 K) and 24 GPa (T_{sc} =1.6 K), respectively. Furthermore, the Kondo lattice system $CeNiGe_3$, which crystallizes in the orthorhombic space group (Cmmm), orders AFM below 5.5 K and exhibits pressure-induced HFSC showing two domes of SC with maxima of T_{sc}=0.3 K around 3.5 GPa and 0.4 K around 7 GPa. We have carried out inelastic neutron scattering (INS) and μSR investigations on $CeTGe_3$ (T=Ni, Co and Ir) at ambient pressure to understand the nature of the 4f-electrons and their role in the SC. Our INS study in the paramagnetic state (above T_N) reveals two well defined crystal field (CEF) excitations at 20 and 27.5 meV in $CeCoGe_3$, at 9.5 and 21 meV in $CeIrGe_3$ and at 9.5 and 16 meV in $CeNiGe_3$ Furthermore, our μSR study on $CeNiGe_3$ reveals four well defined frequency oscillations below 5 K and three frequency oscillations in $CeIrGe_3$ below 8.5 K, confirming long range magnetic ordering of the Ce moment. On the other hand the μSR spectra of $CeCoGe_3$ show a strong damping below 15 K and no frequency oscillations, indicating that the internal fields at the muon sites are high. More interestingly, between 17 and 20 K a clear sign of frequency oscillations is observed. We will discus the role of the 4f-conduction electrons hybridization, observed through the linewidth of the CEF excitations, on the SC of $CeTX_3$ family of compounds.

MO-84

Investigations of vibron stability in the non-centrosymmetric heavy fermion compounds, $Ce(Cu_xAg_{1-x})Al_3$,(x<1)

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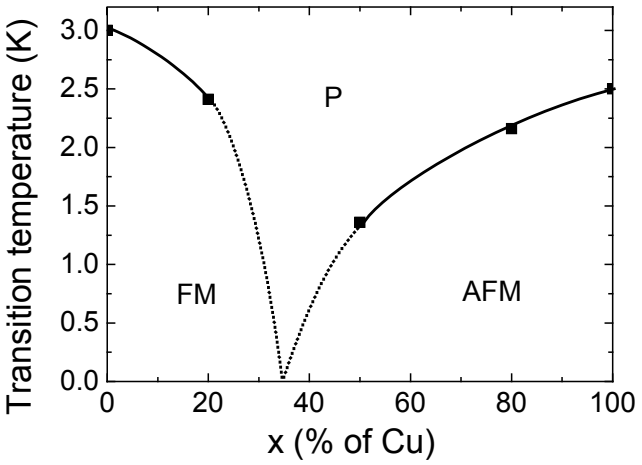
Recently, a new ferromagnetic Ce-compound, $CeAgAl_3$ (T_C = 3.0 K) was studied that shows a tri-valent state for Cerium with weak ferromagnetic (FM) interaction between Ce ions along the ab-plane and some cohercitivity [1]. By other hand, $CeCuAl_3$ is an antiferromagnet (AFM) heavy fermion compound with T_N=2.5 K, which shows a strong magnetoelastic (MEL) or crystal electric field (CEF)-phonon (called as vibron) interaction. [2] The magnetic properties of the $Ce(Cu_xAg_{1-x})Al_3$, 0<x<1 compounds have been studied by using different experimental techniques, adiabatic calorimetry up to 9 T and DC magnetic susceptibility and high-field magnetization up to 9 T. The lattice substitution of cupper by silver atoms has two main purposes: the first one must change the phonon energy spectrum due to the high mass of the silver atoms; and secondly by changing the different dielectric screening at around cerium ions that silver conduction electrons could produce. The transition temperatures are obtained from the specific heat measurements. They have shown an abrupt change between AFM ordering [2] of Cu-rich compounds to FM ordering [1] of Ag-rich compounds at around x=0.35. Different scaling behaviours of DC susceptibility are observed at this critical concentration, as expected from refs. [1,2]. Moreover, the MEL or CEF-phonon coupling is recently observed to be disappeared at around the same critical concentration.[3] From the present investigation, we proposed the existence of a quantum critical point close to x=0.35.

[1] T. Muranaka and J. Akimitsu, Physica C: Superconductivity, Vol. 460-462, Pag. 688-690 (2007).
[2] D.T.Adroja, A.del Moral, C.de la Fuente, A.Fraile, E.A. Goremyhkin, J W. Taylor, A.D. Hillier and F. Fernandez-Alonso, (submitted in Jan-2012 to PRL as Manuscript No. LN2719).
[3] C. de la Fuente, A. del Moral, D.T. Adroja and J. W. Taylor. (ICM2012-Abstract No. AF1882).



Phases diagram of the $CeCu_xAg_{1-x}Al_3$, series. The lines are only visual guides.

MO-85

X-ray photoelectron spectroscopy and magnetic properties of $CeCo_7Mn_5$ compound

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The magnetic properties of $CeCo_7Mn_5$ compound has been investigated combining X-ray photoelectron spectroscopy (XPS) and magnetic measurements in the temperature range (4-300) K and magnetic field up to 10 T. X-ray powder diffraction measurements showed that the compound $CeCo_7Mn_5$ crystallizes in the Th_2Mn_{12} structure type. XPS spectra of Ce 3d and Ce 4d core levels pointed out the intermediate valence state of Ce ions. The exchange splitting of Co 3s, Mn 3s and Mn 2p spectra revealed the existence of the local magnetic moments on Co and Mn sites. Magnetic measurements in the low and high magnetic fields pointed out the antiferromagnetic behaviour of $CeCo_7Mn_5$ compound below the Neel temperature of about 120 K, but also the presence of a ferromagnetic component with a saturation magnetization at 2 K of 0.18 μ_B/f.u. The complex magnetic behaviour of $CeCo_7Mn_5$ compound is analysed in terms of competing ferro- and antiferromagnetic interactions between the Co and Mn magnetic moments from different crystallographic sites and the Mn-Mn distances.

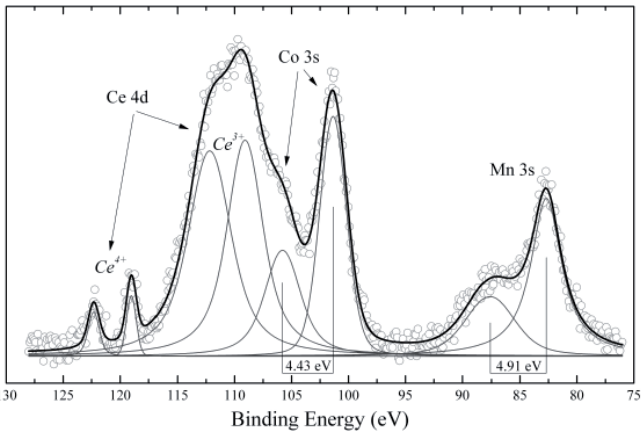

Fig.1. XPS spectrum of the Ce 4d, Co 3s, and Mn 3s core levels in $CeCo_7Mn_5$ (open circles correspond to the experimental spectrum and the continuous curves to the fitting results, after background subtraction).

MO-86

Hydrogenated CeNiSn investigated by muon spin rotation

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CeNiSn is a Kondo semiconductor with no magnetic ordering. Magnetic ordering is induced in CeNiSn by hydrogenation: $CeNiSnH_1$ is antiferromagetic at low T (T_N =4.7 K) while $CeNiSnH_{1.8}$ is ferromagnetic (T_C =7 K) [1,2].

We report the results of our μSR experiments on CeNiSnHx (x=1, x=1.8), performed at ambient pressure and under applied pressure. The μSR under pressure experiments were performed up to 22 kbar and down to 0.26 K. μSR spectra were recorded in zero field (ZF), weak tranverse field (wTF) and longitudinal (LF) configurations. While the ZF μSR spectra at low temperatures show two oscillation frequencies exponentially damped for $CeNiSnH_{1.8}$, for $CeNiSnH_1$ a Bessel function is required to fit the data.

The pressure dependence of the internal field at the muon site is presented and discussed in terms of competing Kondo and RKKY interactions. The results of our μSR experiments performed at temperatures above the magnetic ordering temperature, in zero and longitudinal magnetic field configurations, are also discussed.

[1] B. Chevalier et al., Chem. Mater. 15, 2181 (2003)

[2] B. Chevalier et al., J. Magn. Magn. Mater. 272-276, 576 (2004)

MO-87

Development of the specific heat in the Ce(Ni,Pd)In series

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A large group of the intermetallic ternary *RTX* compounds, where *R* is rare-earth element, *T* transition d-metal and *X* p-metal, crystallizes in hexagonal ZrNiAl-type of structure. Most of these compounds order magnetically at low temperatures, often with complex magnetic structures, but there are also some compounds without magnetic transition down to very low temperatures. The presented study of the development of magnetic behavior in Ce(Ni,Pd)In series is based mainly on the specific heat measurement.

Both parent compounds were previously studied by some experimental techniques as specific heat, magnetic susceptibility or electrical resistivity. CeNiIn is a valence fluctuator without magnetic order at least down to 50 mK and with Kondo like behavior. On the other end of the series, CePdIn orders as heavy-fermion antiferromagnet around 1.8 K. Moreover, there is the significant anisotropy along the crystallographic axes. Most of properties of these compounds are significantly influenced by external and chemical pressure.

The change of the magnetic properties and also the values of the specific heat in this series are caused by isoelectronic substitution of Ni by Pd. The Pd atoms have not only different character of the d-electrons but also larger radius. As a consequence, the lattice parameters change considerably in Ce(Ni,Pd)In series. Both these changes, character of the d-electrons and lattice parameters, are responsible for the dramatic development of the magnetic properties reflected in our study in the specific heat data.

MO-88

High magnetic field study of the metamagnetic phase transition in $LaFe_{12-x}Co_xB_6$ compounds (x=0, 0.05, 0.1, 0.25, 0.5)

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The transition between the antiferromagnetic (AF) and the ferromagnetic (F) states has been investigated for itinerant-

electron metamagnetic $LaFe_{12-x}Co_xB_6$ compounds. The AF state is stable in zero field and F state is field induced. The hysteresis for AF- F transition becomes narrower upon increasing temperature. The temperature dependence of the critical magnetic transition field ($\mu_0 H_C$) is non-monotonic, namely $\mu_0 H_C$ decreases in low temperatures and then increases in high temperatures. Isofield measurements indicate that $LaFe_{12}B_6$ exhibits two transitions with increasing temperature from the AF to F and F to P state due to the characteristic temperature dependence of the transition field. By substituting a small amount of Co for Fe the critical field $\mu_0 H_C$ increases both rapidly and non-linearly and reaches a large value of 55 T for x = 0.5. This critical value is very sensitive to the cobalt content. The initial value of the composition dependence of $\mu_0 H_C$ is very high, $d\mu_0 H_C/dx$ = 88 T per Co atom. The increase in the transition field with increasing Co concentration reveals that the energy difference between the F and AF states becomes larger with increasing Co concentration. From the magnetization measurements, the magnetic phase diagrams in the composition versus magnetic field plane and in the temperature-magnetic field plane are constructed for the $LaFe_{12-x}Co_xB_6$ compounds. Reference magnetization measurements were performed in steady field up to 10 T whereas high-magnetic fields measurements were carried out in pulsed fields up to 55 T as produced using a wire-wound pulse magnet with a duration time ("up" and "down") of about 150 ms.

MO-89

Large magnetovolume effects in $LaFe_{12}B_6$

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Magnetic properties and magnetovolume effects have been investigated for $LaFe_{12}B_6$ compound. This compound crystallizes in the R-3m space group retaining the $SrNi_{12}B_6$ rhombohedral structure type. The La atoms are located on the 3a site whereas the Fe atoms lie on two inequivalent crystal sites, namely 18h and 18g. $LaFe_{12}B_6$ compound orders antiferromagnetically at about 35 K and exhibits a field induced metamagnetic phase transition between the (AFM) and ferromagnetic (FM) states accompanied by large hysteresis cycle. It should be noted that the transition from the AFM to FM state takes place in two steps below 8 K. The hysteresis for AFM- FM transition becomes smaller upon increasing temperature. The temperature dependence of the critical magnetic transition field (H_c) is non-monotonic, namely H_c decreases at low temperatures and then increases at high temperatures. $LaFe_{12}B_6$ shows two transitions with increasing temperature from the AFM to FM and FM to PM state in 6 T due to the characteristic temperature dependence of the transition field. The non-monotonic temperature dependence of H_c is connected with the different temperature dependence of the free energies in the AFM and FM states. To clarify the volume change due to the AFM-FM transition magnetostriction measurements were carried out. The magnetization measurements were performed in an extraction-type magnetometer up to 10 T. The linear thermal expansion has been studied and the magnetostrictions determined along directions parallel and perpendicular to the applied magnetic field using a capacitance dilatometer up to 6 T. The magnetostriction measurements clearly show that the transition is induced by an applied magnetic field obtaining a huge volume magnetostriction ($\Delta V/V \sim 1\%$). The complex temperature dependence of the AFM-FM transition field is explainable by the contribution of the magnetic and elastic energies caused by the large magnetovolume effect.

MO-90

The influence of Gd/Ce substitution on the magnetic properties and electronic structure in the $Ce_xGd_{1-x}Ni_3$ system

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The polycrystalline compounds $Ce_xGd_{1-x}Ni_3$ with a rhombohedral $PuNi_3$ ($x \leq 0.2$) and hexagonal $CeNi_3$ ($x \geq 0.8$) - type of crystal structures have been obtained. The change of the lattice parameters may suggest the unstable valence of cerium in the studied system. The effect of partial substitution Gd by Ce is reflected in a change of the cell volume, the Curie temperature $T_C(x)$ and in the temperature dependence of magnetic susceptibility and electrical resistivity. Thus, $T_C(x)$ decreases from 115K(x=0.0) to ~6.8K (x=0.8). The XPS spectra have been measured at the room temperature. The valence band spectra (VB) as well as the core level lines have been analyzed as the influence of Gd/Ce substitution on the electronic structure. The VB near the Fermi level (E_F) are dominated by Ni*3d* states. In VB region some slight effects of hybridization and changes of intensity of states on E_F have been noticed. The analysis of Ce core level lines reveals the occurrence of possible intermediate valence. The values of the Ce*4f* - state occupation parameter (n_f) and the hybridization energy (Δ) have been estimated. The gradual filling of Ni*3d* band is revealed by a reduction of the 6eV satellite intensities in the Ni*2p* core level spectrum. All these effects can modify the magnetic properties of the investigated compounds.

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MO-91

The analysis of the magnetic properties in the intermetallic $Tb_xGd_{1-x}Fe_3$ compounds

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The polycrystalline compounds $Tb_xGd_{1-x}Fe_3$ with a $PuNi_3$ - type of crystal have been obtained. Based on wide-ranging SQUID magnetometer (Quantum Design MPMS, temperature from 1.9K to 400K and magnetic field up to 7T) series of different magnetic measurements have been carried out. Moreover, the magnetic properties in the paramagnetic range has been studied by means of Faraday type magnetic balance. The partial replacement of Gd by Tb atoms is reflected in the increase of magnetic parameters e.g. the increase within the saturation M_S magnetic moment from $1.6\mu_B$/f.u (x = 0.0) to $3.04\mu_B$/f.u (x = 1.0). The study of the hysteresis loops has been performed in several chosen temperatures. A quite strong dependence of coercivity (H_C) and remanence (M_r) on the temperature and the amount of Tb has been found. The XPS spectra have been measured at the room temperature. The valence band spectra as well as the core level lines have been analyzed as the influence

of Gd/Tb substitution on the electronic structure. The valence bands near the Fermi level are dominated by Fe3d states and indicate the increase of intensity of states for higher terbium content. A strong dependence of the magnetic properties on the changes within the electronic structure has been found.
This work was partially supported by Ministry of Science and Higher Education, grant no. N N202 200039

MO-92

Investigation the nature of the unusual magnetic behavior of $La_{0.65}Nd_{0.35}Mn_2Si_2$ compound by neutron diffraction study

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The magnetic structures of the $La_{0.65}Nd_{0.35}Mn_2Si_2$ have been investigated by powder neutron diffraction experiments between 5 and 350 K. According to magnetic measurements this compound shows multiple magnetic phase transitions. In the temperature ranges of 140 K $\leq T \leq$ 220 K and 5 K $\leq T \leq$ 70 K, this compound has two different magnetic structures that are distinct both crystallographically and magnetically. A canted ferromagnetic structure above 220 and below 46 K. Between 50 K $\leq T \leq$ 70 K there is a mixed phase where canted ferromagnetic and antiferromagnetic structures coexist. Moreover, $La_{0.65}Nd_{0.35}Mn_2Si_2$ has a two-step magnetic transition from AF to FM state between 65 and 22 K. This two-step transition had not been observed so far. The magnetic measurement differs from Venturini and et al. [1] below 70 K since they measured the temperature dependent magnetization data under 1.2 kOe. Unlike to their work, we measured M(*T*) curve under 50 Oe since higher magnetic field might have washed out some features. The temperature variation sof M(T), μ_{Nd}, and (101)–(112) lines below 70 K is shown in Fig. 1. M(T), μ_{Nd}, and (101) line have similar variation with respect to temperature. Eventually, below 55 K the non-smooth increase in (101) line while decreasing temperature should be related the bulk magnetic behaviour of the $La_{0.65}Nd_{0.35}Mn_2Si_2$.

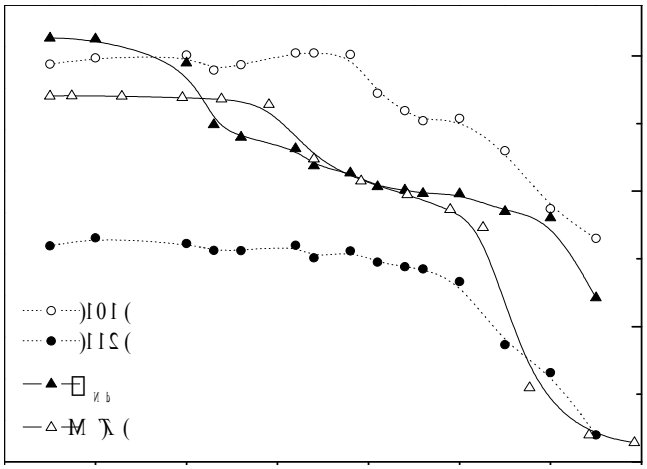

Fig. 1. The variation of the μ_{Nd}, (101)-(112) lines and M(T) of $La_{0.65}Nd_{0.35}Mn_2Si_2$ below 70 K.

[1] G. Venturini, R. Welter, E. Ressouche and B. Malaman, J. Alloys Compd. 210, 213 (1994).

MO-93

Magnetism in $CeCu_xAl_{4-x}$ compounds studied by specific heat

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Ce-based compounds have a special place among the rare earth materials. In many cerium compounds, the 4f states are at the borderline between the localized and the itinerant. Ce compounds show a large variety of magnetic ground states which is the result of the competition between long-range magnetic order of the RKKY type and the screening of the localized moments by conduction electrons. The Ce-based compounds crystallizing in the non-centrosymmetric tetragonal $BaNiSn_3$-type structure have recently attracted much attention showing rich electronic properties including observation of pressure-induced superconductivity in $CeRhSn_3$ and $CeIrSi_3$.
In this work, we focus on the investigation of the $CeCu_xAl_{4-x}$ compounds. The stoichiometric $CeCuAl_3$ has been reported to order antiferromagnetically below T_N = 2.5 K and the interplay between the magnetic and Kondo interactions has been used to describe the observed behavior. The previous magnetization of $CeCu_xAl_{4\_x}$ compounds with x = 0.8, 0.9, 1.0 and 1.1, measured on single crystals, reveal the a-axis as the easy magnetization axis and a clear strengthening of the ferromagnetic interactions with decreasing Cu content. We present the specific heat study of these compounds in the whole homogeneity concentration range between x = 0.7 and 1.1. The work is based on detailed analysis of data measured in a wide temperature range between 0.3 and 300 K. The magnetic part of the specific heat was determined using the La based analogues with the same Cu-Al concentrations. We discuss the development of the type of the magnetic order, the Kondo behavior, the Sommerfeld gamma-coefficient of the electronic specific heat and the crystal-field splitting through the series. The results are also discussed in the context of previous results on $CeCuAl_3$ and related compounds.

MO-94

Magnetic properties of TbFeGa thin films deposited by cosputtering

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TbFeGa ternary alloys have been studied because of their magnetostrictive properties [1]. The introduction of Ga in the Tb-Fe system enables to decrease its coercivity keeping a pretty large magnetostriction constant. We have studied TbFeGa alloys with a Ga doping between 10 and 16 % and a Tb content from 9 to 12 %. Samples were deposited by cosputtering from two targets with $TbFe_2$ and Fe_3Ga nominal composition. The $TbFe_2$ was evaporated using a DC source at 100 W whereas a pulsed power source was used for the Fe_3Ga target. Different compositions were achieved by modifying the pulsed power between 60 and 120 W.

By measuring hysteresis at different in-plane orientations and with the applied magnetic field perpendicular to the sample plane we show that samples deposited with a pulsed power in the Fe_3Ga target between 60 and 100 W exhibit perpendicular magnetic anisotropy (PMA). The anisotropy direction changes to in-plane for a pulsed power of 120 W. We have inferred an anisotropy constant of at least 1×10^6 erg/cm^3 in the samples with PMA, analogous to values achieved in a-TbFe. The x-ray diffractometry patterns exhibit a peak close to the more intense diffraction of the cubic $TbFe_2$ structure. The intensity of that peak shows a tendency to decrease with the pulsed power. This effect can be associated to the reduction of the structure close to that of the cubic $TbFe_2$ with the increase of the Ga content. Similarly to a-TbFe, the PMA disappears upon the annealing. Therefore, the existence of PMA in these alloys is not only related to the pulsed growth power (Ga content) but also to the structural ordering present in the as-deposited samples.

[1] Y. J. Tang, et al. Appl. Phys. Lett. **66**, 388 (1995).

MO-95

The study of magnetism in selected Kramers rare earth oxychlorides

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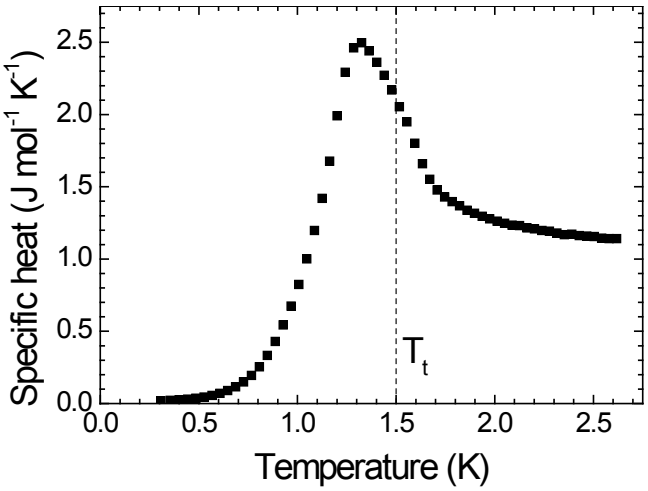
We present study of magnetism in the selected *RE*OCl (*RE* = Nd, Gd, Dy) compounds. These compounds crystallize in PbFCl-type structure [1] and are well studied from infrared spectroscopy point of view [2]. Concerning magnetism in *RE*OCl, the data in the literature are incomplete and focused mainly to higher temperatures. All of these materials are Krammers doublets, so one expects magnetic ordering in all of them, but up to now the magnetic ordering was observed only in DyOCl [3].
We have prepared *RE*OCl powder samples by dissolving rare earth oxides in HCl, drying at 100 °C and subsequent dehydrating at 400 – 500 °C. We have studied heat capacity (temperature range 0.3 K – 25 K) and magnetization and susceptibility (temperature range 2 K – 300 K, hydrostatic pressures range 0 - 0.68(1) GPa) properties in these compounds. Our results indicate the new transition to the ordered magnetic state for NdOCl (at 1.5 K; see figure) and GdOCl (at 5 K) and confirm magnetic ordering for DyOCl. We have found small increase of magnetization saturation value of DyOCl, but no remarkable changes on the Néel temperature ($T_N \sim 9.2$ K) with an applied hydrostatic pressure. All compounds obey Curie Weiss law at higher temperatures, but deviate from it below 26 K. This deviation can be caused by the vicinity of the magnetic ordering, or may be interpreted in terms of on-going quadrupolar order. Both possibilities will be discussed at the conference.

[1] D. H. Templeton and C. H. Dauben, J. Amer. Chem. Soc. 75, 6069 (1953)
[2] L. J. Basile, J. R. Ferraro and D. Gronert, J. Inorg. Nucl. Chem. 33, 1047 (1971)
[3] Jorma Hölsä, R.-J. Lamminmäki, M. Lastusaari, P. Porcher, R. S.-Puche, J. All. & Comp. 303–304, 498 (2000)



The specific heat of NdOCl measured in zero magnetic field.

MO-96

The magnetic properties of new III-V materials

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We have performed ab initio self-consistent calculations based on the full potential linear augmented plane wave method with the generalized gradient approximation to investigate the structural, electronic and the magnetic properties of the less known ytterbium III–V compounds. Ground state properties such as lattice constant, bulk modulus, pressure derivative of the bulk modulus and cohesive energy are reported in the NaCl structure in an antiferromagnetic state, ferromagnetic and paramagnetic. We also give the band structure at equilibrium lattice constant. Our results are in good agreement with numerous experimental and theoretical data where available, and provide predictions where they are not.
Keywords**:** ab initio calculations; paramagnetic, ferromagnetic and antiferromagnetic; Elastic properties; Electronic properties.

MO-97

Evolution of magnetism in $Ho(Co_{1-x}Si_x)_2$: alloying and pressure effects

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The recent reports on parimagnetism [1,2] boosted new research activities dedicated to physics of RCo_2 (R = heavy rare earth metal) compounds which can serve as archetypes of magnetism born of rare-earth localized 4f electrons and itinerant 3d electrons of Co. For long time the Co 3d electron magnetic moment was believed emerging only at T_C owing to the splitting of the Co 3d spin up and spin down subbands in a huge molecular field due to the ferromagnetically ordered Ho magnetic moments. Below T_C the Co moments are coupled antiparallel to the R moments. In 2007 Herrero-Albillos et al. [1] presented for $ErCo_2$ new experimental evidences of the Co moments surviving in

paramagnetic state rather far above T_C and remaining coupled antiparallel the R moments up to a characteristic temperature T_f (at which the AC susceptibility exhibits a small anomaly) and have christened this phenomenon parimagnetism. Analogous appearance of parimagnetism has been recently reported for $HoCo_2$ [2]. Naturally, one may ask whether the onset of long range magnetic ordering at T_C and the onset of parimagnetism T_f have some common underlying mechanism. In this work we present results of our study of the AC susceptibility of $Ho(Co_{1-x}Si_x)_2$ compounds for $x \leq 7.5\%$ exerted to hydrostatic pressure up to 3 GPa in order to investigate the alloying and pressure influence on the two key magnetic phenomena in $HoCo_2$. Whereas Si doping causes dramatic increase of both T_C and T_f the hydrostatic pressure shifts the characteristic temperatures to lower values. The results will be discussed in terms of relevant variations exchange interactions.

[1] J. Herrero-Albillos et al., Phys.Rev.B **76** (2007) 094409.
[2] C.M. Bonila et al., J.Appl.Phys. **111** (2012) O7E315.

MO-98

An^{166} Er-Mössbauer investigation of $ErCr_2Si_2$

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This work reports on a low temperature ^{166}Er-Mössbauer spectroscopy investigation of the tetragonal rare earth intermetallic compound, $ErCr_2Si_2$. Based on the neutron diffraction work of Moze *et al*. [1], the Cr sub-lattice orders with an antiferromagnetic structure well above room temperature at T_N^{Cr} = 692 K, whereas the Er sub-lattice orders ferromagnetically at a much lower temperature of T_C^{Er} 2.4 K. According to specific heat measurements, T_C^{Er} = 1.7-1.8 K [2]. Moze *et al*. determined the Er magnetic moment at 1.8 K to be aligned perpendicular to the c-axis with μ_{Er} = 5.24(5) μ_B. The ^{166}Er-Mössbauer spectrum recorded at the lowest temperature of 1.6 K is dominated by a slightly broadened, 5-line, magnetic spectrum corresponding to a magnetic hyperfine field of B_{hf} = 705(10) T. This is just 8% less than the maximum "free ion" field and implies that the lowest electronic doublet associated with the Er^{3+} ground (J = 15/2) multiplet's crystal field splitting is close to being "fully stretched" with $m_J \approx \pm 15/2$ and $\mu \approx \pm 9$ μ_B. This is consistent with the neutron result only in the context of slow Orbach-type fluctuation of the electronic doublet, where the ^{166}Er-nucleus is sensitive to the instantaneous magnitude of the electronic moment while the neutron diffraction monitors its thermally-weighted time average. Indeed, with increasing temperature, the variation of the spectrum is typical of slow paramagnetic relaxation. The outer absorption lines of the residual 5-line splitting are observed to broaden and eventually collapse to give a single central absorption line for T ≥ 5 K.

[1] O. Moze *et al*., Eur. Phys. J. B 36, 511-518 (2003)
[2] B. Saensunon *et al*., Proc. 34th Annual Condensed Matter & Materials Meeting, Auckland New Zealand, 2-5 Feb, 2010 (http://www.aip.org.au/wagga2010/, article 17)

MO-99

The zero-field magnetic ground state of EuC_6 investigated by muon spectroscopy

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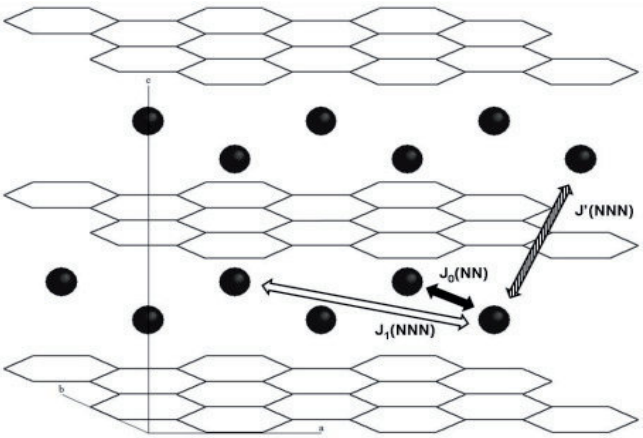
Among the graphite intercalation compounds (GICs) those containing rare-earth elements with a nonzero magnetic moment are particularly attractive. In these systems, part of the valence electrons of rare-earth atoms are transferred to the π-band of graphite, significantly increasing the electric conductivity of the latter. At the same time, the rare-earth ions are supposed to adopt some form of magnetic order due to the exchange interaction mediated by the acceptor's π-band electrons, namely the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction.
A typical example of such compounds is the binary EuC_6 phase, a first-stage GIC in which the europium atoms adopt a 2D hexagonal sublattice commensurate with that of graphite [1]. Its $P6_3/mmc$ 3D structure implies that each Eu atom has six nearest- (NN) and six next-nearest neighbours (NNN) lying in the same layer, as well as six NNN lying on adjacent layers along the *c*-axis (see the figure). This configuration determines the nature of the corresponding interatomic Eu-Eu exchange couplings.
To study the zero-field magnetic ground state of EuC_6 we carried out zero-field muon-spin spectroscopy measurements on high-quality *c*-axis oriented polycrystalline samples. Below the Néel antiferromagnetic temperature (42 K) we find highly damped oscillations in the muon asymmetry that we could model via a Bessel function, indicative of an *incommensurate* magnetic order. The internal magnetic field, as probed by the implanted muons, lies *in the plane* of the europium ions, has an average intensity of 150(22) mT, and seems to arise from a strong contact hyperfine interaction. The latter partially cancels out the dipolar contribution to the local field, in turn due to the localized Eu spins arranged in an antiferromagnetic triangular lattice (frustrated spin lattice) with negligible inter-layer couplings.

[1] H. Rida *et al.*, Carbon48, 3190(2010).
[2] G. Lamura *et al*, Carbon, submitted(2012).



Structure of EuC_6 showing the main three exchange interactions [2].

MO-100

Magnetic phase transitions in $RMn_{2-x}T_xGe_2$ intermetallics studied by neutron diffraction and complementary methods

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Polycrystalline samples of pseudoternary rare earth germanides $RMn_{2-x}T_xGe_2$ (R= Ce, Pr, Nd; T= Fe, Co, Cu) were studied by neutron diffraction (E6, HZB, Berlin and DMC at SINQ, PSI, Villigen), d.c. and a.c. magnetic susceptibility, magnetization and heat capacity measurements in the temperature range 2 – 400 K and in magnetic fields up to 9 T (commercial QD PPMS's at the Jagiellonian University and AGHS, Krakow). The intermetallics were found to crystallize in the body-centered tetragonal $ThCr_2Si_2$- type structure (space group *I4/mmm*) with the transition metal atoms (Mn and Fe/Co/Cu) randomly distributed at the 4(*d*) Wyckoff position. A long range magnetic ordering was observed both in the Mn-sublattice and in the rare earth one, the latter at far lower temperatures. With decreasing temperature several order-order magnetic phase transitions to commensurate or incommensurate magnetic structures were detected in the Mn-sublattice. The magnetic structures were refined in a Rietveld-type profile refinement procedure.

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MO-101

Pressure dependence of magneto-structural properties of Co-doped off-stoichiometric Ni_2MnGa alloys

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The huge shape memory effect and the magnetocaloric effect (MCE) in the Ni_2MnGa compound are based on the first order magneto-structural transition from the high temperature cubic austenite (A) to the low temperature martensite (M) that is accompanied by a change of magnetization. Both effects are much more pronounced in the off-stoichiometric or doped Ni-Mn-Ga compounds than in the stoichiometric Ni_2MnGa compound. Recently, we have revealed a significant quantitative difference between effects of pressure on magnetic properties of $Ni_{2+x}Mn_{1-x}Ga$ and Ni_2MnGa compounds [1]. The huge inverse MCE was determined by indirect and direct methods in polycrystalline $Ni_{50-x}Co_xMn_{25+y}Ga_{25-y}$ compounds in the last year [2,3]. Results of our pressure studies of these compounds show that a decrease of magnetization of martensite under pressure is much more sensitive to an increase of a content of Mn than to a content of Co. Pressure parameter $dlnM/dP$ is of one order higher in the Mn-rich compounds (- $3.9*10^{-2}$ GPa^{-1}) than in Ni_2MnGa (- $3*10^{-3}$ GPa^{-1}). The crystal structure of martensite (with smaller volume) is stabilized by pressure. The parameter dT_{M-A}/dP is positive and it reaches value +35 K/GPa in the Mn-rich compounds in comparison with +0.5 K/GPa in Ni_2MnGa. Using the Clausius-Clapeyron relation, the observed pressure and MCE data were compared with the x-ray determined volume changes that accompanies the first order martensitic magneto-structural transitions and the received conclusions are discussed in detail in the contribution.

[1] J. Kamarad et al.: J. Magn. Magn. Mater. 290-291 (2005) 669
[2] S. Fabbrici et al.: Acta Mater. 59 (2011) 412
[3] G. Porcari et al.: Phys. Rev. B 85 (2012) 024414

MO-102

Electronic and magnetic properties of $NiMn_{1-X}R_XSb$ with R=Er or Dy

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The structural, electronic and magnetic properties of $NiMn_{1-x}R_XSb$ alloys with R=Er or Dy have been investigated by X-ray diffraction, (XRD), X-ray photoelectron spectroscopy, (XPS), magnetization, magnetic susceptibility measurements and band structure calculations. The analysis of the band structure of the doped alloys shows that the half-metallic properties are completely conserved if R atoms substitute Mn atoms, this effect being determined through the coupling between the R(4*f*) spin with the Mn(3*d*) itinerant electron spins. We evaluate the strength of such a coupling by calculating, in an ab-initio fashion, the total energy of $Co_8Mn_7RSi_8$ compound for a parallel and antiparallel *f-d* coupling. It was found that the antiparallel coupling is most favorable, the energy difference being $E_F - E_{AF} = 76K$ for the compound with R=Er. The experimental magnetic moments are in rather good agreement with the calculated ones in case of ferrimagnetic ordering. In order to investigate the hybridization between the Mn and Ni 3*d* states and the Sb 5*p* states, the XPS valence band spectra were calculated and compared to the experimental spectra. The main contribution to the XPS valence band spectra is given by the Ni 3*d* states, as expected considering that the Ni 3*d* cross section for Al Kα radiation is about four times larger than the Mn 3*d* cross section. The spectral feature situated at about 10–11 eV, present in the investigated alloys, is assigned to the Sb 5*s* states. The main difference between the valence band spectra of $NiMn_{0.95}R_{0.05}Sb$ and NiMnSb is between 8.5 eV and 10.5 eV, where the R 4*f* states have a contribution. XRD, XPS and magnetic measurements confirm that heavy rare-earths atoms occupy lattice sites in NiMnSb.

MO-103

Ab initio studies of $Co_2FeAl_{1-x}Si_x$ Heusler alloys

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We present results of extensive theoretical studies of $Co_2FeAl_{1-x}Si_x$ Heusler alloys which have been performed in the framework of density functional theory employing all-electron full-potential

linearized augmented-plane wave (FP-LAPW) scheme as implemented in the Elk code [1]. To study the alloying effects, we use supercell containing 32 atoms (8 times the primitive unit cell of Co_2FeAl) with 8 Z sites, which are occupied by Al and Si atoms, with Si concentrations equal to 0.0, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875, and 1.0. For each Si concentration, we consider also various possible geometric configurations. For each configuration, we perform full optimization of the lattice geometry and calculate further electronic structure, position of the Fermi level, magnetic moment, and spin polarization of the s-states on the Co nuclei. We also have performed calculations for structures, where positions of Fe atoms and atoms at the Z sites (i.e., Al or Si) have been swapped. This allows for the calculation of formation energy of the so-created anti-site defects and further for the estimation of their possible concentrations in the studied Heusler alloysOur calculations demonstrate the following effects of Si alloying. Probability of creation of Fe-Al anti-sites decreases with the growing Si concentration. Si alloying changes position of the Fermi level, pushing it into the gap of the minority spin-band. The hyperfine field on Co nuclei increases with the Si concentration, and this increase originates mostly from the changes in the electronic density of the valence electrons. The theoretical findings agree fairly well with the very recent experimental data [2]. Therefore, we are presently pursuing our studies to deliver theoretical predictions for $Co_2Fe_{1-y}Cr_yAl_{1-x}Si_x$ Heusler alloys.

[1] http://elk.sourceforge.net
[2] M. Wójcik, E. Jędryka, H. Sukegawa, T. Nakatani, and K. Inomata, Phys. Rev. B 85, 100401(R) (2012).

MO-104

Physical properties in the vicinity of the itinerant ferromagnetic quantum critical point on $SrCo_2P_2$ and its family

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In $ThCr_2Si_2$-type ($I4/mmm$) compounds ACo_2P_2 (A = alkaline earth, rare earth), the Co_2P_2 layers consisting of edge sharing CoP_4 tetrahedra and A layers are stacked alternately along the c-axis. This system exhibits a variety of magnetism by changing A, ie. A = La, A = Ca, Ce and A = Sr are an itinerant ferrromagnet, antiferromagnet and an enhanced Pauli paramagnet, respectively [1, 2]. However, in magnetically ordered phases of these compounds, even in the case of antiferromagnets, magnetic moments are ordered ferromagnetically within the Co_2P_2 plane, therefore ferromagnetic interaction within a Co_2P_2 layer would be dominant in this system. In the case of A = Sr, which does not show any magnetic orderings, the magnetic susceptibility shows the Curie-Weiss-like temperature dependence at high temperatures and exhibits a maximum at about 110 K. Such behavior is frequently observed in the vicinity of the ferromagnetic quantum critical point (QCP). In this work, we focused on ferromagnetic spin fluctuations $SrCo_2P_2$ and its substituted compounds, and measured their macroscopic and microscopic physical properties.
In $Sr_{1-x}Ca_xCo_2P_2$ ($x \leq 0.5$) system, the temperature, where the susceptibility shows maximum, decreases and Weiss temperature increases from the negative value to 0 as x increases from 0 to 0.5. Furthermore we observed an itinerant electron metamagnetic transition on high-field magnetization process of $Sr_{1-x}Ca_xCo_2P_2$ ($x \leq 0.5$). In addition, ^{31}K and $1/T_1$ of $SrCo_2P_2$ show characteristic the temperature dependence predicted by the ferromagnetic self-consistent renormalization theory of spin fluctuation. From the results we concluded that this system lies in the vicinity of an itinerant ferromagnetic QCP and the QCP is found to be $x \simeq 0.5$.

[1] M. Reehuis, W. Jeitschko, J .Phys. Chem. Solids 51, 961 (1990)
[2] S. Jia *et al*., Phys. Rev. B 80, 165107 (2009)

MO-105

Physical Properties of $CaFe_4As_3$, $Ca_{1-x}Sr_xFe_4As_3$ and $Ca(Fe_{1-x}M_x)_4As_3$ (M = Cr, Mn, Co, Ni, Cu)

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Recently, layered iron arsenides with edge sharing $FeAs_4$ tetrahedra have attracted much attention for their superconducting properties. AFe_2As_2 (A = Ca, Sr, Ba and partially substituted by K), so called 122 system, is one of such compounds [1]. In contrast, $CaFe_3As_4$ is consist of three-dimensionally connected $FeAs_4$ tetrahedra [2]. $CaFe_3As_4$ does not show any superconducting properties but shows successive spin density wave (SDW) phase transition with T_{N1} = 90 K (incommensurate) and T_{N1} = 26 K (commensurate) [2]. Investigation of details of SDW phase transition in $CaFe_3As_4$ is worthy in a view point of not only magnetism but also comparison of electronic state with Fe-based superconductors. In this study, we investigate substitution effects of $CaFe_3As_4$ for the magnetic and transport properties.
Single crystals of $CaFe_4As_3$, $Ca_{1-x}Sr_xFe_4As_3$ and $Ca(Fe_{1-x}M_x)_4As_3$ (M = Cr, Mn, Co, Ni, Cu) were grown by the tin flux method. They were characterized by X-ray diffraction and also by energy dispersive X-ray spectroscopy. The magnetization and electric resistivity were measured by a SQUID magnetometer and conventional four-prove method, respectively. The commensurate SDW transition temperature T_{N1} is easy to be lowered by substitutions, while the commensurate SDW transition is hard. From the overall substitution effects, it is found that chemical pressure effect is dominant for change of T_{N1} and the change is quite small compared with 122 system, suggesting that the three-dimensional percolation is thought to be important for SDW formation while two-dimensionality is important for the occurrence of the superconductivity.

[1] M. Rotter *et al*., Phys. Rev. Lett. 101, 107006 (2008)
[2] L. L. Zhao *et al*., Phys. Rev. B 80, 020404 (2009)

MO-106

Magnetic properties of R_2CoIn_8 compounds from first principles calculations

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The structural and magnetic properties of RE_2CoIn_8 (RE = rare earth) intermetallic compounds were experimentally studied on polycrystalline samples [1]. In this work the electronic structure

of RE_2CoIn_8 intermetallic compounds is calculated from first principles based on the density functional theory (DFT). The Kohn-Sham single particle equations of the DFT theory are solved using two independent computational methods, namely APW+lo [2] and FPLO [3]. First the structural properties of Y_2CoIn_8 and Gd_2CoIn_8 are studied. The good agreement of the calculated equilibrium volume and c/a ratio with experimental data from [1] is found. Also we minimize the forces at equilibrium volume and predict the symmetry free structural parameters of the space group P4/mmm for Y_2CoIn_8. In the Y_2CoIn_8 the 3d-Co states are almost fully occupied and situated below the Fermi level. We applied the fixed spin moment method and stable paramagnetic ground state for Y_2CoIn_8 was found in agreement with experimental data available. Finally, the crystal field parameters were calculated for RE = Pr, Nd and Dy from first principles [4]. The microscopic tetragonal crystal field Hamiltonian was diagonalized and obtained eigenvalues and eigenfuctions were used to predict anisotropy of magnetic properties at RE_2CoIn_8 single crystals.

[1] D. A. Joshi, C. V. Tomy and S. K. Malik, J. Phys.: Condens. Matter 19, 136216 (2007)
[2] K. Schwarz, P. Blaha, G. K. H. Madsen, Computer Physics Communications 147, 71 (2002)
[3] K. Koepernik and H. Eschrig, Phys. Rev. B 59, 1743 (1999)
[4] M. Diviš, J. Rusz, H. Michor, G. Hilscher, P. Blaha, K. Schwarz, Journal of Alloys and Compounds 403, 29 (2005)

MO-107

Preparation, structural and magnetic characterization of CoFeGe Heusler alloy films

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Heusler alloys (HA) Co_2FeGe are half-metallic ferromagnets with high magnetization and Curie temperature that makes them very attractive objects for modern spintronics applications [1, 2].
We report preparation, structural and magnetic characterization of CoFeGe HA films in the vicinity of stoichiometric composition (SC). The films of 50 nm thickness were deposited on single crystal MgO [100] and Si/SiO_2 substrates at 500°C by magnetron co - sputtering from Co_2Fe and Ge targets in 5 mTorr of Ar. The structure of the films was studied by X-ray scattering and Atomic force microscopy. Static magnetic properties were measured in temperature range 5-380 K using SQUID magnetometer.
Crystalline structure of the films was found to be cubic. The lattice parameter decrease with increasing Co_2Fe content and was lower comparing to the bulk material for all compositions. The films deposited on MgO substrates were epitaxial while those on Si/SiO_2 - polycrystalline. All the films were ferromagnetic with negligible variation of saturation magnetization in the investigated temperature range (less than 3%). This behaviour points to high Curie temperature of the alloy. The value of saturation magnetization increases with x for both substrates from ~700 emu/cc to ~1100 emu/cc for Ge-rich and close to SC. This corresponds to magnetic moment calculated per formula unit (f.u.) ~3.6μ_B/f.u and ~5.6μ_B/f.u., respectively. The latter shows good agreement with theoretically predicted value ~5.7μ_B/f.u. and is slightly lower comparing to 6μ_B/f.u. calculated using Slater-Pauling relation [2]. Epitaxial films on MgO substrates display square hysteresis loops with coercive field (H_c) that changes from ~200 Oe (Ge-rich) to ~20 Oe (close to SC). The variation of H_c is weaker (from ~40 Oe to ~20 Oe) for polycrystalline films deposited on Si/SiO_2.

[1] B. Balke et al., *Sci. Technol. Adv. Mater.* **9**, 014102 (2008).
[2] Y. Takamura et al., *J. Appl. Phys.* **109**, 07B768 (2011).

MO-108

Magnetic properties and the barocaloric effect in itinerant electron systems

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The barocaloric effect i.e., the heating or cooling of magnetic material under applied pressure variation, can be characterized by the entropy change in an isothermal process (ΔS_{iso}) and by the temperature change in an adiabatic process (ΔT_{ad}). The barocaloric effect has not been much studied in the literature due to experimental difficulties and the low values of the caloric potentials ΔS_{iso} and ΔT_{ad}. However, recent theoretical[1,2] and experimental works [3,4] have shown that the barocaloric effect in transition metals compounds and their alloys can be very large so that it can be useful to improve the performance of magnetic refrigerators. These works reopened the discussion about the barocaloric effect and the physical mechanisms involved in it. In this work we theoretically study the barocaloric effect in itinerant electron systems undergoing both second and first order transition. For this purpose we use a Hubbard like Hamiltonian in which the pressure effect and the magnetoelastic interaction are included in the energy hopping term. In the first part of the work we made a systematic study of the behaviour of the barocaloric potentials as a function of the model parameters. Our calculations show that the barocaloric potentials can exhibit the conventional, inverse and anomalous behaviour, depending on the range of the model parameters. In the second part of the work, we apply the model to calculate the barocaloric effect in Heusler alloys. The obtained results are in good agreement with the available experimental data.

[1] L.G. Medeiros Jr et al, J.Appl. Phys 103, 113909 (2008)
[2] N. A. de Oliveira P. J. von Ranke, Phys. Rep. 489, 89 (2010)
[3] L. Manosa et al., Nature Materials 9, 478 (2010)
[4] L. Manosa et al Nature Comm. 2, 595 (2011)

MO-109

Influence of the magnetic field on the structure of metalic alloy during directional solidification

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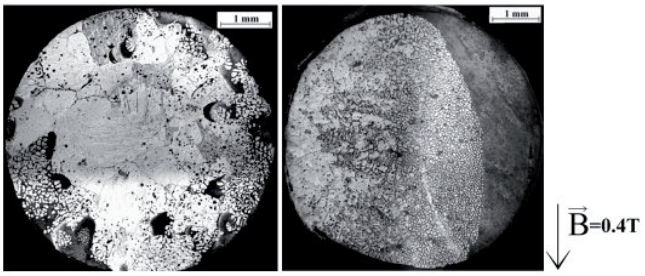
In this work the influence of static and rotating magnetic field on the structure of binary metallic alloys is studied. Slow directional solidification of an alloy is performed with the

specially designed experimental setup. Transverse magnetic field up to 0.4 T is applied to the sample during solidification. At the solidification front of the metal there is always a temperature gradient. Our setup is designed to ensure high temperature gradient at the interface (8 K/mm). All metals and alloys exhibit significant jump of absolute thermopower and electric conductivity during phase transition from solid to liquid and vice versa. Temperature gradient and different thermopowers in solid and liquid phases can be a reason of thermoelectric current circulation in the vicinity of solidification front. If magnetic field is applied in such case then liquid phase convection can be induced. In some cases this convection results as a significant changes in the dendrite or grain structure, or causes macrosegregation within the sample. Sn-Pb and Sn-Bi alloys are used in the experimental results presented here. At low solidification velocities influence on the macrosegregation is quite profound. Rotating permanent NdBFe magnet system is build around experimental setup to create 0.4 T magnetic field. This simplifies the experimental procedure, especially during long experimental sessions.

[1] I.Kaldre, Y. Fautrelle, J. Etay, A. Bojarevics and L. Buligins, Investigation of liquid phase motion generated by the thermoelectric current and magnetic field interaction. Magnetohydrodynamics Vol. 46, No. 4, 371-380, 2010
[2] Li X., Ren Z., Fautrelle Y. Influence of thermoelectric effects on the solid-liquid interface shape and cellular morphology in the mushy zone during the directional solidification of Al-Cu alloys under a magnetic field. Acta Materialia. Vol. 55, Issue 11, June 2007, Pages 3803-3813



Directionally solidified Sn+10%wt.Pb alloy without and with magnetic field. V=0.5 μm/s

MO-110

Structural and Hard Magnetic Properties of MnBi Intermetallic Compound

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The interest regarding MnBi hard magnetic phase results from both the high magnetocrystalline anisotropy of the low-temperature phase (LTP) and the large Kerr rotation angle of quenched high temperature phase (QHTP) [1, 2]. MnBi LTP has been obtained by melting of elemental Mn and Bi components. The sample obtained after melting were annealed at different temperatures: 258°C, 300°C, 400°C and 420°C under dynamic vacuum (10^{-5} mbar). In order to test the influence of milling on the MnBi phase stability, the as melted samples and the annealed samples were also mechanically milled with a Frisch Pulverisette 4 planetary mill. The structural modifications of the samples were investigated by X-ray diffraction (XRD). The remanent magnetisation and the coercive field were deduced from hysteresis curves, performed in magnetic fields up to 7 Tesla at temperatures ranging between 4 and 450K. The X-ray patterns of as melted samples show a better crystallinity of the structure after annealing. In both as melt and annealed samples some quantity of elemental Bi phase was evidenced due to hard diffusion of the elemental components in MnBi matrix. For the milled samples, the proportion of the unreacted Bi phase increases with the milling time. An appropriate annealing results in improvement of MnBi phase content in the alloy. The magnetic coercivity increases by increasing temperature and reaches values of about 2.5 T at 450 K for the sample milled for 2h and annealed at 573 K.

[1] Guillaud C J. Physique Radium 12 143 (1951)
[2] Chen D and Gondo Y J. Appl. Phys. 35 1024 (1964)

MO-111

Magnetic properties and structures of $RRh_{0.8}Ge_2$ (R = Tb – Tm) compounds

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$RRh_{0.8}Ge_2$ (R = Tb – Tm) compounds crystallize in the tetragonal structure space group P4/mbm) in which R atoms occupy three different sites: one 2(a) and two 4(h). The magnetic and neutron powder diffraction data indicate that these compounds are antiferromagnets with the Néel temperature T_N equal 11.5 K (R = Tb), 6.2 K (Dy), 6.6 K (Ho), 5.5 K (Er) and 6.9 K (Tm). Below T_N the additional phase transition at T_t equal 3.8 K for Tb-, 5 K for Ho- and 4.3 K for Er- compounds are observed. The neutron diffraction data for $TbRh_{0.8}Ge_2$ indicate in the temperature range T_t–T_N collinear antiferromagnetic structure described by the wave vector **k** = (½,½,0 is stable). In $HoRh_{0.8}Ge_2$ magnetic moments in the 4(h) sites form collinear AF ordering with **k** = (0,0,0) which is stable up to T_N. The magnetic order in 2(a) site is sine-wave modulated with **k** = (k_x,k_x,0) (k_x = 0.178) and disappears at 5 K. In $ErRh_{0.8}Ge_2$ with increase of temperature the change of the sine-wave modulated structure described by $\mathbf{k_1}$ = (¼,¼,0) at low temperatures to those with $\mathbf{k_2}$ = (⅓,⅓,0) below T_N is observed. The magnetic order in $TmRh_{0.8}Ge_2$ in all sites is described by the wave vector **k** = (k_x, k_x, 0) (k_x = 0.216) and is stable to T_N. The complex magnetic structures of these compounds are analysis basis on the RKKY model of interaction and influence of the crystal electric field. This work was supported by Grant no. N N202 2010 39.

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS
Chair: S. Tacchi

MO-112
CuMnAs: a new epitaxial I-Mn-V room temperature antiferromagnetic compound
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Structures based on antiferromagnetic materials offer an alternative to ferromagnetic or multiferroic materials utilised so far in spintronic applications. A recent experimental report demonstrated a magnetic tunnel junction which utilised an antiferromagnetic layer as the active layer [1]. Elsewhere a current theory paper Maca *et al* suggests that the family of I-Mn-V compounds should be room temperature antiferromagnetic semiconductors, making them attractive for a new generation of antiferromagnetic spintronic devices [2].
We report here on the successful growth and characterisation of a new MBE grown epitaxial I-Mn-V compound: CuMnAs. High resolution x-ray diffraction (XRD) and aberration corrected tunneling electron microscopy (TEM) are combined to resolve the structure and quality of the epitaxial layers. The crystal structure of CuMnAs grown on GaAs(001) substrate is determined to be tetragonal in symmetry, unlike the bulk material. Neutron diffraction reveals a magnetic ordering, the form of which is also supported by *ab initio* density functional theory calculations. Magnetometry measurements of a Fe capped layer reveal a clear exchange bias at room temperature, making this an exciting prospect for possible device utility.

[1] B. G. Park et al, Nature Mater. 10, 347-351 (2011).
[2] F. Maca et al, J.M.M.M. 324, 1606-1612 (2012).

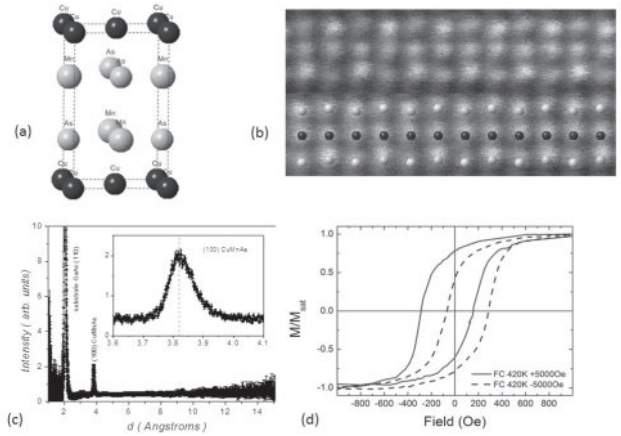

Figure 1 - (a) Structure. (b) TEM image with model. (c) Magnetic neutron peak . (d) Exchange bia

MO-113
A tuneable antiferromagnetic-only-based tunnel junction
D. Petti [1], E. Albisetti [1], H. Reichlova [2], X. Marti [2], J. Gaumez [3], M. Molina Ruiz [4], A. Lopeandia [4], T. Jungwirth [2], R. Bertacco [1]
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Spintronics is nowadays an expanding field with numerous fronts in both fundamental physics and applications, still with ferromagnets as an undismissable item. The introduction of insulating spacing layers in the magnetic tunnel junctions opened the door to a plethora of novel and larger effects, but also to reduce to one only or none the ferromagnetic layers in the devices. For instance, in 2004, the term tunnel anisotropic magnetoresistance (TAMR) was coined after the experiments showing the tunable tunneling from ferromagnetic (Ga,Mn) As into a non magnetic metal [1]. It demonstrated that the tuning of density of states only at one side of the barrier was enough to produce measurable changes in the tunnel resistance. Recent theoretical and experimental works suggested that the magnetic anisotropy phenomena will be present equally in antiferromagnets as in ferromagnetic materials thus opening the door to removing the ferromagnets -and their inherent stray fields- from TAMR based devices. In this work, tunnel junctions have been fabricated on top of atomically flat (001)-oriented $SrTiO_3$ substrates. The multilayer stack, which contains no ferromagnetic layers, comprises antiferromagnetic IrMn and non-magnetic electrodes sandwiching a 2 nm thick MgO insulating barrier. Control experiments indicated that the Neel temperature of the intentionally thin 2 nm thick IrMn is about 120 K. Transport experiments revealed that the set-in of antiferromagnetic ordering plays a role in the electron tunneling, also coexisting with the strain effects induced by the structural transitions of the $SrTiO_3$ substrate below 100 K. We show that the magnetic field-cooling procedure and the strain induced by the phase transitions are suitable tools to manipulate the otherwise elusive antiferromagnetic moments in spintronic devices without net magnetic moment, paving the way towards the realization of tunable spintronic devices only comprising antiferromagnetic layers.

[1] A. D. Giddings et al. Phys. Rev. Lett. 94, 127202 (2005).

MO-114
Tunnel-mediated coupling between antiferromagnetic thin films
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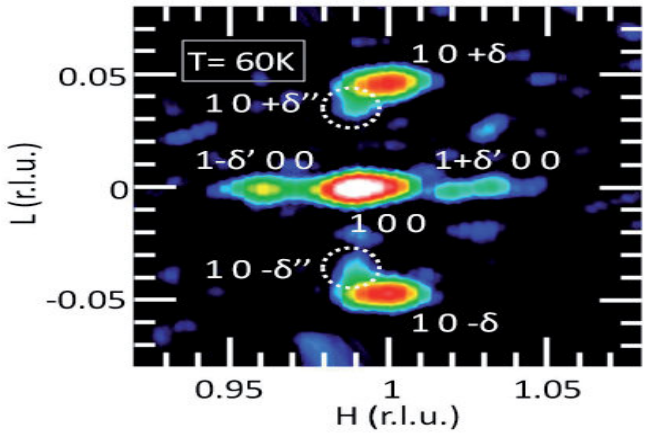
The study, tailoring and control of the coupling between magnetic layers triggered the development of spintronics, notably by leading to the discovery of giant magnetoresistance, and by allowing to tune the coercivity and exchange field of ferromagnetic thin films through exchange bias. Up to now, only systems comprising at least one ferromagnetic film exhibit some magnetic coupling. Here we present a system where two antiferromagnetic layers separated by an ultrathin tunnel barrier interact with each other.
Using neutron diffraction in association with Transmission

Electron Microscopy and high resolution X-ray diffraction, we compared two sets of Cr/MgO/Cr epitaxial trilayers with either thin (4 to 5 monolayers (ML)) or thick (8 to 11 ML) insulating barriers. While the behaviour of the trilayers comprising thick MgO barriers are expected from the structural properties of the individual Cr layers, the magnetic properties of the two Cr layers are no longer independent when the MgO thickness is 5 ML or less[1].
In particular, neutron diffraction measurement evidence supplementary incommensurate phases with enlarged periods at low temperature (see figure), some of which we manage to observe also using X-ray diffraction. This corresponds to a strong alteration of the Cr Fermi surface[2]. We ascribe these peculiarities to a novel form of tunnel coupling between the two Cr layers across the ultra-thin MgO barrier which could be mediated by interface states we recently observed in angle-resolved photoemission experiments. This makes tunnel coupling a general feature of tunnel junctions including magnetically ordered electrodes, which opens new opportunities for spintronics using solely antiferromagnets.



Neutron diffraction pattern of a Cr/MgO(4ML)/Cr trilayer around the (100) position of Cr

[1] M.-A. Leroy *et al, submitted to Nature Nanotechnology*
[2] E. Fawcett, *Rev. Mod. Phys.* 60 **209** (1988)

MO-115

Understanding multiferroic tunnel junctions

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Multiferroic compounds represent a class of multi-functional materials that simultaneously exhibit multiple ferroic orders, offering a variety of new device functionality. However, single phase multiferroics are not currently suitable for commercial devices. Multiferroic tunneling junctions may be the holy grail, drawing together several ferroic attributes in a single device. Several recent experimental works have found that by replacing the inert MgO with a ferroelectric active layer it is possible to observe tunneling magneto-resistance (TMR) and tunneling electro-resistance (TER) [1]. However the values of TMR and TER vary wildly and there is little understanding of the driving mechanisms.
In this work we apply the non-equilibrium Green's function formalism (NEGF) [2] and atomic self-interaction corrected (ASIC) [3] density functional theory to study
several candidate junctions including Fe/BaTiO3/Fe, SrRuO3/SrTiO3/BaTiO3/SrRuO3, and SrRuO3/BaTiO3/SrRuO3. We show that the band symmetry filtering mechanism that is responsible for the magneto resistance in the Fe/MgO/Fe is applicable to these multi-functional barriers and can produce a strong TMR, with nearly 100% polarized current, given the appropriate junction geometry. Furthermore we show that TER can be created by inserting an insulating layer between the ferromagnetic leads and the ferroelectric tunnel barrier. Due to the lack of charge carriers in the insulating barrier, the potential of the insulator is pinned to the potential at the edge of the ferroelectric. This geometry therefore allows the hight of the tunneling barrier to be manipulated by switching the ferroelectric. This mechanism for creating a TER effect is revolutionary as it is driven by the bulk properties of the system and not the fine structure of the interface and therefore is much more attractive for device applications.

[1] Lu et al. Adv. Mater., **24**, 1209-1216 (2012)
[2] Rungger et al. Phys. Rev. B, **78**, 035407 (2008)
[3] Filippetti et al. Phys. Rev. B, **84**, 195127 (2011)

MO-116

Spin-polarized transport through a tunneling junction based on a double quantum dot interacting with a polaron

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Phonon-assisted electronic transport in mesoscopic systems is studied theoretically in case of tunneling through a double quantum dot coupled symmetrically or asymmetrically to ferromagnetic electrodes. The occupation numbers on the dot and current-voltage characteristics for the system are derived by means of the nonequilibrium Green function technique based on equation of motion in the Hartree-Fock approximation. Phonon emission and absorption spectra properties are analyzed for different interdot hopping strength as well as for arbitrary intradot Coulomb correlations and both induced by the polaron shift cases of positive and negative effective charging energy are taken into account. It is found that at sufficiently low temperatures additional phonon-induced resonance peaks appear in the linear spectral function besides the main resonance peaks corresponding to the quantum dot energy levels. It is shown that for positive effective charging energy the electron-phonon interaction leads to the Franck-Condon blockade of the electric current and gives rise to additional steps in the current characteristics, which in turn results in oscillations of the tunnel magnetoresistance (TMR). The induced by the polaronic shift effect of the negative intradot charging energy is also discussed in detail.

MO-117

Giant magnetic-field-induced photoconductivity in a ferromagnetic metal-dielectric heterostructure Co-SiO_2 on a semiconductor GaAs

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Nanosized magnetic materials have attracted much research attention because of their interesting physical phenomena and promising applications for data storage, sensor and device

technologies [1, 2]. We report on strong magnetic-field-induced photoconductivity in ferromagnetic heterostructures Co-SiO_2 on GaAs surface. Metal-dielectric heterostructures formed by Co nanoparticles with average diameter of about 3 nm in SiO_2 matrix with a thickness of 40 nm were prepared by the ion beam deposition technique on (001)-oriented n-GaAs substrates [3]. The photoconductivity in these structures was studied in a spectral range of 1.24-1.6 eV using a modulation-phase-detection technique. It is found that heterostructure Co-SiO_2/GaAs with Co atomic concentration of 60% exhibits a giant magnetic-field-induced photoconductivity in the vicinity of GaAs bandgap of ~1.4 eV at room temperature (see Figure). Light irradiation of heterostructure Co-SiO_2/GaAs leads to a creation of conduction electrons in the conduction band and holes in the valence band, as well as localized electrons and holes trapped on defects within the bandgap of GaAs. It is shown that the existence of spin-dependent barrier at the Co-SiO_2/GaAs interface for injected electrons and a positive feedback at avalanche process due to the holes excited by light close to the interface is responsible for the observed phenomenon. This work was supported by the RFBR (Projects 10-02-01008, 10-02-00516, 10-02-90023 and 12-02-00130).

[1] D. L. Mills, J. Anthony, C. Bland, «Nanomagnetism: ultrathin films, multilayers and nanostructures», Elsevier (2006)
[2] «Nanomagnetism and Spintronics», ed. by T. Shinjō, Elsevier, (2009)
[3] L. V. Lutsev, A. I. Stognij, and N. N. Novitskii, Phys. Rev. B, 80, 184423 (2009)

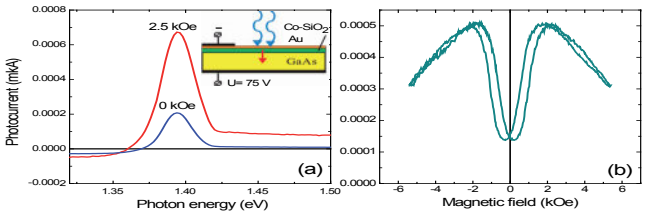

Fig. Photocurrent in the heterostructure Co-SiO_2/GaAs with 60% at. Co versus (a) photon energy and (b) applied magnetic field.

MO-118

Electric-field modulation of switching field distributions in FePt solid-state devices

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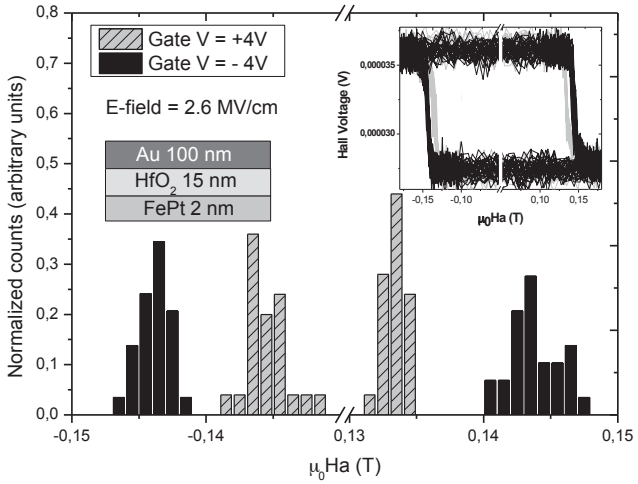
Controlling magnetism with electric fields is a novel and practically oriented concept that can have a major impact in the design of spin dependent technologies. Pioneering work on this area has demonstrated the modulation of the switching field with electric fields in ferromagnetic metals [1] and has generated great interest in the understanding of this effect and in the improvement of the devices' performance. Our study presents the effect of electric fields on solid-state magneto-transport devices based on nanostructured FePt films. As FePt presents a wide distribution of switching fields we analyse the electric-field assisted changes occurring on the switching field distributions rather than on a single switching event. This allows for a more accurate assessment of the electric-field effect which is found to produce switching field shifts larger than the width of the switching field distribution (typically 0.015 T), a necessary requisite to be of practical interest. The dependence of the field-effect on the quality of the dielectric barriers has also been addressed. HfO2 barriers have been found to produce an asymmetric response to the sign of the gate voltage that can be suppressed by annealing. The largest switching field shift achieved in our solid-state devices exceeds 6% for an electric field of 2.6MV/cm. This stands above the values reported for equivalent FePt films in *polymer*-electrolyte gated devices [1] and represents a sensible improvement in the performance and design of FePt field-effect magnetic structures. A marked weakening of the magnetic anisotropy has been observed under positive gate voltages, contrary to what is reported in [1], this discrepancy is discussed in terms of the structure of the dielectric-FePt interface.

[1] M. Weisheit, S. Fähler, A. Marty. Y. Souche, C. Poinsignon, D. Givord, Science **315**, 349-351 (2007).



Switching field distributions for positive and negative applied gate voltages.

MO-119

Magnetically Driven Electron Transport in Fe/SiO_2/p-Si Hybrid Nanostructures

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The results of investigations of the magneto-transport properties of Fe/SiO_2/p-Si hybrid nanostructures with different topologies of a ferromagnetic layer are reported. It was shown that the dominant features of the transport properties of the structures under study are determined by the MIS transition with the Schottky barrier forming at the SiO_2/p-Si interface. The structures exhibit the magnetoresistive effect on dc current [1]. Depending on temperature and bias, either positive or negative magnetoresistance (MR) is observed. Positive MR is related to the processes occuring during passage of a current in the volume of a p-Si semiconductor. Negative MR is related to a thin inversion layer that forms near the SiO_2/p-Si interface.
As was shown by the ac current (20 Hz – 2 GHz) study, in the temperature range 30-100 K there is gigantic magnetoimpedance.

The structure response to the effect of a magnetic field is strongly frequency-dependent with pronounced low- and high-frequency maxima. The effect of a magnetic field on the transport originates from the presence of magnetic surface states at the SiO_2/p-Si interface and their splitting in the magnetic field. The frequency dependence is determined by characteristic times of recharging of the surface centers. Of fundamental importance is that the contribution to the magnetic-field-dependent transport phenomena is made by spin-dependent tunneling between the surface centers and a ferromagnetic electrode.
The strong effect of a magnetic field on photoconductivity is observed also in the same temperature range as the magnetoimpedance. This indicates that the magnetoimpedance and magnetic-field-driven photoconductivity are related to the one type of the surface centers. Also we concluded that a certain contribution in MR is made by the spin-dependent tunneling of photoexcited electrons via the SiO_2 potential barrier.

[1] N.V. Volkov et al., J. Appl. Phys. 109, 123924 (2011)

MO-120

Tailoring and understanding of inter-particle magnetic interaction in sputtered Cu-Co granular films

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The magnetic behaviour of granular systems is generally governed by both the size of magnetic particles and the interactions between them [1]. Such systems are of great significance, both from basic understanding and potential application interest, and are often used as test systems to study the magnetic interactions. One of the main challenges of data storage and information processing technology is the miniaturization of magnetic data bits into the nano-regime without losing stability of the stored information [2]. This requires the understanding of the interaction mechanism operative between nano-sized magnetic particles [3] and developing materials with more stable magnetic states at reduced dimensions. The objective of the present work is to examine effects of interactions between magnetic particles embedded in non-magnetic matrix. As-deposited $Cu_{79}Co_{21}$ granular thin films of thickness varying from 25-100 nm are investigated. Fitting of the magnetoresistance data shows a systematic deviation from simple Langevin-type behaviour as film thickness increases. This deviation is correlated with the magnetic interaction between cobalt particles mediated by the non-magnetic copper matrix. The increase in interaction with the increase of film thickness is satisfactorily accounted for by a modified Langevin function via an additional interaction term that has H^2 dependence. Our fitting requires two particle sizes and an increase in fraction of larger one with thickness. These studies also demonstrate the ability of controlling the interaction, and hence tailoring the blocking temperature and coercivity by varying the thickness of films. We have seen an increase in blocking temperature from 157 K to 276 K on increasing thickness. Thickness and composition of the films together seems to control magnetic response and hence designing of granular systems.

[1] F. Spizzo et.al., J. Magn. Magn. Mater. 262 (2003) 88.
[2] Jian-Qing Wang et.al., J. Appl. Phys. 93 (2003) 9208.
[3] Matthias Hillenkamp et.al., Phys. Rev. B77 (2008) 014422.

MO-121

Strain induced anomalies in the Magnetoresistance behaviour

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Antiphase boundaries (APBs) are natural growth defects occurring due to the crystal structure symmetry difference between the thin film and the substrate. Studies of epitaxial thin films and hetero-structures containing APBs have attracted considerable attention during the last decades as APBs can significantly alter the physical properties of thin films, which is advantageous for the development of spintronics devices [1,2]. One of the important epitaxial heterostructures for these studies is Fe_3O_4 thin films grown on MgO substrates. Since the Fe_3O_4 ($Fm\bar{3}m$) crystal structure is lower in symmetry than MgO (Fm3m) there are several equivalent nucleation sites on the MgO surface, which enforce the formation of APBs at the junction of neighbouring grains. The observation of magnetoresistance (MR) in Fe_3O_4 thin films is attributed to the alteration in spin scattering at antiferromangetically coupled APBs [3], in the presence of a varying magnetic field. Here we report a large anisotropy in the behaviour of MR in Fe_3O_4 (110) films when measured along [100] and [-110] directions, which is strikingly different compared to Fe_3O_4 (100) films. The analysis based on the probability of formation of different density of APBs along [100] and [-110] directions do not support the observation. Fe_3O_4 (110) films showed partial strain relaxation when grown on MgO (110) substrates. We systematically show that the anomaly in the behaviour of MR is predominantly due to strain effects and is not originating from APBs.

[1] S. Lee, A. Fursina, J.T. Mayo, C.T. Yavuz, V. L. Colvin, R. G. S. Sofin, I. V. Shvets and D.Natelson, Nat. Mater. **7**, 130 (2008).
[2] H. C. Wu, M. Abid, B. S. Chun, R. Ramos, O. N. Mryasov and I. V. Shvets, Nano Lett. **10**, 1132 (2010).
[3] S K Arora, R.G.S Sofin and I.V Shvets. Phys. Rev. B **72** (13) 134404 (2005)

MO-122

Magnetization study as a probe of morphology on Fe/MgO granular multilayers

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Discontinuous metal-insulator multilayers (DMIMs) are a particular kind of granular cermets prepared by sequential deposition of a continuous insulating and a discontinuous (granular) metal layer. They exhibit moderate tunneling magnetoresistance (TMR) ratio but an enhanced low-field sensitivity [1], which makes them promising candidates for magnetic sensors.

Recently [2] we have grown Fe(6 Å)/MgO (30 Å) DMIMs on glass and MgO(001) substrates. TMR ratio has been found to increase by a factor of ~4.5 with deposition temperature (T_S) for samples deposited on MgO single-crystals, remaining constant for samples deposited on glass. This was explained in terms of enhanced degree of (001) texturing of MgO layers with increasing T_S for the former.
In this work we discuss the role of T_S on Fe island growth mode onto MgO layers in depth. Boubeta *et al.* [3] demonstrated the influence of deposition temperature on Fe morphology in Fe/MgO films. While low T_S yields flat surfaces, high temperature results in a 3D Fe growth. Magnetization measurements above blocking temperature exhibit sizeable deviation from common Langevin behavior. Fitting of experimental data within an extended model including the island shape anisotropy and dipolar interactions between islands allows us to determine the effective anisotropy constant (K_{eff}, which differs largely from the Fe bulk value) and to elucidate the oblate spheroidal shape and size of Fe islands. Calculated values and a theoretical model can be used to estimate correlations between magnetic moments of Fe neighboring islands. Results are compared with transport and magnetotransport measurements.

[1] G.N. Kakazei *et al.*, J. Appl. Phys. 90, 4044 (2001)
[2] A. García-García *et al.*, Appl. Phys. Lett. 98, 122502 (2011)
[3] C. Martínez Boubeta *et al.*, J. Phys.: Condens. Matter 15, R1123 (2003)

MO-124

Magnetic, transport and structural properties of $SrRuO_3$ thin films

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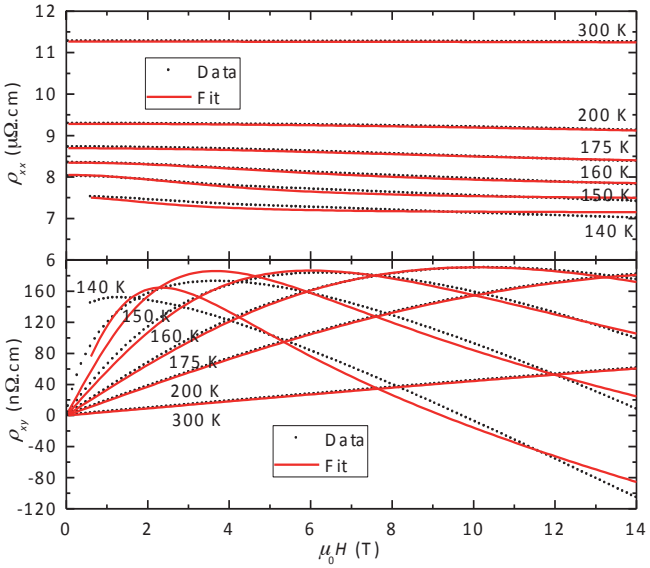
The ferromagnetic oxide metal $SrRuO_3$ (SRO) has attracted attention as it can be grown in thin film form on Si-compatible $SrTiO_3$ (STO) substrates or seed layers. Despite its low T_C = 160 K, the possibility to grow thin film stacks of complex oxides on Si wafers opens the route to integrate the extended magnetic and electric functionality of oxide materials. Here we demonstrate the epitaxial growth of SRO thin films on non-intentionally miscut [001]-oriented STO substrates by pulsed laser deposition (PLD), and carry out structural, magnetic and magneto-transport characterisation of the same. SRO grows with the orthorhombic [110] direction normal to the substrate. By reciprocal space mapping, we have identified two distinct in-plane mosaics with the SRO [001] parallel to STO [100] and STO [010], respectively.
The high-field magnetisation and magneto-transport in SRO have been investigated [1], however no analysis is available of all accessible carrier types. Resistivity and Hall data is analysed within two/three-carrier models, in the temperature region above T_C (140 – 300 K), with an applied field of up to $\mu_0 H \leq$ 14 T. The carrier concentrations vary by a factor of ten and are about $6 \cdot 10^{28}$(majority *p*), $1 \cdot 20^{25}$(majority *n*), $7 \cdot 10^{25}$ m^{-3} (minority *p*) at 140 K. The corresponding scattering times are $3 \cdot 10^{-14}$, $5 \cdot 10^{-12}$ and $1 \cdot 10^{-12}$ s, respectively. The low-temperature saturation magnetisation of the films is 24.6 Am^2kg^{-1} (1.05 μ_B/f.u.), with an intrinsic uniaxial anisotropy constant of 0.63 MJm^{-3} and an apparent one of 0.05 MJm^{-3}. The texture is offset from the normal by about 33°.
In view of its relatively low carrier mobility, SRO could be utilized as the electrode layer in low-temperature all-oxide-MTJ demonstrators and as a seed layer for other ferromagnetic oxides, at and above room temperature.

[1] M. Izumi, K. Nakazawa, Y. Bando, et al, Journ. Phys. Soc. Japan **66**, 3893 (1997)



Resistivity and Hall resistivity of an SRO film on STO.

MO-125

Magnetically correlated Schottky barrier in $La_{1.2}Ca_{1.8}Mn_2O_7$ ceramics

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The double-layered perovskites $Ln_{2-2x}Re_{1+2x}Mn_2O_7$ (Ln = rare-earth and Re = alkali-earth) have attracted remarkable interest due to they exhibit a more larger magnetoresistance (MR) effect than that of the single-layered compound, for example, the CMR is as high as 2×10^4 % (defined here as $(R_H-R_0)/R_H \times$ 100 %) at an applying magnetic field of 7 T for the layered $La_{1.2}Sr_{1.8}Mn_2O_7$ while it is about 200 % at 7 T for similarly doped perovskite materials [1]. For such layered compounds, usually, the magnetotransport property is attributed to the anisotropic transport and exchange interactions [2]. However, the effect of electrical field on the layered oxides is hardly reported. In this work, double-layered perovskite $La_{1.2}Ca_{1.8}Mn_2O_7$ ceramics synthesized by solid-state reaction are investigated using the direct current (DC) and alternating current (AC) methods under a magnetic field of 1 T, respectively. The results show that below the magnetic critical point T_C the nonlinear coefficient of I-V increases with decreasing the temperatures and it goes up to a maximum of 68.6 at the lowest temperature of 14 K. Above the magnetic critical point T_C, however, the nonlinear behaviour of I-V disappears (Fig. 1). The AC measurement shows that the real part of impedance (Zr) decreases with the increase of magnetic or electrical fields (Fig. 2).

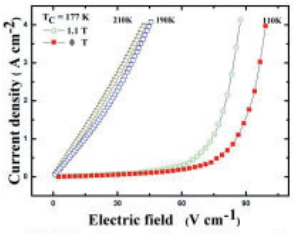

Fig 1. The J-E curves of $La_{1.2}Ca_{1.8}Mn_2O_7$ ceramic at different temperatures.

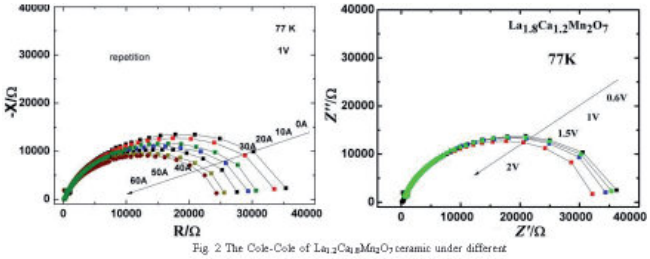

Fig. 2 The Cole-Cole of $La_{1.2}Ca_{1.8}Mn_2O_7$ ceramic under different magnetic (a) and electrical (b) fields at 77 K.

These measuring results indicate that a magnetically correlated Schottky barrier locates at the grain boundaries and it can be regulated by the applying electrical/magnetic fields.

[1] Y. Moritomo, A. Asamitsu, H. Kuwahara, and Y. Tokura, Nature, 380 **(**1996**)**, 141.
[2] H. Asano, J. Hayakawa, and M. Matsui, *Applied Physics Letters* 68 (1996) 3638.

MO-126

Spin injection at the $LaAlO_3/SrTiO_3$ interface

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Future spintronics devices will be built from elemental blocks allowing the electrical injection, propagation, manipulation and detection of spin-based information. Owing to their remarkable multifunctional and strongly correlated character, oxide materials already provide such building blocks for charge-based devices such as ferroelectric field-effect transistors, as well as for spin-based two-terminal devices like magnetic tunnel junctions, with giant responses in both cases. Until now, the lack of suitable channel materials and the uncertainty of spin injection conditions in these compounds has however prevented the exploration of similar giant responses in oxide-based lateral spin transport structures. Ohtomo and Hwang's 2004 striking discovery [1] of a quasi-two dimensional electron system (2DES) at the interface between two band insulators $LaAlO_3$ and $SrTiO_3$ now provides such a conducting oxide-based channel. The first step towards spintronics devices is efficient spin injection, i.e. the injection of a spin-polarized current into a non-magnetic material.
Here, we will demonstrate electrical spin injection into the $LaAlO_3/SrTiO_3$ 2DES by performing magnetoresistance experiments which allow us to probe the occurrence of spin injection from a $Co/LaAlO_3$ magnetic tunnel contact. We analyze, in a local three-terminal measurement scheme, the voltage variation associated with the incoherent precession of the injected spin accumulation driven by perpendicular or longitudinal magnetic fields (Hanle and inverted Hanle effect [2]). The influence of bias and back-gate voltages reveals that the spin accumulation signal is amplified by resonant tunneling through localized states in the $LaAlO_3$ barrier strongly coupled to the 2DES by tunnelling transfer [3]. This recent achievement indicates that such oxide-based systems are suitable for future experiments involving spin propagation, manipulation, and detection.

[1] A. Ohtomo and H. Y. Hwang, Nature 427, 423 (2004)
[2] S.P. Dash et al., Phys. Rev. B 84, 054410 (2011)
[3] N. Reyren et al., accepted in Phys. Rev. Lett.

MO-127

Influence of grain boundaries on the EPIR effect in $Nd_{0.7}Sr_{0.3}MnO_3$ ceramics

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Electrical inhomogeneity, space charge layer and corresponding I-V nonlinearity are the necessary conditions for EPIR effect in perovskite manganites. There are two factors can result in I-V nonlinear characteristics, in which one is the non-ohmic contact between electrode and the surface of oxides, i.e. Schottky barrier, and the other is the interior charged space over grain boundaries inside the sample due to surplus charges accumulated in grain or phase interface. In this work, $Nd_{0.7}Sr_{0.3}MnO_3$ polycrystalline ceramics were synthesized by solid-state reaction under high pressure. The experimental result proves that no EPIR effect can be induced by the grain boundary even though the boundary has a space charged layer and I-V nonlinear characteristic. In order to study why grain boundaries can not produce the EPIR effect, regarding the resistance of the interface between electrode and sample's surface as that of the grain boundary, we simulate the electrical behavior of grain boundaries for the conditions of series, parallel and mixed parallel-series connecting. The simulating results show that the EPIR effect decrease with increasing the number of components both in series or in parallel, till completely disappear with more components added. It proves that the voltage distributing by serial connection and current shunting effect by parallel, which cause the reduction on strength of the stimulation of the external electrical pulse, is the reason why the grain boundary can not induce EPIR effect even with a nonlinear I-V and a charged space. The results also prove that the Schottky barrier of the contact is the real reason for the EPIR of $Nd_{0.7}Sr_{0.3}MnO_3$ ceramics.

MO-128

Effects of crystallization on the static and dynamic magnetic properties of FeNbCuSiB films

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Nanocrystalline magnetic films are good candidates for high frequency applications that demand very high signal/noise ratio [1]. In general, these nanocrystalline magnetic materials have the structure of magnetic nanograins immersed in an

amorphous magnetic matrix [2]. For bulk nanocrystalline materials $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$, sample has high saturation (about 10^3 emu/cm^3), low coercivity and anisotropy quenching [3]. In this work we investigated the effect of annealing temperature and thickness on the magnetic and structural properties of films $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$. The amorphous films with thickness of 100, 200 and 500nm were produced by RF Magnetron Sputtering and were treated for 1 hour under high vacuum. The structural and static magnetic properties of the films as deposited and heat treated were made by X-ray diffraction (XRD) and vibrating sample magnetometer (VSM), respectively. The high-frequency magnetic response of all samples was measured using a coplanar waveguide connected to a Rohde Schwarz ZVA24 vector network analyzer (VNA-FMR). Broadband permeability measurements show typical ferromagnetic resonance phenomena, with several resonant modes associated with the magnetic inhomogeneities and, possibly, spin-wave modes. The dispersion relations were obtained from the experimental data via fittings to lorenzian functions. The relaxation mechanisms of the magnetization were analyzed through the behavior of the FMR linewidth. It was observed that the crystallization process of thinner films results in an increased contribution of two-magnon scattering process to the linewidth, while for thicker films the linewidth is dominated by the terms associated with inhomogeneities and the constant Gilbert damping. The results are discussed in terms of the nanocristallized granular structure, effective magnetic anisotropy and residual stress in the samples.

[1] A. D. C. Viegas, et al, J. Appl. Phys. 101, 033908 (2007).
[2] G. Herzer, Physica Scripta T49, 307-314, (1993).
[3] Y. Yoshizawa et al, J. Appl. Phys. 64, 6044 (1988).

MO-129

Preparation and magnetic properties of $Ni_{80}Fe_{20}/SiO_2/Cu$ composite wires

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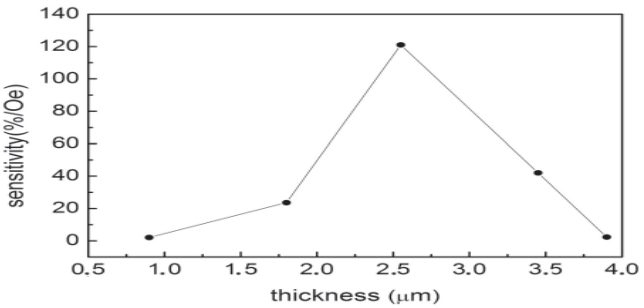
When ferromagnetic materials are driven by an ac current, a giant change of the complex impedance upon applying an external magnetic field can be obtained [1-2]. Since 1994, the so-called giant magnetoimpedance (GMI) effect was found for various soft magnetic materials. The GMI effect can strongly be enhanced by using composite wires with a suitable insulating layer between the conductive core and the magnetic layer [3]. $Ni_{80}Fe_{20}/SiO_2/Cu$ composite wires with a Cu core of a diameter of 60 μm and with a SiO_2 insulating layer of 3.75 μm thickness were prepared by RF magnetron sputtering. Their magnetic properties and the GMI effect were investigated in detail. Influences of the magnetic layer thickness and the relevance of the measurement mode were analyzed in particular. With the optimum thickness of the $Ni_{80}Fe_{20}$ layer, the field sensitivity can reach more than 120 %/Oe. The GMI effect of the composite wires is significantly enhanced to 800 % at a characteristic frequency when being measured in the resonant connection mode.

[1] L.V. Panina and K. Mohri, J. Magn. Soc. Japn. 18, 245 (1994)
[2] K. Mohri, et al., IEEE Trans. Magn. 31, 1249 (1995)
[3] L.Y. Shi, et al., Physica B 404, 3766 (2009)



Dependence of the Magnetic Field Sensitivity on the Thickness of the Ferromagnetic Shell

MO-130

Giant magneto-impedance of iron whiskers at varying temperature

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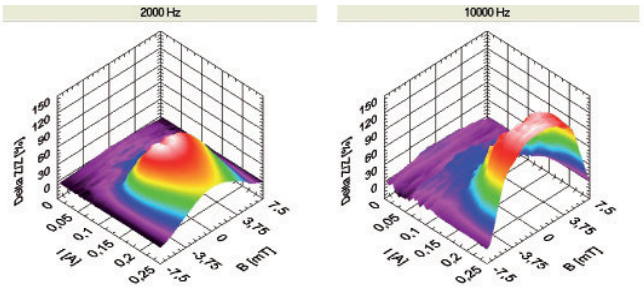
The giant magneto-impedance (GMI) effect involves huge changes of the complex impedance of soft magnetic materials upon application of an external magnetic field. It attracted particular interest in the scientific community after the magneto-impedance measurements on Co-based amorphous wires [1]. Research today mainly focuses on the enhancement of the effect by developing new materials and on potential applications. However, there are specific contributions to the giant magneto-impedance (GMI) effect, especially those being due to domain wall motion, which should further be investigated in order to better understand this interesting effect [2].
For this purpose, iron single crystals (iron whiskers) were grown as specific samples to investigate the GMI effect for AC currents of different magnitudes up to a frequency of 100 kHz, where the domain wall motion takes place and contributes correspondingly. The well-known and simple domain structures enable one to analyze their relationship to the GMI effect. Calculations based on the skin effect permit the determination of the complex values of the effective circumferential permeability. Furthermore, the single crystals have a large mean free electronic path in comparison to amorphous or polycrystalline samples at low temperature. The measured low-temperature impedance changes are on the order of a few hundred percent. The temperature dependence of the GMI can mainly be attributed to the varying mean free electronic path.

[1] L.V. Panina and K. Mohri, Appl. Phys. Lett. 65, 1189 (1994)
[2] M. Langosch, H. Gao and U. Hartmann J. Phys. D: Appl. Phys. 45, 085001 (2012)



Field and current dependence of the GMI effect at frequencies of 2 kHz and 10 kHz at room temperature, respectively

MO-132

Magnetic tunnel junctions with AlGaAs and composite AlAs-GaAs barriers

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Magnetic tunnel junctions (MTJs) with GaAs barriers had been intensively studied and rather modest tunnelling magnetoresistance (TMR) ratios had been reported. AlAs semiconducting compound has an indirect band gap of 2.16 eV and crystallize in zincblende-type structure with a lattice constant almost identical with GaAs one. Thus Fe/X/Fe MTJs with X=AlAs, $Al_{1-x}Ga_xAs$ and composite AlAs-GaAs may represent feasible junctions for spintronic applications.

In present contribution electronic and magnetic properties of Fe/AlAs($Al_{1-x}Ga_xAs$, AlAs-GaAs)/Fe (001) heterostructures are investigated by means of a first principles Green's function technique for surface and interfaces implemented within tight binding linear muffin-tin orbital (TB-LMTO) formalism and in conjunction with the coherent potential approximation (CPA) [1]. The transport properties are studied by means of the linear response of Kubo approach implemented within TB-LMTO-CPA formalism [2]. The results show that electronic and magnetic properties of $Fe/Al_{1-x}Ga_xAs$ interfaces are less sensitive to the barrier composition and rather similar with those of Fe/GaAs ones [3]. For Fe/AlAs/Fe MTJs, for large barriers, the main contribution to the conductance in ferromagnetic state is given by minority-spin electrons and highest TMR values are obtained for As terminated barriers (≈200 %). In case of $Al_{1-x}Ga_xAs$ barriers the calculated TMR values are composition dependent and highest values are obtained for As terminated $Al_{0.7}Ga_{0.3}As$ barriers (≈500 %). Highest TMR values are predicted for As terminated $As_{0.7}Ga_{0.3}Al/GaAs/Al_{0.7}Ga_{0.3}As$ (Fig. 1).

[1] I. Turek, V. Drchal, J. Kudrnovský, M. Šob, and P. Weinberger in "Electronic Structure of Disordered Alloys, Surfaces and Interfaces" (Kluwer Academic Publishers, 1997).

[2] K. Carva, I. Turek, J. Kudrnovský, and O. Bengone, Phys. Rev. B 73 (2006) 144421.

[3] P. Vlaic, N. Baadji, M. Alouani, H. Dreyssé, O. Erikson, O. Bengone and I. Turek, Surface Science 566-568 (2004) 303.

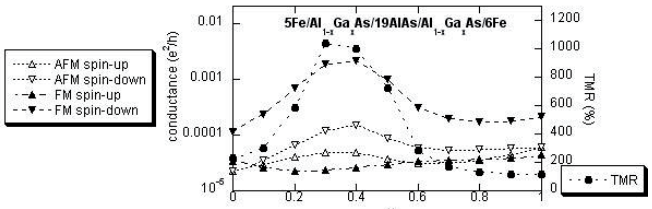

Fig. 1. Composition dependences oconductances and TMR ratios for $Fe/Al_{0.7}Ga_{0.3}As/19AlAs/Al_{0.7}Ga_{0.3}As/Fe$ MTJ

MO-133

Structural, electronic, magnetic and spin dependent transport properties of Fe/X/Fe tunnel junctions with X=LiF and LiBr

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LiF and LiBr alkali halides crystallize in rock salt-type structure having lattice constants of 4.02 Å and 5.5 Å, respectively, and both compounds epitaxially fit bcc Fe structure. LiF and LiBr are insulators with direct band gaps of 13.6 eV and 8 eV, respectively. Thus, Fe/LiF(LiBr)/Fe magnetic tunnel junctions (MTJs) may represent feasible heterostructures for spintronic applications.

In present contribution structural, electronic and magnetic properties of Fe/LiF(LiBr)/Fe (001) MTJs are theoretical studied by means of a first principles Green's function technique for surface and interfaces implemented within tight binding linear muffin-tin orbital (TB-LMTO) method [1]. The spin dependent transport properties are studied by means of the linear response of Kubo approach implemented within TB-LMTO formalism [2]. Total energy calculations evidenced that Fe/LiF (001) interfaces with Fe atoms located atop F ones and Fe/LiBr (001) interfaces with Fe atoms located above Li and Br sites are the most stable ones. The interfacial iron's magnetic moments (≈3 μ_B) are enhanced over bulk value. No exchange coupling is evidenced in case of Fe/LiF/Fe heterostructures while for Fe/LiBr/Fe systems a small ferromagnetic coupling that decreases exponentially with barrier thickness is obtained. Rather small tunnelling magnetoresistance (TMR) ratios (400 %) are predicted for Fe/LiF/Fe MTJs. Spin dependent transport properties of Fe/LiBr/Fe MTJs are close to those of Fe/NaCl/Fe one [3] and characterized by a resonant tunnelling mechanism. High TMR values are predicted for LiBr based junctions in asymptotic regime (Fig. 1).

[1] I. Turek, V. Drchal, J. Kudrnovský, M. Šob, and P. Weinberger in "Electronic Structure of Disordered Alloys, Surfaces and Interfaces" (Kluwer Academic Publishers, 1997).

[2] K. Carva, I. Turek, J. Kudrnovský, and O. Bengone, Phys. Rev. B 73 (2006) 144421.

[3] P. Vlaic, J. Magn. Magn. Mat. 322 (2010) 1438.

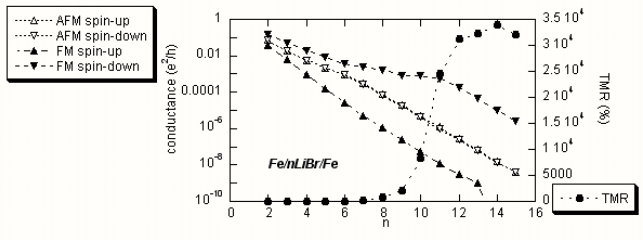

Fig. 1 Conductances and TMR ratios versus barrier thickness for Fe/LiBr/Fe junctions

MO-134

Giant Magnetoresistance of Electrodeposited Ni-Cu/Cu Multilayers

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The dependence of magnetoresistance (MR) on magnetic layer thickness d_{Ni-Cu} was investigated for several electrodeposited Ni-Cu/Cu multilayer series with d_{Ni-Cu} varying from 1 to 5 nm and the nonmagnetic layer thickness kept constant at d_{Cu}=4.2 nm.
The MR(H) curves are shown in Fig. 1 for two multilayers. For d_{Ni-Cu}=5 the bulk scattering within the thick magnetic layers (AMR effect) dominates the observed magnetoresistance (LMR > 0, TMR < 0). For the other multilayers (d_{Ni-Cu} = 1, 2, 3, and 4 nm), the MR(H) curves indicated a clear GMR effect (LMR<0 and TMR<0) and showed a continuous increase of the GMR with decreasing magnetic layer thickness. This is because the bulk contribution to the magnetoresistance due to electron scattering events entirely within the magnetic layer diminishes with decreasing Ni-Cu layer thickness and the GMR effect due to the nanoscale magnetic/non-magnetic multilayer structure becomes dominant as shown for d_{Ni-Cu} = 1 nm in Fig. 1.
For the MR(H) curve of multilayer Ni-Cu(1 nm)/Cu(4.2 nm) in Fig. 1, there is no clear saturation field and no linear high-field region which is certainly due to the small thickness of the magnetic layer. The shape of the MR(H) curve indicates that the observed GMR for the [Ni-Cu(1 nm)/Cu(4.2 nm)] multilayer contains also a contribution arising from the presence of superparamagnetic (SPM) regions in the magnetic layers. By applying a decomposition procedure described in [1], the contributions from spin-dependent scattering events for electron paths through a non-magnetic spacer region between two FM regions (GMRFM term) could be separated from those between a FM region and an SPM region (GMRSPM).
magnetic region which would be a prerequisite to yield a contribution to the AMR.

[1] I. Bakonyi et al., Phys. Rev. B. 70, 054427 (2004).

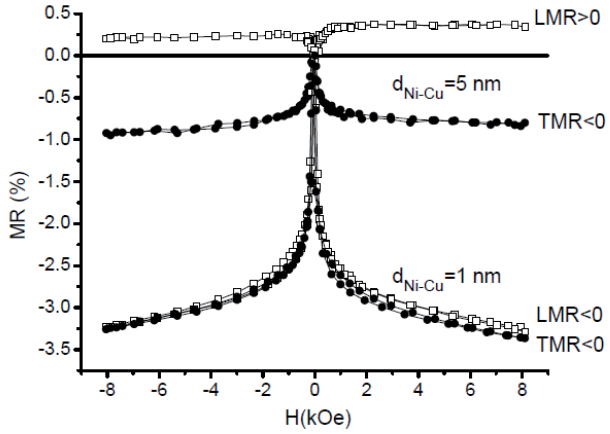

Figure. 1. LMR and TMR curves for d_{Ni-Cu}= 1 and 5 nm.

MO-135

Spacer thickness effects on GMR, exchange bias and coercivity in spin-valve structures

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Effect of thickness of nonmagnetic (NM) spacer on giant magnetoresistance (GMR), exchange bias and coercivity have been studied in F1/NM/F2/AF spin-valve structures. Two sets of samples with the layers sequence of (100)Si/Ta(15)/NiFe(7)/IrMn(15)/Cu(t1)/NiFe(10)/Ta(15) and (100)Si/Ta(15)/NiFe(10)/Cu(t2)/NiFe(7)/IrMn(15)/Ta(15) were made with the thicknesses of the layers given in parentheses in nanometers. The thickness of the Cu NM-layer varied in the range up to 10 nm. DC magnetron sputtering was used for the layers deposition where the system was modified to set a magnetic field of 400 Oe parallel to the substrate, using a pair of permanent magnet plates. The deposition rates for each layer were calibrated by measuring the thickness of the reference layers using the Rutherford backscattering. The magnetic properties of the structures were studied using a vibrating sample magnetometer (VSM), also the dependence of the magnetic resistance as a function of external magnetic field was measured on a specially developed experimental setup. All measurements were carried out at room temperature. The in-plane GMR-effect at room temperature in the second set of the samples was found to be five times larger than in the first set. Presumably, the reason is the scattering in the AF layer with an enhanced loss of the spin polarization, obtained in the pinned F2 layer. Asymmetry for the GMR peaks amplitudes was observed with the change of the direction of the external magnetic field scan, i.e. larger magnetoresistance was observed in the case when the orientation of the magnetization of the pinned F2-layer was opposite to the orientation of the external magnetic field and smaller one when magnetization of the free F1-layer was opposite to the external magnetic field. The Cu-spacer thickness influence on GMR, exchange bias and coercivity is discussed.

MO-136

Magnetization switching of an MgO-based ferromagnetic layer by in-plane current injection

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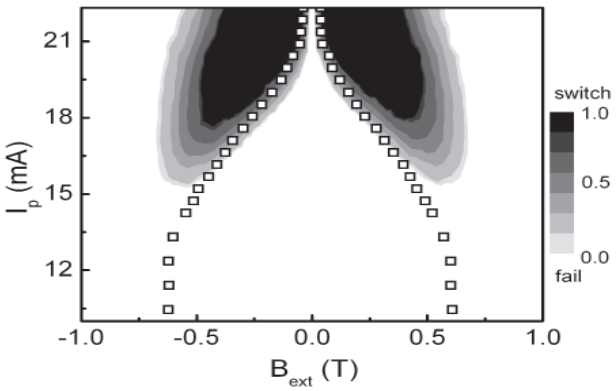
Current induced magnetization switching of an MgO-based high coercivity ferromagnetic layer can be very useful for magnetic tunnel junction applications, especially when the switching current does not flow across the tunnel barrier and does not cause damage to it. Here, we report on the reversible switching of perpendicularly magnetized Pt/X/MgO trilayer

structures, where X stands for Co or CoFeB, by application of an in-plane current and an in-plane magnetic field of constant and small amplitude. This type of switching was first observed in Pt/Co/AlO_x trilayer structure [1] and it is known to originate from the combined effects of current injection and spin-orbit coupling in systems with structural inversion asymmetry. We will describe the dependence of the effective switching field on the current down to 10 ns current pulses. We will also comment on the switching efficiency in these two systems by taking into account their intrinsic properties.

[1] I. M. Miron et Al., Nature 476, 189-193 (2011)



Switching diagram for Pt/Co/MgO structure

MO-137

Low frequency resistance noise in spin-valve stripes with different aspect ratios

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Low frequency resistance noise in giant magnetoresistance (GMR) spin-valves and multilayers has been under intensive investigation in the last two decades, mainly due to their application as magnetoresistive sensors [1]. The low frequency noise in a domain stabilized GMR device is dominated by its 1/*f* noise. It was reported that 1/*f* noise magnitude in spin-valves relates linearly to their fractional sensitivity, $1/R(\mathrm{d}R/\mathrm{d}\mu_0 H)$, during magnetization switching [2, 3]. However, further studies in which the fractional sensitivity is controllably varied are required to verify this relation. It may also be anticipated that other noise mechanisms present in sub-micron GMR devices, where domain wall pinning due to sample edge roughness dominates.

We investigate low frequency noise in a series of spin-valve stripes with different aspect ratios under a hard-axis applied magnetic field. Our samples were patterned from sputtered spin-valve stacks (GMR ~ 5.5% at room temperature) using electron beam lithography and Ar^+ ion milling. The stripes have the same length of 60 μm and different widths of 15, 10, 7.5, 5, 2, 1 and 0.5 μm.

The 1/*f* noise power at both the parallel (P) and the antiparallel (AP) states of the stripes follows an inverted volume scaling relation except that in the narrowest stripe, which shows significantly higher noise power. Random telegraph noise was occasionally observed during magnetization switching in all the samples. Our results suggest the importance of domain wall engineering when designing sub-micron GMR sensors.

[1] J. Lenz and A. S. Edelstein, IEEE Sens. J. 6, 631 (2006)
[2] N. Smith et al., IEEE Trans. Magn. 33, 3385 (1997)
[3] A. Ozbay et al., Appl. Phys. Lett. 94, 202506 (2009)

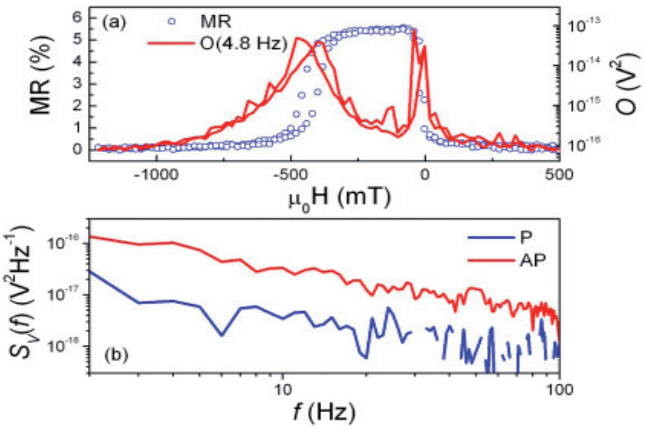

Fig. 1 (a) GMR- and noise- field relations for a w = 7.5 μm spin-valve stripe. (b) The corresponding noise spectra at the P and AP states.

MO-138

Controlling shot noise in double barrier epitaxial magnetic tunnel junctions

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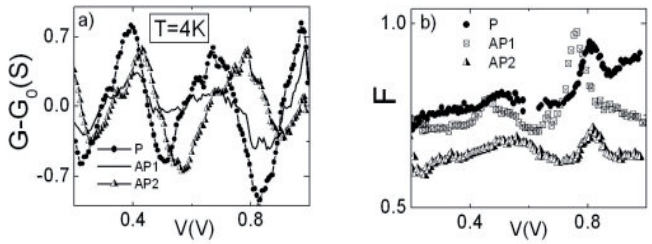
Shot noise (SN) has been shown to be an effective tool to study the statistics of electron tunneling in single barrier magnetic tunnel junctions [1-2]. Here we demonstrate that SN in Fe/MgO/Fe/MgO/Fe double-barrier magnetic tunnel junctions is determined by the relative magnetic configuration of the junction (P, AP1 and AP2 states) and asymmetry of the barriers. A strong barrier asymmetry, in a range where the adjacent ferromagnetic layers are coupled antiferromagnetically, approaches the shot noise to full (Poissonian) SN value. An enhanced conductance and SN at some voltages indicate resonant tunneling through quantum well states formed in the middle magnetic layer (see Figure). The proposed theoretical model of sequential tunneling through the system, with spin relaxation included, successfully accounts for the experimental observations. These results reveal new perspectives for a reliable magnetic control of the most fundamental noise in spintronic structures.

[1] R. Guerrero, et al., Phys. Rev. Lett. **97**, 0266602 (2006).
[2] R. Guerrero, et al, Appl. Phys. Lett. **91**, 132504 (2007).



(a) Bias dependence of conductance relative to the parabolic background. (b) SN normalised by full SN (Fano) for Fe/MgO(10mL)/Fe(5nm)/MgO(9mL)/Fe DMTJ.

MO-139

Switching magnetization of nanomagnets in lateral spin-valves

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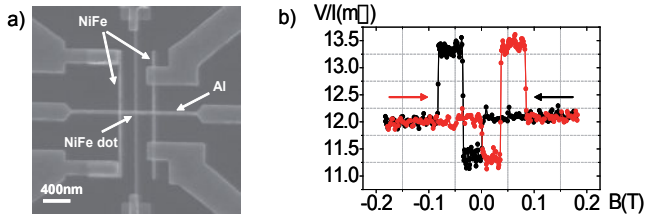
The ability of the spin transfer torque (STT) [1] to act on the magnetization of nanomagnets has promoted many researches in the last decade. Up to now, most of these studies have been done using vertical nanopillars and nanowires, to study current-induced magnetization switching or domain wall propagation.
Lately, lateral spin-valves have attracted an increasing attention, essentially due to its ability to separate the spin current from the charge current: it is then possible to avoid spurious effects created by Oersted fields and Joule heating [2]. Such devices also opened new prospects towards the exploitation of pure spin currents, giving rise to several studies based on the spin Hall effect [3]. In this work, we propose a new multi-terminal device made of two ferromagnetic nanowires and one central dot, bridged by a transversal metallic channel (see figure) to study the spin torque generated by a pure spin current.
The sample characterization is performed using non-local magnetotransport measurements. High spin signals have been achieved, and the insertion of the dot in the middle of the nanostructure allows measuring the spin current absorption as well as the dot switching field. Different dot geometries have been tested, in order to check the effect of the thickness on the STT efficiency.

[1] J. C. Slonczewski, J. Magn. Magn. Mater. 159, L1 (1996).
[2] T. Yang *et al.*, Nat. Phys. 4, 851 (2008).
[3] L. Vila *et al.*, Phys. Rev. Lett. 99, 226604 (2007)



a) SEM image of the device
b) Non-local measurement, showing the different switching fields

MO-141

Spin-disorder resistivity in ferromagnetic metals: the disordered local moment approach

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The spin-disorder resistivity (SDR) of transition metal ferromagnets (Fe, Co, Ni), rare-earth ferromagnet Gd, and Ni_2MnX (X=In,Sn,Sb) class of Heusler alloys is determined from first principles. We identify the SDR at the Curie temperature with the residual resistivity of the corresponding system evaluated in the framework of the disordered local moment (DLM) model which has the zero spin-spin correlation function. The underlying electronic structure is determined in the framework of the tight-binding linear muffin-tin orbital method which employs the coherent potential approximation (CPA) to describe the DLM state. The DLM fixed-spin moment approach is used in the case when the DLM moment collapses. The electronic structure of hcp-Gd is determined using both the open core and LDA+U approaches. The Kubo-Greenwood approach is used to estimate the resistivity. For bcc-Fe and Ni_2MnSn alloy we shall also estimate the temperature-dependent resistivity below the Curie temperature using semiempirical approach. Calculations are compared with an alternative supercell Kubo-Landauer approach developed recently as well as with available experimental data and overall good agreement is obtained. In the case of Ni_2MnSb Heusler alloy an acceptable agreement with the experimental data is obtained only if the disorder present even in the stoichiometric alloy is taken into account.

MO-142

Non-equilibrium Green's function modeling of the magneto-transport characteristics of double barrier magnetic tunnel junctions

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Modeling of the transport characteristics of nanoscale systems is an active area of current research. It acquires significance as it can provide informations concerning the influence of different material characteristics on the transport characteristics. The non-equilibrium Green's function (NEGF) technique serves as a powerful tool in the modeling of the transport characteristics of nanoscale systems and hence it is being widely used. Our present interest is on the transport characteristics of double barrier magnetic tunnel junctions (DBMTJs) and we have used the NEGF techniques [1] to study the transport characteristics of these devices. We have considered DBMTJs exhibiting many body interactions and studied the influence of barrier thicknesses, band occupations, electron correlation effects and applied bias on the transport characteristics of these systems. Our studies show that the DBMTJs exhibit very interesting transport characteristics. The tunnel magnetoresistance (TMR) of these devices is found to be enhanced significantly and the TMR exhibits distinguished features. The details of our results will be described in the paper.

[1] S. Mathi Jaya and M. C. Valsakumar, J. Mag. Mag. Mat. **323**, p. 2554 (2011)

MO-143

Pure spin-currents: a thermodynamic investigation in the non-local geometry.

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Low power consumption is an important issue for high density electronics, and spintronic devices are presented as ideal systems for that point of view. In particular, low dissipation spin current is expected in the case of the three or four terminal devices (i.e.

in the case of non-local geometry). In such a device, the current is injected in a branch (I) of the circuit, while the voltage is measured in another part (branch (II)), which is not connected to the generator (open circuit). The pure-spin current is then defined as a diffusion of carriers having a specific spin throughout the branch (II) of the device together with zero total electric current. The corresponding system is able to show a rich variety of partial equilibrium states [1]. In this work, we focused our attention on the coexistence of three partial equilibrium conditions in the branch (II): the equilibrium of electric charges (zero electric current) associated to the equilibrium of spin in the usual space (zero pure spin-current) but with out-of-equilibrium spins in the spin-space (i.e. non-zero spin-accumulation generated in the part (I) of the device and extended in part (II)). The role of the heat current is also investigated. We will show that the electrostatic voltage at the interface allows the spin-accumulation to be measured. As a consequence the measured giant magnetoresistance is the same as with the presence of pure spin current but the power dissipated in the device is clearly different in both cases.

[1] J.E. Wegrowe and H.J. Drouhin, "Spin-Currents as Spin-Pumping Forces for Spintronics", Entropy 13 (2011) 316.

MO-144

Penetration depth of transverse spin current in ultrathin ferromagnets and nonmagnets

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Spin polarized current entering a ferromagnet (F) and transferring spin angular momentum to the magnetization **M** of the F is known as spin momentum transfer (SMT). The length scale of this phenomenon is of fundamental interest. Since injected spins polarized transverse to **M** are absorbed and exert torque, the penetration depth has been framed in terms of the transverse spin coherence length λc in F. This SMT length scale is thought to be very short, $\lambda c \leq 2$ nm in 3*d* metallic ferromagnets. Experiments have not probed the dependence of SMT in the relevant thickness range $t_F < 2$ nm. The spin pumping effect, which is the inverse process to current-pumped precession, provides an alternative to study the length scale of SMT. In a spin-valve structure (F1/N/F2), precession of F1 sources ("pumps") a spin current across the N and into F2, where it is absorbed identically to spin-polarized electrical current injected through voltage, verified as torque on the magnetization.
We perform broadband (0-24GHz) field swept ferromagnetic resonance (FMR) measurement using a coplanar waveguide with field modulated lock-in detection technique [1]. The extracted the Gilbert damping of F1 as a function of FM2 thickness shows a sharp increase up to 1.1nm and above it remains constant. This confirms that the absorption of spin current by ferromagnets (FM2) is very short and have a cut-off length-like functional form. However, using non-magnetic overlayers instead of F2, an exponential functional form, with a characteristic length λc was observed. Thus, our experiment reveals the difference in spin absorption mechanisms and its length scales in several ferromagnets and nonmagnetic metals.

[1] A. Ghosh, et al., Appl. Phys. Lett. **98**, 052508 (2011).

MO-145

Spin-polarized magnetotransport and antiferromagnetic coupling across silicon regulated by tunneling currents

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Epitaxial Fe/Si/Fe tunnelling structures are attractive due to strong antiferromagnetic coupling (AFC) [1]. However, room temperature (RT) magnetotransport in Si-based structures have not been established so far.
Here, we present the room-temperature (RT) magnetotransport and the enhancement of AFC in Fe/Si/Fe structures prepared by molecular beam epitaxy. In our experiments we utilized the non-destroying ballistic electron magnetic microscopy (BEMM) with the nanometer resolution [2]. Ballistic hot electrons are injected from the scanning tunneling microscope tip across a vacuum tunnel barrier, which prevents from leakage currents and, thus, permits RT studies. In BEMM experiments a first magnetic layer serves as a spin-polarizer and a second one - as an analyzer of the magnetization alignment. The energy filtering by a Schottky barrier formed close to n-doped GaAs substrate enables to separate the tunneling current I_T from the ballistic collector current I_c. This utilizes tunneling currents for manipulating the magnetization alignment and collector currents for the detection of the magnetization alignment. We found that for negative biasing voltages the collector current becomes dependent on the in-plane magnetic field. In our experiments the RT collector current is higher for the parallel alignment and the magnetocurrent exceeds 200 %.
The saturation magnetic field for I_c corresponding to the parallel alignment of magnetizations rises up with I_T, thus demonstrating an additional stabilization of the antiparallel state and substantial increase of AFC. We connect enhanced AFC with local dynamic spin torques mediated by spin-polarized tunneling electrons [3].
This work is supported by the project DFG 9209379.

[1] R.R. Gareev et al, J. Magn,Magn,Mater. 240, 235 (2002)
[2] E. Heindl et al., J. Magn. Magn. Mater. 321, 3693 (2009)
[3] R.R. Gareev et al., Appl. Phys. Lett. 100, 022406 (2012

MO-146

Self-consistent calculation of spin polarized transport and magnetization dynamics in synthetic antiferromagnetic free layers

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Theoretical investigations of spin current driven magnetization dynamics are commonly performed by including the Slonczewski spin torque term in the Landau-Lifschitz Gilbert equation. This is a good approach when considering a single free layer. Recent experimental studies reported magnetization switching [1] or steady state oscillations [2] in synthetic antiferromagnetic (SAF) layers, where two ferromagnetic layers are coupled via exchange interaction across a Ru spacer layer. A typical structure is Pol/Cu/FL1/Ru/FL2, with Pol the polarizing layer and FL1 and FL2 the two ferromagnetic layers of the SAF. In order to investigate

the important question on whether the spin torque across the Ru spacer needs to be considered we have studied theoretically the spin transfer torque (STT) in the frame of the drift-diffusion model [3] for a Pol/Cu/FL1/Ru/FL2 structure. The transport calculations have then been coupled in a self-consistent way to macrospin simulations solving the Landau-Lifschitz-Gilbert equation. The drift-diffusion model allows us to take account of not only the spin transfer torque at the Cu/FM but also the STTs at the FL1/Ru and the Ru/FL2 interfaces. We found that the STT across Ru can considerably affect the magnetization dynamics of a synthetic free layer. We discuss the results as a function of external magnetic field and the strength of the Ruderman-Kittel-Kasuya-Yosida (RKKY)-type exchange interactions through Ru

[1] J. Hayakawa, et al., Jap. J. Appl. Phys. **45**, L1057 (2006); S. Yakata, et al., Appl. Phys. Lett. **95**, 242504 (2009).
[2] D. Houssameddine et al., Appl. Phys. Lett **96**, 072511 (2010)
[3] J. Barnaś et al. Phys. Rev. B **72**, 024426 (2005); S. W. Lee, K. J. Lee, J. Kor. Phys. Soc. **55**, 1501 (2009).

MO-147

Time-resolved scanning tunneling spectroscopy on single magnetic adatoms

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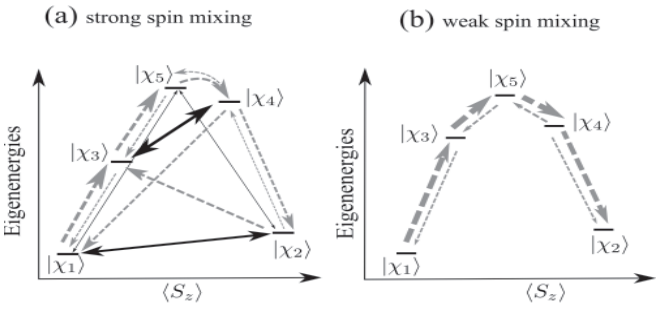
The inelastic tunneling spectroscopy (IETS) provides a very suitable tool for the detailed analysis of the magnetic properties of adatoms and molecules [1]. Furthermore, the inelastic scanning tunneling microscopy (STM) using a spin-polarized tip also allows for manipulating the spin configuration and for tracing the nanosecond spin dynamics of the magnetic adsorbates in a pump-probe manner [2].
Based on a non-perbutative model, we theoretically investigate the excitation mechanism of the sample spin, its dependence on the anisotropic environment (indicated in the figure) and demonstrate how the relaxation dynamics can be monitored with the help of the tunnelling current. The predictions of a simple analytical model support our numerical findings and reveal the underlying physics. We also compare our results to recent experiments [3].



The transition strengths of the sample spin eigenstates for different anisotropy scenarios

1] S. Loth, C. P. Lutz, A. Heinrich, *New J. Phys*. **12**, 125021 (2010)
[2] S. Loth, M. Etzkorn, C.P. Lutz, D. M. Eigler, A Heinrich, *Science* **329** 1628 (2010)
[3] Our manuscript *Theory of spin dynamics of magnetic adatoms traced by time-resolved scanning tunneling spectroscopy* has recently been accepted by *New J. Phys*.

Monday, 10 September 2012
Poster Area, 17.00 – 19.00

PEROVSKITES AND MULTIFERROICS
Chair: M. Ghidini

MO-148

FeO at Iron/Oxide interfaces

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We present density-functional theory (DFT) based first-principles calculations of tunneling and magnetoconductance properties of nanoferronic devices consisting of oxide barriers between iron contacts. Several experimental works have indicated the presence of an iron-oxide layer at the contacts of this barrier, that can significantly alter the tunneling properties of the junction. The effect of this layer is still unclear. From the theoretical point of view, one unexplored point are the electron correlations in the single FeO layer at the interface. We account for these correlations with a Hubbard U parameter determined by the constrained random phase approximation (cRPA) [1] and calculate the change of the tunneling magnetoresistance ratio under this condition, using the full-potential linearized augmented plane wave (FLAPW) method (FLEUR code [2]). The electronic transport properties of nanoferronic junctions have been investigated using an embedded Green-function approach [3].
Work is supported by Helmholtz Young Investigators Group Program VH-NG-409.

[1] E. Şaşiouğlu, C. Friedrich, and S. Blügel, PRB **83**, 121101(R) (2011)
[2] www.flapw.de
[3] D. Wortmann, H. Ishida, and S. Blügel. PRB **66**, 075113 (2002)

MO-149

$Pr_{0.5}Ca_{0.5}MnO_3$ thin films deposited on $LiNbO_3$ substrates

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The $Pr_{1-x}Ca_xMnO_3$ (PCMO) manganite exhibits a very broad composition range with charge and orbital ordering effects. A sufficiently strong static magnetic field applied to this system triggers an insulator to metal transition by which the charge- and orbital-ordered antiferromagnetic insulating ground state is melted into a conducting ferromagnetic metallic state, inducing colossal magnetoresistance [1,2]. The charge ordering transition is highly affected by pressure, electric and magnetic fields, radiation and epitaxial strain in thin films.
Lithium niobate ($LiNbO_3$) is ferroelectric up to 1210 °C and is commonly used in wave guide and integrated optics applications,

due to its optical, electro-optic, piezoelectric, photorefractive, elastic and photoelastic properties [3].
Thin films of $Pr_{0.5}Ca_{0.5}MnO_3$ were deposited on z-cut $LiNbO_3$ by pulsed laser ablation using a KrF excimer laser with λ = 248 nm. The X-ray diffraction measurements have shown that the films grow highly oriented on $LiNbO_3$, with a pseudocubic (111) preferred growth direction. The thicknesses of the films, measured by low angle X-ray reflectivity, are between 13 and 140 nm. The standard four-probe-in-line technique was used to measure the electrical resistivity of the samples, and the results have shown a semiconducting behaviour in all the samples with an anomaly around 240 K, corresponding to the charge ordering transition. The temperature of the transition (T_{CO}) was estimated from the lnρ *vs.* (1/T) plots. The charge ordering temperature was found to be dependent on the strain induced by the lattice mismatch on the films.

[1] A.M. Haghiri-Gosnet and J.P. Renard, J. Phys. D: Appl. Phys. 36, R127 (2003)
[2] W. Prellier et al, J. Phys.: Condens. Matter 13, R915 (2001)
[3] R. S. Weis and T. K. Gaylord, Appl. Phys. A 37, 191 (1985)

MO-150

Optimization of deposition parameters for ferromagnetic $La_{0.67}Ca_{0.33}MnO_3$ / ferroelectric $BaTiO_3$ bilayers

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Multiferroic materials exhibiting simultaneous ferroelectricity and ferromagnetism have potential applications in information storage and the field of spintronics. Ferromagnetic ferroelectric bilayers could be a way to obtain a multiferroic structure. We addressed to deposit the ferromagnetic phase of the La_{2/3} Ca_{1/3}MnO_{3} and the ferroelectric BaTiO_{3} seeking a multiferroic properties in these structures [1-2]. We have optimized the growth parameters as pressure, laser energy and thickness, for depositing BaTiO_{3}(BTO) / La_{2/3} Ca_{1/3}MnO_{3}(LCMO) onto (001) SrTiO_{3} and Nb:SrTiO_{3} by pulsed laser deposition (PLD), at pure oxygen atmosphere and a substrate temperature of 820 ^{o}C. The bilayer structure was studied by x-ray diffraction (XRD). For individual layers, lattice parameter is a_{BTO}=4.068 A, and a_{LCMO}=3.804 A, In the bilayer, Bragg peaks for BTO maintain its position but LCMO peak shift to lower Bragg angle indicating a strained LCMO film. Magnetization measurements reveal that when a sample of LCMO (t = 47 nm) is deposited on a thin film of BTO (t=52 nm), there is an increase in the magnetic transition temperature from 180 K to 220 K, compared with monolayer of LCMO deposited on SrTiO_{3}.
This work was financially supported by Instituto de Nanociencias de Aragón, Zaragoza, Spain, El Patrimonio Autónomo Fondo Nacional de Financiamiento para la Ciencia, la Tecnologia y la Innovacion Francisco José de Caldas, Contract RC 275-2011 and Research Projects "Multiferroic Heterostructures based on Nanostructured Multilayers of Ferromagnetic and Ferroelectric Oxides" 1106-48-925531 Colciencias, Colombia, "Interfacial microstructure influence on magnetic and electric properties in multifunctional oxide heterostructures", CI 7864, Universidad del Valle, Cali, Colombia.

[1] Z. X. Cheng, X. L. Wang, S. X. Dou, M. Osada, and H. Kimura, Appl. Phys. Lett. 99, 092103 (2011).
[2] V. G. Prokhorov, V. A. Komashko, and G. G. Kaminsky, Low Temp. Phys. 33 1, (2007)

MO-151

Low Temperature Magnetoelectric Frequency Dependence of PMN-PT/CFO Multiferroic Composite

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Studies in advanced materials are very important for the electronic industries and for the physics basic concepts understanding. Due to these materials, many electronic devices are possible to be built like magnetic memories and high complex chips, and some physical properties are very well understood as the giant magnetoresistance, used in hard disk memory sensor. However, some materials exhibits properties those are not well understood yet like the coupling between the ferromagnetic and ferroelectric phases in a multiferroic composite. These materials are great interesting in the materials study due to unexpected coupling between electric and magnetic fields which give rise interesting properties such as Magnetoelectric (ME) Effect. In this work we present the ME effect with the magnetic AC frequency dependency at low temperatures of the multiferroic composite $(1-x)Pb(Mg_{1/3}Nb_{2/3})-xPbTiO_3$(PMN−PT) as ferroelectric phase and $CoFe_2O_4$(CFO) as ferromagnetic phase.
The PMN-PT/CFO composite sample was synthesized in an 80/20 composition by hot forging process at 1050ºC for 30 min and 6MPa. The ME measurements were performed using a system adapted by the group in the *Physical Properties Measurement System* (PPMS-Quantum Design). The measurement temperature was 5 K and the frequency range were 10 Hz to 1500Hz. The results shows that there is a strong relationship with the magnetic DC order dependence of the ME effect with the applied magnetic AC frequency. These results are indication that the ME effect is associated with the dynamic magnetostriction dependence of the CFO ferromagnetic grains inside of the PMN-PT ferroelectric matrix.

MO-152

Magnetoelectric Effect at Low Temperatures of PMN-PT/CFO Multiferroic Composite

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Multiferroic materials with coexistence of ferroelectric and ferromagnetic orders are of great interest to applications in multifunctional devices because of simultaneous control of ferroic phases. In these materials, the coupling interaction between the different order parameter could produce new effects, such as magnetoeletric (ME) effect. Van Suchtelen [1,2] established that the ME response is proportional to product of piezoelectric and piezomagnetic coefficients, i.e., the response will be proportional to relative variation derivate of

the material. In composite materials the ME effect appears due to the coupling between the magnetostriction and ferroelectric phases. On the order hand, there are few investigations in composite multiferroic materials at low temperatures. In this work we present the magnetoelectric and magnetostrictive characterization at low temperatures of multiferroic composites based on $(1-x)Pb(Mg_{1/3}Nb_{2/3})-xPbTiO_3$(PMN−PT), as ferroelectric matrix, and $CoFe_2O_4$ (CFO) as ferromagnetic phase.
The samples were synthesized by hot forging process at 1050ºC during 30 min and 6MPa. The ME measurements were performed using a system adapted in the Physical Properties Measurement System (PPMS-Quantum Design) in 300 K and 5 K. The results shows that at room temperatures (300 K) the ME response is proportional to derivate of the relative variation of the sample, as predicted by van Suchtelen model's [2], while at low temperatures (5 K) this model is not in complete agreement. This discrepancy is can be explained using a correction in dynamic magnetostriction of the sample, considering that the magnetostriction at low temperatures is proportional to first and second order of magnetization. Our results present a good concordance with the model including these corrections.

[1] J. van Suchtelen, Philips Res. Rep. 27, 28 (1972),
[2] Ce-Wen Nan et al. JOURNAL OF APPLIED PHYSICS 103, 031101 (2008),

MO-153

Strain effect on magnetocrystalline anisotropy of multiferroic Fe/$BaTiO_3$

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Using the highly precise full-potential linearized augmented plane-wave method within general gradient approximation, we studied the magnetism of Fe monolayer on $BaTiO_3$ (BTO), which has been recently expected as a multiferroic heterostructure. As previously predicted with the pseudo-potential method [C.G. Duan *et al*., Phys. Rev. Lett. 97, 047201 (2006), Appl. Phys. Lett. 92, 122905 (2008)], we approved that the ferroelectric Ti polarization alters significantly the magnetic moment and magneto-crystalline anisotropy energy (E_{MCA}) of Fe/BTO. In addition to the change of E_{MCA} due to the electric polarization, it is also found to be very sensitive to substrate strains. As the compressive strain is applied, the calculated E_{MCA} decreases from 1.4 meV/Fe at the lattice constant (3.991 Å) of BTO to 1 meV/Fe at the compressive strain of 2.2 % which corresponds to the lattice of $SrTiO_3$ (STO). Whereas, the tensile strain increases the E_{MCA} and large value of 2 meV/Fe is obtained at the tensile strain of 3 %. Magnetic moments of Fe and Ti atoms reduce (increases) slightly as the compressive (tensile) strain increases. An example model of Fe/BTO/STO in this study reveals that the changes of magnetization of a ferromagnet in response to the ferroelectric polarization across the interface can also be manipulated by the lattice strain with a suitable third alien.

MO-154

Angular dependence of the magnetoelectric effect in orthorhombic $HoMnO_3$ films

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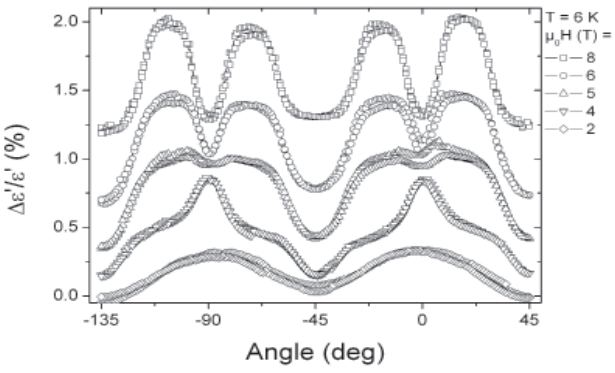
Multiferroic manganites were intensely investigated in recent years, since these serve as model systems for the study of novel mechanisms of ferroelectric order. $HoMnO_3$ is of particular interest, since the ferroelectric order is intimately related to the antiferromagnetic order [1].
In this work epitaxial orthorhombic $HoMnO_3$ films were grown on Nb-doped $SrTiO_3$ (001) single crystal substrates using pulsed laser deposition. X-ray diffractometry showed a uniform crystallographic orientation with the c-axis along the substrate normal and an anisotropic compressive stress along the b-axis of the Pbnm structure. The magnetization of the films was dominated by the paramagnetism of the Ho^{3+} ions and showed a strong anisotropy with respect to the in-plane and perpendicular-to-plane magnetic field direction.
The dielectric permittivity of the films was measured for various magnetic field strengths and orientations. Especially the rotational anisotropy of the magnetoelectric effect was studied for magnetic field rotation in the (110), (1-10) and (001) planes. Whereas magnetic field rotation in the (110) and (1-10) planes showed a twofold rotation pattern with the smallest magnetoelectric effect observed in magnetic fields along the c-axis, in-plane (001) magnetic field rotations revealed an intricate rotational symmetry. A magnetic field induced crossover was observed from a low field region with fourfold rotation patterns to a high field region with rotation patterns up to the 12th order. This complex rotational symmetry arises from spin-orbit coupling of the Ho^{3+} moments that induces a modulation of the magnetoconductance as well as a magnetoelectric effect through the Maxwell-Wagner mechanism.

[1] S. Picozzi et al., Phys. Rev. Lett. 99, 227201 (2007)



Rotational anisotropy of the dielectric permittivity for magnetic fields in the ab-plane

MO-155

Growth, structure, surface topography and magnetic properties of $GdMnO_3$ multiferroic epitaxial thin films

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Epitaxial thin films GdMnO3(GMO) were grown in various regimes on (001) NdGaO3(NGO) and (001) SrTiO3(STO) substrates by RF sputtering. RBS analysis has shown that the films were stoichiometric and have thickness about 100 nm. X-ray analysis showed that when the substrate temperature was 650-900 C the films were single phased (GdMnO3 with orthorhombic structure). But at lower temperature (<750 C) the films on NGO had only one (001)GMO/(001)NGO orientation, and at higher temperatures (>750 C)– two (001)GMO/(001) NGO and (110)GMO/(001)NGO. These data were confirmed by transmission electron microscopy. The films grown on SrTiO3 substrates had two orientations in the whole temperature diapason of the phase existence.

Using AFM the connection of the films obtained topography with their crystallographic structure was studied. Magnetic properties of the films were measured using a SQUID magnetometer. Temperature dependencies of magnetization and hysteresis loops were obtained. The data for both kinds of the films were compared to those ones for the bulk samples.

This work was supported in part by RFBR Grant 11-02-92706-IND_a.

MO-156

The role of crystal symmetry and internal strain on the magnetic orderings and multiferroic properties of quadruple perovskites AM

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The remarkable properties of manganese oxides with *simple* perovskite structure $A\mathrm{MnO_3}$, such as the colossal magnetoresistance and the multiferroicity, arise from peculiar charge, spin and orbital orderings of the Mn e_g electrons driven by cooperative Jahn-Teller distortions of the $\mathrm{MnO_6}$ octahedra. Mastering these properties remains a challenge owing to local structural distortions and electronic inhomogeneities enhanced by chemical substitutions and oxygen defects.

Here we show that these difficulties are absent in *quadruple* perovskites $A\mathrm{Mn_3Mn_4O_{12}}$ (*A* rare or alkaline earth). These compounds share with simple perovskites $A\mathrm{MnO_3}$ a similar pseudo-cubic network of corner-sharing $\mathrm{MnO_6}$ octahedra and similar electronic properties associated with the Mn^{3+} and Mn^{4+} ions. However, they display smaller distortions thanks to the higher symmetry of the oxygen sites and no oxygen defects.

By means of neutron powder diffraction we studied and compared the nuclear and magnetic structures of the isomorphic and isovalent compounds $\mathrm{LaMn_3Mn_4O_{12}}$ and $\mathrm{BiMn_3Mn_4O_{12}}$. Our data analysis gives evidence of a large coupling between the electric dipole of the $6s^2$ lone pair of Bi^{3+} and the magnetic structure of the Mn^{3+} ions. We account for this result by noting that the internal strain induced by the Bi^{3+} dipole is not released on the Mn^{3+} sites thanks to the above structural features of quadruple perovskites. We show that this enables a strong magnetoelastic coupling with the magnetic moment of the Mn^{3+} ions, which provides a hint for enhancing the magnetoelectric coupling in proper ferroelectrics.

MO-157

Magnetic and electrical properties on bulk and thin films of $BiFeO_3$ obtained by wet chemical methods.

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A chemical route was used to synthesize bulk and thin film bismuth ferrite ($BiFeO_3$) with the perovskite structure [1, 2]. These samples were analyzed by X-ray diffraction technique, and dielectric and magnetic measurements were performed. Remarkable differences in the magnetic characteristics at room temperature are observed between bulk and film samples. The absence of ferromagnetic behavior at room temperature in $BiFeO_3$ bulk ceramics contrasts with a well defined hysteresis loop obtained for thin films, which possess a saturation magnetization of 28.15 emu/g and a coercive field of 70 Oe [3]. Dielectric measurements in ceramic samples present an anomaly around 370°C that can be associated to the Néel temperature as a consequence of an anti-ferromagnetic to paramagnetic phase transition.

[1] G.L. Yuan, S.W. Or , Y.P. Wang, Z.G. Liu, J.M. Liu, Sol. Stat. Com. 138, 76 (2006)

[2] S. Habouti · C.-H. Solterbeck · M. Es Souni , Sol-Gel Sci. Techn. 42, 257 (2007)

[3] P. Murugavel, D. Saurel, W. Prellier,Ch. Simon, B. Raveau, Appl. Phys. 85, 4424 (2004)

MO-158

Magnetic and magneto-optical research of silver doped manganite film

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Interest in doped lanthanum manganite increased after discovering of colossal magnetoresistance (CMR). The important fact is the discovery of the high-frequency optical response to CMR in manganites - the magnetorefractive effect (MRE) in magnetoreflection and magnetotransmission modes in IR region [1]. Since CMR and MRE reach their maximum near the Curie temperatures T_C, special attention is paid to creation of new functional materials with $T_C \sim T_{room}$, for

optoelectronics and information technology. Magnetotransport, MRE and magneto-optical Kerr phenomena in manganites are connected with the interaction of spin, charge, and phonon subsystems. The studying of these interactions is impossible without the understanding of magnetic, transport and optical properties. Here we studied magnetic and magneto-optical properties of a $La_{0.9}Ag_{0.1}MnO_3$ film of 320 nm thickness and effective T_C=317 K.

The $La_{0.9}Ag_{0.1}MnO_3$ epitaxial film was prepared by the metalorganic chemical vapor deposition method (MOCVD), using the original two-stage procedure [2]. The sample was investigated at room temperature by magneto-optical Kerr magnetometry and microscopy in both polar and longitudinal configurations, magnetoreflection and by magnetotransmission, Ferromagnetic Resonance Spectroscopy (FMR), Vibrating Sample Magnetometry (VSM) and Brillouin Light Scattering (BLS). We were founded that the hard magnetization axis and easy magnetization axis (EMA) are oriented out-of-plane and in-plane to the film surface, respectively. Domain walls are parallel to EMA. Magnetization reversal process takes place by domain wall propagation. FMR and VSM techniques measurements indicate the existence of two magnetic phases in the film. The BLS spectrum shows the dependence of acoustic phonons on the external magnetic field.

This work was supported by RFBR № 10-02-00038a

[1] Yu. P. Sukhorukov et al., JETP 122, 77 (2011).
[2] A. R. Kaul et al., Russ. Chem. Rev. 73, 861 (2004).

MO-159

LSMO thin films - growth modes and magnetic properties

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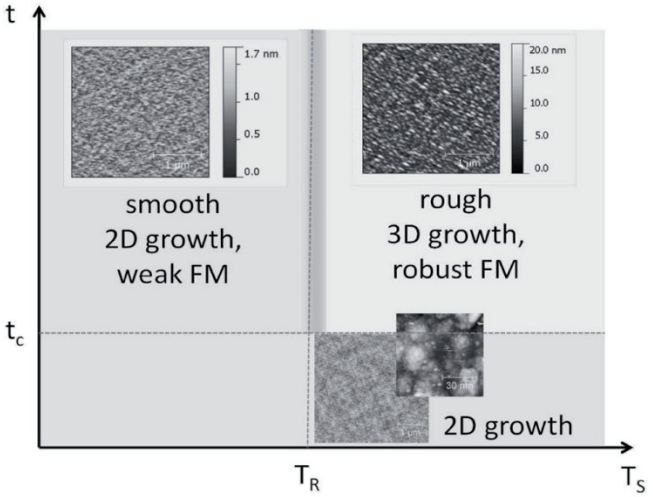
Perovskite manganites are nowadays widely employed as laboratory prototypes for spin sensitive magnetic field-sensors and reading-heads, magnetic field driven switches and other. In particular $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), presenting among this family the highest curie temperature (about 360K), has received the major attention [1]. By performing a detailed study of the growth of epitaxial LMSO on matching $SrTiO_3$ (001) and $NdGaO_3$ (110) substrates [2] we propose a general model for the epitaxial growth of LSMO, reported in the figure.

We demonstrate an interrelation between the growth mode dimension and the magnetic and transport properties. A persistent layer-by-layer bi-dimensional growth is observed up to at least 90 nm thick films for substrate temperatures below the roughening temperature T_R ~ 750°C, but the magnetotransport and the surface magnetism of the film are weaker in respect to the rougher films three-dimensionally grown at substrate temperatures above T_R.

For $T > T_R$ a sharp thickness induced transition from an in-layer (bi-dimensional) to an out-of-layer (three-dimensional) growth is observed at thickness t_C which is strongly related to epitaxial constrains and depends on the film-substrate mismatch.

A microscopic model for the growth of LSMO thin films and quantitative estimations of the diffusion (Ehrlich-Schwoebel) energy barrier are attempted.

[1] J. B. Goodenough, J. Appl. Phys. 81, 5330 (1997)
[2] P. Graziosi *et al.* , submitted.



General representation of the epitaxial growth modes of LSMO. T_S is the substrate temperature and t is the film thickness.

MO-160

Optimization of $Pr_{0,9}Ca_{0,1}MnO_3$ thin films with varying in-situ oxygen annealing treatments

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Among the perovskite manganites, low bandwidth compound $Pr_{(1-x)}Ca_xMnO_3$ (PCMO) at the doping range x = 0.3 - 0.5 has been under research in recent years because of it stable CO state, which has great potential in wide range of applications. However, the low doping regime of PCMO, having a complex phase-separated magnetic ground state, has remained mostly unexplored. Also for the $Pr_{0.9}Ca_{0.1}MnO_3$ persistent photo-induced magnetization has been reported [1], which makes PCMO attractive for photovoltaic applications. For the use of applications it is extremely important that the thin films of these materials are well optimized. Controlling the oxygen content important to their potential applications in thin films is non-trivial and requires careful optimization. *In-situ* oxygen annealing treatment affects the oxygen content in perovskite structure and oxygen vacancy related defects, which are extremely important parameters as they tailor many physical properties dramatically [2]. In this work the optimization of $Pr_{0.9}Ca_{0.1}MnO_3$ thin films is investigated. Using different oxygen annealing conditions in pulsed laser deposition (PLD), several

films were deposited from the stoichiometric target material on SrTiO3 (001) substrate. Their detailed structural and magnetic characterization were done using x-ray diffraction, x-ray photoelectron spectroscopy (XPS) and SQUID magnetometry and these measurements will be discussed in detail.

[1] S. Majumdar, H. Huhtinen, M. Svedberg, P. Paturi, S. Granroth and K. Kooser, J. Phys. Cond. Mat. 23, 466002 (2011)
[2] B. Bryant, C. Renner, Y. Tokunaga, Y. Tokura and G. Aeppli, Nat. Comm. 2, 212 (2011)

MO-161

The effect of film thickness on the magnetic and magneto-transport properties of Sr_2FeMoO_6 thin films

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Magnetoresistive Sr_2FeMoO_6 thin films were grown by pulsed laser deposition with three different thicknesses 150 nm, 270 nm and 500 nm. Structural, magnetic and magneto-transport properties of the films were measured. Structural properties showed that impurity phases are formed when the film thickness exceed limiting thickness over 300 nm. Otherwise no major differences were observed in structural and magnetic properties between the films. The semiconductive upturn was observed in all ρ(T) curves, but it was notably smaller for two thicker films. At 350 K the magnetoresistive (MR) behaviour was very similar for all the films, but at 10 K the negative MR was clearly largest for the thickest film and also the shape of the curve in low fields deviated from others.

MO-162

The effect of stress and interface on magnetic properties of $Pr_{0.7}Ca_{0.3}MnO_3$

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The progress in the techniques devoted to the growth of thin films has created the premises for the discovery and the application of new multifunctional oxides. $Pr_{0.7}Ca_{0.3}MnO_3$ is such an oxide and stands at a critical point in the phase diagram of $Pr_{1-x}Ca_xMnO_3$: between a stabilized charge ordered/antiferromagnetic (CO/AF) phase and a paramagnetic insulating (PI) state above 130 K and a ferromagnetic insulating (FMI) one below 130 K [1]. When an external stimulus, such as magnetic field, light, high pressure, and electric field, is applied, $Pr_{0.7}Ca_{0.3}MnO_3$ collapses to a charge disordered state, which is observed as an insulator–metal transition. The presence of the substrate in thin films and the interfaces at layered structures introduce new degrees of freedom. In this study stress and interface effects on magnetic properties of $Pr_{0.7}Ca_{0.3}MnO_3$ (PCMO) grown by Pulse Laser Deposition (PLD) were investigated by introducing compressive and tensile stress, and by depositing buffer layers. For realizing these ideas we used different substrates such as $SrTiO_3$ (100), to induce tensile stress, $LaAlO_3$ (100), and $YAlO_3$ (100), to induce compressive stress. To study interface effects we deposited $La0.7Sr_{0.3}MnO_3$ (LSMO), $SrRuO_3$ (SRO) between the substrate and PCMO thin film. Magnetization and Ferromagnetic Resonance (FMR) measurements showed that magnetic properties are greatly dependent on stress and interface effects. So by using different substrates and buffer layers materials with various physical properties can be engineered. This work was partially supported by DPT (State Planning Organization of Turkey) through the project No 2009K120730.

[1] H. Sha, F. Ye, P. Dai, J. A. Fernandez-Baca, D. Mesa1, J. W. Lynn, Y. Tomioka, Y. Tokura, J. Zhang, Phys. Rev. B 78, 052410 (2008)

MO-163

Magnetic and structural characterization of as-cast and annealed $BiFeO_3$ synthesized using a ferrioxalate soft chemical evaporation

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Among the multiferroic materials, the BiFeO3 (BFO) compound has been the most studied due to its multiferroic properties at room temperature. It has a rhombohedral distorted perovskite crystalline structure with space group R3c, and exhibits a simultaneous ferroelectric (TC = 1103 K) and an antiferromagnetic (TN = 643 K) behavior [1]. Obtaining stoichiometric single-phased BFO materials, with a proper microstructure, is one of the most difficult task for materials scientists and physicists. Sample composition and particle size are parameters that securely affect the overall physical properties of this kind of compound, once their control is directly related to the structural stability of the BiFeO3. Attempts to improve the physical and microstructural properties have been conducted by using different preparation routes, which influence the final properties of the material. In this work, BiFeO3 polycrystalline samples were synthesized using a ferrioxalate soft chemical evaporation route. According to preliminary results of XRD experiments, the as-cast samples appear to be amorphous, or having a very small particle size distribution. On the other hand, magnetic measurements results suggest the presence of characteristic magnetic nanoparticles. [2]. EXAFS experiments performed at the LNLS synchrotron facility at Campinas, and PDF calculations from X - Ray Diffraction patterns allowed to get information about the possible formation of BiFeO3 nanoparticles in the as-cast state.

[1] Wang J et al., Science 299:1719 (2003).
[2] L.A.S de Oliveira, PhD Thesis, IF/UFRJ, Rio de Janeiro, Brazil, 2010.

MO-164

Investigation of Magnetoelectric Coupling in Self Assembled Ferromagnetic/Ferroelectric Heterostructures

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Creating ferromagnetic/ferroelectric heterostructures is a way for developing multifunctional materials which is called multiferroics. Exchange bias may be used to couple a normal ferromagnet to a

ferroelectric antiferromagnet and thus create a multiferroic system with nonzero magnetization. In implementing this idea we developed a synthesis method for composite films of $MnFe_2O_4$ embedded in $BiFeO_3$ [1]. The method utilizes the Bi volatility to obtain the composite films via thermal annealing of multilayer composed of $BiFeO_3$ and $BiMnO_3$. SEM measurements showed that the cluster size varies depending on the film thickness. The composite films possess both ferroelectric and ferromagnetic properties [1]. Magnetoelectric coupling (MEC) was investigated by Ferromagnetic resonance (FMR) technique. Analysis of FMR data showed that resonance field can be controlled by GHz range electric fields.

[1] C.H. Yang, F. Yildiz, S.H. Lee, Y.H. Jeong, U. Chon, T.Y. Koo, Apply Phys. Lett. 90, 163116 (2007).

MO-165

Strain induced enhanced ferromagnetic behavior and low temperature glassy state in inhomogeneous low doped $La_{0.95}Sr_{0.05}MnO_{3+\delta}$

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Single-phase $La_{0.95}Sr_{0.05}MnO_{3+d}$ system (grain size ~60-80nm) studied here showed two distinct magnetic properties: an unusual higher magnetic-order at 290K(T_{C1}) and a broad transition at ~150K(T_{C2}); and a low-temperature glassy-magnetic-state. High-temperature ferromagnetic-transition is tried to explain with the effect of strain in structure indicated by EELS-spectra and the glassy-state is the result of competing exchange-interaction at low Sr-regions.

HRTEM shows Sr to vary from ~2-9wt% inside grain and ~1wt% at interface. Oxygen-homogeneity is confirmed by EELS K-edge-line at interface and intra-grain, excluding possibility of grain boundary interface to affect magnetic-property. Detailed-EELS showed difference in oxygen K-edge and white-line ratio of Mn L-edge in Mn-rich and La-rich region in intra-grain space indicating the existence of strain in structure. A recent research shows strain-induced large-enhancement of T_C in thin-film-manganites[1]. Our work evidences that highly-strained CMR-materials with local-scale-inhomogeneity can realize generation of strain and can tune the property in spite of low-doping.

However at lower-temperature, antiferromagnetic (AFM) interaction coming from low Sr doping can influence the magnetic state giving low moment and a low temperature irreversibility in the system. The unsaturated magnetization up to 10T at 5K, shoulder in FC at ~35K as well as well-defined hysteresis-loop at 5 K and increase of FC at T <35K, strong irreversibility between ZFC and FC at 5T shows the combined presence of AFM, short-range FM and also `hard spin´ in the system. Field-dependent peak-shift at spin-freezing temperature in ZFC, memory-effect at 35K and relaxation below 35K proves the cluster spin glass in system. A metal-insulator transition at 115K close to T_{C2}, also implies a complete percolation of short range FM clusters, giving an onset of metallic state at 115K. A complete magnetic phase diagram is given for this system demonstrating its temperature dependent rich magnetic behavior.

[1] A.Sadoc, B.Mercey, C.Simon, D.Grebille, W.Prellier, M-B. Lepetit, Phys. Rev. Lett 104, 046804(2010)

MO-166

Exchange bias effect in $La_{1-x}Ag_xMnO_3$ nanopowders

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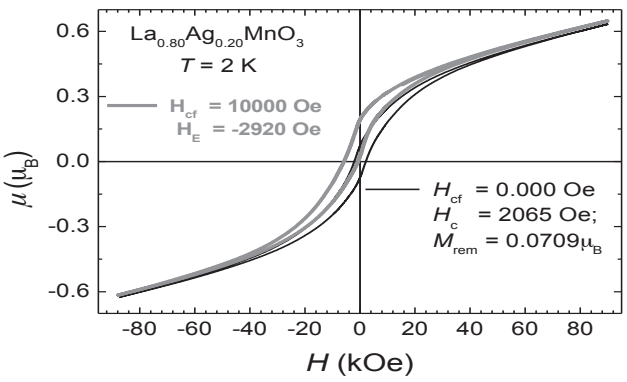
The exchange bias (EB) was discovered more than 55 years ago, by Meiklejohn and Bean [1], and its characteristic signature is the shift of the centre of magnetic hysteresis loop from its normal position at $H = 0$ to $H_E \neq 0$. EB usually occurs in systems which are composed by an antiferromagnet (AFM) that is in atomic contact with a ferromagnet (FM) after the system is cooled, below the respective Néel and Curie temperatures T_N and T_C, in an external cooling field H_{cf}. The EB effect in manganites has attracted attention for their potential application and was studied e.g. on $La_{x-1}Ca_xMnO_3$ [2]. Although the complex AFM background accompanied with FM component in these materials has already been found, the EB effect remains unclear and needs further investigation.

In our paper the effect of mean particles size on EB in $La_{1-x}Ag_xMnO_3$ powders (x = 0.10, 0.15, 0.20) will be present. Magnetization measurements were performed in magnetic fields up to 9 T and in the temperature range between 1.8 K and 400 K by a SQUID magnetometer MPMS and VSM in PPMS. The preparation of powders followed the glycine-nitrate method [3]. The mean particle size of as prepared nanopowders was about 30 nm. The EB effect is very pronounced on as prepared sample (see figure) and can be completely removed by heat treatment. Effect of heat treatment (particle size; ratio Mn^{3+} and Mn^{4+}) on magnetic properties, with special attention to EB, will be discussed in the paper.

[1] W. P. Meiklejohn and C. P. Bean, Phys. Rev.102, 1413 (1956).
[2] Xiao H. Huang et al. J. Am. Ceram. Soc., 94, 1324 (2011)
[3] S.B. Boskovic et al., Ceram Int 33:89 (2007) doi: 10.1016/j.ceramint.2005.07.022



Bias exchange effect in as-prepared nanopowders.

MO-167

Structural and electromagnetic characteristics of perovskites in $La_{1-c-x}Sr_{c+x}Mn_{1-x}Me^{4+}{}_xO_3$ systems (Me=Ge, Ti)

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Experimental data are shown for the influence of substituting quadrivalent ions on the concentration phase transitions "rhombohedral-orthorhombic structure" and "semiconductor-metal" in manganites of specifically designed system $La^{3+}{}_{1-c-x}Sr^{2+}{}_{c+x}Mn^{3+}{}_{1-c-x}Mn^{4+}{}_cMe^{4+}{}_xO_3$ compared with phase diagrams of $La_{1-c}Sr_cMnO_3$. Regularities in the concentration dependences of saturation magnetization, Curie point, resistivity and magnetoresistance were established.

Bulk manganites (c=0.15, 0.17, 0.19; $0.025 \leq x \leq 0.125$) were prepared by solid state reactions in air. The final sintering step was performed at 1473 K for 10 h, and the samples were cooled together with the furnace. In order to provide stoichiometric oxygen content, the samples were processed at 1223 K and corresponding partial pressure of oxygen for 96 h.

All Ge-contained manganites were rhombohedral, while some of Ti-substituted samples (with c=0.15, $x \leq 0.075$) had orthorhombic structure, that gives some evidence for more significant effect of Ge on the shift of phase boundary. Ge-contained compositions with c=0.19 at all x, and with c=0.15, 0.17 at x=0.075 revealed metallic type of temperature dependence of resistivity in appropriate low temperature regions. On the contrary, Ti-substituted manganites with all "c" at x=0.075 had semiconducting type of conductivity, and metallic behaviour was observed in sintered samples with c=0.19 only at $x \leq 0.05$.

Ge-substituted manganites had essentially higher values of magnetization and Curie temperature than analogous compositions with TiPossible approach to the interpretation of experimental results is discussed in terms of electron configurations and ionic radii of substituents taking into account oxygen nonstoichiometry and cation vacancies.

MO-169

Spin excitations of the intermediate phase of half-doped manganites

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Near half-doping, perovskite Mn oxides exhibit rich phase diagrams with a strong competition of different phases, due to the interplay of the magnetic, charge and orbital degrees of freedom. At half-doping, two main phases were introduced in order to describe most of the experimental findings. One is the joint spin, charge and orbital ordering known as CE phase, proposed by J. Goodenough in 1955 [1]. The other is the Zener polaron (or spin dimer) phase proposed in 2002 by Daoud-Aladine et al. [2]. In some half-doped manganites, though, experiments are better described by an intermediate phase between them, introduced in 2004 by Khomskii et al. [3]. In fact, the intermediate phase proposed consists of spin dimers, though formed by a pair of parallel spins of different magnitude in principle (thus allowing for a charge disproportionation p, though not necessarily as large as that of Mn^{3+}-Mn^{4+} in the CE phase). Consecutive spin dimers located along the planar zig-zag chains are oriented at a constant relative angle θ between them. Varying p and θ the intermediate phase allows a continuous interpolation between the CE and Zener polaron phases.

In this work, we propose a microscopic model based on localized spins which has the intermediate phase as its classical ground state. We then use this model to predict the quantum spin excitations of the intermediate phase of half-doped manganites. New inelastic neutron scattering experiments able to measure the spin excitations of three-dimensional manganites, could be compared with our predictions and thus allow to settle the open question about the nature of their ground state at half-doping.

[1] J.Goodenough, Phys. Rev. 100, 564 (1955).
[2] A. Daoud-Aladine et al., Phys. Rev. Lett. 89, 097205 (2002).
[3] Efremov, J. van den Brink, D. Khomskii, Nature Mats. 3, 853 (2004).

MO-170

Raman spectroscopy and magnetic properties of Aurivillius phase doped with Gadolinium

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Chemical Ferroelectric samples with Aurivillius structure and nominal composition $Bi_{(2-x)}Gd_xPb_2(TiNb_2)O_{12}$ (x=0.0 (**BPNT**) and x=1 (**BGPNT**)) were prepared by traditional ceramic route. The samples were prepared considering the incorporation of the Gd^{3+} on the Bi_2O_2 layer of the Aurivillius structure. Magneto-structural analysis was performed using Scanning Electron Microscopy, Raman Spectroscopy and Vibration Sample Magnetometry. The Raman results obtained with laser source of 633 nm exhibit similar characteristics to those obtained for pure $Bi_4Ti_3O_{12}$ [1]. The variation of some frequency modes between both samples suggest the Gd incorporation to the structure [2]. Magnetic measurements show a four order of magnitude difference between the doped and undoped samples below 20 K. A remarkable hysteresis loop was obtained at 5 K for the Gd^{3+} doped sample (σ=28.98 emu/g, H= 7.0 T). This value of σ implies a saturation value of 7.6 μ_B/f.u. that coincides with the magnetic moment of Gd^{3+}[3].

[1] Y.L. Du, M.S. Zhang, Q. Chen, Z.R. Yuan, Z. Yin, Q.A. Zhang, Sol. Stat. Comm. 124, 113 (2002)
[2] M. OSADA, M. TADA, M. KAKIHANA, T. WATANABE and H. FUNAKUBO Jpn. J. Appl. Phys.. 40, 5572 (2001)
[3]J. Kliava, I.S. Edelman, A. M. Potseluyko, E. A. Petrakovskaja, R. Berger, I. Bruckental, Y. Yeshurun, A.V. Malakhovskii and T. V. Zarubina, J. Phys.: Condens. Matter. 15, 6671 (2003) 6671

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Monday, 10 September 2012
Poster Area, 17.00 – 19.00

SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS
Chair: C. Gomez Polo

MO-172
Structural and magnetic properties of (Fe,Co)SiBNb ribbons prepared by rapid solidification
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Fe-Si-B based alloys have been widely studied because of their good soft magnetic properties and high saturation magnetization. The base composition has often been slightly modified to promote nanocrystallization, in order to further reduce the coercive field and reduce losses in electrical machines and power applications. Co substitution has also been attempted in order to improve the thermal stability of the alloys and increase their Curie temperature.
In this study, (Fe_{1-x},Co_{x})_{72}Si_{4.8}B_{19.2}Nb_{4} ribbons have been prepared by rapid solidification. Three alloys have been studied, with x = 0, 0.8, 1. XRD data confirm the amorphous state of the as-quenched ribbons. DSC and magnetization vs. temperature measurements performed with a vibrating sample magnetometer (VSM) allowed to detect crystallization features at temperatures between 570 °C and 630 °C, depending on the composition. Fe-rich alloys have higher crystallization temperatures, but substitution of Fe with Co increases the Curie temperature of the amorphous phase and leads to a lower crystalline fraction after annealing. Hysteresis loops measured with an inductive loop tracer and with a VSM at room temperature display a significant increase of the coercive field in annealed samples. The crystalline phases that precipitate during the annealing process will be identified by means of XRD analysis and Mössbauer spectroscopy. Samples microstructure as a function of annealing temperature and relative Fe,Co content will be correlated to magnetic properties.

MO-173
Giant magnetoimpedance effect in field annealed Fe(Ni,Co)NbB amorphous and nanocrystalline ribbons
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The giant magnetoimpedance effect (GMI) has attracted a great deal of scientific and technological interest because of its applications in magnetic sensors. Extensive research activities in this area have been focused on the soft magnetic amorphous and nanocrystalline alloys in the form of wires and ribbons. These alloys often require specific annealing conditions to achieve the desired response to applied magnetic field. In this work, we report on the effects of both longitudinal and transverse magnetic field applied during the heat treatment on the GMI effect in series of $(Fe_{1-x}Ni_x)_{81}Nb_7B_{12}$ (x=0.33 and 0.5) and $(Fe_{0.5}Co_{0.5})_{81}Nb_7B_{12}$ ribbons prepared by planar flow casting. The amorphous samples were isothermally annealed under a high vacuum at temperatures 623 K $\leq T_a \leq$ 873 K in the presence of transverse (TF) or longitudinal (LF) magnetic field with the magnitude up to 640 kA/m. The reference samples were annealed in a zero magnetic field (ZF). The TEM analysis after amorphous/crystalline transformation has revealed a typical size of grains 5-10 nm. The magnetic measurements showed an increase of coercive field after ZF-annealing, which was particularly significant in the case of $(Fe_{0.5}Co_{0.5})_{81}Nb_7B_{12}$ ribbon. On the other hand, a heat treatment under LF- and TF-conditions resulted in a marked reduction of the coercivity. The GMI measurements were performed over a frequency range 0.1 – 10 MHz. The field annealing results in the modified the GMI response of both amorphous and nanocrystalline ribbons. It was found that all FeNi-based nanocrystalline samples show markedly larger values of GMI ratio ($\Delta Z/Z$) as compared to their amorphous counterparts while opposite tendency is observed for ZF and TF annealed $(Fe_{0.5}Co_{0.5})_{81}Nb_7B_{12}$ ribbons. The maximum GMI ratio $\Delta Z/Z \sim 40\%$ and the GMI field sensitivity $\eta = 14\%$/Oe was observed at frequency 1 MHz for the $(Fe_{0.5}Ni_{0.5})_{81}Nb_7B_{12}$ sample after annealing at 773 K.

MO-174
Magnetic and Transport Properties in Composite Magnetic Microwires
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The magnetic multilayer glass-coated microwires showed a great potential for technological applications particularly in sensing devices. This work presents results on the effect of metallic magnetic coating on the magnetic and transport properties of amorphous $Co_{68.5}Fe_{4.5}Si_{12.5}B_{15}$ soft magnetic glass-coated microwires, subsequently coated with Co-based layers with the thickness between 150 and 1000 nm, deposited by RF sputtering. As a result of the deposition of metallic layers the hysteresis loops changes its shape from a typical zeo-magnetostrictive one, anhysteretic, characterised by transverse anisotrpy and low coercive field, to a hysteresis loop typical for high magnetostrictive materials, with bistable behaviour. It also leads to the increase in the relative magnetic permeability. This behaviour is due to the induced longitudinal anisotropy in the amorphous wires which is not affected by the increase in the thickness of the deposited Co layer, fact demostrated by the unchanged values of the saturation magnetization and coercive field in the multilayer microwires. Although the multilayer composite wires present a bistable behavior the presence of the GMI effect in these wires proves the existence of transverse anisotropy, especially in the region near the surface of amorphous metal core. An increase in the GMI effect in the multilayer magnetic amorphous wire with increasing frequency due to the increase in the skin effect and reduction of the penetration depth has been observed. The MI characteristics of multilayer wires present a slight asymmetry in both the demagnetized and in the magnetized state. The values of the magnetic field in the

area involved in the GMI response increases with increasing the thickness of the deposited metallic layer, indicating its influence on microwire's transverse anisotropy. Thus, the Co layer influences both the longitudinal and transverse anisotropy, affecting the axial magnetization process and the circumferential magnetization process involved in the phenomenon of magnetoimpedance.

MO-175

Electromagnetic selective shielding multilayered material based on amorphous microwires

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Electromagnetic shielding is currently viewed as a critical problem concerning the security of electronic equipment which is highly sensitive to interference with electromagnetic fields manly in the GSM microwave frequencies range (0.8 GHz-3 GHz), as well as the biological protection by the maximum reduction of the effects of electromagnetic radiation on living organisms.
The aim of this paper is to investigate the selective shielding properties of an electromagnetic shielding material in the shape of a multilayered material based on CoFe-glass coated amorphous microwires in the 0.8 GHz ÷ 3 GHz microwave frequency range.
The selective shielding multilayered material allows the selective shielding of the electromagnetic radiation, simultaneously and selectively for several frequency bands, with the central radiation frequency controlled through the lengths of the microwires by combining the magnetic properties of the microwires [1] with their geometrical distribution.
Experimental results indicate that the length (L) of microwires allows the control of the absorption frequency of the microwave incident field with wavelength λ, through the condition L~λ/2 [2]. Using several layers successively arranged one above another we can get a multilayered shielding material in order to increase the shielding effectiveness (SE) with the increase of the number of layers. The shielding effectiveness results of free-space measurements were SE=4÷9.5 dB for the samples with two layers, SE=18÷33 dB for sample with 14 layer, and SE=36÷48 dB for sample with 30 layer.
This type of materials can be used as smart materials for microwave electromagnetic shielding and structural health monitoring.

[1] H. Chiriac and T-A Ovari, Prog. in Mat. Science, 40, 333 (1996)
[2] G. Ababei et al., Rev. of Scien. Instr., 83, 014701 (2012)

MO-176

Influence of the stray field on the velocity of the domain wall in two microwire sytem

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We studied the remagnetization process in systems consisting of two glass coated microwires of the nominal composition of $Fe_{75}B_{15}Si_{10}$ produced by Taylor Ulitovsky method. The three samples were selected for the studies, having the diameter of the metallic core equal to 18μm, 6.9μm, 6.5μm, and the thickness of the glass coating equal to 24.8μm, 24.3μm, 21.8μm. The domain wall dynamics during the magnetization reversal process in two micorwire system depends on among others on the stray field produced by the neighbouring microwires. The hysteresis loop for two microwire system is characterized by the existence of two Barkhausen jumps. We measured the influence of the stray field produced by one microwire on the velocity of the domain wall in the neighbouring microwire, at the first and the second Barkhausen jump. At the first jump the stray field increases the effective field acting on the microwire that is first to remagnetize so the velocity of the domain wall increases, and it is effectively larger than in the single microwire. At the second jump the stray field decreases the effective field acting on the microwire that is second to remagnetize and so the velocity of the domain wall decreases. We also investigated the influence of the external tension on the domain wall dynamics in the two wire system and we want to demonstrate the usefulness of the external tension to fine tuning of the domain wall velocity in the two wires system.

MO-177

Stability of magnetization processes in magnetic glass-coated microwires

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Amorphous glass-coated microwires with positive magnetostriction show magnetic bistability (the magnetization can have only two values + Ms or -Ms) [1]. The switching between the two values appears at the switching field. The switching field is sensitive to many external parameters (magnetic field, temperature, mechanical stress, etc.), which enables to use magnetic microwires as micro-sensing elements in various sensor applications. However, the amorphous structure of glass-coated microwires is in metastable state. Hence, stochastic processes contribute to the switching which results in the distribution of the switching fields [2].
In the given contribution, we are dealing with the possibility to increase the stability of the switching field in magnetic microwires through the thermal annealing. The thermal annealing results in the stabilization of the domain structure and homogenization of the structure of amorphous glass-coated microwires [3] and the switching field distribution width decreases.
Support by the project NanoCEXmat Nr. ITMS 26220120019, Slovak grant APVV-0266-10 and VEGA grant No.1/0076/09 is acknowledged.
[1] A. Zhukov, J. Gonzáles, M. Vazquez, V. Larin, and A. Torcunov, "Nanocrystalline and Amorphous Magnetic Microwires", Encyclopedia of Nanoscience and Nanotechnology, american Scientific Publishers, Valencia, USA, 365 (2001).
[2] R Varga, K.L. Garcia, M. Vazquez, A. Zhukov, P. Vojtanik, Phys. Rev. B 70, 024402 (2004).
[3] J. Olivera, R. Varga, V. M. Prida, M. L. Sanchez, B. Hernando, and A. Zhukov, Phys. Rev. B 82, 094414 (2010)

MO-178

Domain walls collision in Fe-rich and Co-rich glass covered microwires

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We report the results of the investigation of domain walls propagation in Fe-rich microwires using modified Sixtus-Tonks experiments [1] and Co-rich microwires using magneto-optical Kerr effect (MOKE) technique [2].

Magnetic field was generated by solenoid applying rectangular shaped voltage. We used 3 pick-up coils, mounted along the length of the wire. In this paper we studied effect of transversal magnetic field on DW propagation. It was found that under certain transversal magnetic field, H_t, we were able to create the regime of the motion of two DW moving to opposite directions. Changing the H_t we were able to observe DW collision in different parts of microwire. The collision is observed as voltage peak of doble amplutude. The magnetic flux changes two times faster when the magnetization reversal occurs in the form of two domains wall motion toward each other instead of single DW motion.

The DW collision was visualized in Co-rich microwire using MOKE microscope when the surface giant Barkhausen jump induced by circular magnetic field has been observed. It was fixed the nucleation of a circular domains and the long-distance propagation of two circular surface domain walls moving into opposite directions along the microwire.

Using MOKE modified Sixtus-Tonks method we have found also that manipulating amplitude and phase of the magnetic field in the nucleation coil jointly with the dc electric current applying to the microwire, we can accelerate, decelerate, and suppress the domain nucleation process. The influence of the amplitude of the nucleation field on the switching field could be basically considered as an analogy of the temperature influence in the frame of the model of the thermo-activated nucleation and domain wall motion.

[1] M. Ipatov et al., J. Appl. Phys. 106, 103902 (2009)
[2] A. Chizhik et al., J. Appl. Phys. 103, 07E707 (2008)

MO-179

Effect of internal stresses on the magnetic behavior of rapidly solidified amorphous nanowires

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A new range of dimensions has been set up for cylindrically shaped amorphous ferromagnetic wires with the successful rapid solidification of glass-coated submicron amorphous wires and nanowires [1]. The aim of this work is to study the effect of internal stresses on the magnetic behavior of rapidly solidified $Fe_{77.5}Si_{7.5}B_{15}$ amorphous glass-coated nanowires. We calculated the radial distributions of internal stresses induced in the nanowires during preparation, since the metallic alloy is magnetostrictive and the magnetoelastic term which results from the coupling between magnetostriction and the internal stresses induced by both the rapid solidification of metal and the presence of the glass coating is expected to play an important role in establishing the anisotropy axes. Based on the magnetoelastic term analysis, an estimation of the magnetic domain structures was performed. The shape of the radial stress distribution changes significantly when the diameter of the metallic nucleus decreases below 200 nm. Stresses are constant in the inner part, with a preponderant axial tensile component, whilst the radial and circumferential components are equal. This is a very important result, since such a situation has never been encountered in the extensively studied thicker amorphous microwires or in the submicron wires with metallic nucleus diameters larger than 200 nm. A more drastic change in the shape of the radial distribution of internal stresses has been found for nanowires with the metallic diameter below 135 nm. In these wires, the nonlinear part of the distribution vanishes and the part in which stresses are constant is extended over the entire radius. The subsequent analysis of the magnetoelastic term shows that a single domain magnetic structure is formed in these rapidly solidified nanowires.

[1] H. Chiriac, S. Corodeanu, M. Lostun, G. Ababei, T.-A. Óvári, J. Appl. Phys. 107, 09A301 (2010).

MO-180

Magnetic and reflection loss characteristics of substituted strontium ferrite/carbon nanotube nanocomposites

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Substituted strontium ferrite ($SrFe_{12-x}(Mn_{0.5}Ti_{0.5})_xO_{19}$) nanoparticles with x=0-2.5 were formed along the surface modified carbon nanotubes. The volume percentage of nanotubes in both types was 1 to 5 vol% in a step of 1 vol%. Mössbauer spectroscopy indicates that the substituted cations preferentially occupy the $4f_1$ and $2b$ sites. VSM results confirmed that the saturation magnetization of ferrite decorated carbon nantubes is lower than that of the strontium ferrite nanoparticles. Figure 1 shows the variation of reflection loss versus frequency which was observed in composite samples with the thickness of 1.5 mm. The FE-SEM micrographs of nanocomposite were also demonstrated in Fig.1. It is clearly appears that the bandwidth for nanocomposites synthesized by MWCNTs is about 4GHz (8-12 GHz). The maximum reflection loss of this band is -32 dB at resonance frequency of 9.5 GHz for sample with 5 vol% of CNTs. The bandwidth for nanocomposites (ferrite/ single walled carbon nanotubes) prepared by employing single walled carbon nanotubes was 6 GHz in the frequency range of 12-18 GHz. The maximum reflection loss for this band was -35 dB at resonance frequency of 15.2 GHz. It was found that MWCNTs is a suitable candidate for fabricating nanocomposite at microwave X band frequencies (8-12 GHz), while SWCNTs is a good candidate for synthesizing nanocomposite at Ku band (12-18 GHz).

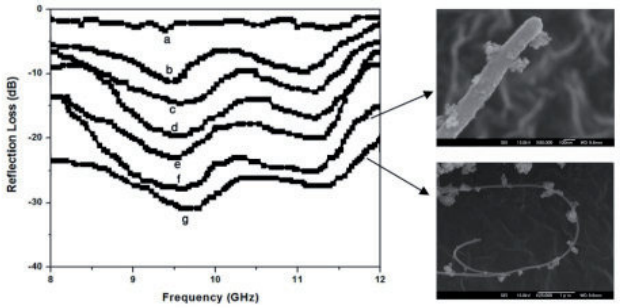

Fig. 1. Reflection loss versus frequency of (a) pure MWCNTs, (b) pure ferrite, nanocomposites with (c) 1 vol%, (d) 2 vol% MWCNTs, (e) 3 vol% MWCNTs, (f) 4 vol% MWCNTs and (g) 5 vol% MWCNTs.

[1] A. Ghasemi, S. Javadpour, X. X. Liu, A. Morisako, IEEE Trans. Magn., 47, 4310-4313, (2011).
[2] A. Ghasemi, V. Šepelák, X. X. Liu, A. Morisako, IEEE Trans. Magn.,47, 2800-2803, (2011).
[3] A. Ghasemi, V. Šepelák, X. X. Liu, A. Morisako, J. Appl. Phys. 107, 09A743-09A745 (2010).

MO-181

Optical and Magneto-Optical Properties of Ion Implanted (YBiCa)_3(FeGe)_50_12 Garnet Films

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We have investigated the optical and magneto-optical properties of the ion implanted (YBiCa)_3(FeGe)_5O_12 garnet films. It has shown that ion implantation influences significantly the magneto-optical properties of the garnet films and practically does not change its optical characteristics. The research of magnetization processes of implanted films showed that implantation leads to a significant inhibition of the growth of anisotropy. The latter is expressed in the decrease of the amount of saturation fields in- plane films. In the proceeding, we have researched the magneto-optical properties of ion implanted (YBiCa)_3(FeGe)_50_12 garnet films after it was annealed at 270^0C. This kind of the experiment is particularly interesting in the matter of annealing process as it reduces the implantation defects and restores crystalline structure of ferrite garnet [1, 2]. We have also determined the spectral dependences of the component of the tensor of dielectric permittivity for the surface of the ferrite-garnet films before and after implantation process. These calculations let us evaluate the influence of implantation on an electronic energy structure of the surface layer for the sample.

[1] P. Gerard and M. T. Delay: Ion implantation profiles in bubble garnets. Thin Solid Films, vol.88, No. 1, (1982), 75-79
[2] L. Kalandadze: Influence of Implantation on the Magneto-Optical Properties of garnet surface. IEEE Trans. on Magnetics, vol. 44, No. 11, (2008), 3293-3295

MO-182

Magnetic and mechanical properties of FeCuNbSiB amorphous thin films having different thickness

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Sputtered soft magnetic films have been intensively studied due to their potential applications, including sensors, actuators and magnetic cores. Soft magnetic amorphous films have several advantages, such as high frequency operation and miniaturization. Among soft magnetic materials, FeCuNbBSi amorphous alloys are good candidates, due to their excellent magnetic softness and thermal stability.
Due to intrinsic low-dimensionality and to the presence of the magnetic film/substrate interface, internal stresses are often produced in thin films. On the other hand, it is well known that magnetic and mechanical properties are strongly influence by internal stresses.
In order to clarify the effect of magnetic layer thickness *t* on internal stresses, magnetic and mechanical properties of $Fe_{73.1}Cu_1Nb_{3.1}Si_{14.7}B_{8.2}$ thin films are studied in this work. Nanoindentation measurements have been performed to correlate internal stresses to magnetic coercivity.
$Fe_{73.1}Cu_1Nb_{3.1}Si_{14.7}B_{8.2}$ thin films with different *t* (250, 500 and 800 nm) were prepared by sputtering on glass substrates. An amorphous ribbon having the same nominal composition was used as target. Amorphous structure of the samples was checked by X-ray diffraction measurements in parallel beam configuration. Room-temperature hysteresis loops were measured by Alternating Gradient Magnetometer (AGFM) (H_{max}=1000 Oe). Nanoindentation measurements were conducted using a Fischerscope with a Vickers indenter.
Results show that H_c values are in the 5 - 35 Oe range. A rather fast decrease with increasing thickness was observed, due to pinning of the domain walls at the film surface irregularities. Hardness measurement results showed that internal stresses increases as thickness increase, while do not have significant affect on the coercivity.

MO-183

Anisotropy control method for magnetostrictive film considering thermal expansion coefficient and inverse magnetostriction effect

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It is important to control a magnetic anisotropy of magnetic film when the film is used for some kind of magnetic devices. There are several methods for giving in-plane uniaxial anisotropy of magnetic film, however, they can induce only a single direction in the plane of the film. In this paper, for a soft magnetostrictive thin film, uniaxial anisotropy control method using a difference of thermal expansion coefficients of layered structure composed of other nonmagnetic film is proposed and discussed. When the film is subjected to annealing to release a residual stress, the differences of the thermal expansion coefficient of the magnetic film and nonmagnetic film produce an inner stress to each other. The inner stress can induce anisotropy of the magnetic film to arbitrary direction due to the inverse magnetostriction

effect. Figure 1 shows the magnetic domain pattern of circle shape FeSiB film deposited on the rectangular Mo under layer. Thicknesses of the films are 1 mm for FeSiB layer and 3 mm for Mo layer respectively. After the fabrication, the film was subjected to thermal annealing under the condition of 3kOe rotating-field at 250°C in 2 hours. As shown in the Fig. 1, it is found that the uniaxial anisotropy is induced to width direction of the rectangular Mo layer. In addition, it was observed that as the major axis of the rectangular Mo under layer was lengthened, the in-plane uniaxial anisotropy of the FeSiB film was gradually strengthened. Further discussion about the uniaxial anisotropy of the film will be made at the conference.

[1] Y. Suwa, et al., IEEE Trans. Magn., 46, 666, (2010)
[2] J. Shin, et al., J. Appl. Phys., 111, 07E511, (2012)

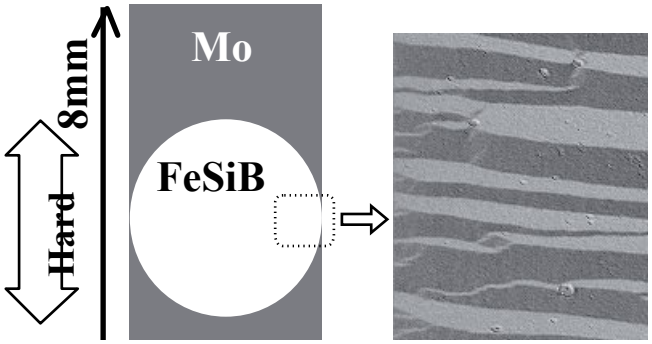

Fig. 1 Magnetic domain pattern of the circle shape FeSiB film on the rectangular Mo layer.

MO-184

Crystallographic and Magnetostriction Properties of Fe and FeB-Alloy Thin Films Formed on MgO(100) Single-Crystal Substrates

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Fe and FeB-alloys are typical soft magnetic materials. The FeB-alloy structure varies from bcc-crystal to amorphous with increasing the B content. The magnetic property is considered to be influenced by the crystallographic property. However, there are very few reports on the relationship between the crystallographic property and the magnetostriction. In the present study, Fe, $Fe_{87}B_{13}$, and $Fe_{75}B_{25}$ films of 500 nm thickness were deposited on MgO(100) single-crystal substrates of 0.5 mm thickness by UHV RF magnetron sputtering. The structure and the magnetic properties were investigated by RHEED, XRD, VSM, Bitter method, and magnetostriction measurements. Figs. 1(a-1)–(a-3) show the RHEED patterns observed for Fe, $Fe_{87}B_{13}$, and $Fe_{75}B_{25}$ films. A clear diffraction pattern corresponding to bcc(100) indicates that a bcc(100)-oriented Fe single-crystal film is obtained. A diffuse diffraction pattern typical for amorphous structure is recognized for the high B content $Fe_{75}B_{25}$ film. A diffuse pattern is overlapped with a bcc(100) pattern for the $Fe_{87}B_{13}$ film. The $Fe_{87}B_{13}$ film consists of a mixture of amorphous and bcc(100) crystal. The Fe and the $Fe_{87}B_{13}$ films showed in-plane magnetic anisotropies with four-fold symmetry reflecting the magnetocrystalline anisotropies of bcc-Fe and bcc-$Fe_{87}B_{13}$ crystals, whereas the $Fe_{75}B_{25}$ film showed isotropic in-plane magnetic anisotropy. Figs. 1(c-1)–(c-3) show the output waveforms of magnetostriction measured for these films under a rotating magnetic field of 1 kOe [Fig. 1(b)]. A sinusoidal waveform is observed for the $Fe_{75}B_{25}$ film, whereas triangle waveforms are recognized for the Fe and the $Fe_{87}B_{13}$ films. The triangle magnetostriction behavior is explained based on the motion of 90° magnetic domain walls under the rotating magnetic filed. The phase of waveform is different between the Fe and the $Fe_{87}B_{13}$ films, which indicates that the sign of magnetostriction is opposite.

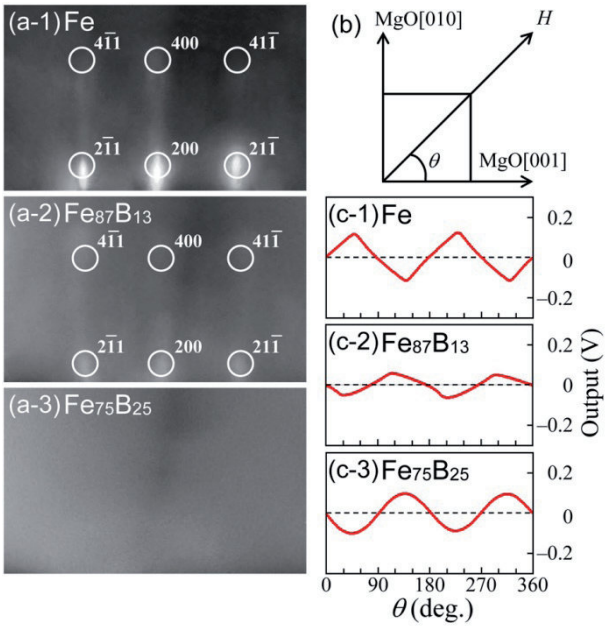

Fig. 1 RHEED, rotating magnetic field direction, and waveform of magnetostriction.

MO-185

Irradiation driven nanocrystallization of FeCuNbSiB amorphous thin films

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FeSiB based nanocrystalline ferromagnetic materials are known for its high magnetic permeability and low noise characateristics, owed to the quenching of the magnetocristalline anistotropy of the nanometric particles of crystalline materials embedded in an amorphous magnetic matrix. In bulk materials, there are several routes to obtain the nanocrystalline state, e.g. thermal annealing, ion irradiation. In the case of magnetic films the route to nanocristallization is still an open question. Ion irradiation of the amorphous precursors films could be an interesting method to drive the nanocrystallization [1]. In particular, irradiation with Ar ions can be an useful tool to establish the nanocrystalline FINEMET state in FeSiB based alloys. In this work, we explore this route by irradiating 100 nm thick $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ films produced by RF magnetron sputtering deposition on silicon substrates under an applied magnetic field. The samples have been subjected to a $1x10^{12}$ cm^{-2} dose

irradiation of Ar ions accelerated at 380 kV under temperatures from room to 250 ºC. All films structures were characterized by XRD and TEM, while the magnetic properties were studied by VSM. Ferromagnetic resonance linewidths were measured by VNA-FMR. The as prepared sample exhibits small coercive field and an uniaxial anisotropy. With the irradiation at room temperature, the coercive fields in both, easy and hard axis, increased significantly, an effect ascribed to irradiation damage. As the irradiation temperature increases, the evolution in the magnetization curves indicates a decrease in the defects in the sample as expected due recovery. This recovery is also observed in the reduction of the measured resonance linewidth. We also observed the increase of the saturation magnetization with with the irradiation temperature, a signature of crystallization. Complementary TEM images were used to verify the effect of irradiation in the evolution of the crystallization with the substrate temperature.

[1] R. Sanz et al, JNCS 353, 879 (2006)

MO-186

Sol-gel preparation, structure, and magnetic properties of nanocrystalline $Ni_{1-x}Zn_xFe_2O_4$ thin films

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Bulk Ni-Zn ferrite has been intensively studied due to its remarkable magnetic properties and low production cost. Recently due to the rapid development of electronic devices with miniature size, high density and multifunctions, special focus has been planced on Ni-Zn ferrite films. The ferrite films have the advantages of low eddy current loss and high resistivity; therefore facilitates the design and fabrication of nanodevices and electromagnetic interference devices. Ni-Zn ferrite films have been prepared through various techniques, which directly affect the structure and properties of the film. Dielectric and microwave properties of Ni-Zn ferrite films with certain compositions have been reported, but the magnetic properties of Ni-Zn ferrite thin film have not been studied in detail. In this work, we report the sol-gel preparation of $Ni_{1-x}Zn_xFe_2O_4$ thin film with various composition ($0<x<0.6$), and the investigation of their magnetic properties. The relationship between the preparation condition, structural, and magnetic properties with be presented and discussed.

MO-187

Structure and magnetic properties of FeNi/Ti sputtered multilayers

N. Villar Alzola [1], A.V. Svalov [1], N. Mayura [2], N.A. Kulesh [2], A. Larrañaga [3], *G.V. Kurlyandskaya* [1]
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Thin permalloy films are versatile materials suitable for different applications. Their main technologically requested parameters are high magnetic permeability and low coercivity. It is known that laminating of a thick magnetic film by a nonmagnetic spacer may further improve the magnetic softness of the multilayer structure [1] including the case of dynamic magnetization [2]. Moreover structural properties depend on the film thickness [3] and therefore spacer introduction changes both magnetic layer thickness and the average grain size. The last parameter is directly connected with the magnetic softness of multilayered structure.

In this work the microstructure, magnetic properties and anisotropic magnetoresistance were comparatively analyzed for FeNi films and FeNi/Ti multilayers prepared by dc magnetron sputtering. The thickness of the FeNi layers was varied in the interval of 12 to 200 nm. The non-magnetic Ti spacer thickness was kept as high as 6 nm. It was found that grain size increases with an increase of the FeNi thickness both in the case of FeNi films and FeNi/Ti multilayers. It did not exceed 15 nm for the single layer films. Laminating of the FeNi films by the Ti spacer caused an increase of the grain size as well as the appearance of a strong crystallographic texture. The values of anisotropic magnetoresistance for permalloy films and FeNi based multilayers were close to each other showing weak dependence on the total thickness of the structure. Coercivity for all types of multilayers was found to be smaller then the coercivity of FeNi films. We discuss the relations between structural features and magnetic properties of FeNi films and FeNi/Ti multilayers.

[1] K. Rook et al., J. Appl. Phys. 69, 5670 (1991)
[2] G.V. Kurlyandskaya et al, Solid State Phenomena 168-169, 257 (2011)
[3] D.G. Neerinck et al., Thin Solid Films 280, 136 (1996)

MO-188

Sweeping-Field Frequency-Dependent Hysteresis Loop Shape Transitions of Co/Pt Multilayers

D. Handoko [1], S. Lee [1], S.K. Oh [1], D. Yang [1], *D. Kim* [1], S. Yu [1]
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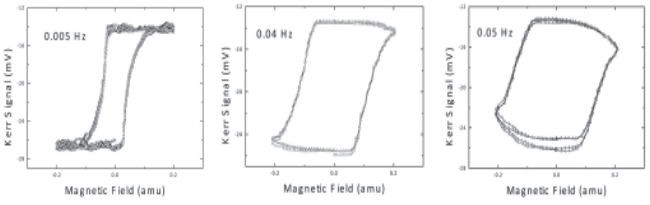
We have investigated the hysteresis loop shape changes with variation of external field sweeping frequencies for Co/Pt multilayer by using magneto-optic Kerr effect (MOKE). Detailed analysis was carried out to understand the shape change of hysteresis loop with respect to the field sweeping rate and the maximum applied magnetic field. At the very slow sweeping rate, a square hysteresis loop of the Co/Pt multilayer with a perpendicular magnetic anisotropy is observed, whereas the hysteresis loop shape starts getting fat and round with increase of the sweeping rate, as demonstrated in the figure. For the case of faster sweeping, the loop shape becomes more round and almost becomes circular until the loop collapses onto a straight line for the faster sweeping rate. These trends are also observed for different maximum applied magnetic fields.



Keywords: MOKE, Co/Pt, hysteresis loop, perpendicular magnetic anisotropy

MO-189

Hysteresis Loop Area Scaling of Co/Pt Multilayers Thin Film

D. Handoko [1], S. Lee [1], S.K. Oh [1], S. Yu [1], D. Yang [1], *D. Kim [1]*
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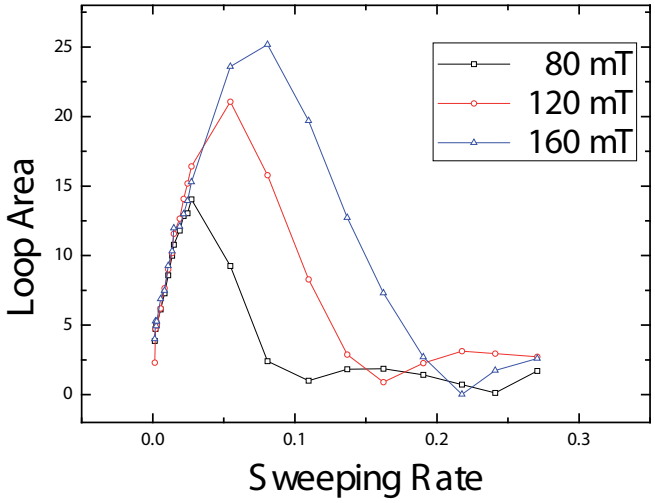
Hysteresis loop area of Co/Pt magnetic multilayers thin films with a perpendicular magnetic anisotropy has been investigated by analyzing Kerr hysteresis loop using the magneto-optic Kerr effect (MOKE). A systematic variation of the sweeping frequency and the amplitude of the applied magnetic field, the Kerr hysteresis loop area was measured. It has been observed that the loop area increases rapidly until it reaches the peak, which can be considered as a loop area resonance, and decreases logarithmically as a function of sweeping rate. As the amplitude of applied magnetic field increases, the similar loop area behavior with different frequency resonance is obtained, as shown in the figure. The loop area scaling behavior is explainable within the context of the Steinmetz law, where the scaling exponent determined from a fitting by the power law is about 0.5.



Keywords: MOKE, hysteresis loop, Steinmetz law, scaling exponent

MO-190

Stripe domains in Permalloy - revisited

J. McCord [1], O. Roshchupkin [2], B. Erkartal [1], J. Grenzer [2], L. Kienle [1], E. Quandt [1]
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Sputtered thick magnetic films are used for numerous applications, e.g. as shields [1] in recording heads or in inductive devices [2]. Magnetic stripe domains are known to form in out-of-plane or perpendicular anisotropy soft magnetic films and thereby degrade the soft magnetic properties of these films. In general it is assumed that perpendicular anisotropy K_{perp} results from effects of magneto-elasticity and magneto-crystalline anisotropy [3]. The existence of stripe domains is moreover determined by a critical thickness, only above which stripe domains can form.
Zero magnetostriction $Ni_{81}Fe_{19}$ films varying in thickness showing stripe domains were deposited by rf-sputtering in argon atmosphere onto oxidized silicon substrates. The occurrence of stripe domains is derived from magnetometry and confirmed by MFM domain imaging. From stripe domain theory a linear decrease of K_{perp} with film thickness is determined. Using X-Ray reflectivity and diffraction, as well as TEM imaging a congruent transformation of the crystalline structure with thickness is derived.
The data is interpreted assuming magnetostatic interactions of grains with weakened exchange across the grain boundaries. From a modified shape anisotropy model a thickness dependent grain structure results in a concurrent inhomogeneous magnetic anisotropy distribution. We show that stripe domains can purely originate from structural features. Magneto-crystalline anisotropy in conjunction with texture as well as magnetoeleastic effects is not required for the occurrence of out-of-plane anisotropy and stripe domains in soft magnetic films.

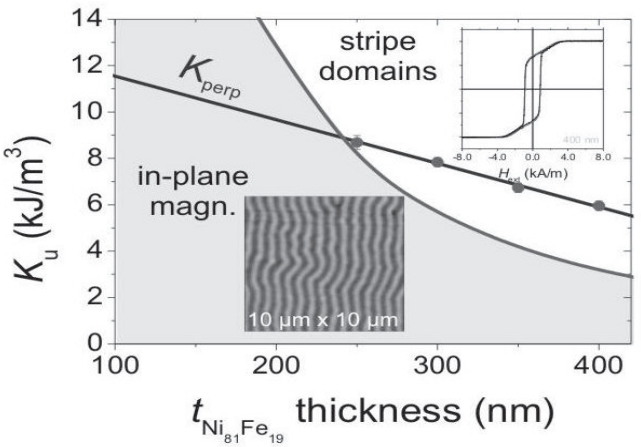

Fig. 1 Dependence of perpendicular magnetic anisotropy with NiFe film thickness. The region of existence of stripe domains is indicated. A typical magnetization loop as well as the magnetic domain structure is shown.

[1] J. McCord, J. Westwood, IEEE Trans. Magn. 37 1755 (2001)
[2] D.S. Gardner et al., IEEE Trans. Magn. 45, 4760 (2009)
[3] P. Zou et al., JAP 91, 7830 (2002)

MO-191

The Temperature Dependent Rotation of Magnetization in the Granular Thin Films and Multilayers

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(1) Institute of Physics of the ASCR, v.v.i., Na Slovance 2, 182 21 Praha 8, Czech Republic

The granular thin films with high uni-axial in-plane anisotropy are good candidates for obtaining high power efficiency and low power loss in high frequency operating devices (like thin film inductors). We have prepared and tested two types of potential samples for these purposes: 1. thin monolayers of a ferromagnetic metal (Fe, Co or $CoFe_2$) of different thickness (3, 5 and 10 nm, respectively), covered with 10 nm of SiO_2 layer and 2. sandwich multilayers composed of ten double layers of the metal and SiO_2.
The thickness of the layers has been examined by the Transmission Electron Microscopy and the X-ray reflectivity. Those results together with magnetization measurements

revealed the granular structure of the layers, with increasing size of the particles for thicker layers.
The room temperature in-plain uni-axial anisotropy has been observed in all samples, as has been expected for such kind of film. The possible evolution of the easy axis of magnetization with the temperature within the samples has been tested using the torsion magnetometry. The out-of plane rotation of the easy axis of magnetization perpendicular to the surface has been observed for the $CoFe_2$ multilayers only. The other samples exhibited the in plane easy axis of magnetization in the whole temperature range investigated.
The mechanism of this effect will be discussed by means of the exchange coupling.

MO-192
Phase Diagram for Chromium-doped FINEMET-type Amorphous Alloys
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(1) Laboratorio de Magnetismo y Materiales Avanzados, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Colombia, Sede Manizales, Manizales, Colombia, (2) Laboratorio de Sólidos Amorfos, Departamento de Física, Facultad de Ingeniería, Universidad de Buenos Aires, Av. Paseo Colón 850, Buenos Aires, Argentina

A study of the magnetic, magneto-impedance, thermal and structural properties for the amorphous alloys Fe_{73.5-x}Cr_{x}Nb_{3}Cu_{1}Si_{13.5}B_{9} with x = 0, 2, 4, 6, 8 and 10 is presented. These alloys were prepared in form of ribbons by a melt spinning technique and their structural state was checked using X-ray diffraction with CuKα radiation. The temperature (*T*) and the field (*H*) dependences of the magnetization were measured using temperature cycling (*H* fixed) and field cycling (*T* fixed) with a VersaLab-Vibrating Sample Magnetometer. Temperature cycle was carried out using procedures of warming and cooling. The temperature and applied field were varied in the ranges $300 \leq T \leq 900$ K and $0 < H \leq 30$ kOe, respectively. The magnetization curves exhibit a Hopkinson anomaly at a certain temperature *THo* just below the amorphous Curie temperature *TCurie,am* with increasing temperature and fall basically to zero before that samples reach its crystallization temperature. It was also found that the magnetization is irreversible below an irreversible temperature *Ti(H)* with respect to the warming-cooling procedures. The complex impedance in these ribbons was measured for applied *dc* magnetic fields from - 80 to 80 Oe at room temperature, via the so-called four-probe technique. Depending on the frequency, the experimentally observed experimentally magneto-impedance curves exhibit two types of behavior, namely single-peak (SP), and two-peak (TP). Here we emphasize the presence of a "*three-peak behavior*" in magneto-impedance curves. The thermal characterization was carried out using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). Particular attention is also given to observation of crystallization kinetics via DSC, TGA, and magnetization. A (*H*,*T*) phase diagram that contains *THo*, *TCurie,am* and $T_i(H)$ for each of the ribbons under study is presented and discussed. The effect of partial substitution of Fe by Cr on the magnetic, magneto-impedance, and thermal properties is discussed.

MO-193
Magnetic properties of soft magnetic cores based on nanocrystalline alloy powder
J. Füzerová [1], J. Füzer [2], P. Kollár [2], S. Roth [3]
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Fe-based nanocrystalline alloy known as VITROPERM, which is prepared by heat treatment from the melt-spun amorphous ribbon, has been focused due to its excellent soft magnetic properties originating from the unique nanocrystalline structure. The soft magnetic properties of mechanically alloyed nanostructured powder cores were studied using magnetic and electric measurements. Rapidly quenched ribbon of $Fe_{73}Cu_1Nb_3Si_{16}B_7$ in amorphous state was ball milled and cryomilled to powder and warm consolidated at a pressure of 700 MPa to get bulk compacts. It was found by investigating the influence of mechanical milling on the magnetic properties of powder samples prepared by milling that the alloy remains amorphous during the whole milling process. The frequency dependencies of the complex permeability and core losses were studied. Investigation of the DC coercivity, hysteresis loss, magnetostriction and electrical resistivity were done. Complex permeability spectra were measured with an impedance analyzer (HP4194A from 100 Hz to 40 MHz). The AC hysteresis loops were measured by AC hysteresisgraphs at the maximum flux density of 0.2 T. The total losses were calculated directly from measured hysteresis loops. It was found that morphology of the initial powder influences the density and the electrical resistivity of the resulting bulk alloys. At high content of small particles high real μ' part of the permeability cannot be expected. On the other hand, reducing the eddy current loss of bulk alloy from cryomilled powder also hinders the core loss at higher frequency. The absolute values of losses and coercivity of Fe-based compacts are similar to that for Co based compacts. We have prepared bulk samples in the form of the small cylinders with coercivity down to 11 A/m. These materials have more degrees of freedom for tailoring their applications due to their flexibility in shape and dimensions.

MO-194
Magnetic properties of spark plasma sintered Ni_3Fe powder prepared by mechanical alloying
B.V. Neamtu [1], I. Chicinas [2], I. Ciascai [3], O. Isnard [4], H. Chiriac [5], T.F. Marinca [2], F. Popa [2]
(1) Material Science and Engineering Department, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, 400614 Cluj-Napoca, Romania and Institut Néel, CNRS et University Joseph Fourier, BP 166, 3, (2) Material Science and Engineering Department, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, 400614 Cluj-Napoca, Romania, (3) Applied Electronics Department, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, 400614 Cluj-Napoca, Romania, (4) Institut Néel, CNRS et University Joseph Fourier, BP 166, 38042 Grenoble Cedex 9, France, (5) National Institute of R&D for Technical Physics, 47 Mangeron Blvd., 700050 Iasi, Romania

Nanocrystalline Ni_3Fe compacts were successfully prepared by spark plasma sintering starting from wet mechanically alloyed powders [1]. The influences of the sintering conditions: sintering

temperature, sintering time and particle size on the magnetic properties are investigated. The success of compaction process in the case of nanocrystalline powder is closely related to the control of the competition between densification and crystallites growth. For sintering temperatures (550 °C and 600 °C) around the recrystallization temperature of the Ni_3Fe intermetallic compound, a moderate crystallite growth was observed, while for higher temperatures (650 °C and 700 °C) a more significant crystallites growth can be noticed even for short sintering time. It is found that high sintering temperature (550 °C and 600 °C), longer sintering duration and larger particle size leads to compacts with improved soft magnetic properties. For higher sintering temperature (650 °C and 700 °C), an increase of the compacts coercivity due to the carbon contamination was observed. The decrease of the contamination level by a decarburizing heat treatment in hydrogen at the temperature of 450 °C during 4 hours, leads to a diminution of the compact coercive field by 50 % and an increase of the permeability of the compact up to 600 %. It has been shown that larger particles are more suitable to obtain compacts with competitive soft magnetic properties due to their low density of defects and to lower demagnetizing fields induced by a lower number of inter-particles air gaps (porosities) [2]. Spark plasma sintering can consequently be considered as a promising compaction technique for processing Ni_3Fe nanocrystalline powder in particular and nanocrystalline soft magnetic alloys in general.

[1] B.V. Neamțu, I. Chicinaş, O. Isnard, F. Popa, V. Pop, Intermetallics, 19, 19 (2011).
[2] M. Anhalt, J. Magn. Magn. Mater. 320, e366 (2008).

MO-195

Influence of contamination with iron on the magnetic properties of mechanically alloyed Supermalloy powders

F. Popa [1], I. Chicinas [1], O. Isnard [2], B.V. Neamtu [1], T.F. Marinca [1], V. Pop [3]
(1) Department of Materials Science and Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, 400641 Cluj-Napoca, Romania, (2) Institut Néel, CNRS / University J. Fourier, BP166, 38042 Grenoble, Cédex 9, France, (3) Faculty of Physics, Babes-Bolyai University, 1 Kogălniceanu, 400084 Cluj-Napoca, Romania

Nanocrystalline soft magnetic Supermalloy (79Ni16Fe5Mo wt. %) powders were obtained by solid state reaction in a planetary ball mill under argon atmosphere. The initial mixture was milled up to 24 h. Several samples were obtained, each having different particle sizes. The alloy is obtained after 12 to 16 h of high energy milling as concluded from X-rays studies [1]. According to scanning electron microscopy, the powder morphology was found to be very different depending upon the processing condition, ranging from large particles (D> 250 μm) to small particles (below 100 μm). It was found that the extra iron introduced by powder contamination during the milling acts as a binder and enhances the particles welding process. As the particle size increases, the samples have larger magnetization than the as-cast sample used for reference. In order to decide if the extra iron remains unreacted or does react with the milled compound, supplementary investigation by neutron diffraction have been realized. The effect of extra iron introduction on the samples composition was investigated by energy dispersive X-ray analysis.
The sample magnetization and powders particle size are connected with the amount of iron introduced by contamination. Supplementary characterization was made by thermomagnetic measurements. At heating no change in the Curie temperature is observed whatever the contamination degrees is, but at cooling from 800 °C the Curie temperature shifts to a value closer to that of the Ni_3Fe as the amount of iron increases. This was explained by the fact that the iron added by contamination can react during the heating of the samples, resulting thus in a composition change.

[1] I. Chicinas, V. Pop, O. Isnard, J. Mater. Sci. 39 (2004) 5305.

MO-196

Structure and magnetic properties of FeBCCu alloys

V. Hrabcakova [1], V. Girman [1], S. Michalik [1]
(1) Department of Condensed Matter Physics/Institute of Physics / Faculty of Science / P.J. Safarik University, 041 54 Kosice, Slovakia

Nanocrystalline materials belong to very often studied materials in the fields of condensed matter physics and materials science. They are characterized by unique soft magnetic properties like high saturation, magnetic flux density, high permeability, low coercivity and low core losses. Thanks to this have nanocrystalline materials wide range of industrial applications (transformers, motors, magnetic components in sensors, power electronics, etc.) All properties of materials also related to their structure. Nanocrystalline materials are single or multiphase polycrystals with grain size less than 100 nm.
In this work is structure and magnetic properties of nanocrystalline $Fe_{84-x}B_{10}C_6Cu_x$ (x=0; 0,2; 0,4; 0,6; 0,8; 1,0; 1,2 and 1,4) alloys studied. Alloy Fe-B-C has high saturation induction at room temperature (over 1,75T) [1] and high coercivity which limits its industrial usage. Cu was added to this system because of decreasing the coercivity [2].
Amorphous ribbons have been prepared by melt-spinning method at first. Nanocrystalline state was obtained during annealing treatment under temperatures of first crystallization. Then the materials were studied by methods like TEM, EDX, DSC and DC hysteresis loops measurements.

[1] S. Hatta, T. Egami, D.C. Graham, Applied Physics Letters 34, 113 (1979)
[2] X. Fan et al., J. Appl. Phys. 109, (2011)

MO-197

Influence of Cr dopants on magnetic and transport properties of Co-Si-B rapidly quenched alloys

M. Semen'ko [1], E. Yarmoschuk [1], *M. Zakharenko* [1]
(1) Department of Physics, Taras Shevchenko national university, 01601, Kyiv, Ukraine

Rapidly quenched alloys (RQAs) on the base of Co-Si-B system are of great importance for industrial applications in different magnetic devices due to low magnetostriction and core loss. Metallic dopants are known to promote an essential modification of their functional characteristics. Here, we present the data on the influence of chromium dopants (up to 6.5 at.%) on thermal stability, magnetic and transport properties of $Co_{72}Si_{18}B_{10}$ RQA. The sequence of the phase transformation upon heating of the as-cast alloys has been ascertained by TEM and X-ray diffraction. It could be presented as: as-cast RQA (A-phase)®amorphous phase A_1+$Co_2(Si,B)$($P6_3/mmc$)®Co_2Si (Pnmm)+ $(Co,Cr)_3B$ (Pmmm).

Crystallization temperature exhibits distinct correlation with the electron/atom ratio evidencing for the key role of the electronic criterion of thermal stability.
It has been revealed that the Curie temperature T_C sharply decreases with increasing of Cr, the appropriate rate is equal to -37 K/at.%Cr. Such behavior of T_C evidences for strong antiferromagnetic coupling between Cr and Co atoms. Localized magnetic moment per Co atom μ_{TM} in the basic RQA $Co_{72}Si_{18}B_{10}$ was found to be in a fairly good agreement with the reference value for pure paramagnetic cobalt. At the same time, Cr admixture causes significant decreasing of μ_{TM}, The performed analysis showed that Cr atom not only provides zero contribution to the total magnetic moment but also suppresses the moments of about 7 neighboring Co atoms due to formation of antiferromagnetic clusters possessing almost zero magnetic moment. These clusters determine also the peculiarities on the temperature dependences of resistivity. The principal feature of these curves consists in the existing of resistivity minimum at relatively high temperature, the position of this minimum being dependent on Cr content. Thorough analysis show the presence of resistivity term $\sim T^{1/2}$ arising due to a weak localization effect.

MO-198

Synthesis of Cu-Ni nanoalloys using a citric acid assisted Pechini process

L.A. Garcia-Cerda [1], E.L. De Leon Quiroz [2], B.A. Puente Urbina [1], D. Vazquez Obregon [2], D. Bueno Baques [1]
(1) Centro de Investigación en Química Aplicada. Departamento de Materiales Avanzados. Blvd. Enrique Reyna Hermosillo #140, C.P. 25294, Saltillo, Coahuila. México, (2) Instituto Tecnológico de Saltillo. Departamento de Metal-Mecánica, Blvd. V. Carranza 2400. C.P. 25280. Saltillo, Coahuila. México

CuNi nanoalloys (4:1, 1:1 and 1:4) were prepared by citric acid assisted Pechini process. A precursor material was prepared using citric acid, ethylene glycol, copper chloride and nickel chloride. The CuNi nanoalloys were obtained by calcination of the precursor material in H2/N2 atmosphere at 600 °C. The composition, structure, morphology and magnetic properties of the CuNi nanoalloys were characterized by atomic absorption spectroscopy (AAS), X-ray diffraction (XRD), transmission electron microscopy (TEM) and vibrating sample magnetometry (VSM). AAS studies confirmed the expected Cu:Ni ratios in these nanoalloys. The XRD patterns showed the formation of CuNi nanoalloys with good crystallinity (Figure 1a). The morphology of CuNi nanoalloys appears small, uniform and spherical with sizes in the range of 20 - 60 nm (Figure 1b). Magnetic measurements reveal that the CuNi nanoalloys show a ferromagnetic behaviour and the magnetization increases with increasing of Ni content.

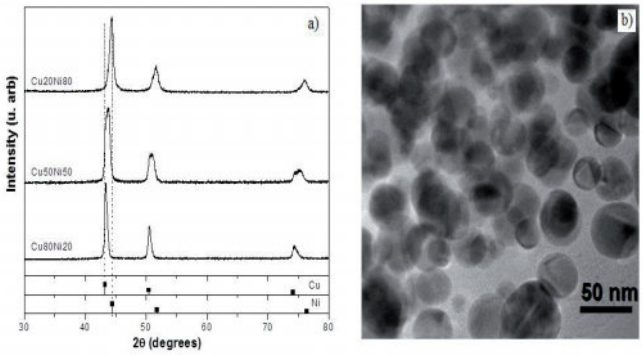

Figure 1. XRD patterns (a) and TEM image (b) for the CuNi nanoalloys.

Tuesday, 11 September 2012

Oral Communications

Tuesday, 11 September 2012
Aida Room

PLENARY
Chair: M. Albrecht

08.30 – 09.15
Materials for ultrahigh density magnetic recording
K. Hono [1], Y.K. Takahashi [1], T.M. Nakatani [1], T. Furubayashi [1]
(1) National Institue for Materials Science, Tsukuba 305-0047, Japan

Hard disk drive (HDD) industries in US and Japan are making continuous efforts in increasing the areal density of magnetic recording. The areal density of current HDDs is 750 Gbpsi and further growth is needed to meet the increasing demand in digital data storage. To realize the areal density exceeding 2 Tbpsi, both media and heads need technical breakthroughs. The bit size will be in the range of 10 - 20 nm, so the size of magnetic grains in recording media must be smaller than 5 nm and the gap width of read sensors must be ~10 nm. In this talk, we will overview our research activities on the materials for media and heads for the next generation ultrahigh density magnetic recording.

Tuesday, 11 September 2012
Aida Room

SEMIPLENARY
Chair: A. Barthélémy

09.15 – 10.00
Magnetoelectric coupling in cycloidal thin film
J. Fontcuberta [1], I. Fina [1], X. Marti [2], V. V. Skumryev [3], L. Fàbrega [1], F. Sánchez [1]
(1) Institut de Ciència de Materials de Barcelona (ICMAB-CSIC). Campus UAB. Bellaterra 08193. Catalonia (Spain), (2) Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 121 16 Prague 2, Czech Republic, (3) Institució Catalana de Recerca i Estudis Avançats (ICREA) and Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Catalonia (Spain)

Antiferromagnetic $AMnO_3$ perovskites with cycloidal magnetic order are known to display ferroelectric polarization at temperatures below the Néel temperature. This magnetic ordering, occurring between collinear E-type and A-type spin orderings, can be stabilized by appropriate tuning of Mn-O-Mn magnetic interactions within the basal-plane of the perovskite structure. It is known that the cycloidal plane can be either the ab or bc planes depending on the Mn-O-Mn bond-angle and temperature and the corresponding ferroelectric polarization develops along a-axis or c-axis respectively; the cycloidal plane can be flopped from bc(ac) to ac(bc) by an appropriate magnetic field. It follows that epitaxial strain in thin films can be instrumental on tailoring their magnetic order and thus the magnetoelectric response.
Here we will show that appropriate combination of rare-earth size and epitaxial strain allows creating new multiferroic materials displaying both, magnetically switchable ferroelectric polarization and ferromagnetic character [1, 2]. Moreover, we will show that the occurrence of antiferromagnetic and ferroelectric domains, leads to hysteresis upon polarization flopping. These properties allow to obtain materials displaying chiral memory, i.e. information can be stored via ferroelectric polarization, on the chiral state of the antiferromagnetic domains [3]. Some implications and prospective will be discussed.

[1] X. Marti et al, Appl. Phys. Lett. 95, 142903 (2009)
[2] J. Fontcuberta et al. Phase Transitions 84, 555 (2011)
[3] I. Fina et al, Phys. Rev. Lett. 107, 257601 (2011)

Tuesday, 11 September 2012
Nabucco Room

SEMIPLENARY
Chair: B. Büchner

09.15 – 10.00
A magnetic analog of the isotope effect in cuprates
A. Keren [1]
(1) Technion-Israel Institute of Technology

Since the discovery of high temperature superconductivity in the cuprates, it has been speculated that their pairing mechanism is due to magnetic interactions. However, this was never demonstrated in the laboratory. Such a demonstration would require an experiment similar to the isotope effect in metallic superconductors, namely, a measurement of T_c versus the strength of the magnetic coupling J, with no other structural changes. We have done this experiment using the $(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})Cu_3O_y$ system with its 4 different families having different T_c^{max}, but identical structures. For each family, we measured the Né
el Temperature T_N, the anisotropies of the magnetic interactions, the spin glass temperature T_g of underdoped samples, the carrier density n, the superconducting carrier density n_s, the crystallographic parameters, and, of course, T_c from under to overdoped compounds. Our measurements allow us to demonstrate that $T_c=cJn_s$ and more.

Tuesday, 11 September 2012
Aida Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

NOVEL SYSTEMS FOR MAGNETOELECTRONICS

Chair: F. Miletto Granozio

10.30 – 11.00

Room temperature ferromagnetism and anomalous Hall effect in $Si_{1-x}Mn_x$ alloys with high Mn content *(invited)*

B. Aronzon [1], V. Rylkov [1], S. Nikolaev [1], V. Tugushev [1], S. Caprara [2], N. Perov [3], A. Semisalova [3], A. Lashkul [4], E. Lahderanta [4]

(1) National Research Centre"Kurchatov Institute",123182 Moscow, Russia, (2) SMC-INFM-CNR and Dipartimento di Fisica, Universita di Roma "La Sapienza", Roma, Italy, (3) M.V. Lomonosov Moscow State University, Moscow, Russia, (4) Lappeenranta University of Technology, Lappeenranta, Finland

A detailed study of the magnetic and transport properties of $Si_{1-x}Mn_x$ (x » 0.35 and x » 0.5) films is presented. Films with the thickness in the range 40 – 300 nm were deposited by pulsed laser deposition on Al_2O_3 and GaAs substrates using two separated Mn and Si targets. In these films we have observe the anomalous Hall effect (AHE) showing hysteresis up to the room temperature. Results of the magnetic measurements and AHE data are consistent and demonstrate the existence of a long range ferromagnetic (FM) order in studied systems with Curie temperature 330 K for both types of structures with Al_2O_3 and GaAs substrate. The temperature dependence of the saturation magnetization and coercive force measured by magnetic and transport methods are similar, and this fact proves the previous statement. However the values of coercivity and magnetization differ for different samples demonstrating a correlation of the AHE and magnetic properties of $Si_{1-x}Mn_x$ (x » 0.35) films with their conductivity and substrate type. The coercive force reaches values 2000 Oe at 80 K and 400 Oe at 300 K and magnetic moment per Mn atom is about $0.3m_B$/Mn exceeding the value for manganese silicides by more then one order of magnitude. $Si_{1-x}Mn_x$ films with x » 0.5 show similar behavior but only in the narrow range of *x* around the value slightly higher 0.5. Theoretical model based on the conception of a two-phase magnetic material, in which molecular clusters with localized magnetic moments are embedded into the matrix of a weak itinerant ferromagnet is discussed. The long-range ferromagnetic order at high temperatures is mainly due to the Stoner enhancement of an exchange coupling between clusters through the thermodynamical spin fluctuations ("paramagnons") in the matrix. Theoretical predictions and experimental data demonstrate a qualitative agreement.

11.00 – 11.30

Tuning ferroelectricity and magnetism by epitaxial strain in $BiFeO_3$ thin films *(invited)*

D. Sando [1], A. Agbelele [2], C. Daumont [1], J. Juraszek [2], M. Cazayous [3], I. Infante [4], W. Ren [5], S. Lisenkov [6], C. Carretero [1], L. Bellaiche [5], B. Dkhil [4], A. Barthélémy [1], *M. Bibes* [1]

(1) Unité Mixte de Physique CNRS/Thales, Campus Ecole Polytechnique, 91767 Palaiseau, France, (2) Groupe de Physique des Matériaux, Université de Rouen/CNRS, France, (3) Laboratoire MPQ, Université Paris Diderot/CNRS, France, (4) Laboratoire SPMS, Ecole Centrale Paris/CNRS, France, (5) University Of Arkansas, Fayetteville, NC, USA, (6) Universiy Of South Florida, Tampa, FL, USA

The strong coupling of ferroic orders (elastic, electric and magnetic) with the various structural degrees of freedom (notably polar and antiferrodistortive) provides multiferroic $BiFeO_3$ with very rich phase diagrams, as well as with a highly tunable, multifunctional character. Applied to $BiFeO_3$ thin films, epitaxial strain engineering reveals various unexpected features as well as novel multifunctional phases with enhanced properties and application potential. Combining advanced characterization techniques (X-ray and neutron diffraction, Mössbauer spectroscopy and piezoresponse force microscopy) and ab initio calculations, we have established that in $BiFeO_3$ strain anomalously drives the Curie temperature down [1]. This sheds light on the interplay between polar and oxygen tilting instabilities but also reveals the possibility to strain-drive the magnetic and ferroelectric transition temperatures close together, offering an original approach to achieve enhanced magnetoelectric responses [2]. The competition between both structural stabilities is also illustrated by the weak influence of strain on polarization [3]. Finally, we will show how Mossbauer and Raman spectroscopy data can reveal strain-driven changes in the spin arrangements and excitations.

[1] I.Infante et al.; *Phys. Rev. Lett.* 105, 057601 (2010) ; B. Dupé et al. *Phys. Rev B* 81, 144128 (2010)
[2] J.C. Wojdel and J. Iñiguez, *Phys. Rev. Lett.* 105, 037208 (2010)
[3] C. Daumont et al, *J. Phys. Condens. Matter* 24, 162202 (2012)

11.30 – 11.45

Band allignment of NiMnSb/III-V semiconductor junctions for spintronic applications: an ab initio study

A. Debernardi [1], M. Peressi [2], A. Baldereschi [2]

(1) Laboratorio MDM, IMM_CNR, 20864 Agrate Brianza, Italy, (2) Dipartimento di Fisica Teorica, University of Trieste, Strada Costiera 11, Trieste, Italy

Recently NiMnSb has been successfully grown epitaxially on several substrates, such as GaAs(001) [1] and InP(001) [2]. However, theoretical studies based on density functional theory have shown that in general the interfacial layer of the Heusler compound looses its half-metallic properties, i.e. the density of states at the Fermi energy become unpolarized, forbidding spin-injection.

By means of supercells, we have computed the structural, magnetic and electronic properties of superlattices formed by pseudomorphic NiMnSb grown on a (001) oriented substrate constituted by GaAs [3], InP or GaSb, to analyze the role of the chemical composition and lattice parameter of the substrate on the band alignments and the magnetic properties of the interface. We have determined some particular interface arrangements

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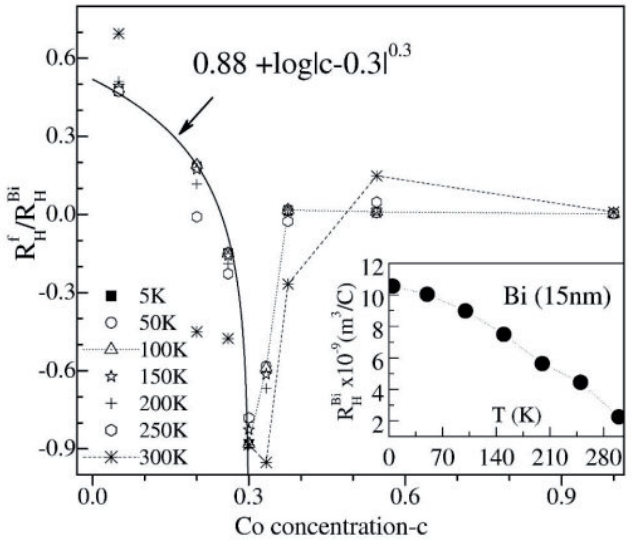
where the spin polarization is maintained. We found that the band alignments do not show any trivial trend, due to the strong effect of the chemical composition of the substrate.
Our results can be extended to describe the band alignment at the infinite junctions between NiMnSb and GaAs or GaSb, while in the case of InP the electron transfer at the interface is strongly influenced by the superlattice period. In particular the latter interface shows ohmic behaviors. We analyze the microscopic mechanisms that produce the loss of the desired half-metallic behavior at the interfaces studied, and we discuss limitations and possibilities (and difficulties) to restore the half-metallicity at the interface to make the heterostructure suitable to inject spin polarized carriers into a semiconductor.

[1] W.Van Roy, G. Borghs, J. De Boeck, J. Cryst. Growth, Vol. 227-228 (2001) 862.
[2] P. Bach, C. Ruester, C. Gould, C.R. Becker, G. Schmidt, L.W. Molenkamp,
J. Cryst. Growth, Vol. 251 (2003) 323.
[3] A. Debernardi, M. Peressi, A. Baldereschi, Comp. Mat. Sci. 33 (2005) 263-268

11.45 – 12.00
Scaling of Hall coefficient in Co-Bi granular thin films
P. Athanasopoulos [1], C. Christides [1], T. Speliotis [2]
(1) School of Engineering, University of Patras, 26504 Patras, Greece, (2) NCSR Demokritos, 15310 Athens, Greece

A series of granular Co-Bi thin films with Co concentrations c=0, 0.05, 0.2, 0.26 0.3, 0.333, 0.375, 0.545, were grown by magnetron sputtering on Si(100)/SiN_X substrates with rectangular shapes of 5x5mm^2. Resistivity and magneto-transport measurements were performed between T=5 and 300K on a PPMS with the Van der Pauw method, applying magnetic fields up to B=9T perpendicular to film-plane.
Resistivity measurements at zero field (ρ_{XX}) as a function of temperature-T exhibit an abrupt increase at about 250K. Scaling theory of localization was assumed, and the ρ_{XX} vs T curves were transformed by considering a 3-dimensional (3-d) scaling function [1]: $\rho_{XX}=[R_3(l_T/L)](l_T/L)$, where l_T is an inelastic mean free path at finite T>0, that scales as T^{-p}, and $R_3(l_T/L)$ is the 3-d resistance of a film with length L. Log-log plots of $[\rho_{XX}(T)/\rho_{XX}(5K)]$ T^2 against T^{-2} give a straight line for all samples in between 5K and 260 K.
Hall coefficient, $R^f_H(T)= (\rho_{XY}/B)$, values at B=8T for c>0, normalized to corresponding $R^{Bi}_H(T)$ values for c=0, reveal a percolation threshold at c=0.3 (see figure) for all T<260K. The Hall coefficient diverges as $\log|c-0.3|^{0.3}$ for c<0.333, indicating a scaling [2] of R_H as well. Scaling of the anomalous Hall coefficient R_S is observed as well, that is due to $R_S\mu(\rho_{XX})^n$ dependence. Macroscopically, the observed scaling of R_H and R_S is a consequence of the phase coherence length that is a power low of T, as derived by the ρ_{XX} vs T data. The derivation of a scaling law between the 3 scaling exponents is under investigation.

[1] M. P. Marder, Condensed Matter Physics (2nd Ed., 2010, Wiley, N. Jersey), p.552
[2] D. G. Bergman, Y. Kantor, D. Stroud, I. Webman, Phys. Rev. Lett. 50, 1512 (1983)



Scaling of R_H with c. Inset, R_H of Bi vs T.

12.00 – 12.15
Large tunnel magnetoresistance effect in Self-Assembled Monolayers based magnetic tunnel junctions
M. Galbiati [1], S. Tatay [1], C. Barraud [1], P. Seneor [1], R. Mattana [1], K. Bouzehouane [1], C. Deranlot [1], E. Jacquet [1], A. Fert [1], F. Petroff [1]
(1) Unité Mixte de Physique CNRS/THALES (UMR137) associée à l'Université de Paris-Sud, 91767 Palaiseau Cedex, France

Molecular spintronics, the combination of chemistry potential to the spin degree of freedom provided by spintronics, is considered to be more than an alternative to conventional spintronics with inorganic materials. Unconventional properties and strong potentialities offered by the flexibility, chemical engineering and low production costs of molecules, add to the opportunity that spin lifetime could be enhanced by several orders of magnitude compared with inorganic materials. Very recently it has been highlighted that the metal/molecule hybridization could strongly influence interfacial spin properties going from spin polarization enhancement to its sign control in spintronics devices [1].
In this scenario, while scarcely studied [2] [3], self-assembled monolayers (SAMs) seem to be the perfect toy barriers to further test these tailoring properties in molecular magnetic tunnel junctions (MTJs) since they are composed by a head, a body and an anchoring group that can be independently tuned thus allowing an easy engineering of the barrier.
We present nanodevices based on SAMs used as tunnel barrier grafted on the half-metallic manganite (La,Sr)MnO3 (LSMO). The prepared LSMO/SAMs/Co magnetic tunnel junctions

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present an area of only few 10 nm^2 to allow the study of the local properties of the system and to avoid defects inside the barrier. We observe a large tunnel magnetoresistance effect at low temperature. We study its dependence on temperature and bias voltage finding that the signal is quite robust. This confirms the high quality of the devices and unravels the potential of self-assembled monolayers as tunnel barrier for conventional spintronics applications and beyond.
Financial support: EU (FP7/2007-2013) project HINTS and IEF Marie-Curie actions (FP7/2007-2013) project NANOCON.

[1] C. Barraud, Nature Phys. 6, 615 (2010)
[2] W. Wang, Appl. Phys. Lett. 86, 153105 (2006)
[3] J. R. Petta, Phys. Rev. Lett. 93, 136601 (2004)

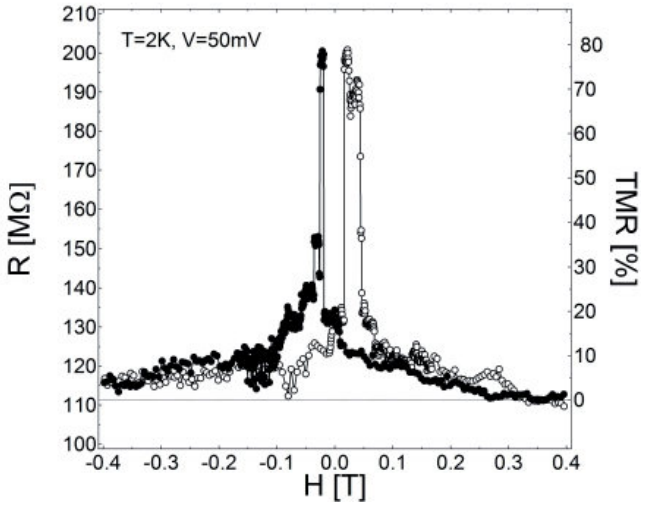

Figure 1 R(H) characterization of a LSMO/SAM/Co nanojunction at T=2K.

12.15 – 12.30
Existence of a magnetically ordered hole gas at the $La_{0.7}Sr_{0.3}MnO_3/SrRuO_3$ interface
M. Ziese [1], F. Bern [1], E. Pippel [2], D. Hesse [2], I. Vrejoiu [3]
(1) Division of Superconductivity and Magnetism, University of Leipzig, 04103 Leipzig, Germany, (2) Max Planck Institute of Microstructure Physics, 06120 Halle, Germany, (3) Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany

The study of spatially confined complex oxides is of wide interest, since correlated electrons at interfaces might form new states of matter. Here $La_{0.7}Sr_{0.3}MnO_3/SrRuO_3$ superlattices with coherently grown interfaces and layer thicknesses down to 1 unit cell were fabricated by pulsed laser deposition. The superlattices were studied by X-ray, AFM, HRTEM, magnetization and magnetotransport measurements. For such small thicknesses $La_{0.7}Sr_{0.3}MnO_3$ films are antiferromagnetic and insulating [1,2]. Despite the small layer thickness, the $La_{0.7}Sr_{0.3}MnO_3$ layers in the superlattices were ferromagnetic with Curie temperatures close to room temperature. Whereas the resistivity of the superlattices showed metallic behaviour and was dominated by the conducting $SrRuO_3$ layers, the off-diagonal resistivity showed an anomalous Hall effect with ferromagnetic loop shape even far above the Curie temperature of the $SrRuO_3$ layers. This indicates the presence of a highly conducting two-dimensional hole gas at the interfaces, which has an extension into the $La_{0.7}Sr_{0.3}MnO_3$ layers of only a few unit cells. The hole gas might be formed by a magnetic proximity effect. This result opens up an alternative route for the fabrication of two-dimensional systems

[1] Z. Fang et al., Phys. Rev. Lett. 84, 3169 (2000)
[2] M. Huijben et al., Phys. Rev. B 78, 094413 (2008)

12.30 – 12.45
Epitaxial growth of Fe_3O_4 films on free-standing bulk GaN (0001)
G. Simon [1], *I. Lucas* [2], J.M. De Teresa [3], M.R. Ibarra [4], P.A. Algarabel [2], J.A. Párdo [5], L. Morellón [1]
(1) INA/Dpto. Física de la Materia Condensada, Universidad de Zaragoza, 50018/50009 Zaragoza, Spain, (2) ICMA, Universidad de Zaragoza-CSIC. Dpto. Física de la Materia Condensada, 50009 Zaragoza, Spain, (3) ICMA/LMA-INA, Universidad de Zaragoza-CSIC. Dpto. Física de la Materia Condensada, 50009/50018 Zaragoza, Spain, (4) INA, LMA-INA, Universidad de Zaragoza. Dpto. Física de la Materia Condensada, 50009 Zaragoza, Spain, (5) INA, Dpto. de Ciencia de Materiales y Tecnología, Universidad de Zaragoza, 50018 Zaragoza, Spain

Ferromagnet-semiconductor (FM/SC) hybrid structures have attracted considerable interest as they offer substantial advantages for spin injection applications. Semiconductor spintronic devices demand a ferromagnetic electrode to inject spin polarized carriers into the SC material but the large conductivity mismatch between both materials usually produces an inefficient spin injection. Therefore, good candidates to overcome this problem are the so-called half-metallic magnetic oxides due to their potential high spin polarization and their low conductivity values. The inverse spinel Fe_3O_4 (magnetite) fits these criteria due to its strong measured spin polarization at the Fermi level [1], low conductivity at RT ($\sigma\sim 200\ \Omega^{-1}cm^{-1}$) and high T_c of about 860 K [2].
In this work, we have focused on the epitaxial growth of Fe_3O_4 thin films on free-standing bulk GaN(0001) substrates [3] by pulsed laser deposition (PLD). Here we show structural, magnetic and transport properties of these hybrid structures comparing the transport measurements with those obtained for Fe_3O_4 grown on insulating MgO (100) substrates [4]. Magnetite grown on GaN and MgO show no big differences with respect to the conductivity values (Fig.1). Sharp Verwey transitions have been found for samples with thickness higher than 18 nm. Besides, no in-plane magnetic anisotropy has been found for the Fe_3O_4//GaN samples showing H_c values up to 600 Oe depending on the thickness. Magnetoresistance has been measured for these samples, indicating the presence of anti-

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phase boundaries (APB´s). This is in contradiction with recent results of samples grown by MBE on GaN templates [5].

[1] Yu. S. Dedkov, et al., Phy. Rev. B. **65**, 064417 (2002)
[2] A. Nielsen, et al., Appl. Phys. Lett. **93**, 1642510 (2008)
[3] http://www.kymatech.com/
[4] A. Fernández-Pacheco et al., Phys. Rev. B **78,** 212402 (2008)
[5] P. K. J. Wong, et al., Phy. Rev. B. **81**, 035419 (2010)

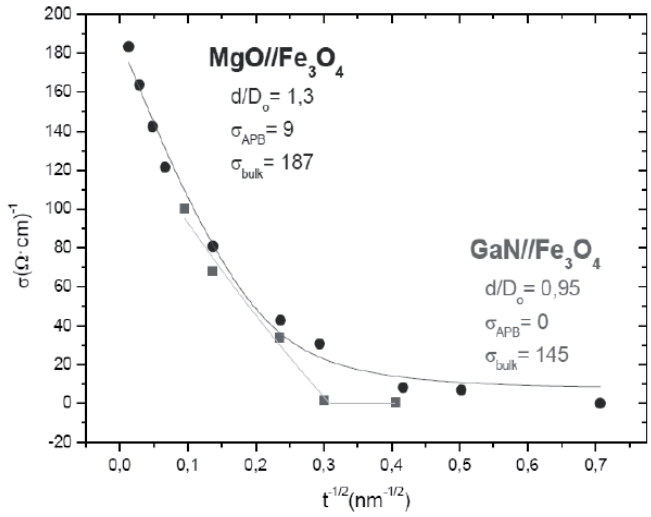

Fig.1. Comparison of conductivity values versus thickness for magnetite samples grown on GaN(0001) and MgO(100)

12.45 – 13.00

Exchange bias with hexagonal Mn_3Ga - a new triangular antiferromagnet

H. Kurt [1], K. Rode [1], H. Tokuc [1], M. Venkatesan [1], P. Stamenov [1], J.M.D. Coey [1]
(1) School of Physics and CRANN, Trinity College, Dublin 2, Ireland

We investigate the use of antiferromagnetic ε-Mn_3Ga (0001) epitaxial films for exchange biasing a $Co_{90}Fe_{10}$/Ru/CoFeB synthetic antiferromagnet in magnetic tunnel junctions (MTJs) with MgO barriers. This triangular antiferromagnet is epitaxially grown by magnetron sputtering on a Ru seedlayer at a substrate temperature of 400°C, well above its Néel temperature [1]. The exchange bias can be set by field-cooling from 100°C, providing a large exchange bias field of H_{ex} =150 mT. A representative tunneling magnetoresistance (TMR) curve is shown in Figure 1a for a MTJ annealed at 300°C. TMR values at room temperature reach up to 200%, which decreases at lower annealing temperatures due to a lower degree of crystallization of the CoFeB electrodes (Figure 1b). The H_{ex} decreases with higher annealing temperatures due to the degradation of the antiferromagnetic/ferromagnetic interface by atomic diffusion or alloying. This new antiferromagnet could be useful for pinning magnetic layers in magnetic tunnel junction sensors and memories requiring low annealing temperatures.

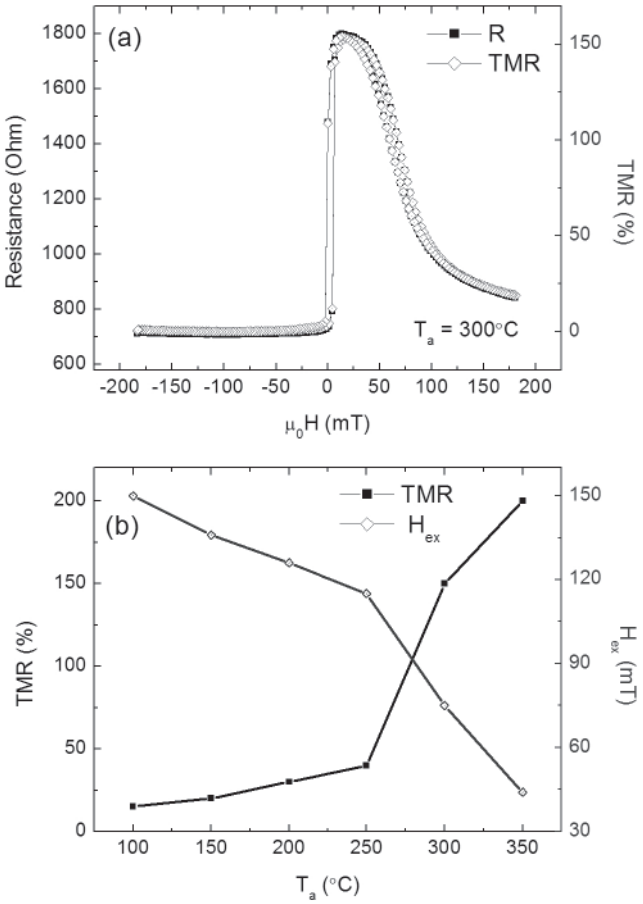

Figure 1 (a) A representative TMR curve for a MgO-MTJ pinned with ε-Mn_3Ga (b) The variation of H_{ex} and TMR with annealing temperature.

[1] E. Krén, and G. Kádár, Solid State Communications **8**, 1653 (1970)

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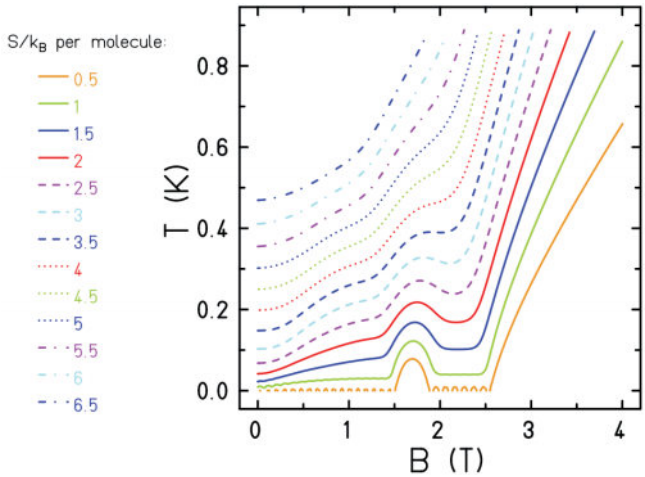
10.30 – 11.00
Magnetocaloric properties of gadolinium based magnetic molecules studied by the Finite Temperature Lanczos Method *(invited)*
J. Schnack [1]
(1) Bielefeld University/Department of Physics/P.O. box 100131/D-33501 Bielefeld, Germany

The magnetocaloric effect enables one to heat or cool by varying the applied magnetic field. Magnetic molecules with a high density of low-lying high spin multiplets are especially desirable in this context since they lead to big entropy changes when sweeping the field isothermally [1].
In this contribution we discuss the magnetocalorics of various gadolinium based heterometallic molecules. Because of the large spin of gadolinium, molecules acquire large Hilbert spaces already with a few Gd ions. For this reason we evaluate their thermodynamic properties by means of the Finite-Temperature Lanczos Method [2]. This method generates very accurate approximations of thermal observables for Hilbert space dimensions of up to 10^{10} and is not restricted to non-frustrated systems as is the case for Quantum Monte Carlo calculations [3].

[1] T. N. Hooper, J. Schnack, St. Piligkos, M. Evangelisti, and E. K. Brechin, Angew. Chem. Int. Ed. (2012) in print.
[2] J. Jaklič and P. Prelovšek, Phys. Rev. B 49, 5065–5068 (1994)
[3] J. Schnack and O. Wendland, Eur. Phys. J. B 78 (2010) 535-541



Typical behaviour of constant entropy curves: in a process of adiabatic demagnetization one would run along one of the curves and e.g. cool by switching off the field.

11.00 – 11.15
Direct Access to the Spin Correlations within Zero Dimensional Spin Systems
T. Guidi [1], M. Baker [2], S. Carretta [3], G. Timco [4], H. Mutka [5], J. Ollivier [5], P. Santini [3], G. Amoretti [3], D. Collison [4], E.J.L. McInnes [4], H. Güdel [6], R.E.P. Winpenny [4]
(1) ISIS facility, Rutherford Appleton Laboratory, Didcot, United Kingdom, (2) Institute for Material Research, Tohoku University, Sendai, Japan, (3) Dipartimento di Fisica, Universita' di Parma, Parma, Italy, (4) School of Chemistry, The University of Manchester, Manchester, United Kingdom, (5) Institut Laue-Langevin, Grenoble, France, (6) Department of Chemistry and Biochemistry, University of Bern, Bern, Switzerland.

Molecular nanomagnets (MNM) are model systems to study the spin dynamics and magnetic correlations in low dimensional magnets. Polycrystalline inelastic neutron scattering experiments are generally used to probe the spin dynamics of MNM through the position and the neutron momentum transfer Q dependence of the magnetic peaks. However, the random orientation of the crystallites results in an orientation average of the magnetic signal and therefore only the amplitude of scattering with respect to the modules of Q is obtained and part of the information is lost. On the other hand, when measuring single crystals, all the information expressed within the scattering profile may be exploited. Inelastic neutron scattering experiments on single crystals of a model Cr_8 antiferromagnetic ring have been used to directly determine the Fourier components of the two-spin dynamical correlation functions at a given frequency. We measured a large portion of $S(\mathbf{Q}, \omega)$ and we demonstrated that from the fit of the $S(\mathbf{Q})$ at a fixed energy transfer it is possible to univocally extract the two-spin correlation functions. The experimentally determined magnetic correlations are found to be in good agreement with the values calculated using the spin Hamiltonian formalism. The described method can be used to determine the dynamical spin correlations when the Hilbert space is too large to perform calculations using the microscopic spin Hamiltonian.

11.15 – 11.30
Accurate first-principles studies of iron-based molecules
A. Droghetti [1], D. Alfe' [2], S. Sanvito [1]
(1) School of Physics and CRANN, Trinity College, Dublin 2, Ireland, (2) London Centre for Nanotechnology, Dept. of Earth Sciences, Dept. of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, UK

Spin crossover (SC) complexes have recently emerged as promising systems for implementing molecular spintronics devices. In fact, the current-voltage characteristic curve depends sensibly on the molecule magnetic moment and, therefore, this can be inferred by an electrical readout [1].
We will discuss several issues connected to the accurate prediction of the molecules' energetic and we will present our recent results based on the diffusion Monte Carlo method. These demonstrate that the ground state of the SC molecules is different in the gas and the in solid phase [2]. We also assess the performances of density functional theory and we argue that the low spin state is usually over-stabilized, not only by the (semi-)local functionals, but even by the most common hybrids (such as B3LYP and PBE0). We then propose that

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reliable results can be obtained by using hybrid functionals with about 50% of exact-exchange [2].
Finally we will also present some preliminary results concerning the electronic structure of the Fe_4 molecular nanomagnet [3].

[1] N. Baadji and S. Sanvito, arXiv:1201.2028v1
[2] A. Droghetti, D. Alfe' and S. Sanvito, in preparation
[3] M. Mannini et al., Nature Materials 8, 194 (2009)

11.30 – 11.45
Magnetic Anisotropy in Single Molecule and Single Chain Magnets Containing Transition Metal and Lanthanide Ions: Experimental
A. Palii [1], S. Ostrovsky [1], O. Reu [1], P. Tregenna-Piggott [2], O. Zaharko [3], W. Wallace [3], R. Clerac [4], K. Dunbar [5], B. Tsukerblat [6], *S. Klokishner* [1]
(1) Institute of Applied Physics, Academy of Sciences of Moldova,MD 2028,Kishinev,Moldova, (2) deceased, (3) Paul Scherrer Institute , 5232 Villigen, Switzeland, (4) Centre de Recherche Paul Pascal,F-33600, Pessac, France, (5) Department of Chemistry, Texas A&M University,TX 77842-3012,College Station,USA, (6) Chemistry Department,Ben-Gurion University of the Negev,P.O.B 653,Israel

In the present report we present the results of our combined experimental (magnetic measurements, INS spectra) and theoretical studies of single molecule (SMM) and single chain (SCM) magnets incorporating 3d and 4f ions. We demonstrate that: (i) for the $[Cu^{II}LTb^{III}(hfac)_2]_2$ cluster [1] the SMM behavior is not a sole consequence of the low-lying levels of the lanthanide ion but a property of the tetranuclear cluster itself. The interplay between the crystal field acting on the Tb^{III} ions and the ferromagnetic Heisenberg-type exchange between the Tb^{III} and Cu^{II} ions produces a barrier for reversal of magnetization. Based upon this study, recommendations are formulated on how the SMM properties for nd-4f clusters may be further improved; (ii) for the trinuclear $\{[L_2Co_2Tb][NO_3]\}$ (LH_3 = (S)P[N(Me)N=CH-C_6H_3-2-OH-3-OMe]$_3$ [2] and the mononuclear $[(Pc)_2Tb]^-\cdot TBA^+$[2] [3] SMMs the strong single-ion anisotropy of the Tb^{III} and Co^{II} ions is shown to be the reason for the observed slow magnetic relaxation ; (iii) the strong axial crystal field acting on the Co^{II} –ions, the spin-orbit interaction, antiferromagnetic exchange and the zig-zag structure of the $[Co(H_2L)(H_2O)]_{\square}$ chain give rise to a canted spin structure and subsequently to an uncompensated magnetic moment.

[1] S. Osa, T.Kido, N. Matsumoto, N. Re, A..Pochaba, J.Mrozinski, JACS 126,420 (2004).
[2] V. Chandrasekhar, B. M. Pandian, J. J. Vittal, R. Clerac, Inorg.Chem. 48,1148 (2009)
[3] N.Ishikawa, M.Sugita, T.Ishikawa, S.Koshihara, Y.Kaizu, J. Phys. Chem. B 108, 265 (2004).

11.45 – 12.00
New phenomena in magnetic deflagration on Mn_{12}-Ac single crystals
S. Velez [1], P. Subedi [2], *J. Tejada* [1], F. Macia [2], S. Li [3], M. Sarachik [3], S. Mukherjee [4], G. Christou [4], A. Kent [2]
(1) Grup de Magnetisme, Departament de Física Fonamental, Facultat de Física, Universitat de Barcelona, Martí i Franquès 1, planta 4, 08028 Barcelona, Spain, (2) Department of Physics, New York University, New York, New York 10003, USA, (3) Department of Physics, City College of New York, CUNY, New York, New York 10031, USA, (4) Department of Chemistry, University of Florida, Gainesville, Florida 32611, USA

Deflagration is a subsonic combustion process governed by thermal conductivity. Recently, it has been observed that molecular magnets exhibit explosive relaxation toward thermal equilibrium that resembles of a flame -deflagration- in which the role of the chemical energy stored in a flammable substance is played by the Zeeman energy. Experiments where avalanches in Mn_{12}-Ac are triggered at a fixed applied bias field have shown that the velocity of the front has maxima at resonant fields due to resonant quantum tunneling of magnetization. During an avalanche, the heat released by the flipping spins of molecules accelerates the relaxation of their neighbors resulting in a subsonic dynamic reversion controlled by a heat propagation law. This phenoma has been also confrmed to occur in manganese based oxides and intermetallic compounds as Gd_5Ge_4, where fast colosal jumps in the magnetoresistance and a magnetoestructural transitions have been proved to occur simultaneous to the magnetic deflagration process, respectively. Using time resolved measurements of local magnetization by an array of micron sized Hall sensors at temperature of 400 mK, and with the use of a 3D vector magnet, we present measurements of triggered avalanches in a Mn_{12}-Ac single crystal in the presence of a small bias magnetic field and under the application of a variable transverse field. For the first time, triggered avalanches at a small bias show that both the ignition time and the speed of the propagating front strongly depend on the initial state of the system. In addition, the speed of the avalanche has been found not to be constant along the sample and incomplete avalanches have been detected below certain Hz value. Finally, for small enough applied bias magnetic field, another regime of magnetic avalanches has been observed. All these observations strongly depend on the strength of the transverse applied magnetic field

12.00 – 12.15
A Switchable Molecular Rotator: a Spin-Crossover Compound comes into the Field of Molecular Machines
J.A. Rodríguez-Velamazán [1], J.A. Real [2], M. Ohba [3]
(1) Instituto de Ciencia de Materiales de Aragón, CSIC-Universidad de Zaragoza, 50009, Zaragoza, Spain @ Institut Laue Langevin, Grenoble Cedex 38042, France, (2) Instituto de Ciencia Molecular (ICMol), Universidad de Valencia, 46980 Paterna, Valencia, Spain, (3) Department of Chemistry, Faculty of Science, Kyushu University, Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

One of the main features of molecular materials is the possibility of combining different properties in a synergic way giving a multifunctional material. Spin-crossover (SCO) compounds are particularly interesting to obtain these combinations of properties since their molecular bistability can be used to switch a second physical property by applying an external perturbation

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(temperature, pressure or light irradiation). Here we report the possibility of switching the rotational motion of a molecular fragment when switching the spin state by one of the mentioned external stimuli. A quasielastic neutron scattering and solid state ^{2}H-NMR spectroscopy study of the polymeric spin crossover compound {Fe(pyrazine)[Pt(CN)$_4$]} shows that the switching of the rotation of a molecular fragment – the pyrazine ligand – occurs in association with the change of spin state.[1] Therefore, coming from the field of spin-crossover compounds, this system meets other of the most exciting branches of crystal engineering nowadays, as is the construction of crystalline molecular rotators in the quest for artificial crystalline molecular machines.[2] The rotation switching was examined on a wide timescale (10^{-13} – 10^{-3} s) by both techniques, which clearly demonstrated the combination between molecular rotation and spin crossover transition under external stimuli (temperature and chemical). The pyrazine rings are seen to perform a 4-fold jump motion about the coordinating nitrogen axis in the high spin state. In the low spin state, however, the motion is suppressed, while when the system incorporates benzene guest molecules, the movements of the system are even more restricted.

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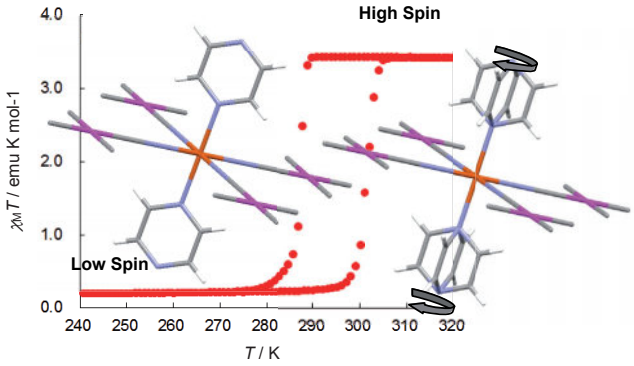
[1] J.A. Rodríguez-Velamazán et al., J. Am. Chem. Soc., 134, 5083−5089 (2012).
[2] Molecular Machines, Vol. 262, in Topics in Current Chemistry (Ed. T. R. Kelly), Springer, Berlin, (2005).



Temperature dependence of $\chi_M T$ for {Fe(pyrazine)[Pt(CN)$_4$]} and representation of the structure with the rotation of the pyrazine rings

12.15 – 12.30
Quantum entanglement in heterometallic wheels
I. Siloi [1], F. Troiani [2]
(1) Istituto Nanoscienze-CNR, S3,41125 Modena, Italy; Dipartimento di Fisica, Università di Modena e Reggio Emilia, 41125 Modena, Italy, (2) Istituto Nanoscienze-CNR, S3,41125 Modena, Italy

Molecular nanomagnets represent a varied class of spin systems, whose physical and structural properties can be tailored by chemical synthesis. This – together with quantum coherence at low temperature – makes them an ideal playground for investigating quantum entanglement [1]. In spite of these potentialities, entanglement in molecular nanomagnets is still a largely unexplored subject [2]. Here we focus on the case of Cr$_7$M wheels, with dominant antiferromagnetic exchange. In particular, we investigate the role played by the chemical substitutions M=Zn, Cu, Ni, Fe, Mn in localizing pairwise entanglement, which we quantify by numerically evaluating the entropy of formation of neighboring spins [3]. We find that pairwise entanglement is strongly modulated by the chemical substitutions, and that such modulations follow two characteristic patterns, depending on whether $s_M < s_{Cr}$ or $s_M > s_{Cr}$ (see figure). Besides, entanglement witnesses – such as internal energy and magnetic susceptibility – are used to identify the temperature range where the Cr$_7$M wheels present thermal (i.e. equilibrium state) entanglement. We find that in all the considered systems – including Cr$_8$ – entanglement persists for values of T at which pairwise entanglement vanishes. This allows to state the presence of (at least) tripartite entanglement in a significant range of temperatures.

[1] R. Horodecki, P. Horodecki, M. Horodecki, and K. Horodecki, Rev. Mod. Phys. 81, 865 (2009).
[2] A. Candini, G. Lorusso, F. Troiani, A. Ghirri, S. Carretta, P. Santini, G. Amoretti, C. Muryn, F. Tuna, G. Timco, E. J. L. McInnes, R. E. P. Winpenny, W. Wernsdorfer, and M. Affronte, Phys. Rev. Lett., 104,037203 (2010).
[3] B. Rothlisberger, J. Lehmann and D. Loss, Phys. Rev. A, 80, 042301 (2009).

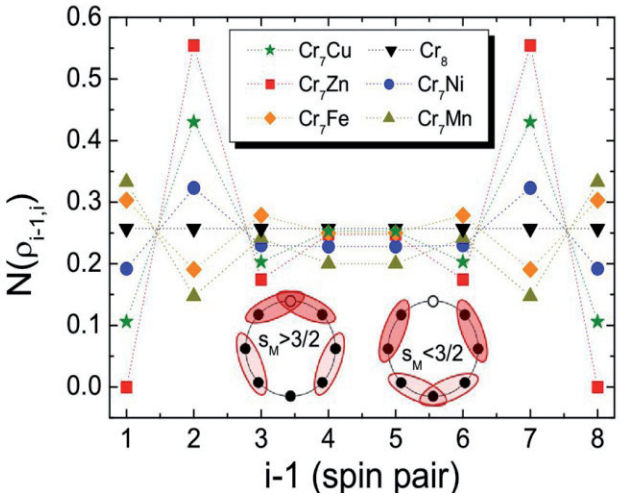


Figure: Negativity as entanglement measure for pairs of neighboring spins in the Cr7M wheels.

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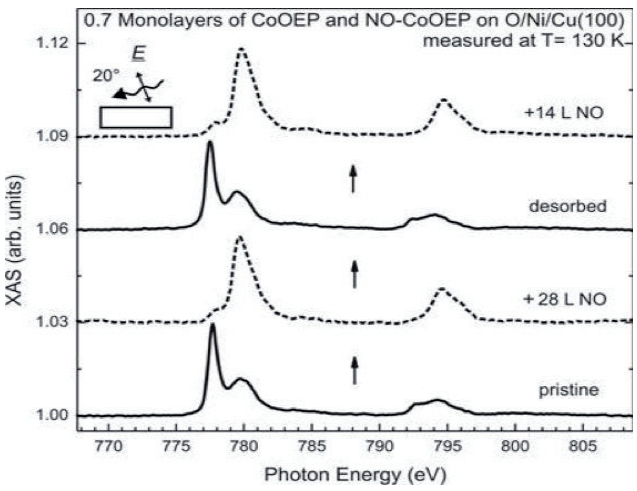
12.30 – 12.45

Tuning the electronic and magnetic properties of adsorbed Co porphyrin molecules by NO as an axial ligand

C.F. Hermanns [1], M. Bernien [1], A. Krüger [1], W. Walter [1], J. Miguel [1], Y. Chang [1], W. Kuch [1]
(1) Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Metalloporphyrin molecules consist of a metal ion, surrounded by a planar porphyrin ligand and two axial coordination sites, which can be occcupied by additional ligands like small molecules or a metal surface. This allows to tune the electronic and magnetic properties of the ion.
Here, we report on X-ray absorption spectroscopy (XAS) measurements of submonolayers of Co octaethlyporphyrin (CoOEP) molecules and NO-CoOEP nitrosyl complexes on bare and oxygen-covered Ni films grown on Cu(100). Angle-dependent N K edge XAS measurements reveal a quasi-flat adsorption of CoOEP on both substrates. By means of CoL3,2 X-ray magnetic circular dichroism (XMCD) we demonstrate how the ferromagnetic substrate, as an additional axial ligand to the CoOEP molecules, induces a magnetic ordering on the spins of the Co ions, which are on both substrates parallel aligned to the Ni magnetization. From the line shape and the energetic position of the Co L3 XA edge a +2 oxidation state of the Co ions for CoOEP on O/Ni/Cu(100) is concluded, just as for isolated CoOEP, despite the interaction with the substrate, while for CoOEP on bare Ni films a partial reduction of the Co ions is deduced.
The adsorption and thermal desorption of NO as second axial ligand to CoOEP on O/Ni/Cu(100) enables the reversible switching of the electronic properties of the Co ions, as demonstrated in fig. 1 by the NO-induced line-shape changes of the Co L3,2 XA spectra. NO-CoOEP nitrosyl complexes exhibit on both substrates a reduced Co XMCD signal at finite temperatures compared to the ones of the CoOEP molecules, whereas Co L3,2 XAS measurements also reveal an NO-induced partial oxidation of the Co ions.
This work is supported by the DFG (Sfb 658).



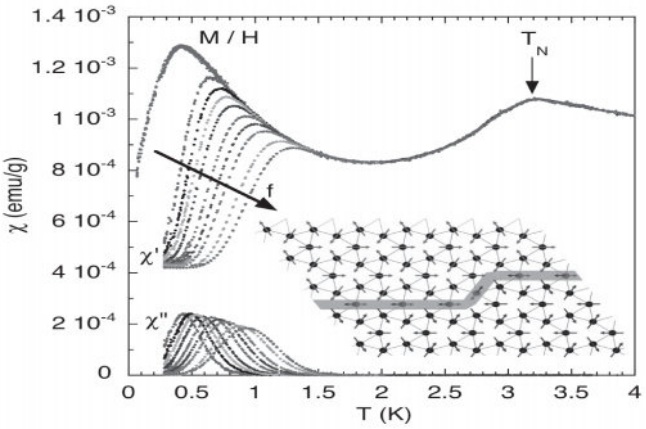
12.45 – 13.00

Magnetic sea ice like phase in new quinternary oxalates kagomé antiferromagnets

E. Lhotel[1], V. Simonet[1], J. Ortloff[1], B. Canals[1], C. Paulsen[1], E. Suard[2], T. Hansen[2], D.J. Price[3], P.T. Wood[4], A.K. Powell[5], R. Ballou[1]
(1) Institut Néel, CNRS, 38042 Grenoble, France, (2) Institut Laue Langevin, 38042 Grenoble, France, (3) WestCHEM, School of Chemistry, University of Glasgow, Glasgow, G12 8QQ, United Kingdom, (4) Chem Lab, University of Cambridge, Cambridge CB2 1EW, United Kingdom, (5) Institute of Inorganic Chemistry and Institute for Nanotechnologie, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany

Using hydrothermal methods we have synthesized a new family of kagomé antiferromagnets of composition $Na_2Ba_3[Fe^{II}_3(C_2O_4)_6][A^{IV}(C_2O_4)_3]$ where A^{IV}=Sn^{IV} or Zr^{IV}. The compounds crystallize in the P321 space group in which the Fe^{II} ions form a distorted kagomé lattice, topologically equivalent to a perfect kagomé one if nearest-neighbour interactions only are considered. The in plane magnetic interactions between the Fe^{II} ions are mediated by unconventional oxalate coordination modes. Although these bridgings lead to rather weak interactions, a remarkable magnetic behavior emerges from this frustrated lattice at low temperature.
First, at 3.2K, an antiferromagnetic transition occurs. We have shown by neutron diffraction that the magnetic moments lie in the kagomé planes and are orientated at 120° from each other in each triangle exhibiting a single magnetic chirality. This magnetic arrangement appears to stem from both the frustrated lattice and the Fe^{II} ions in-plane anisotropy.
Surprisingly, in the ordered phase, our AC susceptibility measurements evidence slow dynamics below 2K, which appear to bear close resemblance though in a two dimensional lattice, with the 1D single chain magnets and the 3D spin ice compounds dynamics. We have shown that in these first kagomé antiferromagnets with a strong magneto-crystalline anisotropy, the spin anisotropy combined with a low exchange path network connectivity lead to domain walls intersecting the kagome planes through strings of free spins. These produce the observed unfamiliar slow spin dynamics in the ordered phase, evolving from exchange-released spin-flips towards a cooperative behavior on decreasing the temperature [1]. This reveals a domain structure of independent magnetic grains: a magnetic analog of the mushy phase of sea ice or earth magma, namely porous solid media with fluid flowing inside interstices.

[1] E. Lhotel et al., Phys. Rev. Lett. 107, 257205 (2011).



χ_{AC} and M/H vs T. Inset: String of exchange-released spins between 180° AF domains.

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10.30 – 11.00
Magnetic living cells: new tools in biomedicine *(invited)*
F. Gazeau [1], *C. Wilhelm* [1]
(1) Laboratory Matière et Systèmes Complexes (MSC) / CNRS and University Paris Diderot / 75013, Paris, France

Magnetic tagging of cells raises up increasing interest due to the various biological or medical applications involving magnetism in living organisms.
Cells containing iron oxide nanoparticles can be tracked by clinical Magnetic Resonance Imaging (MRI) [1]. Beyong imaging, magnetic forces on cells in vitro can be used to sort cells [2], to control cell migration [3] or to force tissue formation [4]. Magnetic targeting of cells in vivo may also be performed to enhance cell therapy [5]. Magnetic nanoparticles inside cells have also revealed themselfves as useful manipulable probes to explore the local mechanical properties of the cell interior [6].
The main requirement for such biophysics and biomedical applications is to supply cells with sufficient magnetization to be detectable by MRI or manipulated by magnetic forces, while maintaining cell viability and functionalities [7]. In particular, the impact of such magnetic labeling on cell behaviors, as stem cell differenciation capabilities must be carefully checked.
By contrast, magnetic nanoparticles can finally be used as therapeutic agents to destroy cancer cells through the magnetic hyperthermia modality [8].

[1] P. Smirnov et al. Magn. Res. Med. 60, 1292 (2008)
[2] N. Pamme and C. Wilhelm. Lab on a Chip. 6, 974 (2006); D. Robert et al. Lab on a Chip. 11, 1902 (2011)
[3] C. Wilhelm et al. Phys Rev E 75, 041906 (2007)
[4] G. Frasca et al. Langmuir. 25, 2348-2354 (2009).
[5] A. Chauderge et al. Cell Transplantation nov (2011); S. Lesieur et al. J Mat Chem 21, 14387 (2011)
[6] C. Wilhelm. Phys Rev Lett 101, 028101 (2008); D. Robert et al. PLoS ONE 5, e10046 (2010); D. Robert et al. Phys Rev E 85, 011905 (2012)
[7] C. Wilhelm and F. Gazeau, Biomaterials 29, 3161 (2008);
[8] J-P. Forting et al. JACS 129, 2628 (2007); F. Gazeau et al. Nanomed. 3, 831 (2008)

11.00 – 11.15
X-ray absorption study of magnetic iron oxide nanoparticles prepared by two pot synthesis
A. Espinosa [1], Á. Muñoz-Noval [2], A. Figuerola [3], T. Pellegrino [3], A. Serrano [2], M. García-Hernández [1], C. Wilhelm [4], F. Gazeau [4], M.Á. García [2]
(1) Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Cantoblanco, 28049 Madrid, Spain, (2) Instituto de Cerámica y Vidrio (ICV-CSIC), Cantoblanco, 28049 Madrid, Spain, (3) Istituto Italiano di Tecnologia, via Morego 30, 16163 Genova, Italy, (4) Laboratoire Matière et Systèmes Complexes (MSC), UMR 7057, CNRS and Université Paris Diderot, 10 rue Alice Domon et Léonie Duquet, 75205 Paris cedex 13, France

In the last decades, the research of magnetic nanoparticles (NPs) has been greatly motivated by their multiple applications in biomedicine as drug delivery and hyperthermia treatment [1, 2]. In this work we investigate spherical-shaped iron oxide nanoparticles (IONPs) prepared by two-pot synthesis approach with a size range between 6 and 18 nm. The IONPs are highly monocristalline and monodisperse. However, in spite of its excellent cristallinity, magnetic measurements confirmed low saturation magnetization values, which are progressively reduced as the particle size increases [3]. A qualitative change in magnetic parameters at 10 nm size together with the appearance of exchange bias are detected. This effect is due to the formation of a magnetically poor shell from the initial seed that enhances the anisotropy and produces a dramatic effect on the heating power of the nanoparticles. The correlation between these results with its structural and electronic properties as the particle size increases was studied with X-ray absorption spectroscopy (XAS) at the K-edge (E=7112 eV) in XANES and EXAFS regimes. XAS in is a powerful technique to study the valence state, the composition and local environment of the Fe in the IONPs and it is able to distinguish between the ferromagnetic spinel phases as magnetite or maghemite, which present the same structure. A step decrease of the iron oxidation with the particle growth revealed structural changes as a consequence of the synthesis method, which is not suitable for hyperthermia applications.

[1] Q. A. Pankhurst, J. Connolly, S. K. Jones, J. Dobson. J. Phys. D: Appl. Phys. 36, R167 (2003).
[2] A. K. Gupta, M. Gupta. Biomaterials 26, 3995 (2005).
[3] M. Levy, A. Quarta, A. Espinosa, A. Figuerola, C. Wilhelm, M. Garcia-Hernandez, A. Genovese, A. Falqui, D. Alloyeau, R. Buonsanti, P. D. Cozzoli, M. A. Garcia, F. Gazeau and T. Pellegrino. Chem. Mat. 23, 4170 (2011).

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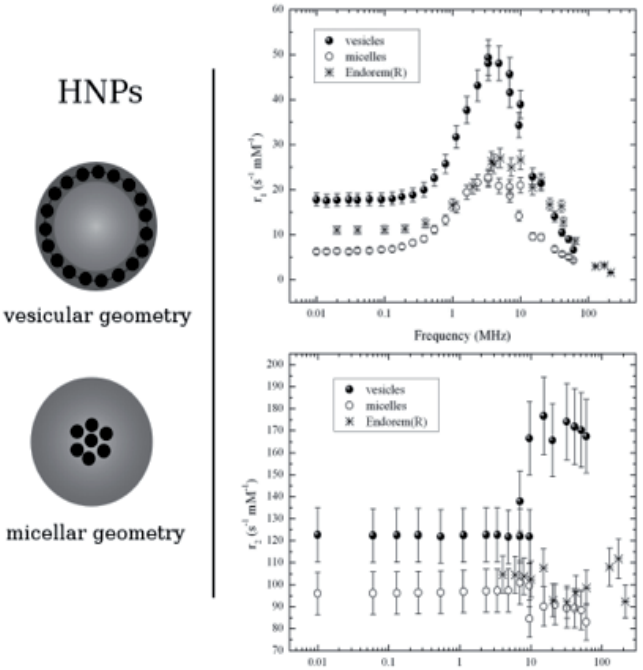
11.15 – 11.30
Hybrid iron oxide-copolymer nanoparticles as improved contrast agents for magnetic resonance imaging
P. Arosio [1], F. Orsini [1], M. Corti [2], L. Bordonali [2], *T. Orlando* [3], C. Innocenti [4], C. Sangregorio [4], J. Thévenot [5], H. De Oliveira [5], O. Sandre [5], S. Lecommandoux [5], A. Lascialfari [1]
(1) Department of Molecular Sciences Applied to Biosystems, Università degli Studi di Milano, and INSTM, I-20134 Milano, Italy, (2) Department of Physics, Università degli Studi di Pavia, and CNISM, I-27100 Pavia, Italy, (3) Department of Physics, Università degli Studi di Pavia, and Consorzio INSTM, I-27100 Pavia, Italy, (4) Department of Chemistry, Università di Firenze, and Consorzio INSTM, I-50019 Sesto F.no, Italy, (5) ENSCPB, Université de Bordeaux/IPB, F-33607 Pessac Cedex, France

Hybrid copolymer nanoparticles (HNP) of either micellar (filled sphere) or vesicular (hollow sphere) geometry have been loaded with non-toxic maghemite (γ-Fe_2O_3) ultrasmall superparamagnetic nanoparticles (USPIO)[1].
Both types of self-assembly hybrid nanoparticles are obtained by "nanoprecipitation" with two different block copolymers sharing common features e.g. amphiphilicity, biocompatibility and biodegradability; all the samples are characterized by narrow and symmetrical size distributions typical of fairly monodisperse samples. After a standard chemico-physical characterization, NMR and SQUID measurements were performed, in order to investigate the magnetic properties of the HNPs.
The NMR relaxometry profiles (in the frequency range 10 kHz $\leq \nu \leq$ 60 MHz) and the ZFC-FC curves confirm the strong superparamagnetic behaviour of these HNPs.
All the longitudinal relaxivity curves (r_1 vs ν) are flat at low frequencies, show a maximum around 10 MHz and then rapidly decrease for higher frequencies. The Néel relaxation, dominating at low frequencies and induced by the reversal of the magnetization through the nanoparticles magnetic anisotropy energy barrier, and the Curie relaxation, predominating at higher frequencies, are the physical mechanisms governing the nuclear relaxation. Our data can be fitted with a heuristic model of the proton relaxation induced by superparamagnetic nanoparticles[2]. Regarding the transverse relaxivity, whatever the HNPs geometry we found that our nanostructures exhibit r_2 values higher than those of commercial contrast agents, which make them promising for clinical use in MRI.
Furthermore, the insertion of a specific drug on the surface of the nanoparticles was successfully achieved: this is a first and fundamental step towards the building of a multifunctional nanostructure for medical purpose.
EU-FP7 Nanother project no. CP-IP 213631-2, is acknowledged for funding the above research.

[1] C. Sanson et al., ACS Nano. 5(2), 1122 (2011)
[2] A. Roch et al., J. Chem. Phys. 110(11), 5403 (1999)



HNPs geometry sketches (left) and relaxivity profiles (right)

11.30 – 11.45
Magnetic properties of a porous silicon/iron oxide system optimized for biomedical applications
K. Rumpf [1], P. Granitzer [1], P. Morales [2], P. Poelt [3], M. Reissner [4]
(1) Institute of Physics/Karl Franzens University Graz/8010 Graz/Austria, (2) Institute of Material Science Madrid/ CSIC/28049 Madrid/Spain, (3) Institute for Electron Microscopy/University of Technology Graz/8010 Graz/ Austria, (4) Institute of Solid State Physics/Vienna University of Technology/1040 Vienna/Austria

Iron oxide nanoparticles of 3.8, 5 and 8 nm in size have been infiltrated into the pores of porous silicon. The aim is to create a superparamagnetic (SPM) nanocomposite system with maximized magnetic field induced moment. Therefore the particle size versus the superparamagnetic behaviour has been figured out. The blocking temperature T_B which indicates the transition between superparamagnetic behaviour and blocked state is not only dependent on the particle size but also on the magnetic interactions between them which can be varied by the distance between the particles. The mesoporous silicon as well as the Fe_3O_4-nanoparticles offer low toxicity, thus the system is a promising candidate for biomedical applications [1]. The magnetic behavior of the nanocomposite has been examined with regard to the magnetic interactions between the particles within the pores. Dependent on the size but also the distance between the particles, which has been adjusted by the various concentrations, T_B has been shifted. Furthermore the modification of the porous silicon template results in a change of the transition temperature due to the variation of the particle distance of adjacent pores. To fabricate distinct composite systems suitable in biomedicine the porous silicon template as well as the loading of the pores with the particles has to be adjusted. The nanocomposite has to be superparamagnetic at room temperature but also to offer a magnetic moment as big as possible. To ensure that there is no remanence after the external field has been switched off, magnetic coupling between

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the SPM particles has to be sufficiently low. To achieve systems with distinct magnetic properties the variation of the particle size as well as of the concentration of the particle solution for the pore filling are possible routes.

[3] L. Gu, J.-H. Park, K.H. Duong, E. Ruoslahti, M.J. Sailor, *Small* **6**, 2546-2552 (2010).

11.45 – 12.00

Ferrimagnetic Maghemite Colloidal Nanocrystal Clusters: From Material Design to Imaging and Hyperthermia Treatment

A. Kostopoulou [1], A. Lappas [1], K. Brintakis [1], A. Douvalis [2], S. Velu [3], K. Thangavel [4], F. Orsini [4], A. Lascialfari [3], D. Sakellari [5], K. Simeonidis [5], M. Angelakeris [5], L. Manna [6]
(1) Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, 71110 Heraklion, Greece, (2) Department of Physics, University of Ioannina, 45110 Ioannina, Greece, (3) Dipartimento di Fisica "A.Volta",Universita degli Studi di Pavia, I-27100 Pavia/Dipartimento di Scienze Moleculari Applicate ai Biosistemi, Universita degli Studi di Milano, INSTM,I-20134 Milano,Italy, (4) Dipartimento di Scienze Moleculari Applicate ai Biosistemi, Universita' degli Studi di Milano, and INSTM, I-20134 Milano, Italy, (5) Department of Physics, Aristotle University, 54124 Thessaloniki, Greece, (6) Istituto Italiano di Tecnologia, 16163 Genova, Italy

Rapid advances in the chemical routes for the synthesis of high quality magnetic nanocrystals (NCs) and surface methods have opened new prospects in biomedicine. The ability of magnetic NCs to enhance MRI sensitivity and magnetic heating efficiency renders them promising candidates for diagnosis and therapy.
We investigate the hyperthermal and relaxometric properties of a complex, non-toxic magnetic nanoarchitecture, the hydrophilic Colloidal Nanocrystal Clusters (CNCs), assemblies of small primary NCs of maghemite (Scheme), which were prepared via a high-temperature polyol process [1]. The carboxylate functional group of the capping agent (polyacrylic acid) strongly coordinates the primary NCs making them negatively charged, while balancing electrostatic and magnetic forces determine the CNCs size. Complementary Mössbauer spectroscopy and SQUID magnetometry show that the CNCs in aqueous dispersions are ferrimagnetic and the strong dipolar intra-cluster interactions play a crucial role in their response. The proton NMR relaxometry curves, collected over a wide frequency range, show a four-time enhanced transverse relaxivity, r_2, compared to that of the superparamagnetic commercial contrast agent Endorem$^{(R)}$ (Figure 1a). Magnetically induced hyperthermia and its quantifiable measure, Specific Loss Power (SLP), are strongly correlated not only to the morphological, structural and magnetic profile of the individual nanoparticles, but to the magnetic intra-cluster interactions, as well. As CNCs grow in size they start to exhibit ferromagnetic features generating a different heat mechanism (hysteresis losses) with enhanced SLP values but they eventually (>50 nm) turn into multidomain particles where the heating efficiency is again diminished. (Figure 1b) [2]. As a consequence, such nanoarchitectures promote the multifunctional perspectives of iron-oxide nanomaterials in theranostic nanomedicine.

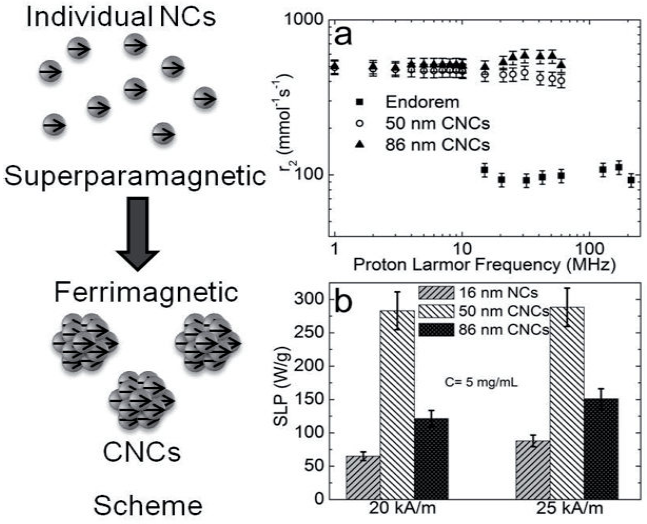

Figure 1. Relaxivity, r_2 (a) and Specific Loss Power, SLP, for Small NCs and CNCs (b).
[1] A. Kostopoulou et al., Photon. Nanostruct.: Fundam. Appl. 9, 201 (2011)
[2] L. Lartigue et al., J. Am. Chem. Soc 133, 10459 (2011)

12.00 – 12.30

Magnetic tool for in-vivo magnetic capture: Applications in blood filtering and proteomic diagnostics *(invited)*

F. Dumas-Bouchiat [1], A. Zaccaria [2], N.M. Dempsey [3], D. Givord [3], F. Berger [4]
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We have recently reported on the development of arrays of high performance micro-magnets (NdFeB, SmCo) on the one hand using a laser-based technique (Thermo-Magnetic Patterning) [1] and on the other hand using a lithography-based process (Topographic Patterning) [2]. The extrinsic magnetic properties (remanence, coercivity) of the µ-magnets are comparable to high quality commercial bulk magnets. A combination of Scanning Hall Probe Microscopy and simulations indicate that these µ-magnets produce stray magnetic field gradients as high as 10^6T/m [3].
Based on the high quality and on the autonomous nature of these µ-magnets, they are very well adapted to use in point-of-care devices to trap magnetic carriers and very small nanoparticles (down to the sub-10 nm size).
To study the trapping efficiency of µ-magnet-based systems, different magnetic structures were investigated ex-vivo in

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microfluidic devices [4] and fluid circulation with different micro/nano magnetic particles.
Based on these results, we have developed a specific magnetic tool, the "MAGPIE" (MAGnetic Probe for In-vivo Experiments) to trap magnetic carriers circulating in the human body (blood, cerebrospinal fluid).
In this communication, we will show results on the ex-vivo and in-vivo trapping of magnetic particles using such a tool. The efficiency of the device was tested using commercial MRI magnetic particles used today in humans.

[1] F. DUMAS-BOUCHIAT et al, *Applied Physics letters* 96 (2010) pp102511.
[2] A. WALTHER et al, **J***ournal of magnetism and magnetic material,* 321 (2009) pp590.
[3] M. KUSTOV et al, *Journal of Applied Physics* 108 (2010) pp063914.
[4] L.F. ZANINI et al, *Applied Physics Letters,* 99 (2011) pp232504.

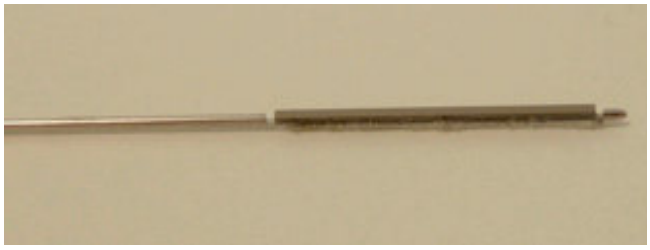

Fig.1 : Optical image of a MAGPIE implant (600µm×2cm) stuck on a cylindrical holder.

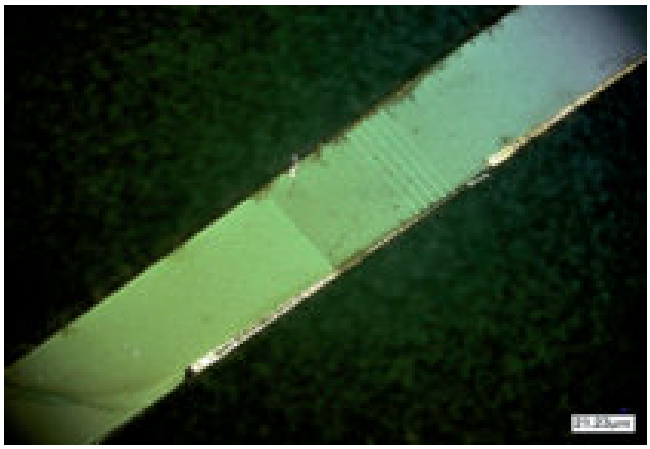

Fig.2: Optical image of a MAGPIE surface capture of MRI magnetic nanoparticles (30 nm) from circulating blood. The dark stripes constitute stacks of nanoparticles.

12.30 – 12.45
On-chip sorting of single magnetic particles in bifurcated networks of magnetic domain wall conduits
A. Torti [1], V. Mondiali [1], A. Cattoni [2], R. Bertacco [1]
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The manipulation of magnetic particles in suspension over a chip surface carrying molecules or biological entities is of overwhelming importance in biochemistry, biology and medicine. Recently the use of domain walls (DWs) in magnetic conduits has been proved to be a viable path to achieve highly controllable motion of single micro and nanoparticles, with spatial resolution down to 100 nm[1] and relatively high speed (up to mm/s).This method is based on the controlled motion of DWs in ferromagnetic stripes (magnetic conduits) which act as attracting poles for magnetic particles in suspension over the conduits. In this way the injection and displacement of a single DW in a ferromagnetic stripe results in the motion of the particle. The methods has been successfully applied to the manipulation of both biomolecules[1] stick on top of the magnetic particles and of cells[2] decorated by magnetic particles.
In this paper we demonstrate the on-chip sorting of individual magnetic particles (beads) at the bifurcation of a magnetic conduit for the propagation of DWs. We discuss the design, fabrication and the micromagnetic characterization of such a basic unit cell for the realization of complex networks. Calculations of the forces and mechanical torques acting on the particles, treated as extended objects above the magnetic conduits, are presented to support the design and the interpretation of experimental data. Finally the sorting of magnetic particles with micrometric diameter is demonstrated. At variance with other techniques for the on-chip manipulation of particles, our methods allow for fine manipulation of magnetic particles with diameter down to 250 nm, independently of the medium where they are propagating, and without perturbation of the viability of biochemical entities carried by the particles.

[1] *M. Donolato et al., Adv Mater.* ***2010****, 22, 2706-2710.*
[2] *M. Donolato et al., Lab Chip.* ***2011****, 11, 2976-2983.*

12.45 – 13.00
Magnetocardiography recordings with spintronic-based sensors
P. Campiglio [1], L. Caruso [1], E. Paul [1], A. Demonti [1], L. Azizi-Rogeau [1], L. Parkkonen [2], C. Fermon [1], M. Pannetier-Lecoeur [1]
(1) DSM/IRAMIS/SPEC - CNRS URA 2464, CEA Saclay, 91191 Gif-sur-Yvette, France, (2) Elekta Oy, 00530 Helsinki, Finland

Thanks to emerging technologies, new ultra-sensitive sensors have been proposed as an alternative to low-Tc SQUIDs. In particular, by combining in a unique device superconducting and magnetoresistive elements, a mixed sensor has been developed. Its detectivity at high frequencies is around few tens of fT/√Hz, while at low frequencies it is limited by the 1/f noise coming from the magnetoresistance. Thanks to their good sensitivity, mixed sensors are promising candidates to detect biomagnetic signals. We present here

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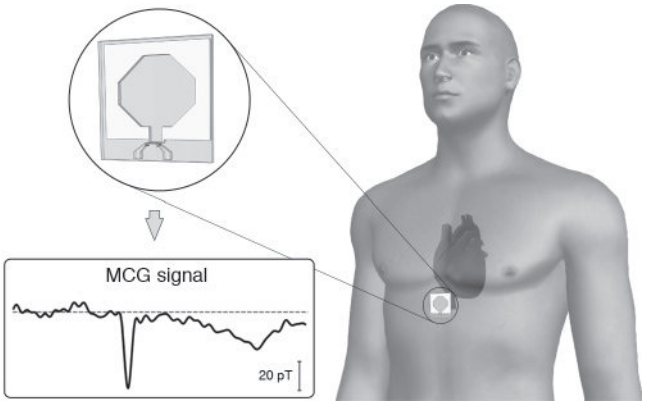
results in this direction, and in particular the recording of magnetocardiographic (MCG) signals. These were acquired in a shielded environment from a healthy volunteer. In a first stage a single channel acquisition system has been used [2], and now several mixed sensors are employed simultaneously. The principal features of the cardiac cycles are clearly visible in our MCG signals, as well as their spatial variations. Thanks to the feasibility of the measurement and their immunity against RF perturbations, mixed sensors could expand the clinical use of MCG. Moreover, if their sensitivity is further improved, the sensors will be able to detect magnetoencephalographic signals.

[1] M. Pannetier et al., Science 304, 1648 (2004)
[2] M. Pannetier-Lecoeur et al., Appl. Phys. Lett. 98, 153705 (2011)



Averaged MCG signal as recorded by a mixed sensor (inset) on a volunteer.

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SPIN EXCITATIONS AND ULTRAFAST DYNAMICS
Chair: M. Muzenberg

10.30 – 11.00
From modification to control of the spin order using ultrashort light pulses *(invited)*
E. Carpene [1], C. Piovera [2], C. Dallera [2], E. Puppin [3]
(1) CNR-IFN, Dip.to Fisica, Politecnico di Milano, 20133 Milano, Italy, (2) Dip.to Fisica, Politecnico di Milano, 20133 Milano, Italy, (3) CNISM, Dip.to Fisica, Politecnico di Milano, 20133 Milano, Italy

Femtomagnetism has become a well-established discipline of material research: it is based on the modification of the magnetic order triggered by ultrashort (tens of femtoseconds) optical pulses. The pioneering work of Beaurepaire et al. [1] revealed that a single laser pulse can reduce the magnetization of a Ni thin film by 50% on a time scale of 100 fs. Nowadays, the phenomenological aspects of the optically-induced demagnetization are undisputed, although the underlying physical mechanism is still controversial. Supported by the experimental evidence, we will illustrate one of the possible demagnetization scenario based on the electron-spin wave scattering. The ability to modify the magnetization on the sub-picosecond time scale has also important technological side-effects. The need for faster magnetic recording devices has driven researchers to seek efficient ways to reverse the magnetization. Several methods have been investigated to accomplish the most rapid spin reorientation and, to date, the precessional motion in an external field is the most effective route to control the magnetization in ferromagnets. Here, we show that using short laser pulses, the magnetization of a thin ferromagnetic layer can be optically and repeatedly commuted between well defined directions on a timescale of 100 picoseconds.

[1] E. Beaurepaire, J.-C. Merle, A. Daunois, and J.-Y. Bigot, Phys. Rev. Lett. **76**, 4250 (1996).
[2] E. Carpene, C. Piovera, C. Dallera, E. Mancini, E. Puppin, Phys. Rev. B **84**, 134425 (2011).

11.00 – 11.30
Ultrafast magnetization dynamics of Lanthanide ferromagnets *(invited)*
U. Bovensiepen [1]
(1) University of Duisburg-Essen, Faculty of Physics, Lotharstr. 1, 47048 Duisburg, Germany

Magnetization dynamics on ultrafast time scales is excited by femtosecond laser pulses and opened the fascinating field of magnetism under optically excited non-equilibrium conditions [1]. This dynamics is investigated using pump-probe experiments and transition metal ferromagnets and their compounds were studied in considerable detail. In this talk ultrafast magnetization dynamics of the lanthanides Gd, Tb, and their alloy will be presented. We employ the time-resolved magneto-optical Kerr effect, which is sensitive to 5*d* conduction electrons and their spin polarization [2]. To analyze the 4*f* magnetic moment

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we analyze the x-ray magnetic circular dichroism using the femtosecond slicing beamline at the synchrotron facility BESSY II in Berlin, Germany. We observe a two step demagnetization for Gd and Tb with an identical ultrafast demagnetization time of 750 fs and a slower quasi-equilibrium time, which differs for Gd (40 ps) and Tb (8 ps). This slower time scale is explained by the different quasi-equilibrium spin-lattice coupling for Gd and Tb. The ultrafast time scale is explained by spin-dependent scattering of hot conduction electrons [3]. We find these time scales also in the results of time-resolved MOKE experiments for Gd. In TbGd alloys we identified a continuous change in the quasi-equilibrium time scales as a function concentration while the ultrafast component remains constant. As an outlook a recently developed approach and the respective opportunities to probe and employ spin-dependent ballistic electron propagation through a layer stack Au/Fe/MgO(001) [4] will be presented.

[1] A. Kirilyuk et al., Rev. Mod. Phys. 82, 2731 (2010).
[2] M. Sultan et al., Phys. Stat. Sol. B **248**, 2323 (2011).
[3] M. Wietstruck et al., Phys. Rev. Lett. **106**, 127401 (2011).
[4] A. Melnikov et al., Phys. Rev. Lett. **107**, 076601 (2011).

11.30 – 11.45
Electron-phonon spin flip processes and ultrafast demagnetization
K. Carva [1], M. Battiato [2], D. Legut [3], P.M. Oppeneer [2]
(1) Charles University in Prague, DCMP, CZ-12116 Prague, Czech Republic, (2) Uppsala University, S-75120 Uppsala, Sweden, (3) VSB Ostrava, Nanotechnology Centre, CZ-708 33 Ostrava, Czech Republic

Spin flip processes have recently gained increased attention due to its implications for the ultrafast demagnetization phenomenon. The Elliott-Yafet electron-phonon spin-flip scattering, suggested to be the dominant microscopic mechanism [1], is studied here. We have calculated the spin-flip Eliashberg function [2] based on ab initio electron-phonon coupling matrix elements, which allows us to obtain the spin-flip (SF) probability with much higher accuracy. The demagnetization is stimulated by a fs laser pulse and takes place in a strongly non-equilibrium situation. This situation is handled within our calculation, which is critical for obtaining reliable information about ultrafast demagnetization. Calculations have been performed for three ferromagnetic metals Fe, Co and Ni. The spin-flip probability depends strongly on electron energy and therefore on the precise shape of electron redistribution induced by a laser.
We consider two specific cases for electronic system excited by a laser: thermalized very hot electron distributions, as well as highly non-equilibrium electron distributions that are expected to be present immediately after the fs laser excitation. Employing this approach we compute the electron-phonon SF rates and examine the evolution of the total spin momentum. We find that the demagnetization rate is very low for any thermalized electron distribution (including those with electron temperature of the order of thousands Kelvin) as compared to non-equilibrium distributions present within first femtoseconds following the pump laser [2]. This is due to the density of states and the specific energy-dependence of SF probability. A comparison of SF probabilities and demagnetization rates is provided for all three metals.

[1] B. Koopmans, G. Malinowski, F. Dalla Longa, D. Steiauf, M. Fähnle, T. Roth, M. Cinchetti, M. Aeschlimann, Nature Mater. 9, 259 (2010).
[2] K. Carva, M. Battiato, P. M. Oppeneer, Phys. Rev. Lett., 107, 207201 (2011)

11.45 – 12.00
Non-Optical Triggering of Ultrafast Demagnetization by a Pulse of Hot Electrons
C. Stamm [1], A. Eschenlohr [1], N. Pontius [1], T. Kachel [1]
(1) Institute for Methods and Instrumentation for Synchrotron Radiation Research, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany

Since its first discovery [1], ultrafast demagnetization of a thin ferromagnetic film is triggered by fs laser pulses. Here we use laser-excited hot electrons as an alternative method to initiate the demagnetization process. A fs laser pulse is used to create electron-hole pairs in Au. Due to their high mobility, the hot charge carriers travel from the 30 nm Au film into an adjacent ferromagnetic Ni layer of 15 nm thickness. This initiates a very efficient and ultrafast quenching of the magnetization in Ni down to 20 % of the original value. As optical measurements such as MOKE cannot probe through the Au layer, we use x-ray magnetic circular dichroism to follow the evolution of the magnetization with fs time resolution [2]. The time scale for the demagnetization of the Au/Ni structure is found to be 330 fs, slightly longer than the 140 fs measured on a Ni reference sample. This corresponds to a propagation speed of the hot charge carriers of the order 100000 m/s, which is in accordance with the recently proposed superdiffusive spin transport mechanism [3].

[1] E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996)
[2] C. Stamm et al., Nature Materials 6, 740 (2007), and Phys. Rev. B 81, 104425 (2010)
[3] M. Battiato et al., Phys. Rev. Lett. 105, 027203 (2010)

12.00 – 12.15
Spin Dynamics at Nanometers and Femtoseconds: The Importance of Imperfections
A. Reid [1], C. Graves [2], T. Wang [2], S. De Jong [3], W. Schlotter [4], B. Wu [2], A. Tuskamoto [5], A.V. Kimel [6], R. Coffee [7], Y. Acermann [8], R. Hartmann [9], J. Stöhr [4], T. Rasing [6], A. Scherz [3], H. Dürr [3]
(1) SIMES, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA, (2) Stanford University, Stanford, CA 94305, USA, (3) SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA, (4) LCLS, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA, (5) Nihon University, Tokyo, Japan, (6) Radboud University Nijmegen, Nijmegen, 6525 AJ, The Netherlands, (7) LCLS, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA, (8) ETH Zürich, Zürich 8092, Switzerland, (9) MPG-ASG Hamburg, Hamburg 22607, Germany

The response of metallic ferromagnetic order to transient ultrafast laser excitation has produced some of the most puzzling

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results in recent condensed matter physics research. Magnetic order can be dissolved at a rate that seems to test conservation laws [1]; or reappear in a new (reversed) magnetic state [2], and even transiently order against the magnetic exchange interaction [3]. However, previously only the macroscale magnetization dynamics have been observed and the behaviour on the intrinsic nanometer length scales has remained unknown.
We explore the transient behaviour of laser-pumped spin order in the prototype metal-alloy system GdFeCo, with femtosecond time and nanometer spatial resolution, using resonant magnetic x-ray scattering. Eighty femtosecond x-ray pulses, produced from the Linac Coherent Light Source, are used to probe the elemental dynamics of spin–spin correlations from the macroscale, down to a length of 10 nm following excitation with a 50 fs infrared laser pulse. Our results reveal the importance of nanoscale inhomogeneities which, a short delay time after initial excitation, serve as localized hot-spots of angular momentum transfer. This highlights the importance of carrier transport and material mircostructure to guiding the chaos of non-equilibrium into new final states.

[1] E. Beaurepaire, et al., Phys. Rev. Lett. 76, 4250 (1996)
[2] K. Vahaplar, et al., Phys. Rev. Lett, 103 (2009)
[3] I. Radu et al., Nature, 472 (2011)

12.15 – 12.30
Doppler velocimetry of a current drive spin helix
L. Yang [1], J. Koralek [2], J. Orenstein [1], D. Tibbetts [3], J. Reno [3], M. Lilly [3]
(1) Department of Physics, University of California, Berkeley, California 94720, USA and Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA., (2) Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA., (3) Sandia National Laboratories, Albuquerque, New Mexico 87123, USA.

We present direct observation of the translational motion of spin helices in GaAs quantum wells under the influence of applied electric fields. Previously, the lifetime of such helices was observed by time-resolving the amplitude of light diffracted from the periodic spin polarization [1]. This technique cannot be applied to tracking the motion of current-driven spin helices because diffraction amplitude is insensitive to translation of the center of mass of a periodic structure. In this work, we describe a new experimental technique, Doppler spin velocimetry, capable of resolving displacements of spin polarization at the level of 1 nm on a picosecond time scale [2]. This is accomplished through the use of heterodyne detection to measure the optical phase of the diffracted light. We discuss experiments in which this technique is used to measure the motion of spin helices as a function of temperature, in-plane electric field, and photoinduced spin polarization amplitude. Several striking observations will be reported -- for example, the spin helix velocity changes sign as a function of wavevector and is zero at the wavevector that yields the largest spin lifetime. Another important observation is that the velocity of spin polarization packets becomes equal to the drift velocity of the high-mobility electron gas in the limit of small spin helix amplitude. Finally, we show that spin helices continue propagate at the same speed as the Fermi sea even when the electron drift velocity exceeds the Fermi velocity of 10^{7} cm-s^{-1}. Supported by DOE under Contract No. DE-AC02-05CH11231 and DE-AC04-94AL85000.
[1] J. D. Koralek et al., Emergency of the persistent spin helix in semiconductor quantum wells, Nature 458, 610-613 (2009).
[2] L. Yang et al., Doppler velocimetry of spin propagation in a two-dimensional electron gas, Nature Physics 8, 153-157 (2012).

12.30 – 12.45
Magnetism on the timescale of the exchange interaction: explanations and predictions
J. Mentink [1], J. Hellsvik [2], D. Afanasiev [3], B. Ivanov [3], A.V. Kimel [1], A. Kirilyuk [1], O. Eriksson [2], M. Katsnelson [1], T. Rasing [1]
(1) Radboud University Nijmegen, Institute for Molecules and Materials, Heijendaalseweg 135, 6525 AJ Nijmegen, the Netherlands, (2) Department of Physics and Astronomy, Division of Materials Theory, Box 516, SE-75120 Uppsala, Sweden, (3) Institute of Magnetism, NASU, 03142 Kiev, Ukraine

Ferromagnetic or antiferromagnetic spin ordering is governed by the exchange interaction, the strongest force in magnetism. Understanding spin dynamics in magnetic materials is an issue of crucial importance for progress in information processing and recording technology. However, rather little is known about the behaviour of spins in a magnetic material directly after being excited on a timescale equivalent to or faster than that corresponding to the exchange interaction (10–100 fs), that is, in a non-adiabatic way. After the first demonstration of ultrafast laser-induced demagnetization in ferromagnetic nickel [1], many intriguing observations have been reported on magnets with multiple magnetic sublattices, including ultrafast changes of the anisotropy [2] and magnetization reversal [3]. Nevertheless, the theoretical understanding of ultrafast laser-induced spin dynamics is still a challenge. In particular, so far the role of the exchange coupling between different magnetic sublattices has largely been ignored. In this contribution we present a general theoretical framework for the analysis of ultrafast longitudinal spin dynamics in multi-sublattice magnets [4]. We distinguish relaxation of relativistic and exchange origin and show that when the former dominates, non-equivalent sublattices have distinct dynamics despite their strong exchange coupling. Even more interesting, in the exchange dominated regime sublattices can show highly counter-intuitive transitions between parallel and antiparallel alignment. Moreover, our theory predicts that exchange relaxation enhances the demagnetization speed of both sublattices only when they are antiferromagnetically coupled.

[1] E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996).
[2] A. V. Kimel et al., Nature 429, 850 (2004).
[3] C.D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007).
[4] J.H. Mentink et al., Phys. Rev. Lett. 108, 057202 (2012).

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Chair: M. Muzenberg

12.45 – 13.00
Estimation of the amplitude-phase coupling parameter from the temperature dependence of the linewidth on spin transfer oscillators
F. Garcia-Sanchez [1], J.F. Sierra [1], U. Ebels [1], M. Quinsat [2], A.S. Jenkins [1], D. Gusakova [1], L.D. Buda-Prejbeanu [1], B. Dieny [1]
(1) SPINTEC, UMR CEA/CNRS/UJF-Grenoble Grenoble-INP,INAC, Grenoble, F-38054, (2) CEA-LETI, MINATEC-Campus, 17 Rue des Martyrs, 38054 Grenoble, France

Large angle self-sustained oscillations induced by the spin momentum transfer effect in spin transfer oscillators (STOs) give rise to the generation of microwaves whose frequencies can be tuned by the injected DC current amplitude. This new phenomenon is of great potential for future telecommunications applications. The tunability in such STOs is given by the non linear parameters ν (amplitude-phase coupling parameter) and Γ_p (amplitude relaxation rate) [1,2]. These parameters are able to account for the locking range and the spectral linewidth, as well as the noise properties.

Previously, we have extracted such non linearities from the amplitude and phase noise power spectral densities [3]. However, such method is only valid in the range of small ν (ν<10).

While the amplitude relaxation rate is evaluated from the autocorrelation function of amplitude fluctuations we present an alternative method to extract the non linear amplitude-phase coupling parameter. The method is based on the statistical properties of the oscillation amplitude as a function of temperature and on the temperature dependence of the spectral linewidth. The advantage of this approach is that the accuracy can be increased simply by increasing the number of averaged periods. The method has been evaluated by using numerical simulation in the macrospin approach for different magnetic oscillations: in-plane precession modes and out-of-plane precession modes. Whereas Γ_p has a similar value for both in plane and out of plane oscillations, ν is strongly enhanced for the latter configuration. Our simulations show that a large value of the amplitude-phase coupling parameter gives rise to a non trivial linewidth dependence on temperature in such modes.

[1] A. Slavin, and V. Tiberkevich, IEEE Trans. Magn. **45**, 1875 (2009).
[2] V. S. Tiberkevich et al. Phys. Rev. B, **78**, 092401 (2008).
[3] M. Quinsat et al. Appl. Phys. Lett, **97**, 182507 (2010).

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MAGNETIC SHAPE MEMORY, MAGNETOELASTIC AND MULTIFUNCTIONAL MATERIALS
Chair: V.A. Chernenko

10.30 – 11.00
Functional Properties of Magnetic Heusler Alloys From First Principles *(invited)*
P. Entel [1], M. Siewert [1], M.E. Gruner [1], V.D. Buchelnikov [2], V.V. Sokolovskiy [3], V.A. Chernenko [4]
(1) Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany, (2) Condensed Matter Physics Department, Chelyabinsk State University, 454021 Chelyabinsk, Russia, (3) Physics Department, Chelyabinsk State University, 454021 Chelyabinsk, Russia, (4) Dpto de Electricidad y Electronica, Universidad del Pais Pais Vasco UPH/EHU, 48080 Bilbao, Spain

Magnetic Heusler alloys of X_2YZ type where X and Y are transition metal elements and Z is from the III-V group of the periodic table of elements, show complex magnetic phases and multiple intermediate martensitic structures. The complex magnetic phases arise from competing ferromagnetic and antiferromagnetic interactions in the disordered Mn-excess alloy series $Ni_2Mn_{1+x}(Ga, In, Sn, Sb)_{1-x}$ where the interaction between the magnetic moments is governed by the existence of two different distances between nearest neighbor Mn atoms. In addition, the strong interplay of magnetic and structural degrees of freedom is decisive for the functional properties associated with the magnetic shape-memory effect and the magneto-, elasto- and barocaloric effect, as well as the exchange bias effect, respectively. Based on first-principles calculations in conjunction with Monte Carlo simulations using a spin-lattice model Hamiltonian [1] with *ab initio* parameters, we will discuss how the different functional properties arise from the complex spin-spin interactions between the magnetic ions. We will show that this knowledge can be used to fine tune and optimize the various functional properties of the Heusler alloys by compositional changes and by considering quarternary alloys where the additional element (Co, Cu, Pt or Gd) can be used to control the magnetic interactions as recently discussed for the quartenary magnetic shape memory system Pt-Ni-Mn-Ga [2].

[1] V.D. Buchelnikov et al., J. Phys. D: Appl. Phys. 44, 064012 (2011)
[2] M. Siewert *et al*., Appl. Phys. Lett. 99, 191904 (2011).

11.00 – 11.30
Magnetic domain structure of epitaxial Ni-Mn-Ga films *(invited)*
A. Diestel [1], A. Backen [1], V. Neu [1], L. Schultz [1], *S. Fähler* [1]
(1) IFW Dresden, Institute of Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany

For the magnetic shape memory effect, knowledge about the interaction between martensitic and magnetic domain structure is essential. In the case of Ni-Mn-Ga bulk material and foils, a staircase-

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like magnetic domain structure with 90°- and 180°-domain walls is known for modulated martensite. In the present paper we show that the magnetic domain pattern of thin epitaxial films is fundamentally different. Here we analyze epitaxial Ni-Mn-Ga films by atomic and magnetic force microscopy to investigate the correlation between the twinned martensitic variants and the magnetic stripe domains. The observed band-like domains with partially perpendicular out-of-plane magnetization run perpendicular to the microstructure domains defined by twinning variants. These features can be explained by the finite film thickness, resulting in an equilibrium twinning period much smaller than the domain period. This does not allow the formation of a staircase domain pattern. Instead the energies of the magnetic and martensitic microstructures are minimized independently by aligning both patterns perpendicularly to each other. By analyzing a thickness series we can show that the observed magnetic domain pattern can be quantitatively described by an adapted band domain model of Kittel.

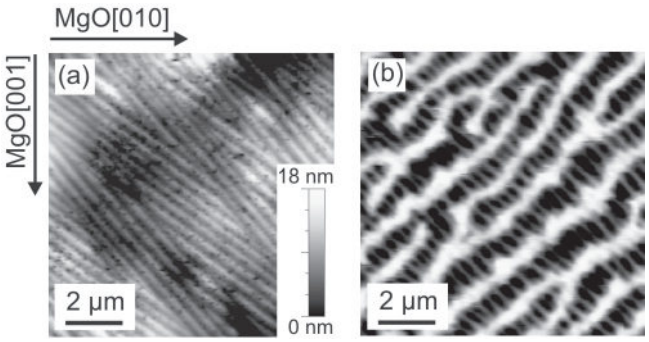

Fig. AFM (a) and MFM (b) micrograph of a 2 µm thick epitaxial Ni-Mn-Ga film revealing that magnetic domains are aligned perpendicular to the twin boundaries.

[1] A. Diestel, A. Backen, V. Neu, L. Schultz and S. Fähler, ArXiv: 1203.3840,

11.30 – 11.45

Giant strain at the magnetic-field induced transformation in Co- and In- doped NiMnGa multifunctional alloys

S. Fabbrici [1], J. Kamarád [2], Z. Arnold [2], A. Paoluzi [3], D. Serrate [4], P.A. Algarabel [4], M. Doerr [5], E. Van Elferen [6], F. Albertini [3]
(1) MIST E-R Laboratory, 40129 Bologna, Italy, (2) Institute of Physics AS CR, 162 53 Praha 6, Czech Republic, (3) IMEM, CNR, 43124 Parma, Italy, (4) Instituto de Ciencia de Materiales de Aragon, Universidad de Zaragoza, E-50009 Zaragoza, Spain, (5) Institut fur Festkorperphysik, Tech Univ Dresden, D-01062 Dresden, Germany, (6) High Field Magnet Lab, Radboud University, NL-6525 ED Nijmegen, Netherlands

Ni-Mn based Heusler alloys provides an interesting playground of physical properties. The interplay between reversible martensitic transformation (MT) and magnetically ordered states gives rise to a series of functional properties, such as giant magneto- and baro-caloric effects, giant magnetoresistance, magnetic shape memory and magnetic superelasticity, that can be exploited in innovative devices. The path towards applications relies on the enhancement of the MT sensitivity to external forces, e.g. magnetic field (dT_{M}/dH) or pressure (dT_{M}/dp), allowing for the actuation of the transformation itself.
In this contribution we will show how Co-doping Mn-rich Ni_{2}MnGa greatly improves these key features with respect to the ternary alloy.
Previously we have shown that proper Co-doping allows to revert the order of the structural and magnetic transitions, giving rise to a reverse MT between a paramagnetic low-temperature phase and a ferromagnetic high-temperature one [1]. The reverse transformation increases the magnetization jump at the MT and consequently dT_{M}/dH well beyond the maximum values showed by the ternary alloy Ni-Mn-Ga. The corresponding magnetocaloric effects are greatly enhanced [2, 3].
Recent X-ray diffraction studies performed across the MT also highlighted increased structural discontinuity ($\Delta V/V$) values, higher than any other Ni-Mn based Heusler alloy; this feature increases the sensitivity of the MT to the applied pressure, allowing for remarkable dT_{M}/dp values and for the realization of reversible magnetic-field induced transitions ($\Delta V/V$ up to 1% in relatively low fields), a feature confirmed by magnetostriction measurements in high magnetic fields (up to 30T).
Finally, we will show how the additional doping of In further improves the aforementioned functional properties, pushing these materials among the most promising Heuslers for future applications.

[1] S. Fabbrici et al., Appl. Phys. Lett. 95, 022508 (2009)
[2] S. Fabbrici et al., Acta Mater 59, 412-419 (2011)
[3] G. Porcari et al., Phys Rev B 85, 024414 (2012)

11.45 – 12.00

Magnetic field effect on the transformation of a Ni-Mn-In metamagnetic shape memory alloy

J.M. Barandiarán [1], V.A. Chernenko [2], E. Cesari [3], D. Salas [3], J. Gutiérrez [1], P. Lázpita [1], I. Orue [4]
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Mn-rich Ni-Mn-X Heusler compounds (X=In,Sn and Sb), are known as metamagnetic shape memory alloys (MSMAs), and exhibit giant magnetic field-induced strain, large inverse magnetocaloric effect and other interesting features at the martensitic transformation (MT). In the present work, we analyze the influence of the magnetic field on the transformation properties of the alloy $Ni_{50}Mn_{36}In_{14}$.
At low field (0.05 T) the following temperatures are found: martensitic start Tms = 277 K, austenitic finish Taf = 288 K, austenite Curie temperature Tca =313 K and martensite Curie temperature Tcm =220 K. The dependence of the martensitic transition temperature on the field exhibit a nonlinear behavior, while the change in magnetization, ΔM, remains

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constant. Through the Clausius-Clapeyron (CC) equation, $dT/dH=\Delta M/\Delta S$, where ΔM and ΔS are magnetization and entropy jumps at MT respectively, the change of slope can be attributed to a decrease of ΔS with the applied field, if ΔM is fixed. This is explained by an enhancement of the negative magnetic entropy contribution to the full entropy change accompanying the MT. The applied magnetic field increases the difference between the Curie and Martensitic temperatures (Tc-Tm). This can lead to a decrease of the first order character of the transformation, and one should expect a concurrent reduction of ΔS. The CC equation confirms a 40% decrease of ΔS at 12T.
In order to further explore these aspects, we have carried out a determination of the volume change, ΔV, at the transformation by means of strain gauges glued to the specimen. At zero field the transformation is accompanied by a 0.4 % volume change. ΔV steadily decreases as a function of the applied field and, extrapolating to higher fields, will drop to zero at 16 Tesla. This can be understood as an inverse invar-like magnetovolume effect on the martensitic transformation.

12.00 – 12.15
Rearrangement of martensitic variants in Ni_2MnGa studied with the phase-field method
C. Mennerich [1], F. Wendler [1], M. Jainta [1], B. Nestler [2]
(1) Institute of Materials and Processes (IMP), Karlsruhe University of Applied Sciences, 76133 Karlsruhe, (2) Institute of Applied Materials - Reliability of Components and Systems (IAM-ZBS), Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe

Magnetic shape memory (MSM) alloys offer large recoverable strains in conjunction with fast reaction times, important features for components used in actuators or dampers. Decisive is the MSM effect that takes place entirely in the martensitic state. The macroscopic properties intimately depend on the the microscale, i.e. interlinked transformation processes of the underlying crystallographic microstructure and the magnetic domain structure. The exact properties are determined by the kinetic pathway the material follows during its evolution. To model the effect, we chose the phase-field method, using non-conserved order parameters that are directly related to the eigenstrain states of the martensitic variants [1]. The governing energy functional is based on the interpolation of individual bulk free energies of the individual phases. These include the magnetic Zeeman, demagnetization, exchange and anisotropy energy, and the linearized elastic energy. Stress-free strains reflect the elastic energy landscape. The evolution equations for the order parameters are derived using in a time dependent Ginzburg-Landau equation, while for the magnetization the Landau-Lifshitz-Gilbert equation is adopted. For the elastic displacement fields either a dynamic damped wave equation is solved, or mechanical equilibrium is assumed. Based on this modeling approach, simulations in 2D and 3D are set up to study nucleation, growth and rearrangement of martensitic variants and magnetic domains in a representative volume element (RVE) of a larger tetragonal 5M Ni2MnGa specimen. Properties of the specimen are included by suitable boundary conditions for magnetization, elastic displacements and phase fields. The applicability of the model is verified by comparing simulation results with results from the literature. Different external magnetic and mechanical fields are applied to the RVE in different initial states. The results of the simulation studies are presented and magnetization vs. field and stress vs. strain diagrams are discussed.

[1] C. Mennerich et al.: Arch. Mech. 63, 5–6, pp. 549–571

12.15 – 12.30
Effect of magneto-elastic coupling on lattice softening in ferromagnetic Ni-Mn-Ga and Co-Ni-Al cubic austenite
O. Heczko [1], J. Kopecek [1], H. Seiner [2], P. Sedlak [2], M. Landa [2]
(1) Institute of Physics ASCR, 18221 Prague, Czech Republic, (2) Institute of Thermomechanics ASCR, Prague, Czech Republic

Ni-Mn-Ga and Co-Ni-Al are examples of ferromagnetic Heusler alloys undergoing the martensitic transformation from cubic phase, called austenite to low symmetry martensite phase. While both alloys transform to martensite only Ni-Mn-Ga is exhibiting large magnetic field induced deformation in the modulated martensite phase. It is generally accepted that anomalous shear lattice softening of parent cubic phase is a precursor of martensitic transformation. In ferromagnetic material the lattice softening can be affected by magneto-elastic interaction.
The evolution of the elastic constants of the alloys with magnetic field and temperature above martensitic transformation was studied by resonant ultrasound spectroscopy.
In Ni-Mn-Ga cubic austenite we experimentally observed very strong softening effect and strong dependence of the shear elastic constant on magnetic field prior premartensitic transformation at 250 K. However, after further cooling the shear coefficient again increased and at martensitic transformation at 220 K the coefficient is nearly the same as in paramagnetic state. After annealing and slow cooling which reduced the amount of antiphase boundaries the rate of softening weakened. However, the minimum of shear coefficient at premartensitic transformation is retained and after this transformation the elastic coefficient increased, too. The high rate of softening was ascribed to the magnetoelastic coupling and concurrent sharp increase of elastic damping on domain wall pinning on antiphase boundaries. This behaviour is in sharp contrast to ferromagnetic Co-Ni-Al. In this case the softening effect is relatively weak and monotonously decreases towards martensitic transformation at about 210 K. We believe that it is due to weak magnetoelastic coupling in this material. Question is if and how these contrasting observations are relevant to magnetic shape memory effect.

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12.30 – 12.45

Epitaxial Ni-Mn-Ga/MgO(100) thin films with thickness ranging from 10 to 100 nm

P. Ranzieri [1], S. Fabbrici [1], L. Nasi [1], L. Righi [2], F. Casoli [1], V.A. Chernenko [3], E. Villa [4], F. Albertini [1]

(1) IMEM-CNR Parco Area delle Scienze 37/A, 43124 Parma, Italy, (2) Dipartimento Chimica GIAF Università di Parma, Viale Usberti 17/A, 43124 Parma, Italy, (3) Universidad del Pais Vasco, Departamento de Electricidad y Electronica, Bilbao 48011, Spain, (4) IENI-CNR Corso Promessi Sposi 29, 23900 Lecco, Italy

The Ni_2MnGa alloy is a magnetic shape memory (MSM) material. The ferromagnetic order and a martensitic transition make it very attractive for multifunctional devices [1]. The peculiar structure of the martensite, characterized by differently oriented twinned variants, can be modified by overcoming a relatively low *blocking* stress to allow the twin boundary motion. This can be done by an external stress and a magnetic field. Due to the importance of the crystal quality and device miniaturization, intense research has been made on thin film epitaxial growth. It was demonstrated that epitaxy can be achieved on different substrates [2].

We have grown epitaxial Ni-Mn-Ga thin films with thickness ranging from 10 to 100 nm on MgO. In this range of thicknesses, the Curie temperature and the martensitic transition temperature are very sensitive to the thickness. From temperature dependent X-ray measurements we have found that for very low film thickness (10 and 20 nm) the austenitic phase was impeded to transform, even at very low temperature. For the other samples, the martensitic transformation indeed occurs, and the T_M differs from the bulk. An in-depth structural characterization reveals details of the martensitic structure and twin orientation that can be explained by the lattice constraints imposed by the substrate. While for films up to 75 nm only one variant configuration is observed, for the thicker films (100 nm), the martensitic structure evolves through the formation of different variants. Also the magnetic properties and the magnetic domain configuration of the samples are consequently modified.

[1] A. Planes, L. Manosa and M. ACet, J. Phys. Cond. Matt. 21, 233201 (2009).

[2] M. Thomas, O. Heczko, J. Buschbeck, U.K. Rößler, J. McCord, N. Scheerbaum, L. Schultz and Fähler S. New. J. Phys. 10, 023040 (2008).

12.45 – 13.00

Twinning in shear and uniaxial loading in five layered martensite Ni-Mn-Ga single crystals

I. Aaltio [1], Y. Ge [1], S. Hannula [1]

(1) Aalto University, School of Chemical Technology, Department of Materials Science and Engineering, FI-02150 Espoo, Finland

Mobile twin boundaries of the five layered Ni-Mn-Ga martensite single crystals allow shape changes under exceptionally low stress. According to the experimental results, twinning stress under uniaxial loading in high quality crystals can be even as low as 0.05 MPa. The low twinning stress enables efficient magnetic actuation of Ni-Mn-Ga. When referring to parent phase coordinates, the twinning plane in the five-layered martensite is (101) and the twinning direction is [10-1]. It is commonly accepted that the twin boundary motion in these materials results from a shear stress acting on the twinning plane, although the details of deformation mechanism are still under discussion. We studied the mechanical behavior of five-layered martensitic Ni-Mn-Ga in shear loading and compared the results with those of uniaxial loading, when external magnetic field was not applied. The results show that the direction of applied shear load in relation to the existing martensite crystal structure influences twinning significantly. The onset stress for twinning in the shear and uniaxial modes are essentially in the same level.

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MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 1

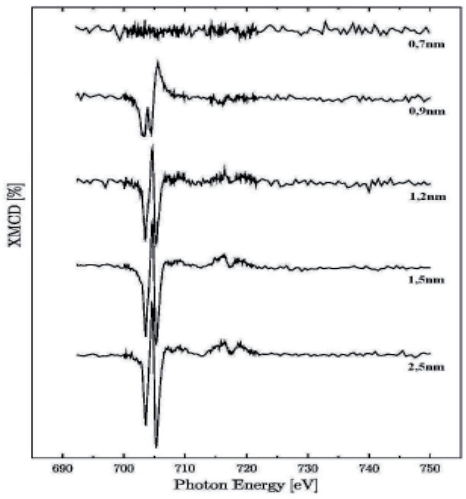
Chair: L. Mattera

14.45 – 15.00

Magnetism of ultrathin Fe_3O_4 on Ag(100) and Pd(111) by XMCD and MOKE

G. Gomes [1], T. Bueno [1], H. Pfannes [1], R. Paniago [1], A. De Siervo [2]
(1) UFMG, Belo Horizonte, BRAZIL, (2) IF-UNICAMP, Campinas, BRAZIL

There is a large scientific and technological interest in magnetic materials in ultrathin film form due to the anisotropy created by the low dimensionality which can change physical properties. The magnetic characterization of magnetite (Fe_3O_4) is important for understanding a series of phenomena, such as spin polarization, metal-insulator transition and superparamagnetism. In this study we have prepared iron oxide ultrathin films on Pd (111) and Ag(100). The XMCD study was performed at the Brazilian Synchrotron Light Laboratory (LNLS) by measuring the dichroism of the L_2 and L_3 absorption edges of Fe. Films with thicknesses varying between 0.3 nm to 3nm were prepared and for each sample we have qualitatively examined the surface structure of Fe_3O_4 by low energy electron difraction (LEED) to correlate with its magnetic response. In the XMCD experiment the population of Fe^{2+} and Fe^{3+} ions in tetrahedral and octahedral sites in the structure of magnetite (inverted spinel) was investigated. This way, we were able to determine the critical thickness of magnetite formation in the [111] and [100] direction. We observe a transition from FeO (antiferromagnetic) to Fe_3O_4 (ferrimagnetic) in the thickness range between 0.9 and 1.2 nm. For thicker films a 50 times smaller dichroic signal was measured for the oxygen K edge as compared to the iron $L_{3;2}$ edges, due to the magnetic moment induced by ferrimagnetic ordering of neighboring ions (Fe^{2+} and Fe^{3+}). MOKE measurements have shown an easy axis of magnetization in the surface plane in agreement with the XMCD results.



Determination of the critical thickness of magnetite formation in the [111] direction.

15.00 – 15.30

Probing magnetization reversal at the nano-scale *(invited)*

P. Vavassori [1]
(1) CIC nanoGUNE Consolider, Tolosa Hiribidea 76, 20018 Donostia-San Sebastian, Spain and Ikerbasque, Basque Foundation for Science, Alameda Urquijo 36-5, 48011 Bilbao, Spain

Nanomagnets have applications that range from sensors and computing to medical imaging and drug delivery and look set to play one of the central roles in modern technology for decades to come. Thanks to the continuous development of novel high-resolution fabrication techniques, the range of objects from relatively large micron particles to individual atomic chains can be reasonably readily produced. The tiny size of magnetic structures in modern and future nanodevices demands novel approaches to magnetic metrology in terms of spatial resolution and sensitivity. The magneto-optic Kerr effect (MOKE) is widely used in studying technologically relevant magnetic materials. The MOKE profits from high surface sensitivity, material and depth sensitivity, its nondestructive character, and the possibility to measure all components of the magnetization vector.[1] Thanks to these unique features, MOKE continues to be a key experimental tool of magnetic nanostructures research. Recently, successful attempts have been made to extend MOKE to diffraction techniques (D-MOKE) in order to exploit the interference effects of light for arrays of nano-structures.[2] We present here an improved implementation of D-MOKE that allows the retrieval of field dependent magnetization configuration in the unit cell of an array, hereby demonstrating that the methodology is a powerful optical tool for lens-less diffraction-limited optical imaging of the collective magnetic behavior of nano-structures.[3] We finally show that magnetometry measurements based on MOKE and high-resolution optical microscopy can be used as a flexible and noninvasive probe of magnetization reversal for individual ultra-small nano-structures with a magnetic moment sensitivity of down to $\mu \sim 1x10^{-16}$ Am^2 for single sweep measurements.[4]

[1] P. Vavassori, Appl. Phys. Lett. **77**, 1605 (2000).
[2] M. Grimsditch and P. Vavassori, J. Phys: Condens. Matter **16**, R275 (2004).
[3] T. Verduci *et al.,* Appl. Phys. Lett. **99**, 092501 (2011)
[4] E. Nikulina *et al.*, Appl. Phys. Lett., in press (2012)

15.30 – 15.45

Interaction of visible light and magnetic materials at the microscale

M. Savoini [1], R. Medapalli [1], B. Koene [1], A.R. Khorsand [1], S. El Moussaoui [2], L. Le Guyader [2], A. Tsukamoto [3], A. Itoh [4], L. Duò [5], M. Finazzi [5], F. Nolting [2], A. Kirilyuk [1], A.V. Kimel [1], T. Rasing [1]
(1) Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, Nijmegen, The Netherlands, (2) Paul Scherrer Institut, CH-5232 PSI-Villigen, Switzerland, (3) 1) College of Science and Technology, Nihon University, 7-24-1 Funabashi, Chiba, Japan, 2) PRESTO, Japan Science and Technology Agency, 4-1-8 Honcho Kawaguchi, Saitama, Japan, (4) College of Science and Technology, Nihon University, 7-24-1 Funabashi, Chiba, Japan, (5) Dipartimento di Fisica, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milano, Italy

Controlling the sample magnetization with femtosecond optical pulses has become a widely studied topic in the last decades, and holds a lot of appealing perspectives for practical applications. One of the main challenges at the present stage

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SURFACES/INTERFACES 1

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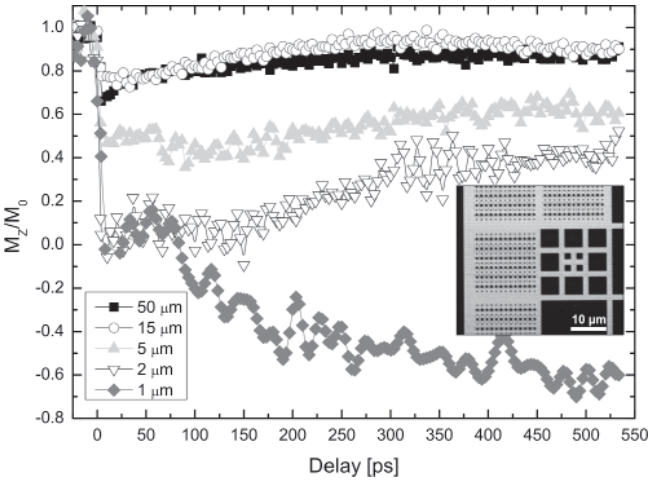
is to confine these optical effects on areas of small, submicron sizes, comparable with the laser wavelength and beyond.
Here we present our measurements on a microstructured sample of GdFeCo alloy, performed with all-optical techniques developed to obtain submicron spatial sensitivity and femtosecond temporal resolution. We show that we can address the magnetization dynamics on such scales and we demonstrate that smaller structures behave in a similar way as continuous films, but require lower absorbed energy densities to ignite the magnetization reversal process. We support our observations with FDTD simulations and show that when the beam wavelength and lateral size of the structure are of the same order of magnitude, optical effects like interference play a crucial role in determining the electric field distribution within the structure. Such an effect originates a magnetization reversal patterns within homogenously illuminated structures and/or for an increase in the absorbed energy by the magnetic layer.



Magnetization dynamics in different microstructures (shown in the inset) as a function of their sizes at a fixed illumination fluence at 400nm laser light impinging on the sample (about 2 mJ/cm^2).

15.45 – 16.00
Perpendicular magnetic anisotropy of cobalt films in contact with graphene
N. Rougemaille [1], A. N'Diaye [2], J. Coraux [1], C. Vo-Van [1], O. Fruchart [1], A. Schmid [2]
(1) Institut Néel, CNRS & Université Joseph Fourier, BP166, F-38042 Grenoble Cedex 9, France, (2) Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, California 94720, USA

Owing to its peculiar electronic band structure, high carrier mobility and long spin diffusion length, graphene is a promising two-dimensional material for microelectronics and spintronics. Graphene also shows interesting magnetic properties when in contact with a ferromagnetic metal (FM). For instance, graphene carries a net magnetic moment of 0.25 μB per carbon atom when deposited on Fe/Ni(111) [1], and a 25 meV spin splitting can be induced in graphene due to proximity with a heavy element [2].
While these works illustrate potential advantages of integrating graphene within a magnetic stack, the influence of graphene on the magnetic properties of a FM is still largely unexplored. In particular, non-magnetic overlayers generally affect the magnetic anisotropy energy (MAE) of thin layers, where interfaces play an important role. We can then wonder how an interface with graphene would influence the MAE of a thin FM film. However, the fabrication of atomically flat graphene/FM and FM/graphene interfaces is not an easy task (graphene growth on metals is usually conducted at temperatures for which thin film dewetting can occur, and metal evaporation on graphene often yields clustered deposits).
Using spin-polarized low-energy electron microscopy, we study how a graphene top layer affects the magnetic properties of atomically flat, nm-thick Co films grown on Ir(111) [3]. We show that the spin-dependent unoccupied band structure of Co is modified by the presence of graphene, and that perpendicular magnetic anisotropy is favored over an unusually large thickness range. Compared to the vacuum/Co interface, the MAE is estimated to be several times larger for a graphene-terminated Co surface.

[1] M. Weser et al., Phys. Chem. Chem. Phys. 13, 7534 (2011)
[2] A. Varykhalov et al., Phys. Rev. Lett. 101, 157601 (2008)
[3] N. Rougemaille et al., submitted to Appl. Phys. Lett.

16.00 – 16.15
Hydrogen induced spin reorientation transition in ultrathin Co films
S. Gallego [1]
(1) Institute of Materials Science of Madrid, Spanish National Research Council, 28049 Madrid, Spain

Ultrathin Co films on Ru(0001) show two atomically abrupt consecutive spin reorientation transitions (SRTs) as a function of film thickness, due to a subtle interplay of surface induced electronic effects and strain [1-2]. For films with perpendicular magnetic anisotropy, a new SRT can be gradually induced upon hydrogen adsorption, that takes place for coverages under one third of a monolayer [3]. The unique features of the process, reversible and not involving relevant structural modifications, has a significant impact on the detection of minute amounts of H in ultra high vacuum experiments. Here we show, based on first principles calculations, how the effect can be understood in terms of the modification of the electronic structure of the surface Co atoms due to their strong binding to H. The electronic and magnetic properties of the film evolve non-homogenously as a function of H coverage, altering the competition between the dipolar and band energy contributions to the magnetic anisotropy, and finally leading to the SRT. Furthermore, the inhomogeneous nature of the effect can be exploited to induce a distinct multiple SRT as a function of film thickness, by adsorbing H on the Ru surface prior to Co deposition. In this case, H significantly enhances the magnetic anisotropy of the film, leading to an oscillatory SRT as shown in the figure.

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SURFACES/INTERFACES 1
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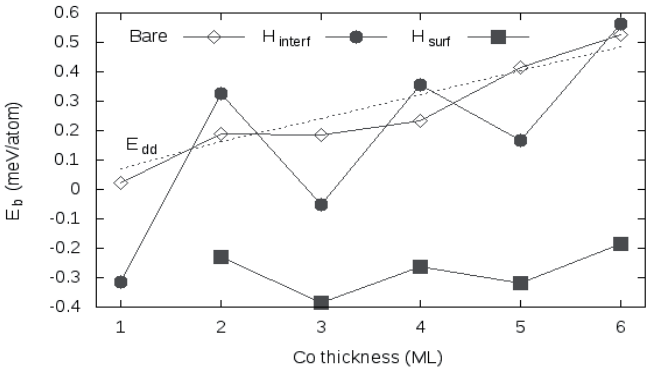
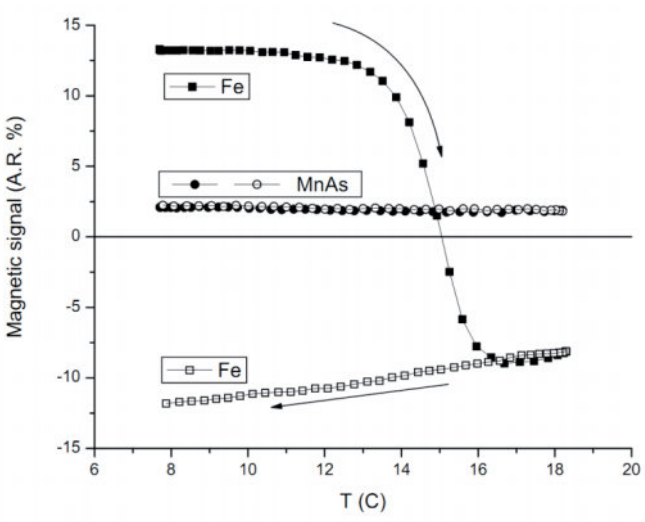
[1] F. El Gabaly et al., Phys. Rev. Lett. 96, 147202 (2006).
[2] F. El Gabaly et al., New J. Phys. 10, 073024 (2008).
[3] B. Santos et al., Phys. Rev. B (in press, 2012). DOI: 10.1103/PhysRevB.00.004400



Magnetic anisotropy energy of Co/Ru(0001) films with and without H

16.15 – 16.30
Temperature-controlled Fe magnetization switching in Fe/MnAs/GaAs(001)
M. Sacchi [1], *M. Marangolo* [2], M. Eddrief [2], V.H. Etgens [3], R. Brietwieser [4], C. Spezzani [5]
(1) Institut des NanoSciences de Paris, Université Pierre et Marie Curie, 75005 Paris, FRANCE and Synchrotron SOLEIL, L'Orme des Merisiers Saint-Aubin - BP 48 91192 Gif-sur-Yvette, FRANCE, (2) Institut des NanoSciences de Paris, Université Pierre et Marie Curie, 75005 Paris, FRANCE, (3) VeDeCo, Université de Versailles Saint-Quentin en Yvelines, 55 Av. de Paris – Versailles, 78035 Versailles and Institut des NanoSciences de Paris, Université Pierre et Marie Curie, 75005 Paris, FRANCE, (4) Center for Condensed Matter Science, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, TAIWAN, (5) Sincrotrone Trieste, S.S.14 - km 163,5, 34149 Basovizza (TS), ITALY

The magnetization of a Fe layer deposited on MnAs/GaAs(001) switches sign by thermal cycling close to room temperature, without recourse to external magnetic fields. This is achieved via temperature control of the template micromagnetic structure. The interplay between epitaxial constraints and phase transitions in MnAs/GaAs(001) originates peculiar morphological and magnetic behaviors [1]. At T ~ 40 ºC, bulk MnAs undergoes a phase transition between the ferromagnetic (FM) α-phase and the non-magnetic (NM) β-phase. In MnAs/GaAs(001), the two phases coexist over an extended temperature range (~15-45 ºC) in the form of a regular set of stripes alternating FM-α and NM-β phases. The α/β ratio within a period (≈1μm) can be controlled by fine tuning the temperature around ambient. When the stripes form, intense dipolar fields are generated at the surface [2].
By means of x-ray resonant magnetic scattering, which is an element selective and magnetic sensitive technique, we show that an Fe layer on MnAs/GaAs(001) presents two stable magnetic configurations at low temperature, either parallel or antiparallel to the magnetization of α-MnAs, and that we can switch from the parallel to the anti-parallel configuration via a thermal cycle of a few degrees, without applying any external field. We address also the dependence of the switching process on the details of the thermal cycle.
Beyond the example of Fe/MnAs/GaAs(001), our results show that developing templates whose structural and/or magnetic properties are tailored to display well defined temperature dependence is a new approach to the control of the local magnetization [3].
[1] L.Däweritz, Rep.Prog.Phys.**69**,2581(2006).
[2] M.Sacchi et al., Phys.Rev.B**81**,240801(2010).
[3] M.Marangolo, M.Sacchi, Method for changing the direction of magnetization in a ferromagnetic layer, French patent n. 2947375(26/08/2011); US patent pending.



Fe- and Mn-selective temperature dependent magnetic scattering in a 8-18 ºC cycle.

16.30 – 16.45
High Magnetic Moment Gd Thin Films
G. Scheunert [1], W. Hendren [1], R. Bowman [1]
(1) Centre for Nanostructured Media / Physics and Astronomy / Queen's University Belfast / BT7 1NN Belfeast / UK

There has been considerable effort to realise high saturation magnetisation beyond that of FeCo and its saturation field of 2.45T at room temperature. Attempts in pushing this limit are mainly based on adding different materials to the FeCo alloy to optimise its structure [1].
There are numerous applications where large saturation is required particularly in thin film form. To achieve this we are revisiting the rare earth metal Gadolinium which, according to literature on single crystals, exhibits a saturation field of up to 2.66T at cryogenic temperatures with a Curie point of around 294K [2].
Our 50-100nm thick Gd layers are prepared via UHV DC

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sputtering and we have investigated in the influence of different seed layers, the sputtering parameters, and heat treatment on the crystallography and hence the magnetic structure.
The best seed material we found is Tantalum, which also completely prevents oxidation of the thin films under standard atmospheric conditions when used as a capping material. The granularity of the Gadolinium layers, reduced by higher sputtering rates and heating the substrate during the deposition, strongly influences all the properties: Small grains lead to softer films, displaying a superparamagnetic transition at ~20K, and have lower magnetization values of only around 2T (T_C = 275K), whereas bigger grains lead to values of up to 2.25T (T_C = 290K). This is consistent with previous reports on pure Gadolinium thin films of around 750nm thickness [3].

[1] K. Noma, Trans. Mag. 42, 140 (2006)
[2] S. Yu. Dan'kov, Phys. Rev. B 57, 3478 (1998)
[3] Y. Yamada, Thin Solid Films 459, 191 (2004)

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

OPTICAL SWITCHING AND SPIN WAVES

Chair: C. Serpico

14.45 – 15.15
Modeling of magnetisation dynamics in ferrimagnetic materials under ultra-fast heat produced by fs laser pulse *(invited)*
O. Chubykalo-Fesenko [1], U. Atxitia [2], T. Ostler [2], R.W. Evans [2], J. Barker [2], R. Chantrell [2]
(1) Instituto dew Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain, (2) University of York, UK

Ultrafast laser-induced magnetic switching in rare-earth transition-metal ferrimagnetic alloys CoFeGd has been recently reported to occur under ultra-fast heat alone [1]. During this process the occurrence of a ferromagnetic-like state has been observed [2]. The physical explanation of a purely heat driven reversal via the transient state is unclear. To get an insight into this highly non-equilibrium process we perform atomistic modelling of a disordered CoFeGd ferrimagnet showing that even an application of the external field with the magnitude up to 40T cannot prevent this system from the reversal. This demonstrates the key role of the inter-sublattice exchange field. To understand the role of different sub-lattices and internal relaxation, we derive a novel micromagnetic two-component Landau-Lifshitz-Bloch (LLB) equation for ferrimagnet. This equation describes a mutual relaxation of sublattices which occurs simultaneously under internal damping, intra and inter-sublattice exchange. The model allows us to calculate element and temperature-dependent relaxation rates in CoFeGd and to present a simple picture of the magnetisation reversal under ultra-fast heat pulse alone. The process is explained within the LLB equation as a dynamical instability of the linear motion slightly before or after the pulse. The non-equivalence of the two sub-lattices is an essential part of the process. We also show the possibility to control the transient ferromagnetic state in ferrimagnetic materials.

[1] T.Ostler , et al Nature Commun. 3, 666 (2012)
[2] I. Radu, et al Nature, 472, 205 (2011).

15.15 – 15.30
Magneto-optical four wave mixing signals generated in a Garnet film using femtosecond laser pulses
M. Sanches Piaia [1], M. Barthélémy [1], M. Vomir [1], J. Bigot [1]
(1) Institut de Physique et Chimie de Matériaux de Strasbourg/ Département d'Optique Ultra-rapide et Nanophotonique, CNRS/ Université de Strasbourg UMR7504, 67034 Strasbourg , France

The interaction of ultra-short light pulses with magnetic materials is a subject of great interest. It can be used to investigate the ultrafast dynamics of magnetization through magneto-optical techniques. In this context, the use of femtosecond laser pulses instead of pulsed magnetic field can result in a great

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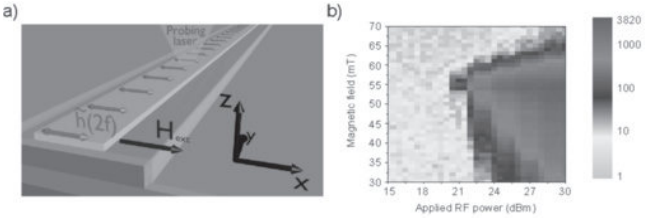
improvement to the speed of writing and reading the elementary bits of information in magnetic recording media. Being able to coherently manipulate the magnetization of a magnetic material would be an ultimate goal.
Recently it has been shown that, prior to the known incoherent demagnetization that accompanies the thermalization of the spins, a coherent response is present in the pump-probe Faraday or Kerr magneto-optical signals [1].
The coherent response is related to the coupling between the laser field and the spins, that precedes the thermalization of the spins and relaxation of population. However, in a classical Faraday or Kerr configuration, it is difficult to extract the pure coherent component as it is followed by the spin population dynamics.
In the present work, we demonstrate that the coherent magneto-optical response can be directly measured in a degenerated four-wave mixing configuration by applying a static magnetic field. The experiments were performed in a Bismuth doped Garnet thin film that is transparent in near infrared allowing an efficient self-diffraction emission in a two beams configuration. The coherent interaction will be discussed and the experimental results compared to the ones obtained simultaneously in a Faraday configuration.

[1] Bigot, J.-Y., Vomir, M. & Beaurepaire, E. Nature Phys. **5**, 515-520 (2009)

15.30 – 15.45
Mode selective parametric excitation of spin waves in a $Ni_{81}Fe_{19}$ microstripe
T. Brächer [1], P. Pirro [1], B. Obry [1], A.A. Serga [1], B. Leven [1], B. Hillebrands [1]
(1) Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Due to their potential application in logic devices and microwave signal processing spin-wave excitations have been intensively studied. However, experiments in micro-structured systems remain a challenge since the spin-wave lifetime in commonly used materials like Permalloy ($Ni_{81}Fe_{19}$) is restricted to a few nanoseconds. A possible approach to address this issue is the prolongation of the spin-wave lifetime by using the technique of parallel parametric amplification [1].



We present the experimental observation of parallel parametric amplification of selected thermal spin-wave modes in a transversally magnetized $Ni_{81}Fe_{19}$ microstripe [2], investigating the nature of the amplified modes.
By employing Brillouin light scattering microscopy we identify the dominant group, i.e. the spin-wave mode that is preferentially amplified. We show that due to the existing spin-wave quantization in the system it is possible to select one specific mode to be parametrically excited by changing the bias magnetic field. This gives access to trans- versal spin-wave eigenmodes of the stripe, promising the ability to amplify externally excited propagating spin waves that carry information, and also allows for the generation of modes localized at the stripe edges. We explain the mode-selectivity by the wave-vector dependent ellipticity of precession in a thin magnetic stripe.
a) Scheme of the measurement and the investigated microstructure. b) Threshold characteristics of the microstripe.

[1] V.S. L'vov, Wave Turbulence under Parametric Excitations: Applications to Magnetics, Springer, Berlin (1994)
[2] T. Brächer et. al., Appl. Phys. Lett. 99, 162501 (2011)

15.45 – 16.00
Spin-Wave Excitations In Dynamically Reconfigurable Magnetic Dot Arrays
R. Verba [1], V.S. Tiberkevich [2], *A.N. Slavin* [2]
(1) Faculty of Radiophysics/ Taras Shevchenko National University of Kyiv/ 01601 Kyiv/ Ukraine, (2) Department of Physics/ Oakland University/ MI 48309 Rochester / USA

A general theory of collective spin-wave excitations in a two-dimensional array of magnetic nano-dots coupled by dipole-dipole interaction is developed. It is demonstrated that all the properties of spin waves in an array existing in any spatially periodic ground state (e.g., ferromagnetic (FM) or chessboard antiferromagnetic (CAFM)) are determined by the same state-independent array's demagnetization tensor which depends on the spin-wave wave vector $\boldsymbol{k}$, size and shape of the array's elements (nano-dots), and the geometry of the array's lattice [1]. The applications of the developed general theory are illustrated on particular examples: (i) spin wave spectra in FM and CAFM ground states of a square array and (ii) localized spin-wave excitations associated with an isolated "defect" in a ferromagnetic ground state of a square array.
The possibility of a rapid switching of the ground state in a two-dimensional array of magnetic nano-dots having perpendicular axial shape anisotropy is investigated. The switching to the FM ground state can be achieved by applying a short rectangular out-of-plane magnetic field pulse having sufficiently large amplitude. The switching to the CAFM ground state is more complicated and requires the application of a magnetic field pulse directed in the dot plane and having a sufficiently long trailing edge (tail). Under the action of such a pulse the dot array splits into clusters. The sizes of the formed clusters depend on the duration of the tail of the applied magnetic field pulse, and, when the tail duration exceeds 100 nanoseconds, any noticeable inhomogeneous broadening of the microwave absorption line caused by the cluster formation is eliminated. The obtained results open a way for practical use of coupled arrays of magnetic nano-dot as materials with rapidly reconfigurable microwave absorption.

[1] R. Verba, G. Melkov, V. Tiberkevich, and A. Slavin, Phys. Rev. B **85**, 014427 (2012).

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16.00 – 16.15
Spin-wave diffraction on a single antidot in yttrium iron garnet films
V. Bessonov [1], *R. Gieniusz* [1], U. Guzowska [1], M. Kisielewski [1], H. Ulrichs [2], A. Stognij [3], A. Maziewski [1]
(1) Faculty of Physics, University of Białystok, Lipowa 41, 15-424 Białystok, Poland,, (2) Institute for Applied Physics and Center for Nonlinear Science, University of Muenster, Correnssstasse 2-4, 48149 Muenster, Germany,, (3) Scientific-Practical Materials Research Center at National Academy of Sciences of Belarus, ul. P. Brovki 19, Minsk, 220072 Belarus

We studied experimentally the diffraction of surface spin waves on a single antidot with a diameter of 50 μm in an yttrium iron garnet film with a thickness of 4.5 μm. Surface magnetostatic spin waves were excited by an rf magnetic field generated by a 50 μm wide microstrip antenna located near the antidot on the garnet film. The carrier wave length of the excited spin waves was comparable to the diameter of the antidot. The diffraction of the spin waves by the antidot was analyzed by spatially resolved Brillouin light scattering spectroscopy. This technique allows for a two-dimensional visualization of the diffraction pattern.
These patterns show a strong spatial anisotropy, dominated by so-called semicaustic spin-wave beams. The direction of the semicaustic beams was experimentally investigated as a function of the excitation frequency, the static magnetic field, and as a function of the angle between wave vector k and magnetic field H. The physical origin of the anisotropic diffraction pattern is the anisotropy of the dipolar interaction. To corroborate this argument, we numerically calculated the directions of the semicaustic beams from isofrequency curves in k-space, applying the theory of magnetostatic spin waves in thin films. These results are in good agreement with the experiment.
This work was supported by the Team Program of the Foundation for Polish Science.

16.15 – 16.30
Prediction and description for measuring the inertial regime in uniform ferromagnets
J.E. Wegrowe [1]
(1) Ecole Polytechnique, LSI, CNRS and CEA/DSM/IRAMIS, Palaiseau F-91128, France

The intimate relation between the angular momentum and the magnetization - expressed through the gyromagnetic relation $M = \gamma L$ - is well known and is easy to evidence with magnetomechanical measurements of the type Einstein - De Haas. On the other hand, the dynamical equations for the angular momentum of a rigid rotator find also an illustration in the behavior of a gyroscope or a spinning top. However, the movement of the spinning top consists not only of precession but also of nutation, i.e. inertial effects.
According to the gyromagnetic relation, the dynamics of a single domain ferromagnet should follow the same behavior as that of a symmetrical spinning top. [1] However, the Landau-Lifshitz-Gilbert equation that describes the dynamics of the magnetization does not contain inertial terms. We investigate here under what physical conditions the inertial terms are present in the dynamics of a uniform ferromagnet [2].
The possibility of measuring the inertial effects is discussed in terms of ferromagnetic resonance [3] and spectroscopy. Some preliminary experimental results will be shown.

[1] J.E. Wegrowe, M.-C. Ciornei, “Magnetization Dynamics, Gyromagnetic Relation, and Inertial Effects”, Am. J. Phys. (2012). In press.
[2] M.C. Ciornei, M. Rub\’i, and J.-E. Wegrowe, “Magnetization dynamics in the inertial regime: Nutation predicted at short time scales”, Phys. Rev. B 83, 020410(R) (2011)
[3] E. Olive, Y. Lansac, J.-E. Wegrowe, “Beyond Ferromagnetic Resonance: the Inertial Regime of the Magnetization”, submitted

16.30 – 16.45
Theoretical study of dynamical switching of a single spin by exchange forces
R. Wieser [1], V. Caciuc [2], C. Lazo [3], H. Hölscher [4], E.Y. Vedmedenko [1], R. Wiesendanger [1], S. Heinze [3]
(1) Institute of Applied Physics, University of Hamburg, D-20355 Hamburg, Germany, (2) Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany, (3) Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany, (4) Institut für Mikrostrukturtechnik, Forschungszentrum Karlsruhe, P.O. Box 36 70, D-76021 Karlsruhe, Germany

We demonstrate the possibility to dynamically manipulate the spin of a single atom or molecule with the magnetic tip of an atomic force microscope or spin-polarized scanning tunneling microscope due to the acting exchange forces. We choose a single transition metal benzene molecule as model system and calculate the exchange interaction with an Fe tip using density functional theory. This system can be seen as a special description of a more general physics describing the exchange interaction between adatoms and magnetic tips, e.g. 5d-transition metals on graphene. The exchange energy displays a Bethe-Slater type behavior with ferromagnetic coupling at large tip-sample distance and antiferromagnetic coupling at closer proximity. The exchange energies reach maximum values of a few 10 meV which allows to switch single spins by overcoming the energy barrier due to the magneto-crystalline anisotropy. The spin dynamics of the system was explored by solving the time dependent Schrödinger equation with additional relaxation term. We discuss eight possible scenarios, defined by the occurrence of quantum tunneling, relaxation, initial state and tip sample distance.

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14.45 – 15.15
The art of deposition of epitaxial growth FePt films on Glass substrates for ultrahigh magnetic recording densities *(invited)*
T. Speliotis [1], G. Giannopoulos [1], *D. Niarchos* [1]
(1) Institute of Materials Science, NCSR Demokritos, Athens, GREECE

Commercial hard disks for current recording media are deposited on glass-like substrates. Most of the scientific studies of FePt which is a candidate for ultrahigh density magnetic recording are on epitaxial grown films on MgO (001) substrates. Here we report on the "art of deposition" of FePt alloy thin film on glass substrates at low temperatures, with ordered $L1_0$ structure as a promising material for perpendicular magnetic recording (PMR) applications. FePt films have huge uniaxial magnetocrystalline anisotropy (K_u), high saturation magnetization (Ms), high coercivity (Hc) and outstanding corrosive resistance. The K_u value of $L1_0$ FePt is about 7 MJ/m^3 which sets the superparamagnetic limit of $L1_0$ FePt as small as 2.8 nm. A number of underlayers have been used to induce texture such as Cr, CrRu, MgO and very recently TiN. We will present an effective and efficient way to prepare $L1_0$ FePt (001) thin film, by sputtering, with perpendicular magnetic anisotropy at low ~ 325 ^{0}C order-disorder transformation temperature. Here we report a systematic study of the epitaxial growth of FePt(001) on textured MgO(200)/Cr(200) with the relationship FePt(001)[100] || MgO(001)[100] || Cr(200)[110], through optimization of deposition temperature and layer thickness of Cr and MgO underlayers. For FePt we varied the deposition temperature and Argon sputtering pressure. To monitor the (001) texture we have used XRD, AFM, FESEM and VSM and SQUID magnetometry. We have achieved perpendicular anisotropy, coercivity in excess of 1T even at low 325 ^{0}C deposition temperatures.

15.15 – 15.30
Granular $L1_0$ FePt-X(X = Ag, B, C, SiO_x, TaO_x)Thin Films for Heat Assisted Magnetic Recording
S. Granz [1], M. Kryder [1]
(1) Carnegie Mellon University, Data Storage System Center, 15213 Pittsburgh, PA USA

Ordered $L1_0$ FePt thin films are of interest as potential heat assisted magnetic recording media. In order to achieve the microstructure and magnetic properties to support recording at densities beyond 1 Tbit/in^2, it is has been found necessary to add segregants into the FePt films. We have conducted a study of the effects of a number of segregants, X, on the microstructure and magnetic properties of FePt-X(X=Ag, B, C, SiO_x, TaO_x) thin films, deposited by RF sputtering with various volume concentrations (0-50%), various in-situ heating temperatures (425-575^{o}C), various Ar pressures (10-40 mTorr) and various sputtering powers (25-200 W) onto 1" Si substrates with a MgO texture (002) underlayer (20 nm). The magnetic properties and microstructure of FePt-X films with various segregants were compared. It was observed that introducing segregants (B, C, SiO_x, and TaO_x) into the FePt reduced ordering and grain size of the FePt-X thin films. Ag was found to offset the reduction of ordering in the FePt-X films. The B, SiO_x and TaO_x promoted columnar growth whereas C promoted a secondary nucleation layer but produced the least reduction of ordering (Figure 1). By varying the volume content of the segregants, the grain size of the FePt-X can be controllably reduced throughout the 2.5-10 nm range. It was found that TaO_x produced the best exchange decoupling, thermal durability, grain isolation and hindered coalescence as compared with the films deposited with B, C or SiO_x. With the FePt-C films sputtered at 450^{o}C, we achieved perpendicular coercivity measured at room temperature as high as 25kOe; whereas with B, SiO_x, and TaO_x, we observed perpendicular coercivities as high as 11kOe. These FePt-X thin films with small grain size, columnar microstructure and high coercivity are believed to be favorable for application in Heat Assisted Magnetic Recording.

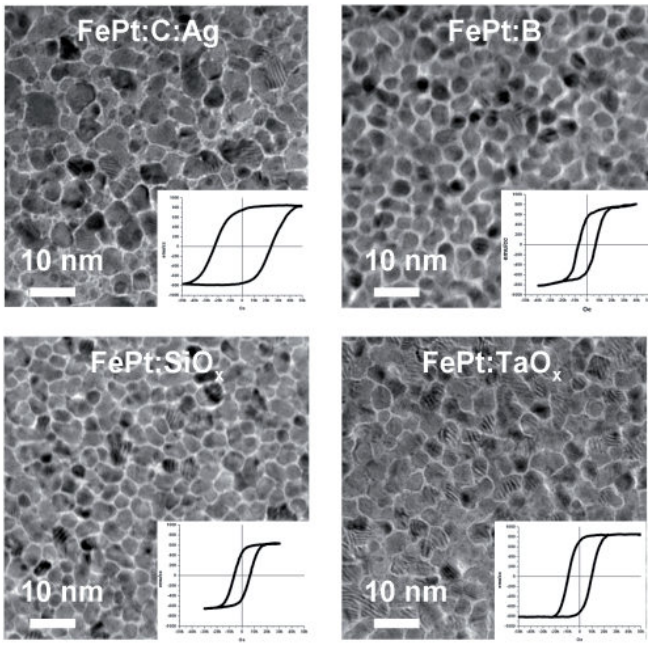

Figure 1: TEM and M-H Loops of FePt:C:Ag, FePt:B, FePt:SiO_x and FePt:TaO_x

15.30 – 15.45
Magnetoelectric effects in Fe/MgO/Fe tunnelling junctions on $BaTiO_3$(001)
G. Radaelli [1], S. Brivio [2], I. Fina [3], C. Rinaldi [1], R. Bertacco [1]
(1) LNESS and CNISM, Dipartimento di Fisica - Politecnico di Milano, Via Anzani 42, 22100 Como, Italy, (2) Laboratorio MDM – IMM –CNR, via Olivetti 2, 20864 Agrate Brianza (MB), Italy, (3) Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Campus UAB, 08193 Bellaterra, Spain

Looking for novel schemes for electrical writing of the magnetic information in spintronic devices, materials or interfaces displaying magnetoelectric (ME) coupling plays a major role. The first step in this direction is to develop a method to affect the magnetic properties of a ferromagnetic layer through an electric field. The study of the Fe/$BaTiO_3$ (BTO) interface is interesting

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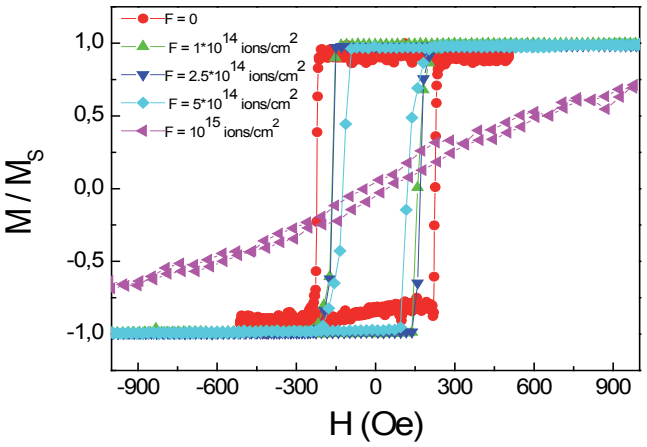
because of the interfacial ME coupling predicted by Duan et al [1] and Sahoo et al [2]. Experimental studies on Fe films grown on BTO single crystal substrates [3] demonstrated that sizable ME effects exist, mainly due to magnetostriction. In view of integration, however, the crucial point is the investigation of purely electrical ME phenomena at the interface between Fe and BTO thin films.
We report on fully epitaxial Fe/BTO//Nb:SrTiO3(001) and Fe/BTO/$La_{0.7}Sr_{0.3}MnO_3$//$SrTiO_3$(001) interfaces grown by combining the use of molecular beam epitaxy and pulsed laser deposition. A good quality and epitaxy of Fe on BTO has been reached, as proved by studies of growth dynamics and dielectric properties of BTO epitaxial films, in situ low energy electron diffraction and X-ray photoemission spectroscopy. Finally, epitaxial Fe/MgO/Fe/BTO heterostructures have been deposited and magnetic tunnelling junctions (MTJs) fabricated via optical lithography. Preliminary experiments testing the electric control of the TMR have been performed at different temperatures. A modulation of the TMR on the order of 10%, induced by application of an electric field across the BTO film, has been detected at 150 K. This result attests the great potential of this system for the electric control of magnetization in spintronic devices.

[1] C. Duan et al. *Phys. Rev. Lett.* **97**, 047201 (2006)
[2] S. Sahoo et al. *Phys. Rev. B* **76**, 092108 (2007)
[3] S. Brivio et al. *Appl. Phys. Lett.* **98**, 092505 (2011)
[4] G. Radaelli et al. *Appl. Phys. Lett.* **100**, 102904 (2012)

15.45 – 16.00
Tailoring magnetism in films with perpendicular anisotropy by light ion irradiation for spintronics applications
I. Barisic [1], S. Eimer [1], J.P. Adam [1], N. Vernier [1], G. Agnus [1], T. Devolder [1], C. Torre [1], D. Ravelosona [1]
(1) Institute d'Electronique Fondamentale/Université Paris Sud/CNRS UMR 8622, 91405 Orsay, France

Materials with perpendicular magnetic anisotropy (PMA) are considered as the most promising to reach ultra high density for new generation of spintronic devices. Particularly, one crucial breakthrough in spin electronics has recently been achieved regarding the possibility to move magnetic domain walls (DWs) in magnetic tracks using the sole action of an electrical current instead of a conventional magnetic field. This important discovery has opened a perspective for a paradigm shift in mass storage design. One crucial issue for this technology is to locally pin magnetic domain walls with high thermal stability. For that, one promising approach is to use ion irradiation through a mask to locally modify magnetic anisotropy. [1-2]
Here, we study the influence of light ion irradiation on the magnetic properties of CoNi and CoFeB ultrathin films with perpendicular anisotropy, which are considered as the most promising candidates for spintronics applications. We show that PMA can be modified in a very controlled way, from perpendicular to in-plane (see Fig. 1), by using light ion irradiation. The crystallinity and roughness of the samples are not affected during the process. These results suggest a pathway to further optimize these materials for current induced DW motion in wires and logic devices.

[1] J.Fassbender et al., J.Phys.D: Appl. Phys. 37, 179 (2004).
[2] C.Chappert et al., Science 280 1219 (2004).



16.00 – 16.15
Spherical Co- and Ba-ferrite nanoparticles as media for advanced particulate magnetic tape recording: A micromagnetic study
J. Fidler [1], J. Lee [2], D. Süss [1]
(1) Vienna University of Technology, Institute Solid State Physics, Wiedner Hauptstr. 8-10, A-1040 Wien, Austria, (2) Seoul National University, National Creative Research Center for Spin Dynamics & Spin-Wave Devices, Seoul 151-744, Republic of Korea

We have studied the influence of various head field models on the recording behaviour of spherical $CoFe_2O_4$ (M_s=400emu/cc, K_1=-2.0x10^{6}erg/cc) and $BaFe_{12}O_{19}$ (Ms=275emu/cc, K_1=1.25x10^{6}erg/cc) nanoparticles with a diameter of ~15 nm as candidates for high density tape recording media with an areal recording density up to 30 Gb/inch^2 [1] using an integrated numerical finite element micromagnetic simulation together with the nudged elastic band method. The microstructural models as input for the micromagnetic simulation were prepared by an implementation of the Lubachevsky-Stillinger packing algorithm [2]. The track model of the magnetic storage layer consists of about10000 nanoparticles and has a length of 9000nm, a width of 200nm and a thickness of 30-60nm. In detail we analyzed the signal to noise ratio of the read back signal as a function of the head to media distance (d=20nm and 40nm), head speed and deep gap field (8-14 kOe) up to a linear density of 508 kfci (linear bit length 50nm). The writing simulations on the particulate media models were performed by overlapping the write head field boxes on the finite element media models. Magnetization dynamics of the particles under the head field is calculated using the Landau-Lifshitz-Gilbert equation. An extremely sharp bit transition has been observed for the random Co-ferrite media with random texture (Fig.1) due to the cubic magnetocrystalline anisotropy. It should be noted that the energy barrier for thermal switching for such $CoFe_2O_4$ nanospheres was

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found to be in the order of 12 k_BT, which excludes these media from tape recording application.
The support of the INSIC TAPE Program is acknowledged.

[1] G. Cherubini, et al, IEEE Trans.Magn. 47 (2011) 137-147.
[2] A. Donev, et al., Phys Rev Lett, 92 (2004) 255506.

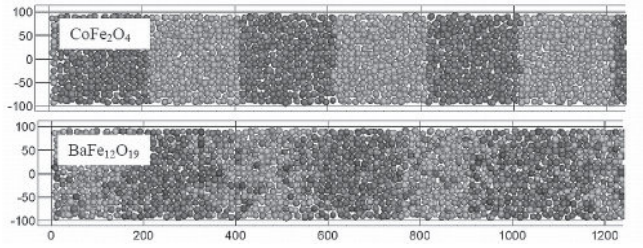
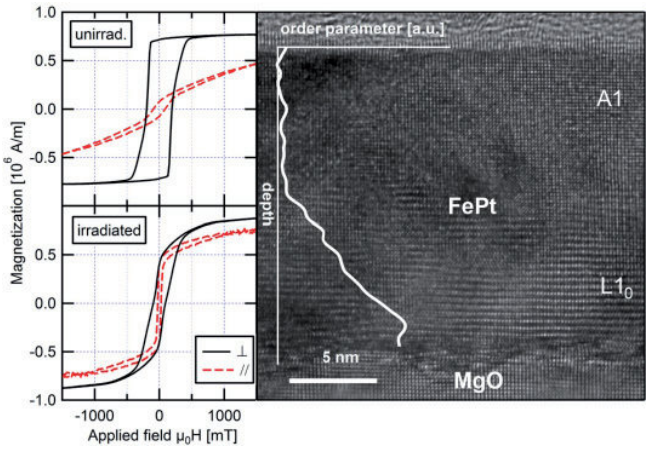


Fig.1 Final states of written bits at random texture for a linear bit density of 125 kfci.

16.15 – 16.30
Anisotropy-graded exchange-coupled composite media obtained by ion irradiation of FePt $L1_0$
A. Di Bona [1], P. Luches [1], S. D'Addato [2], S. Valeri [2], F. Albertini [3], F. Casoli [3], P. Lupo [3], L. Nasi [3]
(1) Centro S3 – Istituto Nanoscienze – Consiglio Nazionale delle Ricerche, via G. Campi 213/A, 41125 Modena, Italia, (2) Dipartimento di Fisica – Università di Modena e Reggio Emilia and Centro S3 – Istituto Nanoscienze – Consiglio Nazionale delle Ricerche, via G. Campi 213/A, 41125 Modena, Italia, (3) Istituto dei Materiali per l'Elettronica ed il Magnetismo – Consiglio Nazionale delle Ricerche, Parco Area delle Scienze 37/A, 43124 Parma, Italia.

The effect of Ar^+ irradiation on chemically ordered FePt thin films has been investigated. Epitaxial $L1_0$ FePt films with high uniaxial perpendicular anisotropy and high coercivity have been grown on MgO(001) by RF sputtering. Ar^+ ion irradiation at 5 keV and low doses (< 10^{15} ions/cm^2) is found to be effective in turning the chemically ordered, magnetically hard, $L1_0$ phase into the cubic A1, magnetically soft phase [1,2]. Due to the limited penetration depth of the ions, a thin, magnetically soft layer builds up at the surface of the film. This results in an exchange-coupled, anisotropy-graded, composite media with perpendicular anisotropy and domain wall assisted switching. The spatial distribution of the chemical order parameter has been determined by high resolution transmission electron microscopy. Irradiation at different angles allow the control of the anisotropy depth profile via the chemical disorder of the material, and therefore the magnetic switching of the system. A model for the depth distribution of the chemical order parameter, based on Monte Carlo calculations, is proposed. Ion erosion (sputtering) of the film has been observed at doses significantly higher than that needed for the magnetic transition to occur. The magnetic properties and coupling regimes of the resulting exchange coupled systems are discussed.

[1] B. D. Terris, D. Weller, L. Folks, J. E. E. Baglin, A. J. Kellock, H. Rothuizen, and P. Vettiger, J. Appl. Phys. 87, 7004 (2000).
[2] F. Albertini, L. Nasi, F. Casoli, S. Fabbrici, P. Luches, G. C. Gazzadi, A. di Bona, P. Vavassori, S. Valeri, and S. F. Contri, J. Appl. Phys. 104, 053907 (2008).



Left: Hysteresis loops of 20 nm FePt film before and after ion irradiation. Right: HR-TEM cross-section image after ion irradiation; line graph: intensity of the Fourier filtered images obtained by selecting the (001) superstructure spots.

16.30 – 16.45
Compensating the demagnetizing field of an in-plane free layer by exchange coupling with a perpendicular multilayer
Y.C. Lau [1], K. Oguz [1], K. Rode [1], J.M.D. Coey [1]
(1) School of Physics and CRANN, Trinity College, Dublin 2, Ireland.

Magnetic exchange coupling of two ferromagnetic layers via a non-magnetic metallic spacer [1] has been the subject of extensive research effort. An antiferromagnetically-coupled Co-Fe/Ru/Co-Fe trilayer frequently forms part of the reference layer of magnetic tunnel junctions (MTJ) [2]. MTJs are used in applications ranging from high-density recording to spin transfer torque magnetic random access memory (STT-MRAM) [3]. However, state-of-the-art current-induced magnetization switching still requires a high switching current density, j_c, and it is of paramount importance to reduce j_c while conserving the thermal stability of the device. Here, we demonstrate the demagnetizing field compensation of an in-plane ferromagnetic free layer by exchange coupling to a perpendicular ferromagnetic multilayer. The MTJ stack is shown in Fig. 1. The bottom reference layer is a synthetic antiferromagnet with a 3 nm $Co_{40}Fe_{40}B_{20}$ layer in contact with the MgO barrier. The top $Co_{50}Fe_{50}$ free layer of thickness t, is exchange-coupled via a 1.2 nm Ru layer to a $[Co_{90}Fe_{10}/Pt]_{x5}$ multilayer. Tunnel magneto-resistance (TMR) data in Fig. 1 shows an increase of magnitude with t. We interpret this in terms of a continuous rotation of the free layer magnetization from perpendicular to in-plane as t increases. The angle θ between the free layer magnetization and the film plane is plotted against t in the inset of Fig. 1. We suggest that balancing the demagnetizing field of the free layer

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by exchange coupling with a perpendicular stack could reduce j_c in such MTJs.

[1] S. S. P. Parkin, Phys. Rev. Lett. 67, 3598-3601 (1991)
[2] S. Yuasa and D. D. Djayaprawira, J. Phys. D: Appl. Phys. 40 R337–R354 (2007)
[3] T. Kawahara, *et al.*, Microelectronics Reliability 52, 4, 613-627 (2012)

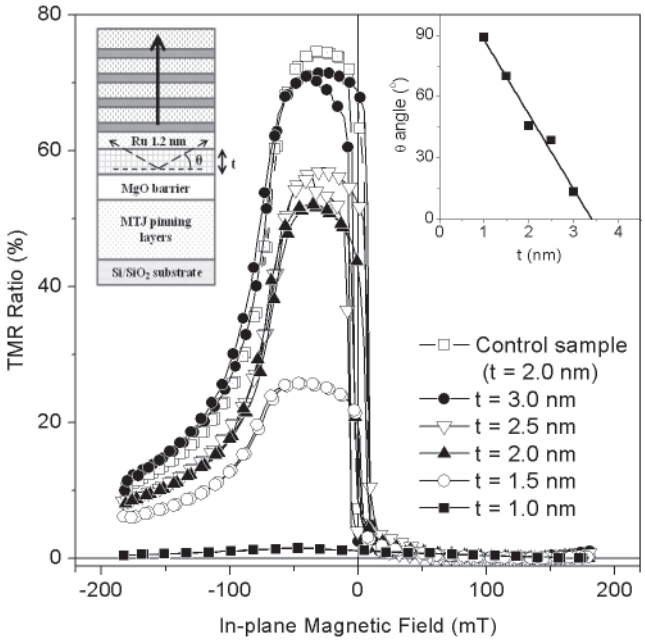

Fig. 1. TMR of MTJs at various $Co_{50}Fe_{50}$ layer thicknesses. The MTJ stack and a plot of θ versus *t* are shown in the insets.

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14.45 – 15.15
Magnetricity and Magnetic Monopoles in Spin ice *(invited)*
S.T. Bramwell [1]
(1) University College London, UK

The analogy between spin configurations in spin ice materials like Ho_2Ti_2O7 and proton configurations in water ice, H_2O, has been appreciated for many years (see Ref. [1] for a review). However it is only in the last few years that this equivalence has been extended into the realm of electrodynamics [2,3]. In this talk I shall describe our recent experimental work that identifies emergent magnetic charges ("monopoles"), transient magnetic currents ("magnetricity") and the universal properties expected of an ideal magnetic Coulomb gas (magnetic electrolyte - "magnetolyte"). These universal properties include the Onsager-Wien effect, "corresponding states" behaviour, Debye-Huckel screening and Bjerrum pairing [4-6]. I will describe experimental results for both traditional spin ice materials ($Ho_2Ti_2O_7$, $Dy_2Ti_2O_7$) and a recently discovered system ($Dy_2Ge_2O_7$).

[1] Bramwell and Gingras, Science, 294 1495 2001
[2] Castelnovo et al., Nature 451 42 (2008)
[3] Ryzhkin, JETP 101 481 (2005);
[4] Bramwell et al. Nature 461 956 (2009)
[5] Fennell et al., & Bramwell Science 326 415 (2009)
[6] Giblin, Bramwell et al., Nature Physics 7 252 (2011)
[7] Zhou, Bramwell et al., Nat Comm. 478, 1483 (2011)

15.15 – 15.30
Thermal Ordering and Excitations in Artificial Spin Ice
J.P. Morgan [1], Z. Budrikis [2], J. Akerman [3], A. Stein [4], R.M.L. Evans [1], K. Livesey [5], R.L. Stamps [6], S. Langridge [7], C.H. Marrows [1]
(1) School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK, (2) School of Physics, The University of Western Australia, Crawley 6009, Australia, (3) Institutode Sistemas Optoelectrónicos y Microtecnología (ISOM), Universidad Politécnica de Madrid, 28040 Madrid, Spain, (4) Center for Functional Nanomaterials, Brookhaven National Laboratory, New York 11973, USA, (5) Dept of Physics and Energy Science, University of Colorado, Colorado 80918, USA, (6) SUPA School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, UK, (7) ISIS, STFC Rutherford Appleton Laboratory, Didcot OX11 0QX, UK

Artificial spin ice is a tunable 2D metamaterial, built from single domain nanomagnets [1–3]. Fig.1a shows an SEM image of a NiFe square ice, fabricated on Si substrate by electron beam lithography and evaporation: a periodic lattice with strong local anisotropies captures the essence of geometrically frustrated materials e.g. pyrochlore spin ice, with coupled Ising-like

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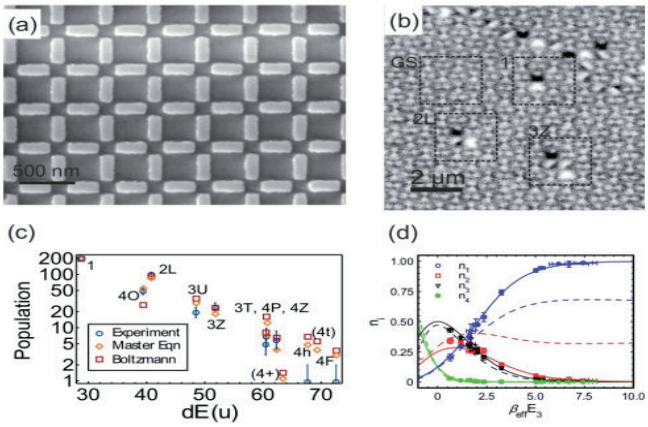
moments converging at interlinked vertices. They realise well-known statistical mechanical vertex models and allow real-space observation of magnetic order.
To date, the "effective thermodynamics" of rotating field protocols has drawn significant attention, however, such methods fail to access the predicted two-fold degenerate ground state (GS) in athermal systems [1]. We present the first experimental observation and subsequent studies of true *thermal ordering* in artificial spin ice [2,3].
Magnetic force microscopy surveying of as-fabricated arrays, Fig.1b, reveals long range self-ordered GS domains supporting a rich variety of defects – antiferromagnetic domain walls and localised "monopole" excitations, analogous to fractionalised ionic defects in water ice. We hypothesise early growth-stage ordering driven by dipolar interactions and thermalisation which eventually arrests as elemental volumes increase. Boltzmann and master equation calculations yield excellent agreement with observed excitation populations, Fig.1c.
Ordering is dependent on coupling and quenched disorder strength, controlled by lattice constant and buffer layer roughness respectively, as observed in Monte Carlo simulations of thermal annealing. Mean field calculations based on the canonical ensemble parameterise vertex populations by an effective temperature, Fig.1d, implying that equilibrium is closely approached. Within a dipolar energy band structure, evidence is found for emergent quasi-particle interactions between monopole defects.

[1] R.F. Wang et al., Nature 439, 303 (2006)
[2] J.P. Morgan et al., Nature Physics 7, 75 (2011)
[3] Z. Budrikis et al., NJP 14, 035014 (2012)



(a) SEM and (b) MFM of as-fabricated ASI with (c) defect and (d) vertex populations.

15.30 – 15.45
Monopoles and the stray field from spin ice
S.J. Blundell [1], T. Lancaster [2], J.S. Moeller [1], F. Pratt [3], D. Prabhakaran [1]
(1) Oxford University Department of Physics, Oxford, OX1 3PU, UK, (2) Durham University Department of Physics, Durham, DH1 3LE, UK, (3) ISIS, Rutherford Applelton Laboratory, Didcot, OX11 0QX, UK

Spin ice is the name given to compounds such as $Dy_2Ti_2O_7$ in which the magnetic Dy ions sit on a pyrochlore lattice and are constrained by easy-axis anisotropy to only point in or out of each tetrahedron. The natural excitations of this system are believed to be magnetic monopoles [1] and at low temperatures spin ice is believed to behave as a dilute distribution of itinerant monopoles, a so-called magnetic Coulomb liquid. It has been argued that spin ice should conduct magnetic charge in an analogous manner to an electrolyte and a muon-spin rotation experiment was used [2] to measure the monopole charge on the basis of relaxation assumed to originate from the Wien effect. This result has proved rather controversial [3,4] and it has recently been shown in detail how the behavior observed in the muon experiments on spin ice can result from the macroscopic stray field of magnetized spin ice [4]. We have carried out muon experiments to test the approach given in [4] and show that a macroscopic stray field can indeed account for the low-temperature data. Our results also allow us to study the out-of-equilibrium behavior of spin ice and to extract aspects of monopole physics.

[1] C. Castelnovo et al., Nature **451**, 42 (2008)
[2] S. T. Bramwell et al., Nature **461**, 956 (2009)
[3] S. R. Dunsiger et al., Phys. Rev. Lett. **107**, 207207 (2011).
[4] S. J. Blundell, Phys. Rev. Lett. **108**, 147601 (2012).

15.45 – 16.00
Avalanches in the spin-ice compound $Dy_2Ti_2O_7$
E. Lhotel [1], *C. Paulsen* [1], M. Jackson [1], K. Matsuhira [2], Z. Hiroi [3], S.R. Giblin [4], S.T. Bramwell [5], D. Prabhakaran [6]
(1) Institut Néel, CNRS, 38042 Grenoble, France, (2) Kyushu Institute of Technology, Kitakyushu 804-8550, Japan., (3) Institute for Solid State Physics, University of Tokyo, Kashiwa Chiba 277-8581, Japan, (4) ISIS Facility/Rutherford Appleton Laboratory, Chilton Oxfordshire OX11 0QX, UK, (5) London Centre for Nanotechnology and Department of Physics and Astronomy, University College London, London WC1H 0AH, UK, (6) Department of Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, UK

Avalanches of the magnetization, that is to say abrupt reversals of the magnetization at a given field, have been reported in the spin-ice compound $Dy_2Ti_2O_7$ [1]. This out-of-equilibrium process often results from the difficulty for the heat released by the spin flipping process to be dissipated in the sample and to be absorbed by the external thermal bath, due to a low thermal conductivity and/or a bad thermal coupling of the sample to his environment. Although this phenomena is quite usual in low temperature magnetization studies, a key point is to determine the physical origin of the starting of the avalanches. In particular, in spin-ice compounds, the origin of the avalanches might be related to the monopoles physics inherent to the system.
We have performed a detailed study of the avalanches phenomena in three singles crystals, oriented along the [111]

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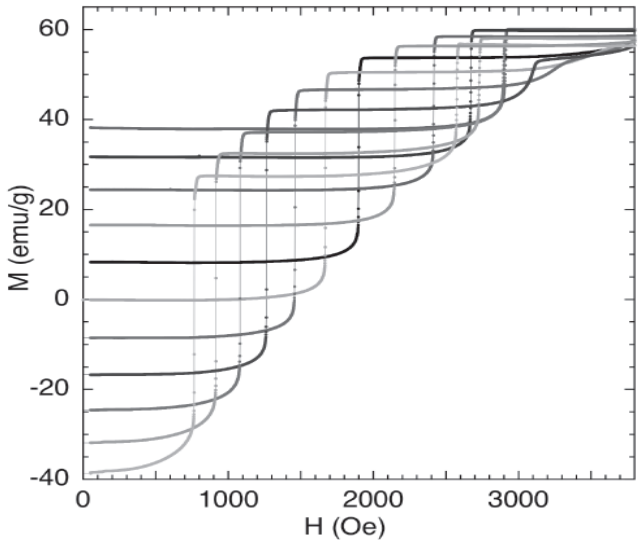
or the [100] direction. We find that the avalanches are quite slow compared to the avalanches reported in other systems such as molecular magnets. Our measurements show that the avalanches trigger after a delay of about 500 ms and that the reversal of the magnetization then occurs in a few hundreds of milliseconds. These features suggest an unusual propagation of the reversal, which might be due to the monopoles motion. The avalanches fields seem to be reproducible in a given direction for different samples, but they strongly depend on the initial state of magnetization. On the other hand, the value of the magnetization at the end of the avalanche at a given field always matches with the corresponding equilibrium value at 900 mK.
[1] D. Slobinsky et al., Phys. Rev. Lett. 105, 267205 (2010).

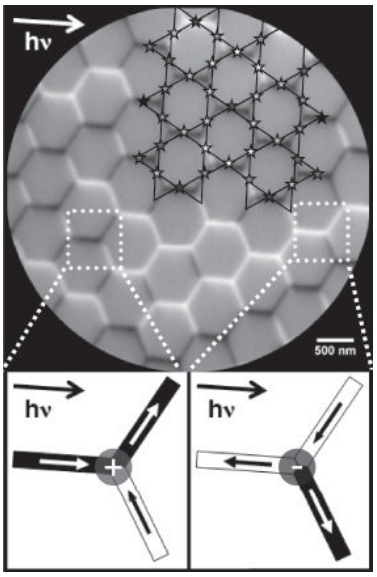


M vs H at 76 mK, measured along [111] at a field sweeping rate of 8.75 Oe.s^{-1} and starting from different field cooled states.

16.00 – 16.15
Emergence of a magnetic charge crystal in artificial dipolar spin ice
N. Rougemaille [1], F. Montaigne [2], B. Canals [1], A. Duluard [2], D. Lacour [2], M. Hehn [2], R. Belkhou [3], O. Fruchart [1], S. El Moussaoui [3], A. Bendounan [3], F. Maccherozzi [4]
(1) Institut Néel, CNRS & Université Joseph Fourier, BP166, F-38042 Grenoble Cedex 9, France, (2) Institut Jean Lamour, CNRS-Nancy Université, BP 239, F-54506 Vandoeuvre, France, (3) Synchrotron SOLEIL, L'Orme des Merisiers Saint-Aubin, 91192 Gif-sur-Yvette, France, (4) ELETTRA, Sincrotrone Trieste, I-34012 Basovizza, Trieste, Italy

Using lithography techniques, we have fabricated geometrically frustrated arrays of nanomagnets on a kagome lattice (see Figure). Due to their elongated shape, magnetization can only point along the long axis of the nanomagnets, which can be considered as Ising spins. Each vertex of the array is then defined by the spin state of a set of three Ising spins. The nanomagnets being magnetic dipoles, the magnetic configuration of a vertex can also be characterized by the magnetic charge it carries: the 3-in or 3-out spin configuration are equivalent to a magnetic charge state ±3, while the other spin configurations are equivalent to a charge state of ±1.

Combining Monte Carlo simulations and X-PEEM magnetic imaging on artificial arrays of cobalt nanomagnets, we found that the long range (i.e. beyond nearest neighbors) dipolar interactions between the nanomagnets can not be neglected. This result has profound consequences: while the main interest for frustrated compounds arises from the massive degeneracy of their ground state [1], this degeneracy is fully lifted when long range, dipolar interactions are included in the model [2]. One argument we used to demonstrate this result was to compare predictions from dipolar spin ice models and our experimental observations. In particular, as the system reaches low-energy spin configurations when we demagnetize the arrays, it goes through a (predicted) phase transition where spins fluctuate while the magnetic charges at the vertices crystallize to form a perfectly ordered arrangement of alternating +1 and –1 magnetic charges [3].
[1] R. F. Wang et al., Nature 439, 303 (2006)
[2] G. Moller and R. Moessner, Phys. Rev. B 80, 140409 (2009)
[3] N. Rougemaille et al., Phys. Rev. Lett. 106, 057209 (2011)



5 µm magnetic image of an artificial array of Co nanomagnets

16.15 – 16.30
Using networks to study athermal dynamics in spin ice
Z. Budrikis [1], P. Politi [2], R.L. Stamps [3]
(1) School of Physics, University of Western Australia, Australia, (2) Istituto dei Sistemi Complessi CNR, Italy, (3) School of Physics and Astronomy, University of Glasgow, UK

Artificial spin ices are two dimensional, geometrically frustrated systems, comprised of submicron islands of magnetic material. These are constrained by shape anisotropy to act as Ising spins, and are large enough that their magnetisation reversal is

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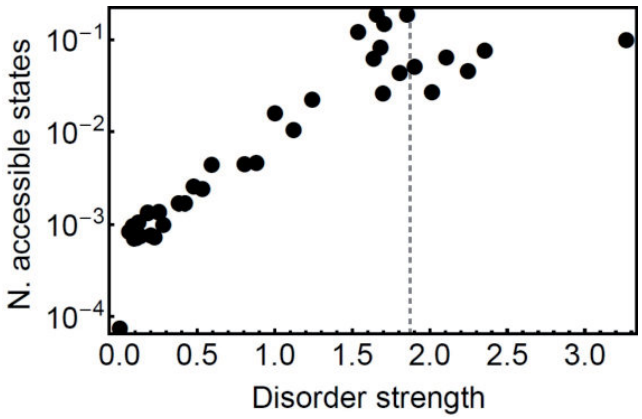
inaccessible to thermal dynamics. Accordingly, dynamics must be induced by external fields which act uniformly on all spins. These global dynamics are highly constrained and many states are inaccessible, regardless of their energy. For example, states obtained by field-driven demagnetisation typically only have short-range ground state ordering [1].
In this talk, we show how the field driven dynamics can be mapped onto a directed network in which nodes represent spin configurations and two nodes are linked if an external field can drive the system from one configuration to the other [2]. The network contains information about dynamics under any sequence of applied fields, and analysis of the network allows us to extract general information about the system's behaviour. A related approach has proved fruitful in a diverse range of contexts, from protein folding to the random field Ising model.
We apply this model to study the effects of quenched disorder on dynamics, and show how disorder can affect the accessibility of states. For example, as seen in the figure, the number of states reachable from a saturated initial configuration increases by three orders of magnitude when disorder is introduced (the vertical bar indicates the disorder strength of a typical experimental system). We also show that disorder increases the reversibility of dynamics [3].

[1] R. F. Wang et al., Nature 439, 303 (2006).
[2] Z. Budrikis, P. Politi and R. L. Stamps, Phys. Rev. Lett. 107, 217204 (2011).
[3] Z. Budrikis, P. Politi and R. L. Stamps, New J. Phys., in press.



Fraction of states accessible from a saturated state versus disorder strength.

16.30 – 16.45
Determination of absolute magnetic chirality in a langasite single crystal
A. Bombardi [1], L. Chapon [2], F. Fabrizi [3], P. Radaelli [3], C. Stock [4], D. McMorrow [5], S. Cheong [6]
(1) Diamond Light Source Ltd., Harwell Science and Innovation Campus, Didcot, Oxfordshire, OX11 0DE, United Kingdom, (2) Institut Laue-Langevin, BP 156, FR-38042 Grenoble Cedex 9, France, (3) Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom, (4) NIST Center for Neutron Research, 100 Bureau Drive, Gaithersburg, Maryland 20899, USA Clarendon Laboratory, (5) London Centre for Nanotechnology, Department of Physics and Astronomy, University College London, London WC1E 6BT, United Kingdom, (6) Rutgers Center for Emergent Materials and Department of Physics and Astronomy, Rutgers University, 136 Frelinghuysen Rd., Piscataway, New Jersey 08854, USA

The langasites are a large family of compounds discovered in the 80's that were first studied due to their piezoelectric and optical properties [1]. In the case of Ba3NbFe3Si2O14 the magnetic Fe3+ ions form a planar triangular arrangement of triangle whereas the 3-dimensional aspect comes into play through chiral magnetic exchange. The long range ordered state [2,3] is characterized by an incommensurate propagation vector τ =(0, 0, 1/7), with all equal magnetic moments pointing in the ab plane forming angles of 120 degrees amongst themselves. This arrangement is the classical compromise of frustrated spins on a triangular, with two possible configurations for the magnetic moments compatible with this structure are all in (out), 2 in(out) and 1 out(in) and these configurations have been labeled as belonging to opposite triangular chiralities (tc = ±1). In the c direction the propagation vector τ establish the pitch of the circular helix that can turn clockwise or anticlockwise so that two helical chiralities are possible (hc = ±1). In the system a single chiral state is realized [3].
We reinvestigated the magnetic ground state of Ba3NbFe3Si2O14 on a structurally enantiopure single crystal using non resonant x-ray magnetic scattering. This technique is sensitive to the chirality of the helical order previously reported in this compound and it allows a unique determination of its sign. Accurate measurements of the magnetic interaction vector revealed that some aspects of the long range magnetic ordering escaped the neutron investigation. We discuss the implications on the degeneracy of the ground state.

[1] M. Kitaura et al, Phys. Rev. B 69, 115120 (Mar 2004)
[2] K. Marty et al, Phys. Rev. Lett. 101, 247201 (Dec 2008).
[3] K. Marty et al, Phys. Rev. B 81, 054416 (Feb2010).

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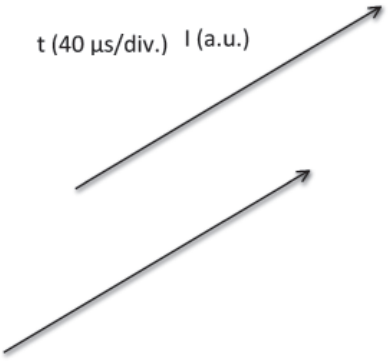
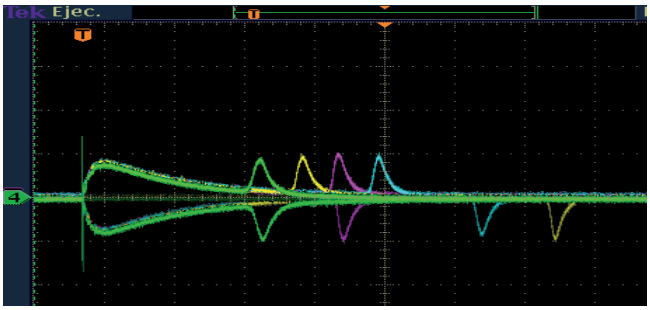
14.45 – 15.15
Controlled motion of single domain wall in magnetic wires by local fields *(invited)*
M. Vázquez [1], A. Jimenez [1], G. Badini-Confalonieri [1], R.P. Del Real [1]
(1) Institute of Materials Science of Madrid, CSIC. 28049 Madrid. Spain

Magnetization reversal in magnetic wires is attracting increasing interest in connection with advanced spintronics and logic devices [1]. Reversal process is investigated intensively in lithography nanostrips, including the presence of transverse and vortex-like domain walls and the influence of notches and electrical current in their motion. Interest is also emerging on bistable micro and submicrometer amorphous wires where reversal proceeds by nucleation & propagation of a single domain wall, DW [2]. Such cylindrical wires are model systems for basic studies on dynamics of single DWs reaching velocities of km/s under few Oe applied field whose mobility and motion damping depend on various parameters (see [3] for updated state-of-the-art)
We introduce most recent work demonstrating the possibility to control the DW position and velocity by suitable application of local field. We firstly make use of multiple pick-up coils in a Sixtus&Tonks-like experiment to follow the motion and position of single DW under the simultaneous action of homogeneous and local fields, and confirm that linear behavior between DW speed and homogeneous applied field is limited to fields below the nucleation of multiple walls. Tuning the local field between antiparallel and parallel configuration to homogeneous field enables respectively the trapping of DW in given position, or nucleate local reverse domain so injecting head-to-head and tail-to-tail pairs of DWs suitable for DW-based storage information.

[1] S. Parkin et al. Science 320 (2008) 190; D. Allwood et al., Science 309 (2005) 1688.
[2] M. Vazquez, H. Chiriac, A. Zhukov, L. Panina, T. Uchiyama, Phys. Stat. Sol.A 208 (2011) 493.
3] M. Vazquez, G.A. Basheed, G. Infante, R.P. del Real, Phys. Rev. Letters 108 (2012) 037201.

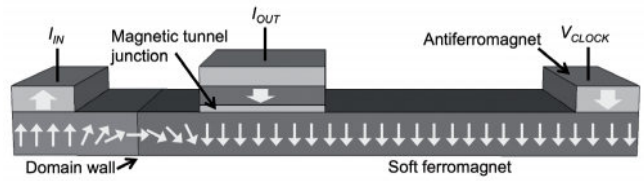




Motion of a single DW depinned from the wire end is recorded by induced peaks in consecutive coils (downward), and of two DWs moving in opposite directions (upward).

15.15 – 15.45
Low Energy Domain Wall Logic in Short, Narrow Ferromagnetic Wires *(invited)*
J.A. Currivan [1], F. Liu [2], M. Baldo [3], C.A. Ross [2]
(1) Harvard/Physics, 02138, Cambridge, MA, USA, (2) Massachusetts Institute of Technology/Materials Science and Engineering, 02139, Cambridge, MA, USA, (3) Massachusetts Institute of Technology/Electrical Engineering and Computer Science, 02139, Cambridge, MA, USA

We report on using narrow soft ferromagnetic wires to engineer more energy-efficient logic gates. We demonstrate a prototype of the magnetic logic device, and simulations that show it can scale to switching energies and voltages below those of complementary metal oxide semiconductor (CMOS) transistors. Information is stored in a transverse domain wall in a short, narrow soft ferromagnetic wire, with magnetization fixed on the wire ends using IrMn antiferromagnetic pinning. The wire is a thin film of CoFeB with perpendicular magnetic anisotropy. The domain wall is translated by current-induced spin torque transfer, and information is read out by a MgO magnetic tunnel junction. Similar devices have been proposed for memory[1], but we demonstrate in the prototype that they can be used to perform logic, e.g. a single device can perform a NAND operation. Fabrication is done using electron-beam lithography, UHV sputter deposition, and ion beam etching.
We present results from modeling the device behavior in circuits, demonstrating that the device satisfies all the important qualities of beyond-CMOS logic. The energy consumption scales well with size, the device has gain, acts as a single non-volatile universal gate that can be successfully integrated into complex circuits, and is compatible with CMOS. The results show that domain wall based logic is a promising contender to replace CMOS at the end of its roadmap.



Cartoon of magnetic logic gate.

[1] Fukami, S.; Suzuki, T.; Nagahara, K.; et al. *VLSI Technology, 2009 Symposium on.* 2009, 230-231.

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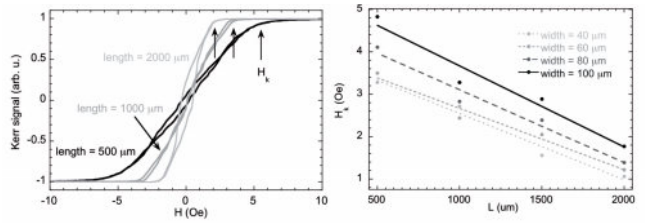
15.45 – 16.00
Tailoring the effective magnetic anisotropy of thin film magneto-impedance microsensors by combined induced and shape anisotropies
E. Fernández Martín [1], A. Barrainkua [1], *A. García-Arribas* [1], A.V. Svalov [1], G.V. Kurlyandskaya [1], D. Navas [2], J.M. Barandiarán [1]
(1) Departamento de Electricidad y Electrónica, Universidad del Pais Vasco UPV/EHU, 48080 Bilbao, Spain, (2) Departamento de Química Física, Universidad del Pais Vasco UPV/EHU, 48080 Bilbao, Spain

Soft ferromagnetic materials exhibit Magneto-Impedance (MI) effect manifested by a great change of their electrical impedance under an applied magnetic field. It is caused by the reduction of the effective section for current flow due to the skin effect, controlled by the variation of the permeability when a magnetic field is applied. In magnetic wires, the impedance relative change can reach 800% with huge sensitivities to small fields, up to about 500% per Oesterd [1]. However, competitive sensors must combine high performance with small size and smooth interfacing with electronics. Thin film-based MI sensors are well-adapted to fulfil those requirements. They must display a small and well-defined transverse anisotropy in order to obtain high sensitivities at low magnetic fields. In this work we report the attempt to tailor the anisotropy in MI thin films by a combination of induced and shape contributions.
Multilayered films $[FeNi(170nm)/Ti(6nm)]_2/FeNi(170nm)$ were deposited by sputtering onto silicon. Thin Ti layers allow obtaining 0.5 μm thick films with the required magnetic softness [2]. An in-plane magnetic field was applied during the deposition process to induce a uniaxial anisotropy. The deposit was patterned by photolithography to define rectangular samples with different lengths and widths. The induced magnetic anisotropy axis was oriented perpendicular to the long axis of the rectangles for all samples. Therefore, the competition between the induced anisotropy and the shape anisotropy terms produces large variations in the effective anisotropy that shows a tendency to decrease as length increases, as deduced from Kerr hysteresis loops.

[1] G.V. Kurlyandskaya, H. Yakabchuk, E. Kisker, N.G. Bebenin, H. García-Miquel, M. Vázquez, V. O. Vas´kovskiy, J. Appl. Phys., **90** (2001) 6280.
[2] G.V. Kurlyandskaya, A.V. Svalov, E. Fernández, A. García-Arribas, and J.M. Barandiaran, J. Appl. Phys. **107** (2010) 09C502.

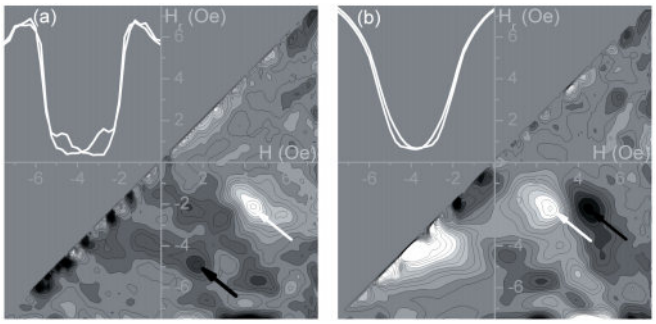


Hysteresis loops and effective anisotropy for different shaped samples

16.00 – 16.15
Inhomogenous magnetization structure in soft amorphous ribbons probed by GMI-FORC technique
L.C. Costa [1], *F. Béron* [1], K.R. Pirota [1]
(1) Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas, 13089-859, Campinas, Brazil

Soft amorphous ribbons with transversal anisotropy generally present (quasi) anhysteretic axial magnetization curve. On the other hand, the measurement of the giant magnetoimpedance (GMI) effect yields to a well-defined hysteresis area for the same configuration. This effect, related to the magnetization process of the magnetic system, consists of the variation of the electric impedance of soft magnetic materials in the presence of static magnetic field. Finally, first-order reversal curve (FORC) method represents a powerful experimental technique to probe the irreversible processes occurring in a system [1]. Mainly applied to magnetization curves, a proper FORC analysis gives the statistical distribution of the parameters from elementary (local) hysteretic process.
We previously applied the FORC formalism to low frequency (kHz) hysteretic giant magnetoimpedance (GMI) curves of FeCoSiB amorphous ribbons with transversal anisotropy [2]. Our results showed that the FORCs can be separated into three groups, based on their behavior. An interlinked hysteron/anti-hysteron model was proposed to interpret the hysteresis behavior.
In this work, we extended and raised the frequency range (10 MHz - 1 GHz), using a vector network analyzer. The FORC distributions exhibit an abrupt change when increasing the frequency, passing from the hysteron/anti-hysteron model (a) to the succession of a negative (black) and positive (white) peaks along a given reversal field value (b). The FORC distribution modification reflects a transformation of the irreversible processes occurring in the area probed by GMI and therefore, an inhomogeneous magnetization structure along the ribbon thickness. It can be described by the penetration depth associated to the modification frequency, which exhibits a relation with the ribbons anisotropy constant.

[1] I. D. Mayergoyz, Phys. Rev. Lett. 56, 1518 (1986)
[2] F. Béron, L. A. Valenzuela, M. Knobel, K.R. Pirota, J. Magn. Magn. Mater. 324, 1601 (2012)



FORC diagrams of GMI real part (a)10 MHz (b)1 GHz

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16.15 – 16.30
Influence of thermocycling on dE-effect in amorphous $Fe_{67}Co_{10}Cr_3Si_5B_{15}$ ribbons
A. Gavriliuk [1], A. Semenov [1], *A. Mokhovikov* [1], E. Golygin [1], A. Gafarov [1], N. Morozova [1], A. Zinchenko [1]
(1) Physics faculty/Irkutsk State University, 664003 Irkutsk, Russian Federation

Amorphous Fe-based ribbons with high magnetostriction attract recently a lot of attention due to their outstanding soft magnetic properties for applications in magnetic and temperature sensors [1]. This work investigated the influence of thermocycling on field dependencies of the ΔE-effect in amorphous $Fe_{67}Co_{10}Cr_3Si_5B_{15}$ ribbons have pretreated by thermomagnetic annealing. Experimental results show that the elasticity modulus enlarges with increasing of the magnetic field; it's regardless of circumstances of a pretreatment sample. This fact is untypical for all range of amorphous Fe-based ribbons with uniaxial induced anisotropy [2]. For an explanation of given results, we studied and analyzed the dynamic magnetic properties of investigated ribbons and proposed the model, which describe the behavior of field dependencies of ΔE-effect at thermocycling.

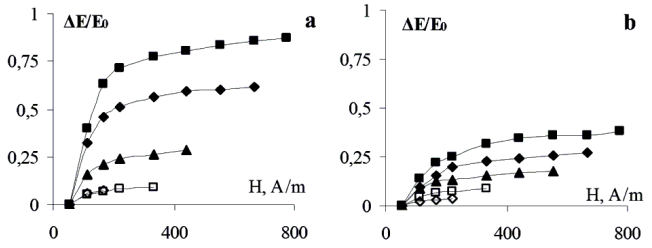


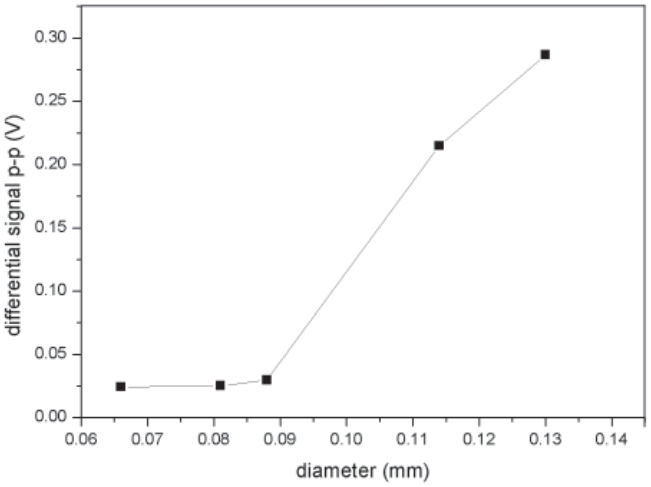
Fig.1. Field dependencies of the ΔE-effect in amorphous $Fe_{67}Co_{10}Cr_3Si_5B_{15}$ ribbons have pretreated by thermomagnetic annealing at T_{pre}=390°C for the first cycle "heating-cooling": a – heating sample, b – cooling sample.
■–T= 30°C, ♦– T=90°C, ▲– T = 150°C, □– T =210°C, ◊ – T =240°C.

[1] Craig A. Grimes et al., Sensors, 11, 2809-2844 (2011)
[2] A. A. Gavriliuk et al., Technical Physics, V.51, N. 6, 746-751 (2006)

16.30 – 16.45
Non-destructive testing by GMI sensors
D. Chen [1], Q. Zhang [1], *H. Gao* [2], U. Hartmann [2], Z. Zhao [1]
(1) Department of Physics, Engineering Research Center for Nanophotonics & Advanced Instrument, Ministry of Education, East China Normal University, Shanghai 200062, China, (2) Institute of Experimental Physics, Saarland University, P.O. Box 151150, D-66041 Saarbruecken, Germany

Magnetic non-destructive detection methods have been widely utilized for inspection of various materials and devices [1-2]. Among these testing methods, the magnetic flux leakage (MFL) method is the most applied technique. Here we report the detection of pinholes in steel using giant magnetoimpedance (GMI) sensors. The GMI sensors were made of $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ microwires with a diameter of 16 μm and a length of 5 mm. A pick-up coil is wrapped around the microwire. The driving ac current through the wire induces an axial magnetization variation and thus a voltage in the pick-up coil. The sensors were moved by a specially designed positioning system with a signal analysis system connected. Before detecting the flaws, all sensors have been calibrated. Three pinholes in a straight line on the steel plates were fabricated by employing a laser beam. Te diameters of the pinholes on different plates varied from 68 μm to 130 μm. To increase the magnetic flux leakage of the flaws, an electromagnet was used to magnetize the steel plates during testing. A wavelet analysis method was used to extract relevant data from the signals. Output signals are fairly independent of the sensor´s lift height between 0.7 mm and 5 mm. Experimental results show that the testing system can identify positions and sizes of pinholes when their diameters are larger than 68 μm.

[1] M.M. Tehranchi, et al., Sens. Acta A 170, 55 (1997)
[2] S.M. Dutta et al., IEEE Trans. Magn. 45, 1966 (2009)



Detector Output as a Function of Pinhole Diameter

Tuesday, 11 September 2012
Macbeth Room

nB nanoScale Biomagnetics Sponsored Symposium *FUNDAMENTALS AND APPLICATIONS OF MAGNETIC HYPERTHERMIA*

Chair: P. Vavassori

17.15 – 17.30
Building a standard on Inductive nanoHeating
Nicolás Cassinelli[1]
(1)CEO nB nanoScale Biomagnetics
C/ Panamá 2, Local 1, 50012, Zaragoza, Spain

The technique of heating magnetic nanostructured materials using magnetic induction (Inductive nanoHeating: InH) has proven of great potential on clinical therapies such as cancer treatment or controlled drug release, and also on a wide range on industrial applications. Characterization of power absorption of magnetic colloids in presence of an alternating magnetic field is a fundamental procedure during development phases of the involved nanosistems, such as measurement of many different physical parameters in the presence of high magnetic fields is in several kinds of InH experiments.
Similarly to almost any other scientific methodologies, in InH experiments lies a tight correlation between the quality of methods and materials and the validity of the conclusions. Nevertheless, even though during the last two decades the interest on InH study kept increasing uninterruptedly, a standard on procedures, materials and parameters of interest which would facilitate comparison among systems studies by different authors, validation of experimental results or repeatability of results in virtually identical experimental conditions cannot be proclaimed yet. This is caused by the application –in an explicit or sometimes implicit manner- of a set of hypothesis tending to simplify devices and methods, and at the same time contribute to the validation of the exposed conclusions. These hypotheses are founded on poorly based beliefs and, in many cases, the fundamental cause for large numerical and analytical divergence among the results obtained by different researchers in similar experimental conditions.
The main sources of experimental errors, such as field intensity determination, temperature sensing, field and temperature geometrical distribution, and others, will be discussed. Detailed study of experimental hypotheses will result, in the short or medium-term, in a set of standards that will help unifomize the field and dramatically shorten the time-to-market of current and future InH related R&D ventures.

17.30 -17.45
Fundamental aspects and recent advances in magnetic hyperthermia
B. Mehdaoui[1], J. Carrey[1], A. Meffre[1], L.M. Lacroix[1], V. Connord[1], S. Lachaize[1], B. Chaudret[1], *M. Respaud*[1]
(1) Laboratoire de Physique et Chimie des Nano Objets, INSA, Université de Toulouse, 135, avenue de Rangueil, F-31077 Toulouse, France

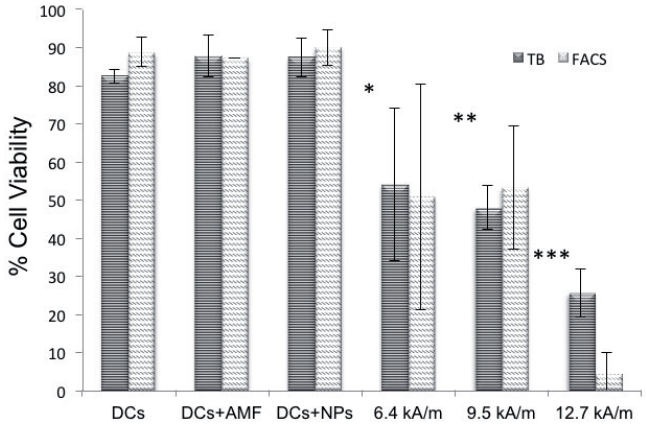
Increasing the temperature of cancerous tumours has been recognized since the 70's as a method to improve the efficiency of anticancer therapies such as radiotherapy or chemotherapy. This method, known as hyperthermia, requires raising the temperature of the tumour in the range 40-43°C. Among the numerous approaches, magnetic hyperthermia is one of the most promising route, through the use of magnetic nanoparticles. Nowadays, the chemical elaboration methods allow for very well controlled nanoparticles. A fine tuning of the magnetic core give high specific absorption rate values in human compatible conditions, while surface functionalisation with molecules ensure biocompatibility, targeting or drug delivery.
After a short introduction aiming at defining the main requirements in terms of heating capacity, the presentation will focused in the fundamental aspects of losses in magnetic nanoparticles, and especially the basic phenomenon leading to the heat release, both their simulations and their measurements. Based on experimental data and theoretical calculations, I will then discuss the fundamental question of the optimization of the nanoparticles to get high heating capacity by adjusting the particle size, and their basic magnetic properties, namely both the magnetic anisotropy and spontaneous magnetization.

[1] Mehdaoui, B., Meffre, A., Carrey, J., Lachaize, S., Lacroix, L.-M., Gougeon, M., Chaudret, B., Respaud, M. Optimal Size of Nanoparticles for Magnetic Hyperthermia: A Combined Theoretical and Experimental Study. *Adv. Funct. Mater.* **2011**, *21*, 4573-4581.
[2] Carrey, J., Mehdaoui, B., Respaud, M. Simple models for dynamic hysteresis loop calculations of magnetic single-domain nanoparticles: Application to magnetic hyperthermia optimization, *J. Appl. Phys.* **2011**, *109*, 083921.
[3] Mehdaoui, B; Carrey, J.; Stadler, M; Cornejo, A; Nayral, C; Delpech, F; Chaudret, B; Respaud, M; Influence of a transverse static magnetic field on the magnetic hyperthermia properties and high-frequency hysteresis loops of ferromagnetic FeCo nanoparticles, *Appl. Phys. Lett.* **2012**, 100, 052403

17.45- 18.00
Is the magnetic hyperthermia mechanism a universal one? The case of dendritic cells
L.Asín[1], T.E. Torres[1,2], M.R. Ibarra[1,2], A. Tres[3], *G.F. Goya*[1,2]
*(1) Instituto Nanociencia Aragón, University of Zaragoza, Zaragoza, Spain (2) Departamento de Física de la Materia Condensada, Universityt of Zaragoza, Zaragoza, Spain (3) Servicio Oncología, Hospital Universitario Lozano-Blesa, Zaragoza, Spain * E-mail: goya@unizar.es*

We present a series of *in vitro* experiments using human-monocyte-derived dendritic cells (DCs) previously loaded with magnetic nanoparticles (MNPs) as heating agents, as a proof of concept of a "Trojan Horse" strategy for immune-related therapies. Direct observation during TEM and dual-beam SEM/FIB techniques demonstrated that the final distribution of MNPs

was in the cytolosic area inside phagocytic/endosomal vesicles and a neglible amount attached to the cell membrane. In a series of experiments, these magnetically loaded DCs were submitted to alternating magnetic fields (AMF) of f=255 kHz and different amplitudes (up to 12.7 kA/m) for different times from 5 to 30 min. These experiments showed that it is possible to induce cell death with no detectable temperature increase in the culture medium. Up to 98% of induced cell death occurred for quantites of uptaken MNPs as low as 1.5 pgFe3O4/cell. Moreover, we found that it is possible to control the magnitude of induced cell death by an adequate tuning of the physical AMF parameters and exposure time as well as through the control of the amount of loaded MNPs. Flow cytometry analysis performed allowed us to identify the cell death route as a necrotic-like process.
We propose that the cell death mechanism could be due to MNPs confined within the lysosomes that cause the disruption of lysosomal membranes when submitted to AMF, thus releasing the lysosomal material into the cytoplasmatic space and triggering cell death. These results represent anew and challenging concept of cell death caused by the action of an intracellular agent and, at the same time, pose the question of whether there is a universal mechanism by wich magnetic hyperthermia will work on different cell types.



Effect of the different AMF amplitudes (f=255 kHz, t=15min) on the MNPs loaded DCs

Tuesday, 11 September 2012

Posters

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

DISORDERED AND FRUSTRATED MAGNETIC SYSTEMS

Chair: P. Santini

TU-1

Importance of interplane coupling on the magnetic phases of quasi-two-dimensional tantalites

E. Santos [1], J. Da Cunha [1], *O. Isnard* [2], C. Lacroix [2], M. Gusmao [1]
(1) Instituto de Fisica, Universidade Federal do Rio Grande do Sul, CP 15051, 91501-970 Porto Alegre, Brazil, (2) Institut Néel, CNRS / Université Joseph Fourier, B.P. 166, 38042 Grenoble Cedex 9, France

We propose a three-dimensional model to describe magnetic interactions in a class of tantalite compounds of compositions $A_xA'_{1-x}Ta_2O_6$, with A, A' = Fe, Co or Ni. Due to the quasi-two-dimensional nature of the magnetism in these compounds, experimental data have been previously interpreted using two-dimensional models. These are anisotropic Heisenberg models or Ising models, and include competing exchange interactions from different neighbors. Taking into account all the relevant exchange terms, which include interplane interactions, we show that the latter allow us to understand the various low-temperature magnetic phases observed by neutron diffraction in this family of compounds. This is done by studying the eigenvalues of the exchange-interaction matrix in wave-vector space for different sets of coupling parameters, of which those relative to in-plane interactions have been obtained from high-temperature-series analysis of the magnetic susceptibility.

[1] Kinast E J, Antonietti V, Schmitt D, Isnard O, da Cunha J B M, Gusmao M A and dos Santos C A 2003 Phys. Rev. Lett. 91 197208
[2] Kinast E J, dos Santos C A, Schmitt D, Isnard O, Gusmao M A and da Cunha J B M 2010 J.Alloys and Compounds 491 44
[3] Santos E G, de Oliveira Neto S R, Kinast E J, da Cunha J B M, Isnard O and Gusmao M A 2010 J. Phys.: Condens. Matter 22 496004

TU-2

Magnetic ordering in quantum Ising systems with quasiperiodic longitudinal field at zero temperature

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We consider the one-dimensional quantum Ising model with spin-1/2 particles for different distributions of a longitudinal field h_z(r). The case of a random magnetic field h_z(r) has been extensively studied following the interest of the effect of disorder on phase transitions [1]. Even though phase transitions do not take place in one- dimensional systems, it is interesting to observe the formation of magnetically ordered domains driven by both interaction couplings and external factors. We thus study the antiferromagnetic quantum Ising model in field h_z(r) obeying spatial distributions given by periodic, quasiperiodic and random functions. The influence of quasiperiodicity has been found to have an important impact when introduced as a modulation for coupling and local parameters in the systems [2, 3]. We investigate the resulting magnetic ordering by measuring the static spin structure factor, which is found to display not only an incommensurate momentum dependence structure in cases other than the periodic one but also reflects the formation of magnetic structures driven by the external field. We also present results for low-lying energy dynamics, such as spectral density functions. Measurements were carried out using the density-matrix renormalization group method, which is a highly efficient method to investigate quasi-one-dimensional strongly correlated systems.

[1] D. S. Fisher, Phys. Rev. B 51, 6411 (1995)
[2] K. Hida, Phys. Rev. Lett. 86, 1331 (2001)
[3] Y. Arredondo and O. Navarro, Solid State Commun. 150, 1313 (2010)

TU-4

Interplay of structural and magnetic properties in the two-dimensional quantum magnet $Cu(en)(H_2O)_2SO_4$

R. Tarasenko [1], A. Orendáčová [1], E. Čižmár [1], S. Maťaš [2], M. Orendáč [1], I. Potočňák [3], K. Siemensmeyer [2], S.A. Zvyagin [4], J. Wosnitza [4], A. Feher [1]
(1) Institute of Physics, P.J. Šafárik University, SK-041 54 Košice, Slovak Republic, (2) Helmholtz-Zentrum Berlin, D-14109 Berlin, Germany, (3) Institute of Chemistry, P.J.Šafárik University, SK-041 54 Košice, Slovak Republic, (4) Dresden High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden Rossendorf, 01314 Dresden, Germany

The title compound $Cu(en)(H_2O)_2SO_4$ has been previously identified as a potential realization of the quasi-two dimensional spatially anisotropic triangular Heisenberg antiferromagnet with spin 1/2 and effective intralayer exchange coupling, $J/k_B \approx -1.4$ K [1]. Powder neutron diffraction studies were performed at 0.45 K, 2 K, 6 K, 20 K and 40 K in zero magnetic field selecting incident neutrons of wavelength $\lambda = 2.45$ Å. Electron paramagnetic resonance (EPR) measurements of single crystals have been realized in the X-band range in the temperature range from 2 K to 300 K in magnetic fields up to 0.5 T. A monotonic decrease of the lattice parameters *a* and *b* was observed with decreasing temperature. On the other hand, the temperature dependence of *c* shows a maximum at about 20-30 K. The analysis of the *g*-factor confirmed, that coordinating ligands around the Cu(II) ion form a distorted octahedron elongated along the local *z* axis and the distortion is maintained down to low temperatures. In the temperature range from 100 to 300 K $g_{c'}$ and $g_{a'}$ decrease monotonously with decreasing temperature. However, at temperatures below 50 K a significant increase of $g_{a'}$ and a decrease of $g_{c'}$ was observed. This behavior could be related to the growing influence of hydrogen bonds [2]. Alike the *g*-factors, the EPR linewidth decreases monotonously in the temperature range from 300 to 100 K for the orientation $B \| c'$, below temperature 50 K it increases rapidly. The strong increase of both, *g*-factors and linewidth below 30 K correlates with the aforementioned changes of the lattice parameter *c*.

This work was supported by the projects APVV LPP-0202-09, VEGA 1/0078/09 and Deutsche Forschungsgemeinschaft, EuroMagNET (EU contact No. 228043).

[1] M. Kajňaková et al., Phys. Rev. B 71, 014435 (2005)
[2] S. Brown et al., Inorganic Chemistry 46, 8577 (2007)

TU-5

Muon spin relaxation in the frustrated two-dimensional antiferromagnet Cu(tn)Cl_2

A. Orendáčová [1], R. Tarasenko [1], P.J. Baker [2], M. Orendáč [1]
(1) Institute of Physics, P. J. Šafárik University, Park Angelinum 9, 040 00 Košice, Slovakia, (2) ISIS Facility, STFC Rutherford Appleton Laboratory, Chilton, Oxon OX11 0QX, United Kingdom

Previous studies of magneto-structural correlations in Cu(tn)Cl_2 (tn=1,3-diaminopropane = $C_3H_{10}N_2$) revealed that the compound represents a quasi-two-dimensional (2d) S=1/2 spatially anisotropic triangular antiferromagnet realized by a square lattice with the nearest-neighbour coupling J/k_B = 3 K, frustrating next-nearest-neighbor J'/J < 0.5, and interlayer coupling J" /J ≈ 10^{-3} [1]. The absence of long-range magnetic order down to T = 60 mK in zero magnetic field and the T^2 behaviour of the specific heat observed below 0.4 K indicate a high degree of 2d magnetic order. An additional specific heat anomaly, appearing in the fields lower than B_{sat} = 6.6 T has been ascribed to bound vortex-antivortex pairs associated with a Berezinski-Kosterlitz-Thouless phase transition [2]. Neutron spectra of polycrystalline material studied down to 0.5 K in B = 0 and 4 T did not display magnetic peaks expected below 1 K [3]; thus muon spin relaxation (MuSR) has been investigated at temperatures from 4 K down to 40 mK. In the whole temperature range, the MuSR spectra are characterized by an exponential-like behaviour without oscillations typical for a magnetically ordered state. Analysis of the spectra using a stretched exponential $A(t) = A\exp(-\lambda t)^{\beta}$ yields the temperature dependence of the relaxation rate γ and the parameter β. Both parameters show anomalous behaviour at the temperature 0.7 K which coincides with the temperature where previous analysis of the magnetic phase diagram anticipated a potential phase transition to ordered state. The values of β suggest that the relaxation above 1 K is due to quasi-static nuclear magnetic moments, while at lower temperatures the effect of static fields due to the formation of 2d short range order appears.

[1] V. Zeleňák, et al, Inorg. Chem. 45, 1774 (2006).
[2] A. Orendáčová, et al, Phys. Rev. B 80, 144418 (2009).
[3] A. Orendáčová, et al, BENSC Experimental Reports 2008, 63.

TU-6

Frustration and Inhomogeneous Magnetism in the Spin-2 Anisotropic Triangular Lattice System a-$NaMnO_2$

A. Lappas [1], A. Zorko [2], *O. Adamopoulos* [1], D. Arcon [2], C. Stock [3], M. Green [3]
(1) Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Vassilika Vouton, 71110 Heraklion, Greece, (2) Jozef-Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia, (3) NIST Center for Neutron Research, 100 Bureau Drive, Gaithersburg, Maryland 20899-8562, USA

The two-dimensional (2D) anisotropic (J_1-J_2) Heisenberg antiferromagnet is a valuable scheme for studying exotic states arising from restrictions imposed by lattice topology. A rich phase diagram is predicted against J_2/J_1, when various perturbations lift the ground state degeneracy due to geometric frustration. To realize experimentally the anisotropic triangular lattice we exploit the 2D delafossite structural type AMO_2; here metal-oxygen octahedra form layers separated by hexagonal nets of monovalent A cations. When M is Jahn-Teller active (e.g. Mn^{3+}), the symmetry is lowered from trigonal, in the parent delafossites, to monoclinic promoting ferro-orbital ordering. The structure of α-$NaMnO_2$ has been determined by neutron powder diffraction (Fig.1a). It realizes a zigzag spin-2 chain model (J_1=intrachain, J_2=interchain) with dominant direct-exchange perpendicular to the ferro-orbital ordering. On cooling α-$NaMnO_2$, a surprising structural transition from monoclinic to triclinic symmetry and antiferromagnetic (AFM) order (T_N=45 K) are stabilized [1]. The ground state degeneracy is lifted due to the strong magnetoelastic coupling. Furthermore, neutron inelastic scattering (INS; Fig.1b) points that despite the underlined 2D coupling, frustration-induced dimensionality reduction renders the magnetic excitations, unexpectedly, 1D in nature [2]. The observed single-mode is described by a 1D AFM chain Hamiltonian involving J_1 (73 K) and the magnetic easy-axis anisotropy (D=3 K), giving rise to a spin-gap (Δ=87 K) below T_N. However, the gap is not expressed in ^{23}Na-NMR spin-lattice relaxation (T_1), which shows a power-law rather than exponential dependence (Fig.1b) and thus points to the existence of quasi-elastic modes. These low-energy excitations that are missed in INS may be responsible for an inhomogeneous form of magnetism as detected by local-probe ^{23}Na-NMR and μ^+SR techniques.

[1] M. Giot et al., Phys. Rev. Lett. 99, 247211 (2007)
[2] C. Stock et al., Phys. Rev. Lett. 103, 077202 (2009)

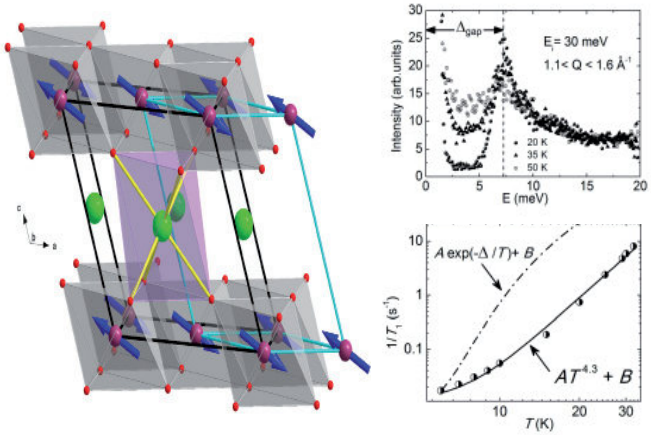

Figure 1. Crystal and magnetic structures (left); INS data and ^{23}Na-NMR spin-lattice (right).

TU-7

{[Cu(tn)$_2$]$_3$[Pt(CN)$_4$]$_2$}[Pt(CN)$_4$] – a spin-1/2 antiferromagnetic trimer system

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(1) Institute of Physics, Faculty of Science, P.J. Šafárik University, Park Angelinum 9, SK-04154 Košice, Slovakia, (2) Institute of Chemistry, Faculty of Science, P.J. Šafárik University, Moyzesova 11, SK-04154 Košice, Slovakia

Magnetic and thermodynamic properties of a novel trinuclear spin-1/2 copper compound {[Cu(*tn*)$_2$]$_3$[Pt(CN)$_4$]$_2$} [Pt(CN)$_4$] (*tn* = 1,3-diaminopropane) were investigated. The effective magnetic moment of the title compound shows a sharp decrease at low temperatures, suggesting the presence of the weak antiferromagnetic exchange coupling among the copper ions. The magnetization measured at 2 K reaches full saturation at magnetic field 5 T. The analysis of the

temperature dependence of susceptibility using a spin-trimer model yields exchange coupling J/k_B = -0.9 K with g-factor g = 2.13. With the aim to identify the magnetic ground state, the specific heat measurements were performed down to the temperature 90 mK in zero magnetic field. The temperature dependence of specific heat is characterized by the presence of a Schottky-like maximum at 420 mK. A λ-like anomaly indicating the formation of long-range order in the system was observed at 110 mK. The specific heat can be well described by the model of isosceles spin trimer with antiferromagnetic exchange couplings $J_1/k_B = J_2/k_B = -0.95$ K and $J_3/k_B = -0.16$ K, which agrees well with the expected exchange path configuration predicted from the structural data. In addition, the entropy removed in the measurement range, calculated from the experimental specific heat, represents the full magnetic entropy for spin-1/2 magnetic system suggesting a low level of frustration in the title compound. The X-band ESR spectrum of powdered sample is characterized by the presence of a single isotropic resonance line with g = 2.115, which is unusual for Cu(II) compounds experiencing Jahn-Teller effect. The observation of the isotropic resonance line results from three mutually perpendicular orientations of local g-tensors of the three Cu(II) ions in the molecule.

This work was supported, in part, by VEGA 1/0078/09 and ERDF EU funds, under the contract No. ITMS26220120047.

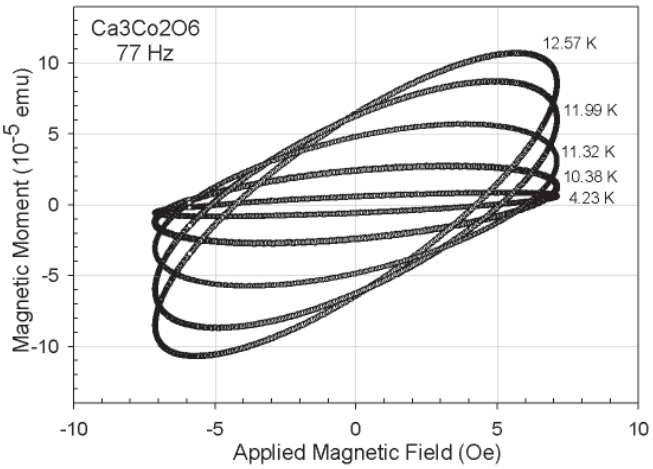
TU-8

Magnetic dynamics of the spin chains system $Ca_3Co_2O_6$ studied by dynamic hysteresis

M. Prester [1], I. Zivkovic [1], D. Drobac [1], V. Surija [1], K. Prsa [2]
(1) Institute of Physics, HR-100000 Zagreb, Croatia, (2) EPFL Lausanne & ETH Zuerich, CH-1002 Lausanne,Switzerland

Magnetic ground state of a system with frustrated interactions represents in general an unresolved, system-specific, problem. The case of ferromagnetic spin chains system Ca3Co2O6 is intriguing: its long range ordered state (T<25 K), usually vaguely referred to as 'partially disordered antiferromagnet', features a coexisting long- and short-range ordered phases, revealing a striking time dependence in their relative volume fractions [1]. We report on our studies of interesting hysteretic magnetic dynamics permeating the whole temperature range of the latter transformation of magnetic phases. Unlike standard ac susceptibility route, magnetic dynamics of Ca3Co2O6 was studied by the use of measuring dynamic hysteresis, recently shown [2] to represent a powerful tool in studies of magnetic dynamics in general. Together with the measurements we present a simple model which, on basis of usual assumptions of the classical spin-lattice theory and Arrhenius activation, perfectly describes experimental behaviour of the main dynamic hysteresis parameters, coercive field and the hysteresis area. Obviously dissipative dynamics is ascribed to relaxation of magnetically uncompensated antiferromagnetic clusters, spontaneously emerging by cooling within the long-range ordered matrix. Mechanisms of magnetic relaxation is thoroughly studied and discussed, paying special attention on the intriguing possibility of the residual low-temperature dissipation to originate from quantum tunneling.

[1] S. Agrestini et al., Phys. Rev. Lett. 106, 197204 (2011)
[2] M. Prester et al., Phys. Rev. B. 84, 064441 (2011)



A set of appropriately calibrated dynamic hysteresis of Ca3Co2O6 in the temperature range of magnetic-phases transformation.

TU-9

Effect of bond disorder on weakly-coupled spin-1/2 antiferromagnetic Heisenberg chains

M. Thede [1], F. Xiao [2], C. Landee [2], E. Morenzoni [1], A. Zheludev [3]
(1) Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, 5232 Villigen-PSI, Switzerland, (2) Department of Physics and Carlson School of Chemistry, Clark University, USA, (3) Laboratorium für Festkörperphysik, ETH Zürich, 8093 Zürich, Switzerland

We study the effect of chemical disorder on magnetic ordering in the quasi-one-dimensional antiferromagnets $Cu(py)_2(Cl_{1-x}Br_x)_2$. The two end compounds are S = 1/2 linear-chain systems with J = 2.3 meV and J = 4.5 meV, for x = 0 and x = 1, respectively. Weak inter-chain interactions lead to long range order at T_N = 1.1 K and T_N = 0.7 K, respectively. Partial substituting Br for Cl randomizes the bond strength in the spin chains. We probe magnetic and thermodynamic properties of $Cu(py)_2(Cl_{1-x}Br_x)_2$ with susceptibility, specific heat and MuSR measurements. For all samples, the temperature dependence of the magnetic susceptibility follows expectations for a S=1/2 Heisenberg chain. Specific heat data reveals more interesting behaviour. While at the Cl end a very slow decrease of T_N with x is observed, on the Br side, suppression of T_N relative to x=1 is much more rapid. This disparity in the behaviour samples is consistent with MuSR measurements. For the two end-compounds and $Cu(py)_2(Cl_{0.95}Br_{0.05})_2$, there is a clear evidence of static long range magnetic behavior below T_N. However, $Cu(py)_2(Cl_{0.05}Br_{0.95})_2$ show totally different muon spectra, indicating a strong in homogeneity of the static magnetization.

TU-10

Magnetic behavior of $Ni_xFe_{1-x}Nb_2O_6$ quasi-one-dimensional system: are the Ising chains isolated by frustration?

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Physical properties of the $Ni_xFe_{1-x}Nb_2O_6$ compounds

are investigated combining x-ray and neutron powder diffraction with magnetic and calorimetry measurements as well as ^{57}Fe Mössbauer spectroscopy. This system is known to present quasi-one-dimensional magnetism, with the magnetic moments arranged along weakly interacting Ising chains. Partial substitution of the magnetic ion tends to suppress the magnetic ordering observed in the end members of the series. When this happens, the low-temperature magnetic specific heat agrees well with what is expected for isolated Ising chains. The lowest temperature powder neutron-diffraction patterns exhibit evidence for the occurrence of short-range order, and analysis of these diffuse neutron-scattering patterns allow us to obtain information on the magnetic correlations. The suppression of magnetism is consistently interpreted as resulting from the magnetic-cation disorder induced by substitution, which enhances the system's tendency for frustration of topological origin.

[1] P.W.C. Sarvezuk, E.J. Kinast, C.V. Colin, M.A. Gusmao, J.B.M. da Cunha, O. Isnard, Phys. Rev. B. 83 (2011) 174412
[1] P.W.C. Sarvezuk, M.A. Gusmao, J.B.M. da Cunha, O. Isnard, submitted

TU-11

Very low temperature magnetization measurements in $Tb_2Ti_2O_7$

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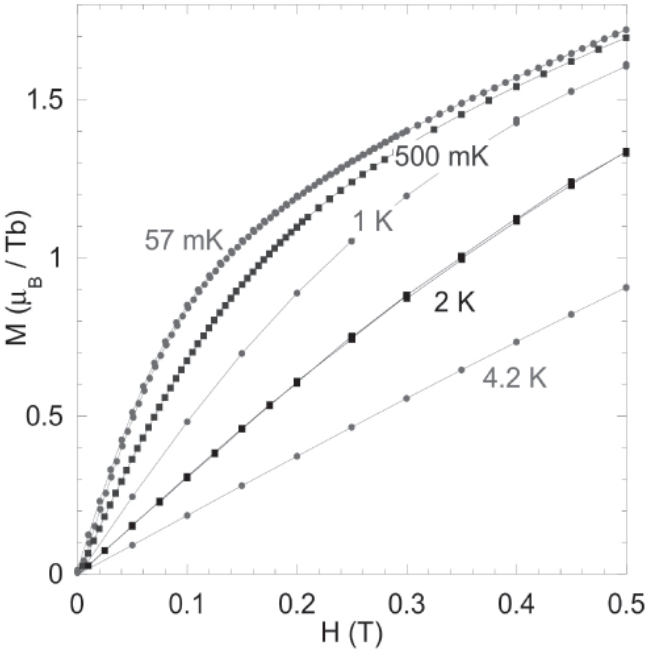
The nature of the low temperature ground state of the pyrochlore compound $Tb_2Ti_2O_7$ remains a puzzling issue. Experimentally, fast dynamics and short-range correlations evidenced by microscopic probes [1] seem to coexist with a freezing measured by magnetization measurements [2,3].
We have performed a detailed study of the magnetization and AC susceptibility down to
60 mK. The measurements were made on four single crystals synthesized in different conditions and with different specific heat behaviors, with the applied field along the [111] or the [110] direction. Our results show that magnetization as well as AC susceptibility are almost sample independent. In particular, we observe no evident signature of the magnetization plateau in the [111] direction which was proposed in the quantum spin ice model [4]. Another important result is that the AC dynamic behavior, associated with a freezing around 200 mK, seems to be intrinsic, and independent of the applied field direction [5]. The frequency dependent features remain up to 4 K and cannot be described by a canonical spin-glass behavior.

[1] J.S. Gardner et al., Phys. Rev. Lett. 82, 1012 (1999).
[2] N. Hamaguchi et al., Phys. Rev B 69, 132413 (2004).
[3] G. Luo, S.T. Hess and L.R. Corruccini, Phys. Lett. A 291, 306 (2001).
[4] H.R. Molavian and M.J.P. Gingras, J. Phys.: Condens. Matter 21, 172201 (2009).
[5] E. Lhotel et al., arXiv:1201.0859.



M vs H measured along the [111] direction, between 57 mK and 4.2 K.

TU-12

Magneto-structural transitions in the frustrated spinel compound $GeCo_2O_4$

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In the $GeCo_2O_4$ spinel compound (cubic Fd-3m), the magnetic Co^{2+} ions form a pyrochlore lattice, prone to magnetic frustration. This material presents a structural transition at 23.5 K, from cubic to tetragonal, concomitant with the magnetic ordering transition toward an antiferromagnetic arrangement despite first neighbour ferromagnetic interactions [1]. Additionally, a rich (H,T) phase diagram has been revealed through magnetization and neutron diffraction measurements on single-crystal under magnetic fields with polarized neutrons and polarization analysis up to 12 T. These investigations have shown successive field-induced spin-reorientation and/or domain reorganization for specific directions of the field, some of them even associated with structural transitions because of competing interactions and strong spin-lattice coupling. The interplay between the spin and lattice degrees of freedom is further evidenced through strong modifications of the extinction effect, in particular at the high field transition where a narrow extinction peak is observed on intense nuclear reflections.

[1] S. Diaz, S. deBrion, G. Chouteau, B. Canals, V. Simonet, P. Strobel, Phys. Rev. B 74, 092404 (2006).

TU-13

Frustration induced complex phase diagram in the spinel $GeFe_2O_4$

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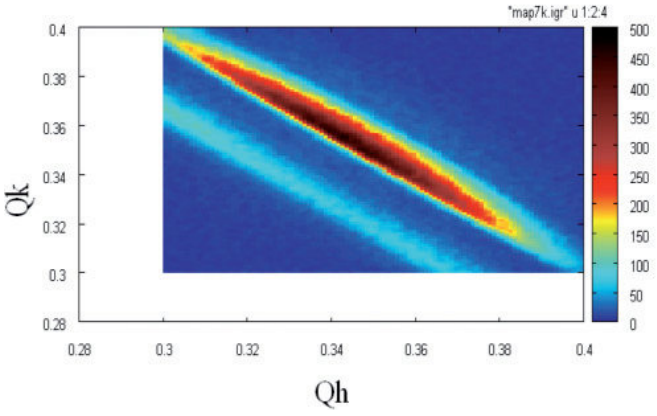
The spinel compound $GeFe_2O_4$ (cubic space group Fd-3m) is a very interesting material, in particular concerning its magnetic properties and potential multiferroic behavior. Indeed, the magnetic Fe^{2+} ions crystallize in a pyrochlore lattice (corner-sharing tetrahedra), which can induce geometric frustration. This, as in the compounds $GeCo_2O_4$ and $GeNi_2O_4$ related compounds [1], might lead to the observation of a complex phase diagram (H,T). Macroscopic measurements (magnetization, specific heat) on powder and single-crystals, as well as neutron diffraction on powder (D2B) and on single crystal under magnetic field up to 12 T (D23) have confirmed the complexity of the phase diagram. A phase transition toward an incommensurate magnetic arrangement is observed at 8.4 K followed by a second transition at 6.8 K to a second magnetic phase with a commensurate (2/3,2/3,0) propagation vector.
Several transitions and/or spin reorientation processes are observed under magnetic field in particular when the field is applied along the (111) and (110) crystallographic directions. The magnetic domains reorientation has a remarkable influence on the crystal structure quality, observable through the extinction effect on intense nuclear Bragg reflections at high magnetic field. Another very interesting aspect of this compound is that its magnetic point group is non centro-symmetric, a necessary condition for multiferroicity. Further measurements of the dielectric constant and electric polarization are foreseen to study the possibility of ferroelectricity in $GeFe_2O_4$.

[1] Diaz *et al*., Phys Rev. B **74** (2006) 092404



Coexistence of two propagation vectors at 7K

TU-14

Anomalous low-frequency fluctuations in the itinerant pyrochlore $Sm_2Mo_2O_7$

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A magnetic spin-ice-like ground can be reached not only in insulators but also in metallic materials. This possibly originates from the competition between the pyrochlore geometry and the dipolar, exchange and indirect RKKY-like interactions [1]. $Sm_2Mo_2O_7$ has been recently proposed as a good candidate for such phenomenology at temperatures $T < 20$ K. Here the net magnetic moment per tetrahedron is polarized by a ferromagnetic ordering of the Mo^{4+} moments (with $T_C = 80$ K) [2].
Here we discuss our experimental investigation of a $Sm_2Mo_2O_7$ single-crystal. The aim of our study was to check the validity of the described picture by especially concentrating on the dynamic magnetic features as examined by muon spin spectroscopy. The $1/T_1$ relaxation rate of μ shows a broad peak at T = 20 K and a much sharper anomaly at T = 80 K, in qualitative agreement with previous data taken at ISIS [3]. The $1/T_1$ peak at 80 K is anomalously quenched upon the application of an external field as low as 2 kOe. The high resolution at very short times allowed us to monitor also the appearance of an increasing distribution of local fields for $T < 80$ K, possibly due either to the generation of an incommensurate FM ordering or to the entrance of the system into a glassy-like phase. Interesting insights into the dynamical properties of such phase for $T < 20$ K have been obtained also by AC susceptibility measurements, suggesting that a large distribution of characteristic correlation times of the spin fluctuations is actually present.

[1] A. Ikeda et al., J. Phys. Soc. Jpn. 77, 073707 (2008).
[2] S. Singh et al., Phys. Rev. B 77, 020406(R) (2008).
[3] Y. Jo et al., J. Korean Phys. Soc. 47, 123 (2005).

TU-15

Orbital topology, interlayer spin coupling, and magnetic anisotropy of the $CuFeO_2$ compound

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Complex magnetic oxides exhibit a rich variety of intriguing phenomena arising from the interplay between multiple coupled degrees of freedom eventually determining their macroscopic behaviour. A particularly interesting class of materials in this respect are the geometrically frustrated spin systems, with the multiferroic two dimensional delafossite system ($CuFeO_2$) as one of the more intriguing examples. This material exhibits a staircase of metamagnetic phase transitions, originating from spin-spin, spin-phonon, spin-orbit, and spin-field interactions. The physical properties of this material have been unraveled by a variety of experimental and theoretical approaches, including x-ray absorption experiments, as well as band structure

calculations. One of the surprising findings is the presence of a finite spin density on the nominally $3d^{10}$ Cu^{+} site which plays a pivotal role in the low temperature magnetic properties and the field induced multiferroic state of this material [1].

[1] M. Malvestuto, Phys. Rev. B **83**, 134422 (2011)

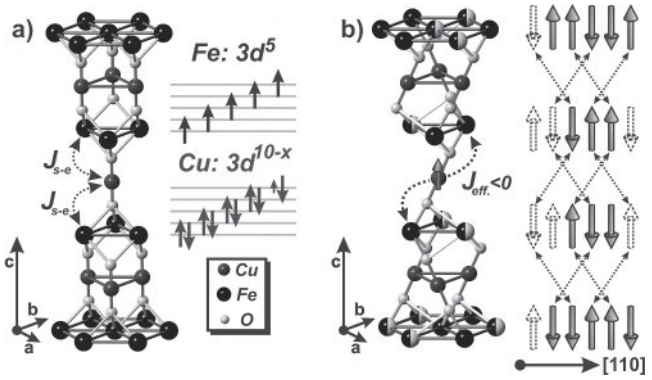

Fig1. Schematic crystal structures of $CuFeO_2$ at high (a) and low (b) temperature.

TU-16

Floating-Zone Growth of Magnetically Frustrated $CoAl_2O_4$ Single Crystals

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We report the first successful floating-zone growth of high quality $CoAl_2O_4$ single crystals with volume up to 1 cm^3 free from inclusions and sub-grains. The neutron rocking curves of the $CoAl_2O_4$ crystal have the width of about 0.3 degree proving the excellent quality of the grown samples. Lattice constant and inversion parameter are defined from the X-ray synchrotron measurements. All crystals have a spinel structure with the lattice constant a_0=8.09853(1) Å. The inversion degree for the single crystal (about 8 %) is among the lowest reported so far for stoichiometric $CoAl_2O_4$. Magnetization measurements give the effective magnetic moment μ_{eff}=4.63μ_B per Co^{+2} ion in a good agreement with previous measurements on ceramic samples. The evidence for spin liquid in the frustrated diamond lattice antiferromagnet $CoAl_2O_4$ has been studied by means of single-crystal neutron scattering in zero and applied magnetic fields at 1.5-300 K.

TU-17

Ground state ordering of artificial spin ice

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Using electron beam lithography in combination with appropriate imaging techniques, it has become possible in recent years to design, pattern and investigate artificial spin ice systems, which are two-dimensional arrangements of nanomagnets. These provide an ideal and highly tunable model system to directly investigate frustrated behavior, and using photoemission electron microscopy it is possible to visualize the moment configurations in such a system [1, 2]. So far the systems investigated were patterned films with Curie temperatures far above room temperature, so that the magnetic configurations could only be manipulated by applying magnetic fields, whether achieving low energy states via demagnetization [1] or the observation of emergent magnetic monopoles during magnetization reversal [2]. Inspired by the recent work of Morgan et al. [3], we present a thermal ground state ordering in the artificial kagome spin ice building blocks, consisting of a finite number of hexagonal rings of nanomagnets, which occurs during the early stages of film deposition. In infinite arrays of the artificial kagome spin ice, while a unique ground state is not observed, the ice rule is obeyed at every vertex. A strong dependence of the magnetic ordering on the film thickness and coupling strength is observed and, following a thermal anneal, high frequencies of ground states are achieved in the building blocks.

[1] E. Mengotti, L.J. Heyderman, A. Fraile Rodríguez, A. Bisig, L. Le Guyader, F. Nolting, and H.B. Braun, Phys. Rev. B 78, 144402 (2008)
[2] E. Mengotti, L.J. Heyderman, A. Fraile Rodríguez, F. Nolting, R. V. Hügli, and H.B. Braun, Nature Physics 7, 68 (2011)
[3] J. Morgan, A. Stein, S. Langridge, C.H. Marrows Nature Physics 7, 75 (2011)

TU-18

Chiral nature of monopole defects in artificial spin ice

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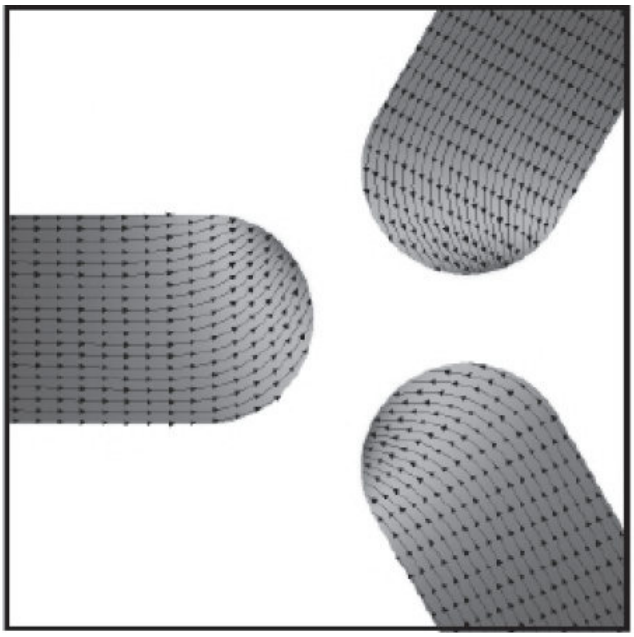
Since the pioneer work of Wang and coworkers [1], many studies on artificial spin ice systems have shown that patterned arrays of nanomagnets can provide an uncharted arena in which the physics of magnetic frustration can be observed. In particular, this approach offers the appealing opportunity to investigate a wide range of phenomena within the concept of lab-on-a-chip, and to test many theoretical predictions from spin models. Contrary to condensed matter systems, artificial arrays have the advantage of being accessible at room temperature. Magnetic microscopy techniques then allow imaging of the local spin configuration, and thus the observation of how spins locally accommodate the frustration. For example, magnetization reversal in an artificial kagome spin ice exhibits very intriguing features. After saturation of the array with a positive magnetic field, a few pseudo-spins can be reversed by applying a negative field. This reversal leads to a spin configuration that breaks the ice rule where the spins have been switched. This violation of the ice rule can also be seen as an excess (or deficit) of magnetic charges at a vertex and can be considered as a classical magnetic monopole. After the switching of a given element, magnetization reversal proceeds by an avalanche process along lines of the arrays [2-3].
In this contribution, we show that the micromagnetic properties of the nanomagnets brings additional complexity in frustrated artificial arrays that, by essence, is absent in classical spin

models. In particular, we reveal peculiar features such as the chirality of monopole defects that could explain the observed 1D avalanche process.

[1] R. F. Wang et al., Nature 439, 303 (2006)
[2] S. Ladak et al., Nature Phys. 6, 359 (2010)
[3] E. Mengotti et al., Nature Phys. 7, 68 (2010)



Micromagnetic simulation showing the chiral nature of a monopole defect

TU-19

Structural and Magnetic Properties of Iron Nanoparticles in Silver Films from Muon Spin Rotation and EXAFS

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Silver films containing nanometer size clusters of iron (nominal conc. 0.1-2 at %) have been studied by Mössbauer spectroscopy, Low-Energy Muon Spin Rotation (PSI, Switzerland) and EXAFS (LNLS, Brazil).
EXAFS data support previous conclusions drawn from Mössbauer, magnetization and magneto-resistivity data that the iron clusters comprise only a few atoms. The number of nearest iron neighbors suggests that low-dimensional iron aggregates are formed. They may be positioned at grain boundaries or dislocations of the silver matrix.
Below about 20 K spin glass freezing due to inter-particle interactions is found from Mössbauer spectroscopy and muon spin rotation in agreement also with magnetization and resistivity data. Whereas Mössbauer spectra are insensitive to the fast fluctuations of cluster moments at higher temperatures, muon spin rotation in magnetic fields applied perpendicular to the polarized muon spins allows tracing the fluctuations of superparamagnetic moments. The temperature dependence of the damping of the muon spin rotation signal shows Arrhenius behavior between 10 to 100 K. Depending on the shape of damping the activation energy of superparamagnetic fluctuations of cluster moments ranges between about 20 K k_B and 40 K k_B. Above about 120 K muon spin depolarization indicates diffusion and trapping of muons close to magnetic clusters.

[1] W. T. Herrera et al., Phys. Rev. B **84**, 014430 (2011)
[2] W. T. Herrera et al., Hyperfine Interact **203**: 149 (2011)
[3] G. Rollmann et al., Comput. Mater. Sci. **35**, 275 (2006)

TU-20

Statics and dynamics of magnetic frustration in random Fe-substituted manganites

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Facts as the splitting in the 'zero-field-cooled' (ZFC) and 'field-cooled' (FC) thermomagnetic curves at low magnetic fields, the divergence in the nonlinear susceptibility at the spin-freezing temperature, Tg, and the slow spin dynamics characterize the macroscopic spin glass (SG) state [1]. We present a comparison between the Fe-doped manganites $La_{0.7}Pb_{0.3}Mn_{1-x}Fe_xO_3$ with x = 0.2 and 0.3, in which all those behaviors have been observed. Magnetic frustration turns out to be progressively settled in, reducing strongly the long-range ferromagnetic interaction, when the Fe-amount is varied from x = 0.2 to x = 0.3. The x = 0.3 composition displays no spontaneous magnetization and only applied magnetic field induced magnetic moment $M_{DC}(H,T)$ from high field, and reentrant behavior is reduced to a bare existence with a sharp ZFC peak around 50 K at H = 100 Oe. The AC-susceptibility confirms the dynamic nature of the transition for both compounds and helps to elucidate the delicate balance between order and disorder promoted by the competition between ferromagnetic and antiferromagnetic Fe-Mn interactions, through the observed peaks and frequency shift of real and complex components. These macroscopic results have further confirmed by muon spin relaxation spectroscopy. Measured spin relaxation rates are clearly faster for x = 0.3 than for x = 0.2 sample, clearly indicating the existence of magnetic clusters of different sizes, as previously remarked for these compositions [2, 3]. In consequence, the x = 0.3 compound appears as a percolative limit of a randomly frustrated magnet in the series, formed by very small ferromagnetic correlated islands embedded within a clustered environment.

[1] J. A. Mydosh, *Spin Glasses: An Experimental Introduction* (Taylor and Francis, London, 1993).
[2] J. Gutierrez *et al.,* Phys. Rev. B **73**, 54433 (2006).
[3] Y. Bitla *et al.*, New J. Phys. **12**, 93039 (2010).

TU-21

Modifying the magnetic properties in thin film Fe (Zr) amorphous alloys by ion implantation

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Amorphous FeZr alloys order ferromagnetically, with a maximum in the ferromagnetic transition temperature near 226K for a Zr content of about 12 at. %. Interestingly, hydrogen can be introduced into the alloy, enhancing its Curie temperature T_c, magnetic moment and soft magnetic properties. In order to understand the magnetism of the $Fe_{1-x}Zr_x$ binary system, and the effect of hydrogen on the magnetic interaction, we have investigated in details the magnetic properties of such amorphous thin films. $Fe_{1-x}Zr_x$ films with compositions x=7.5, 9.5, 11.5, 12.5 and 13.5 at. % were synthesized by co-sputtering on Si substrate in ultra high vacuum (UHV) conditions. The compositions, structural and magnetic properties of the films were investigated by Rutherford Backscattering spectrometry (RBS), X-ray diffraction, and SQUID magnetometry respectively before and after hydrogenation. The magnetization curves at low temperature show a continuous increase with increasing field up to the highest measured field (5 T) confirming the presence of random anisotropy. This anisotropy is heavily suppressed by hydrogen implantation, yielding films with tunable soft magnetic properties.

TU-22

Crystal-field levels of Tb^{3+} in $Tb_2Ti_2O_7$

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In the rare-earth (RE) titanates $R_2Ti_2O_7$ (R stands for a RE element) with pyrochlore structure magnetic interactions are frustrated, which leads to an unusual magnetic state known as spin ice [1]. In pyrochlore structure the R^{3+} ions stands in the corners of the R_4 tetrahedra. In the spin-ice state the magnetic moments are directed along the three-fold axes of tetrahedron. The spin-ice state was established only for a few titanates (R = Dy and Ho). It can be realized under the condition of the Ising-type anisotropy of the R^{3+} ion, driven by the crystal field (CF) [2]. The Tb^{3+} ion in the terbium titanate possesses the Ising-type anisotropy [2], nevertheless, the spin-ice state does not realize in $Tb_2Ti_2O_7$. The possible reason for this could be the low-lying CF-levels of Tb^{3+}. The literature data on the CF splitting of the ground Tb^{3+} multiplet in $Tb_2Ti_2O_7$ studied by neutron scattering and Raman spectroscopy are contradictory. We report on transmission spectroscopic study of $Tb_2Ti_2O_7$.

The CF energies for the ground multiplet were derived (1.5, 10, 14 and 17 meV) Very unusual behavior of spectral lines at low temperatures (T<15 K) was registered. We interpret this behavior in terms of the strong interionic interaction that leads to transformation of terbium energetic spectrum. Our suggestion is confirmed by the unusual behavior of CF energies according to the recent neutron data [3]. The strong interionic interaction leads to the mixing of ground and first excited (1.5 meV) states, thus Ising type anisotropy is not realized for $Tb_2Ti_2O_7$.

Support by RFBR (grant 12-02-00858-a) is acknowledged.

[1] A.P. Ramirez, et al., Nature **399**, 333 (1999).
[2] B. Z. Malkin, et. al., Phys. Rev. B **70**, 075112 (2004).
[3] I. Mirebeau, et al., Phys .Rev. B **76**, 184436 (2007).

TU-23

Magnetic phase diagram of $Pb_3TeCo_3V_2O_{14}$

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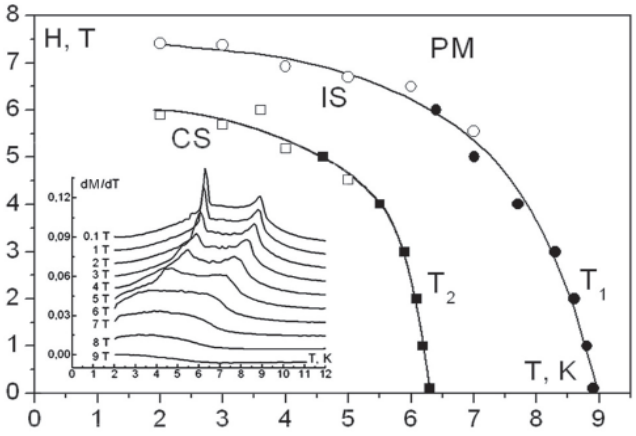
The double magnetic phase transition was found recently in $Pb_3TeCo_3V_2O_{14}$ ($Ca_3Ga_2Ge_4O_{14}$ crystal structure, sp. gr. $P321$ [1]) at T_1 = 8.9 K and T_2 = 6.3 K [2,3]. The magnetic moments of Co^{2+} ions (S-3/2) form commensurate spiral structure (CS) at $T < T_2$, and incommensurate structure (IS) in the range $T_2 < T < T_1$ [3].

In present work, the magnetization $M(H,T)$ was investigated in the temperature 2–20 K and magnetic field 0.01–9 T ranges, resulting in a magnetic phase diagram of $Pb_3TeCo_3V_2O_{14}$.

The magnetic phase transitions manifest themselves as a slope changes on the $M(T)$ curves at $H \leq 5$ T and as a double peak anomaly on the derivation dM/dT curves as shown in the Inset to Fig.1. The anomalies shift to lower temperature and smears at increasing magnetic field. The positions of the anomalies on dM/dT curves $T_1(H)$ and $T_2(H)$ are shown on the magnetic phase diagram of $Pb_3TeCo_3V_2O_{14}$ (Fig.1, solid points). $M(H)$ curves also demonstrate a slope changes at the phase transitions at $T \leq 8$ K. The open points on the Fig.1 depict the anomalies $H_1(T)$ and $H_2(T)$ of the dM/dH curves.

It was found that in the range 2–8.9 K and 0–7.4 T there are two phase-boundary lines between low-(T,H) CS state, intermediate IS state, and high-T paramagnetic (PM) state. The positions of two quantum critical points can be estimated as $H_1(T\rightarrow 0) \sim 6.3$ T and $H_2(T\rightarrow 0) \sim 7.6$ T.

[1] B.V. Mill, Russ. J. Inorg. Chem. 54, 1205 (2009)
[2] M. Markina et al., Book of Abstracts of Moscow International Symposium on Magnetism, 25-30 August, 2011
[3] H.J. Silverstein, et al., Chem. Mater. 24, 664 (2012)



The magnetic phase diagram of $Pb_3TeCo_3V_2O_{14}$. Inset: $\partial M/\partial T$ curves.

TU-24

Magnetically frustrated system $SmPd_2Al_3$ studied by neutron diffraction

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$SmPd_2Al_3$ exhibiting a complex low-temperature magnetic behavior with four consecutive magnetic phase transitions at temperatures of 3.4, 3.8, 4.3 and 12.5 K [1] and 1/3 and 1/2 magnetization plateaus on low-temperature magnetization curves is a distinctive example of Sm magnetism. The complexity of magnetism in this compound is caused by specific features of the Sm^{3+} ion, namely by nearness of the ground-state multiplet $J = 5/2$ and the first excited multiplet $J = 7/2$ in conjunction with strong crystal field influence. Consequently, a dramatically reduced magnetic moment in comparison with the theoretical Sm^{3+} free-on value is observed. We have established a magnetic phase diagram of this compound based on the magnetization data. To obtain detailed information regarding the magnetic structure of each magnetic phase, a single-crystal neutron diffraction experiment has been carried out. To reduce the problem of the strong thermal-neutron absorption by the natural Sm isotope we have performed the experiment at the ILL Grenoble D9 diffractometer with the hot source providing neutrons of a short wavelength (λ = 0.5 Å) which are much less absorbed by the natural Sm. The four successive magnetic phases have been detected by the neutron diffraction experiment at the values of the critical temperatures 3.5, 4, 4.5 and 12.4. Despite the still strong Sm neutron absorption and the low effective magnetic moment we have successfully determined the magnetic k-vector (1/3 1/3 0) of the phase existing in the temperature interval 12.4 - 4.5 K which classifies the $SmPd_2Al_3$ compound to the unique group of magnetically frustrated systems. Extinction of the (5/3 5/3 0) reflection was detected below the 4.5 K denotes likely coming of the magnetic incomensurate phase. Discussion will be drawn in the context of recent theoretical approaches to geometrically frustrated magnetic systems and influence of magnetic field kinetic effect on magnetic state.

TU-25

The new order parameter for the second phase transition

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The average magnetization is generally used as the order parameter to describe an order-disorder transition of magnetic systems. For ferromagnets, antiferromagnets, spin glasses (SG) as a new order parameter could be used the relative average size of percolation cluster (i.e. of the maximal cluster for finite lattices). The main advantage of this order parameter is universality.

In this paper we investigate the simplest model of the magnetism description - Ising model, which one allows research the transition to order both analytically and numerically. Percolation cluster is formed by spins from the nearest environment, which are in the energy minimum (Ground State Spins). Monte Carlo simulation showed, that the temperature behavior of the size of percolation cluster $\gamma_1(T)$ γ_2(T) in ferromagnet repeats the temperature behavior of the average magnetization! In an antiferromagnet the average magnetization is zero, and could not be used as the order parameter for this system, despite the presence of a phase transition. But we show that the function $\gamma_1(T)$ allow define the Neel point in an antiferromagnet and describe transition paramagnet-antiferromagnet.

In two-dimensional Edwards-Anderson (EA)[1] model of a SG ($\pm J$) on the simple square lattice the order parameter $\gamma_1(T) = 0$ for any finite temperature. Therefore we calculate the function γ_2(T) for SG. In this case the percolation cluster is formed by nearest neighbors spins, with a negative energy of interactions. The function γ_2(T) has an abrupt jump at a finite temperature $T_f > T_c$ for the ferromagnetic system, $\gamma_2(T) = 0$ the paramagnetic state and $\gamma_2(T) \rightarrow 1$ at $T < T_f$. A similar behavior for the function $\gamma_2(T)$ is observed for the EA SG. In the future we plan to investigate the behavior of the order parameter for SG lattices in space dimension greater than 2 ($D > 2$).

[1] Edwards S.F., Anderson P.W. Short-Range Ising Model of Spin Glasses // J. Phys. F. 1975. Vol. 5.P.965—974.

TU-26

Chaos under Magnetic Hysteresis

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The hysteresis phenomenon occurs in a wide variety of physical manifestations, with profound implications in understanding the phenomenological connections at system level.

Modeling physical systems by iterative techniques is one powerful approach to study of the systemic inter-component interaction methods. In the iterative model arise situations where model behavior is switching between two distinctly states, indicating the emergence of regimes characterized by hysteresis. Such behavior often leads to a dynamic chaotic system which asks using techniques of complexity.

For any magnetic hysteresis behavior, is possible to find a recursive relation. Same properties conduct to many models for the systemic features, with large implications involved. The iterative model can doing a correlation between the logistic map (analyzed into the specific domain) and proper physical features of the system considered.

An interesting situation is when, after suffering a linear increase steady, one parameter (control parameter for logistic equation) attempting to return its previous value, through the same rate, but in decreasing. In this case, some systems returning to the states already covered, while others pass into new states still untouched. The latter case has a hysteresis behavior and hiding behind interesting systemic properties.

Research in the behavioral study of dynamic systems with hysteresis, conducted by the author, shows a new way to approach the dynamics of the physical systems.

[1] H. Aswath Babu, H. Wanare, *Negative and positive hysteresis in double-cavity optical bistability in three-level atom*, ArXiv Optics, Cornell University, PhysRevA. 83.033818 (2011).

[2] J. Sieber, P. Kowalczyk, S.J. Hogan, M. diBernardo, *Dynamics of symmetric dynamical systems with delayed switching,* ArXiv Maths, Cornell University, Journal of Vibration and Control 16(7-8), pp. 1111-1140 (2010).

[3] P. Grünberg, D.E. Bürgler, H. Dassow, A.D. Rata, C.M. Schneider, *Spin-transfer phenomena in layered magnetic structures: Physical phenomena and materials aspects*, Acta Materialia 55, 1171-1182, 2007.

TU-27

Stabilization of Néel order with increasing magnetic field in frustrated magnets

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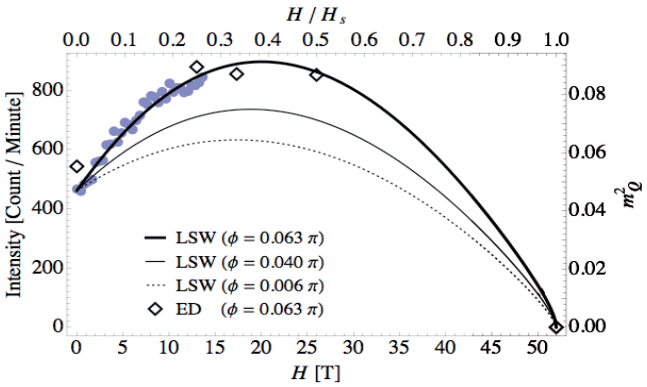
For low-dimensional frustrated quantum magnets, the dependence of the staggered moment m_s on a magnetic field is nonmonotonic: For small and intermediate fields, quantum fluctuations are gradually suppressed, leading to an increase of $m_s(H)$. For large applied magnetic fields however, the classically expected monotonous decrease is recovered. For the same reasons, the Néel ordering temperature T_N of such compounds first increases and then exhibits a reentrant behavior as a function of the field strength. The quantitative analysis of this behavior is an excellent tool to determine the frustration parameter of a given compound. We have developed a general finite-size scaling scheme for numerical exact-diagonalization data of low-dimensional frustrated magnets in the presence of a finite magnetic field. We have also derived a linear spin-wave (LSW) theory to complement and extend our numerical findings. Based on our LSW theory, including a small interlayer coupling, we use a self-consistent RPA approach determining T_N by the condition of a vanishing staggered moment [1].

We apply our findings to the recently measured field dependence of the magnetic ordering temperature T_N and the staggered moment of $Cu(pz)_2(ClO_4)_2$ [2] in the framework of the $S = 1/2$ two-dimensional (2D) J_1-J_2 Heisenberg model. The observed increase of both quantities with increasing field strength can be understood naturally using an intermediate frustration ratio $J_2/J_1 \approx 0.2$, which is an order of magnitude larger than a prior estimate from an analysis of the zone-boundary dispersion of the magnetic excitations of $Cu(pz)_2(ClO_4)_2$.

[1] M. Siahatgar et al., Phys. Rev. B **84**, 064431 (2011)
[2] N. Tsyrulin et al., Phys. Rev. B **81**, 134409 (2010)



Magnetic neutron scattering intensity $\propto m_s^2$ of $Cu(pz)_2(ClO_4)_2$ at the AF point

TU-28

Low temperature antiferromagnetism and ferromagnetism in Ge:As near the phase transition insulator - metal

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(1) A.F. Ioffe Institute, 194021, St. Petersburg, Russia, (2) A.F. Ioffe Institute, 194021, St. Petersburg, Russia; Umea University, Sweden

Magnetic properties of the As impurity in Ge near the phase transition insulator – metal (IM) were investigated by the electron spin resonance (ESR). The samples were prepared by the transmuted neutron doping of the samples with the As concentration $n_s = 3.6 \cdot 10^{17}$ cm^{-3}. As a result, we had the sample series with the decreasing electron concentration (3.6 □ 1)$\cdot 10^{17}$ cm^{-3} and the increasing compensation $K = 0$ □ 0.8. It was found that the susceptibility was almost non-depended from the temperature and the spin density decreased when the temperature was fallen in the range 100 □ 10 K. We believed that this is the result of the antiferromagnetic pair formation. These pairs transited in the ferromagnetic ones in the temperature range lower than ~ 10 K. The signs of this transition: the quick growth of the susceptibility, the spin density increase and the inner magnetic field appear.

We believe that these effects are the manifestation of the exchange interaction in the impurity system of Ge. It is known [1, 2] that this interaction includes two addendums. The first one is the result of the electron kinetic energy and leads to their antiferromag-netic coupling. The second one is the result of the coulomb energy and leads to the ferromagnetic coupling. The kinetic energy is more then coulomb one in the high temperature range and in the non-compensated samples. Then the antiferromagnetic pairs are observed. In the low temperature range in compensated samples, the coulomb energy is more and the ferromagnetic pairs are observed. The transition temperature depends on the compensation and grows with it.

[1] H. Kamimura. In book "Crystallin Semicon- ducting Materials and Devices". Eds by P.N. Butcher, N.H. March and M.Tosi, (Plenum, 1986).
[2] N. Ashkroft, N. Mermin. Solid State Physics, Holt, Rinehart & Winston, NY 1976.

TU-29

Theoretical study of elastic and magnetoelastic properties of single crystals and powder samples of $R_2Ti_2O_7$ (R=Tb, Dy)

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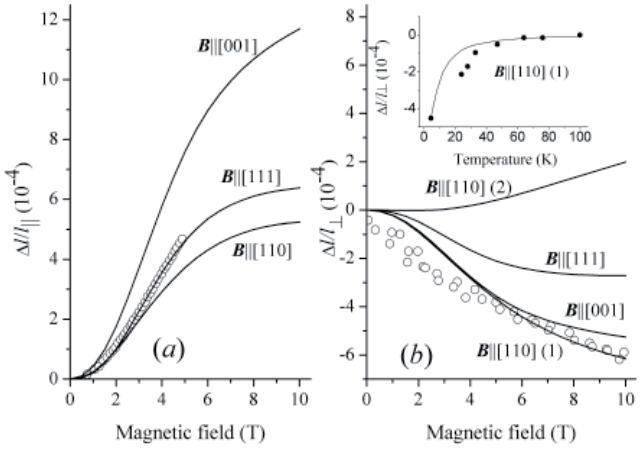
(1) Institute of Physics, Kazan Federal University, 420008, Russian Federation

The titanates $R_2Ti_2O_7$ cause enormous interest during last years due to a wide variety of magnetic behaviours at low temperatures. Experimental investigations revealed that the parastriction in $Dy_2Ti_2O_7$ has an ordinary magnitude for paramagnets of ~10^{-6} in magnetic fields ~1 T at liquid helium temperatures but $Tb_2Ti_2O_7$ exhibits the giant parastriction of ~10^{-4} [1]. Elastic constants of $Dy_2Ti_2O_7$ have usual temperature dependences but elastic constants of $Tb_2Ti_2O_7$ exhibit anomalous softening at low temperatures [2].

In the present work we describe elastic and magnetoelastic properties of $Tb_2Ti_2O_7$ and $Dy_2Ti_2O_7$ in the framework of a single model based on semi-phenomenological calculations of crystal field energies and electron-deformation coupling constants of rare earth ions in the pyrochlore lattice [3]. The main features of the field and temperature dependences of the magnetization, parastriction and elastic constants in $Tb_2Ti_2O_7$ and $Dy_2Ti_2O_7$ which have been presented in the literature can be reproduced satisfactorily when taking into account the microscopic parastriction (sublattice displacements, corresponding to Raman active lattice vibrations, induced by the magnetic field). New effects such as giant anisotropy of the transversal parastriction and decreasing of elastic constants in the magnetic field directed along the [110] axis in $Tb_2Ti_2O_7$ are predicted.

[1] I. V. Aleksandrov et al., ZhETF 89, 2230 (1985); J. C. P. Ruff et al., Phys. Rev. Lett. 105, 077203 (2010)
[2] Y. Nakanishi et al., Phys. Rev. B 83, 184434(2011)
[3] V. V. Klekovkina et al., J. Phys.: Conf. Ser. 324, 012036 (2011)



Field dependences of the longitudinal (a) and transversal (b) parastriction of $Tb_2Ti_2O_7$ at 4.2 K for B||[111] and 4.5 K for B||[001] and B||[110]. Inset: Temperature dependence of the transversal parastriction in [001] direction in the field B||[110], B = 6 T. Symbols correspond to experimental data [1].

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

ELECTRONIC STRUCTURE AND CORRELATION EFFECTS IN MAGNETIC SYSTEMS

Chair: C. Franchini

TU-30

First-principles study of S=1/2 Kagome antiferromagnet

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3-D systems with interacting spins usually develop static long-range order when they are cooled. However, quantum fluctuations are enhanced in low dimensionality system with low spin value and lead to suppress the long-range ordering, and can show some extremely subtle, complex, and sometimes even useful magnetic behavior in solids. Here, using first-principles calculations, we investigated the atomic structural and magnetic properties of S=1/2 Kagome antiferromagnet A_xCu_4-x(OH)_6Cl_2 (A=Zn, alkali metal ion). Cu ions are indeed found to locate at the tetragonally elongated intralayer site and Zn ions favorably rest on the higher symmetry interlayer site, in support of experimental contention. The intra- and inter-layer exchange interactions are studied in details. The effect of Dzyaloshinskii-Moriya interaction is also discussed.

[1] M. P. Shores, E. A. Nytko, B. M. Bartlett, and D. G. Nocera, J. Am. Chem. Soc 127, 13462, (2005)
[2] S. Chu, T.M McQueen, R. Chisnell, D.E. Freedman, P. Müller, Y.S. Lee, and D.G. Nocera, J. Am. Chem. Soc. (2010).

TU-31

Magnetic ground state and 2D behavior in pseudo-Kagome layers system $Cu_3Bi(SeO_3)_2O_2Br$

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(1) Laboratory for Neutron Scattering, Paul Scherrer Insitute, CH-5232 Villigen, Switzerland, (2) Josef Stefan Institute, Ljubljana, Slovenia, (3) Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

We study [1] the magnetic ground state, anisotropic magnetic properties and low-dimensional metamagnetic behavior of a layered Kagome-like system $Cu_3Bi(SeO_3)_2O_2Br$ [2] by bulk magnetization, magnetic susceptibility measurements, powder and single crystal neutron diffraction. At T_N =27.4 K the system develops an alternating antiferromagnetic order of layers, which individually exhibit canted ferrimagnetic moment arrangement (figure), resulting from the competing ferro- and antiferro-magnetic intralayer exchange interactions. A magnetic field $B_C \sim$ 0.8 T applied along the easy c-axis (perpendicular to the layers) triggers a metamagnetic transition, when every second layer flips, i.e., resulting in a ferrimagnetic structure. Significantly higher fields are required to rotate the ferromagnetic component

towards the b- or c-axis. We estimate the exchange coupling constants and present features indicative of the XY character of this quasi 2D system.

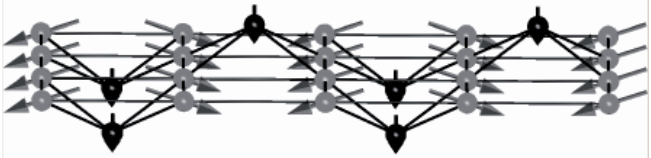

Figure. Magnetic arrangement of an individual layer. Cu atoms occupying two different sites are presented by black and grey spheres.

[1] M. Pregelj et al., Rhys. Rev. B submitted
[2] P. Millet et al., J. Mater. Chem. 11, 1157 (2001)

TU-32

Advanced ab initio methods for magnetism in complex oxydes

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(1) CNR-IOM UoS di Cagliari c/o Dipartimento di Fisica, I-09042 Monserrato, Italy

A great technological potential stems from the interplay of orbital and charge ordering, magnetism, ferroelectricity, magnetoelectric coupling in complex oxides. The ab-initio approach would be ideal for a thorough understanding of these systems; but standard LSDA approaches fail for strong correlated systems. Recently the novel VPSIC technique has been introduced [1]. We present two examples of its improvements w.r.t. LSDA: Fig.1 compares the Néel temperatures for MnO and NiO [2] calculated by Heisenberg Hamiltonian based on ab-initio parameters computed by LSDA, PBE, and two beyond-local approaches: the VPSIC, and hybrid HSE functional (very accurate but computationally expensive). Notwithstanding the differences in conceptual starting point, VPSIC and HSE match, with an impressive improvement, over LSDA and PBE, for what concern the agreement with the experiment (indicated by the dashed lines). For MnO, LSDA and PBE describe a fake transition from antiferro insulator to ferromagnetic metal, at small volumes (indicated by the dashed areas), due to the artificial magnetic moment collapse under pressure. VSIC and HSE, instead, both restore the correct AF-insulating state at any considered pressure.

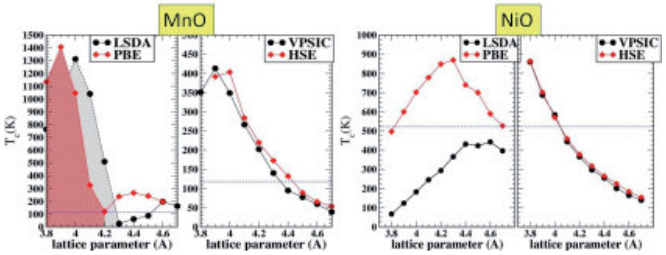

Figure 1: Néel temperature for MnO and NiO calculated by 2-parameter Heisenberg Hamiltonian.

A second example of the VPSIC capability is furnished by the calculated properties of two titanates, LTO and YTO [1], which, despite the close similarity in structure and chemistry display very different electronic and magnetic properties. The theory is capable to distinguish the phenomenologies of the two systems on the basis of their small difference in octahedral rotations: the different orbital ordering (checkboard AF for YTO, FM for LTO) and magnetic ordering (FM for YTO and AF-G type for LTO) are indeed both correctly reproduced by VPSIC.

[1] A. Filippetti, *et al*., Phys. Rev. B, **84**, 195127 (2011).
[2] T. Archer *et al*., Phys. Rev. B, **84**, 115114 (2011).

TU-33

Charge compensation in La, Nd and Pr substituted strontium M-type hexaferrites

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In present work we focus on mechanism of charge compensation in strontium M-type hexaferrites with Sr^{2+} substituted by trivalent lanthanum or rare earth cations. Spectroscopy of nuclear magnetic resonance (NMR) was employed and the signal of ^{57}Fe was measured in powder samples with composition $Sr_{(1-x)}R_xFe_{12}O_{19}$ where R = La, Nd, Pr and concentrations of substitutions were $x_{La} = 0, 0.25, 0.5, 0.75, 1$, $x_{Nd} = 0.125, 0.25, 0.300$ and $x_{Pr} = 0.125, 0.25, 0.375$. The NMR spectra were recorded at 4.2 K in a zero external magnetic field. The observed dependence of spectral parameters with the substitution concentration is compatible with the mechanism of charge compensation by formation of Fe^{2+} ions in 2a sublattice.
For La substitution we also tested this assumption by performing electronic structure calculations using full potential augmented plane wave method as implemented in WIEN2k code. The calculations as well as spectral intensities indicate that ferrous ions are preferentially formed in 2a sublattice.
We did not observe shifts of resonant frequencies in spectra of Nd and Pr substituted ferrites reported by Pieper et al. [1] who assigned these shifts to polarons.

[1] J. Magn. Magn. Mater., Volumes 272-276, Part 3, s. 2219-2220, 2004

TU-34

Electronic structure of doped $LiFePO_4$ olivines

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LiFePO4 olivine, crystallizing in the orthorhombic Pnma structure, has attracted a lot of attention because of its potential as a cathode for Li rechargeable batteries [1]. Whereas rather large ionic conductivity related to Li ions is promising in application, the extremely low electrical conductivity of LiFePO4, typical for an insulator, precludes usage of this compound as a cathode. Thus, the developmental work has focused on increasing electrical conductivity of LiFePO4, e.g. via cation doping into Fe sites [2].
In the work, we present the spin polarized electronic structure of LiFePO4 doped by other transition metals like Mn, Co and Ni. All calculations have been performed in the framework of density functional theory (DFT) using the based on plane-waves methods QUANTUM-ESPRESSO code. For the exchange-

correlation potential we use generalized gradient approximation (GGA) with additional Hubbard U-type interaction for the localized d-states of transition metals. The previous results showed that DFT+U approach is essential to obtain proper band gap of pure LiFePO4 [3].
We show the band structures and the density of states (DOS) of doped systems and compare our results with pure LiFePO4.

[1] S. Y. Chung et al, Nature Materials 1, 123 (2002).
[2] D. Shanmukaraj et al, Mat. Sci. Eng. B 149, 93 (2008).
[3] F. Zhou et al, Solid State Communications 132 ,181 (2004).
This work was partly supported by the European Union, within the European Regional Development Fund, through the Innovative Economy grant (POIG.01.01.02-00-108/09).

TU-35
Nuclear magnetic resonance and Mössbauer spectroscopy of magnetite: comparative analysis
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The present work comprises a comparison of the data obtained by the ^{57}Fe NMR spectroscopy and Mössbauer spectroscopy of pure single crystal magnetite samples. We focused on the phase below the Verwey transition. The Mössbauer spectroscopy yields information on hyperfine field, isomer shift (IS) and electric field gradient (EFG) for groups of non-equivalent, though similar iron sites. On the other hand, the NMR provides more precise values of hyperfine field and allows to distinguish all 24 crystallographically and magnetically non-equivalent positions of the iron ions in low-temperature phase of pure magnetite (however the unambiguous assignment of the resonance lines to corresponding iron sites is not completed yet). Thus these methods can be considered as complementary techniques and the analysis of results of both methods altogether may contribute new information.
The Mössbauer spectra were decomposed into five components assuming the P2/c structure of magnetite and the corresponding values of hyperfine field, IS and EFG were evaluated for all these components. Iron valences drawn from isomer shifts can be compared to those obtained from the recently solved low-temperature magnetite structure [1]. Consequently, frequencies of 24 NMR spectral lines corresponding to the real Cc structure were grouped into five sets to match the five Mössbauer components while considering temperature dependences and hyperfine field anisotropy [2, 3]. Therefore the (average) values of IS and V_{zz}-component of EFG tensor were assigned to particular groups of NMR signals. Due to their nature, the results can serve as a counterpart to ab-initio calculations employed in the long-time effort to determine the electronic structure in magnetite below the Verwey transition.

[1] M. S. Senn et al., Nature 481, 173-176 (2012)
[2] P. Novák et al., Ferrites, Proceedings of the Eight International Conference on Ferrites, 2000, Kyoto, pp. 131-134
[3] M. Mizoguchi, J. Phys. Soc. Jpn. 70, 2333-2344 (2001)

TU-37
First-Principles Calculations for the Anisotropy and Gilbert Damping Parameter in Cobalt Systems
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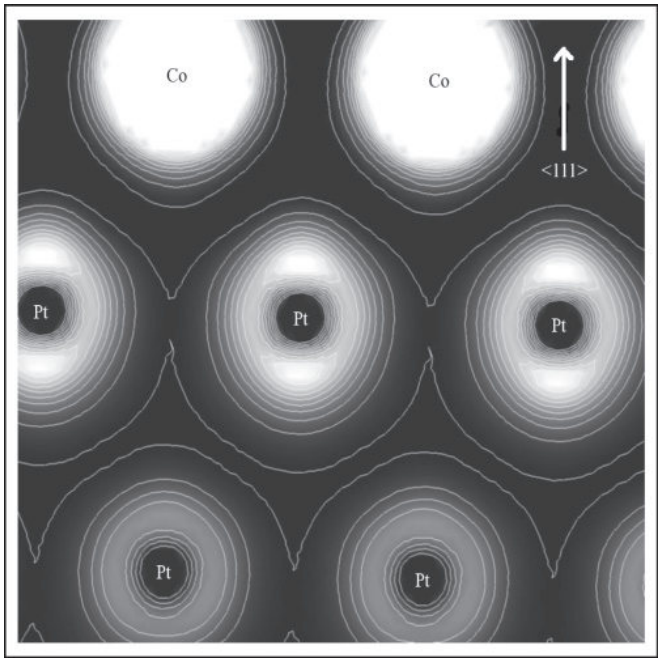
(1) Department of Physics, University of Bath, BA27AY, Bath, UK

We present results of computational investigations into the magnetic properties of cobalt systems, with the aim of parameterising micromagnetic simulations of Pt/Co/Pt layers which exhibit perpendicular magnetic anisotropy and current-driven domain wall motion. Consequently, specific systems in this study are FCC cobalt, HCP cobalt, Co_xPt_{4-x} for x = 1,2,3, and Pt_xCo_y (111) multilayers. Ab initio all-electron density functional theory calculations are performed using the Elk code [1] on ordered cobalt and cobalt platinum alloys. The parameters we are seeking are the magnetocrystalline anisotropy and the Gilbert damping parameter for the damping of magnetic precession about the effective micromagnetic field. Spin-orbit coupled linearised augmented plane wave computations are performed, with the magnetocrystalline anisotropy evaluated using the force theorem, and the damping parameter computed using the breathing fermi surface and torque correlation models [2]. The latter two models concern the problem of changing eigenvalues with precession due to inter- and intra-band transitions, allowing us to formulate the damping parameter in terms of a scattering time. Using Drude-like lifetime approximations an estimate of the damping parameter is found, values of which are similar in vein to those reported recently by Gilmore et al [3], but still an order of magnitude different to those reported experimentally. Implications of these results could be that disorder greatly increases Gilbert damping, or there are other contributions not described by the breathing Fermi surface or torque correlation models.

[1] http://www.elk.sourceforge.net
[2] V. Kamberský, Czech. J. Phys., Sect. B 26, 1366 (1976).
[3] K. Gilmore, Y. U. Idzerda, and M. D. Stiles, J. Appl. Phys. 103, 07D303 (2008).



Anisotropic Platinum Atom Spin Density in Pt_7Co_2 Multilayer (Black < White)

TU-38

Local moment formation in Anderson-Holstein Model

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(1) University of Hyderabad, School of Physics, Hyderabad, 500046, India

We consider an Anderson-Holstein model consisting of an electron in a localized level, coupled to a dispersionless phonon mode. We also consider that the localized level electron is coupled to a continuum of non-interacting electron states. To eliminate the electron-phonon coupling term in the Hamiltonian we use a nonperturbative canonical transformation usually referred to as the Lang-Firsov transformation. It is found that the effect of the electron-phonon interaction is to renormalize the localized electron energy and the on-site correlation at the localzed site. We show that the hopping integrals get exponentially reduced which implies that there may be a mass renormalization leading to band narrowing for the continuous electron band. This also implies that the electron hopping is accompanied by a phonon cloud. Performing a zero-phobon averaging of the transformed hamiltonian gives an efective Anderson model which we solve by the Green function method using an equation of motion approach within the frame-work of a simple mean-field approximation. We display the effect of electron-phonon interaction on the formation of local moment. It is observed in general that electron-phonon interaction suppresses the electron-electron repulsive interaction strength (U) as a result of which the magnitude of the magnetic moment decreases as the electron-phonon coupling constant λ increases. We show the contour line in the λ -U plane, the points on which give the the magnetic solutions. We also show the phase diagram for the magnetic phase.

TU-39

Non-perturbatively phonon-renormalized electronic interactions

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Many magnetic materials feature appreciable electron-phonon interactions (EPI). While usually stronger than EPI's, nevertheless both one- and two-body electronic interactions can be strongly renormalized by them. Several estimates of such effects are available in the literature, obtained from different types of numerical evaluations. Despite applying very refined numerics, full consensus on the issue of which interactions are affected, and to what extent, has not yet been achieved. In this situation, solving exactly a simple model can be of some help in orienting the full-fledged numerical computations. We have therefore studied a dimer where two electrons in a non-degenerate orbital, besides being subjected to all one- and two-particle electronic interactions, also interact with both on-site and inter-site phonons, through coupling terms of arbitrary strength. We have succeeded in performing an exact unitary transformation of displacement type to all orders in the two EPI parameters, realizing a non-perturbative treatment. The transformed fermionic and phononic operators are highly non-linear functions of the EPI's coupling parameters. A subsequent averaging at zero temperature over squeezed states (i.e. Bogolyiubov-transformed harmonic oscillator states), independently for both phonons yields the explicit analytical expressions for the electronic interaction parameters non-perturbatively renormalized by the phonons. Finally, the numerical minimization of the ground state energy in the 4-dimensional space spanned by the parameters characterizing displacement and Bogolyiubov transformations identifies the true ground state, and consequently the true values of the renormalized parameters.

TU-40

Electronic Structure of $DyPc_2$, An Organic SMM

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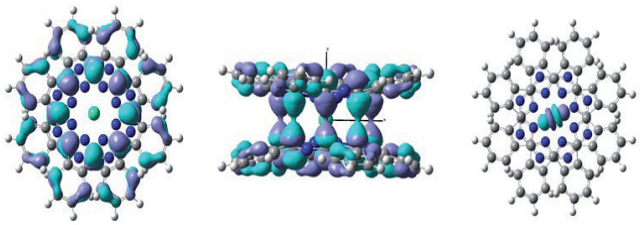
Understanding the electronic structure of DyPc2, an organic SMM. This has a sandwich structure, with the lanthanide ion in the centre.
Our motivation is to use electronic structure codes to understand the magnetic anisotropy of the molecule, particularly when placed on a thin insulating surface Cu(100) c(2x2)-N. This copper nitride surface
We carried out ab initio density functional theory calculations to understand the ground state electronic structure of the molecule. We used the Gaussian 09 package with the B3LYP functional and ECPs for the central dysprosium ion. Our results showed that the SOMO and LUMO are ligand molecular orbitals and the f-orbitals that are of interest for the spin state are (eV) below the Fermi level. We found that DFT was not sufficient to characterise the highly localised f-orbitals and so we are now carrying out quantum chemistry calculations that will take relativistic effects into account.

There are a series of three calculations that we are carrying out in succession: Complete Active Space SCF (CASSCF) includes static correlation terms, CASPT2 adds dynamic correlation perturbatively and finally calculations using the MOLCAS 7.6 quantum chemistry package. This is following a recent paper [3] that computed the g tensor. These include subsequent CASPT2 and RASSI-SO calculations that add dynamic correlation effects perturbatively and spin-orbit coupling effects respectively.

[3] G. Cucinotta et al., Angew. Chem. Int. Ed., 51, 1606 (2012)



Molecular orbitals of DyPc_{2} from DFT calculations. SOMO orbital a)from above, b)from the side and c) an occupied f-orbital.

TU-43

On the nature of diamagnetic properties of electrons in metal-ammonia systems

V. Mukhomorov [1]
(1) Agrophysical Institute

The concentration dependence and temperature dependence of the static magnetic susceptibility are analyzed on the assumption that polaron and large bipolaron singlet formations coexists in the metal-ammonia systems. The particular attention is devoted to analyzing the equations of motion for a bipolaron in magnetic field. The theory is based on the assumption that both single-particle and two-electron bound singlet formations of the Landau-Pekar bipolaron type exist in the polar dielectric system. Experimental studies of the spin susceptibilities of metal-ammonia systems confirmed that as the electron concentration increases, a compensation of the spin angular momenta of the electron does in fact occur.
A theoretical approach is proposed to describe the concentration and temperature dependence of the static magnetic susceptibility of a metal-ammonia system. A mechanism is also suggested to explain the transition of the electron system from the paramagnetic state to the diamagnetic one. The formation of bipolarons is initiated at alkali metal concentrations of ~$5 \cdot 10^{17}$cm^{-3}, and in the range $3 \cdot 10^{18}$-10^{19}cm^{-3}, the number bipolarons and polarons is equalized, and as the concentration alkali metal increases further, the number of diamagnetic bipolaron formations begins to exceed the number of single-particle polaron states. The theoretical values of the susceptibilities of electronic system describe well the experimental values [1]. It is important to stress that in this comparatively narrow range of concentrations the maximum of the optical absorption band undergoes a long-wavelength shift which is identified with the formation of singlet bipolarons [2]. The concentration changes in the optical characteristics are completely correlated with a drop in the spin susceptibility of the electronic subsystem.

[1] S. Freed and N. Sugarman, J. Chem. Phys. 11, 354 (1943)
[2] V. K. Mukhomorov, Bipolarons. Structure. Properties. Lambert Academic Publishing, Saarbrücken, 2011

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC MEMORIES AND MAGNETIC RECORDING
Chair: F. Casoli

TU-45

Control of ferromagnetic-antiferromagnetic transition in $L1_0$ FePtRh film using Pt ion implantation

T. Hasegawa [1], H. Yamada [1], T. Tomioka [1], Y. Kondo [2], H. Yamane [2], S. Nagamachi [3], A. Arakawa [1], S. Ishio [1]
(1) Graduate School of Engineering and Resource Science, Akita University, 1-1 Tegata Gakuen-machi, Akita 010-8502, Japan, (2) Akita Industrial Technology Center (AIT), 4-11 Sanuki Araya, Akita 010-1623, Japan, (3) Ion Technology Center Co. Ltd, 2-8-1 Hirakata Tsuda-yamate, Osaka 573-0128, Japan

For the fabrication of BPM, flat-patterning methods that modify the physical properties of films while maintaining a smooth, flat surface, have been proposed.[1] By substituting Rh for Pt in the equiatomic FePt alloy, the L1_0 phase can be stabilized. The resultant L1_0 FePt_1-xRh_x film has a high Ku (1.7 × 10^7-6.6 × 10^7 erg/cm^3) and exhibits a ferromagnetic (FM)-antiferromagnetic (AF) transition.[2] Films with x values in the ranges of 0–0.32 and 0.34–0.40 are FM and AF, respectively.

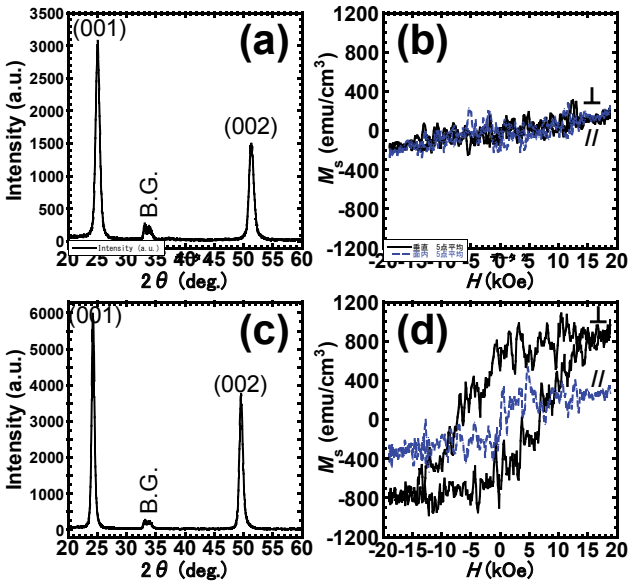


Fig. 1 XRD (2θ-θ) patterns and VSM curves of FePt_0.64Rh_0.36 films (6.12 nm thick) (a) (b) before and (c) (d) after Pt ion implantation.

Figures 1(a) and 1(c) show XRD (2θ-θ) patterns for AF FePt_0.64Rh_0.36 films (6.12 nm thick) before and after Pt ion implantation, respectively. Pt ions were implanted at 7–9 keV with the dose of 6.0 × 10^15 ions/cm^2. All of films were annealed at 973 K for 1 min prior to the XRD measurements. Only (001) and (002) peaks are observed due to its [001] orientations. Magnetization curves before and after Pt ion implantation are shown in Figs. 1(b) and 1(d), respectively.

Non-magnetic curve is obtained on the film before the implantation due to its AF phase. On the other hand, FM hysteresis curve with Ms ≈ 800 emu/cm^3 and Hc ≈ 7.1 kOe is obtained on the film after the implantation. This magnetic change is caused by the FM-AF transition. Using this result, a BPM with FM dots and AF spacing can be realized by locally implanting Pt ions into the AF FePtRh film.
This work was supported by NEDO (11B07008d).

[1] B. D. Terris et al., Appl. Phys. Lett. 75, 403 (1999).
[2] T. Hasegawa et al., J. Appl. Phys. 106, 103928-1 (2009).

TU-46

Tailoring the magnetic properties in FePt films by adjusting the value of the magnetocrystalline anisotropy

G. Giannopoulos [1], T. Speliotis [1], *D. Niarchos [1]*
(1) Institute of Materials Science, NCSR Demokritos, Athens, GREECE

Achieving magnetic recording densities in excess of 1Tbit/in^2 requires not only perpendicular media with anisotropy larger than 6 MJ/m^3, which makes the FePt alloy as the best choice, but also narrow distribution and small sizes below 10 nm for a reduced S/N ratio. By adding C there is an advantage for grain size reduction [1] and improvement of average lateral diameter distribution. An isolated spherical particle nanostructure is also favored [2]. With the addition of SiO_2 better shape control is being achieved with cuboid-like particles [3]. Single films were prepared by magnetron co-sputtering from FePt and either C or SiO_2 targets on single crystal MgO (001) substrate, while in each case C and SiO_2 percentage varied up to 30%. Here we present our results of tailoring the nanostructure and magnetic properties of FePt films by co-sputtering with C or SiO_2. With C or SiO_2 addition we have achieved to control the variation of the magnetic anisotropy, to produce the nanograins with controllable shape and size and the form isolated nanoparticles with high uniformity and narrow average size distribution. Better results were obtained with C with respect to the uniformity of grains and SiO_2 with respect to the shape but in case of SiO_2 results are far from optimum. A drastic change in nanostructure with C addition in FePt observed. From columnar grains with diameter larger than 120nm a gradual reduction down to 12nm was verified along with desirable shape control. By adding SiO_2 an also significant reduction in grain diameter of isolated particles observed along with a large coercive field reduction.
Work supported by the EU project TERAMAGSTOR

[1]. Huang et al, *J. Appl Phys*. **109**, 063910 (2011)
[2]. Chen et al, *J. Appl Phys*. **105**, 07B702 (2009)
[3]. E. Yang, *J. Appl. Phys* **104**, 023904 (2008)

TU-47

Hard magnetic (001)-textured FePtCu bit patterned media

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(1) Inst. of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany, (2) Obducat Technologies AB, 20125 Malmö, Sweden, (3) Center for Microtechnology, Chemnitz University of Technology, 09126 Chemnitz, Germany, (4) Inst. of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria

To overcome the areal density limit of conventional magnetic materials for hard disk drives like CoCrPt due to thermal instability problems, new materials with high K_u and new concepts for magnetic recording will be necessary [1]. In order to resolve the □recording trilemma□ the recording principle of bit patterned media has been proposed [2] and in combination with FePt based alloys an areal density of 1 Tb/in.² could be probably exceeded [1]. In this study hard magnetic FePtCu thin films were prepared by sputtering at room temperature and post annealing with Rapid Thermal Annealing. The dot array with a dot size of 20 nm was then fabricated by post patterning using nanoimprint lithography followed by various etching steps. Despite of the small grain size it has been found that the remanence of the patterned film is still one and the switching field distribution (SFD) rather small, because the SFD is mainly determined by the distribution of the intrinsic magnetic properties of the dots which will vary due to edge effects during post patterning [3].

[1] Y. Shiroishi et al., IEEE Trans. Magn. 45, 3816 (2009)
[2] R.M.H. New et al., J.Vac.Sci. Technol.B. 12, 3196 (1994)
[3] J. Lee et al., Appl. Phys. Lett. 99, 062505 (2011)

TU-48

Preparation of $L1_0$ Ordered FePd, FePt, and CoPt Films with Flat Surfaces on MgO Single-Crystal Substrates

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$L1_0$ ordered alloy films with high K_u like FePd, FePt, and CoPt have been investigated for applications to perpendicular recording media, etc. High-temperature processing is necessary to prepare the ordered alloy films. Film deposition at an elevated substrate temperature tends to enhance film surface roughness. Flat film surface is required for practical device applications. In the present study, $L1_0$ ordered FePd, FePt, and CoPt alloy films with very flat surfaces were successfully prepared on MgO(001), (110), and (111) single-crystal substrates by employing a two-step process. Single-crystal films with disordered structure were grown at a low substrate temperature of 200 °C. Then, the films were annealed at 600 °C to transform the disordered structure into $L1_0$ ordered structure. Fig. 1(a) shows the XRD spectra of FePd, FePt, and CoPt films formed on MgO(001) after annealing, and the order degrees (S) calculated from the XRD data. The order degrees are similar to those of films deposited directly on MgO(001) at 600 °C which possess rough facetted surfaces [1]. Figs. 1(b) and (c) show the AFM images of FePd/MgO(001) specimens before and after annealing. Flat film surface (R_a = 0.2 nm) is kept almost unchanged after annealing at 600 °C. Fig. 1(d) shows the magnetization curves of FePd/MgO(001) specimen after annealing. The film shows perpendicular magnetic anisotropy reflecting the magnetocrystalline anisotropy of $L1_0$ crystal. Similar tendencies of surface roughness and magnetic property were recognized on MgO(110) and MgO(111) substrates. Similar results were obtained for FePt and CoPt films. The two-step process is very effective in the preparation of $L1_0$ ordered alloy film with very flat surface, which is important for practical device applications.

[1] M. Ohtake *et al*., *J. Appl. Phys*., **111**, 07A708 (2012).

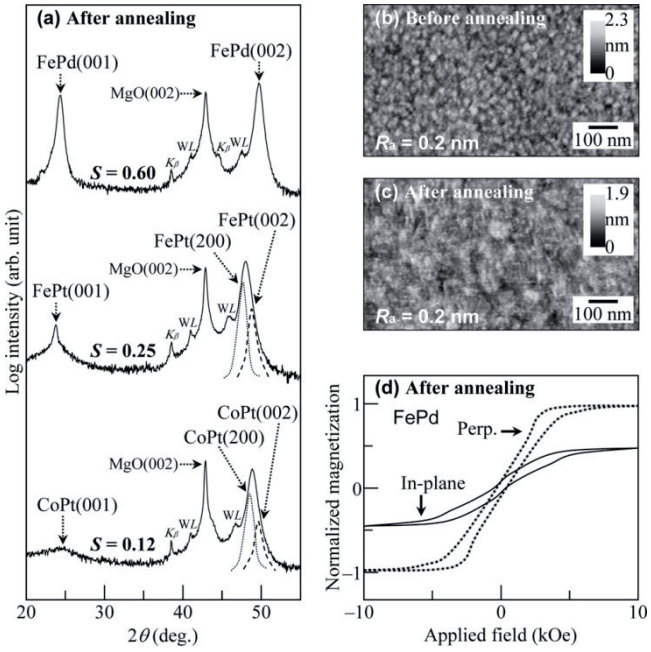

Fig. 1 (a) XRD spectra. (b, c) AFM images. (d) Magnetization curves.

TU-49

Correlation between structural and magnetic properties of FePt:Cu thin films

S. Laureti [1], E. Agostinelli [1], M. Albrecht [2], C. Brombacher [2], F. D'Acapito [3], D. Fiorani [1], D. Makarov [4], G. Varvaro [1]

(1) ISM-CNR, Area della Ricerca Roma1, Via Salaria km 29.300, 00015 Monterotondo Scalo (RM), Italy, (2) Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany, (3) CNR-IOM-OGG c/o ESRF GILDA CRG BP220 F-38043 Grenoble (France), (4) Institute for Integrative Nanosciences, Leibnitz Institute for Solid State and Materials Research, D-01069 Dresden , Germany

L10 (fct) FePt thin film with perpendicular anisotropy is a good candidate for ultra high density magnetic recording [1]. The addition of third elements to the FePt alloy allows tailoring the magnetic properties and reducing the transition temperature from the magnetically soft fcc chemically disordered to the hard fct chemically ordered phase [2].

This work is focused on the correlation between structural (XRD, XAS), microstructural (TEM) and magnetic properties (SQUID, vector-VSM) of FePt:Cu alloy films as a function of the Cu content (from 0 to 21 at.%). The results revealed a significant influence of the presence of Cu on the magnetic properties, with the increase of perpendicular magnetic anisotropy (PMA) when increasing the Cu content from 0 to 9 at.%. On the contrary, when the Cu content is further increased (21 at.%), a decrease of PMA was observed without sensible degradation of the (001) texture.

A detailed XAS study was carried out by using linear dichroism to exploit the enhanced sensitivity to differently oriented bonds and get a more detailed description of the atomic environment. XAS showed that for a Cu concentration up to 9 at.% the Cu atoms are predominantly located at the Fe sites, and their effect is to enhance the chemical ordering. Although the fct structure is retained in all the samples, with the increase of the a/c ratio of the unit cell, the analysis indicated that Cu occupies a significant fraction of Pt sites, thus inducing a decrease of the chemical ordering of the alloy.

The EU Project "Terabit Magnetic Storage Technology" (TERAMASTOR) is acknowledged.

[1] S. N. Piramanayagam and T. C. Chong, Developments in data storage, John Wiley & Sons (2011)
[2] C. Feng, Q. Zhan, B. Li, J. Teng, M. Li, Y. Jiang, and G. Yua, Appl. Phys. Lett. 93, 152513 (2008).

TU-50

Effect of interlayer exchange coupling on magnetization reversal process in ECC media with high coercivity

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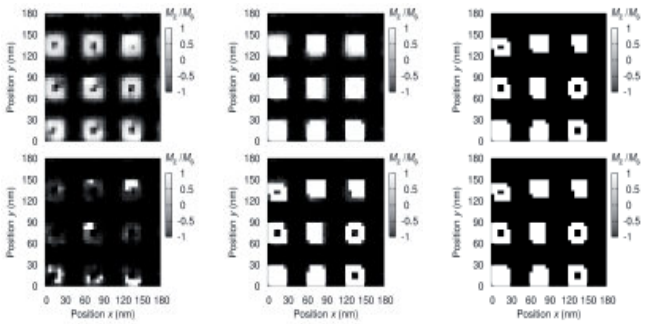
Exchange coupled composite (ECC) media [1] with high coercivity are promising approaches to achieve ultra-high recording density in hard disks [2]. It is important to elucidate magnetization change in soft and hard layers of the ECC media at the time of recording, and interlayer exchange coupling between the layers has an essential role for the magnetization change. In this study, magnetization change with a lapse of time in the each layer is investigated for various values of interlayer exchange stiffness constant $A_{\text{interlayer}}$ by using micromagnetic simulation. Magnetic printing [3] was used to record signal which has dot pattern with bit size of 30 nm × 30 nm. Fig. 1 shows magnetization change with time for $A_{\text{interlayer}}$ of 4×10^{-7} erg/cm and printing field H_a of 4 kOe. When the H_a is applied, initially, magnetization reversal in the soft layer occurs (Fig. 1(a)), and then magnetization reversal in the hard layer follows that of the soft layer (Fig. 1(b)). Finally, magnetization of the soft layer is affected by that of the hard layer and coincides with it after removal of H_a (Fig. 1 (c)). For weak $A_{\text{interlayer}}$ such as 1×10^{-7} erg/cm, magnetization of the soft and hard layers is independently reversed, while magnetization of both layers is simultaneously reversed for $A_{\text{interlayer}}$ stronger than 5×10^{-7} erg/cm.

[1] R. H. Victora et al., *IEEE Trans*. Magn., **41**, 2828 (2005).
[2] Y. Shiroishi et al., *IEEE Trans*. Magn., **45**, 3816 (2009).
[3] N. Sheeda et al., *IEEE Trans*. Magn., **45**, 3676 (2009).



(a) Elapsed time of 100 ps after application of H_a
(b) Elapsed time of 378 ps after application of H_a
(c) After removal of H_a

TU-51

Exchange coupled composite behavior in epitaxial $L1_0$/Co bilayers

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$L1_0$ FePt is a promising material for ultra-high density magnetic recording because of its high anisotropy and corrosion resistance. However its high coercive field exceeds the writing field of available heads which is limited by the head materials. In order to overcome the writing problem, Exchange Coupled Composite (ECC) media have been suggested. ECC media consist of two or more regions in which the hard magnetic region stores the information and the soft region(s) assists the magnetization reversal of the hard region. $L1_0$/Co bilayers were deposited on MgO (001) substrates by a six-target ultra-high vacuum sputtering system. A target of chemical composition $Fe_{50}Pt_{50}$ was used for the hard layer. To obtain isolated grains the thickness of the FePt was fixed to a value of 3.2 nm and the deposition was done on a heated at 700 ^{0}C MgO(001) substrate, according to Volmer-Weber proposed growth mode. After sputtering the substrate was cooled down to room temperature and, after thermal relaxation, the FePt grains covered with a cobalt film of variable thickness (nominal values from 3.2 to 50 nm). The structural properties were investigated by x-ray diffraction (XRD) and high resolution scanning electron microscopy (HRTEM). The bilayers showed strong superstructure (001) peaks and the FWHM ($\Delta\omega = 0.9^0$) of the rocking curve indicates that the films have good (001) orientation. The magnetic properties of L10/Co ECC media were investigated by SQUID and a vector VSM. A coercivity of 30.2 kOe is found for the single FePt granular layer, whereas the coercivity dramatically decreases on increasing the Co layer thickness (e.g, a 4 times reduction of coercivity is found at 9.6nm). The magnetization reversal mechanism of $L1_0$/Co ECC media is discussed by analyzing the angle dependence of remanent magnetization and recoil loops.

TU-52

Magnetic domain structure in thin CoPt perpendicular magnetic anisotropy films

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CoPt-based films with high perpendicular magnetic anisotropy are suited to the recording layer of hard disks. It is important to elucidate magnetic domain structure of the films because it directly relates to SN ratio. In this study, we investigated the influence of thickness on domain structure of $Co_{80}Pt_{20}$ films especially in thin film thickness region with experiment, and analyzed magnetization state with micromagnetic simulation. CoPt / Ru (20 nm) / Pt (100 nm) films were deposited on glass substrate using sputtering. Thickness was varied from 3 to 50 nm. Domain structure was observed using a magnetic force microscope (MFM). The films with thickness over 10 nm exhibited maze domain structure, while those thinner than 10 nm showed irregular domain [1]. Squareness ratio of perpendicular hysteresis loop of the films having irregular domain structure was 1. Fig. 1 shows averaged stripe half period (SHP) estimated from MFM images and simulation as a function of film thickness. SHP becomes smaller as film thickness becomes thinner in the films more than 13 nm, while for the films less than 13 nm SHP becomes larger as the thickness becomes thinner. As previously reported, anisotropy energy and magnetostatic energy increase with decrease of film thickness [2], [3]. From the simulation it was clarified that competition of these two factors decides SHP of films.

[1] Y. Yang, J. S. Chen, G. M. Chow, J. Appl. Phys., 109, 07B744 (2011).
[2] T. Shimatsu, H. Sato, Y. Okazaki, H. Aoi, H. Muraoka, Y. Nakamura, S. Okamoto, O. Kitakami, J. Appl. Phys., 99, 08G908 (2006).
[3] T. Wielinga, J. C. Lodder, J. Worst, IEEE Trans. Magn., 6, 1107 (1982).

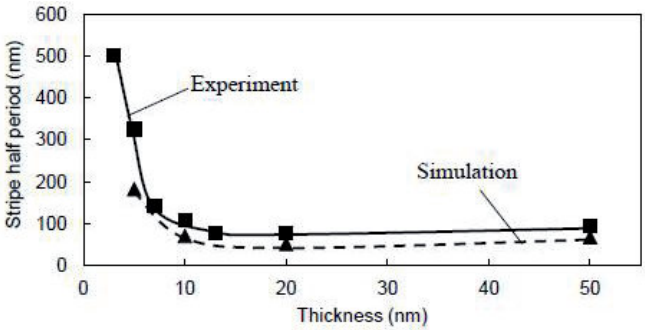

Fig. 1: Stripe half period as a function of film thickness.

TU-53

Effect of variation of trailing edge shield exchange stiffness on writer performance for perpendicular magnetic recording

S. Basu [1], M. Gubbins [1], E. Meloche [2], M.A. Bashir [1], R.W. Lamberton [1]

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Modern writers for perpendicular magnetic recording use wrapped around by shields at air bearing surface (ABS). The shields have multiple functionalities, e.g. the trailing edge shield (TES) improves the downtrack gradient of the field which enables sharp written transitions. The shield properties are critically important for the writer performance and the head reliability.

We have studied the effect of exchange stiffness constant, A, of the TES on the writer performance using micromagnetic modeling. Fig. 1(a) shows the current waveform used to drive the writer. Three different TES saturation magnetization (B_S) of 1.0, 1.5 and 2.0T were also used. The thickness of the shield (t_S) was varied from 20–200nm and A for Permalloy of 13pJ/m was used. To establish the effect of exchange, simulations with A=0 were also run. All the writer performance metrics were calculated at 17nm from the ABS. The maximum downtrack gradient of perpendicular field (H_{perp}) is calculated on the 1.0T Stoner-Wolfarth effective field contour. Results show that max-H_{perp} is higher for $t_S \leq 100$nm [fig. 1(b)] and for all B_S when A=0, but a changeover is observed when the t_S=200nm [fig. 1(c)] whereby the max-H_{perp} is higher for A=13pJ/m and for B_S=1.5 & 2.0T. Similarly, the downtrack gradient of H_{perp} also shows an opposite changeover, when for A=13pJ/m is higher for t_S=50nm

and all B_S [fig. 1(d)] to A=0 being higher for B_S=1.5 & 2.0T and t_S=200nm [fig. 1(e)]. This is attributed to change in TES dynamics with reduced exchange promoting easier flux flow through TES for higher t_S and higher B_S

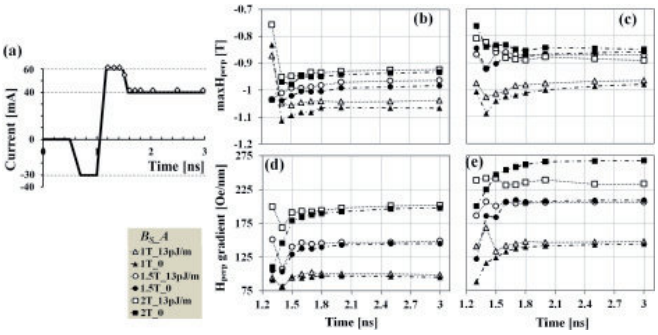

Figure 1: (a) Applied current profile with data recordings (symbols). maxH_{perp} [(b) & (c)] and downtrack H_{perp} gradient [(d) & (e)] as a function of time (lines are guide to eye) for t_S (b) 100 & (c) 200nm & (d) 50 & (e) 200nm

TU-54

Reversal asymmetry in exchange biased IrMn/NiFe bilayers probed with anisotropic magnetoresistance

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The interfacial exchange interaction between an antiferromagnetic (AF) and an adjacent ferromagnetic (FM) layer modifies the magnetic switching behavior of the latter by causing a shift (known as exchange bias[1]) and broadening of the hysteresis loop of the FM layer[1, 3] There has been large interest in exchange coupled AF/FM systems due to the wide variety of poorly understood phenomena associated with it[2]. In particular, training effect[2, 3] and the reversal asymmetry[2] have received renewed attention in recent years. In the present paper, it is demonstrated that the anisotropic magnetoresistance (AMR) is sensitive to the reversal asymmetry and can clearly distinguish between the two reversal processes, each occurring on either branch of the hysteresis loop. Bottom-pinned $Ir_{22}Mn_{78}/Ni_{20}Fe_{80}$ bilayers of structure Si/SiO_2/ Ta(5nm)/IrMn(15nm)/ NiFe(10nm)/Ta(5nm) were grown at room temperature by using a load-locked ion-beam sputtering system at a working pressure of 1.5×10^{-4} Torr. During growth, a static magnetic field of 200Oe was applied in-plane. The samples were annealed in presence of an applied in-plane magnetic field of 3kOe at 250ºC for 1 hr in a vacuum of 4×10^{-6} Torr, followed by field cooling to room temperature.
AMR measurements were performed at different temperatures (from 100K to 15K) employing field cooled (FC) procedures in magnetic annealed IrMn/NiFe bilayers. These bilayers exhibited *negative exchange bias* and a *large training effect* at 15K, accompanied with distinct *reversal asymmetry*. Based on the preliminary investigations, the observed reversal asymmetry, which is found to vanish on warming above about 50K, appears to have originated from temperature dependent crossover from uniaxial to biaxial anisotropy. Detailed results will be presented in the conference.

[1] J. Nogues et al., J. Magn. Mag. Mater. 192, 203 (1999)
[2] M. S. Lund et al., Phys. Rev. B 76, 104433 (2007)
[3] H. Fulara et al., J. Appl. Phys. 110, 093916 (2011)

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

Chair: M. Barandiaran

TU-55

Exchange coupling in AFM/SL/FM (SL = Cu, Alumina or Cr) thin films

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This work reports on modifications of the exchange bias (resulting from the exchange coupling between an antiferromagnetic (AFM) layer, IrMn, and a ferromagnetic (FM) one, Co, when different type of material is used as a spacer layer (SL) at the IrMn/Co interface, as a function of the spacer's thickness. Conventional X-ray diffractometry, small-angle X-ray reflectivity and transmission electron microscopy were used for the structural characterization of the films. Magnetization and ferromagnetic resonance measurements were employed for the magnetic characterization of the samples. The IrMn/SL/Co films were deposited at room temperature by magnetron sputtering onto Si(100) substrates using three different types of materials as spacers, namely Cu (a nonmagnetic metal, [1]), Alumina (a nonmagnetic insulator, [2]) and Cr (a weak AFM), and subsequently annealed in a presence of a strong magnetic field. Considerable increase of the exchange-bias field and decrease of the coercivity were observed after the annealing for the IrMn/Co samples and for those with very thin Alumina and Cu spacers. It was also obtained that, for both as-made and annealed samples, the bias decreases rapidly with the increase of the spacers' thickness, becoming practically zero for spacers thicker than 0.5 and 1.0 nm for the Alumina and Cu layers, respectively. Numerical simulations were used in order to reproduce the experimental data from which the FM and AFM anisotropy parameters were extracted. Their variations with the SL's type and with its thickness were compared and discussed.

[1] J. Geshev, S. Nicolodi, L. G. Pereira, L. C. C. M. Nagamine, J. E. Schmidt, C. Deranlot, F. Petroff, R. L. Rodríguez-Suárez, and A. Azevedo, Phys. Rev. B 75, 214402 (2007)
[2] S. Nicolodi, A. Harres, L. G. Pereira, J. E. Schmidt, M. A. Sousa, F.Pelegrini, A. D. C. Viegas, C. Deranlot, F. Petroff and J. Geshev, J. Appl. Phys. 110, 063922 (2011)

TU-56

Effect of antiferromagnetic/ferromagnetic coordination number in exchange bias systems

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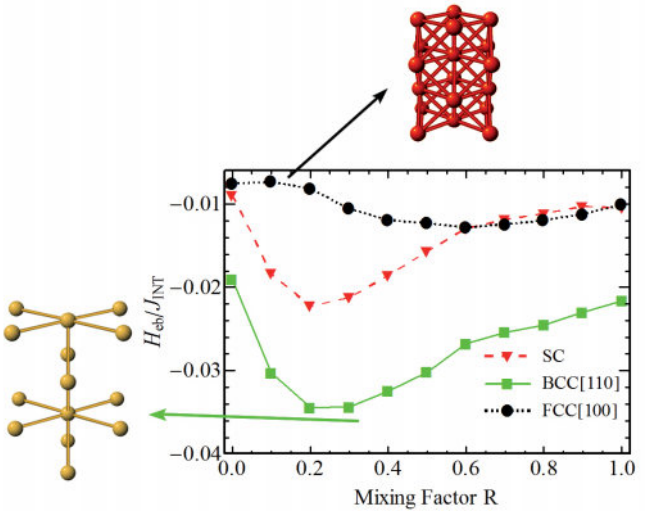
An important effect used in the hard disks read heads is the giant magnetoresistance applied in a spin-valve structure consisting of a multilayer thin film. The device produces a spin polarised

current using a reference layer consisting of a ferromagnet coupled to an antiferromagnetic pinning layer. This constitutes a so-called exchange bias system in which a horizontally shifted hysteresis loop is observed after a cooling process. We present an investigation of the mechanism behind the exchange bias phenomenology using the domain state model [1] through Monte-Carlo simulation techniques. In particular, the effect of ferromagnetic/antiferromagnetic coordination number in the system is investigated. The coordination number can be controlled by the using interface roughness [2], which on the atomistic scale is the mixing of the two materials in one layer and by using different crystallographic structures. We used, in addition to a simple cubic structure, the body-centered cubic along (110) orientation and face-centered cubic structure along (100) orientation, in all of which the antiferromagnetic interface is fully compensated. The results show a strong dependence on the interface roughness, as shown in the figure for body and face-centered cubic structures, especially for low values where lone ferromagnetic spins behave like antiferromagnetic spins. Although, the increase of coordination number using more dense crystallographic structure leads to stronger exchange bias field this is not always the case. This is due to atomistic compensation where ferromagnetic spins in face-centered cubic structures are neighboured by four antiferromagnetic spins at the interface, which are fully compensated resulting zero effective interaction at the interface.

[1] U. Nowak, K. D. Usadel, J. Keller, P. Miltényi, B. Beshoten and G. Güntherodt, Phys. Rev. B 66, 14430(2002)
[2] J. Spray and U. Nowak, J. Phys. D: Applied Physics 39, 4536 (2006)



Exchange bias field dependence on interface mixing for different crystallographic structures.

TU-57

Remanence plots technique applied to exchange-bias systems

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Exhaustive work has been done on the exchange bias (EB), both theoretically and experimentally, over the last decades. Attempts have been made to estimate interactions in EB-systems using the isothermal remanence magnetization (IRM) and dc demagnetization (DCD) curves. One of the problems of applying this approach to EB concerns the origin of the reference frame when attaining the remanence curves. Note that this method has been originally developed to characterize magnetic interactions in monophase uniaxial or cubic anisotropy systems [1-3] with symmetric major hysteresis loops, where the saturation remnant magnetizations of both loop branches have equal values and opposite signs. If a loop is entirely shifted from the origin, however, there exists only one zero-field remnant magnetization and the method becomes unfeasible.
A practical solution for this problem is changing the reference frame in a manner that its origin coincides with the center of the shifted loop. Now, the new remnant magnetizations have equal values and opposite signs, making the use of the remanence plots viable. In many cases, however, the biased loops are intrinsically asymmetric so two pairs of IRM and DCD curves coexist thus increasing the number of distinct delta-M and Henkel plots. The routine proposed here was applied to polycrystalline IrMn/Co bilayers where the bias is initialized either by annealing or by light-ion irradiation, both performed in strong magnetic fields. Results obtained on initially ac or dc demagnetized samples are presented and compared. Possible sources for the experimentally obtained deviations of the remanence plots from the respective theoretical ones are pointed out and discussed.

[1] E. P. Wohlfarth, J. Appl. Phys. 29, (1958) 595; O. Henkel, Phys. Stat Sol. 7, 919 (1964)
[2] P. E. Kelly et al., IEEE Trans. Magn. 25, 3881 (1989)
[3] J. Geshev and M. Mikhov, J. Magn. Magn. Mat. 104-107, 1569 (1992)

TU-58

Magnetic, structural and morphological study of Fe/NiO and NiO/Fe exchange coupled structure interfaced with Si

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Much research into thin film magnetism over the past few decades has been driven by important and useful features associated with interfaces involving magnetic materials. In this context, ferromagnetic (F)/antiferromagnetic (AF) bilayer or vice versa is an exchange coupled system to result in the exchange bias effect, which was discovered more than fifty years ago [1]. The interface of such exchange coupled F/AF bilayer with silicon has been investigated in this study for its possible applications in 'Spintronics'.
Bilayer structures of F/AF (i.e., Fe/NiO) and AF/F (i.e., NiO/Fe) have been interfaced with etched and cleaned n-Si wafer by electron beam evaporation technique. Morphological and structural studies have been characterized from AFM and XRD facilities. Domain structure analysis has been performed from MFM facility. Magnetization measurements have been carried out by VSM to determine the magnetization characteristics.
It has been found from XRD study that there is a strong interfacial intermixing to form the various phases of oxides and silicides. AFM micrographs show the granular morphology of the structure with a large grain size of ~ 400 nm. MFM features show a large domain size corresponding to AFM grain size for Fe/NiO/nSi structure and very small domain of nanometer size for NiO/Fe/nSi structure. M-H characteristics show that the magnetic behavior is only significant for Fe/NiO/nSi structure with a significant coercivity and exchange bias as compared to

NiO/Fe/nSi interfacial structure. Thus, it has been found that Fe/NiO/nSi structure can be used in magneto-electronic device applications. It seems that the observed result of significant exchange bias and coercivity is due to the microstructural and chemical structure changes in the antiferromagnetic layer along with the roughness data as obtained from AFM features.

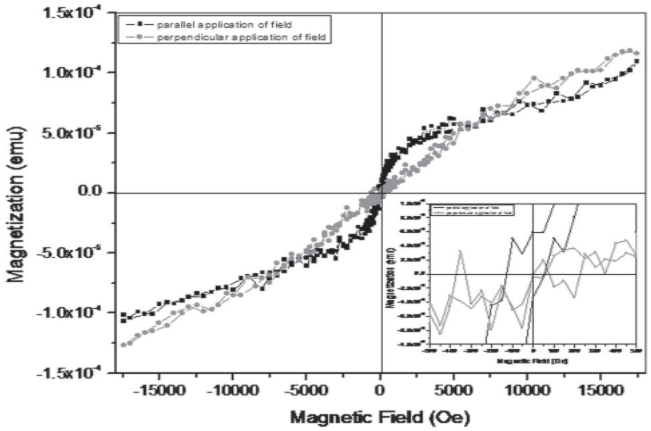

Fig.: Magnetization (i.e., M-H) characteristics of Fe/NiO/nSi interfacial structure

[1] W.H. Meiklejohn and C.P. Bean, Phys. Rev. 102, 1413 (1956).

TU-59

Enhancement of the exchange bias using ultrathin Fe interlayer in IrMn/Co films

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Although discovered in 1956, the magnetic exchange bias (EB), owing to exchange interaction between a ferromagnet (FM) and an antiferromagnet (AF), still attracts substantial attention. Various aspects of the effect that still remain unclear, e.g., the nature of the AF/FM interface coupling. It has been shown that in AF/SL/FM systems (here SL stands for a spacer layer) even a very thin non-magnetic SL can annihilate the EB [1]. Using of a FM as a SL in top-pinned EB bilayers, however, could either increase or suppress the bias [2].

Here we report a systematic study on the EB modifications in bottom-pinned IrMn/SL/ Co trilayers when iron SLs with thicknesses between 0.25 and 1.5 nm are used. The EB effect was initialized through 40 keV He ion irradiation using different fluences in a presence of magnetic field of 5.5 kOe. The magnetic characterization was performed via alternating gradient-field magnetometry at room temperature. We chose to explore this type of EB system since it provides the constancy of the structure of the first-deposited IrMn layer in each sample. Hence, the observed variations of the properties of the series are certainly incited by the insertion of the Fe layer.

A significant initial increase of the EB field with the SL thickness was observed for all fluencies up to 0.75 nm, followed by a gradual decrease. It is worth noting that we obtained an EB almost twice higher than that of the IrMn/Co bilayer. Mechanisms that might be responsible for the variations of the magnetic properties of IrMn/SL/Co trilayer with the iron thickness are pointed out and discussed.

[1] J. Geshev et al, Phys. Rev. B 75, 214402 (2007); S. Nicolodi et al, J. of Appl. Phys. 110, 063922 (2011)

[2] M. Ali, C. H. Marrows, B. J. Hickey, Phys. Rev. B 77, 134401 (2008)

TU-60

Angular dependence of coercieve and exchange bias fields in Co(NiFe)/IrMn bilayer structures

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Magnetic properties of ferromagnetic/antiferromagnetic (FM/AF) thin-film structures for spin-valve applications have been studied in details. Multilayer structures Ta/Co/IrMn/Ta and Ta/FeNi/IrMn/Ta were deposited on Si wafer at room temperature by DC magnetron sputtering. Thickness of the antiferromagnetic layers changed from 20 nm to 60 nm. The working pressure of argon in the chamber was kept at $3*10^{-3}$ Torr. Uniform forming magnetic field of 420 Oe was applied parallel to the sample's plane during the deposition. Beside the biased structures, Ta/Co/Ta and Ta/FeNi/Ta films were made in order to check the properties of ferromagnetic layers free of the influence of IrMn layer.

Magnetic properties were investigated with help of Vibrating Sample Magnetometer (VSM) by Lake Shore (System 7404). Magnetization loops were measured for eight different orientations of the samples. Magnetic field was always applied in plane, the angle between the field and the axis of unidirectional anisotropy of the ferromagnetic layer changed from 0^o to 360^o with step of 45^o. Using these data we have estimated the coercive force (H_c) and the exchange bias field (H_{eb}). Angular plots and dependences on the thickness of the antiferromagnetic layer (d_{AF}) were built for H_c and H_{eb}.

Both the coercive force and the exchange bias field were found to be non-monotonic functions of d_{AF}. The values of H_{eb} for any direction at d_{AF}=40 nm were lower than every value of H_{eb} at any other thickness of the antiferromagnetic layer. Classical angular dependence of the magnetization loops was observed only for the sample with d_{AF} = 60 nm. We suppose that in the other samples direction of the easy magnetization of ferromagnetic layer is not parallel to the direction of the easy magnetization of the antiferromagnetic layer.

TU-61

Effect of Ultrathin Ru Seed Layer Growth on the Exchange Anisotropy of Sputtered IrMn/CoFe

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The exchange bias is an essential physical phenomenon for the fabrication of high density hard disk drives and spin-valve based devices. Performance requirements make IrMn the material of choice as antiferromagnet. The exchange biasing of the ferromagnetic pinned layer by the antiferromagnetic layer is dependent on microstructural features such as grain size, roughness, and crystal texture. All these characteristics are in

close relation to the growth of the buffer/seed underlayers used. Ru is a suitable underlayer for IrMn as it grows with closed packed hcp (002) planes parallel to the substrate, and due to its high melting point, which prevents the diffusion of Mn atoms. The large unidirectional anisotropy values reported on IrMn-based exchange biased systems have been associated to the formation of ordered $L1_2$ IrMn [1] and (111)-fcc texture after annealing [2]. In this work we report on the use of ultrathin, 1.5 nm thick, Ru seed layers for the preparation of exchange-biased IrMn/CoFe bilayers. Ru growth rate was varied in order to modify grain size and roughness of the underlayer. The samples were grown by magnetron sputtering, and characterized by grazing incidence x-ray diffraction, vibrating sample magnetometry, and electron microscopy. An enhancement of exchange field with Ru growth rate has been observed. We have used a granular model [3] to explain the effects of microstructure on the exchange anisotropy. This work was supported by CAPES (PNPD), CNPq and FAPEMIG.

[1] M. Tsunoda, K. Imakita, M. Naka, and M. Takahashi, J. Magn.Magn. Mater., 304, 55 (2006).
[2] G. Anderson, Y. Huai, and L. Milowslawsky, J. Appl. Phys., 87, 6989 (2000).
[3] K. O'Grady, L. E. Fernandez-Outon, G. Vallejo-Fernandez, J. Magn. Magn. Mater. 322, 883 (2010).

TU-62

Magnetic interactions in exchange-coupled unbiased IrMn/NiCu films

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Systems composed of a ferromagnet (FM) exchange-coupled to an antiferromagnet (AF) have shown a great potential for technological applications. These normally evidence exchange bias (EB), i.e., a shift of the magnetization curve along the magnetic field axis, often accompanied by a coercivity enhancement. Recently, we showed that unconventional AF/FM (NiO/NiCu) bilayers exhibit EB [1] despite that their Curie temperature is lower than the AF's Neel temperature. We also explored NiCu coupled to a stronger AF, i.e., IrMn (unpublished) and showed that although the respective hysteresis loops are unbiased their coercivity could be tailored via ion irradiation or magnetic annealing. We found that the coercivity enhancement in this system results from the presence of the AF in accordance with theoretical predictions that the AF breaks the FM layer into domains and the FM domain size is smaller than that of a FM layer alone [2]. To verify the nature of the interactions in this exchange-coupled though unbiased system, we employed isothermal remanence magnetization (IRM) and dc demagnetization (DCD) curves. We compared data acquired on the as-made film with those of a film irradiated with Ge ions, both showing isotropic in-plane magnetic behavior. The remanence plots obtained from the DCD and IRM curves showed several distinct and interesting characteristics. E.g., the Henkel plots of the as-made and irradiated samples obtained after dc demagnetization appear to be practically identical despite the great difference in coercivity, indicating that the irradiation-induced coercivity enhancement should not be associated with interactions. However, the plots obtained after ac demagnetization, though rather different, indicate strong (magnetizing) exchange interactions. Systematic research is needed to clarify the role and type of interactions present in this unconventional system.

[1] K. D. Sossmeier et al, J. Appl. Phys. 109, 083938 (2011)
[2] Z. Li and S. Zhang, Phys. Rev. B 61, R14897 (2000)

TU-63

Ion irradiation effects on IrMn-based exchange biased systems

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Ion irradiation has been shown as a useful tool to tailor magnetic properties of materials, allowing manipulations in a very controlled way [1,2]. Nanopatterning of magnetic properties can be obtained by using masks as well as focused ion beam, that can imprint structural or even compositional modifications in a very small scale. Contrary to traditional magnetic annealing where alloy formation could occur in some systems at high temperatures, ion irradiation at low/medium energies can induce modifications avoiding macroscopic heating. The exchange bias (EB) effect, extensively studied due to its applications in magnetic media devices, can also be tuned by means of ion irradiation/implantation. In the literature one finds induction, increase, or suppression of the EB through ion implantation or irradiation. The mechanisms concerning the exchange coupling effects are not quite clear as well as the mechanisms of the EB-induced modifications via ion irradiation. Hyperthermal heating and defect creation induced by the ion bombardment are supposed to be related to the magnetic modifications. In this work we studied the influence of the ion irradiation on IrMn/Co and IrMn/Py EB systems and investigated how it correlates with the effects induced by the ion bombardment. It has been recently shown that defect creation is associated with magnetic modifications [3]. A phenomenological model that considers magnetic granular structure of both FM and AF materials is used to explain the results.

[1] J. Fassbender, D. Ravelosona and Y. Samson. J. Phys. D: Appl. Phys. 37 R17 (2004)
[2] J. Fassbender and J. McCord. J. Magn. Magn. Mater. 320, 579 (2008)
[3] D. Schafer, P. L. Grande, L.G. Pereira and J. Geshev. Journ. Appl. Phys. 109, 23905 (2011)

TU-64

Permeability dependence of exchange biased FeNi/FeMn multilayers on layer thickness and number

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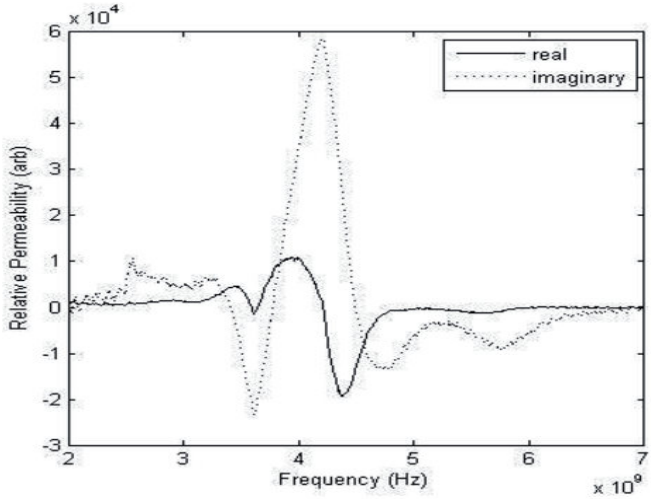
The ability to shield from magnetic fields is necessary for the successful operation of many devices. As technology becomes more complex, shielding is required across greater frequency ranges and for multiple frequencies simultaneously. Control of magnetic permeability across high frequencies can be achieved with exchange biased materials by varying the number of multilayers and their thicknesses [1]. FeNi/FeMn thin films were deposited via sputtering onto Si wafers. An analysis of VNA S parameters was used to extract the complex permeability of the multilayers [2]. The results were compared to the hysteresis loops to determine the optimum magnetic properties for low permeability in the ranges 2-7GHz.

[1] N. N. Phuoc, F. Xu, C. K. Ong, Appl. Phys. Lett. 94, 092505 (2009).
[2] Y. Ding, T. J. Klemmer, T. M. Crawford, J. Appl. Phys. 96, 2969 (2004).



Relative permeability of Ta(5nm)/[$Ni_{80}Fe_{20}$(20nm)/$Fe_{50}Mn_{50}$ (15nm)]x5/Ta(5nm) calculated from VNA S parameters.

TU-65

Exchange bias in NiFe-based F/AF-bilayer structures with alternative order of layer deposition

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The magnetic properties of NiFe-based bilayer structures were investigated with alternative sequence of the deposition, either with antiferromagnetic (AF) on the top (TS-structure) or below (BS-structures) the ferromagnetic (F) layer. The samples of (100) Si/Ta(30nm)/NiFe(7nm)/IrMn(15nm)/Ta(30nm) and of (100)Si/ Ta(30nm)/IrMn(15nm)/NiFe(7nm)/Ta(30nm) were deposited by DC magnetron sputtering in argon at the pressure of $3*10^{-3}$ Torr. To compare the magnetic properties of bilayer samples with intrinsic properties of ferromagnetic single layer which is not pinned by exchange interaction with antiferromagnetic layer, the Ta(30nm)/ NiFe(7nm)/Ta(30nm) structure was also deposited. The magnetic properties of these structures were obtained from the ferromagnetic resonance (FMR) and vibrating sample magnetometry (VSM) measurements. The structure properties of the samples were examined by atomic force microscopy. At room temperature the TS-structure demonstrated exchange bias of 85 Oe. The coercivity of this structure in the easy axis direction was 9 Oe that is lower than coercivity of free F-layer (17,5 Oe). The TS-sample coercivity with the magnetic field applied in direction perpendicular to easy axis was significantly lower than that of free layer: 3 Oe in case of TS-structure and 29 Oe in case of free layer. The BS-structure showed the exchange bias up to 121 Oe, much higher than that in TS-structure. In line with exchange bias, a larger coercivity was observed in the BS samples, equal to 136 Oe along the easy axis and 72 Oe in perpendicular direction that is much higher than coercivity of TS-structure and the free layer. The differences in the magnetic properties of TS- and BS-structures were presumably caused by different structures at the F/AF interface.

TU-66

Influence of temperature, annealing, and nonmagnetic spacer on interlayer coupling in $Fe_{20}Ni_{80}$/Tb-Co films

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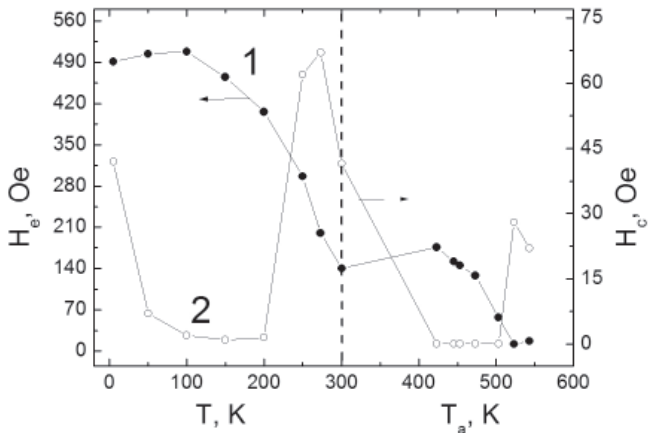
Thin magnetic films based on exchange coupled ferromagnetic and antiferromagnetic layers have attracted great interest in the last few decades due to the exchange bias effect and its application in spintronics technology [1]. Although it is clear that the antiferromagnetic or ferrimagnetic layer induces the exchange bias, the magnetic coupling mechanism remains obscure because of the complexity of the magnetic frustration at the interface. For application of such media it is important to study the interlayer coupling, aiming to understand how the interfacial frustration generates the ferromagnetic layer properties like the pinning field and coercivity.

In this work magnetic properties of the exchange coupled $Fe_{20}Ni_{80}/Tb_{35}Co_{65}$ bilayers have been investigated. Samples were prepared by magnetron sputtering technique; magnetic anisotropy was formed by applying the external magnetic field 150 Oe. Thicknesses of the Tb-Co and FeNi layers were 110 nm and 50 nm respectively. Magnetic measurements were performed by using vibrating sample and SQUID magnetometer in temperature range from 5 to 300 K.

For initial characterisation dependencies of spontaneous magnetization, coercivity, and magnetic anisotropy of Tb-Co monolayer on temperature and annealing temperature were measured. For FeNi/Tb-Co bilayers temperature and annealing temperature dependencies of coercivity H_c and exchange bias field H_e of the permalloy layer were performed (see graphic). The same measurements were done for FeNi/Ti(1nm)/Tb-Co films. The introduction of the nonmagnetic spacer changed dramatically the temperature behaviour of FeNi layer magnetic properties by leading to almost monotonic decrease of H_e and H_c. In conclusion we gave an interpretation of the dependencies observed in terms of variations in FeNi/Tb-Co magnetic interface.

[1] K. O'Grady, L.E. Fernandez-Outon, G. Vallejo-Fernandez, J.Magn.Magn.Mater. 322, 883 (2010)



Dependencies of the exchange bias field (curve 1) and coercivity (curve 2) on temperature (left side) and annealing temperature (right side) of the FeNi layer in $Fe_{20}Ni_{80}/Tb_{35}Co_{65}$ film

TU-67

Exchange bias in Heusler alloy films

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Half-metallic Heusler alloy (HA) electrodes are important for spintronic devices [1, 2]. It would be desirable if one HA electrode were pinned by an antiferromagnet (AFM) to form a reference layer in a magnetic tunnel junction (MTJ). EB in HA is hardly recognized and confines to a few reports on HA/AFM bilayers in MTJ using Co2MnSi/IrMn [1], Co2FeAl/IrMn [2] or to specially fabricated Co2FeSi/IrMn [3] bilayers.

Here, we report on EB in various types of HA/AFM structures comprising Ni2MnSn, Co2MnSn, and Co2FeSi as HA and NiMn, FeMn, IrMn as AFM layers. All films were prepared by magnetron sputtering at room temperature (RT) on Si substrates with a Ta buffer layer and field-annealed at 673 K to transform HA into an ordered state and to set AFM layers. Most of the structures comprise HA(5-20)/AFM(10-20) bilayers, {AFM(10-20)/HA(5-20)/AFM(10-20)}*3 or {AFM(10-20)/Co(0.5-1)/HA(5-10)/Co(0.5-1)/AFM(10-20)}*3 multilayers. The numbers denote thickness in nm. A relatively strong EB (at RT) with the exchange-bias field H_{eb}=30-250 Oe was found in Co2FeSi/IrMn bilayers and multilayers in accordance with Ref. [3]. For Ni2MnSn/NiMn and Co2MnSn/FeMn structures EB is absent at RT. Ultrathin Co layer added at HA/AFM interfaces either results in establishing a small H_{eb}=10 Oe for Co2MnSn/Co(1)/FeMn or increases it up to 400 Oe for Co2FeSi/Co(0.5)/IrMn multilayers. Field cooling to 10 K results in establishing a relatively high EB at T< 70 K in all HA/AFM structures. Our results show that EB in HA has intrinsic origin at low T and interface origin related to the strength of exchange constant in HA.

[1] Y. Sakuraba et al. J. Phys D: Appl. Phys. **40**. 1221 (2007).
[2] W. Wang et al. Phys. Rev. B **82**, 092402 (2010).
[3] N. P. Alley et al. IEEE Trans. Magn. **47**, 3490 (2011).

TU-68

Enhancement of exchange bias, FMR frequency and thermal stability in ferromagnet/antiferromagnet multilayers by oblique deposition

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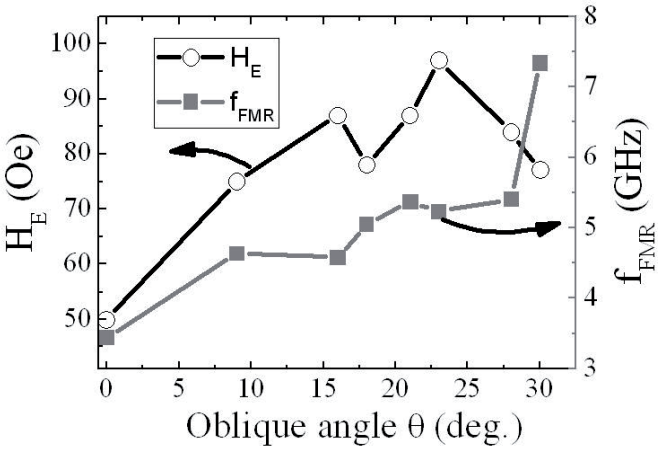
Although oblique deposition technique has been widely known as an effective deposition technique to tailor the in-plane uniaxial magnetic anisotropy [1], there has been little work in the literature focusing on the influence of oblique depostion on exchange bias effect in ferromagnet(FM)/antiferromagnet(AF) system. From application point of view in microwave devices, both oblique deposition technique and FM/AF exchange bias system are useful for pushing ferromagnetic resonance frequency to higher range [1, 2]. The application of oblique deposition technique into exchange bias system may be expected to drive the resonance frequency to even much higher range. Hence in the present work, we carry out a sytematic study of the effect of oblique deposition angle on the magnetic properties and microwave characteristics of exchange bias FeCo/MnIr multilayers. Our results demonstrated that exchange bias is significantly increased with the increasing of oblique deposition angle and this behavior may tentatively be ascribed to more defects of the AF creating during oblique deposition. The ferromagnetic resonance was also found to be greatly enhanced with oblique deposition angle due to the rise of the uniaxial anisotropy and exchange bias as well. The static and dynamic magnetic results will be discussed in conjunction with the structure of the films and with the analysis based on LLG equation. Thermal stability study of the films from 25°C to 150°C shows that high frequency characteristics of these films are not changed much indicating that exchange bias films fabricated by oblique deposition technique is quite promising for microwave applications in gigahertz range.

[1] N.N. Phuoc, F. Xu, and C.K. Ong, J. Appl. Phys. 105, 113926 (2009).
[2] N.N. Phuoc and C.K. Ong, Physica B 406, 3514 (2011).



Dependences of exchange bias field (H_E) and resonance frequency (f_{FMR}) on oblique deposition angle for [FeCo (50 nm)/MnIr(12 nm)]$_{10}$ multilayers

TU-69

Magnetooptical studies of NiFe/Cu/Co spin valve multilayers with induced magnetic anisotropy

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In this work we present a study of magnetooptical (MO) properties of NiFe/Cu/Co spin valves with magnetic anisotropy induced by magnetic field (70 mT) applied along a certain direction during the deposition. Investigated samples (schematically shown in Figure 1) were prepared by ion beam sputtering using Co, Cu and $Ni_{80}Fe_{20}$ targets at the Ar^+ pressure of 1.2E-4 mbar (the CoO layer acts as a buffer layer providing a better growth of Co overlayer). The copper spacer thickness was 3 and 5 nm.

Induced anisotropy may influence exchange interactions

between magnetic layers. Systematic study of these interactions is important for understanding of fundamental micromagnetic effects and practical applications in magnetoresistive read heads and spin-transfer-torque devices. Since these effects manifest themselves as small changes in magnetic properties, MO spectroscopy in polar and longitudinal configurations and vector magnetometry were used as effective probe techniques.
Polar MO Kerr effect spectrum at saturation for the sample with t_{Cu} = 3 nm is shown in Figure 1. The spectrum displays features typical for magnetic nanostructures containing NiFe layers [1]. Theoretical spectral dependence of polar Kerr Effect calculated by transfer matrix method is also displayed in figure 1. One can see that the theoretical model describes experimental values reasonably which indicates good quality of interfaces.
Partially supported by Czech Science Foundation (P204/10/P346 and P205/11/2137).

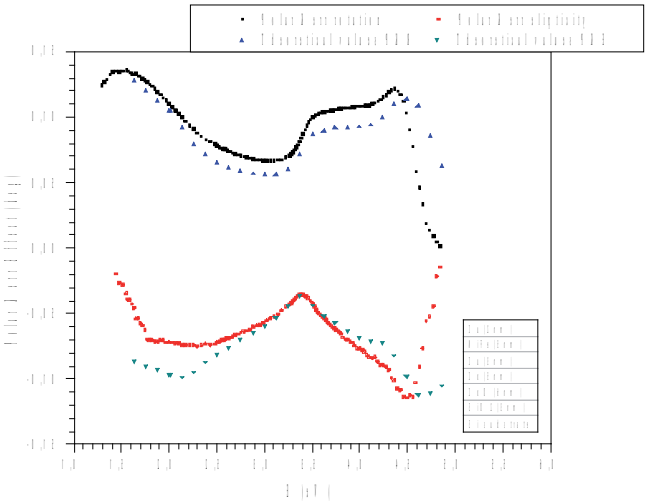

Fig. 1: Experimental and theoretical spectra of polar Kerr effect.

[1] R. Antos, et. al, J. Magn. Soc. Jpn. 30, 630 (2006).

TU-70

Controllable nucleation and propagation of topological magnetic solitons in CoFeB/Ru ferrimagnetic superlattices

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The use of domain walls in three-dimensional nanowires has been proposed as a route for magnetic storage [1]. However, the complexity of fabricating this type of nanostructure makes this technology difficult to implement. Synthetic lattices formed by ferromagnetic layers coupled anti-ferromagnetically (AF) can form topological magnetic solitons when the magnetization reversal is via a surface spin-flop mechanism [2]. These solitons are analogous to domain walls in nanowires, separating two anti-phase domains, which extend along the third (perpendicular to the thin film plane) dimension. Here we investigate the nucleation and propagation of magnetic solitons in $(CoFeB/Ru)_N$ synthetic lattices, with $2 \leq N \leq 6$. These systems are extended ferrimagnets (FiMs), since the properties of one of the edge layers are varied with respect to the other films. Figure 1 shows the Kerr signal of a FiM with N = 6. For the values of anisotropy and coupling chosen, the nucleation of localized solitons can be controlled. These lattice frustrations are stable for a wide range of fields, and can be uni-directionally propagated along the system by means of the AF coupling field between layers. The switching behaviour of synthetic FiMs is complex, and highly dependent on the ratio between the properties of the distinct edge layer and the bulk. A complex phase diagram will be presented showing different regions, including nucleation, propagation and denucleation of localized solitons.

[1] S.S.P. Parkin, M. Hayashi, and L. Thomas, *Science* **320**, 190 (2008)
[2] S. G. E. e Velthuis, J. S. Jiang, S. D. Bader, and G. P. Felcher, *Phys. Rev. Lett.* **89**, 127203 (2002)

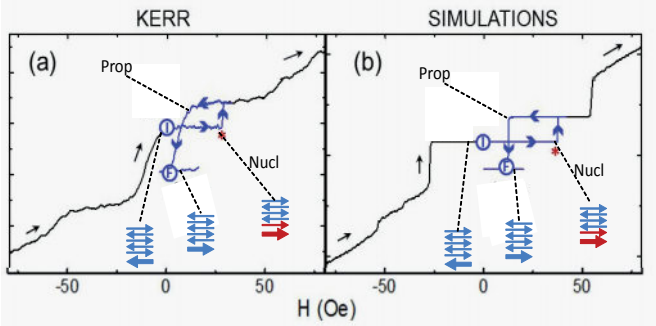

Figure 1. Nucleation and propagation of magnetic solitons in a FiM lattice with 6 layers. (a) Experimental Kerr signal. (b) Macrospin simulations.

TU-71

Exchange-bias and magnetic anisotropy in Mn/Co/Cu(001)

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We investigated the exchange coupling and exchange bias (EB) phenomena in the highly ideal antiferromagnetic (AF)/ferromagnetic (FM) Mn/Co/Cu(001) system. Mn/Co multilayers grow epitaxially on Cu(001) single crystal with an fct structure with both Mn and Co magnetically ordered at room temperature [1].
The simple structure morphology and magnetism of this bilayer allows to exploit its macroscopic magnetic properties for arguing interesting microscopic features of the AF Mn magnetic configuration, correlating them with EB. We therefore addressed the macroscopic magnetic properties of the system versus the thickness of the AF Mn film and the nanoscale morphology of the Mn/Co interface. The coercive field and magnetic anisotropy energy (MAE) of Mn/Co/Cu were measured in-situ, in ultra-high vacuum conditions, as a function of the thickness of the Mn AF layer in real-time during the growth, from the early stages of the Mn deposition up to 20 monolayers thickness.
In the Mn-thickness evolution of the coercive field and of the MAE we have identified distinctive features correlated to different evolution stages of the AF magnetic structure, like the completion of the first AF monolayer, the onset of the antiferromagnetic ordering at 2 monolayer thickness [2] and the possible formation of AF domain walls, prerequisite for the onset of EB [3]. These features further allow insights in the elusive domain wall dynamics within the AF.

The nanoscale tuning of the FM morphology prior to the AF growth allowed to manipulate the system's anisotropy and assess the role of Mn in the MAE's evolution and the influence of a nanoscale patterned AF/FM interface on EB.

[1] J.T. Kohlhepp and W.J.M. de Jonge, Phys. Rev. Lett. 96, 237201 (2006)
[2] W.L. O'Brien and B.P. Tonner, Phys. Rev. B 51, 617 (1995)
[3] A.P. Malozemoff, Phys. Rev. B 35, 3679 (1987)

TU-72

Critical thickness for exchange-bias in Mn/Co/Cu(001) bilayers

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The exchange interaction at the interface between a ferromagnetic (FM) and an antiferromagnetic (AF) layer may leads to the onset of the well-known exchange-bias effect (EB), manifested as the displacement of the hysteresis loop along the magnetic field axis with respect to FM-layer-only loop. A number of experimental observations noticed that, in order for EB to appear, the thickness of the AF layer must exceed a critical value.
We investigated the critical AF thickness effect in the highly ideal, fully epitaxial antiferromagnetic (AF)/ferromagnetic (FM) Mn/Co/Cu(001) system. The Mn/Co multilayer grows epitaxially on Cu(001) single crystal with an fct structure and in this phase both Mn and Co are magnetically ordered at room temperature [1]. The Mn/Co/Cu(001) bilayers also exhibit large H_e, a convenient critical temperature T_N and do not involves any alloyed substances, but rather elemental AF and FM [1].
In this work we address the issue of the critical thickness t_{AF} for the EB onset starting from the exchange-biased Mn/Co/Cu(001) system and gradually reducing the effective thickness of the AF Mn layer, by means of superficial oxidation under ultra-high vacuum conditions.
The oxide layer thickness and the oxidation state were carefully evaluated by means of high-resolution XPS measurements and X-ray absorption spectra. We concluded that the oxidation involves only the topmost AF atomic layers excluding any oxygen diffusion at the Mn/Co interface. We observed that for AF/FM bilayers having t_{AF} slightly above the critical thickness the EB disappeared for oxygen exposures as low as 20 Langmuirs (1 L=$1\cdot10^{-6}$ torr · 1s), while systems with t_{AF} largely exceeding the critical value were unaffected. The implications for the AF critical thickness effect are discussed.

[1] J.T. Kohlhepp and W.J.M. de Jonge, Phys. Rev. Lett. 96, 237201 (2006)

TU-73

Granular interface model for polycrystalline exchange-bias systems

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Considered as an important part of the modern magnetism, the exchange bias (EB) phenomenon has been first observed in 1956. Although extensive research on the subject has been performed since then, it continues to offer challenging questions since there is no generally-accepted theory that predicts the magnetic behaviour of real systems. The EB arises from the exchange coupling between a ferromagnet (FM) and uncompensated spins (UCS) at the interfacial region with an adjacent antiferromagnet (AF). Its most-known manifestations are the magnetization curve's displacement along the magnetic field axis and a coercivity enhancement. In the present work a realistic model for polycrystalline AF/FM bilayers with granular interfaces is proposed where the FM grains' magnetizations are assumed to be exchange-coupled to both stable and partially-stable UCS arising from the interfacial region. When properly aligned, the stable UCS contribute for the bias while the others are associated with rotatable anisotropy responsible for the coercivity enhancement. The contribution of the rotatable grains, usually assumed as an additional uniaxial anisotropy, is approached differently in our model where both anisotropy and coupling parameters of the UCS are taken into account. A variation of this approach has been recently employed to depict athermal training effects in EB systems [1]. The model was used here to reproduce static magnetization curves obtained on a magnetron-sputtered Co/IrMn bilayer which, after deposition, has been irradiated with 40 keV He ions in a presence of a strong magnetic field. Excellent agreement between experiment and simulations was obtained for all in-plane orientations of the measuring magnetic field. It is worth emphasizing that the nonzero coercivity of the hard-axis loops, commonly observed in real systems and not reproduced by most of the models, is naturally attained in the framework of ours.

[1] A. Harres and J. Geshev, J. Phys.: Condens. Matter 23, 216003 (2011)

TU-74

Nucleation and propagation of horizontal domain walls in ferro/rare-earth ferrimagnet heterostructues

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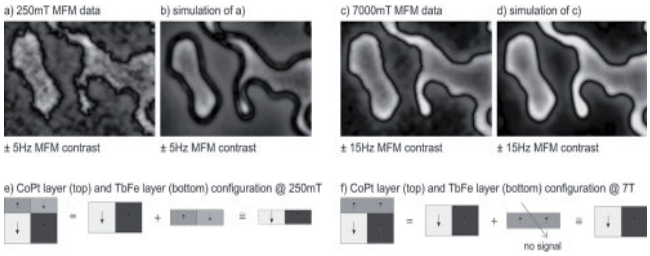
Coupling the magnetization of different types of magnetic thin film materials is crucially important for the function of modern magnetic thin film-based devices.
Here we study the magnetization process of a magnetic bi-layer systems consisting of a low-coercivity ferromagnetic and a highly coercive rare-earth ferrimagnetic thin film. We fabricated a 40 nm-thick $Tb_{23}Fe_{77}$ layer (sample 1) to characterize magnetically the ferrimagnet, and a $TbFe_{40nm}\backslash[Co_{0.4nm}Pt_{0.7nm}]_{\times5}$ bilayer (sample 2) to investigate the ferro/ferrimagnet coupling. The coercive field of sample 1 was strongly temperature dependent. Below 40K it was beyond 7T, showed a minimum of 3T at about 240K and a divergence at T_{comp} of 325K. Magnetization curves of sample 2 display a gradual completion of the switching process and little hysteresis, reminiscent of magnetization rotation. For a detailed understanding of the magnetization reversal process magnetic force microscopy was performed.
For sample 1, the MFM contrast remained constant and no domain wall motion was observed in fields up to 7T. MFM data acquired on sample 2 again showed no domain wall motion, but a strong variation of the contrast. In fields below 0.8T the

contrast was only about 1/3 of that of sample 1, increasing gradually for fields between 0.8-3T to reach the contrast of sample 1 above 3T. Moreover, in intermediate fields (0.8-4T) sub-domains on a length-scale of the grain-size of the CoPt film appeared. The comparison of the MFM data to simulations revealed that a high-energy horizontal domain wall is formed above 0.8T that propagates towards the interface and finally becomes compressed with an extension less than 1nm at the ferro/ferrimagnet interface.



Comparison of the contrast levels of sample 1 and 2 and 1.5µm x 1µm MFM images recorded at various fields.

TU-75

Tunable hysteresis loop shift in orthogonally coupled [Pt/Co]-NiFe ferromagnetic layers

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Exchange bias (EB) is frequently used in magnetic random access memories and magnetoresitive read heads to pin the magnetization of a reference layer. Setting EB is usually achieved by cooling a ferromagnetic (FM)-antiferromagnetic bilayer under an applied field through the blocking temperature. The possibility of inducing EB-like effects has been recently demonstrated in systems consisting of two coupled FM materials: [Pt/Co] multilayer (with out-of-plane anisotropy)-NiFe (with in-plane anisotropy) [1,2]. A shift along the field axis in the in-plane hysteresis loop of the NiFe is obtained without necessity of a field cooling procedure. Recent experimental results in combination with micromagnetic simulations have shed light on the magnetic configuration responsible for the loop shift [3]. It is the result of the exchange coupling between the magnetization of the NiFe and the magnetization of vortices cores, which form in the domain walls separating the upwards and downwards magnetized domains in the [Pt/Co].
We will show that effective tuning of the loop shift may be achieved by acting on the strength of the out-of-plane (OOP) anisotropy of the [Pt/Co] multilayer, i.e., on the pinning strength of the vortices cores. Two successful approaches have been followed for this purpose: (a) variation of the first Pt thickness which acts as buffer for the structure; and (b) heat treatment of the bilayer. An improved texture and mosaicity of the [Pt/Co] multilayer thus resulted in an enhanced effective OOP anisotropy. As a consequence a twofold increase of the EB field (about 100 Oe in magnitude) was achieved for the treated structures. The two approaches have been systematically implemented for variable [Pt/Co] repeats and NiFe thicknesses.

[1] J. Sort et al., Phys. Rev. B 70, 174431 (2004)
[2] A. Bollero et al., Phys. Rev. B 73, 144407 (2006)
[3] A. Bollero et al., Phys. Rev. B 84, 094423 (2011)

TU-76

Modeling exchange – spring layered systems with perpendicular anisotropy using ferromagnetic resonance measurements

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We have experimentally studied the FePt/Fe_3Pt bilayer system using ferromagnetic resonance studies at room temperature. Measurements were taken as a function of the direction of the applied external magnetic field. Results show that the effect of exchange coupling is manifest by the induction of a strong perpendicular anisotropy into the soft layer (Fe_3Pt) from the hard layer (FePt). We have used the angular variation of the resonance field to allow us to assess the anisotropy constants for three different thicknesses of the soft layer (2, 3.5 and 5 nm), where we note that in order to fit the angular variation of the resonance field we require both second and fourth order anisotropy constants. We observe a decrease of the overall perpendicular anisotropy as the soft layer thickness increases. We note that the hard layer does not contribute to the spectra under the experimental conditions used (9.3 GHz, magnetic fields up to 1T). We have modeled the bilayer system using the free energy of the system, which includes the effective anisotropies of the layers. In order to fully appreciate the effects of exchange coupling, we have used previously published data to find the best fit to data thus allowing us to assess the most appropriate values of the anisotropy constants for the FePt/Fe system. The results indicate that the best way to model these hard – soft coupled ferromagnetic layers is by using a variable effective anisotropy constant in the soft layer, from which almost exact solutions can be obtained. Averaging the anisotropy over the entire layer gives a good measure of the effective anisotropy and the thickness dependence of the effective anisotropy agrees very well with that found experimentally.

TU-77

Spatial Resolution and Switching Field of Magnetic Force Microscope Tip Coated with FePd-Alloy Thin Film

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Magnetic force microscope (MFM) tips with high switching fields (H_{sw}) have been prepared by coating sharp non-magnetic tips with high K_u magnetic materials such as FePt and CoPt ordered alloys [1]. FePd-alloy is reported to show higher degree

of $L1_0$ ordering compared with those of FePt and CoPt materials when annealed under similar temperatures. In the present study, MFM tips were prepared by coating Si tips of 4 nm-radius with $Fe_{50}Pd_{50}$ (at. %) alloy films by varying the thickness from 20 to 80 nm at RT followed by annealing at 600 °C. The effects of coating thickness on the H_{sw} and the resolution were investigated. For H_{sw} estimation, MFM observation was performed for MFM tip repeatedly before and after applying a magnetic field. The magnetic field direction was opposite the magnetization direction of MFM tip and the field was increased in a step-wise of 0.1 kOe. H_{sw} was estimated as the magnetic field where the MFM contrast reversed. Fig 1(a) shows the MFM images of perpendicular medium recorded at 1000–1500 kFCI observed by using a FePd film coated tip. Magnetic bits of 25.4–16.9 nm are distinguishable. MFM resolution is estimated as the half of critical wave length (λ_c), where $1/\lambda_c$ is estimated from the signal line intersecting the noise line [1]. Fig. 1(c) shows the FePd film thickness dependence on the H_{sw} and the resolution. When the FePd film thickness is decreased from 80 to 20 nm, the H_{sw} decreases from 1.5 to 0.9 kOe, whereas the MFM resolution improves from 9.4 to 8.1 nm. Spatial resolutions of less than 10 nm with H_{sw} greater than 1 kOe are realized with FePd-alloy coated tips.

[1] L. Gao *et al*., *IEEE TMAG*, **40**, 2194 (2004).

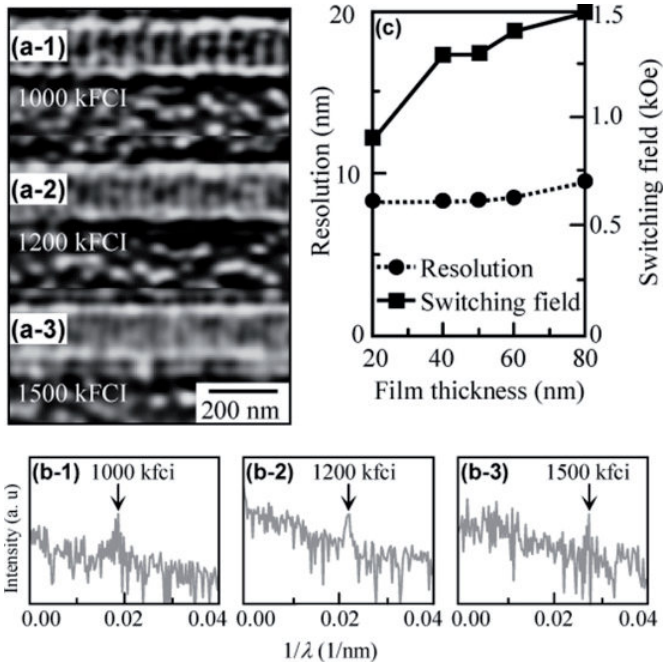

Fig. 1 (a) MFM images, (b) power spectra, and (c) dependences of film thickness.

TU-78

Magnetization reversal of weak ferromagnet $Pd_{0.99}Fe_{0.01}$

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The hybrid structures composed of thin superconducting and ferromagnetic films are widely studied nowadays because they are supposed to be used in low temperature electronics. The magnetic layer in the structures is used for controlling the properties of superconducting films. Therefore the magnetic layer has to meet some special requirements. It has to be soft magnetic material switched by weak magnetic fields. It should have small value of spontaneous magnetization, preferably with small scale labyrinth magnetic structure to control the superconductivity, but do not destroy it [1]. The resistance switching of Nb-FeNi-Nb and Nb-PdFe-Nb structures by weak magnetic field was recently demonstrated [2,3]. To explain the results, the authors speculate about the magnetic ordering and magnetic domain structure of thin magnetic layers.

Here we report the results of particular study of magnetic properties of $Pd_{0.99}Fe_{0.01}$ thin films. The experiments were performed by magnetooptic visualization technique and by SQUID magnetometry in the temperature range 4 – 15~K.

The magnetization reversal under the action of magnetic field of different directions was studied. The temperature dependence of magnetization saturation was determined. The magnetic hysteresis loops were drawn. The influence of PdFe on magnetic field penetration into Nb-PdFe hybrids at temperature below T_c^{Nb} was studied. Based on the experimental results we conclude that the Fe-atoms are not distributed homogeneously in $Pd_{0.99}Fe_{0.01}$ thin films, but they are arranged in ferromagnetic nanoclusters with dimensions of about 20-30 nm, which are mutually spaced with an interval about hundreds nanometers.

[1] A.I. Buzdin, Rev. Mod. Phys. 77, 935 (2005)
[2] A.Yu. Rusanov et al,: ZETF Lett. **87**, 204 (2008)
[3] V.V. Bolginov et al., ZETF Lett. 95, 408 (2012)

TU-79

Tuning morphology and magnetism in epitaxial $L1_0$-FePt films

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The $L1_0$-ordered FePt alloy, characterized by a magneto-crystalline energy density of 7×10^6 J/m^3 [1], is expected to have applications in high-density perpendicular magnetic recording media and spintronic devices [2, 3].

Its employment can provide high thermal stability with an easy magnetization axis perpendicular to the film plane, opening a wide scenario of applicability also in magnetic heterostructures, such as: spin valves, spin torque switching devices, magnetic nanopillars exploiting spin-polarized current, magnetic exchange-coupled media.

In the last decade, numerous studies have been conducted to investigate the growth of $L1_0$ FePt films with a well-defined (001) crystalline texture perpendicular to the film plane, focusing on technical applications as well as the basic mechanism of $L1_0$ ordering, magnetic properties and morphology tuning.

To control the size of the magnetic nanostructures and to induce the required (001) texture, deposition on single crystalline MgO (001) is usually carried out.

The deposition on $SrTiO_3$ (STO), with reduced misfit value (Δ=1.5% with a_{STO}=0.393 nm) between the two materials, makes this substrate an attractive choice.

In this work the correlation among FePt thin film morphology,

crystal structure, magnetism has been investigated as a function of the substrate (i.e., MgO and STO) with the aim of tuning morphology and magnetism.
The effect of lattice misfit on structure, morphology and magnetic properties has been studied.
Promising results have been obtained on the ordering temperature reduction and morphology tuning on STO compared to MgO substrate, without the employment of any other solution (i.e., seed layer, buffer layer, thermal treatments).
These results are exploitable in a wide range of application such as spintronic devices and recording media.
[1] O.A. Ivanov et al., Fiz. Met. Metalloved. 35, 81 (1973)
[2] S.N. Piramanayagam and K. Srinivasan, Journ. Magn. Magn. Mat. 321, 485 (2009)
[3] M. Yoshikawa et al., Ieee T. Magn. 44, 2573 (2008)

TU-80

Robust exchange coupling in a CoO/FePt film grown on Pt(001) single crystal

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Exchange interaction at the interface of ferromagnetic (FM) and antiferromagnetic (AFM) materials is of crucial importance in information storage technology. Besides the FM/AFM interface structure, the epitaxial relationship between layers and substrate modifies the magnetic properties of each layer individually. Band structure calculations predict that epitaxial distortions should significantly affect the magnetic properties and magnetic anisotropy of CoO films [1].
We report here the structural and magnetic properties of the CoO/FePt system grown on Pt(001) substrate. We used *in situ* grazing incidence x-ray diffraction (GIXRD) to study the growth of the ultra-thin (~3 nm) cobalt oxide film by reactive molecular beam epitaxy. The oxide layer has been grown on a 1.5 nm-thick chemically ordered FePt layer in coherent epitaxy on Pt(100). The ordered FePt layer has the tetragonal axis perpendicular to the surface and an enhanced perpendicular magnetic anisotropy [2]. The oxide structure corresponds in a first approximation to a CoO(111) film, with large roughness. A deeper structural study reveals a clear monoclinic distortion, associated to the anisotropic stress at the interface with FePt(001).
The magnetic behavior has been studied by magneto-optic Kerr effect (MOKE) and soft x-ray absorption spectroscopy (XMCD and XMLD). Perpendicular magnetic anisotropy and exchange bias shift have been observed by MOKE after field cooling from room temperature. XMLD at the Co L_3 edge reveals a Néel temperature of 295 K, as for the bulk AFM single crystal. The bias shift is maintained up to the Néel temperature, demonstrating the robustness of the AFM ordering of the CoO film. This unusual behavior should be related to the good crystalline quality and induced monoclinic distortion.

[1] A. Boussendel et al. Phys. Rev. B 81, 184432 (2010).
[2] M.M. Soares et al. J. Appl. Phys. 109, 07D725 (2011).

TU-81

Magnetic order-disorder phase transition in Fe-Al alloy thin films

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The $Fe_{1-x}Al_x$ system exhibits an order-disorder phase transition for $0.33 < x < 0.62$: the chemically ordered *B*2 phase is paramagnetic whereas the chemically disordered *A*2 phase is ferromagnetic. Disorder can be induced locally by ion-irradiation which is ideal for thin films since complete depth penetration is possible at relatively low ion-energy. This is particularly interesting as a pathway for magnetic patterning to create magnetic nano-composite materials [1]. We characterize the phase transition in $Fe_{60}Al_{40}$ films prepared by magnetron sputtering on $Si(001)/SiO_2$ substrates, and by pulsed laser deposition on Al_2O_3 single crystals [2].
Magnetron sputtered films (60 nm in thickness) are chemically disordered and a saturation moment (M_s) of 190 emu/cc at 300 K is observed. To induce chemical ordering, the film was annealed to 820 K for 1 hr. The annealed film exhibits a hysteresis loop however, with a reduced M_s of 10 emu/cc. The film was irradiated with Ne^+ ions at 11 keV and flux of 2×10^{14} ions/cm^2 (0.55 displacements per atom). Irradiation induced disorder leads to an increase in M_s to 109 emu/cc confirming the occurrence of a reversible $A2 \rightarrow B2$ phase transition. M(T) dependence of the annealed sample measured after cooling in zero field and in 1 T field (ZFC/FC) exhibits splitting at 100 K suggesting the presence of nanocrystalline secondary phases that may coexist with the *B*2 phase. We demonstrate the possibility to tailor the magnetic behaviour of nanocomposites wherein the *B*2 and *A*2 phases are imprinted locally on the thin films.

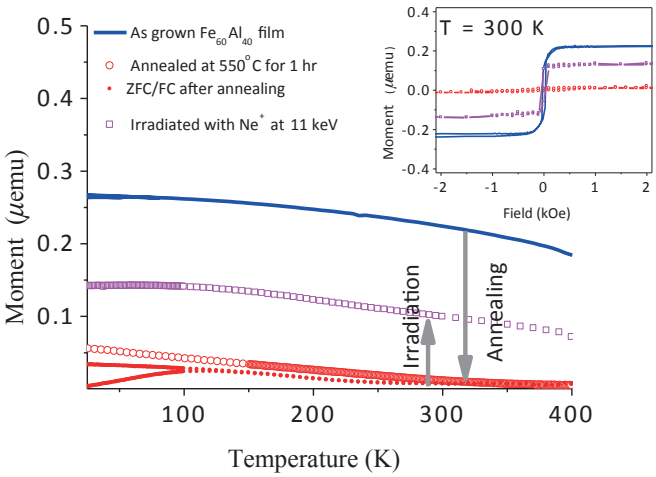

Figure: M(T) dependence for as-grown 60 nm- $Fe_{60}Al_{40}/SiO_2$ (line), annealed film (circles) and after irradiation (squares). The inset shows hysteresis loops measured at 300 K. Also shown are the ZFC/FC curves for the annealed film.

[1] J. Fassbender et al., *Phys. Rev. B* 77, 174430 (2008)
[2] **M. Trautvetter** et al., *Appl Phys A* 102, 725 (2011)

TU-82

Magnetic and structural properties of Sm-Co thin films

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Relatively thick Sm-Co films are attractive for permanent magnets with application in MEMS technology as they exhibit high intrinsic coercive forces and large remanent moment values. Thin Sm-Co films, on the other side are attractive for ultrahigh density recording medium as they allow thermal stability even in nanometer ordered grains. Sm-Co films were deposited by dc magnetron sputtering on Cu seedlayers that were deposited on thermally oxidized Si(001) wafers. The microstructure of the thin films was investigated by X-ray diffraction and electron microscopy, while the magnetic properties such as remanent magnetization and coercive field were analyzed by VSM measurements.

Here, we present a systematic study of the influence of Co-Sm film thickness and annealing conditions (deposition on pre-heated substrates or post-annealing) on the structural and related magnetic properties. We observe an increase in coercivity with increasing thickness of the Co-Sm film. This behavior is accounted to the internal stress induced by the lattice mismatch between the Cu seedlayer and the Sm-Co film for the as-deposited films at room temperature**.** In contrast, for deposition on pre-heated substrates the coercivity is strictly related to the phase formation of the Sm-Co.

TU-83

Critical behavior and low-temperature phase in GdCr films

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Gadolinium and related compounds have been of interest not only for observing a variety of interesting physical phenomena, including several magnetic ordering states, but also for understanding physical processes near the critical point, as their *TC* is in the range of room temperature and thus easily accessible. In this work, we investigated the low-temperature phase and critical behavior at high temperature of inhomogeneous gadolinium-chromium (GdCr) thin films using *dc* magnetization measurements. The films were prepared as Cr(50nm)/Gd(100nm)/Cr(50nm) multilayers grown onto Si(110) single crystal substrates by means of sputter deposition. The magnetization of the samples was measured using zero field cooling (*ZFC*) and field cooling (*FC*) procedures at several applied fields. In the vicinity of room temperature, the magnetic behavior is compatible with a ferromagnetic (*F*) ground state, which undergoes a rounded ferromagnetic-paramagnetic (*F-P*) phase transition (*PT*) at a critical temperature *TC*. At temperatures below the critical temperature, however, a clear difference between the magnetization measured in the *ZFC* and *FC* procedures is observed. The *FC* magnetization (*MFC*) increases with decreasing temperature. The *ZFC* magnetization (*MZFC*), in contrast, additionally to the rounded *F-P* phase transition at *TC*, shows a peak at a certain temperature *Tg* < *TC*. It was also found that *MZFC* is time dependent at low field and irreversible below an irreversible temperature *Ti(H)*, the temperature at which the *ZFC* and *FC* curves depart from each other. This irreversible behavior is accompanied by an excess of magnetization $\Delta MH \equiv MFC\text{-}MZFC$ in the *FC* curves as compared with the *ZFC* ones. Particular attention is paid to this irreversible behavior. A (*H*,*T*) phase diagram that contains *TC(H)*, *Tg(H)*, and *Ti(H)* for each of samples under study is presented and discussed.

TU-84

Magnetic anisotropies and stripes rotation in FeGa thin films studied by Brillouin Light Scattering and Magnetic Force Microscopy

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Galfenol alloys $Fe_{1-x}Ga_x$ exhibit a strong magnetostriction, whose size is very sensitive to Ga concentration [1]. In this work, we have studied the magnetic properties of $Fe_{1-x}Ga_x$ epitaxial films deposited onto ZnSe/GaAs (100) as a function of both the film thickness and the Ga concentration, by means of Brillouin Ligth Scattering (BLS) and Magnetic Force Microscopy (MFM).

Thinnest films show an in-plane magnetic anisotropy resulting from the superposition of a biaxial term, typical of the bulk Fe, and a uniaxial anisotropy with the easy axis along the [1-10] direction. We found the intensity of the in-plane anisotropy decreases on increasing both the film thickness and the Ga concentration. In particular, for a $Fe_{0.80}Ga_{0.20}$ 72 nm thick we observed an in-plane isotropic behaviour.

MFM measurements have pointed out the presence of stripe domain patterns at remanence for films with Gallium concentration greater than 14% and a thickness of 72 nm. In-field MFM has been employed to perform experiments of domains rotation: after the induction of stripes by the application of a field (up to 3 kOe) along a preferred orientation of the crystal, the rotation process has been produced by the application of another field placed at 45 or 90 degrees from the first one and followed by detecting the MFM signal at different field intensities. Depending on the specific orientations considered, we have observed coherent rotation of linear stripes together with transitions from stripes to labyrinth domain patterns or saw-tooth zig-zag periodic patterns. The stripes period was on the average of 120 nm. In any case, the stripes maintained the direction of the external applied field, even after field removal. This effect is known as *rotatable anisotropy* and is a consequence of magnetostriction.

[1] M. Eddrief et al., Phys. Rev. B 84, 161410 (2011)

TU-85

Magnetooptical spectroscopy of strained $La_{0.67}Sr_{0.33}MnO_3$ thin films grown by pulsed laser deposition

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High quality $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) ultrathin layers are of interest for applications in magnetic sensors and spintronic devices as they exhibit colossal magnetoresistance. Their ferromagnetic properties are dominated by the double-exchange (DE) interaction originating from the e_g electron transfer between Mn^{3+} and Mn^{4+} ions via the O^{2-} *2p* state. Since the DE electron transfer probability strongly depends on Mn^{3+}-O-Mn^{4+} geometry, the main factor responsible for the change of the magnetic properties is a strain arising in the film when the lattice mismatched substrate is used for the deposition. LSMO thin films used in this study were grown by pulsed laser deposition on $SrTiO_3$ substrates. The deposition at low oxygen pressures with the use of a beam homogenizer leads to the high quality LSMO films with surface roughness bellow 0.2 nm. Magneto-optical (MO) spectroscopy offers an opportunity to study physical properties of ultrathin magnetic layers when other conventional methods might not be effective. The film thickness ranges from 5 to 96 nm. MO spectrometer based on azimuth modulation was used and spectra in polar and longitudinal configuration were obtained. All the spectra display features typical for LSMO films, including the thinnest 5 nm thick film. MO Kerr effect observed in this film reflects high magnetic ordering even at such low thickness. All the spectra manifest high quality of the LSMO films prepared with the use of the beam homogenizer. As an example there is shown a spectrum of 10 nm thick film in polar configuration on Figure 1. It displays typical LSMO spectral features and excellent agreement of the measured spectra with the theoretical calculations almost in the whole investigated energy range.

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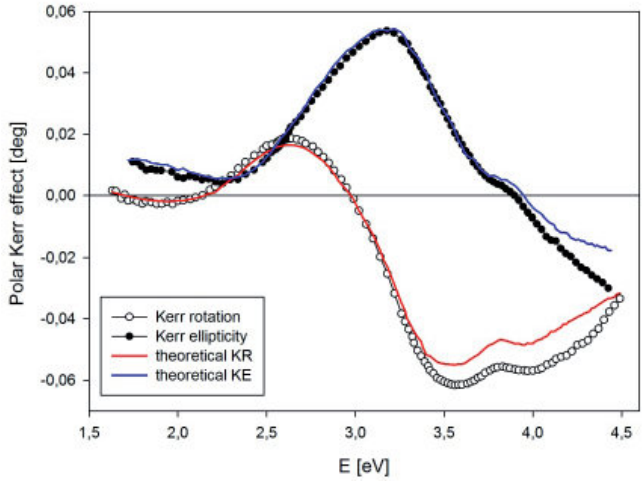

Figure 1: Experimental and theoretical polar Kerr effect of 10 nm thick LSMO film

TU-86

Toward the assembly of magnetic molecules on LSMO manganites

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La_{0.7}Sr_{0.3}MnO_{3} (LSMO) thin films have proven to act as an efficient spin injection electrode in various hybrid organic/inorganic spintronic devices[1]. Good control of the electronic structure of LSMO surface is a key issue to ensure the right way to proceed toward the optimization of such spintronic devices, mainly built in vertical geometry, where molecules act as a decoupling layer between two ferromagnetic electrodes (LSMO and, for example, Co) without hindering the spin transport. In this context and moving toward devices based on novel and conceptually different molecular decoupling layers[2], including single molecule magnets[3] we present here a multi-technique characterization of an LSMO surface prepared by channel spark ablation[1]. We performed a theoretical and experimental analyses based on periodic DFT calculations, X-ray angle-resolved photoemission measurements, Ion Scattering Spectroscopy, AFM, STM and X-ray absorption based characterizations, with a strong focus on the surface properties and, in particular, on the nature of the termination layer. Preliminary data relative to the formation of a molecular/LSMO interface upon deposition of magnetic molecules will be also presented.

This research has been realized with the financial support of EU through ERC-AdG MolNanoMaS and of Italian MIUR through the FIRB project n° RBAP117RWN.

[1] Dediu, V. A.; Hueso, L. E.; Bergenti, I.; Taliani, C. Nature materials 2009, 8, 707-16.
[2] Gatteschi, D.; Cornia, A.; Mannini, M.; Sessoli, R. Inorganic chemistry 2009, 48, 3408-19.
[3] Gatteschi, D.; Sessoli, R., Villain, J. Molecular Nanomagnets, Oxford. Univ. Press, Oxford, 2006.

TU-87

Control of the magnetic and electronic properties of $LaMnO_{3+d}$ thin films during pulsed laser deposition growth

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Perovskite-type ferromagnetic materials have a variety of applications in industry as well as in the field of materials research. Many of these materials are derivatives of $LaMnO_3$, which is doped on the *A*-site with lower valent cations like Ca^{2+} or Sr^{2+}. By changing the amount of the dopant, this allows one to tune the magnetic and structural properties of the material. The parent compound $LaMnO_{3+\delta}$ also reveals a strong dependence of the magnetic and electronic properties on the excess oxygen content, δ. The antiferromagnetic and insulating state of the stoichiometric parent compound at δ = 0 changes over to a magnetic spin-glass as δ increases. With further doping the insulator develops a ferromagnetic order,

whose moment increases until δ ~0.11-0.14. Upon further increase to δ> 0.14 the material becomes conducting. This behavior is well-knows for the of $LaMnO_{3+\delta}$ ceramics, but has not yet been systematically explored in the thin films. Here we present such a systematic study of $LaMnO_{3+\delta}$ thin films that have been grown by pulsed laser deposition. The oxygen content as well as the magnetic and electronic properties of the films have been changed *in-situ* by selecting the background gas for deposition (O_2 and N_2O) and by varying the depositing parameters such as background gas pressure, substrate temperature and laser fluence. High quality thin films with different oxygen contents were obtained, covering the range from the antiferromagnetic insulator to the ferromagnetic insulator on the phase diagram (i.e. with δ from 0 up to 0.14). The saturation magnetic moment at 10 K in these films ranges from 0 to 3.0 μ_B per Mn ion, respectively. A thin ferromagnetic and insulating $LaMnO_{3+\delta}$ layer has also been sandwiched between two superconducting $YBa_2Cu_3O_{7-\delta}$ layers to study the tunneling of electrons between the $YBa_2Cu_3O_{7-\delta}$ layers, which may be useful for applications in spin-filters.

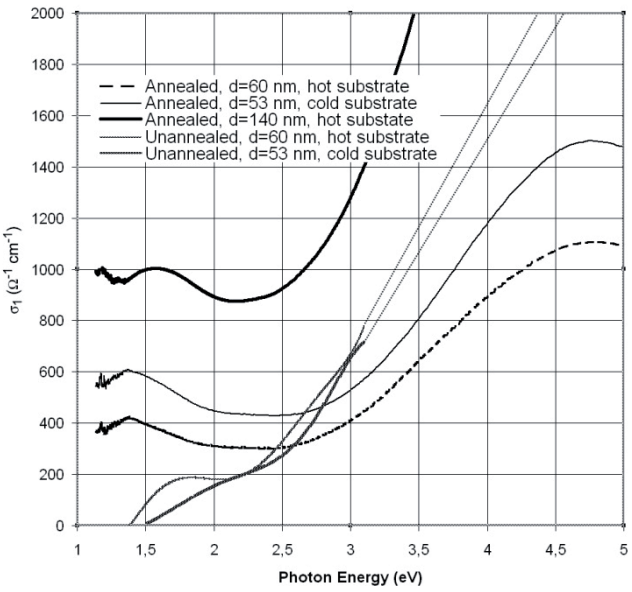

Fig. The optical conductivity spectra of LSMO films deposited on the Al_2O_3 substrates.

TU-88

LSMO films optical conductivity in dependence on their production technology

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Results of study of LSMO thin films optical properties depending on their production mode and the following thermal treatment are presented. The investigated films are deposited by DC magnetron sputtering of $La_{0,7}Sr_{0,3}MnO_3$ target in argon-oxygen atmosphere on hot (T=700 °C), and on cold (T=20 °C) single crystal (012) Al_2O_3 and (111) GGG substrates. The thicknesses of the films were measured by multiangle ellipsometry at wavelength 633 nm. The optical transmission was measured in a range 1.2 - 5 eV, at room temperature.

The maximum of optical conductivity nearby 1 eV is absent for the unannealed films with thicknesses less than 100 nm deposited on cold and hot Al_2O_3 substrates (this maximum corresponds to double exchange [1]). But, the 3 hours annealing in air in the temperature interval 750 - 900°C brings films to an oxygen-excessive content [2], and leads to appearance of 1 eV maximum. The optical conductivity of the films with thickness more than 100 nm deposited on a hot Al_2O_3 substrate has a weak annealing dependence.

Ellipsometric measurements showed that prepared LSMO-films with thickness less than 100 nm at the GGG-substrates are heterogeneous. Their optical conductivity spectra have no maximum near 1 eV, before and after annealing.

The main results of studies LSMO films optical conductivity spectra are presented in the figure.

[1] M. Ziese, Rep. Prog. Phys. 65, 143 (2002)

[2] Yu.M. Nikolaenko, S.V. Kara-Murza, A.A. Tikhii, I.V. Zhikharev at al., ArXiv: Phys. D/1111.7180

TU-89

Development of epitaxial films for current induced domain wall motion

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For future applications of current-induced motion of magnetic domain walls (DWs) in memory devices [1], low current densities and high domain wall velocities at zero magnetic field are required. High DW velocities (> 600m/s) have been observed in polycrystalline Py based spin-valve nanostripes [2], but DW pinning by defects hinders long-distance DW displacements.

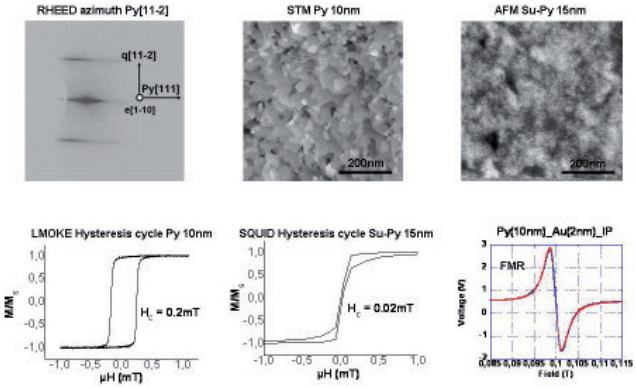
We studied the epitaxial growth by pulsed laser deposition under ultra high vacuum of single crystal fcc(111) Py ($Fe_{20}Ni_{80}$) and fcc(111) supermalloy (Su-Py = $Fe_{15}Ni_{82}Mo_3$) films on single crystal sapphire (0001) substrates with and without an fcc (111) Ir buffer layer. The reflection high energy electron diffraction streaks pattern confirms single crystalline growth with in-plane epitaxial relation, sapphire(1-100) // Ir(1-10) & Py(1-10) and sapphire(11-20) // Ir(11-2) & Py(11-2). The STM and AFM images show very flat Py and Su-Py surfaces with average roughness 0.086nm and 0.147nm respectively.

Both Py and Su-Py single layers show very soft magnetic behaviour with coercive fields of 0.2 and 0.02 mT respectively. The Ir\Py and Ir\Su-Py bilayers also show the soft magnetic behaviour with coercive fields of 0.3mT and 0.07mT respectively. Py films show a weak uniaxial magnetic anisotropy, induced by the substrate steps, while Su-Py films having very weak magnetostriction show an isotropic behaviour.

We used ferromagnetic resonance (FMR) to obtain values of the Gilbert damping constant α . The experimental resonance curve has perfect lorentzian fit. The value of alpha, calculated using g = 2.1, f = 9.77GHz and M = 1T, is 0.007 for Py(10nm) and 0.0105 for Ir(10nm)\Py(10nm).

[1] S. S. P. Parkin, M. Hayashi, and L. Thomas, Science 320, 190 (2008)

[2] V. Uhlir et al., Phys. Rev. B 81,224418 (2010)



TU-90

Study of substrate induced anisotropy in Co-N thin films

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Nitrides of magnetic transition metals are good candidates for technological applications in spintronic devices due to their high saturation magnetization values and chemical ability to allow sharp interfaces with semiconducting nitrides [1, 2].

In this work, Co-N thin films were deposited by reactive sputtering of cobalt in Ar + N_2 mixtures, using deposition conditions previously optimized for the formation of cobalt nitride in glass substrates. Several substrates (Corning glass and single crystals with different crystalline structures - TiO_2, MgO and Al_2O_3) were used in order to study the role of the substrate in the final structural and magnetic properties. The composition and structure of the obtained films were determined by X-Ray Diffraction, Atomic Force Microscopy and Rutherford Backscattering Spectrometry. The magnetic properties of the films were studied as a function of temperature and applied magnetic field using SQUID magnetometry. All Co-N films display strong ferromagnetic behaviour at room temperature and magnetic anisotropy related with the substrate used. The influence of the substrate and corresponding crystalline orientation in the film magnetic parameters is presented and discussed.

This work was supported by Portuguese funds through FCT-*Fundação para a Ciência e a Tecnologia* project PTDC/FIS/102270/2008.

[1] J. M. D. Coey, P. A. I. Smith, *J. M. M. M.* **200**, 405 (1999)
2] M. Ribeiro Jr., M. Marques, L. M. R. Scolfaro, L. K. Telest and L. G. Ferreira, *Phys. Semic.* **893**, 1227 (2007)

TU-91

Magnetization reversal in O-implanted Co thin films

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Since its discovery in 1956, the exchange bias (EB) phenomenon has been extensively studied in rather diverse systems, namely core/shell particles, thin bilayer and multilayer films, ferromagnetic (FM) nanoparticles embedded in an antiferromagnetic (AF) matrix, etc. The most-known EB manifestation is the shift of the hysteresis loop of the FM constituent along the magnetic field axis.

In this work we present the effect of implanting O ions in 30 nm thick Co films fabricated by molecular beam epitaxy on thermally-oxidized Si(100) using 40 keV ions at 2×10^{17} ions/cm^2 fluence. The implantation gave rise to a rather uniform implantation profile of O and, according to TRIM, resulted in an atomic O concentration at half depth of the Co layer of around 26%. Longitudinal Magneto-Optical Kerr Effect (MOKE) measurements gave an EB field of up to 210 Oe at low temperatures. Both asymmetric magnetization reversal and training effect, i.e., variations of the EB and hysteresis loop's coercivity upon subsequent field cycling, were observed.

In order to shed light on the magnetization processes that take place in this system, numerical simulations were performed through a model for polycrystalline exchange-bias systems with granular interfaces [1,2] from which the main magnetic parameters and their variations with the training were extracted. The model assumes that the magnetizations of the FM grains are exchange-coupled to both stable and partially-stable uncompensated spins at the AF/FM interface. The very good agreement between experimental and simulated hysteresis loops for magnetic field applied along both easy and hard magnetization orientations in the film's plane strongly indicates that the magnetization reversal is dominated by (inhomogeneous) magnetization rotation rather than by domain-wall formation and propagation.

[1] Z. Li and S. Zhang, Phys. Rev. B 61, R14897 (2000)
[2] A. Harres and J. Geshev, J. Phys.: Condens. Matter 23, 216003 (2011)

TU-92

From capacitive to tunneling conduction through annealing in granular insulating Co-Zirconia thin films

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In situ TEM observations of granular Co-Zirconia thin films, prepared by Pulsed Laser Deposition, were performed using an electronic microscope equipped with a heating specimen holder. Comparing the images before and during heating at 300ºC one can observe, at a glance, that the number of small particles increases. After annealing at 400ºC, a bimodal Particle Size Distribution has to be assumed to fit experimental data,

evidencing two effects of annealing: nucleation of new particles from Co atoms dispersed in the matrix, and growing of the previously existing particles by adhesion of neighbor atoms and by coalescence.
Magnetic characterization by measuring the temperature dependence of the magnetization after field cooling and zero-field cooling was done with the as-prepared samples and after annealing. The experimental results are fitted assuming PSD which confirm what was observed by direct TEM imaging.
The temperature dependence of the dc resistivity corresponds to thermally-assisted tunneling and Coulomb blockade. Ac conductance measured for the as-cast sample displays characteristic features of the universal behavior found in dielectrics. The annealing produces two effects: the frequency marking the onset of ac conduction increases and the slope of this dispersive region decreases. Although similar previous results have been associated to quality changes at the interface, our TEM characterization demonstrates that annealing produces the appearance of small and closer particles: too small to allow capacitive conduction and close enough to provide tunneling channels to thermally activated charge carriers.
These results are successfully simulated assuming a random resistor-capacitor network, which represents the competing conduction channels between Co particles through thermally-assisted tunneling and capacitive conductance. The annealing effects are reproduced increasing the proportion of resistive paths and decreasing of its impedance, what agrees with TEM observations.

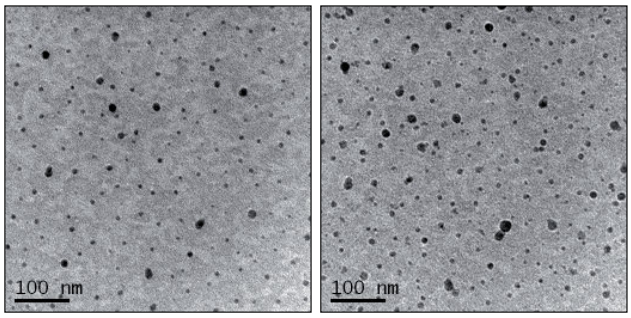

Figure 1. TEM images of the same Co-Zirconia film before and during heating at 300ºC.

TU-93

The role of the interface in the magnetic interaction between Fe-Phthalocyanine and Co film

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The control of organic nanostructures suitable for nano-electronics, spintronics and sensor applications can be achieved by tuning their electronic, optical, catalytic and magnetic properties at organic/inorganic interfaces. The feasibility of incorporating organic materials into spintronics devices requires the comprehension of the electronic and magnetic interaction at organic/ferromagnetic interface [1-2]. Several open aspects still need to be explored at the organic/ferromagnetic interfaces: i) the type of magnetic coupling; ii) the role of the organic molecules and iii) the role of substrate surface magnetism.
With this respect, the choice of the molecules and the substrates are primary parameters. Metal-phthalocyanines (C32H16N8-M, MPc) are large planar molecules showing a high level of flexibility that makes them ideal building blocks for functionalized organic systems [3]. Cobalt is commonly used as a spin injector in real devices. Co films, epitaxially grown on Cu substrate, show magnetic anisotropy from perpendicular to in plane directly related to the film thickness.
In this work, we have investigated the behaviour of FePc films deposited on ferromagnetic Co film by X-ray absorption Spectroscopy and X-ray Magnetic Circular Dichroism. We have observed and monitored the magnetic coupling between Fe within FePc and the substrate at room and low (80 K) temperatures. We have analyzed the evolution of the magnetic coupling as a function of FePc thickness and Co surface magnetism. We have found that only FePc molecules at the interface are mainly involved in the coupling with Co film. Furthermore, we have established that only Co atoms at interface contribute to the magnetic coupling with the molecules.

[1]A. L. Rizzini *et al*, Phys. Rev. Lett. **107**, 177205 (2011)
[2]H. Wende *et al*, Nat. Mat., **6**, 516 (2007)
[3]S.R. Forrest, Nature **428**, 911 (2004)

TU-94

Kondo phenomena in metal-contacted organic radical molecules

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Kondo physics is relatively unexplored in organic radical molecules. Experimentally, magnetic molecular break junctions at low temperatures are difficult to realize. Moreover, there is a challenge in achieving sufficient molecule-contact coupling so as to have an observable Kondo temperature without at the same time cancelling the unpaired spin of the radical. We investigated theoretically the possibility of observing zero-bias anomalies in scanning tunneling spectroscopy of nitric oxide, thiazyls, and other organic radical molecules, either adsorbed on Au(111) or in Au contact geometries, using a combined ab initio/many-body approach [1]. Spin-polarized fully relativistic DFT+U calculations demonstrate that NO as well as TTTA and BBDTA thiazyl radicals maintain magnetic moments in Au nanocontact and surface deposited geometries. For NO/Au(111) at the Au top site, the molecule forms an angle of approximately 60 degrees with the surface normal. The combination of bending and weak adsorption generates a relatively unhindered rotational degree of freedom, and we study its interplay with the Kondo effect. DFT calculations also show that thiazyl radicals are able to form junctions between a metal surface and a Au STM tip. Multi-orbital Anderson impurity models are constructed to link our ab initio results to numerical renormalization group calculations of zero-bias Kondo anomalies. The importance of correcting self-interaction error in these systems is discussed.

[1] P. Lucignano et al., Nature Mat. 8, 563 (2009)

TU-95

Magnetic and structural properties of nanocrystalline electrodeposited Ni films

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Nanocrystalline materials generally have crystalline grain size in a range of 1-100 nm which exhibit extraordinary physical, chemical and mechanical properties in comparison to normal polycrystalline materials.

Electrodeposition was performed on copper foils from a modified Watts bath with and without 5 g/L saccharin (as a grain refiner). Current density was applied in a range of 0.05-0.3 A.cm^{-2} to find an optimum magnitude.

Results show that for Ni electrodeposited from Watts bath containing saccharin, the hardness of Ni films reaches a maximum about 540 HV at 0.2 A/cm^2. According to Hall-Petch equation, this value corresponds to crystalline grain size smaller than 100 nm. Therefore, increasing of hardness when current density increases in a range of 0.05-0.2 A.cm^{-2} can be due to the reduction of grain size. Increasing current density to values higher than 0.2 A.cm^{-2} makes the current density exceed the limiting value.

XRD pattern taken from Ni film electrodeposited from Watts bath containing saccharin under 0.2 A.cm^{-2} shows that the electrodeposited film is polycrystalline with an average grain size less than 19.81 nm, Fig.1. Based on atomic force microscopy examinations, it can be qualitatively shown that kinetic roughening persists for nanocrystalline Ni films electrodeposited from Watts bath.

The main aim was to study the correlation between crystalline structure and magnetic properties of Ni films with different thickness (from 200 to 20000 nm), Fig.2. When ***H*** is perpendicular to the sample plane, we found spatial distribution M_r/M_s = 0.85-0.89 for all thickness, but coercivity of films decreases as the thickness of electrodeposited increases. We attribute this behavior to increase of shape anisotropy constant with thickening the films.

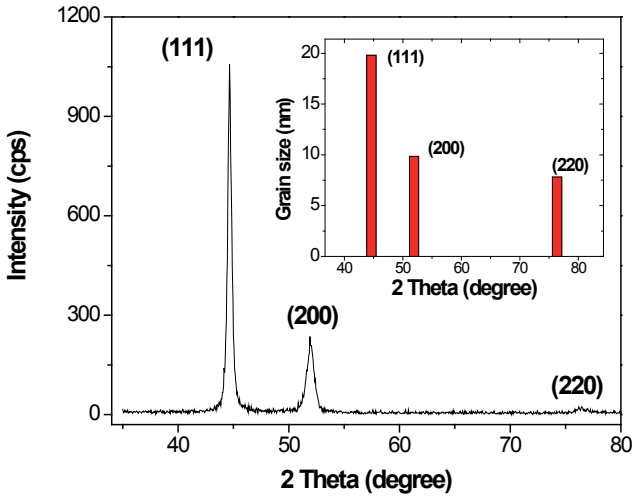

Figure 1- XRD pattern of Ni films with the calculated grain size.

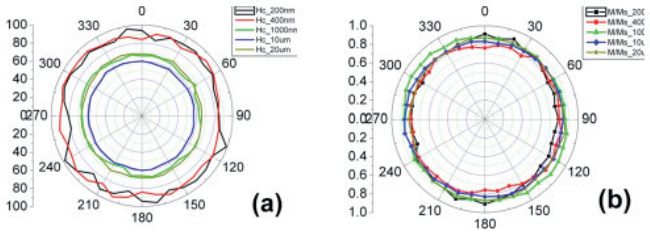

Figure 2 - Dependence of $H_c=f(\varphi)$ *(a)* and $M_r/M_s=f(\varphi)$ (b) when ***H*** is rotated in-plane.

TU-97

Oxygen assisted epitaxial growth of ultra-thin Cr films on Fe(100)

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Cr deposition on Fe(100) has been the subject of intense investigations since the discovery of an oscillatory behaviour in the magnetization of the top Fe layer in Fe/Cr/Fe trilayers, as a function of the thickness of the antiferromagnetic spacer [1]. Apart from being an excellent model system for thin film magnetism, Fe/Cr multilayers played a fundamental role in the development of the well assessed technology of giant magneto resistive devices [1].

The magnetic properties of such systems can be affected by the interplay of several parameters, such as Cr/Fe interfacial mixing, the sharpness of the Cr/Fe interface, strain and defects. We propose an atomic scale investigation of such interface properties by presenting a scanning tunnelling microscopy (STM) study of Cr deposition on the Fe-*p*(1x1)O surface [2], from the first stages of interface formation up to few atomic layers. Different growth temperatures have been exploited, up to about 700 K. The mechanisms of adatoms diffusion, interface chemical interactions and film growth have been studied in detail, also with the support of x-ray photoemission spectroscopy (XPS), Auger electron spectroscopy and low-energy electron diffraction (LEED). The results will be compared with the case of Cr film growth on the pristine Fe(100) surface [3].

The experimental data are discussed in the light of *ab-initio* simulations of the electronic, energetic, and geometric properties of the growing film.

The relevance of our observations will also be examined in the light of possible technological advantages over existing Cr growth recipes.

[1] B. Heinrich, J.A.C. Bland (Eds.), *Ultrathin Magnetic Structures*, Springer Verlag, Berlin, (1994).

[2] A. Picone, G. Fratesi, A. Brambilla, et al., Phys. Rev. B 81, 115450 (2010).

[3] A. Davies, Joseph A. Stroscio, D. T. Pierce, and R. J. Celotta, Phys. Rev. Lett. 76, 4175 (1996).

TU-98

Ab initio studies of magnetism of sp-impurity-decorated grain boundaries and surfaces in cobalt and nickel

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The macroscopic mechanical behaviour of polycrystalline metallic materials is largely determined by cohesion of the grain boundaries (GB) which is strongly affected by segregated impurities. Here we present a systematic ab initio study of segregation of 4 non-magnetic sp-impurities (Al, Si, P, S) at Σ5(210) GB and (210) free surface (FS) in fcc ferromagnetic cobalt and nickel and analyze their effect on structure, magnetic and mechanical properties. Interstitial impurities modify the magnetic moments at the GB and in its immediate neighborhood much stronger than the substitutional ones. Whereas there is a slight enhancement of magnetization at the clean GB and FS with respect to bulk nickel (3–7 % and 24 %, respectively), most of the above impurities nearly kill or substantially reduce the magnetic moments at the FS and, when segregating interstitially, also at the GB (i.e. Si, P, S) - they produce magnetically dead layers at the boundary, which are caused by a strong hybridization of sp-states of the impurities with the d-states of nickel and a redistribution of electron states in both majority and minority bands. Reduction of magnetic moments at the Σ5(210) GB in fcc ferromagnetic cobalt is, in absolute values, very similar to that in nickel. However, as the magnetic moment in bulk cobalt is higher than that of nickel, we do not observe magnetically dead layers here. Most of our results are theoretical predictions and we hope that they may motivate experimentalists to conduct new investigations in this field.

This research was supported by the Grant Agency of the Czech Republic (Projects No. P108/12/0311 and 106/09/H035), the Grant Agency of the Academy of Sciences of the Czech Republic (Project No. IAA100100920) and by the Project CEITEC–Central European Institute of Technology (CZ.1.05/1.1.00/02.0068) from the European Regional Development Fund.

TU-99

Structure Analysis of Ni Thin Films Epitaxially Grown on bcc Metal Underlayers of (211) and (110) Orientations

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3*d* ferromagnetic transition metal (Fe, Co, Ni) films with metastable structures have recently attracted much attention to MTJ devices, since the application property like resistivity variation is greatly enhanced by changing the magnetic layer to a metastable magnetic layer [1]. Ni is a typical soft magnetic material with fcc structure. hcp structure is metastable and does not appear in the bulk phase diagram. bcc nonmagnetic metal underlayers with (100) and (211) orientations were employed to prepare hcp-Co and Co-alloy thin films with the *c*-axis parallel to the substrate. Such bcc underlayers are considered to stabilize the hcp structure. In the present study, 40-nm-thick Ni films were deposited on bcc-Cr, V, and Fe underlayers at room temperature. Metastable hcp-Ni films were obtained in early stages of film growth on the (211) plane of bcc-Cr, V, Fe, whereas fcc-Ni films were formed on the (110) plane of these underlayers. Fig. 1(a) shows the RHEED pattern observed for a 2-nm-thick Ni film grown on Cr(211) underlayer. A clear diffraction pattern corresponding to hcp(1-100) texture is observed. With increasing the thickness, the intensity ratio of RHEED spot "P" to spot "Q" decreases [Figs. 1(b,e)], which indicates that the fcc(211) pattern shown in Fig. 1(d) is starting to overlap with the hcp(1-100) pattern. Fig. 1(f) shows the cross-sectional HR-TEM image around the Ni/Cr interface. hcp and fcc crystals separately exist on the Cr(211) underlayer. A large number of stacking faults exist parallel to the close-packed plane. These results suggest that hcp structure starts to transform from these stacking faults into fcc structure in the lateral direction by atomic displacement parallel to the hcp(0001) close-packed plane.

[1] S. Yuasa *et al.*, APL, **89**, 042505 (2006)

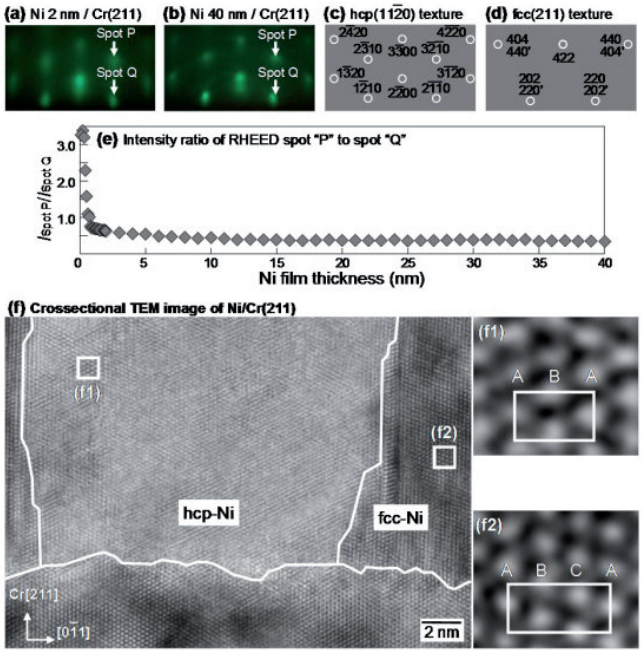

Fig. 1 (a,b) RHEED patterns. (c,d) RHEED spot maps. (e) $I_{spot\ P}/I_{spot\ Q}$. (f) TEM image.

TU-100

Perpendicular magnetic anisotropy in epitaxial Fe/MgO multilayers

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Magnetic multilayers composed of 3d metal and oxide (MO) sublayers are of great interest due to their possible application in magnetic recording industry. Recently the perpendicular magnetic

anisotropy(PMA) of interface-origin has been theoretically predicted for Fe/MgO(001)[1]. In addition it was shown that magnitude of PMA can be tuned by external electric field[2].
We studied magnetism of epitaxial Fe films sandwiched between MgO(001) using nuclear resonant scattering(NRS) of X rays for Fe thicknesses ranging from 2-8ML. The numerical analysis of the NRS spectra measured at 10K shows that magnetization for all Fe thicknesses is out of plane. When increasing temperature the collapse of magnetic order occurs via superparamagnetic relaxations. In order to stabilize PMA at room temperature Fe/MgO multilayers were studied with ultrathin MgO spacers mediating interlayer exchange coupling between Fe sublayers. [Fe_{n}/MgO_{m}] superlattices were grown by molecular beam epitaxy on MgO(001) single crystal substrate for different Fe and MgO thicknesses (n and m denotes number of Fe and MgO monolayers respectively). Analysis of RT Conversion Electron Mössbauer Spectroscopy(CEMS) spectra measured for (Fe_{2}MgO_{2})_{10} and (Fe_{4}MgO_{2})_{10} indicates transition from paramagnetic to ordered magnetic state as a function of Fe thickness. Moreover CEMS spectra accumulated for multilayers with varying MgO thickness indicate clearly spin reorientation transition between in plane magnetization direction for Fe_{4}MgO_{2} to out of plane for Fe_{4}MgO_{3}. In addition with increasing number of repetition the enhancement of PMA occurs. CEMS data were complemented with MOKE measurements.

[1] K. Nakamura, T. Akiyama, T. Ito, M. Weinert, and A. J. Freeman, Journal of Magnetics 16, 161 (2011)
[2] T. Maruyama, Y. Shiota, T. Nozaki, K. Ohta, N. Toda, M. Mizuguchi, A. A. Tulapurkar, T. Shinjo, M. Shiraishi, S. Mizukami, Y. Ando Y. Suzuki, Nature Nanotechnology 4, 158 - 161 (2009)

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS
Chair: C. De Julian Fernandez

TU-101
Epitaxial growth and magnetic properties of cobalt-iron films on $SrTiO_3$(100) substrate
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Cobalt-iron films are extensively investigated because of its significance in manufacturing of tunneling magnetoresistance heads and magnetic-random-access-memory devices. For such applications, high-quality epitaxial films are strong candidates, as they exhibit excellent uniformity and magnetic anisotropy. However, the crystallographic quality of epitaxial film depends on the chosen substrate material and its crystal structure. In the present study, the cobalt-iron films were deposited on single-crystalline $SrTiO_3$(100) substrates. Epitaxial growth has been confirmed by RHEED and x-ray measurements. The morphology of the films was investigated by atomic force microscopy (AFM), and, in selected samples, by magnetic force microscopy. The magnetization was measured using a vibrating-sample magnetometer and magnetic anisotropy was determined from the ferromagnetic resonance measurements. This system is characterized by low strains at the interface. This feature leads to flat and smooth CoFe film surface observed at AFM images. The films, of the domain structure with 200-500 nm in size, exhibit four-fold in-plane magnetic anisotropy.

TU-102
Electric field effect on magnetic properties in Fe ultra-thin film
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The electric field effect on magnetism has been intensively studied by using a field-effect structure consisting of a gate electrode, a solid gate insulator layer (or an ionic liquid), and a ferromagnetic channel [1-4]. Although ferromagnetic semiconductors are pioneering materials to investigate the effect [1], recently even in ultra-thin ferromagnetic metal

films, the electric field effect on magnetism has been reported [2-4]. Last year, we demonstrated a Curie temperature modulation in Co by applying electric field [4]. The modulation of the electron density by applying electric field is expected to result in the change of the Curie temperature, however, the clear origin of it has not been fully understood. Thus, to compare the difference on the effect in the various ferromagnetic transition metals is crucial to understand it. Here, we report the electric field effect on the magnetization properties and Curie temperature in Fe ultra-thin films using field effect structures.

This work was partly supported by the PRESTO program of JST, a Grant-in-Aid for Young Scientists (A) from MEXT, a Grant-in-Aid for Scientific Research (S) from JSPS, and JSPS through its "Funding Program for World-Leading Innovative R & D on Science and Technology" (FIRST Program).

[1] H. Ohno, *et al*., *Nature* **408**, 944 (2000).
[2] M. Weisheit, *et al.*, *Science* **315**, 349 (2007)
[3] T. Maruyama, *et al.*, *Nature Nanotechnol.* **4**, 158 (2009).
[4] D. Chiba, *et al., Nature Mater.* **10**, 853 (2011).

TU-103

Magnetostriction of Permalloy Epitaxial and Polycrystalline Thin Films

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Permalloy (Py, Ni – 20 at. % Fe) is a typical soft magnetic material with fcc structure. Magnetostriction is one of the important material properties and considered to be influenced by the film orientation. In the present study, Py single-crystal films of (100), (110), and (111) orientations were prepared on single-crystal substrates through hetero-epitaxial growth by UHV RF magnetron sputtering. Py polycrystalline films were also formed on glass substrates. The influence of film orientation on the magnetostriction was investigated by using a laser displacement meter under different magnetic fields [1]. Figs. 1(b) and (c) show the output waveforms of magnetostriction of a Py(100) single-crystal film measured under rotating magnetic fields of 10 and 1000 Oe [Fig. 1(a)], respectively. A triangle waveform is recognized under a low field, whereas a sinusoidal waveform is observed under a higher field of 1000 Oe. The magnetostriction behavior is explained based on the magnetic domain structure. Under a low rotating filed of 10 Oe, 90° magnetic domains are formed in the Py film, as shown in Fig. 1(d), and the domain wall moves, where the output waveform is proportional to $\Delta l/l$ as shown in the inset of Fig. 1(e). Thus, the waveform output is calculated to vary as shown in Fig. 1(e). Under a higher field, the magnetization of film saturates and no magnetic domains are formed, where the $\Delta l/l$ is given as shown in the inset of Fig. 1(f) and the output waveform is calculated to change as shown in Fig. 1(f). These calculated waveforms are in agreement with the experimental results. The magnetostriction behavior of Py films with different orientations will be compared at the conference

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[1] T. Kawai *et al*.: *Thin Solid Films*, **519**, 8429 (2011).

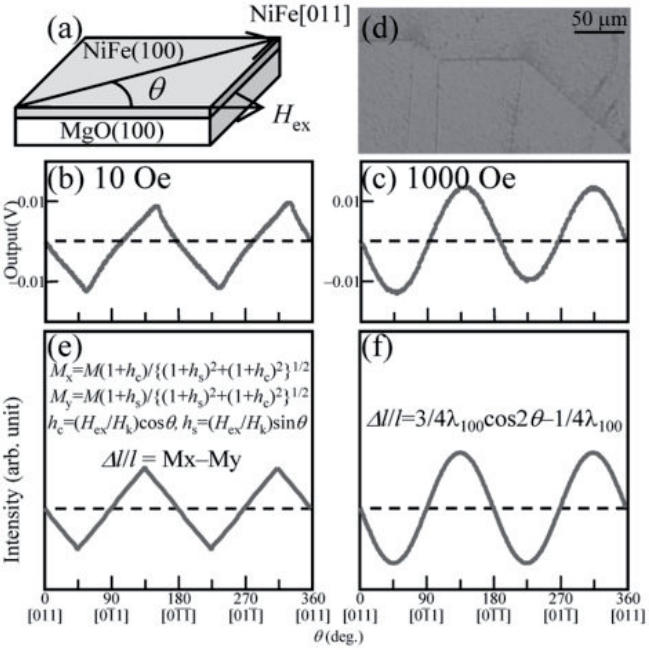

Fig. 1 (a) Rotating field direction, (b,c,e,f) output waveform, and (d) Bitter image.

TU-104

Bias-voltage controlled tunneling resistance in a ferromagnet-metal-insulator-ferromagnet tunneling junction

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The topic of spin-dependent tunneling (SDT) in a magnetic tunneling junction (MTJ) continues to receive considerable attention, in regard both to its fundamental physics and its potential applications. SDT in an MTJ is characterized by the tunneling resistance (TR). An MTJ consists of an FM_1-I_3-FM_4 structure, where FM_1 and FM_4 are ferromagnetic electrodes and I_3 is a thin insulator. The change of SDT in the MTJ is measured by the tunneling magnetoresistance (TMR) ratio. In the FM_1-I_3-FM_4 MTJ, SDT is extremely sensitive to the interface structures between the insulator and each electrode. Thus, modulating one of the interfaces can change SDT. One way to achieve this is to insert a thin nonmagnetic (M_2) layer between one of the ferromagnetic electrodes, FM_1 or FM_4, and the insulator I_3. The M_2-inserted MTJ is the FM_1-M_2-I_3-FM_4 structure [1]. In this paper, we adopt the spin-polarized free-electron model [2] and extend our previous work [3] to investigate how SDT, the TR, and the TMR in the FM_1-M_2-I_3-FM_4 MTJ are affected by the bias voltage. We find a new method of changing the tunneling resistance. Unlike the traditional method of varying the magnetizations configuration between the two ferromagnetic layers, the proposed method uses the polarity of the bias voltage with a small strength to change the tunneling resistance in the FM_1-M_2-I_3-FM_4 MTJ. Under suitable conditions, we show that both tunneling resistance changes resulting from the polarity of the bias voltage and from the magnetizations configuration are equal in magnitude, and are larger than that in a conventional FM_1-I_3-FM_4 MTJ.

[1] S. Yuasa, T. Nagahama and Y. Suzuki, Science 297, 234 (2002)
[2] S. Zhang and P. M. Levy, Phys. Rev. Lett. 81, 5660 (1998)
[3] S.-P. Chen, J. Appl. Phys. 107, 09C716 (2010)

TU-105

Saturation Magnetisation in Rare Earth and Iron-Cobalt Alloys through Antiferromagnetic spacer layers

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Hard drive capacities have been increasing exponentially for the last 30 years driven by the demand for greater storage. The write poles in the read/write head now use Fe-Co material systems with a maximum theoretical saturating magnetisation of 2.4T. Exploiting rare earth systems to achieve increased saturations is of significant current interest [1] and could potentially provide benefit. However the results reported therein arose from thin film deposited by MBE. To fully exploit the potential of rare earth coupling more scaleable processes such as sputtering must be demonstrated. In the presentation we discuss our work to explore effective ferromagnetic coupling between a ferromagnetic and rare earth layers. First we demonstrate RKKY coupling in Fe/Cr/Fe with Cr layers as thin as 0.2-2 nm prepared by UHV magnetron co-sputtering on 75mm silicon wafers to establish control of deposition conditions. We then extend this to investigate and discuss results attained with vibrating sample and SQUID magnetometry with Gd and Dy coupling to $Fe_{70}Co_{30}$ onto heated (to 300°C) 150mm silicon wafers.

[1] B. Sanyal et al. Phys. Rev. Lett. 104, 156402 (2010).

TU-106

The magnetic field effects on the electrodeposited CoCu binary alloy onto Cu seed-layer:structure-magnetic properties relationship

A. Franczak [1], A. Levesque [1], P. Żabiński [2], R. Kowalik [2], M. Czapkiewicz [3], D. Li [4], Q. Wang [4], F. Bohr [1], J.P. Chopart [1]

(1) Laboratory of Engineering and Material Science, University of Reims Champagne-Ardenne, BP 1039, 51687 REIMS Cedex 2, France, (2) Laboratory of Physical Chemistry and Electrochemistry, AGH University of Science and Technology, 30059 Krakow, Poland, (3) Department of Electronics, AGH University of Science and Technology, 30059 Krakow, Poland, (4) Key Laboratory of Electromagnetic Processing of Materials (Ministry of Education), Northeastern University, 110004 Shenyang, China

Since the discovery of giant magnetoresistance (GMR) in metallic multilayers, a great interest has been developed due to its potential applications. The Co-Cu system has attracted considerable attention for its almost zero solubility at room temperature, which makes it a well-suited candidate for the production of metastable alloys. Among all of the production techniques, the electrodeposition of magnetic multilayers as well as granular alloys exhibiting GMR still finds a great deal of attention to both scientific and technological community. In granular alloys, the alternate magnetic-nonmagnetic regions similar to multilayer structures are mimicked via phase separation tendencies between magnetic and nonmagnetic components. The resulting structure consists of embedding nanometric ferromagnetic or superparamagnetic granules in nonmagnetic matrix. The Co-Cu binary alloy is one of the natural choices for such a heterogeneous alloy due to magnetic (Co) and nonmagnetic (Cu) combination along with immiscibility at ambient temperatures. On the other hand, the electrochemically grown multilayers and granular alloys do not exhibit as high GMR effects of prepared systems as physical methods, which are mainly related to differences in their microstructure. The microscopic process of growth strongly affects magnetic properties of materials. Superimposing an external magnetic field offers possibilities to influence the deposition process mainly by magnetohydrodynamic (MHD) effects, which cause a change in the microstructure of grown layers in correlation with the above mentioned properties. Furthermore, magnetic fields applied during the electrodeposition induce an orientation of particles in the direction of easiest magnetization in the case of multilayered system such as Co-Cu/Cu [1]. The present work will show the magnetic fields effects on the magnetic properties of electrodeposited Co-Cu binary alloys onto Cu seed-layer and the relation between nanoscale structure and magnetic properties.

[1] M. Uhlemann, A. Gebert, M. Herrich, A. Krause, A. Cziraki, L. Schultz,
Electrochim. Acta 48, (2003) 3005.

TU-107

Tailoring the structural and magnetic properties of Co/Pt multilayers by Swift heavy ions

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$L1_0$ CoPt is a potential candidate for magnetic storage due to its large K_u value of 10^7 ergs/cm^3 [1]. The high K_u value of CoPt stabilizes smaller grains of CoPt against superparamagnetism. However, as deposited CoPt films crystallize with fcc structure. To achieve the desired phase, high deposition temperature or post deposition annealing at temperature higher than 650 °C is required. High deposition temperature increases the grain size. Embedding $L1_0$ CoPt particles in SiO_2 provides control on the CoPt grain size and intergranular magnetic interaction [2]. However, the effects of SiO_2 addition on chemical ordering and magnetic properties of Co/Pt multilayers will be interesting to probe.
In this study we have prepared different set of thin films containing different number of multilayers of Co and Pt with SiO_2 as a buffer and capping layer on quartz substrates by sputtering. Ion beam irradiation is a versatile means for synthesizing nano-materials or modifying their structure [3]. In the present investigation, irradiation with swift heavy ions of CoPt particles with the $L1_0$ structure embedded in a silica film has shown that structural and magnetic properties can be tailored by varying the ion dose and energy. And thickness of these multialyers plays a key role in determining the effect of irradiation. Magnetic Measurements show the high value of coercivity for both longitudinal as well as in perpendicular direction.

[1] Florent Tournus,Alexandre Tamion,Nils Blanc,Abdelkrim Hannour,Laurent Bardotti,Brigitte Prével,Phy. Rev. B 77, 144411 2008
[2] Yang Yang, K. K. M. Pandey, J. S. Chen, G. M. Chow, J. F. Hu,J. Appl. Physics 105, 07B709 2009
[3] White C W, Withrow S P, Budai J D, Boatner L A, Sorge K D, Thompson J R, Beaty K S and Meldrum A 2002 Nucl. Instrum. Meths. Phys. Res. B 191 437

TU-108

Microstructural evolution and magnetic properties in $Fe_{50}Pd_{50}$ sputtered thin films submitted to post-deposition annealing

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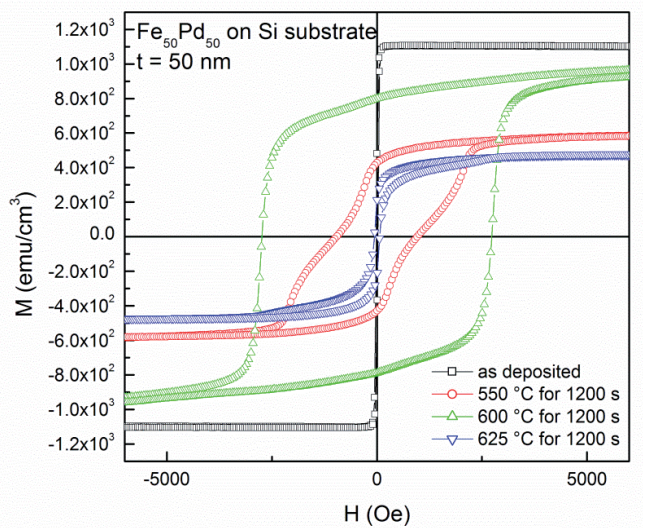
Tetragonal intermetallic phases such as FePt, CoPt and FePd have been intensively studied as active ferromagnetic materials for high density data storage. $Fe_{50}Pd_{50}$ thin films (t = 50 nm) have been deposited on Si substrates by sputtering technique. As-prepared films consist of a Fe-Pd disordered solid solution, being deposited without heating the substrate. The order-disorder transformation towards the $L1_0$-ordered tetragonal phase has been induced by post deposition annealing in vacuum (T_a = 550 – 625 °C for 1200 s). As-deposited and annealed thin films microstructure was studied by means of SEM microscopy. Crystal structure has been identified by XRD diffraction technique. Room-temperature magnetisation curves were measured by an Alternating Gradient Magnetometer in the parallel and perpendicular configuration in all as-prepared and post-annealed samples. Annealing treatment induces the precipitation of the high-anisotropy $L1_0$ tetragonal phase, as marked by the increasing of the coercive field with respect to as-prepared samples (see Figure below). However, the distribution of the c-axis of the tetragonal phase results to be isotropic as shown by the very similar behavior of the hysteresis loops measured in the parallel and perpendicular configurations. MFM microscopy has been exploited to study the magnetic domain pattern (in the demagnetised and out-of-plane remanent state). A complex multidomain configuration strongly dependent on the microstructure is observed. The presence of the $L1_0$ phase induces a typical maze domain structure in all annealed samples. The mean domain spatial dimension *d* is directly connected with the perpendicular magnetic anisotropy value. B analyzing the MFM images exploiting a FFT transformation, *d* is constant in all annealed samples up to T_a = 600°C. For higher annealing temperatures, the dimension is seen to decrease indicating a disappearance of the ordered tetragonal $L1_0$ phase in agreement with magnetic and microstructural data.



Room-temperature magnetization loops for as-deposited and selected annealed films.

TU-109

Thermal Stability of $L1_1$ Ordered Phase in CoPt-Alloy Thin Films Formed on MgO(111) Single-Crystal Substrates

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High K_u magnetic thin films with perpendicular magnetic anisotropy have been investigated for applications to high-density magnetic recording media, MRAM, etc. Metastable $L1_1$ ordered CoPt-alloy thin film is one of the strong candidates, since it shows K_u greater than 10^7 erg/cm^3 [1–3]. Formation and stability of $L1_1$ ordered phase is considered to be influenced by the substrate temperature for film formation as well as the post annealing temperature. In the present study, $Co_{50}Pt_{50}$ (at. %) films of 40 nm thickness were formed on MgO(111) substrates by UHV RF magnetron sputtering. The influences of substrate temperature and post annealing temperate on the $L1_1$ ordered phase stability were investigated. CoPt(111) epitaxial films were obtained at substrate temperatures ranging between room temperature (RT) and 600 °C. Fig. 1(a) shows the out-of-plane XRD spectra. CoPt(111) superlattice reflections are observed for the films grown below 400 °C, which indicates that $L1_1$ ordered phase is formed. As the substrate temperature increases up to 300 °C, the order degree (*S*) increases. With further increasing the temperature, the *S* decreases. The $L1_1$ ordered phase is apparently stabilized around 300 °C. Figs. 1(b)–(e) show the magnetization curves. The films grown below 400 °C show strong perpendicular magnetic anisotropy reflecting the magnetocrystalline anisotropy of $L1_1$-CoPt crystal and the order degree. The influence of post annealing on the $L1_1$ ordered phase stability will also be presented at the conference.

[1] S. Iwata *et al.*, *IEEE Trans. Magn.*, **33**, 3670 (1997).
[2] T. Shimatsu *et al.*, *J. Appl. Phys.*, **103**, 07E114 (2008).
[3] A. –C. Sun *et al.*, *Sctipta Mater.*, **61**, 713 (2009).

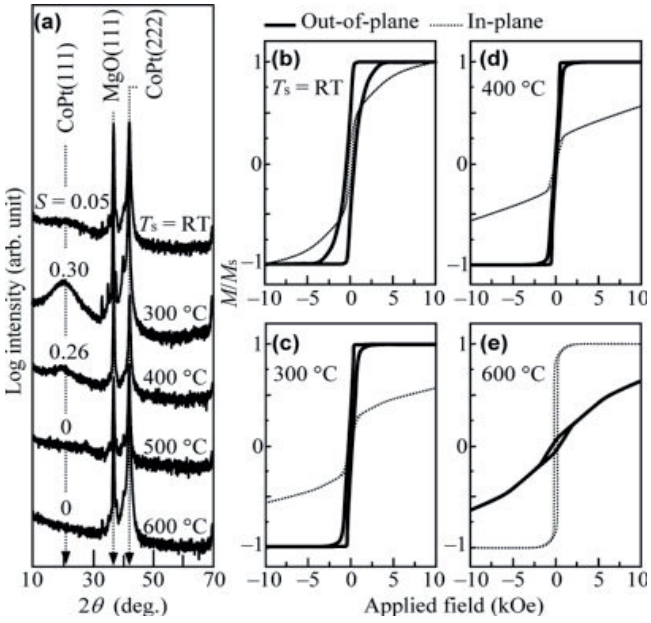

Fig. 1 (a) Out-of-plane XRD spectra and (b)–(e) magnetization curves of CoPt films.

TU-110

L1o ordered FePd thin films with in-plane magnetisation

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Permanent magnets having desirable properties are attractive for a number of uses in the micro and nano scale; for example in microelectronic mechanical system and ultrahigh density magnetic recording media. One of the permanent magnetic materials that offer most interest is FePd particularly with regard to cost relative to FePt. Most of the research published on this material has been focused on its use as in ultrahigh density magnetic recording media and for this requires the formation of the tetragonal ordered L10 – phase with out of plane magnetisation and a high coercivity which are important for increasing storage density in the recording media.
In this work we focus on production of Fe50Pd50 thin films with the tetragonal ordered L10 – phase and utilise it high coercivity but try to orientate the magnetisation in-plane. We discuss the influence of film thickness, film composition, seeding underlayers, annealing temperature and annealing time on the orientation and magnetic properties of the tetragonal ordered L10 – phase in Fe50Pd50 thin films.

TU-111

Temperature dependence of the magnetic domain structure in disordered FePt films

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FePt thin films have been extensively investigated in the last years due to their potential application as ultrahigh density magnetic media. However, the high anisotropy L10 magnetic phase only forms after proper annealing at high temperatures and as-made films generally grow in a disordered, relatively soft magnetic phase. A set of films with thicknesses between 9 nm and 94 nm were fabricated using dc magnetron sputtering on oxidized Si (100) substrates. Due to the fabrication conditions the films tend to grow with an in-plane compressive stress which, due to the positive magnetostriction coefficient of the alloy, induces an easy magnetization axis normal to the film plane. Even in the cases in which this anisotropy is lower than the demagnetization energy (the ratio between these two quantities defines the quality factor, Q) it is possible to observe a domain structure in the form of stripes, with a component of the magnetization pointing out of the film plane alternatively in the "up" and "down" directions. In our samples, with Q~0.3, a transition between planar to stripe-like domains is expected for film thicknesses above 30-40 nm, but this critical thickness depends on Q, so that a change in the domain structure could be observed if this parameter is varied. Due to the different thermal expansion of FePt and Si a reduction in Q is expected when the temperature is lowered. From M vs. H loops measured at different temperatures in the range 80 K – 300 K, we have effectively observed a change in the coercive field which can be associated to a transition from stripe-like to in-plane domains. The transition temperature range is broad, indicating a gradual variation between the two magnetic configurations, but changes systematically with film thickness, consistent with an interfacial induced strain.

TU-112

Interplay between lattice clamping and helical ordering in Eu(110) thin films

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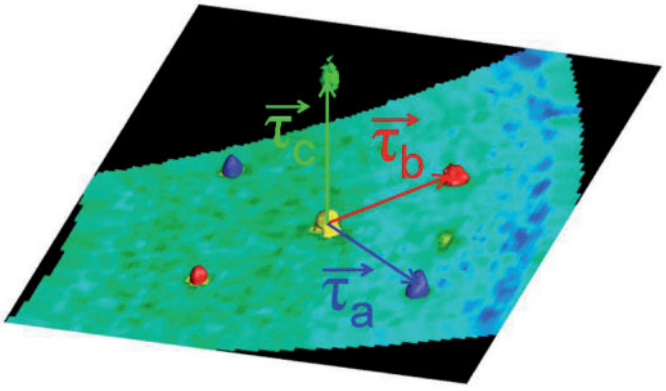
Europium exhibits peculiar chemical and physical properties (bcc structure, low melting point, large atomic radius) compared to other rare-earth, which are commonly attributed to the stability of the divalent state. It is thus a model system for fundamental studies, particularly when deposited as thin films for which surfaces and interfaces can dramatically influence the physical properties of the sample and strain can alter the energy balance. A helical ordering appears at T_N=90 K in bulk europium, the crossing of T_N corresponding to a slight distorsion of the bcc structure along the propagation vector of the helix (which is along one of the <100> directions of the crystalline structure).
We have developed a specific Molecular Beam Epitaxy process to grow high quality Eu(110) thin films onto α-Al_2O_3 substrates (mosaic spread is 0.6°). Neutron diffraction is a unique tool to study these europium thin films since it gives direct insight both on the structural and magnetic properties of the samples (each helical domain correspond to a pair of satellite peaks around the nuclear Bragg reflection). Measurements were performed at the LLB/Orphée reactor using the 6T2 4-circles diffractometer, which 2D detector allowed us to record reciprocal space maps of the regions of interest. The magnetic properties of the films differ significantly from those of bulk samples: the helix with an in-plane propagation vector disappears below a thickness-dependent temperature, and we observed a small tilt angle between the [100] and [010] directions and the propagation vectors of the two corresponding helices. The tilt is temperature-, field- and thickness-dependant. Moreover, the domain population shows strongly hysteretic temperature dependence. These effects can be related to the clamping of the film lattice with the substrate, through exchange and magnetoelastic mechanisms.



Reciprocal space map obtained with neutron diffraction on a 75 nm Eu film at 80 K

TU-113

Synthesis Fe-Pt powder by electric discharge and investigation of their magnetic and structural properties

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The grain size of the materials used in permanent magnet powder metallurgy should not be too small or too big. Using wet chemical methods FePt alloys have been synthesized down to 20nm but this size is not appropriate for powder metallurgy. The ball-milling method can not be used for synthesis because of the ductility of the alloy. In this study we have produced FePt particles with dimensions in the order of microns for the first time using a home-made compact electrical discharge device [1]. The production has been carried out in various conditions resulting powders which contain spherical particles with different sizes. The size distribution of these particles was obtained from optic microscope images. Crystallographic phase analysis was done using XRD. These powders were subjected to annealing (300-1000K) under Argon and 10% Hydrogen to obtain a regular L10 phase. The magnetic properties of the new structure forming during and after the annealing were observed by AC susceptibility measurements. The Curie temperature was determined from thermomagnetic analysis. The hysteresis curves of samples annealed at different temperatures were obtained from VSM. As a result of these procedures, the optimal particle synthesis and annealing conditions for best permanent magnet properties have been determined.

[1] O. Kamer, Rev. Sci. Instrum. 82, 123906 (2011); doi: 10.1063/1.3673468

TU-114

Effect of Co-doping on magnetic state and properties of FeRh alloys

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The FeRh alloys exhibit a first order magnetic phase transition from the low temperature antiferromagnetic (AF) phase to the ferromagnetic (F) phase at the critical temperature T_t of about 330 K [1]. T_t can be varied in a broad region (120 K – 400 K) by substitutions of Fe or Rh by other d-elements [2]. The AF-F transition is accompanied by the giant magnetocaloric effect, significant resistivity change, and volume expansion [1, 2]. In this work we measured magnetization and electrical resistivity of $Fe_{0.49}Rh_{0.51}$ samples with partial substitution of Co for Fe suggesting that the change of the 3d electron concentration at the substitution will affect the AF-F transition and properties of alloys. The growth of the Co content up to $x = 0.35$ in $(Fe_{1-x}Co_x)_{0.49}Rh_{0.51}$ is found to decrease the T_t value. Above this concentration, only ferromagnetic ordering has been revealed in the whole temperature range below the Curie temperature $T_C \sim 670$ K. As is seen from Figure 1, the Co-doped alloy shows nearly the same difference in the resistivity $\Delta\rho = \rho_{AF} - \rho_F$ in AF and F states around the critical temperature as the parent alloy ($x = 0$), while the isothermal entropy change (ΔS) is estimated to be 40% less than that for $Fe_{0.49}Rh_{0.51}$. The lower value of ΔS observed at the AF-F transition in $(Fe_{1-x}Co_x)_{0.49}Rh_{0.51}$ alloys is attributed to lowering electronic contribution to the entropy change when the T_t value decreases.

This work was supported by the Ural Branch of the RAS (project 12-T-1012).

[1] J. S. Kouvel, J. Appl. Phys. 37 (3), 1257 (1966)

[2] N. V. Baranov, E. A. Barabanova, J. Alloys Compd. 219, 139 (1995)

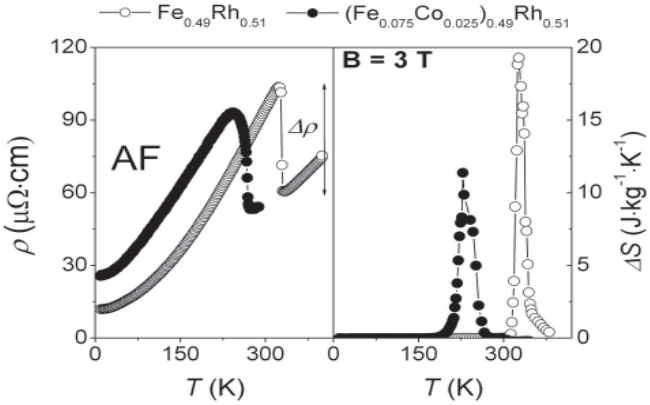

Fig.1 The resistivity and entropy changes of FeRh and Co-doped FeRh alloys

TU-115

Influence of Ga for Co substitution on the magnetic and electronic structure of $TmCo_5$ compound

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RCo_5 type intermetallic compounds are among the best high performance permanent magnets and are therefore of great interest for applications in electric systems, such as motors, detectors or actuators [1].

Nowadays, an active field of fundamental research is devoted to study the influence of p-type elements (Al, B or Ga…) for Co substitution which can induce significant changes in the electronic structure and implicitly in the magnetic properties of RCo_5 type compounds [2].

In the present study, we investigate the structural and magnetic properties of $TmCo_4Ga$ compound. Magnetic measurements performed in magnetic fields up to 10 T at temperatures ranging from 2 to 700 K revealed a decrease of the spontaneous magnetization and Curie temperature in comparison with $TmCo_5$. Neutron powder diffraction experiments allowed us to investigate the magnetic structure. Another considerably important aspect of this study was probing the electronic structure by means of X-ray photoelectron spectroscopy. A strong influence of the Ga for Co substitution was observed in the shape of the valence band. By correlating the results from all these different techniques we aim to elucidate the Tm and Co magnetic states under the influence of Ga.

[1] E. Burzo et al., Landolt-Börnstein Numerical Data and Functional Relationships in Science and Technology, New series, Group III, Vol. 19, subvolume d2, Springer-Verlag, Berlin, (1990)

[2] A. Laslo et al., Journal of Applied. Physics 107, 09A732 (2010)

TU-116

Magnetic structures in $Tm_3Cu_4X_4$ (X = Ge, Sn) compounds

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Tm_{3}Cu_{4}Ge_{4} crystallizes in the orthorhombic Gd_{3}Cu_{4}Ge_{4}-type crystal structure (space group Immm) whereas Tm_{3}Cu_{4}Sn_{4} crystallizes in a distorted variant of this structure (monoclinic space group C2/m). The analysis of the experimental data revealed the presence of an antiferromagnetic order below 2.8 K in both compunds. In Tm_{3}Cu_{4}Ge_{4} the magnetic unit cell is doubled when compared to the crystal one and the propagation vector is k = [0,1/2,0]. A larger magnetic unit cell was found in Tm_{3}Cu_{4}Sn_{4} - the propagation vector describing this magnetic phase is equal to k = [1/2,1/2,0] (for simplicity the orthorhombic description is used for both the germanide and the stannide). Below 2.1 K in Tm_{3}Cu_{4}Ge_{4} and 1.8 K in Tm_{3}Cu_{4}Sn_{4} an incommensurate antiferromagnetic order develops. This magnetic phase is related to k = [1/4,0,k_{z}] where k_{z} is close to 0.49 in the germanide and 0.47 in the stannide. Both magnetic transitions were confirmed by heat capacity measurements.
This research project has been supported by the European Commission under the 7th Framework Programme through "Research Infrastructures" action of the "Capacities" Programme, contract number CP-CSA_INFRA-2008-1.1.1. Number 226507-NMI3

TU-117

Effect of the Al for Co substitution on the structural and magnetic properties of $TmCo_5$ compound

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RCo_5 type intermetallic compounds are well known to be among the best high performance permanent magnets [1, 2]. These materials have many applications in electric systems, such as motors, detectors or actuators.
An active field of fundamental research is devoted to study the influence of p-type elements (Al, B or Ga…) for Co substitution on the structural, electronic and magnetic properties of RCo_5 type compounds. $SmCo_4M$ (M=Ga, Al) compounds have been shown to exhibit particularly strong magnetocrystalline anisotropy in comparison with the $SmCo_5$ phase [3].
The present work reports on the investigation of the structural and magnetic properties of the $TmCo_4Al$ compounds. The ordering temperature and magnetization are found to be dramatically reduced after substitution. Crystalline and magnetic structures were studied by powder neutron diffraction experiments performed at 2 K and 100 K, using the D1B instrument at the Institute Laue Langevin. These results were refined using the Rietveld method allowing us to determine the preferential site on which the substitution takes place and also the amplitude of the local magnetic moments. These neutron results are also discussed in the light of isothermal magnetization measurements as well as thermomagnetic analysis.

[1] E. Burzo et al., Landolt-Börnstein Numerical Data and Functional Relationships in Science and Tehnology, New series, Group III, Vol. 19, subvolume d2, Springer-Verlag, Berlin, (1990)
[2] K.H.G. Buschow, Ferromagnetic materials I, North Holland Publishing Company, Amsterdam 1980
[3] A. Laslo et al., Journal of Applied. Physics 107, 09A732 (2010)

TU-118

Interplay of ferromagnetism and crystal field effects on the magnetic and thermal properties of binary $YbNi_2$ intermetallic

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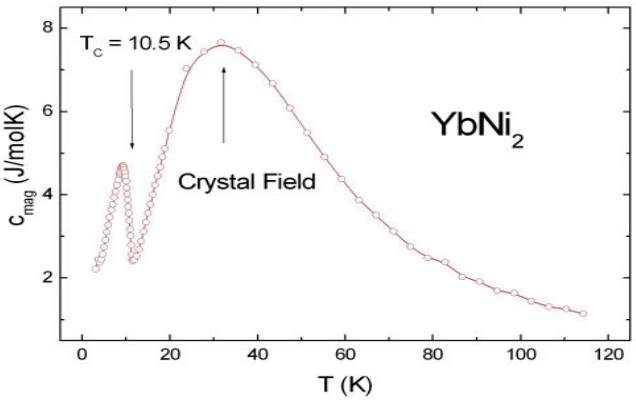
(Rare-Earth)Ni_2 alloys have been investigated to reveal the influence of their crystal field on the magnetocaloric effect [1]. For the $YbNi_2$ alloy, a relationship between crystalline field effects and exchange interactions was established by Mössbauer spectroscopy [2]. However, details of the magnetic and thermodynamic properties have not been investigated yet. We have further studied this material, and the DC and AC magnetic susceptibilities results are consistent with a ferromagnetic behaviour below T_C = 10.5 K, one of the highest Curie temperature found in Yb compounds [2, 3]. Moreover, the temperature dependence of the specific heat shows a lambda anomaly with a peak of 5.12 J /molK at 9.4 K. The analysis of the experimental data also shows an additional magnetic contribution around 32 K stemming from the crystal field of a quartet at Δ_1 = 72 K and a doublet at Δ_2 = 126 K, according to the splitting of the Yb^{3+} ion in cubic symmetry. From the jump of the magnetic contribution of the specific heat, a relatively high Kondo temperature T_K = 27 K is estimated. At low temperatures, below the magnetic transition, the extrapolation of c_{mag}/T vs T plot gives a huge value of the electronic coefficient γ = 544 mJ/molK, which is a clear signature of a heavy fermion behaviour. The uncommon ground state of the title binary intermetallic is compared with those reported for other ferromagnetic Yb alloys.

[1] P. J. von Ranke *et.al*, Phys. Rev B 63, 184406 (2001)
[2] I. Nowik, B. D. Dunlap, J. Phys. Chem. Solids **34**, 465 (1973).
[3] D. P. Rojas *et. al.,* J. Magn. Magn. Mat. **226-230**, 72 (2001).



Magnetic contribution to the specific heat of the $YbNi_2$ alloy. Two contributions associated to the ferromagnetic ordering (10.5 K) and crystal field effects (32 K), respectively, are observed.

TU-119

Magnetic Testing of Phase Transformation in Lean-Duplex Stainless Steel

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In the last decades the development of low cost stainless steels has been carried out to reduce the cost fluctuation of certain expensive elements like Ni and Mo. The requirement of high strength steels with good corrosion resistance can be satisfied by a new type of two-phase stainless steel called lean-duplex stainless steel (LDSS).

In this work V2101Mn lean duplex stainless steel was investigated. The phase transformation of the metastable austenite (γ) to the thermodynamically more stable α'-martensite due to cold rolling was studied. Samples were cold rolled to 20%, 40%, 60% and 80% thickness reduction. The phase identification was done by optical and scanning electron microscope. Vickers hardness tests were also performed on each specimens.

The DC magnetization curves of the samples were measured by a Stäblein-Steinitz (SS) type double-yoke tester [1]. In our laboratory we constructed and built up a new measuring set up keeping the basic principle of the SS measurement using modern electronics and magnetic field sensors. The magnetometer is completely controlled by a 16 bit input-output data acquisition unit. After cyclic demagnetization procedure the series of symmetrical minor hysteresis loops and the saturation loop were measured.

The applied SS measuring set-up was found to be especially suitable for testing the ferritic-martensitic phase transformation of lean duplex stainless steel due to cold rolling deformation.

[1] F. Stäblein, R. Steinitz: Ein neuer Doppeljoch-Magnetstahlprüfer, Archiv für das Eisenhüttenwesen. 8, (1935), 549-554.

TU-120

The kinetics of magnetic properties and structure of $Fe_{66}Co_{24}Si_3B_7$ amorphous alloy

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Amorphous alloys have excellent magnetic properties such as high saturation magnetization, high permeability, low coercivity and losses, which determine their application. It is shown that nanocrystallization leads to improvement of soft magnetic characteristics of alloys.

The aim of this work is to study the devitrification process of $Fe_{66}Co_{24}Si_3B_7$ amorphous alloy. Based on X-ray profiles the state of amorphous melt-spun alloy is microcrystalline, i.e. amorphization of the rapidly quenched alloy is based on the mechanism of suppression of growth processes.

Using differential scanning calorimetry and X-ray diffraction analysis of melt-spun alloy during annealing has been shown that structural relaxation processes have complex multi-step nature, primarily related with instability of alloy. Within the amorphous state the endothermic processes are accompanied by the removal of quenching stresses and the excess free volume withdraw.

The devitrification process of melt-spun ribbon starts with a surface crystallization - the appearance of a solid solution nanocrystals of Co in α-Fe. Two-stage crystallization process (the second exothermic peak at 549°C) leads to an equilibrium state. At 800°C along with surface the bulk crystallization is complete.

The magnetic structure-sensitive properties, such as coercivity and magnetic moment, can be considered as structural relaxation indicators in amorphous alloys. The original amorphous material when heated to crystallization temperature partially passes to the crystalline state, causing the increase in the residual magnetic moment and the coercivity.

The Curie temperature of as-quenched amorphous alloy hasn't been determined during the experiment, because the crystallization temperature for this alloy is below the amorphous state's Curie point. Heating the alloy up to these temperatures causes a sharp increase in residual magnetic moment. This magnetic moment's behaviour for alloys based on Fe is natural, since positional disorder strongly affects the mean atomic magnetic moment's magnitude. The Curie temperature of the investigated alloy in crystalline state is approximately 800^0C.

TU-121

Magnetic properties of $Fe_{1-x}Co_xSi$ single crystals

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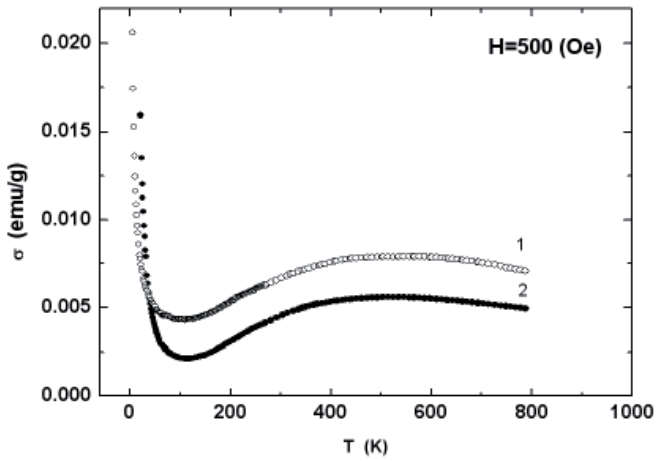
In the present paper the results of experimental investigation of magnetic properties of $Fe_{1-x}Co_xSi$ monocrystalline samples are shown in the temperature range from 4.2 to 800 K. Measurements were carried out with MPMS. Samples were synthesized by the close-spaced vapor transport technique [1]. Technique was chosen as simplest and it is similar to equilibrium state of the crystal growth. Average size of synthesized crystals is up to 2 mm. Concentration of cobalt is equal to $x = 0.005 \div 0.025$. According to X-ray analysis the structure of all synthesized samples corresponds to FeSi structure. The low-temperature magnetic properties of FeSi both single crystal and polycrystalline solid have been explained by the theory of impurity centers originated from crystal nonstoichiometric. Polycrystalline $Fe_{1-x}Co_xSi$ samples in the impurity limit ($x \leq 0.01$) have been studied recently [3]. It was found out that the qualitative dependence of susceptibility of polycrystalline $Fe_{1-x}Co_xSi$ samples is similar to it for pure FeSi, but the absolute value of susceptibility increases. In order to study low-temperature magnetic properties of $Fe_{1-x}Co_xSi$, monocrystalline samples having perfect structure have been grown. In these case concentration of cobalt is also within impurity limits and up spin subband is shifted in such a way that valence and carrier band are not overlapped. Picture 1 shows the temperature dependence of magnetization of $Fe_{1-x}Co_xSi$ monocrystals. It is clear that low-temperature tail of magnetization is also common with $Fe_{1-x}Co_xSi$ monocrystals when $x \leq 0.01$. These data indicates that reason of low-temperature tail of magnetization appearance is magnetic clusters originated from crystal nonstoichiometric.



[1] J. Ouvrard, R. Wandji, B. Roques, *J. Cryst. Growth*, **13** (1972) 406.
[2] G.S. Patrin, V.V. Beletsky, D.A.Velikanov, G.Yu.Yurkin, *PSS,* **48** (2006) 658.
[3] G.S. Patrin, V.V. Beletsky, D.A.Velikanov, G.Yu.Yurkin, *JETP*, **139** (2011) 351

TU-122

The Effect of Platinum Impurities and Stacking Faults on the Magnetocrystalline Anisotropy Energy of Cobalt

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Cobalt-based alloys are ubiquitous in high-density magnetic recording technology. Understanding the effect of impurities and stacking faults on their magnetic properties is an important aspect in developing related devices. [1, 2] Using the screened Korringa-Kohn-Rostoker (SKKR) method [3] we investigate from first principles the variation in the magnetocrystalline anisotropy energy (MAE) of hexagonal close-packed (HCP) cobalt with the addition of platinum impurities as well as the layer-resolved MAE across four types of stacking fault. To this end, we perform calculations on a bulk cobalt system in which one of the atomic layers contains a fractional, substitutional platinum impurity or in which there is one isolated stacking fault. As illustrated in fig. 1, we found that at small concentrations of platinum impurities the MAE is reduced, while at larger concentrations the MAE is enhanced. We show that this variation in MAE can be attributed to on-site Pt contributions and, particularly, to induced MAE contributions on the Co sites. The latter ones give rise to pronounced Friedel oscillations in the calculated MAE that may cause size effects in nano-sized samples. Our calculations suggest that stacking faults always reduce the MAE and for some types of stacking fault there is a re-alignment of the easy axis at the fault. Similar to the Pt impurities, we find that the effect of a stacking fault on the MAE is relatively long-ranged, stretching over 7-9 atomic layers on either side of the fault.

[1] J. Jaworowicz et al., App. Phys. Lett. **95** (2009) 022502
[2] V. Sokalski et al., J. App. Phys. **110** (2011) 093919
[3] J. Zabloudil, R. Hammerling, L. Szunyogh and P. Weinberger, Electron Scattering in Solid Matter, Berlin: Springer 2005

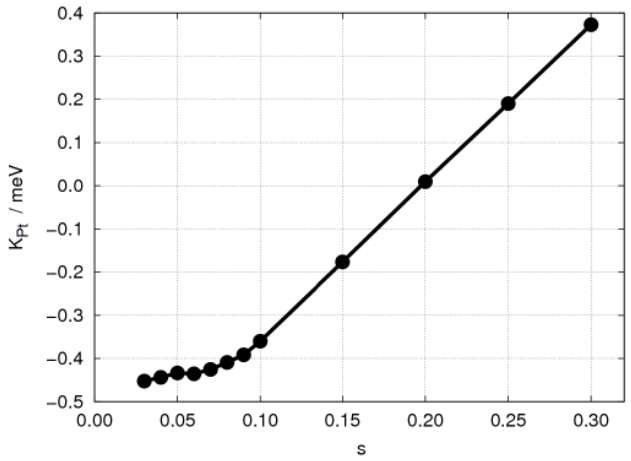

Fig. 1 Calculated excess MAE per Pt atom as a function of the Pt concentration.

TU-123

On the magnetic moment formation and hyperfine fields at Cu isotopes impurities diluted in Fe host: a theoretical study

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The formation of local magnetic moments in impurities embedded in metallic systems has been the concern of condensed matter theorists since the pioneer Friedel´s works. New values of magnetic hyperfine fields at Cu impurities in Fe metallic host were recently obtained [1]. These measurements were made by combining resonance frequencies from experiments involving NMR on oriented nuclei on ^{59}Cu, ^{69}Cu and ^{71}Cu with magnetic moment values obtained from collinear laser spectroscopy measurements on these isotopes at low temperature [1]. Motivated by this experimental work, we proposed a theoretical model to explain the experimental data for the magnetic hyperfine field. In this model, the magnetic moment at Cu impurity diluted in iron comes from a charge potential due to the Cu impurity charge difference and from an itinerant magnetic field produced by the Fe elements of the Host. Our model incorporates, some aspects of first principles calculations and model approaches [2,3]. In order to study the different Cu isotopes with A=59, 67 and 71 as impurity, we have incorporated the Cu volume in the effective charge to be screened. Our self consistently calculated values of the magnetic hyperfine fields are in very good agreement with the available experimental data [1].

[1] V. V. Golovko, Phys. Rev. C84 014323 (2011)
[2] A.Troper, Hyperf. Interc 133, 221 (2001)
[3] J. Van Acker et al, Phys. Rev. B43, 13916 (1991).

TU-124

Uniqueness of Structure and Magnetic Symmetry Group of Spin Glass State (sgs)

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The uniqueness of structure and magnetic symmetry group of spin glass state (sgs) consists in the Gaussian type randomness appearing for both the global magnetic coupling constant and the

magnetization vector **M**, the latter effect bringing to the statistical features of the magnetic structure and the magnetic symmetry group of *sgs*. In the derivation of both cases the use has been made a. o. of the central limit theorem of the theory of probability (the Lyapunov theorem) [1, 2]. The explanation of uniqueness of structure and magnetic symmetry group of *sgs* has its roots in the appearance of a certain probability function in the second term of the assumed Hamiltonian [1, 2]. This term describes the random distribution of either dopants or defects in the ferromagnetic matrix under the percolation threshold. The authors have earlier proved that a certain spontaneous minimum magnetic field **H** is necessary for the stability of *sgs* to appear [3]. The structure of *sgs* can then be described in such a way that **M** is situated along a generatrix of a given cone whose axis coincides with the direction of **H** [2]. Let us call φ the angle between **M** and **H**. Any precession of **M** around the direction of **H** at $\varphi = const$ (it means at constant energy) makes the symmetry operation of *sgs*. Thus the symmetry group of this precession is *SO(2)* [2].

[1] J. Warczewski, P. Gusin et al., *Journal of Non-Linear Optics, Quantum Optics* 30 (2003), 301-320
[2] J. Warczewski, P. Gusin, D. Wojcieszyk, *Mol. Cryst. Liq. Cryst. 554 (2012), 209-220*
[3] J. Warczewski, P. Gusin et al., *J. Phys.: Condens. Matter, 21 (2009), 035402-035407*

TU-125

Anomalous magnetic properties of terbium iron garnet below room temperature

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The anomalous magnetic behavior below room temperature of the Tb^{3+} ions in the terbium iron garnet ($Tb_3Fe_5O_{12}$ or TbIG) is studied by specific heat $C_p(T)$ measurements performed on spherical single crystal in the 5-300 K temperature range. Powder neutron diffraction patterns have been recorded at three temperatures (13, 20 and 160 K) on the high flux diffractometer D1B at the Institut Laue-Langevin Grenoble (France). Some previous patterns collected below room temperature [1] have been revisited. A peak is detected in the curve of the magnetic contribution $C_p^{Tb3+}(T)$ vs T where a maximum appears at 90 J/K.mol near 55 K. The zero value of $C_p^{Tb3+}(T)$ is reached at 170 ± 20 K where the previous 'momentum angular compensation point' T_J has been located between 150 and 190 K [2]. The temperature dependence of the cubic component m'_{1x} of the magnetic moment vector m'_1 associated to C'_1, one of the two sites of the Tb^{3+} sublattice in the true magnetic space group $R\bar{3}c$', presents a broad variation with a maximum near 60 K and a decreasing in the 80–160 K temperature range. Above 160 K, the magnetic structure is described by the Néel ferrimagnetic model where the equality $m'_{1x} = m'_{1y}$ is found. The results confirm the abrupt change in the long-range ferrimagnetic order of the Tb^{3+} ions predicted by Belov [3] near the so called low-temperature point T_B = 56 K. The Landau's theory of second order phase transitions does not apply to TbIG below the Néel temperature T_N(553 K) without magnetic field. [1] M. Lahoubi, M. Guillot, A. Marchand, F. Tchéou and E. Roudaut, I.E.E.E. Trans. on Magn. Vol. MAG-20, No.5, 1518 (1984). Doi: 10.1109/TMAG.1984.1063257

[2] T. J. Nelson and D. C. Mayer, I.E.E.E. Trans. on Magn. Vol. MAG-7, No.3, 616 (1971). Doi: 10.1109/TMAG.1971.1067149
[3] K. P. Belov, Phys.Usp. 39, No.6, 623 (1996).

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

PEROVSKITES AND MULTIFERROICS

Chair: C. Vecchini

TU-126

Structural and magnetic properties of Cu-doped LaSrFe perovskites

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The structural and magnetic properties of Cu doped La_{0.8}Sr_{0.2}FeO_{3} perovskites are investigated. LaFeO_{3} based perovskites exhibit a wide variety of magnetic properties, like weak ferromagnetism, exchange bias, charge disproportion and ordering effects, as well as multiferroic effects. Moreover these oxides have been investigated in other research fields, such as sensing and energy, being the LaSrFeCu perovskites the most promising cathode material for solid oxide fuel cells[1]. Doping of the LaFeO_{3} based perovskites with Cu is expected to produce the modification of the structure and to induce charge disproportion effects. Here, we present the complete structure and magnetic determination of Cu-doped LaSrFe perovskites using XRD, neutron powder diffraction, Mössbauer spectroscopy and magnetic measurements.
Powdered samples of the Lanthanum ferrites with general formula La_{0.8}Sr_{0.2}Fe_{1-x}Cu_{x}O_{3-w} ($0 \le x \le 0.2$) were prepared by citrate auto-combustion technique. For x in the range 0-0.10 the material is monophasic with *Pmma* orthorhombic symmetry, and crystallizes in the perovskite-like cell of LaFeO_{3}, Fe/Cu cations occupy octahedral sites and La/Sr cations are twelve-fold coordinated. For $x = 0.20$ the material is biphasic, with a main *Pmma* orthorhombic phase and a secondary rhombohedral phase with space group *R-3c* (hexagonal setting). At room temperature, the magnetic structure was successfully modelled for the monophasic samples (x = 0.05 and 0.10) assuming a G-type antiferromagnetic interaction between Fe/Cu neighbouring cations. However magnetic characterizations indicate the coexistence of weak ferromagnetism and antiferromagnetism. These oxides exhibit high coercive fields and irreversibility fields that are larger than any other reported for iron-based perovskites. Mössbauer spectra show the presence of Fe^{3+} and Fe^{5+} ions. The correlations between the structural, chemical and magnetic properties for these oxides with different Cu content will be discussed. This work was supported the Regione Lombardia – INSTM project "Catalizzatori per l'Energia e l'Ambiente Nanostrutturati" 2010–2012.

[1] J. Wackerl, et a., Appl. Electrochem. 39, 1243 (2009)

TU-127

Correlation between magnetic properties and Co content in the $Pb_2Mn_{1-x}Co_xWO_6$ system

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In the frame of multifunctional materials showing the co-presence of magnetic and electrical properties, the lead–based double perovskites $Pb_2BB'O_6$ are recognized as a system with peculiar and unusual characteristics. Differently from the family $A_2BB'O_6$ (A=Ca^{2+},Sr^{2+} B'=Mo, Re B=Fe, Mn) which is well known for the large magnetoresistive effect and high T_c temperatures, the presence of Pb^{2+} in the A site leads to a series of different structural distortions generally associated to antiferroelectric order. On the other hand the presence in the B site of d-elements may lead to the formation of magnetic systems.

This is the case of Pb_2MnWO_6 (PMW) and Pb_2CoWO_6(PCW). The former presents an orthorhombic structure [1] at room temperature with cationic ordering of the B site and symmetry-correlated shifts of Pb atoms giving rise to a global antiferroelectric character. The PMW perovskite shows at 45K a typical antiferromagnetic transition. The second system has a monoclinic incommensurate structure at room temperature [2] that, close to 230K, converts to the orthorhombic system showing the same structural features of PMW. For instance also PCW is antiferroelectric with a small poling field, and shows a magnetic transition detected at 7K.

In this work we have synthesized the series $Pb_2Mn_{1-x}Co_xWO_6$ ($0<x<1$). The PXRD and electron diffraction data suggest that the co-presence of Mn and Co stabilizes the crystal structure featuring PMW system. The investigated compositions are insulating with high dielectric permittivity at RT. The magnetic properties of the PMCW solid solutions show unexpected behaviour with transition temperatures well beyond 150K. Possibly, this could be ascribed to the presence of some different type of magnetic interaction with respect to the two end members.

[1] J. Blasco et al. J. Phys. Condens Matter 18 (2006) 2261-2271

[2] G. Baldinozzi et al. Acta Cryst. B56, (2000), 570-576.

TU-128

Competition of the ferromagnetic and C-type antiferromagnetic ground states in $La_{0.6}Tb_{0.2}Ca_{0.2}CoO_3$ perovskite

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The crystal and magnetic structure of $La_{0.6}Tb_{0.2}Ca_{0.2}CoO_3$ perovskite was determined from the powder neutron diffraction measured at the temperatures from 1.8 to 300 K. Magnetic properties were probed by the ac/dc magnetization measurements. The orthorhombic *Pbnm* cell with *a>b~c* is retained over the whole measured temperature range. The high temperature part of the magnetic susceptibility can be approximated by the Curie-Weiss law with effective moment $\mu_{eff}^2 = 28.6\ \mu_B^2$ and Weiss temperature $\theta = 22$ K. The value of the effective moment can be compared with a weighted sum of magnetic moments of 0.2 Tb^{3+} ($\mu_{eff} = 9.72\ \mu_B$), and 0.2 Co^{4+} and 0.8 Co^{3+}, both in the intermediate spin state (S = 1.5 and 1, respectively), which gives total $\mu_{eff}^2 = 27.5\ \mu_B^2$. The character of the low temperature part of the dc ZFC/FC and ac susceptibility indicates the formation of a cluster-glass phase with a freezing temperature $T_S = 49$ K and a frequency shift of T_f characterized by a parameter $K = 0.0026$. Emerging magnetic peaks in neutron diffraction data below $T_N = 12$ K reveal an antiferromagnetic order of Co ions of the C-type (linear ferromagnetic chains along *c*-direction coupled antiferromagnetically in the *ab*-plane). Orientation of the magnetic moments changes from *z*- to *y*-direction with lowering temperature and magnetic moment saturates at a value of 0.50 μ_B/Co. We explain this relatively low value by a phase separation of long-range ordered antiferromagnetic and glassy ferromagnetic clusters. Antiferromagnetic order is easily destroyed by the magnetic field and a metamagnetic transition to ferromagnetic state is observed already above 0.5 T at 2 K.

TU-129

Magnetic properties of $La_{0.9}Ag_{0.1}(Mn_{1-x}Co_x)O_3$ under pressure

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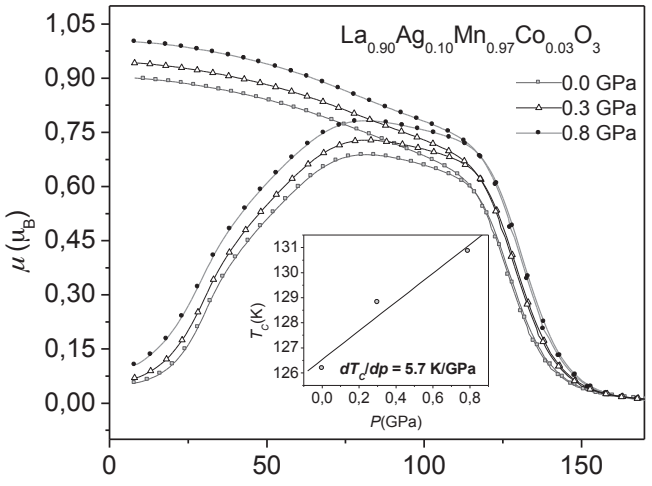
It is well known that the partial occupation of site *A* in ABO_3 by two different atoms e.g. one trivalent as La and one univalent as Ag, can tune the size mismatch of *A*- or *B*-site ions in the ABO_3-type perovskite and then will alter the Mn^{3+}–O^{2-}–Mn^{4+} network, which can manipulate the competition between the double-exchange, superexchange, and Coulomb interaction among Mn ions and finally the magnetotransport properties. Recently, Tang *et al.* [1] reported the synthesis and magnetic properties of Ag-doped manganite $La_{1-x}Ag_xMnO_3$ with the Curie temperature T_C considerably increased to about 310 K but the role of Ag in the enhancement of T_C in the $La_{1-x}Ag_xMnO_3$ system has been unresolved yet.

In our paper magnetic properties of $La_{0.90}Ag_{0.10}(Co_xMn_{1-x})O_3$ ceramics (x = 0.00, 0.01, 0.03) have been studied in pressure range up to 0.9 GPa. The preparation of the ceramic samples followed the malic acid gel method [2]. Hydrostatic pressure was generated by a CuBe pressure cell filled with a mixture of mineral oils serving as the pressure transmitting medium [3]. Magnetization measurements were performed in magnetic fields up to 5 T and in the temperature range between 1.8 K and 300 K by a SQUID magnetometer MPMS. Hydrostatic pressure increases T_C for all samples but the pressure effect is smaller for samples with higher content of Co e.g. the pressure coefficient $dTc/dp = 5.7$ K/GPa for x = 0.03 (see figure). Hysteresis loop is affected marginally; μ_s increases and H_c decreases with pressure.

[1] T.Tang et al., JMMM 222, 110 (2000)

[2] G. Gritzner et al., Applied Physics A-Materials Science & Processing 90, 359 (2008)

[3] J. Kamarád et al. Rev. Sci. Instruments 75, 5022 (2004)



Temperature dependence of magnetization under pressure was measured in magnetic field $\mu_0 H$ = 5 mT; insert shows pressure dependence of T_C.

TU-130

X-ray photoelectron spectroscopy and magnetic properties of $La_{1.2}R_{0.2}Ca_{1.6}Mn_2O_7$ perovskites with R = Pr, Nd, and Sm

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The magnetic properties of $La_{1.2}R_{0.2}Ca_{1.6}Mn_2O_7$ double layered manganites (R = Pr, Nd, Sm) are investigated by combining X-ray photoelectron spectroscopy (XPS) and magnetic measurements performed in the temperature range 4.2-600 K and magnetic field up to 12 T. The X-ray diffraction analysis shows that the polycrystalline nanopowders, synthesized by a sol-gel method, are single phase with a $Sr_3Ti_2O_7$-type tetragonal structure and grain sizes of 20-30 nm. The electronic structure of the three compounds is studied by analyzing the XPS valence band and core level spectra. The Mn 3s core level spectra show an exchange splitting of about 4.7 eV, from which the Mn formal valency was estimated to be around 3.65^+ [1]. This proves the existence of both Mn^{4+} and Mn^{3+} ions in $La_{1.2}R_{0.2}Ca_{1.6}Mn_2O_7$ where R = Pr, Nd, or Sm. All samples show a transition from a magnetic order state to a paramagnetic one below room temperature, with a decrease of the Curie temperature when La is substituted by Pr, Nd, or Sm. In the temperature range 400-500 K the magnetic susceptibility of all samples obeys a Curie-Weiss law. After considering the small contribution of the R ions to the effective magnetic moment, the calculated effective magnetic moments for the Mn atoms are around 4.2 μ_B in all samples, in excellent agreement with the data obtained from XPS spectra. The magnetic entropy changes were determined from magnetization isotherms and the relative cooling powers RCP(S) were calculated. A moderate magnetocaloric effect was found for all samples, with the maximum entropy change located at temperatures near the magnetic transition ones. The high RCP(S) values together with the broadened magnetic entropy curves suggest the possibility to use these materials for magnetic refrigeration devices.

[1] V.R. Galakhov et. al., Phys. Rev. B 65, 113102-113105 (2002).

TU-131

Low temperature investigation of magnetic phase separation in A(Ru,Mn)O_3 oxides (A= Ca, Sr)

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Among the ruthenium oxides, isostructural metallic $SrRuO_3$ and $CaRuO_3$ show a rich variety of electronic and magnetic properties [1-4]. Substitution of manganese for ruthenium in the $SrRuO_3$ perovskite is capable of inducing unexpected magnetotransport effect owing to the fact that $SrRuO_3$ is a metallic itinerant ferromagnet, whereas $SrMnO_3$ is an insulating antiferromagnet. Ferromagnetism occurs at relatively large substitution $x \geq 0.1$ in the case of $CaRu_{1-x}Mn_xO_3$ [3-4].

We report results of our macroscopic magnetic and muon spin relaxation (μSR) measurements on high quality polycrystalline samples $SrRu_{1-x}Mn_xO_3$ and $CaRu_{1-x}Mn_xO_3$ ($0 \leq x \leq 1$). For $SrRu_{1-x}Mn_xO_3$ we have found a spin glass-like behavior for $0.2 \leq x \leq 0.4$. The maximum value for T_C was about 200 K for x = 0.6, while the corresponding T_N = 118 K, in $CaRu_{1-x}Mn_xO_3$. The spin glass-like behavior was found from "classical" magnetic measurements: zero field cooled and field cooled magnetization as well as from ac susceptibility measurements. We proved that such a behavior is a result of the magnetic phase separation in the system. With its high sensitivity to signals both from paramagnetic and ordered volume fractions, muon spin relaxation (μSR) is a probe well suited to shed new light on magnetic phase separated systems. We analyzed the phase separation scenario in the two systems and we concluded that this coexisting state is not the mixed state of FM and AFM interactions among localized spins, but the coexistent state of ferromagnetic and antiferromagnetic spin fluctuations.

[1] J. M. Longo et al., J. Appl. Phys. 39, 1327-1328 (1968).
[2] G. Cao et al., Phys. Rev.B 56, 321-329 (1997).
[3] Xiao-Yu Zhang, et al., J. Phys.: Condens. Matter 19 , 266211 (2007)
[4] H Kawanaka et al, J. Phys.: Condens. Matter 21, 296002 (2009).

TU-132

Giant Spontaneous Generation of Voltage in $Pr_{0.6}Ca_{0.4}MnO_3$ Single Crystal

A. Abramovich [1], L. Koroleva [1], A. Morozov [1], Y. Dolzhenkova [1], R. Szymczak [2]

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It is known that in $Pr_{1-x}Ca_xMnO_3$ manganites the ferromagnetic metallic phase is absent. In the concentration area of $0.3 < x < 0.5$ an inhomogeneous magnetic insulating ground state takes place, where charge and orbital ordered antiferromagnetic phase of CE-type coexists with the ferromagnetic phase. In our work we have studied $Pr_{0.6}Ca_{0.4}MnO_3$ single crystal grown by the floating zone method. In this compound charge and orbital ordering occurs at T_{CO} = 220 K, and an antiferromagnetic ordering occurs at T_N = 150 K. In this sample we have found the spontaneous generation of voltage (SGV). The voltage observed between the ends of the sample are considered as spontaneous since the current sources in a closed circuit are absent. The voltage value depends on the cooling rate of the sample. SGV increases with decreasing temperature, at first slowly (in the temperature interval 300 K – T_{CO}), then more rapidly (T_{CO} – T_N). Starting from T_N SGV is increasing exponentially and

reaches a giant value of 5.2 mV at 85 K (the lowest temperature at which the measurements were performed) at cooling rate 5.6 K/min. The magnetic field influences on SGV value within the temperature range 85<*T*<150 K only. SGV value is reduced by 2.5% at a magnetic field of 10 kOe at 85 K. We are supposed that SGV is connected with the existence in the sample of areas having different concentration of charge carriers.

TU-133

The magnetic properties of iron-cobalt perovskite phases are controlled by the heterogeneous distribution of the oxidation states

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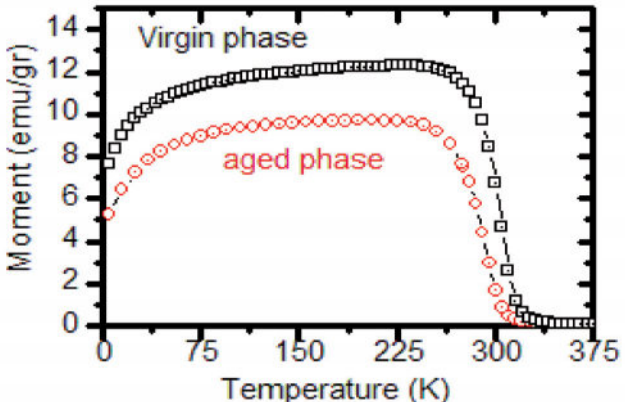
$SrFe_{1-x}Co_xO_{3-\delta}$ system is of great interest for numerous reasons. For example, one can underline series of derived-perovskite structures are expected depending on the oxygen content since the both end compounds ($Sr_8Fe_8O_{23}$ and $Sr_8Co_8O_{23}$) and $Sr_8Fe_4Co_4O_{23}$ do show oxygen vacancies ordering at room temperature [1]. About magnetic properties, $SrFe_{0.5}Co_{0.5}O_3$ is known to be room-temperature ferromagnet with metallic conductivity when the oxygen deficiency δ tends to zero [2], which makes it a good candidate for magnetic refrigeration applications based on Magneto-Caloric Effects [3].
On this symposium "Perovskite and Multiferroics", we propose to expose our last fundamental work performed on $SrFe_{0.5}Co_{0.5}O_{3-\delta}$ perovskite materials with a special attention paid on the relationship in between the magnetic properties and the oxidation state distribution depending on the oxygen deficiency δ.
Starting from $Sr^{2+}Fe^{3+}_{0.14}Fe^{4+}_{0.36}Co^{3+}_{0.50}O_{2.68\pm0.02}$, we highlight that the distribution of cobalt and iron oxidation states are heterogeneous. We will then discuss the ferromagnetic properties after an electrochemical oxidation process to reach δ=0.17 and after a reduction process following an air aging [4].

[1] J.P. Hodges, S. Short, J.D. Jorgensen, X. Xiong, B. Dabrowski, S.M. Mini, C.W. Kimbal : J. Solid State Chem. 151, 190-209 (2000) ; R. Le Toquin, W. Paulus, A. Cousson, C. Prestipino, C. Lamberti, J. Am. Chem. Soc. 128, 13161-13174 (2006) ; K. **Świerczek**; B. Dabrowski,L. Suescun,S. Kolesnik, J. Solid State Chem. 182, 280–288 (2009)
[2] Kawasaki, S.; Takano, M.; Takeda, Y. J. Solid State Chem.121, 174 (1996).
[3] C. Yin, Q. Liu, R. Decourt, M. Pollet, E. Gaudin, O. Toulemonde J. Solid State Chem 184, 3228 (2011)
[4] O. Toulemonde, J. Abel, C. Yin, A. Wattiaux, and E. Gaudin : Chem. Mater. 24, 1128 (2012)



TU-134

Thermobaric treatment effect on the electro- and magnetoresistance of single crystal and polycrystalline $Nd_{0.7}Sr_{0.3}MnO_3$

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Both magnetoresistive and electroresistive properties such as colossal electroresistance (CER), electric pulse induced resistance switching effect (EPIR), etc. in $R_{1-x}D_xMnO_3$ compounds (*R*- rare-earth, *D*- alkaline earth metals) open perspectives for a potential application of these materials in resistance random access memory elements. As the electrotransport properties of the manganites strongly depend on the structural and atomic defects, oxygen vacancies, etc., a new way to regulate the electroresistance by tuning microstructure under high pressure conditions was explored.
Single crystal and polycrystalline samples of $Nd_{0.7}Sr_{0.3}MnO_3$ were subjected to thermobaric treatment at a quasihydrostatic pressure of 9 GPa and a temperature of 1000C (HPT) for 10 min with subsequent quenching to 300K and 80K. X-ray and SEM- analysis showed that the HPT-treated samples have preserved the orthorhombic pseudoperovskite structure Pnmb with slightly changed lattice parameters. A remarkable change of temperature dependence of the resistivity was observed in the polycrystalline samples $Nd_{0.7}Sr_{0.3}MnO_3$ after the thermobaric treatment. The resistivity value increased by two orders of magnitude and the Metal-Isolator transition temperature (T_{MI}) decreased by 50-100 K For these samples also a significant electroresistance (700%) and magnetoresistance (30%) effects were observed.
In $Nd_{0.7}Sr_{0.3}MnO_3$ single crystal the decrease of T_{MI} after HPT is more modest- of about 20K. The electroresistance and magnetoresistance effects are less pronounced than in the polycrystalline sample of the same nominal composition.
The results are discussed in the framework of different contribution to the charge transport mechanisms in rare-earth-doped manganites.
The work was supported by the Ural Division of the Russian Academy of Sciences (Grant No. 08-02-92205)

TU-135

Structural distortion induced magnetic anomalies in $LaMn_{0.5}Co_{0.5}O_3$ single crystals

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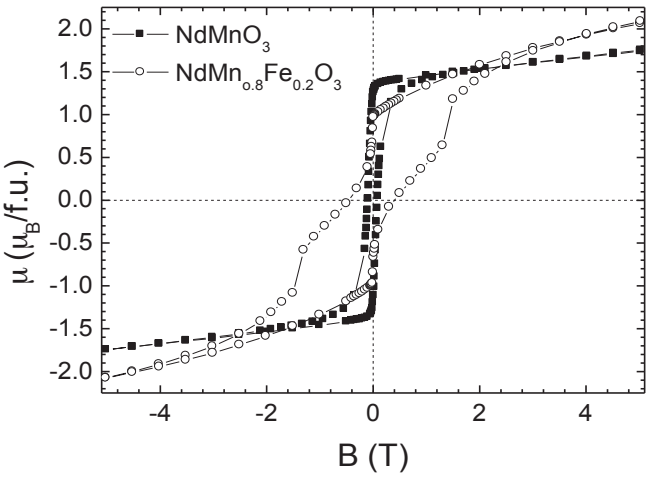
For the first time we have successfully grown oriented single crystal of the ferromagnetic-insulator and distorted perovskite system $LaMn_{0.5}Co_{0.5}O_3$ using a four-mirror optical float zone furnace. We have observed a very prominent strain dependent

structural distortion in the as grown crystal compared to that of the strain relaxed one from, both powder as well as the single crystal x-ray diffraction analysis. This induced strain, abruptly changes the physical property of the two samples. The ac susceptibility measurement shows a distinct enhancement (~ 6 K) of the ferromagnetic transition temperature (T_C) in the as grown strained crystal (T_C~ 149 K) compared to that for the strained relaxed one (T_C~ 143 K). The temperature dependence of the stretching and bending mode in the Raman spectroscopy provides direct evidences of this huge structural distortion. The bending mode frequencies show strain induced oxygen octahedral tilting in the Pbnm perovskite structure. Additionally, the corresponding stretching mode suggests increase of the transition metal- oxygen bond length d_{TM-O} for the strain-induced crystal. Besides, this temperature dependent stretching mode and its full width half maxima shows that the system possesses a strong spin phonon coupling around the corresponding T_C in both the strained as well as the strain relaxed crystal.



The magnetization curves of $NdMnO_3$ and $NdMn_{0.8}Fe_{0.2}O_3$ measured at T = 2 K.

TU-136

Magnetism study in $NdMn_{1-x}Fe_xO_3$ doped system.

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Both, $NdMnO_3$ and $NdFeO_3$ compounds exhibit interesting magnetic properties due to two different magnetic sublattices. In case of $NdMnO_3$, the Mn sublattice orders at T_N = 82 K with magnetic moments parallel to *b*-axis and Nd sublattice orders feromagnetically (moments parallel to *c*-axis) at $T_1 \approx 20$ K [1]. In $NdFeO_3$, Fe sublattice orders above room temperature and undergoes spin reorientation in temperature range 70 – 160 K [2], but Nd sublattice orders only at very low temperatures ($T \approx 1.5$ K). Despite very different magnetic behaviour of both compounds, there is only limited information on the effects of iron substitution on the manganese site [3].

We have prepared polycrystalline samples of $NdMn_{1-x}Fe_xO_3$ ($0 \leq x \leq 1$) compounds by melting the stoichiometric amount of starting oxides in the vertical zone mirror furnace. We have measured the basic magnetic properties and studied its evolution with iron doping. We have found that for small iron doping both transition temperatures decrease, but hysteresis loop broadens and changes from simple, ferromagnetic-like, to more complicated multistep curve (see figure). Also, on the zero-field-cooled and field-cooled magnetization data we have found indications for pole inversion effect.

The study of higher iron concentrations ($x > 0.2$) is still in progress. We also attempt to grow single crystals by float zone method and we believe that we will be able to present the complete set of experimental data and interpretation for the full concentration range.

[1] T. Chatterji, B. Ouladdiaf and D. Bhattacharya, J. Phys.: Condens. Matter 21, 306001 (2009)

[2] W. Sławiński, R. Przeniosło, I. Sosnowska and E. Suard, J. Phys.: Condens. Matter 17 4605 (2005)

[3] I.O. Troyanchuk, J. Magn. Magn. Mater. 231 53 (2001)

TU-137

Effect of pressure on magnetic properties of $Bi_{0.4}Ca_{0.6}Mn_{1-x}Ru_xO_3$ manganites: suppressed exchange bias

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Pressure effects on the magnetization of Ru-doped charge-ordered manganite $Bi_{0.4}Ca_{0.6}Mn_{1-x}Ru_xO_3$ (x = 0.1, 0.2) were investigated in the temperature range 5 - 290 K and under pressure up to ~10 kbar. It was found that the x = 0.2 sample is mostly ferromagnetic (FM) while the x = 0.1 composition exhibits a FM cluster glass behavior and exchange bias (EB) effects at low temperatures. The EB described by exchange bias field $H_E = -(H_1+H_2)/2$, where H_1 and H_2 are the negative and positive fields at $M = 0$, and remanence asymmetry $M_E = (M_1+M_2)/2$, where M_1 and M_2 are the magnetization values at $H = 0$. Both, H_E and M_E/M_S (M_S - spontaneous magnetization), show a similar temperature dependence, see Fig. 1. Moreover, the simple linear relationship $M_E/M_S \mu H_E$ proposed for single-domain FM particles within antiferromagnetic (AFM) matrix [1] holds well between 5 and 50 K, see the inset of Fig. $Bi_{0.4}Ca_{0.6}Mn_{0.9}Ru_{0.1}O_3$ demonstrates a substantial pressure-enhanced ferromagnetism evidenced by ~70% increase in M_S at 10 K under 10.3 kbar. An applied pressure strongly increases the FM to AFM phase ratio leading to a notable decrease in both coercive field H_C, and H_E. We show that the observed pressure-induced changes of M_S, H_C and H_E in $Bi_{0.4}Ca_{0.6}Mn_{0.9}Ru_{0.1}O_3$ may be well described within a simple model for the system of FM size-variable clusters embedded in an AFM matrix. Our interpretation is based on the assumption that an applied pressure does not change the topology of phase separation but leads to an increase in the diameter of spherical FM clusters, keeping their concentration invariable.

[1] D. Niebieskikwiat and M. B. Salamon, Phys. Rev. B. 72, 174422 (2005)

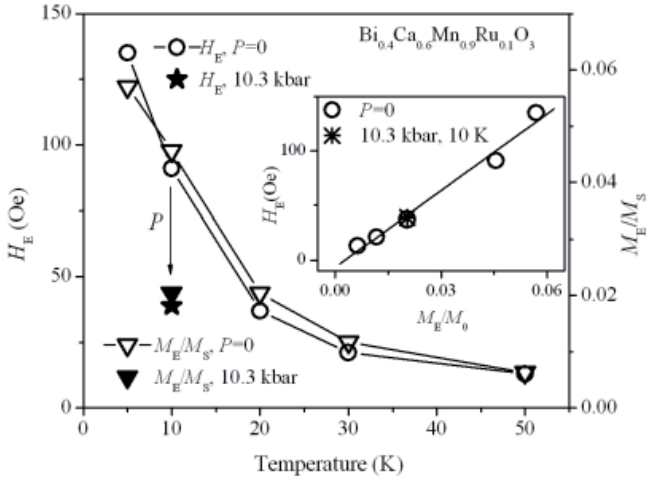
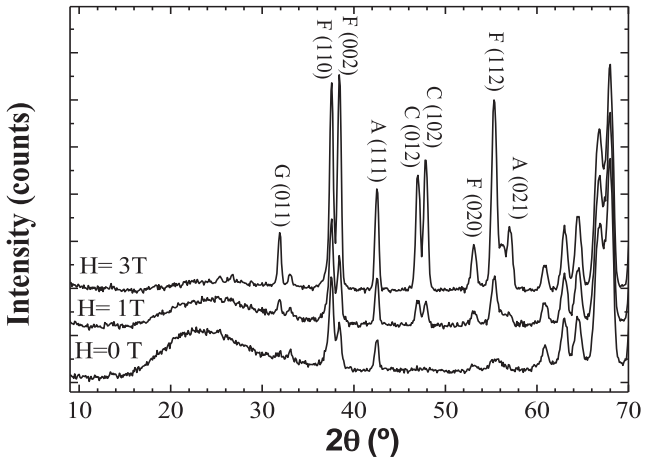


Fig. 1 $H_E(T)$ and $M_E/M_S(T)$ for x=0.1 sample at $P = 0$, and at 10.3 kbar and 10 K.



Neutron patterns of Tb_2MnCoO_6 at different magnetic fields.

TU-138

Metamagnetic transition in Tb_2MnCoO_6

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Tb_2MnCoO_6 has been obtained as single phase. It belongs to the family of double perovskites adopting a monoclinic cell with $P2_1/n$ space group. Refinement of the neutron powder pattern at room temperature reveals the presence of '*antisite*' defects (28%) and the refined bond lengths suggest the preponderance of Mn^{4+} and Co^{2+} cations in the cell. Magnetic properties have been studied using dc magnetization and neutron diffraction. The temperature dependence of the magnetization reveals a magnetic transition at ~100 K with a strong irreversibility between ZFC and FC conditions. However, neutron diffraction shows the onset of a ferromagnetic contribution at the same temperature. This property is ascribed to the ferromagnetic superexchange interaction between Mn^{4+} and Co^{2+} cations.

The most striking property of this compound is the presence of a field induced transition at low temperature. This is revealed in some magnetic hysteresis loops below 100 K where, in addition to the spontaneous magnetization, the presence of a plateau is noticed. We have studied the origin of this type of metamagnetic transition collecting powder neutron patterns as a function of both temperature and magnetic field. Some magnetic peaks appear in the pattern after applying magnetic field as it is shown in the inserted figure. The patterns have been successfully refined considering the strong magnetic anisotropy of the Tb^{3+} cation and the geometry of the measurement. The refinements indicate that the new peaks arise from the long range magnetic ordering of Tb^{3+} moments in the *ab*-plane induced by the magnetic field. The arrangement is a combination of C_xF_y and C_yF_x types using the Bertaut's notation [1]. The ferromagnetic ordering of Mn and Co moments continues after applying the magnetic field without noticeable changes.

[1] E. F. Bertaut, J. de Physique Colloque C1, 462 (1971).

TU-139

The irreversibility in $Sm_{0.55}Sr_{0.45}Mn_{1-x}Co_xO_3$ manganites

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The doped perovskite manganites $R_{1-x}A_xMnO_3$, with R=rare-earth and A=alkaline–earth, have fascinated material scientis due to their interesting properties such as colossal magnetoresistance(CMR), charge ordering and electric phase separation [1]. In $R_{1-x}Sr_xMnO_3$ (R=Ca, Pr, Na, Sm, and Eu), the competition between ferromagnetic phase and charge/orbital ordered insulating phase has been described comprehensively [2].When R=Sm and x=0.45 the Curie temperature T_c is strongly suppressed and CMR is enhanced [3]. In this work, we have studied the irreversible magnetization between zero-field-cooled(ZFC) and field-cooled(FC) states of $Sm_{0.55}Sr_{0.45}Mn_{1-x}Co_xO_3$ manganite. X=0 sample shows the typical ferromagnetic transition. However the T_c is reduced as Co-doping increases, showing the absence of the double exchange Mn^{3+}-Mn^{4+} ions interaction. Co-doped samples show a large magnetic irreversibility and the temperature dependence of thermoremanent magnetization(TRM) is close to the difference of σ_{ZFC}-σ_{FC} magnetization, suggesting the glass behaviour of those compounds.

[1] Y. Tokura, Colossal Magnetoresistive Oxides, Gordon and Breach, New York (2000)
[2] Y. Tomioka and Y. Tokura, Phys. Rev. B 70, 014432 (2004)
[3] M. Egilmez, K. H. Chow, and J. Jung, Appl. Phys. Lett. 89, 062511 (2006)

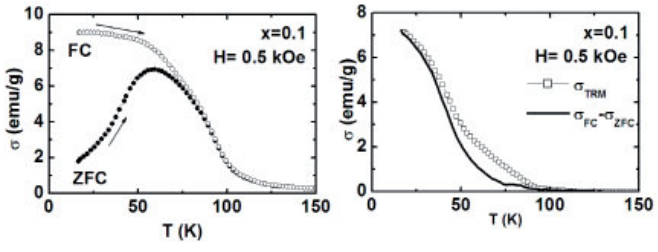

Figure 1. Temperature dependence of magnetization σ (T) and TRM between FC and ZFC magnetization(σ_{FC}- σ_{ZFC}) for $Sm_{0.55}Sr_{0.45}Mn_{0.9}Co_{0.1}O_3$ measured at the external field of H=0.5

kOe.

TU-140

Deconstructing the magnetocaloric effect in a phase separated system

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The magnetocaloric effect (MCE) is the change of entropy, enthalpy or temperature induced by the application of an external magnetic field [1]. Besides the technologic impact due to the possibility of development of magnetic refrigeration systems, the MCE provides an extremely sensitive tool for the study of magnetic systems.

In this work we present a deep study on the MCE in the phase separated manganite La0.305Pr0.320Ca0.375MnO3 using different methods. Measuring differential thermal analysis we can obtain the adiabatic temperature change. We compare this result with those extracted from magnetization curves using a Maxwell relation and Clausius-Clapeyron equation. Heat capacity measurements as function of the applied magnetic field are also presented to complete the general picture.

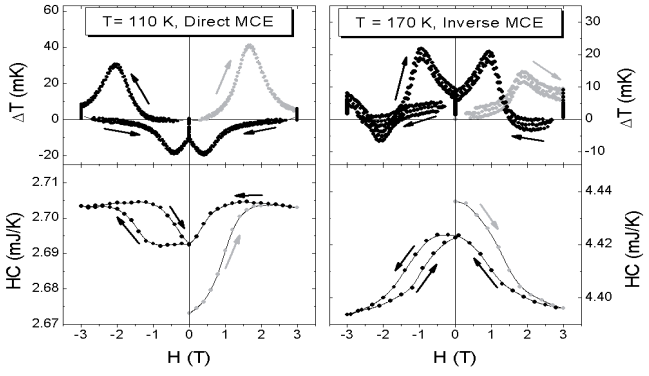
In the temperature region between 150 and 180 K an inverse magnetocaloric effect is observed and analyzed in the framework of three phase coexistence [2].

Another interesting feature is the particular behaviour presented by the “virgin curves”, probably related with a frozen state induced by the intrinsic disorder of the system [3].

[1] S. Spichkin, The Magnetocaloric Effect and its Applications , IOP Publishing Ltd., Bristol (2003)

[2] M. H. Phan, M. B. Morales, N. S. Bingham, H. Srikanth, C. L. Zhang and S. W. Cheong Phys. Rev. B 81, 094413 (2010)

[3] L. Ghivelder and F. Parisi, Phys. Rev. B 71, 184425 (2005).



Differential thermal analysis and heat capacity as function of the magnetic field at two selected temperatures with direct and inverse magnetocaloric effect.

TU-141

Magnetooptical elements on the base of manganites for optoelectronic: new prospects

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Doped manganites with colossal magnetoresistance (CMR) are still being under consideration as promising functional material for magnetooptical devices. We demonstrated that besides CMR a giant negative magnetotransmission (MT) and a giant positive magnetoreflection of natural light can be obtained both in the visible and infrared range, in the wide temperature region in manganites’ crystals, epitaxial films and nanostructures [1,2]. These effects achieve up to a few tens of percent in a weak magnetic field nearly 3kOe and were proposed to creation, e.g. twinned modulator of electromagnetic radiation [3]. The results and phenomenological calculations of the effects will be discussed. The important problem concerns with the obtaining of huge effects at lower magnetic field or increasing the optical efficiency of magneto-optical elements.

In this work, optical transparent composites made from mixture of manganite powders in different matrix were studied. The discovered value of MT effect in these composites is comparable with the one for manganite films. The origin of MT as well as magnetic properties and the magnetoreflection of composites and finding new matrix are being studied. It is interesting that the obtained magneto-optical composites can be in different geometrical form of various sizes (e.g. lens) in comparison with films-layer structures grown by any typical methods. Moreover, such kind of composites is easy to produce in production quantities. Therefore, composites on the base of manganites may be proposed as magnetooptical elements for optoelectronics.

Supported by the program of DPS RAS “Physics of new materials and structures”, grant MK-1048.2012.2 and RFBR № 10-02-00038.

[1] Yu.P. Sukhorukov, A.V. Telegin and A.B. Granovsky, JETP. 138, 402 (2010)

[2] A.B. Granovskii, Yu.P. Sukhorukov and A.V. Telegin, JETP. 112, 77 (2011)

[3] Yu.P. Sukhorukov, B.A. Gizhevskii et al., Rus-Patent 2439637. Bul.1 from 10.01.2012.

TU-142

Pr/Mn (co)substitution-induced structural and magnetic phase transitions in $BiFeO_3$ perovskite

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$BiFeO_3$ remans the only material with the proven multiferroic behavior far above the room temperature. The compound crystallizes in the noncentrosymmetric rhombohedral structure (S.G. *R3c*) compatible with the polarization directed along the main hexagonal axis. Magnetic moments of Fe^{3+} ions form the cycloidal-modulated *G*-type antiferromagnetic structure. Possibility to tune and control the multiferroic behavior of $BiFeO_3$ via a chemical substitution motivated numerous investigations of the related solid solutions. In this communication, we are reporting on crystal structure and magnetic properties of the $Bi_{1-x}Pr_xFe_{1-y}Mn_yO_3$ ($x,y \leq 0.3$) compounds at room temperature. In the parent $Bi_{1-x}Pr_xFeO_3$ series, a rhombohedral (*R3c*) and two orthorhombic (*Pnam* and *Pnma*) structural modifications were found. The *R3c* phase is stable at $0 \leq x < 0.12$. The homogeneous *Pnam* structure is realized at $0.16 \leq x \leq 0.25$. Single-phase compounds with the *Pnma* structure can be obtained at $x \geq 0.28$. In the intermediate compositional ranges, a two-phase structural state is formed. The rhombohedral compounds possess the main antiferromagnetic phase and exhibit a metamagnetic behavior associated with the field-induced removal of the spatially-modulated antiferromagnetic structure; decrease of the threshold field of the magnetic phase transition and appearance of the small remnant magnetization are observed with increasing Pr content. The orthorhombic compounds with the *Pnam* and *Pnma* structures are weak ferromagnetic and demonstrate the spontaneous magnetization close to that releasing upon the field-induced suppression of the spin cycloid in the rhombohedral phase. Mn doping effectively modifies the initial *R3c* and *Pnam* structures to stabilize new phase demonstrating incommensurable structural modulation. Magnetic behavior of the Mn-containing samples changes in correlation with the evolution of their structural state. Within compositional range of the rhombohedrally distorted compounds, the manganese substitution gives rise to suppression of the dominant antiferromagnetic interaction. In the weak ferromagnetic Mn doping-induced phase, a gradual decrease of room temperature spontaneous magnetization takes place with increasing Mn content.

TU-143

Magnetic characterization of manganese cobaltite spinel doped with bismuth using neutron diffraction data

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Perovskite and spinel materials presenting multiferroic properties as well as interplay between ferroelectricity and magnetism, have received renewed interest since a large variety of chemical elements can be located on specific positions, substituting the cations in these structures. Thanks to the Bi insertion, the magnetic properties of the $Bi_xCo_{2-x}MnO_4$ spinels can be enhanced [1]. This work describes the synthesis and characterization of $Bi_xCo_{2-x}MnO_4$ ($0.0 \leq x \leq 0.3$) obtained by a polymeric precursors approach, followed by specific thermal processing. Materials were structural and morphologically characterized by XRD together with Rietveld refinement and SEM-EDX. Bismuth insertion provokes a competition between Co and Mn to occupy the octahedral sites in the manganese cobaltite spinels $Co_xMn_{3-x}O_4$ [2], and triggers the formation of a mixed-valence state. Therefore, a physical characterization is imperative, where the $Co^{2+}/Co^{3+}/Mn^{2+}/Mn^{3+}/Mn^{4+}$ cations should be accurately identified. The $Bi_xCo_{2-x}MnO_4$ samples, crystallizing in the *Fd3m* cubic spinel, were studied in a SQUID magnetometer followed by Neutron Diffraction characterization at various temperatures. The inverse susceptibility exhibited ferrimagnetic behaviour, as also shown by the strong antiferromagnetic and ferromagnetic interactions present in the *ZFC*/*FC* curves. The M(H) loops performed below T_C showed larger loop areas with decreasing temperature, indicating enhanced ferromagnetism. Neutron diffraction allowed identifying the cation elements, showing a redistribution of Mn and Co on the tetrahedral and octahedral sites in the structure and the presence of mixed valence states of Mn (Mn^{2+} and Mn^{3+}). The effective moment, evaluated from the magnetic susceptibility, agrees with data of the magnetic structure obtained by neutron diffraction. The position of magnetic atoms, obtained from the *K* diffusion vector, and their magnetization direction can explain the ferrimagnetic behaviour of the $Bi_xCo_{2-x}MnO_4$ compounds.

[1] R. Kumar. et. al. J.Appl. Phys. **105**, 07D910 (2009)
[2] N.E. Rajeevan. et.al. J. Phys. Condens. Matter. **21,** 406006 (2009)

TU-144

Magnetic dynamic effects in $TbMn_{1-x}(Ga/Sc)_xO_3$ samples (x=0.4,0.5,0.6)

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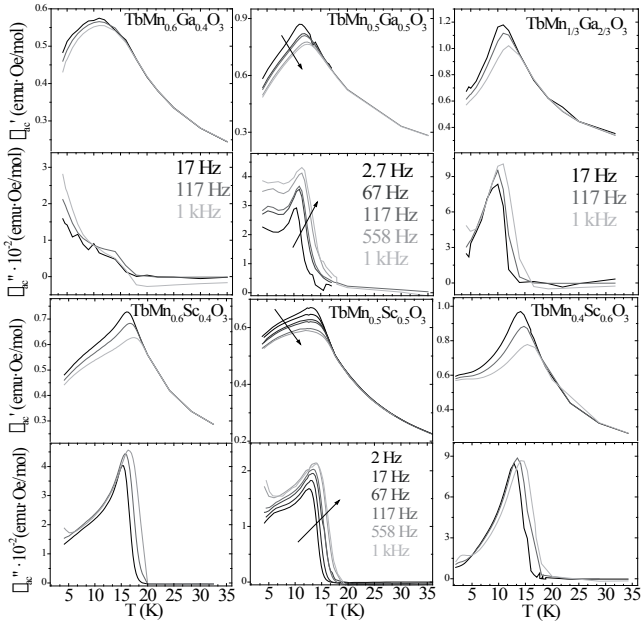
Contrary to the behaviour of $LaMn_{1-x}(Ga/Sc)_xO_3$ diluted manganites, Mn substitution by non-magnetic ions in $TbMnO_3$ is detrimental to magnetic long range ordering [1]. We have studied the magnetic behaviour of $TbMn_{1-x}(Ga/Sc)_xO_3$ powder samples at the intermediate region, (x=0.4, 0.5, 0.6), by means of ac magnetic susceptibility and dc magnetization.
Neutron diffraction experiments have shown that these samples do not display long range magnetic ordering at low temperatures. However, as shown in the figure, these samples show magnetic dynamic behaviour. In all cases, magnetic ac susceptibility displays a peak at low temperatures whose intensity strongly depends on the frequency of the alternating field applied. In particular, the peak at χ' lowers its intensity and the peak in χ'' is more intense while the frequency increases. Besides this fact, the peak always shifts to higher temperatures when the frequency increases. These dynamical processes are characteristic of a spin glass system, where there is also magnetic disorder leading to magnetic frustration [2]. The use of Vogel-Fülcher law and the critical slowing down law leads to similar good results. From the fits we obtained higher relaxation times for these processes than in a canonical spin glass system, so the magnetic moments of Mn interact to rearrange in nanometric clusters, and they freeze to give rise to a cluster-glass behaviour [3].
In addition, the ZFC and FC curves show irreversibility at low

magnetic fields (H=100, 2500 Oe), which corroborates the cluster-glass conduct.

[1] J. Blasco et al. Phys. Rev. B 66, 174431 (2002). J. Blasco et al., J. Phys.: Condens. Matter 24, 076006 (2012).
[2] J. Mydosh, J. Magn. Magn. Mater. 157, 606 (1996).
[3] De K, Patra M, Majumdar S and Giri S J. Phys. D: Appl. Phys. 40, 7614 (2007)



Ac susceptibility measurements of $TbMn_{1-x}(Ga/Sc)_xO_3$, $0.4 \leq x \leq 0.6$, at different frequencies and H_0=4 Oe.

TU-145

^{151}Eu Mössbauer study of the magneto-electric properties of the multiferroic $Eu_{0.8}Y_{0.2}MnO_3$

M. Lantieri [1], G. Spina [2], *L. Cianchi* [1], F. Del Giallo [1]
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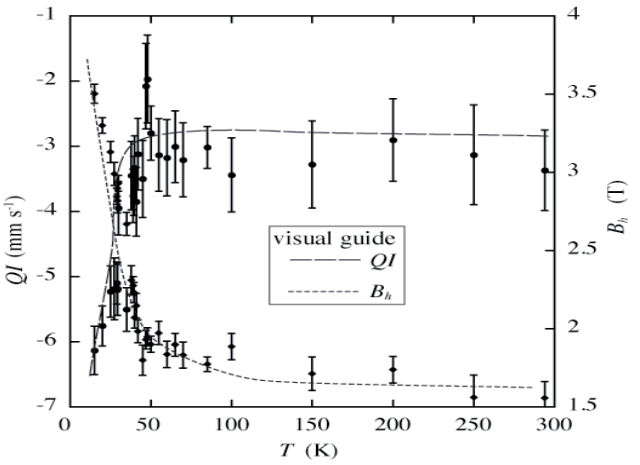
We report a study of *f*-electrons contribution to the magnon-phonon coupling in multiferroic $Eu_{0.8}Y_{0.2}MnO_3$, from the ^{151}Eu Mössbauer spectra collected in the temperature range 16-294 K. The analysis of the spectra shows a strong correlation between the temperature variations of the hyperfine magnetic field B_h and of the principal component V_{zz} of the electric field gradient tensor. In particular, between 16 and 30 K, B_h decreases and $QI = eQV_{zz} < 0$ (Q = ground state nuclear quadrupole moment) increases with T, both keeping practically constant for higher temperatures, see figure. This result could denote an interference of the *f*-electrons in the magnetic properties of the compound and in electromagnons formation [1-2].

[1] J. Hemberger, F. Schrettle, A. Pimenov, P. Lunkenheimer, V. Yu. Ivanov, A. A. Mukhin, A. M. Balbashov, and A. Loidl, Phys. Rev. B **75**, 035118 (2007)
[2] R. Valdés Aguilar,1 A. B. Sushkov, C. L. Zhang, Y. J. Choi, S.-W. Cheong, and H. D. Drew, Phys. Rev. B **76**, 060404(R) (2007)



Trend of QI and B_h vs. T

TU-146

Field dependent giant reversal of magnetization in Bi_2FeMnO_6, an RT multiferroic double Perovskite

D. Delmonte [1], F. Mezzadri [2], E. Gilioli [2], G. Calestani [3], C. Pernechele [1], M. Solzi [1], R. Cabassi [2], G. Spina [4]
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We have recently synthesized Bi2FeMnO6, a novel multiferroic compound belonging to the class of bismuth-based double perovskites. In this system the electric properties are ascribed to the stereochemical effect induced by the 6s2 lone pair of the Bi ion, while magnetism depends on the complex pattern of interactions involving iron and manganese. Single-crystal X-ray diffraction allowed us to determine the crystallographic structure of the system, suggesting the presence of antiferroelectricity. The magnetic characterization indicates an unconventional magnetic behavior producing a complex ferrimagnetic transition around 500 K followed, at lower temperatures, by a field-dependent giant reversal of the magnetization. We registered the higher negative value of the magnetization -0.75emu/g, for an applied field of 70 Oe. Larger fields gradually inhibit the magnetization reversal process, which is completely suppressed at 2700 Oe. The reversal of magnetization is usually interpreted as the competition of DM interactions with single-ion anisotropy [1], however our studies show a completely different nature of this complex phenomenon. Indeed Fe-57 Mossbauer spectroscopy revealed the presence of iron ions with dramatically different behavior: a little part of them being ordered parallel to the applied field at RT, and a large population of paramagnetic ones that gradually align antiferromagnetically with respect to the first class of ions as the temperature is decreased. As a result, in absence of a sufficiently large applied field, the magnetization goes down to negative values below 250 K. Moreover, the study of the electric permittivity as a function of temperature reveals the presence of anomalies in concomitance with the start of the magnetization reversal process, suggesting the possibility of magnetoelectricity in Bi2FeMnO6.

[1] P.Mandal et al., Phys. Rev. B 82, 100416(R) (2010)

TU-147

Magnetic and dielectric characterisation of $BiMn_7O_{12}$ multiferroic polymorphs

C. Pernechele [1], M. Buzzi [1], F. Mezzadri [2], G. Calestani [3], M. Solzi [1], A. Migliori [4], R. Cabassi [2], F. Bolzoni [2], E. Gilioli [2]

(1) Dipartimento di Fisica, Università di Parma, 43124 Parma, Italy, (2) IMEM-CNR, 43124 Parma, Italy, (3) Dipartimento di Chimica e Giaf, Università di Parma, 43124 Parma, Italy, (4) IMM-CNR, 40129 Bologna, Italy

Magnetoelectric multiferroics are attracting wide interest concerning the realization of multifunction devices. Applications can be found out in data storage devices as well as in spintronic one, exploiting the additional degrees of freedom given by ferroelectricity [1]. On the other hand, in the field of solid-state physics, understanding the conditions of coexistence of magnetism and ferroelectricity is a challenging task. An interesting material belonging to the class of lone-pair driven multiferroics is the quadruple perovskite $BiMn_7O_{12}$, in which ferroelectricity is induced by the stereochemical effect produced by the Bi^{3+} ion. In this work we present magnetic and dielectric characterization carried out on $BiMn_7O_{12}$ samples obtained by solid state reaction synthesis in high pressure and high temperature conditions [2]. The structure, solved from single crystal XRD data, shows the existence of three different polymorphs: monoclinic, rhombohedral and cubic. χ(T) measurements confirm that the low temperature ordered state for each phase is antiferromagnetic with a small net momentum that can be ascribed to spin canting induced by Dzyaloshinskii-Moriya interaction. A peculiar hysteresis loop shape can be associated to each crystal structure: while the monoclinic phase presents a major square loop, rhombohedral and cubic samples show sheared loops appearing to be minor ones in the same field range. From the dielectric characterization appears that while monoclinic sample presents two clear peaks at the two magnetic ordering temperature confirming magnetoelectric coupling, the rhombohedral one shows no clear signs of dielectric constant anomalies at the magnetic transition temperatures. Moreover, TEM characterization evidenced for the rhombohedral sample short range polar twinning (extending on few tens of nanometers) suggesting also this phase to be ferroelectric.

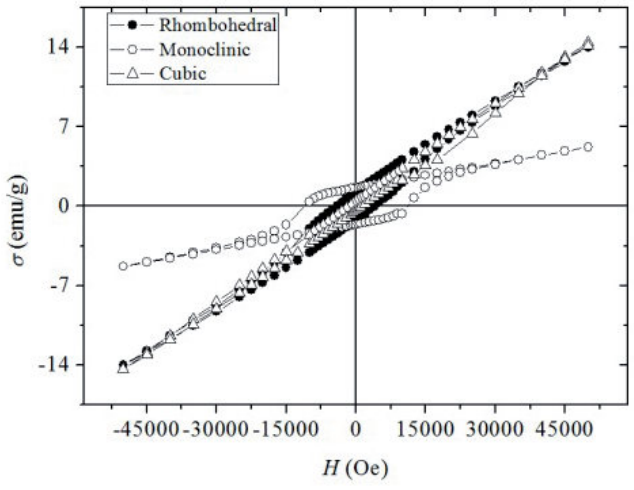

Figure: 5K M(H) hysteresis loops oh the three polymorphs.

[1] R. Ramesh et al. Nat. Mater. 6 21-29 (2007)
[2] F. Mezzadri et al. Phys. Rev. B 79, 100106 (2009)

TU-148

Ferroelectric polarization induced by magnetic ordering in delafossite $AgFeO_2$

N. Terada [1], D. Khalyavin [2], P. Manuel [2], Y. Tsujimoto [1], K. Knight [2], P. Radaelli [3], H. Suzuki [1], H. Kitazawa [1]

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$AgFeO_2$ belongs to the triangular lattice antiferromagnet delafossite family. While a similar system, $CuFeO_2$, has been extensively investigated as a frustrated magnet and a multiferroic material[1,2], the magnetic and dielectric properties of $AgFeO_2$ have not been investigated so far due to the lack of a high quality sample. Although a neutron diffraction measurement was reported recently [3], no detailed magnetic structure was reported. In the present work, we have performed neutron diffraction and dielectric measurements with a high quality powder sample of $AgFeO_2$.
The neutron diffraction experiments were carried out with the long-wavelength diffractometer WISH at ISIS. The temperature dependence of the magnetic intensity is shown in Fig. 1(a). For 9 K < T < 15 K (ICM1 phase), magnetic peaks are indexed by a propagation vector Q=(-1 q 1/2) with temperature dependent q ~ 0.383. In the ICM1 phase, the magnetic structure has been refined to be sinusoidally modulated structure with collinear magnetic moments (magnetic point group is 2/m1′). Below 9K (ICM2), the Q vector is changed to Q=(-1/2 q 1/2) with q ~ -0.206, which is also temperature dependent. The magnetic structure in ICM2 phase was refined to be a cycloid structure with slight ellipsoidal modulation, and the polar magnetic symmetry m1′. Ferroelectric polarization was also observed below 9 K, as shown in Fig. 1(b). In this presentation, we discuss the correlation among magnetic orderings, ferroelectric polarization and lattice deformations.

[1] M. Mekata et al. J. Phys. Soc. Jpn. 62, 4474 (1993)
[2] T. Kimura et al. Phys. Rev. B 73, 220401 (2006)
[3] A. Vasiliev et al. J. Phys. Cond. Matt. 22, 016007 (2009)

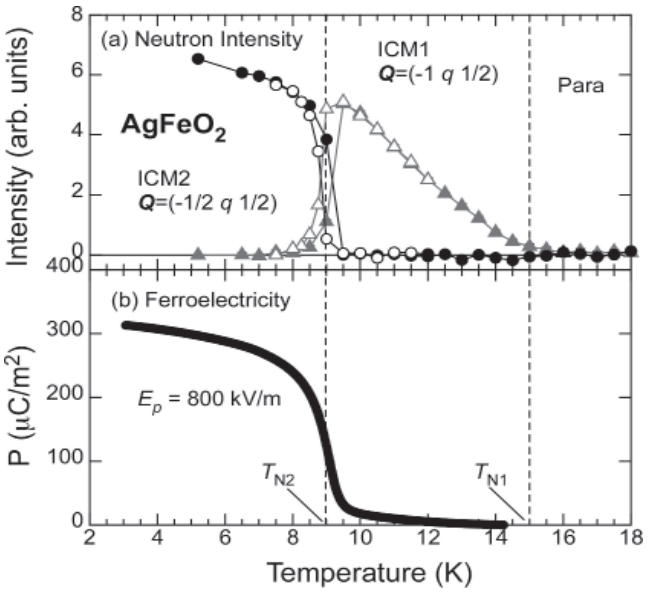


Fig. 1: Temperature dependence of (a) magnetic neutron diffraction intensity (open and closed symbol denote data measured with decreasing and increasing temperature processes, respectively), and (b) the ferroelectric polarization in $AgFeO_2$.

TU-149

$CdCr_2S_4$: Magneto-electric clusters arising from Cr^{3+} dynamic off-centering

G.N.P. Oliveira [1], A.M. Pereira [2], A.M.L. Lopes [1], J.S. Amaral [3], A.S. Santos [4], T.M. Mendonça [2], C.T. Sousa [2], Y. Ren [5], V.S. Amaral [3], J.G. Correia [6], *J.P. Araujo [2]*

(1) CFNUL – Center Nuclear Physics, University of Lisbon, Av. Prof. Gama Pinto, 2, 1649-003, Lisboa, Portugal, (2) IFIMUP and IN - Institute of Nanoscience and Nanotechnology and Department of Physics and Astronomy, Faculty of Sciences, University of Porto, Rua do Campo Alegre, 687, 4169-007 Porto, Portugal, (3) CICECO and Departament of Physics, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal, (4) Neutron Scattering Science Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA, (5) APS - Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois 60439, USA, (6) ITN - Instituto Tecnológico e Nuclear, EN 10 - Apartado 21, 2686-953 Sacavém, Portugal

The quest for improved multiferroic materials is, nowadays, a hot topic of research promising routes for the development of several technological applications based on the magnetoelectric coupling. In this respect, the most appealing multiferroic materials are those, which display a strong coupling between the magnetic and polar degrees of freedom.

In this work, we provide clear-cut experimental evidence for the origin of the relaxor-like behaviour on the cubic spinel $CdCr_2S_4$. Here we definitely settle that this behavior arises from Cr off-centering displacement from its coordination sphere being thus responsible for the observed colossal magnetoelectrical effects. Our findings were achieved by a singular combination of local probe techniques namely Pair Distribution Function and Perturbed Angular Correlation. We further show that the off centering of the magnetic Cr-ion gives rise to a peculiar entanglement between the polar and magnetic degrees of freedom, stabilizing, in the paramagnetic phase, short range magnetic clusters. This phenomenon was unveiled by low-field high-resolution magnetization measurements, analyzed using a modified Landau theory with a linear coupling between the magnetic and polar order parameters.

Our work provides fundamental comprehension of the magneto-electric coupling, essential for opening new routes to tune these materials for suitable applications namely in the Spintronics industry.

TU-150

Structure, microstructure and magnetic properties of $Pb_2Fe_2O_5$ nanowires fabricated with AAO template

L.A.S. De Oliveira [1], K.R. Pirota [1]

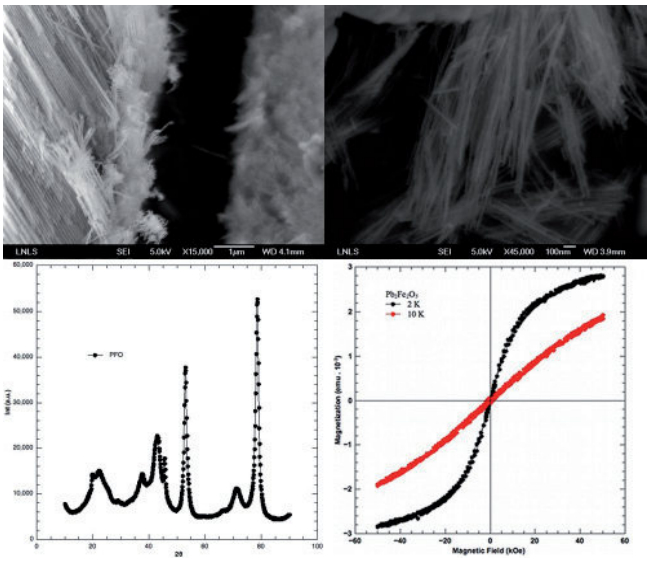
(1) Universidade estadual de Campinas

One-dimensional nanostructures, such as nanowires and nanotubes, have become the focus of studies because of their unique size-dependent properties and their relevant applications in mesoscopic physics. The anion-deficient perovskite $Pb_2Fe_2O_5$ (PFO) is a new multiferroic material [3] that presents crystallographic shear structure [1,2]. In this work, we report the fabrication of highly ordered PFO nanowires by a sol-gel technique using two-step anodic aluminum oxide (AAO) as template. The nanowires present 35 nm in diameter and 5 μm in length, as confirmed by scanning electron microscopy (SEM) measurements. The obtained nanowires present the expected phase ($Pb_2Fe_2O_5$) as confirmed by X-ray diffraction (XRD) and high-resolution transmission electron microscopy (HRTEM). The PFO nanowires magnetic behaviour for different temperatures are also presented. The relationship between the size of PFO nanowires and their physical properties has also aroused much interest due to their special applications such as ultra-high density vertical magnetic recording.

[1] A. M. Abakumov et al., Angew. Chem. Int. Ed. 2006, 45, 6697 –670

[2] J. Hadermann et al., Solid State Sciences 10 (2008) 382-389

[3] M. Wang and G. Tan, Materials Research Bulletin 46 (2011) 438–441



TU-151

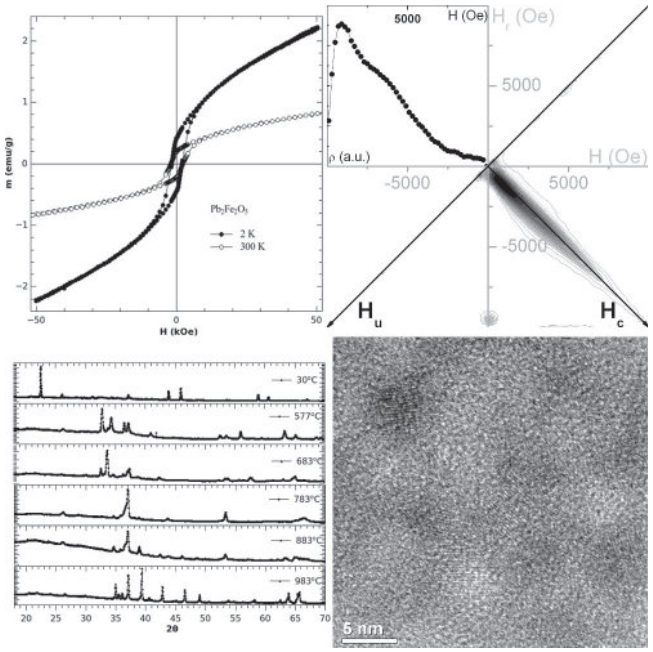
Synthesis and magnetic properties of multiferroic $Pb_2Fe_2O_5$ nanoparticles

L.A.S. De Oliveira [1], F. Béron [1], K.R. Pirota [1]

(1) Universidade Estadual de Campinas

Because of the technological importance of perovskite-based oxides, numerous pathways towards new structures have been developed, including ordering at the A and/or B cation sites of the perovskite (ABO3) structure, vacancy ordering at the anion site, the intergrowth of perovskite and related structures, and the formation of hexagonal perovskite polytypes [1]. However, it has been generally accepted that crystallographic shear structures cannot be realised in perovskites. The anion-deficient perovskite $Pb_2Fe_2O_5$ is a new multiferroic material [3] that presents crystallographic shear structure [1,2]. In this work, $Pb_2Fe_2O_5$ (PFO) nanoparticles were synthesized by sol-gel route using lead and iron nitrate and 2-methoxyethanol as precursors. The phase evolution, starting with the as-cast powders, were characterized in-situ by X-ray diffraction from temperatures ranging from 300 K to 1173 K. The morphology of the nanoparticles was determined by field emission transmission electron microscopy (FETEM). The $Pb_2Fe_2O_5$ nanoparticles show ferromagnetic behaviour at room temperature with 2.3 kOe of coercive field. The first-order reversal curve (FORC) diagram, that is related to the local irreversible processes, exhibits a large coercivity distribution close to a log-normal function. It shows also presence of non-negligible reversible process, which can arise from coherent rotation of the PFO nanoparticles or from the minor paramagnetic PbO phase.

[1] A. M. Abakumov et al., Angew. Chem. Int. Ed. 2006, 45, 6697 –670
[2] J. Hadermann et al., Solid State Sciences 10 (2008) 382-389
[3] M. Wang and G. Tan, Materials Research Bulletin 46 (2011) 438–441



Clockwise: Hysteresis curves at 2 K and 300 K, FORC diagram with the corresponding coercivity distribution, phase evolution performed in-situ with synchrotron radiation and TEM image of the nanoparticles.

TU-152

Structural and Magnetic Properties of Single Phase $Bi_{1-x}Pr_xFeO_3$ Nanoparticles

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Multiferroic materials have attracted much attention due to their fascinating fundamental physics and technological applications in magnetic/ferroelectric data storage systems, quantum electromagnets, spintronics, and sensor devices. Single-phase BiFeO3 is one of very important multiferroic materials characterized by the high Curie (T_C ~ 830 °C) and Néel (T_N ~ 375 °C) temperatures, which makes it possible to be one of the prime candidates for room temperature magnetoelectric application [1]. Even though BFO is AFM often a weak FM component is observed due to canting of Fe^{3+} spins at room temperature. The spontaneous magnetization can be improved by changing the Fe–O–Fe bond angle or the distribution of mixed Fe ions which in turn, can be achieved either by Bi site substitution or the change in the oxygen content, within the same crystallographic phase.
We have synthesized $Bi_{1-x}Pr_xFeO_3$ (x = 0, 0.05 and 0.10) nanoparticles by polyol-mediated method. Bismuth, iron and praseodymium nitrate solutions were mixed in the appropriate ratios to produce Pr-doped samples. The synthesized powder is characterized by XRD, TEM, XPS and Mössbauer spectroscopy. XRD studies show that samples calcined in air crystallize in a rhombohedrally (R3c) distorted $BiFeO_3$ structure without any secondary phase formation. The average particle size of prepared material calculated from TEM analysis is in the range of 40-100 nm. A large coercivity of 5400 Oe and enhanced saturated magnetization of 0.72 emu/g are obtained at 300 K, which are mainly attributed to the antiferromagnetic core and ferromagnetic surface of the nanoparticles, together with the structural distortion. Temperature and field dependence of magnetization curves reveal the frustrated magnetic behavior of this system.

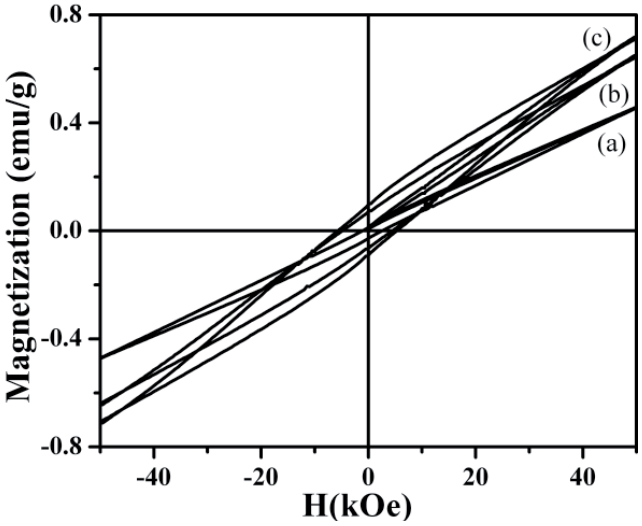

Fig : M-H loops of (a) 0%, (b) 5% and (c) 10% Pr-doped $BiFeO_3$ samples

[1] G. Catalan and J.F. Scott, Adv. Mater. 21, 2463 (2009)

TU-153

Pr and Cr co-doped $BiFeO_3$ nanotubes: an advance multiferroic oxide material

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Recently, multiferroic materials have drawn intense research attention because of the strong coupling among their electric, magnetic and structural order parameters leading to unique and simultaneous ferromagnetism and ferroelectricity in the same compound.
As now a day's nanoscale materials are trying to use in practical purposes, it is interesting to find how multiferroic properties varies with shape and size of the materials.
Arrays of single phase perovskite-type pure and doped $BiFeO_3$ (BFO) nanotubes (NTs) with compositions $BiFeO_3$, $Bi_{0.9}Pr_{0.1}FeO_3$, $BiFe_{0.9}Cr_{0.1}O_3$ and $Bi_{0.9}Pr_{0.1}Fe_{0.9}Cr_{0.1}O_3$ have been synthesized using AAO template (pore diameter ~250 nm) by wet chemical liquid phase deposition technique. All the NTs show ferromagnetic nature at room temperature (RT). Better magnetic properties are observed in the $Pr_{0.1}Cr_{0.1}$BFO NTs with the value of saturation magnetization (M_S) ~0.049 emu/g, remanant magnetization (M_R) ~0.012 emu/g and coercive field (H_C) ~103.3 Oe. Increase in ferromagnetic signature in the co-doped BFO NTs is believed to be due to the collapse of the space-modulated spin structure. Significant increase in the ferroelectric characteristics in co-doped BFO NTs suggests lowering of leakage current due to the reduction of the oxygen vacancies in the structure. Strong Magnetodielectric effect (MD), expressed by $[\varepsilon_r(H)-\varepsilon_r(0)]/\varepsilon_r(0)$ is

observed in doped BFO NTs, where the increase of the dielectric constant is noticeable with the increase of the applied magnetic field. The co-doped BFO NTs shows noticeable increase in MD effect at a lower field (1-2 kOe).

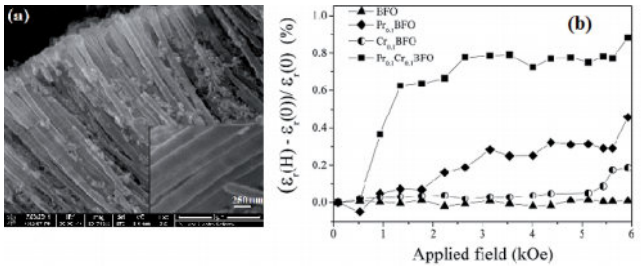

Figure. (a) SEM image of the $Pr_{0.1}Cr_{0.1}$BFO NTs. Inset of (a) shows the high magnification SEM image of the same NTs. (b) Magnetic field-induced change in MD of the pure and doped BFO NTs measured at frequency (*f*) of 1 kHz at RT

TU-154

Magnetic phase transition in $BiCoO_3$ nanoparticles

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(1) National Institute of Technolgy,Rourkela,769008,Odisha,India

Bismuth cobaltite (BiCoO_3) nanoparticles are prepared by sol-gel auto combustion method. The single phase confirmation is done by x-ray diffraction study (XRD), which also confirms crystallization in cubic structure with space group I23 and lattice parameter a=101.769(2) nm (obtained via Reitveld refinement). The AFM study results the particle size of ~75nm. Transition from weakly ferrimagnetic to antiferromagnetic states is observed as a sudden increase in the magnetization (M) at ~ 30K in the M~T plot while warming. The slight nonlinearity in the M-H curve carried out at 10K and linearity at room temperature (T = 300K) confirms the weakly ferrimagnetic-antiferromagnetic transition [1]. The antiferro-ferrimagnetic transition temperature remains intact even on application of 1 tesla magnetic field. The change in the magnetic state may be attributed to the switching of Co^3+ and Co^2+ ions in the octahedral sites due to electron hopping [2]. The complex magnetic structure may be arising due to cooperative interactions between the various spin states.

[1] Singh et.al., Phys. Rev. B 77, 144403 (2008)
[2] Nethravathi et.al., J. Phys. Chem. B 109, 11468, (2005)

TU-155

Combustion synthesis of bismuth manganite doped with alkaline earths (Ca, Sr): crystallographic properties and magnetic behavior.

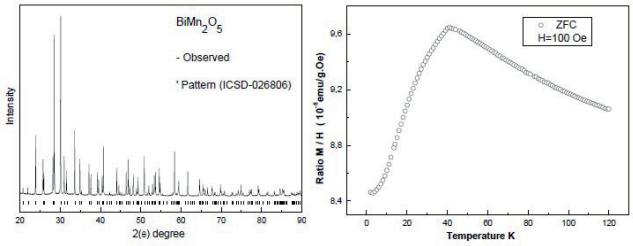
R. Ferreira [1], R. Lebullenger [2], O. Peña [2], P.N. Lisboa-Filho [3]
(1) POSMAT – Programa de Pós-Graduação em Ciência e Tecnologia de Materiais, UNESP - Univ Estadual Paulista, Bauru-SP, Brazil., (2) U.M.R. 6226 Sciences Chimiques de Rennes,Campus de Beaulieu,Rennes,France., (3) Faculdade de Ciências,UNESP – Univ Estadual Paulista,Departamento de Física,Bauru-SP,Brazil.

Advanced oxide materials with nominal composition $BiMn_2O_5$ has originated great interest because the Bi^{3+} ion ($6s^2$) is responsible for ferroelectric behavior while the manganese ions (Mn^{2+}, Mn^{3+}, Mn^{4+}) contribute to the magnetic properties. Simultaneous presence of these two properties gives to the compound the characteristics of a multiferroic material. Of particular interest is the great tendency of (Ca,Sr)-doped compounds to present charge-ordering (CO) at very high temperatures [1].

The main objectives of this work concern the synthesis and characterization of materials with nominal composition $Bi_{1-x}M_xMn_2O_5$ (M = Ca, Sr). These materials are obtained by urea combustion synthesis at temperature of 500°C and heat-treated at 900°C for 4 hours [2].

Monophasic material $BiMn_2O_5$ shows a mullite-type orthorhombic perovskite structure (left-hand Figure), space group Pbam with lattice parameters: a = 7,56 Å, b = 8,53 Å, c = 5,76 Å [3]. The ZFC-FC magnetization curves under an applied field of 100 Oe showed an antiferromagnetic response with a maximum at T_N= 40 K (right-hand Figure).

The synthesis, crystallographic and magnetic studies are in progress to investigate the role of (Ca,Sr)-doping in the occupation of the crystallographic sites and their role in the magnetic ordering.



[1] C.Frontera, C.; et al. J. of Magnetism and Magnetic Materials. 272, 1734 (2004)
[2] Civera, A.; et al. Catalysis Today. 83, 199 (2003)
[3] Muñoz, A.; et al. Physical Review B. 65, 144423-1 (2002)

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

SENSORS, MEMS AND MAGNETIC DEVICESS
Chair: P. Freitas

TU-156
MgO Tunnel Junction Magnetic Field Sensors at High Frequencies
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Micron sized MgO magnetic tunnel junctions with 1.7 nm tunnel barrier were fabricated and characterized at DC and high frequencies to be used as magnetic field sensors [1]. Both DC and AC properties of the sensors were measured by tunneling magnetoresistance (TMR) and impedance spectroscopy between 100 Hz and 40 MHz as a function of applied external magnetic field. Several different types of sensors were investigated: Single and multiple MTJ-sensors. In the first case, single junctions were measured. A simple RLC circuit model was applied to impedance spectroscopy results to investigate magnetocapacitance properties in order to evaluate and compare different sensing schemes such as resistive and capacitive sensing. Contrary to the previous reports in the literature [2,3], we didn't observe field dependent spin capacitance despite excellent agreements in other parameters such as resistance of the junction and interface capacitance. We attribute this discrepancy to the size of our junctions and reach a conclusion that limits the applicability of the spin-capacitance concept to large area devices. Then multiple tunnel junctions in serpentine geometry were measured. Using the same circuit model, we measured non-zero magnetocapacitance in multiple junction sensors unlike single junction devices. We explain this as a result of the sensor geometry.

[1] S. Ingvarsson et al., Appl. Phys. Lett. 96, 232506 (2010)
[2] P. Padhan et al., Appl. Phys. Lett. 90, 142105 (2007)
[3] H. Kaiju et al., J. Appl. Phys. 91, 7430 (2002)

TU-157
GMR Multilayer Sensors Customized to Various Applications
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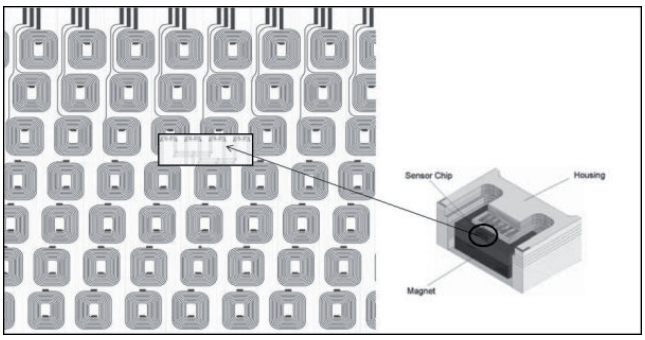
Magnetic multilayers [1,2] are well suited as magnetic field sensors to a wide range of magnetic applications. The antiferromagnetic coupling strength of the magnetic layers is dominated by the thickness of the nonmagnetic interface. Each application needs a multilayer stack customized individually to meet special requirements.
In low field applications commonly flux guides are used to intensify the sensitivity, e. g. for endpoint or nanoparticle detection. In addition multilayer sensors are also used at very high magnetic field applications, e.g. for position measurements. Here the sensor system consists of a permanent magnet, which magnetizes e.g. toothed wheels or bars, and a GMR multilayer sensor, sensitive at fields of up to 400 kA/m. Because of the robust build-up of the sensors, consisting only of metal layers, of silicon oxide and nitride or alumina for passivation and protection, the GMR sensors can be used in harsh environments. High dynamic position measurements of the valve lift can be measured even in a firing engine.
The same system of magnet and multilayer sensor can also be used to test arrays of magnetic circuits which are used in magnetographic printing systems [3] as shown in the figure below. The magnetic poles are characterized by the same principle like in position measurements: The magnetic poles are saturated by a permanent magnet, small defects in the magnetic circuits are detected by a GMR gradiometer sensor comparing each pole to his neighbors.
[1] A. Fert et al., Physical Review Letters 61 (21) (1988)
[2] P. Grünberg et al. , Phys. Rev. B **39**, 4828 (1989)
[3] Jean-Jacque P. Eltgen and Jean G. Magnenet, IEEE Trans. on Magn. 16(5) (1980)



GMR Sensor System for Testing 2D Magnetic Circuit Arrays

TU-158
MgO Magnetic Tunnel Junction sensors in Full Wheatstone bridge configuration for current detection
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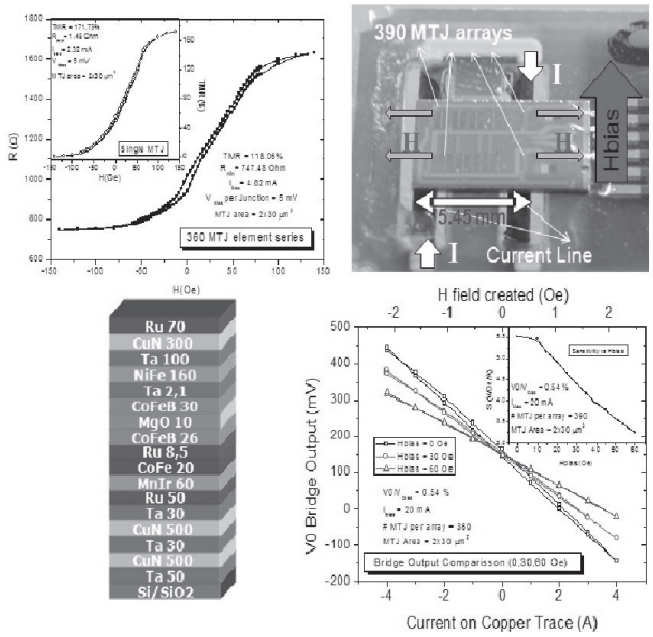
Magnetoresistive (MR) sensors such as magnetic tunnel junctions (MTJ) are becoming increasingly important in large industrial domains. For electrical current measurement, MTJs are far from achieving its major potential, always lacking the specific designs that enable the sensors to work in optimal conditions [1]. For magnetic field and/or electrical current sensors, the stability of the sensor output must be ensured over a wide range of temperatures. Usually this issue is addressed by integrating the sensors in a Full Wheatstone Bridge which ensures the output thermal stability and provides a null-voltage output in the absence of an external stimulation field, retaining the full output voltage of a single device [2].
We designed a Wheatstone bridge current sensor using MTJ as MR elements composed of:Ta50/CuN500/Ta30/Ru50/MnIr60/CoFe20/Ru8.5/CoFeB26/MgO10/CoFeB30/Ta2.1/NiFe160/Ta100/CuN300/Ru70 (thickness in Å), with a resistance-area

product of 100 Ω×μm^2. Each of the bridge's four resistances consists in 390 MTJs array. A printed circuit board (PCB) was designed to sense the external current passing through a U-shaped copper trace placed under the PCB. The separation between the sensor and trace is kept at 1.1 mm.
A tunnel magnetoresistance of 170 % of was measured in a single junction, while 120 % was obtained for the corresponding series elements, with a sensitivity of 7.36 Ω/Oe in a 65 Oe linear range. The DC sensor sensitivity in response to external DC current sweeps of ±4 A lead to an average sensitivity of 5.5 V/Oe/A.

[1] P.P.Freitas, et al. "Optimization and integration of magnetoresistive sensors", Journal of SPIN, Vol.1 (1), pp 71-91 (2011)
[2] M.D. Cubells-Beltrán, IEEE Sensors Journals 9 (2009) 1756-1762



TU-159

Magnetic tunnel junction sensors connected in series: linearization and field detectivity

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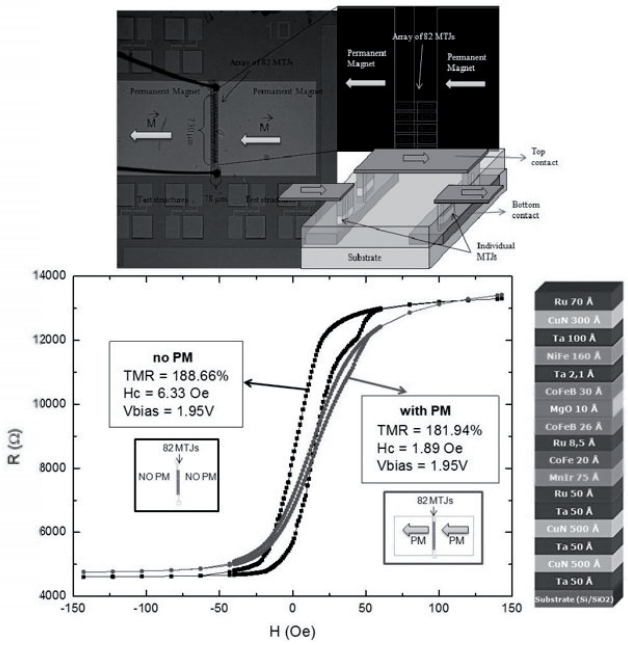
Magnetic tunnel junctions (MTJ) have been used in many applications, replacing other magnetoresistive (MR) devices, mainly due to their large magnetoresistance values (TMR). However large TMR obtained with crystalline CoFeB/MgO-based stacks is usually associated with non-linear, high hysteresis response. A linear, centered at H=0 Oe response of MgO sensors can be obtained using thin CoFeB layers (in the 1.5nm range) but with a decrease of TMR [1]. Moreover, MTJ have a voltage bias dependence and limited electrical robustness [2]. One strategy to overcome this last issue is to use arrays of MgO-based MTJ connected in series, which comprises also improvements in the field detectivity [3]. Thought their large footprint, the series of MTJs are well suited for applications in which spatial resolution is not a request, for example, lateral flow magnetic detection assays, current field sensors, etc.
This work describes the integration of a series of 82 MgO-MTJs elements comprising thick free layer (Figure1). Bulk film properties measured by CIPT indicated TMR ~200% and RxA ~7000 Ω.μm2. The structure is integrated within 120nm-thick CoCrPt permanent magnets (PM), for improved control of the sensor linear response.
Upon microfabrication series-MTJ sensors with TMR ~190% and sensitivities ~ 2.5%/Oe were obtained, and the effectiveness of PM in reducing the overall coercivity of the series was achieved. Their higher robustness was verified up to 10V. From noise measurements, field detectivities of 100pT/√Hz were obtained at 30kHz.

[1] J.M.Almeida, et al., J. Appl. Phys.105, pp.07E722 (2009).
[2] P.P.Freitas et al., Journal of SPIN, 1 pp.71-91 (2011).
[3] R.Guerrero et al., Appl. Phys., 105, pp.113922 (2009).



Device picture/illustrative schematics and transfer curve of 2 arrays with/without PM.

TU-161

Optimization of the response of Hall sensors to localized magnetic fields

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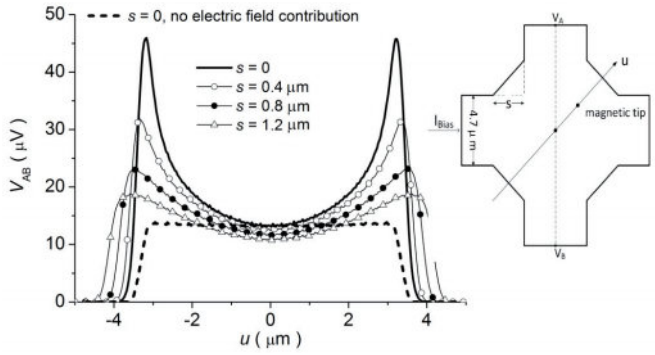
Magnetic tips used in magnetic force microscopy can be also employed to scan the response of (sub)-micrometer Hall devices to a localized magnetic field [1]. Despite the high resolution, the optimization of magnetic sensitivity requires a clear separation of magnetic and electric field contributions.
Here, semiconductor Hall effect devices are modelled in the presence of a magnetic tip with surface electrostatic charges due to parasitic effects. A finite element model is applied to compute the transverse voltage under the assumption of

diffusive transport regime, considering magnetic and unwanted electric fields from the tip [1-2]. The tip magnetic coating is described as a 3D distribution of dipoles, while the electric field contribution is introduced as a local variation of charge density inside the device.
The attention is focused on double cross InAs devices with variable size and different shape of sensing area. We study how geometry and bias current affect the transverse Hall voltage measured while the tip scans over the junction area. The aim is to find the optimal design and working conditions, with specific reference to the reduction of electrostatic charging signals and increase of the magnetic sensitivity. As an example, the graph shows the influence of cross shape on the transverse voltage computed for different tip positions along the direction indicated in the scheme. The elimination of sharp corners enables the attenuation of electrostatic effects (up to 2.5-3 times), with only a small change in the magnetic sensitivity due to the effective area increase.

[1] L. Folks et al., J. Phys.: Condens. Matter 21, 255802 (2009).
[2] A. Manzin, V. Nabaei and O. Kazakova, J. Appl. Phys. 111, 07E513 (2012).



Combined magnetic and electrostatic contributions to the transverse voltage computed along the *u*-direction for different values of *s* (see scheme), considering a magnetic tip at a distance of 25 nm above the device surface.

TU-162
Mapping sensitivity of a graphene Hall bar to local magnetic and electric fields
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The room temperature response of an epitaxially grown graphene Hall bar to local electric and magnetic fields has been studied in the diffusive regime using a custom-built scanning probe microscope. The local fields are produced by a metallic magnetic tip mounted on a tuning fork sensor. In contrast to the conventional 2-dimensional electron gas heterostructures, the carriers in a graphene device can be easily approached by the tip enabling higher sensitivity and better spatial resolution. However, in all such experiments it is extremely difficult to differentiate between the electrostatic and magnetic influence, as shown in figure 1. The asymmetric pattern of the transverse voltage observed at the intersection of current and voltage arms arises due to induced inhomogeneity in the current flow [1-2]. Here we studied the response by varying the tip bias as well as current magnitude and direction and demonstrated a method of compensating for the electric field and thereby increasing the magnetically sensitive region of the Hall cross. The asymmetric edge pattern depends strongly on current flow direction and the tip bias potential, whereas the response in the middle of the cross is only determined by the magnetic field. We have studied the spatial resolution of graphene devices by varying the height of the magnetic tip above the sensor and quantitatively confirmed the results by extensive theoretical modelling.

[1]G. Papp and F. M. Peeters, “Resistance maps for a submicron Hall electrosensor in the diffusive regime,” Journal of Applied Physics, vol. 101,113717, 2007.
[2]L. Folks et al., “Near-surface nanoscale InAs Hall cross sensitivity to localized magnetic and electric fields,” J. Phys.: Condens. Matter, vol. 21, 255802, 2009.

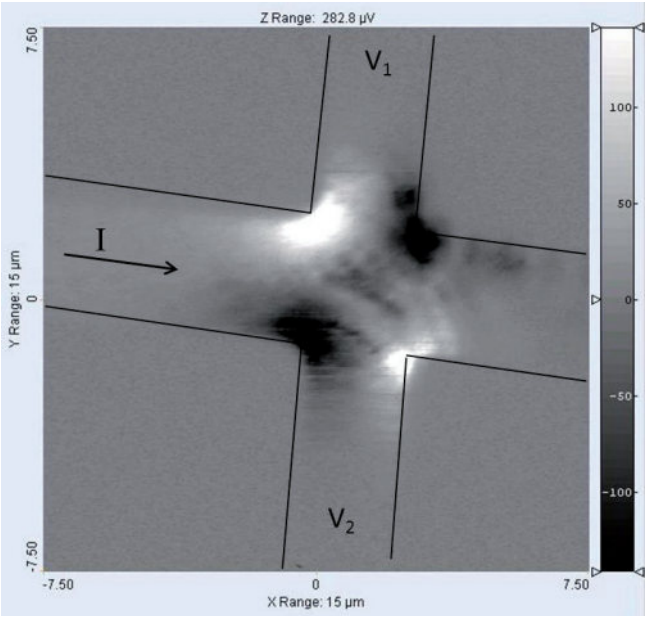

Figure 1: Mapping of a combined magnetic and electrostatic response of a graphene Hall sensor when scanned using an unbiased magnetic tip.

TU-163
The use of GdCo thin films as Magneto Optic Imaging Films
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Magneto Optic Imaging Films (MOIF) are used to characterise the stray magnetic fields produced by magnetic flux sources such as superconductors and hard or soft magnets. While uniaxial MOIF reveal the direction of the z-component of the field, planar MOIF can be used to quantify the amplitude of the field [1]. MOIF typically consist of a monocrystalline garnet

layer of a few μm in thickness, which is a soft magnetic material with a high Kerr rotation angle, grown by liquid-phase epitaxy on a transparent substrate of gadolinium-gallium garnet. The lateral resolution of such MOIF is typically restricted to above 5 μm, because of the thickness of the active layer and the ill-defined gap between it and the flux source.
Here we will report on the use of sputtered ferrimagnetic GdCo thin films as MOIF. GdCo was chosen because of its deposition-induced out-of-plane anisotropy, which leads to the formation of domains which are easily observable by polar Kerr microscopy [3]. These GdCo MOIF were used to characterise the stray magnetic fields produced by Thermo-Magnetically Patterned hard magnetic films (NdFeB, SmCo) [2]. Deposition of the GdCo layer on transparent substrates allows the simple fabrication of large size MOIF with a lateral resolution comparable to epitaxially grown garnet MOIF. Even more interestingly, the deposition of the GdCo layer directly upon the protective capping layer of the hard magnetic layer, to produce a so-called "integrated MOIF", leads to an increased lateral resolution, only limited by the optical resolution, compared to garnet MOIF.

[1] R. Grechishkin et al., in *Magnetic Nanostructures in Modern Technology*, edited by G. Asti, L. Pareti and M. Ghidini, (Springer, 2007), p. 195.
[2] F. Dumas-Bouchiat et al., Appl. Phys. Lett. 96, 102511 (2010).
[3] A. Hrabec et al., Appl. Phys. Lett. 99(5), 052507 (2011)

TU-164

Fundamental study on the liquid magneto-optic device with magnetophotonic crystal structure

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Light waveguide based on a liquid with a modulated refractive index–magnetic fluid–is shown to control the flow of light by a spin subsystem.[1] Polarization of light propagating in a magnetic fluid changes as the refractive index changes upon application of the external magnetic field. However, transmissivity of a magnetic fluid is low, and efficiency of the waveguide for optical applications is also low.
In this work a new liquid magneto-optic device for modulating light intensity is studied. Optical extinction in a magnetic Fe_3O_4 fluid was compensated by a dye providing amplification. Study on the optical amplification rate by the dye was performed, showing that the polarization plane of amplified rays was kept.
The magnetic fluid was mixture of a dye (Pyrromethene 556, 1 wt.%), Fe_3O_4 (4.5 wt.%) in water. This magnetic fluid was sandwiched between two dielectric multilayers $(SiO_2/Ta_2O_5)^{5.5}$. Thickness of this magnetic fluid was about 28 μm; this was defined by the thickness of a polymer spacer. Such magnetophotonic crystal(MPC)[2] was illuminated with a Nd:YAG laser beam of a wavelength of 450 nm. Spectrum of pyrromethene 556 luminescence for wavelength corresponding to localized modes of MPC was observed. Application of the external magnetic field across MPC caused a spectral shift of the luminescence spectrum. This shift showed the change of the refractive index of the magnetic fluid.
Demonstrated results approved the concept of liquid magneto-optic devices allowing modulation of the flow of light by the external magnetic field.

[1] Demetri Psaltis et. al., Nature, 442 (2006)
[2] M. Inoue et. al., J. Appl. Phys. 85, 5768 (1999)

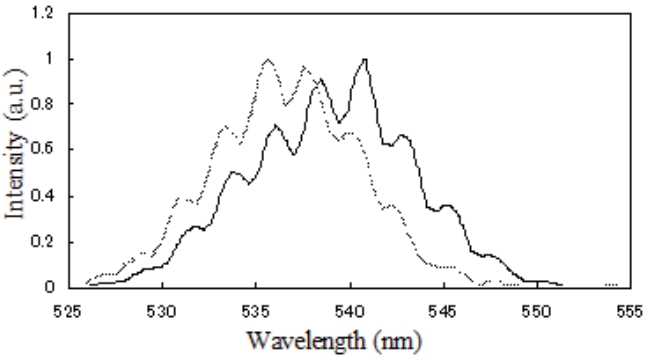

Fig. 1 The localized mode spectrum of magnetophotonic crystal with liquid magneto-optic layer. The line is without external magnetic field, and the dashed line is with external magnetic field(2 kOe).

TU-165

Influence of annealing in vacuum and in air on the magnetic, crystallographic and morphological properties of thin YIG films

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Current research is focused on the characterization of magnetic thin films for their wide application areas. The Yttrium Iron Garnet (YIG) is chosen by our laboratory for the integration of passive components in the microwaves domain (isolators and circulator) [1], and also for the miniaturization of integrated inductors and transformers [2]. Magnetic and morphological characterization at high and low frequencies is essential for the development of these components.
To manufacture a micro-inductor of solenoid type, we have deposited on an alumina substrate, by RF sputtering, a thin YIG film between two layers of copper [3]. These films are amorphous after deposition. The annealing at 740°C for 2 hours is necessary for YIG films to be crystallized and to have magnetic properties. To avoid the deterioration of copper layers, the classical thermal annealing (CTA) was replaced by Vacuum thermal annealing (VTA). For this reason we have performed a furnace for VTA, the YIG film is sandwiches between two heaters in the vacuum chamber. To obtain a precise shape of the integrated inductor, we have used the photolithography technique in a clean room.
It is then interesting to study the magnetic, crystallographic and morphological properties of YIG films after annealing with both techniques of thermal treatment. To check the quality of the prototype, we have done different characterizations: VSM, Kerr effect, XRD, SEM and LCR meter HP4284A. The results obtained with VTA were better than of CTA comparing them with bulk YIG properties. The measured inductance has permitted to determine the relative permeability of the YIG thin film.

[1] E. Gamet et al., J. Magn. Magn. Mater. 288, 121 (2005)
[2] A. Kriga et al., J. Magn. Magn. Mater. doi:10.1016/j.jmmm.2012.02.043 (2012)
[3] A. Siblini, I. Khalil and J.P. Chatelon, sensor Letters 5, 51 (2007)

TU-166

Tuning the magnetoimpedance response with an exchange bias field

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Since its discovery in 1994 the magnetoimpedance effect (MI) has been widely used in sensitive magnetic field sensors, but its intrinsic nonlinear characteristics are disadvantageous for sensor applications near zero field. Linearization is generally performed by applying a dc bias field to the sensing element but this adds to the complexity of the device, so other methods to establish an asymmetrical MI (AMI) response are desirable. In multilayer systems this has been accomplished in several ways, including the use of exchange-bias [1, 2]. The magnitude of the shift produced by the exchange bias (EB) in both the hysteresis loop and the GMI response strongly depends on the thickness of the ferromagnetic material [3]. The MI ratio increases with increasing thickness of the FM layer in FeNi/IrMn multilayer system, which is attributed to the stronger pinning of the FM adjacent to the IrMn. The asymmetrical MI peak positions are shifted to higher magnetic field as the probe frequency increases, so linear MI behavior can be obtained around zero external field by tuning the frequency [2].
Additionally, AMI response and the number of peaks can be controlled as a function of both; the exchange bias angle and the direction of the external magnetic field. The shift in the MI corresponds to the shift in the hysteresis loops. When the applied field is parallel to the direction of the exchange bias an asymmetric response is observed, and the asymmetry increase with angle reaching a maximum when the applied field is perpendicular to the exchange bias direction. This shows a way to control the asymmetric behaviour of the GMI curve which has practical applications in sensors.

[1] C. García et al. Appl. Phys. Lett. **96**, 232501 (2010)
[2] C. García at al. J. Appl. Phy., 109, 07D735 (2011)

TU-167

Mechanical Testing of Iron based Bulk Metallic Glasses and Their Suitability for Force Sensors

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Iron-based bulk metallic glasses (BMGs) have been known mainly for their outstanding magnetic softness, making them an attractive material for electronic industry as the cores of inductive components. It was also found that they exhibit very good mechanical properties, such as high hardness, high compressive strength and large strain to fracture [1]. The combination of these properties may lead to the elaboration of e.g. high load stress sensors with small dimensions.
In this work, thermal, mechanical and magnetic properties of (Fe-Co-Ni)-(Zr/Si)-Nb-B alloys in the form of rapidly quenched rods of 1.2 and 2 mm in diameter were studied. It was found that the supercooled liquid region's width is of over 40 K, suggesting that the alloys' glass forming ability (GFA) is high. The BMGs with Zr exhibit wider supercooled liquid region than these with Si. However, in practice, the GFA of the former alloys is worse. The scanning electron microscope images provide the fractured surface, which reveals partial crystallinity of the Zr-doped alloys and amorphousness of Si-doped alloys. Microhardness measured at 50 g load is from 500 to 2000 HV (the less cobalt, the higher), and the compressive strength reaches nearly 4000 MPa for Si-doped alloys and 2000 MPa for Zr-doped ones. This substantial difference may be attributed to partial crystallinity of the latter alloys.
The addition of Ni to the alloys significantly improves the GFA, which results in the reduction of coercive field: the alloy without Ni exhibits the coercivity of 19 A/m, and the one with Ni – only 2 A/m. The magnetic hysteresis loops of fully amorphous rods measured under compression, exhibited a clear dependence of permeability vs. stress, proving that iron-based bulk metallic glasses may be promising materials for magnetoelastic force sensors.

[1] A. Inoue, B.L. Shen, C.T. Chang, *Acta Mater.* 52 (2004) 4093-4099.

TU-168

High Permeability Flexible Bulk Material for Magnetic Micro Head Applications

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The term “gentelligent” describes a new feature of the inherent combination of a component and its corresponding information, which includes the geometric values or information that is generated while manufacturing or usage. This information can be used for further development, maintenance or for components’ identification. The storage material of the components is “magnetic magnesium”, which is Mg with embedded hard magnetic γ-Fe_2O_3 particles. For the data storage directly on the components an adopted magnetic recording head is developed and fabricated. Due to the varying storage surfaces depending on the geometry of the gentelligent components, the flexible writing head which adapts its own geometry to the surface topography during data storage process is required. This recording head uses a special design which allows an application of flexible NiFe, Cu and polymer foils in the micro head structure. The chosen highly magnetic permeability bulk material is a 50 µm thick NiFe81/19 foil which serves as one part of the flexible flux guide. An evaluation of the recording head by a numerical Finite Element Method (FEM) was carried out with the simulation software ANSYS™. The geometry of the head was optimized according to Karlqvist, where the horizontal *H*-field component in the air gap has to be higher than the coercivity of the storage medium. In this case it thus has to exceed the γ-Fe_2O_3 value of 23 kA/m. The cross section of the head gap in the bottom flux guide is 10 µm × 200 µm. For the evaluation of the magnetic tracks, a GMR sensor was used. At first the alternating sequences of “0” and “1” were created on the gentelligent sample’s surface. After that the GMR sensor was used to read out the bits at the same sample’s surface position. The stored alternating sequences were detected.

TU-169

Performances of interleaved and Face to Face integrated magnetic transformers

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Nowadays, large studies are performed on integrated transformers using non magnetic materials [1]. In order to reduce the size and to improve their performances, transformers with thick ferrite films are studied. Interleaved and stacked (Face to Face orientation) transformers using YIG films (figure 1) are simulated, using HFSS software, realized and characterized, using probing system and a vector network analyzer, on a broad frequency band (up to 200 MHz).

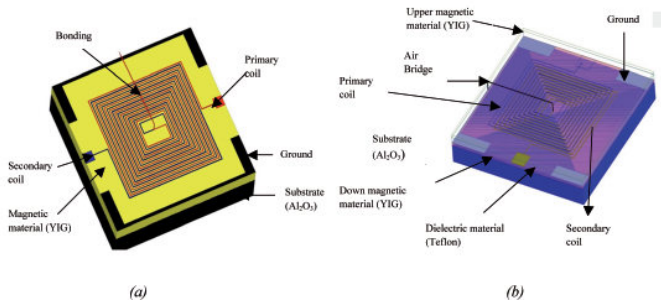

Figure 1: Transformers schematic view. (a) Interleaved structure (b) Face to Face structure

An electrical model based on [2] has been used in order to determine primary and secondary parameters of the transformer as well as the magnetic coupled coefficient, k.

Simulation results allow optimizing the magnetic coupled coefficient and minimizing the capacitor between primary and secondary coils according to the transformer dimensions. For example, in the interleaved structure, the magnetic coupled coefficient is very sensitive of the distance between coils. Results show that when the distance between coils decreases, the magnetic coupled coefficient increases by a ratio of 25%.

According to [3], this coefficient must be greater than 0.7 in order to have a sufficient isolation on the secondary coil. In our case, this parameter is obtained when coils distance are less than 200µm which correspond to a high electromagnetic field between coils.

In the final paper, comparison for all parameters model and for the two structures will be presented.

[1] C.C. Lim and al, IEEE Trans. On Microwave Theory and Techniques 56, 2301 (2008)

[2] D.C. Laney and al, Proc. On IEEE MTT-S International Microwave Symposium Digest, 855 (1999).

[3] S.S.Mohan and al, Proc. On IEEE International Electron Devices Meeting, 531 (1998).

TU-170

Programmable Input for Nanomagnetic Logic Devices

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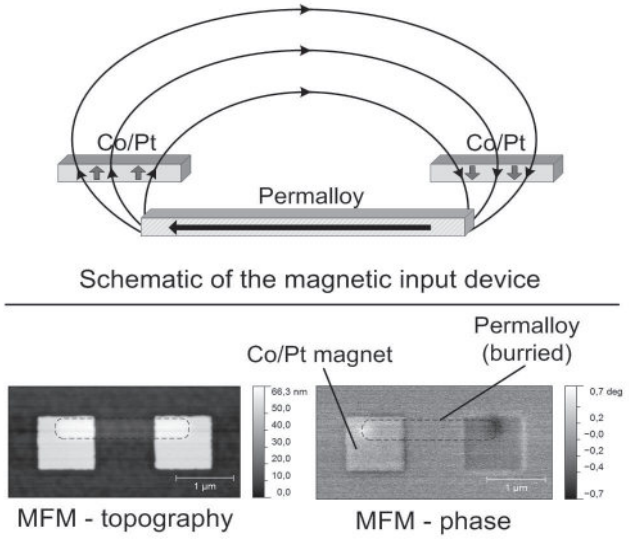
Nanomagnetic Logic (NML) is envisioned to complement state-of-the-art CMOS technology by providing non-volatile computing states for low power applications. Investigations on the interaction between magnetic layers offer new opportunities for NML devices [1]. In this work, this magnetic interaction is used to experimentally demonstrate a programmable hard-magnetic nanodot suitable for on-chip programmable magnetic inputs in NML systems [2].

A single-domain Co/Pt nanomagnet with perpendicular magnetic anisotropy is placed on top of one end of a permalloy bar, separated by a thin dielectric layer (Figure). The permalloy bar of the introduced input structure is magnetized by week easy-axis in-plane fields. The generated fringing fields of the pole are strong enough to control the magnetization of the superimposed Co/Pt nanomagnets, which have high crystalline perpendicular magnetic anisotropy. This magnetostatic interaction results in a shift of the hysteresis curve of the Co/Pt nanomagnet, measured by magneto-optical Kerr microscopy. The Co/Pt nanomagnet is fixed by the coupling field of the permalloy and thereby too hard to be effected by the magnetic power clock of the NML system. MFM measurements verify the functionality of the programmable magnetic input structure. The MFM image in the figure shows the magnetization of the Co/Pt nanomagnets controlled by the coupling fields of the permalloy poles, acting like a local magnetic bias field. The coupling fields are extracted from micromagnetic simulations and are in good agreement with experimental results.

A programmable magnetic input, based on magnetic interaction of two magnetic layers is presented. It is used to switch the logic functionality of the majority gate from NAND to NOR during runtime, offering programmable Nanomagnetic Logic.

[1] Csaba et al, J. Appl. Phys. 111, 07E337 (2012)

[2] J. Kiermaier et al, Solid State Electronics 65-66, 240 (2011)



Co/Pt magnets, controlled by the poles of permalloy, are visible in the MFM image.

TU-171

Autonomous hard micro-magnet based systems for continuous magnetic separation

L.F. Zanini [1], N.M. Dempsey [1], D. Givord [1], G. Reyne [2], F. Dumas-Bouchiat [1]

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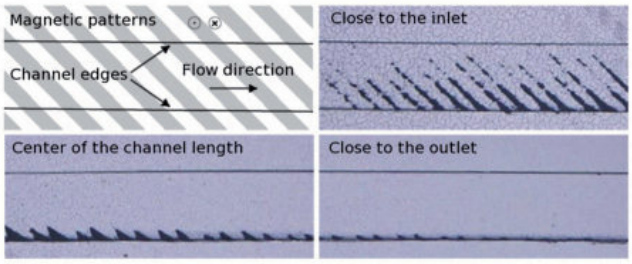
We have recently reported the fabrication of micro-magnetic patterns on hard magnetic films using a laser-based technique, namely Thermo-Magnetic Patterning (TMP) [1]. Magnetic characterizations showed that high-quality, flat micro-magnet arrays can be produced with this fast and simple technique. The magnetic quality (remanence Mr≈1T, coercivity μ_0Hc≈2T) of these micro-magnets are comparable to commercially available macro-magnets. Moreover, due to the microscopic size of the flux sources, field gradients of several Mega T/m are generated on a restricted zone above the micro-magnet arrays. Such spatially precise field gradients are of very high interest for High Gradient Magnetic Separation of magnetic particles and biological entities.

The TMP micro-magnets have been used to capture and position superparamagnetic particles ranging from tens of nm to several µm, dispersed in liquid solution or internalized by eukaryotic cells [2].

Due to the flatness of the magnetic layer, these films are easily integrated to polymer-based microfluidic channels. Chessboard-like magnet arrays were used to capture magnetic particles in a micro-channel and separation from a mixed solution containing non-magnetic particles was performed with purity up to 99.9% [3].

Here, we present novel microfluidic devices based on magnetic patterns which can be used to focus particles on single lines and to sort them in continuous flow by deviation towards precise zones in a micro-channel. The magnetic field configurations and particle trajectories are predicted with analytical simulations and compared to quantitative experimental results (particle counting by flow cytometry). The positive results obtained with these autonomous systems make them promising for the lab-on-chip field and point-of-care applications.

[1] F. Dumas-Bouchiat, L. F. Zanini et al. Appl. Phys. Lett. (2010)
[2] L. F. Zanini, O. Osman et al. J. Appl. Phys. (2012)
[3] L. F. Zanini, N. M. Dempsey et al. Appl. Phys. Lett. (2011)



Superparamagnetic particles deviated in the microfluidic channel.

Tuesday, 11 September 2012
Poster Area, 17.00 – 19.00

SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

Chair: M. Vazquez

TU-172

The effect of cobalt on magnetic properties of Ni_2MnCo_x

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The Heusler alloys are very interesting group of materials for different of applications[1]. In the given contribution we are dealing with the Heusler alloys of $Ni_2MnInCo_x$ (x= 0, 5, 7.5) composition in the form of glass-coated microwires. The microwires are prepared by Taylor-Ulitovsky method [2] that allows quick and easy preparation of microwires from small amount of materials. In addition the microwires prepared by Taylor-Ulitovsky method have well-defined direction of easy magnetization [3]. The microwires with composition of $Ni_2MnInCo_x$ show the phase transition near the room temperature. The addition of Co increases the Curie Temperature. DC hysteresis loops have been measured by the Superconducting Quantum Interference Device (SQUID) in parallel and perpendicular direction with respect to wire´s axis at 10, 100, 200 and 300K. The $Ni_2MnInCo_x$ microwires have also well-defined easy magnetization axis that is identical with the wires axis. Measuring magnetization near Curie temperature shows rapid increase of magnetization measured at low field below T_C and decrease of magnetization above T_C in narrow temperature range. This effect is very interesting for application of magnetocaloric effect [4].

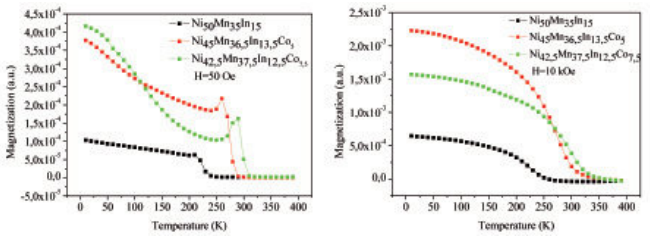

Fig. Magnetic measurements of magnetization by changed of temperature at H=50Oe (left fig.) and H=10 kOe (right fig)

Support by the project NanoCEXmat Nr. ITMS 26220120019, Slovak grant APVV-0266-10 and VEGA grant No.1/0076/09 is acknowledged.

[1] A.Hirohata, et al., Current Opinion in Solid State and Material Science, 10 (2006), 93.
[2] V.S.Larin et al., J. Magn. Magn. Mater., 249 (2002), 39.
[3] R.Varga, et al., Scripta Materialia 65 (2011), 703.
[4] J.D.Santos, R.Varga, B.Hernando, A.Zhukov, J. Magn. Magn. Materi., 321, (2009), 3875.

TU-173

The effect of SiO_2 content on magnetic properties of Fe-SiO_2 nanocomposites

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In this work $Fe_{1-x}(SiO_2)_x$ nanocomposites with different x values (0.0, 0.5, 1.0, 1.5 and 2.0) were prepared by mechanical milling using a high energy SPEX 8000D mixer/mill. The raw materials were extra pure iron and silica powders. Phase identification of the milled powders was carried out by XRD method and mean crystallite sizes were determined by Scherrer's formula. Particles shapes and sizes were investigated by SEM. toroidal shape samples were formed using PVA as a binder and then sintered at 1000 °C under argon atmosphere. Initial permeability of the samples was measured with respect to frequencies up to 1MHz. Dc resistivity of each composite was also measured on disk shape sintered samples with the same sintering conditions used for toroidal samples by 2 probe method. Permeability measurement results show that as x value increases, the permeability increases too, but the frequency range in which the permeability is constant, decreases. Also by increasing silica content, the value of DC resistivity will increases, which makes the composites suitable for high frequency applications due to the reduction of eddy currents loss.

TU-175

Hyperfine interactions with hyperthermia effects on ferrites nanoparticles

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Recently, ferrite nanoparticles have shown the novel magnetic properties due to their small sizes [1-3]. Especially, spinel ferrites, MFe_2O_4 (M=Mn, Co, Ni, Cu, Zn, etc.) are interesting not only in recording and microwave applications but also in the fields of hyperthermia, target drug delivery, and the magnetic resonance imaging (MRI). We have investigated the $Mn_{1-x}Zn_xFe_2O_4$ ($0 \leq x \leq 0.8$) using high temperature thermal decomposition. We have also measured and analyzed the magnetic and hyperthermic properties of $Mn_{1-x}Zn_xFe_2O_4$. The crystal structure was cubic spinel with space group of *Fd3m* by x-ray diffraction. The lattice constants (a_0) were increased with Zn concentration from 8.3901 to 8.4106 Å. From FESEM measurements and Scherrer equation, we have obtained the average diameter of particles to be 19 ± 1 nm. The values of magnetization (M_s) were also increased with Zn concentration from 57.7 to 83.2 emu/g. The hyperfine interaction between the Fe and its environment in the crystal lattice was characterized by field induced Mössbauer spectroscopy. The canting angle between hyperfine field and external field direction, which calculated from 5 T external magnetic field-induced spectra at 4.2 K, was increased with Zn concentration. The hyperthermia properties were measured with pure powder and in the agar solution, which is similar to the human blood. The temperature versus time measurements under 50 kHz and 25 mT showed that the temperature increases up to about 120 °C and 50 °C, respectively. It can be explained that Zn concentration, especially in case of x=0.5, is important factor in hyperthermia applications due to its magnetic anisotropy energy, which leads to increasing of the thermal energy.

[1] J.-H. Lee et al., Nature Nanotechnol. 6, 418 (2011)
[2] Y. Piao et al., Nature Mater. 7, 242-247 (2008)
[3] U. I. Tromsdorf et al., Nano Lett. 7, 2422-2427 (2007)

TU-176

Structural, and magnetic properties of self-assembled substituted strontium ferrite nanoparticles

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Recently, we have focused on the application of nanocomposite of ferrites in the stealth technology [1-3]. In this research work, magnetic multi-walled carbon nanotube nanocomposites have been created by the assembly of Ni-Co-Sn substituted strontium ferrite nanoparticles onto surface-primed MWCNTs at different volume percentage of carbon nanotubes. XRD,TEM, EDP and Mössbauer spectroscopy were used to demonstrate the successful attachment of ferrite dot array to MWCNTs. Figure 1 compares ^{57}Fe Mössbauer spectra of the $SrFe_{12-x}(Ni_{0.5}Co_{0.5}Sn)_{x/2}O_{19}$ samples with various x in the range from 0 to 2.5. Based on the results of the analysis of the Mössbauer spectrum of the substituted material (x = 1), the crystal chemical formula of $SrFe_{11}(Ni_{0.5}Co_{0.5}Sn)_{0.5}O_{19}$, emphasizing the site occupancy at the atomic level, may be written as follows: $Sr(Fe_2)_{4f2}(Fe_5Ni_{0.25}Co_{0.25}Sn_{0.5})_{12k}(Fe_1)_{2a}(Fe_2)_{4f1}(Fe_1)_{2b}O_{19}$. Thus, it can be concluded that Ni, Co and Sn ions in $SrFe_{12-x}(Ni_{0.5}Co_{0.5}Sn)_{x/2}O_{19}$ preferentially occupy the 12*k* sites. Vibrating sample magnetometer shows the relatively strong dependence of coercivity, and saturation magnetization with the volume fraction of MWCNTs. Reflection loss of the MWCNTs/doped strontium ferrite nanocomposites is evidently enhanced compared to that of pure MWCNTs and ferrite nanoparticles. It was found that the maximum reflection loss is increased significantly by an increase in volume percent of MWCNTs in nanocomposites. The investigation of the complex relative permeability and permittivity indicates that better reflection loss property can be ascribed to the better magnetic loss and matched characteristic impedance, rather than improvement in dielectric loss

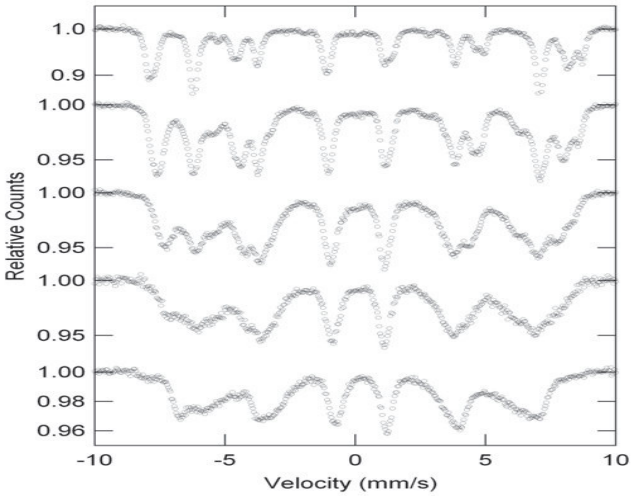

Fig. 1. ^{57}Fe Mössbauer spectra of $SrFe_{12-x}(Ni_{0.5}Co_{0.5}Sn)_{x/2}O_{19}$ for x = 0, 0.5, 1, 1.5, 2.5 (from top to bottom).

[1] A. Ghasemi, S. Javadpour, X. X. Liu, A. Morisako, IEEE Trans. Magn., 47, 4310-4313, (2011).
[2] A. Ghasemi, V. Šepelák, X. X. Liu, A. Morisako, IEEE Trans. Magn.,47, 2800-2803, (2011).
[3] A. Ghasemi, V. Šepelák, X. Liu, A. Morisako, IEEE Trans. Magn. 45, 2456-2460, (2009).

TU-177

Magnetoabsorption and magnetic hysteresis in Ni ferrite nanoparticles

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Spinel ferrites are widely used for electrotechnical equipment since their discovery in the forties. Nanoscale devices with engineered physical and magnetic properties result in substantial improvement in the quality of materials that are useful in a variety of applications. In the last years there is a strong interest in ferrite nanoparticles due to the fact that nanoscale materials possess properties that are comparable to or superior to those of bulk materials counterparts, as well as its potential applications in sensors or microwave devices.
Nickel ferrite nanoparticles were prepared by a modified sol-gel technique employing coconut oil, and then annealed at different temperatures in 400-1200 ºC range. This route of preparation has revealed to be one efficient and cheap technique to obtain high quality nickel ferrite nanosized powder. Sample particles sizes obtained with XRD data and Scherrer's formula lie in 13 nm to 138 nm, with increased size with annealing temperature.
Magnetic field induced microwave absorption in nanoscale ferrites is a recent an active area of research, in order to characterize and explore potential novel applications. In the present work microwave magnetoabsorption data of the annealed nickel ferrite nanoparticles are presented. These data have been obtained with a system based on a network analyzer that operates in the frequency range 0 - 8.5 GHz. At fields up to 400 mT we can observe a peak according to ferromagnetic resonance theory. Data with high magnetic fields allow also the determination of permeability and permitivity. Hysteresis loops have been obtained at room temperature with inductive method. Sample annealed at higher temperature exhibits different coercivity and saturation magnetization figures, revealing its multidomain character.
Finnancial support from Accion Integrada Hispano/Lusa AIB2010PT-00265 and Junta de Castilla y Leon Ref: VA230A11-2 is acknowledged.

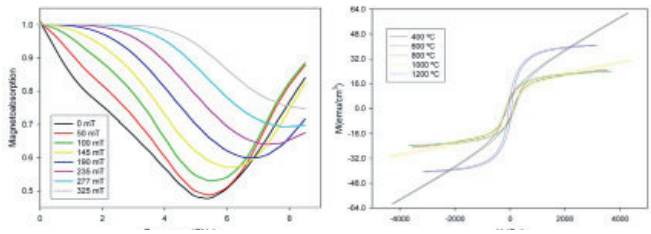

Figure 1:a) Magnetoabsorption of 1200º C annealed nanoparticles b) Hysteresis loops

TU-178

Coulometry and Voltammetry of Ultrasmall Colloids: Introduction to a new Field

F.A. Tourinho [1], E.P. Marinho [1], C.L. Filomeno [1], T.A.G.P. Cotta [1], J. Depeyrot [2]

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The characterization of aqueous colloidal dispersions based on spinel ferrite nanoparticles by ordinary spectroscopy methods UV-VIS-IR is usually difficult because of the high optical absorption coefficient of these materials. On the other hand, a set of electrochemical techniques can be used, such as potentiometry and conductometry, which have recently proved to be a powerful tool [1]. In this work we investigated a new electrochemical field based on the electrolysis of ultrasmall colloids at the interface electrode/dispersion under conditions of complete polarization. A square wave voltammetry (SWV) of a collection of non-interacting magnetic nanoparticles based on maghemite and colbalt ferrite revealed voltammetric diffusion-controlled currents that differ from those obtained with true solutions (free ions). The Nernst potential corresponding to the peak intensity is attributed to the reduction of iron ions of the nanostructure from Fe(III) to Fe(II). This peak is shifted about 1 V in the direction of cathodic potential when compared to the free ions case indicating that the reduction process is easier for the later. Then, we realize a controlled-cathode-potential electrolysis (potentiostatic coulometry) of the same samples. In this case, the integrated current leads to the concentration of iron ions involved in the reduction process by using the Faradays law. For maghemite nanoparticles, the results indicate that only two thirds of the iron atoms, present in the octahedral sites of the nanocrystal structure, were reduced. Then, oxygen vacancies have to be considered to achieve the electroneutrality. For cobalt ferrite based nanoparticles, the results show that all iron atoms of the cobalt ferrite core are reduced. These results well match the core-shell characteristics of the synthesized nanoparticles [2].
Acknowledgments: CNPq, CAPES and FAPDF.

[1] A. F. C. Campos et al, Braz. J.Phys. 39, 230 (2009).
[2] J. A. Gomes et al, J. Phys. Chem. C 112, 6220 (2008).

TU-179

A study on magnetic properties of Co substituted magnetite nanoparticles

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In this work Co substituted magnetite ($Co_xFe_{1-x}Fe_2O_4$, x = 0, 0.25, 0.5, 0.75) nanoparitcles were prepared via coprecipitation method. The starting materials were corresponding stoichiometric quantities of high purity $FeCl_3$, $FeCl_2.4H_2O$, $CoCl_2$ and NH_4OH, all of analytical grade from Merck Company. Stoichiometric ratios [$(1+x)Fe^{2+}$+xCo^{2+}:Fe^{3+} equals to 1:2] of $FeCl_3$, $FeCl_2.4H_2O$ and $CoCl_2$ were mixed in distilled water. Ammonium hydroxide (NH_4OH) with a ratio (1:5) for total metal chlorides: ammonium hydroxide was added as fast as possible. A black precipitate was obtained after the rapid addition of NH_4OH. The precipitates were washed several times with deionized water and dried at room temperature. Phase identification of the dried precipitates was carried out by XRD method and their magnetic properties were measured by a homemade AGFM. The results show that by substitution of Co for Fe ions their crystal structures remain unchanged with a spinel structure, but their lattice constants changed. Magnetic measurements show that by increase in Co contents in magnetite structure the coercivity of magnetite increases and the compositions become harder from point view of magnetic properties. Also variation of magnetic susceptibility with respect to temperature was measured and

the results show that all curves have a maximum. In conclude results of this study show that it is possible to achieve a desired susceptibility by a convenient heat treatment.

TU-180

Magnetic properties of composites based on Fe powder and phenol-formaldehyde resin modified with Silicon dioxide

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Soft magnetic composites, which are used in electromagnetic applications, can be described as ferromagnetic powder particles surrounded by an electrical insulating layer. The aim of the study was to prepare the composites with different insulator composition within iron powder to improve the soft magnetic properties. The thermogravimetric analysis of Fe/PFR-SiO_2 composite was performed. A correlation between mechanical hardness and flexural strength of Fe/PFR-SiO_2 composite was studied in dependence on the amount of nano-SiO_2 in the coating. The morphology of coated Fe powder particles implies a very uniform coating without any visible exfoliation. Magnetic and electric properties of composites based on Fe powder particles and phenol-formaldehyde resin (PFR) modified with nanometer-sized SiO_2 are investigated in detail. Complex permeability spectra were measured with an impedance analyzer from 100 Hz to 40 MHz. The DC magnetic properties (magnetization and hysteresis curves) were obtained by measurements of DC hysteresis loops by a fluxmeter based DC loop tracer. The AC hysteresis loops were measured in frequency range 50 Hz-1 kHz by MATS-2010M and in frequency range 1 kHz -100 kHz by MATS-2010SA at the maximum flux density of 0.05 T, 0.1 T and 0.2 T, respectively. The specific electrical resistivity of the ring sample was measured by the 4 point technique.
Permeability and core loss are structure sensitive and depend on factors such as powder size and shape, porosity, and specific electrical resistivity. The results show that optimum content of SiO_2 can improve mechanical and soft magnetic properties. The influence of the SiO_2 content in the resin on the magnetic properties and electrical resistivity is discussed in detail.

TU-181

DC and AC permeability of Fe-based composite material

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The application of the group of soft magnetic composites (SMCs) has expanded by the introduction of new materials with significantly improved low and medium frequency AC magnetic properties in the last years. The possibilities of further improvement of magnetic properties of SMCs to extend the variety of application are still not exhausted.
SMCs are ferromagnetic powder particles separated with an electrically insulated layer and each particle produces demagnetizing field oriented opposite to the external magnetic field. The demagnetizing field degrades in general the soft magnetic properties of SMCs, especially the permeability decreases very significantly. Logical requirement in SMC is low insulation material content leading to the reduction of the demagnetizing field but on the other hand sufficiently high value of the specific resistivity must be kept.
The aim of this work was to analyse the role of the resin content on DC and AC permeability of Fe-based composite material.
The samples of composite material were prepared in the form of the ring by a compaction of the powder prepared by a mixture of iron powder ASC100.29 (Höganäs) and commercial thermoset resin (iron content 90 and 80 vol. %).
The results of the DC permeability calculated from magnetization curves show, that the maximum permeability decreases with the increase of resin content. The initial permeability calculated from the magnetization curve measured in weak magnetic field (according to the Rayleigh rule) shows similar tendency with resin content as for maximum permeability. The decrease of the initial and maximum permabilities with resin content caused by the demagnetizing field is lower than expected according to the theoretical assumptions for SMC with regularly arranged ferromagnetic particles. This behaviour together with AC frequency dependence of complex permeability is discussed.

TU-182

Phase transition with Mössbauer spectroscopy on spinel vanadate

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The vanadium spinels AV_2O_4 have attracted a lot of attention due to their interesting phenomena such as magnetoelastic and Jahn-Teller effects [1]. It is known that the spinel vanadate FeV_2O_4 exhibits successive structural phase transitions and has received considerable interests because of the possibility of nonvolatile memory devices [2, 3]. We have investigated the hyperfine interaction for the ferrous (Fe^{2+}) in the spinel FeV_2O_4 by Mössbauer spectroscopy. The crystal structure at room temperature was found to be cubic normal spinel structure with lattice constant a_0=8.3827 Å by the Rietveld refinement. Temperature dependence of magnetization show ferromagnetic property with a large coercivity of 1.4 T at 5 K. An anomaly in magnetization curve is found to be close 72 K. The Néel temperature (T_N) was determined to be 109 K. Mössbauer spectra have been taken at various temperatures ranging from 4.2 K to room temperature. A systematic change in the Mössbauer spectrum with decreasing temperature is found and attribute to the Jahn-Teller distortion. The Mössbauer spectra of FeV_2O_4 show asymmetrical eight lines due to large electric quadrupole interactions including the contribution of lattice distortion below T_N. The magnetic hyperfine field and electric quadrupole interaction at 4.2 K have been fitted with Mössbauer hyperfine parameters of H_{hf}=8.2 T, ΔE_Q=3.05 mm/s, δ=0.94 mm/s. The unusual reduction of magnetic hyperfine field below 85 K is observed. It can be explained in terms of cancellation effect between the mutually opposite orbital current field (H_L) and Fermi contact field (H_C). Isomer shift at room temperature is 0.81 mm/s, which means that the charge state of the Fe ions was ferrous in character.

[1] G.-W. Chern et al., Phys. Rev. B 81, 125127 (2010)
[2] T. Suzuki et al., Phys. Rev. B 77, 220402 (2008)
[3] H. Takei et al., Appl. Phys. Lett. 91, 072506 (2007)

TU-183

Structural and magnetic properties of $CuFe_2O_4$ synthesized by reactive milling and heat treatment

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Copper ferrite powder, $CuFe_2O_4$, was synthesized from stoichiometric mixture of CuO and α-Fe_2O_3 by a reactive milling followed by heat treatment. In the as milled samples, various phases are observed depending on milling time : solid solution CuO-α-Fe_2O_3 cubic - $CuFe_2O_4$, Cu_2O, Fe and Cu. In order to obtain $CuFe_2O_4$ in the whole sample volume heat tretments were applied. After the heat treatment at 600 °C for 6 h the samples consist in α-Fe_2O_3, CuO and cubic-$CuFe_2O_4$. Increasing the heat treatment at 800 and 1000 °C for 6 h, $CuFe_2O_4$ was obtained for almost all the samples. A sample of cubic-$CuFe_2O_4$ h was milled for the crystallite size reduction. It was found that after the heat treatment at 800 °C for 6 h in the samples tetragonal and cubic-$CuFe_2O_4$ coexist and the amount of cubic copper ferrite increased for the samples milled longer. The magnetisation for these samples increases also upon increasing the milling time. The magnetisation of the samples heat treated at 800 °C for 6 h is lower comparison with the that of the samples heat treated at 1000 °C for 6 h. This is linked with the tetragonal to cubic structure transformation of $CuFe_2O_4$ by increassing the heat treatement temperature. After the heat treatment at 1000 °C for all the milling time, the magnetisation is larger and close to the value of the partial inverse structure of $CuFe_2O_4$ with one Cu^{2+} in tetrahedral sites (16 μ_B/f.u.). The magnetisation of the nanocrystalline ferrite obtained by the mechanical milling of cubic-$CuFe_2O_4$ is lower due to the spin canted effect and to millling induced cation redistribution in the spinel.

TU-184

Influence of Cr-dopping on chalcogenide $Sn_2P_2S_6$ physical properties

S. Ilkovič [1], *M. Reiffers [1]*, V. Šebeň [1], K. Šterbáková [1], V. Burger [1], L. Parma [2], O. Chobal [3], I. Rizak [4], V. Rizak [4]
(1) Faculty of Humanities and Natural Sciences, University of Prešov, 17.novembra, SK-081 16 Prešov, Slovakia, (2) Faculty of Humnities and Natural Sciences, University of Prešov, 17.novembra, SK-081 16 Prešov, Slovakia, (3) Uzgorod national university, Uzhgorod, Ukraine, (4) National aerocosmic university - KHAI, Kharkiv, Ukraine

$Sn_2P_2S_6$ is a ferroelectric semiconductor, where at room pressure the transition from paraelectric into ferroelectric state occurs at T_0 = 337 K. The study of the isomorphous substitution of the sulphur by the selenium in $Sn_2P_2S_6$ revealed that the phase transition shifted to lower temperatures. In $Sn_2P_2Se_6$ was observed the diffraction evidence of the incommensurate phase with anomalous behaviour of physical properties above T_0. Moreover, as it is well-known, the behaviour of the temperature dependence of electrical resistivity of Sn2P2S6 chalcogenide depends on the temperature change rate due to pyroelectric effect. Previously, we have studied heat capacity, magnetization, susceptibility and electrical resistivity of the chalcogenides $(Pb_ySn_{1-y})_2P_2S_6$ where Pb content varies from 0 till 0.8. The increasing Pb content shifts phase transition to the ferroelectric state at about 337 K towards to lower temperatures while magnetic field till 3 T has no influence on this transition. The temperature behaviour of susceptibility shows the temperature independent Pauli paramagnetic contribution. The magnetic dependencies of magnetisation displayed the saturation of small magnetic moment with increasing magnetic field for y > 0.4. Therefore, in this contribution we have investigated the influence of the substitution of Sn by Cr atoms on the temperature dependences of electrical resistivity. Moreover, we have studied the magnetic and thermal properties of Sn2P2S6 dopped by the Cr. We compare our previous results obtained on the substitution of Sn by Pb with the influence of Cr. We have observed that the temperature cycling has only a small influence on the magnitude of an electrical resistivity and no inlfuence on the temperature behaviour. From this follows that Cr is depressing the influence of pyroelectric effect in some temperature region, what can be potentially used for thermometric purposes.

TU-185

Analysis of the energy losses in Fe-based composite material

Z. Birčáková [1], P. Kollár [1], J. Füzer [1], M. Fáberová [2], R. Bureš [2]
(1) Institute of Physics, Faculty of Science, P. J. Šafárik University, Košice, Slovakia, (2) Institute of Materials Research, Slovak Academy of Sciences, Košice, Slovakia

Soft magnetic iron composites (SMCs) find increasing use in various DC and AC electromagnetic applications, replacing traditional materials.
The aim of this work was to analyze the contribution of hysteresis, eddy current and excess losses to the total losses of Fe-based SMC with various magnetic content (prepared by compaction of Ancorsteel iron with phenol-formaldehyde resin – 5-20 vol.%) in the frequency range DC-1 kHz at lower maximum flux densities up to 0.2 T and to apply Bertotti's statistical theory in order to describe the frequency dependence of excess losses.
Firstly, we found that material with higher magnetic fraction exhibits lower hysteresis losses because of better interactions between particles (influence of particle size was excluded).
Secondly, the inter-particle and intra-particle eddy current losses were calculated. We found that larger amount of insulator in SMC ensure better insulation of magnetic particles which results into small values of inter-particle eddy current losses (eddy current paths are closed in particles), in comparison with material with worse insulated particles.
Last but not least part of this work was detailed study of excess losses resulting in an explanation of frequency dependence of these losses in SMCs. Excess losses were obtained by subtracting eddy current losses from dynamic losses which show linear frequency dependence.
Due to higher resistivity and higher numbers of active magnetic objects in SMCs, the theory of magnetic objects in confrontation with observed linear dependence leads to the description of excess losses, which is the same as provided by another approach – first order Taylor expansion of Bertotti's formula for excess losses.
The linear dependence of excess losses on frequency is an interesting result observed in SMCs for frequency range DC-1 kHz at lower maximum flux density which contrasts with the f ^{1/2} law typical for many magnetic materials.

TU-187

Influence of magnetostriction on hysteresis loss of electrical steel sheet

H. Tada [1], H. Yashiki [1]

(1) Corporate Research and Development Laboratories, Sumitomo Metal Industries, ltd., 660-0891, Amagasaki, Japan

Hysteresis loss was proportional to magnetostriction independently of Si and Al content [1]. However, this reason has not been revealed. In this investigation, in order to reveal the relation between hysteresis loss and magnetostriction, hysteresis loss and magnetostriction generated by magnetic wall motion at magnetic flux density of 0.5 to 1.0T and frequency of 400Hz under stress of GO were measured. Here, stress direction was parallel to magnetizing direction and measurement direction. The angle θ between rolling direction and magnetizing direction was 0, 55 and 90°. The magnetizing direction is parallel to <100> at θ=0°, <111> at θ=55° and <110> at θ=90°. Fig.1 shows the relation between hysteresis loss and magnetostriction. Here, to change the hysteresis loss and magnetostriction, they were measured under the compressive or tensile stress. Hysteresis loss and magnetostriction of θ=0 and 90° sample increased with compressive stress and decreased with tensile stress, while those of θ=55° sample didn't change by the stress. Hysteresis loss of θ=0 and 90° sample was proportional to magnetostriction. The intercept, $Wh_{\lambda p\text{-}p=0}$, of θ=0 and 90° sample was the hysteresis loss generated by 180° magnetic wall motion because magnetostriction doesn't accompany 180° magnetic wall motion. $Wh_{\lambda p\text{-}p=0}$ of θ=0° sample was smaller than that of θ=90° sample because the volume of θ=0° sample where 180° magnetic walls moved was smaller than that of θ=90° sample. The volume is affected by magnetic flux density, saturation magnetic flux density and the magnetizing direction. In this presentation, the relation among hysteresis loss, magnetostriction and the volume where magnetic walls moved will be discussed.

[1] H. Tada, H. Fujimura, H. Yashiki, CAMP-ISIJ vol.2 (2009), 237

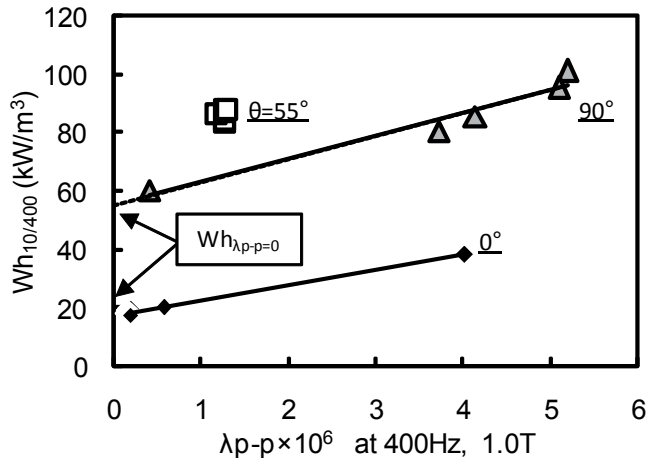

Fig.1 Influence of magnetostriction on hysteresis loss

TU-188

Coercivity and permeability characterisation by microstrip transmission line method

J.W. Burssens [1], S. Ediger [2], H. Peus [1], J. Lange [3]

(1) Melexis N.V., (2) Fachhochschule Kaiserslautern, (3) Fraunhofer-ISIT

In magnetic hall sensors small soft magnetic structures are plated or glued on top of hall plates in order to be sensitive to in-plane magnetic fields. Up to now there is lack of a cheap fast method that can measure both permeability and coercivity on a small structure.

To characterize the magnetic properties of materials there are already several methods developed, going from VSM over MOKE to stripline methods and ferrite-eight coils. But up to now no method is integrating a permeability and coercivity measurement on a small planar structure, like the ones obtained in a CMOS process.

To overcome these problems we extended the microstrip transmission line method to be able to measure the Rayleigh constant. The combination of the coercivity and permeability enable us to estimate the coercivity of the deposited material. Further the possible pitfalls of this measurement (like domain closure resonance) are lined up.

In a third step, a process control structure is proposed which integrates the impedance line with a stress estimation tool.

[1] W.B. Weir, Proc. IEEE 62 , 33 (1975)

[2] S. Mallegol, IEEE, Trans Micorowave Theo. and Techn., 1065-1075 (2006)

[3] S. Yabukami et al. / J. Magn. Magn. Mat. 254–255, 111–114 (2003)

[4] B. Viala, Le ferromagnétisme en couches minces pour les hyperfréquences (2012)

[5] Herzer, Handbook of magnetic materials, vol. 10 (1997)

TU-189

2D Modeling procedure of RM type ferrite cores including real power losses as a function of operating frequency

R.A. Salas [1], J. Pleite [1]

(1) Departamento de Tecnología Electrónica, Universidad Carlos III de Madrid, 28911, Leganés (Madrid), Spain

Soft ferrite cores exhibit several qualities that make modeling difficult. In particular, the nonlinear nature and the wide variety of core topologies make it difficult to obtain the characteristic parameters of the equivalent electric circuit for use in all working ranges (linear, intermediate, and saturation). There are ideal 2D modeling procedures that do not include the real power losses in the inductors [1]-[2].

In this paper, we show a 2D modeling procedure valid for real working conditions. We present and analyze power loss in the ferrite core as a function of frequency and the excitation level from the linear to the saturation region. We show the results of an RM14/I inductor with 28 turns and a soft ferrite core made of MnZn from the manufacturer "Ferroxcube". In Figure 1(a) we show the real inductor and in Figure 1(b) the 2D equivalent inductor with the mesh generated in the 2D proposed procedure. The validation of the 2D procedure consisted in comparing the results of 2D simulations with experimental measurements at two frequencies: 500 Hz (quasi-static condition) and 40 kHz (working frequency of ferrite). In Figure 1(c) we present power loss P and resistance R showing a good agreement between the

2D results and measurements and also showing how the losses in the saturation region increase strongly with frequency.

[1] R. A. Salas et al., J. Magn. Magn. Mater. 320 (2008)
[2] R. A. Salas and J. Pleite, IEEE Trans. Magn. 47 (2011)

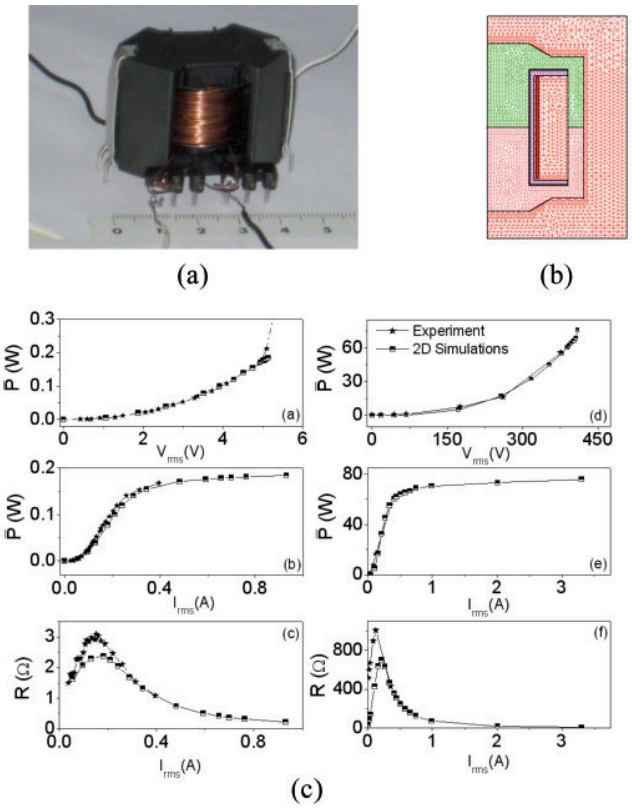

Figure 1: (a) Real inductor with RM core. (b) Cross-section used in the 2D simulations with the generated mesh. (c) Power loss P and resistance R at 500 Hz ((a), (b), (c)) and 40 kHz ((d), (e), (f)). Vrms is the rms voltage and Irms is the rms current.

TU-190

Analysis of the behavior and 2D Modeling of ferrite inductors with E geometry: comparison with 3D model and real measurements

R.A. Salas [1], J. Pleite [1]
(1) Departamento de Tecnología Electrónica, Universidad Carlos III de Madrid, 28911, Leganés (Madrid), Spain

Soft ferrite cores present nonlinear phenomena, such as saturation and hysteresis, which must be included in any model requiring precision. Our previous publications have attempted to do just this by means of Finite Element Analysis (FEA) [1]-[3] but our methodology has not been applied to E cores. E cores are usually used in power electronics, for example in converters and inverters for photovoltaic solar energy.
We present the behaviour of magnetic flux and inductance as a function of current intensity level from the linear to the saturation region and the 2D modeling procedure for a soft ferrite inductor with two E-type halves. It reproduces saturation as well as geometric effects such as different air-gap thickness, sizes of the core and number of turns. In Figure 1(c) we show the results of the model and the comparison with real measurements and the 3D model obtained for a specific E20/10/5 core with 15 turns The 3D and real results are very similar while the 2D results show only a slight discrepancy and therefore are considered valid for electronic circuit simulation programs with the advantages of simplification, low computational cost and easy calculation procedure compared to other procedures. In Figure 1(a) we show the real inductor and in Figure 1(b) we show the cross-section used for the 2D simulations.

[1] R. A. Salas et al., J. Magn. Magn. Mater. 320 (2008)
[2] R. A. Salas and J. Pleite, J. Appl. Phys. 107, (2010)
[3] R. A. Salas and J. Pleite, IEEE Trans. Magn. 47 (2011)

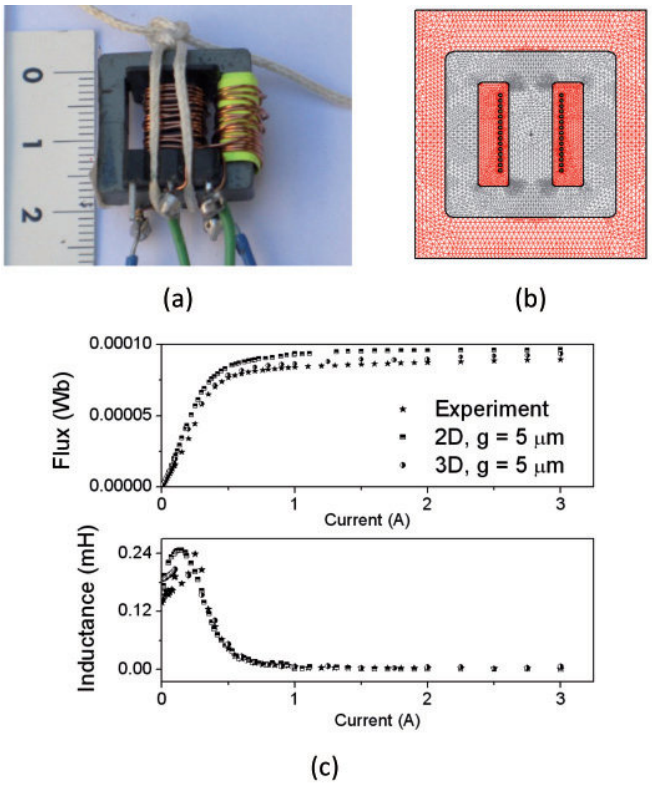

Figure 1: (a) Real inductor. (b) Cross-section used in the 2D simulations with the generated mesh. (c) Flux-Current curves and Inductance-Current curves (g is the gap thickness)

TU-191

High-frequency losses in thin laminations and their prediction

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(1) INRIM, Istituto Nazionale di Ricerca Metrologica, Electromagnetism Division, 10135, Torino, Italy

The magnetization process in thin amorphous and nanocrystalline ribbons has been investigated and modeled in the frequency range from DC to 1 GHz. Very thin transverse anisotropy laminations display excellent broadband magnetic behavior, ensuing from the dominant role of magnetization rotations. Quantitative interpretation of such behavior has not been done so far. It is not clear, in particular, what are the respective roles of eddy current and spin damping dissipation mechanisms. Combining fluxmetric, aftereffect, and high-speed magneto-optical experiments one obtains that the domain wall processes, the obvious source of losses at low and medium frequencies in

spite of negligible contribution to the magnetization, fully damp on attaining the MHz range. Here the energy dissipation chiefly descends from the rotations and conforms to the so-called classical regime. In order to describe the high-frequency spin dynamics, the coupled Maxwell and Landau-Lifshitz-Gilbert equations are therefore considered [1][2]. A numerical solution of such equations by a finite element approach has therefore been worked out. It is based on a very fine time discretization and a computing scheme preserving the magnetization modulus. From the calculation of hysteresis loop and eddy current density at each mesh point, the separate contributions to the rotational losses by the eddy currents and the spin damping mechanism are eventually attained. The overall energy loss behavior versus frequency is thus predicted in terms of separate contributions by the domain wall processes and the rotations.

[1] C. Serpico, I.D. Mayergoyz, and G. Bertotti, "Analysis of eddy currents with Landau-Lifshitz equations as a constitutive relation", *IEEE Trans. Magn*., vol. 37, pp. 3546-3549, (2001).
[2] P. Ciureanu, L.G.C. Melo, D. Seddaoui, D. Ménard, and A. Yelon, "Physical models of magnetoimpedance", *J. Appl. Phys.*, vol. 102, p. 073908, (2007).

TU-192

Rotor Losses in a Switched Reluctance Motor – Analysis and Reduction methods

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(1) Institute of Electrical Measurement and Measurement Signal Processing, Graz University of Technology, 8010 Graz, Austria, (2) Institute of Sensor and Actuator Systems, Vienna University of Technology, 1040 Vienna, Austria

A flywheel storage system for an automotive application has typically a high power capability and a low energy content (e.g. 20 kW and 300 kJ). Additionally several constraints, such as size, weight, and cost, have to be fulfilled. Therefore typically a compact design, in which the rotor of the needed electrical machine simultaneously acts as storage mass is chosen.
To maximize the energy density of the flywheel a high strength rotor is needed, which is achieved only by a reluctance motor [1]. The comparison between synchronous and switched reluctance machines shows clear advantages for the switched one, except with respect to the rotor losses. This represents a big issue, since the machine is running in vacuum and the rotor can dissipate its heat only by means of radiation.
This paper will deal with the analysis of the rotor losses and possibilities to reduce them. For this purpose the magnetic field of the motor is simulated with a FEM software resulting in a detailed description of the rotor losses and their distribution. The influence of the converter, especially due to the ripple current, is investigated. Also a specific pulse pattern is analysed, whereby every pole in the rotor is always magnetized only in the same direction as the previous magnetization. In theory this should significantly reduce the hysteresis losses. Experimental measurements will be carried out to measure the actual reduction of the rotor warming.

[1] R. Krishnan, Switched reluctance motor drives: modeling, simulation, analysis, design, and applications. CRC Press LLC, (2001)

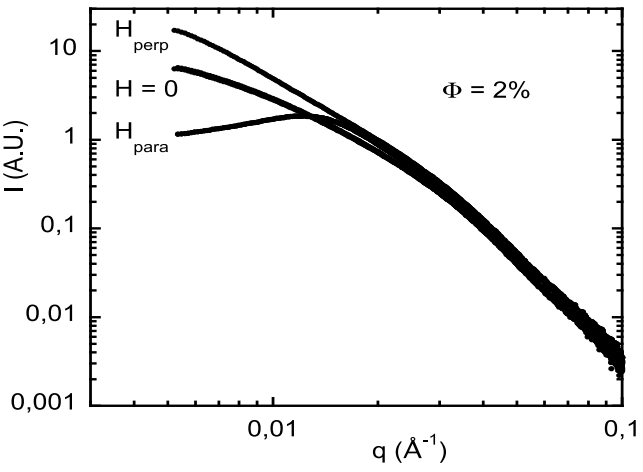
TU-193

Local under-field microstructure of slightly attractive Magnetic Fluids

A.F. Silva [1], F.L.O. Paula [1], R. Aquino [2], J. Depeyrot [1], F.A. Tourinho [3], E. Dubois [4], R. Perzynski [4]
(1) Complex Fluids Group, Instituto de Física, Universidade de Brasília, 70919-970, Brasília-DF, Brazil, (2) Complex Fluids Group, Faculdade UnB Planaltina, 70910-900, Brasília-DF, Brazil, (3) Complex Fluids Group, Instituto de Química, Universidade de Brasília, 70904-970, Brasília-DF, Brazil, (4) Université Pierre et Marie Curie, PECSA - UMR 7195,75005 Paris, France

Biotechnical applications of aqueous Magnetic Fluids (or Ferrofluids) are quite numerous. Such colloidal dispersions are based on magnetic monodomain nanoparticles (NPs), typically 10 nm in diameter, which are stabilized in the aqueous dispersion by electrostatic repulsion. Their colloidal stability needs to be finely tuned, in particular under applied field as their resulting microstructure has a determining influence on their physical properties. For example, the existence of aggregates, small chains or individual nanoparticles drastically modifies their viscosity or their magnetic susceptibility. In home-made aqueous ferrofluids, based on chemically synthesized NPs, controlling synthesis parameters such as pH, ionic strength, NP coating, NP diameter and volume fraction allows to tune the interparticle repulsion [1]. In Small Angle Scattering experiments, such monitored ferrofluids present under-field an anisotropy of their structure factor S(q) (q scattering vector) which is related to the anisotropy of the total interparticle interaction, driven by the magnetic dipolar contribution [2]. Depending on its weight with respect to that of the isotropic repulsion, this interaction anisotropy leads to small anisotropic modulations of the structure when the isotropic repulsion is strong or to drastic destabilizations when attraction dominates. The present study focuses on the under-field microstructure of home-made aqueous ferrofluids based on $CoFe_2O_4$ and $MnFe_2O_4$ NPs [3] by Small Angle X-ray Scattering (SAXS–LNLS–Brazil) in the intermediate situation of slightly attractive interactions in zero field. The local microstructure of such ferrofluids becomes anisotropic under applied field, becoming repulsive along the field and remaining slightly attractive in the perpendicular direction (see below).
Acknowledgments: CAPES-COFECUB, CNPq, CNRS, FAPDF

[1] F. Cousin et al, Phys. Rev. E 68 021405 (2003)
[2] G. Mériguet et al, J. Phys. Chem. B 110 4378 (2006)
[3] J. A. Gomes et al, J. Phys. Chem. C 112 6220 (2008)



SAXS intensity of a $CoFe_2O_4$ ferrofluid slightly attractive at pH=2.

TU-194

Analytical formulation for quasi-static hysteretical loop

O. Geoffroy [1]

(1) Grenoble Electrical Engineering Laboratory, BP46, F38-402 Saint-Martin d'Hères Cedex, France

We propose a new analytical description of the static hysteretical loop $J(H, H_m)$, H_m denoting the magnitude of the excitation field. The model was successfully confronted with experimental measurements carried out on an iron alloy.

The main idea is to take profit of the relations existing between the branches of the loop $J_a(H,H_m)$ or $J_d(H,H_m)$ (subscript a for ascending, d for decreasing), the **F**irst **M**agnetization **C**urve $J_f(H)$ and their derivatives at the connection points ($H = +^{-} H_m$). This leads to focus on the difference $J_f - J$. We thus propose the general formulation

$$J_f - J_a = \frac{f(H_m)}{ch(\alpha H)}\, g(H,H_m)\,(1 - H/H_m) \qquad J_f - J_d = -\frac{f(H_m)}{ch(\alpha H)}\, g(H,H_m)\,(1 + H/H_m)$$

$$g(H,H_m) = \frac{ch(\alpha H_m) - ch(\alpha H)}{ch(\alpha H_m)} \qquad f(H_m) = \sum_0^n \beta_i th(\alpha H_m)^i \qquad (1)$$

The expression of the FMC is derived from (1) noting that the initial point of a branch is a reversal point. This implies that the susceptibility is there equal to the reversible susceptibility along the FMC $\chi_{rev}(H_m)$. Differentiating (1) at $H = - H_m$ leads thus to the irreversible part $\chi_{firr}(H) = \partial J_f / \partial H - \chi_{frev}(H)$ along the FMC, that is

$$\chi_{firr}(H) = 2\,\alpha\, f(H)\, \frac{sh(\alpha H)}{ch(\alpha H)^2} \qquad (H > 0) \qquad (2)$$

Integrating (2) leads to a simple analytical expression of the irreversible polarization $J_{firr}(H)$ along the FMC.

The reversible susceptibility $\chi_{frev}(H)$ is simply measured. The reversible polarisation $J_{frev}(H)$ is then substracted from the experimental FMC to obtain the experimental irreversible polarisation. Numerical values of parameters α and β_i ($0 < i < 4$) are finally obtained by a fitting procedure. Expression of polarization J_a or J_d along the branches of the loop are then obtained reinjecting expression $J_f(H)$ in (1).

The experimental loops and modelized were compared, with very good results for $0 < H_m < H_C$. For bigger H_m, some adjustments have to be done to take into account of the sharpness of the branches at the vicinity of H_C.

TU-195

BH-Loop Evaluation from Measurements on Soft Ferrite Toroids

P. Fulmek [1], P. Haumer [1], B. Schweighofer [2], M. Recheis [2], H. Wegleiter [2]

(1) Applied Electronics Materials, ISAS, Vienna University of Technology, Vienna, Austria, (2) Institute of Electrical Measurement and Measurement Signal Processing, Graz University of Technology, Graz, Austria

The measurement of BH-loops of magnetic materials is preferably done in a closed-flux arrangement to avoid demagnetising effects. If magnetic field and flux density are reliably homogeneous over the sample region, the extraction of the material's BH-loop from measurement is quite trivial. This condition, however, is hardly ever fulfilled for real specimen. As ferrite toroids are commonly used in many sorts of electrical devices, they are rather characterised by the electrical properties of the complete device, than by their materials' properties and the device geometry. Accordingly international standards for the characterisation of magnetic materials have defined and extended limits for the geometrical aspect-ratio of ring-shaped specimen to allow the comparison of different products rather than to characterise the magnetic materials.

In this work we concentrate on the extraction of the ferrite materials DC-magnetic properties from inductive measurement of different ferrite ring-samples. Standard measurements introduce an intrinsic error by relying on a definition of a mean magnetic path length and the mean magnetic flux-density, assuming that both values will simultaneously assemble a point on the material's BH-loop. The cylindrical symmetry of the sample allows to exactly extract the material's BH-loop from measurements. The measurement signals (primary current, secondary voltage) define the magnetic field strength at all points in the sample, and the total flux over a sample cross-section. The primary current exactly gives the applied magnetic field, the magneto-motoric force (mmf). The flux-versus-mmf characteristic is used to accurately determine the material's BH-loop. Results of DC-measurements on ferrite samples with different geometrical shapes are compared.

[1] F. Fiorillo, Measurement and Characterization of Magnetic Materials, Elsevier, 2004.
[2] DIN EN 60404-6 (IEC 60404-6) (2003)
[3] T. Nakata et al., IEEE Trans.Magn. 28-5, 2456 (1992)

TU-196

Optimization of active magnetic bearings for automotive flywheel energy storage systems based on soft magnetic material properties

M. Recheis [1], H. Wegleiter [1], B. Schweighofer [1], P. Fulmek [2]

(1) Institute of Electrical Measurement and Measurement Signal Processing, Graz University of Technology, Graz, Austria, (2) Institute of Sensor and Actuator Systems, Vienna University of Technology, Vienna, Austria

The design and optimization of a magnetic bearing system for an automotive flywheel energy storage system (FESS) does include optimization criteria, requirements and limitations. First, the overall system weight is the most important optimization criterion for an automotive application. Keeping manufacturing and operating costs as low as possible comes secondly. A minimal package size in a certain shape, for ease of integration, constitutes the third criterion. The most important requirement for one magnetic bearing component is the required maximum force. The maximum force is defined by gyroscopic torque due to vehicle deflection and linear force due to vehicle movement. The vehicle movement also defines the needed force rise time. The main mechanical limitation for the active magnetic bearing is the rotors tangential stress due to centrifugal force. The main electric limitation is the power consumption and losses of the magnetic bearing system, which affect the FESS's level of efficiency. This paper will present a sequential iterative optimization strategy that covers all the three mentioned criteria. The optimization is based on the soft magnetic material's mean B-H curve and loss curve, the FESS's geometry and mass and the magnetic bearing's power electronics. The optimization results of different steel sheet laminations will be compared and discussed. Additionally the advantages and disadvantages of high flux and high strength soft magnetic steel sheets are presented.

TU-197

Numerical Analysis of Magnetic Oscillation DC-AC Converter Using Bridge-onnected Magnetic Circuit

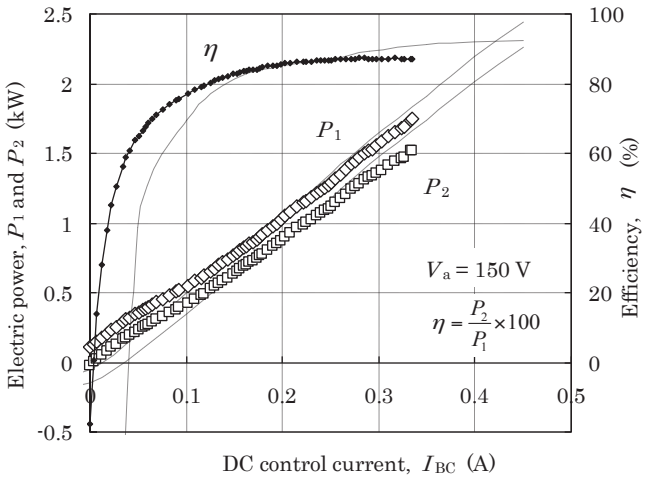
S. Okanuma [1]

(1) Department of Mechanical and Electrical Engineering, Fukushima University, Fukushima 960-1296, Japan

This paper describes a numerical circuit analysis of a magnetic oscillation type direct current/alternating current (dc-ac) converter using a bridge-connected magnetic circuit. The converter can supply electric power to an ac-voltage source such as a line electric power source, and whose output electric power can easily be controlled by dc-current which flows through a winding of the bridge-connected magnetic circuit [1]. I present a simulation model of the bridge-connected magnetic circuit and the magnetic oscillation circuit based on a general purpose circuit simulation program called "SPICE" to quantitatively analyze it. A magnetic core model for SPICE is constructed by using current controlled current source, voltage controlled voltage source and non-linear dependent voltage source [2], and relation between magnetic flux and magnetomotive force is assumed by using a power series. The comparison between calculated results and measured results [1] of the electric power control characteristics is shown as the following figure. Where, P_1 is input electric power from the dc-voltage supply and P_2 is output electric power to the line electric power source. η is the electric power conversion efficiency. I_{BC} is dc-current for control. V_a is effective voltage value of the ac-voltage source. The calculated results are shown by the dotted lines in the figure. Amorphous magnetic cores are used in the oscillation circuit and the bridge-connected magnetic circuit. The magnetic characteristics of the cores is approximated by a power series, whose maximum order is 45. From this figure, it is revealed that the calculated results almost agree with the experimental results.

[1] S. Okanuma and Y. Ogata, *IEEE Trans. Magn.*, VOL. 46, No. 2, pp. 586-589 (2010)

[2] O. Ichinokura, et al, *J. Appl. Phys.* 69, pp. 4928-4930 (1991)



Control characteristics of input and output electric power of the converter.

Wednesday, 12 September 2012

Oral Communications

Wednesday, 12 September 2012
Aida Room

PLENARY
Chair: K. Hono

08.30 – 09.15
Racetrack Memory: The Spin on Domain Walls!
S.S. Parkin [1]
(1) IBM Almaden Research Center, 95120-6099, San Jose, CA, USA

The formation and manipulation of magnetic domain walls (DWs) is of considerable interest both from a scientific as well as a technological perspective. A number of very interesting and potentially useful memory and logic devices based on the controlled manipulation of DWs in magnetic nano-elements have recently been proposed and are under intensive investigation. Using spin torque transfer from spin-polarized currents a series of domain walls can be moved in lock-step at high speed along magnetic nano-wires, enabling the Racetrack Memory [1]. Racetrack Memory (RM) promises a high-performance, non-volatile memory with very high density, resulting in a low-cost storage-class memory. A recent demonstration of a fully integrated first-generation RM with arrays of 256 racetracks will be discussed [2]. This demonstration used in-plane magnetized nano-wires formed from permalloy. We contrast the current induced motion of DWs in such nano-wires with nanowires formed from oligatomic Co and Ni layers in which the magnetization is perpendicular to the plane of the nanowire. We demonstrate in the latter case an additional interface-induced DW driving force which can drive the domain walls in either the same direction as in permalloy (electron flow), or in the opposite direction, depending on subtle changes in the structure of the nanowire. Moreover, we show that this additional force can lead to very high domain wall velocities of up to almost 1 km/sec. The large out-of-plane magnetic anisotropy in the Co/Ni multilayered racetracks also leads to very narrow domain walls allowing them to be closely spaced, and so allowing for much higher RM storage capacities. The particular properties of perpendicularly magnetized racetracks are so advantageous that they enable a new generation of Racetrack Memory.

[1] S.S.P. Parkin et al., Science **320**, 190 (2008).
[2] A.J. Annunziata et al. and L. Thomas et al., Proc. IEEE Electron Devices Meeting (2011).

Wednesday, 12 September 2012
Aida Room

SEMIPLENARY
Chair: L. Morellón

09.15 – 10.00
Dynamical generation of spin currents
E. Saitoh [1]
(1) Institute for Materials Research,Tohoku University,980-8577,Sendai,Japan

Spin current, a flow of electrons' spins in a solid, is the key concept in spintronics that will allow the achievement of efficient magnetic memories, computing devices, and energy converters. I here review phenomena which allow us to use spin currents in insulators [1]: inverse spin-Hall effect [2,4], spin pumping, and spin Seebeck effect [4-6]. We found that spin pumping and spin torque effects appear at an interface between an insulator YIG and Pt. Using this effect, we can connect a spin current carried by conduction electrons and a spin-wave spin current flowing in insulators. We demonstrate electric signal transmission by using these effects and interconversion of the spin currents [1]. Seebeck effect (SSE) is the thermal spin pumping [5]. The SSE allows us to generate spin voltage, potential for driving nonequilibrium spin currents, by placing a ferromagnet in a temperature gradient. Using the inverse spin-Hall effect in Pt films, we measured the spin voltage ge nerated from a temperature gradient in various ferromagnetic insulators. This research is collaboration with K. Ando, K. Uchida, Y. Kajiwara, S. Maekawa, G. E. W. Bauer, S. Takahashi, and J. Ieda.

[1] Y. Kajiwara & E. Saitoh et al. Nature 464 (2010) 262.
[2] E. Saitoh et al., Appl. Phys. Lett. 88 (2006) 182509.
[3] A. Ando & E. Saitoh et al., Nature materials 10 (2011) 655 -659.
[4] K. Uchida & E. Saitoh et al., Nature 455 (2008)778.
[5] K. Uchida & E. Saitoh et al., Nature materials 9 (2010) 894 - 897.
[6] K. Uchida & E. Saitoh et al., Nature materials 10 (2011) 737-741.

Wednesday 12 September 2012
Nabucco Room

SEMIPLENARY
Chair: J. Fontcuberta

09.15 – 10.00
Electronic states and magnetism and of atomic scale structures
C. Carbone [1]
(1) Istituto di Struttura della Materia, Consiglio Nazionale delle Ricerche, 34149 Trieste, Italy

Advances in nanotechnology, like the ability of controlled atom manipulation at surfaces, have brought the properties of atomic-scale structures into the focus of research in magnetism. In a very broad class of such systems one faces the question of properly describing how the competition between electron quantum confinement, hybridization, and correlation effects ultimately determines the magnetic properties. Selected studies making use of synchrotron radiation-based spectroscopic techniques will illustrate aspects of the electronic and magnetic state of single atoms, simple molecules, and very thin films interacting with metal surfaces. The hierarchy of the electronic interactions will be discussed with respect to the survival or quenching of the magnetic moment for an isolated atom as well as to the charge and magnetic state for the metal center of a molecule. In particular, novel effects on the quantum confined electronic states of atomic films which arise from the joint action of the spin-orbit and exchange interactions will be illustrated together with their implications for spin-polarized transport and magnetization manipulation.

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NANOSTRUCTURES 2

Chair: C. Binns

10.30 – 10.45

Surface and interface effects on magnetism in hybrid nanostructures

H. Srikanth [1]

(1) Functional Materials Laboratory, Physics Department, University of South Florida, Tampa, FL, USA

Magnetic nanostructures are considered basic building blocks in spintronics and high-density data storage applications. Surface and configurational effects in oxide nanoparticle assemblies have been increasingly found to play significant roles in controlling the magnetic anisotropy. Modification of the surface spin structure in magnetic oxide nanoparticles can be achieved by methods such as controlling the particle shapes, use of mechanical milling or surfactant chemistry to alter the coordination of surface atoms and forming interfaces with non-magnetic metals. We discuss how these effects often lead to novel magnetic properties, useful for applications, such as tunable exchange bias and enhanced magnetocaloric effect (MCE). Spin freezing, at surfaces and interfaces in core-shell and hybrid nanoparticles, is best studied through dynamic susceptibility experiments. We will present dynamic radio-frequency (RF) transverse susceptibility as a unique and powerful probe of surface and interface magnetism in nanostructures.

10.45 – 11.15

Magnetically Capped Rolled-up Nanomembranes *(invited)*

R. Streubel [1], D.J. Thurmer [2], D. Makarov [2], F. Kronast [3], T. Kosub [1], V. Kravchuk [4], D.D. Sheka [5], Y. Gaididei [4], R. Schäfer [6], O.G. Schmidt [1]

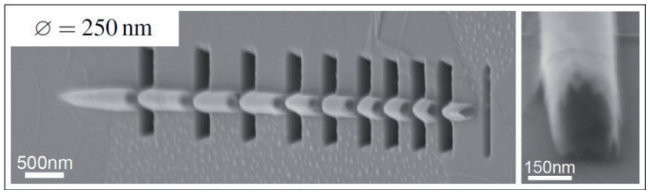
(1) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany and Material Systems for Nanoelectronics, TU Chemnitz, 09107 Chemnitz, Germany, (2) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany, (3) Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany, (4) Bogolubov Institute for Theoretical Physics, 03143 Kiev, Ukraine, (5) National Taras Shevchenko University of Kiev, 03127 Kiev, Ukraine, (6) Institute for Metallic Materials, IFW Dresden, 01069 Dresden, Germany and Institute for Materials Science, TU Dresden, 01069 Dresden, Germany

Over the past years, much effort has been dedicated to studying and tuning the magnetic properties of structurally confined magnetic media. This confinement modifies both magnetic equilibrium domain patterns and magnetization reversal processes. Conventionally, lithography approaches are applied to pattern magnetic films. Recently, it was demonstrated that tuning the curvature of magnetic nanostructures is a novel and elegant way towards tailoring the physical phenomena at the nanoscale [1], allowing to overcome limitations apparent in planar counterparts [2].

Here, we address curvature-driven changes of static magnetic properties in cylindrically curved soft-magnetic segments with different length and radii of curvature. We applied a strain-engineering approach, known as rolled-up nanotechnology [3] that exploits differential strain within an epitaxially grown membrane to fabricate (on-chip integrable) non-magnetic rolled-up tubes with cylindrical cross-section and a diameter down to 250 nm (see Figure). On these architectures, a 20 nm thick soft-magnetic permalloy ($Ni_{80}Fe_{20}$) film is deposited in order to obtain magnetic cap structures with a curvature-induced thickness gradient.

Joint experimental and theoretical studies, including X-ray magnetic circular dichroism photoelectron emission microscopy (XMCD-PEEM), are carried out. A quantitative comparison between the magnetization reversal processes in caps with different diameters is given. The phase diagram of magnetic equilibrium domain patterns as a function of diameter and length is generated. The anisotropic magnetostatic interaction in cylindrically curved architectures originating from the thickness gradient reduces substantially the magnetostatic interaction between closely packed curved nanowires. This feature is beneficial for the concept of racetrack memory, since a much higher areal density might be achieved than possible with planar counterparts.

[1] M. Albrecht *et al.,* Nature Mater. **4**, 203 (2005)
[2] M. Yan *et al.*, Phys. Rev. Lett. **104**, 057201 (2010)
[3] O.G. Schmidt and K. Eberl, Nature **410**, 168 (2001)



Rolled-up nanomembrane cut by ion beam etching to provide curvature template.

11.15 – 11.30

Stability of ferromagnetic patterns inscribed in membranes holding magnetic nanowires

E.E. Vogel [1], E. Cisternas [1]

(1) Department of Physics, Universidad de La Frontera, Temuco, Chile

Magnetic nanocylinders (NCs) can be grown in porous membranes. The relative orientation of the magnetizations among the cylinders of such membranes is originally random producing nil net magnetization. However, the magnetization of individual cylinders can be orientated within a sector of the membrane upon applying a local magnetic field as the field of the tip of a magnetic force microscopy. In the present paper we consider ways to minimize the energy of the inscribed ferromagnetic sector as to increase stability so this information can be used as permanent information.

We consider a cylindrical membrane (radius *R* and thickness *2L*) and a great amount of parallel magnetic NCs trapped in it. The membrane axis is parallel to the magnetic NCs axes. In the case of porous alumina membrane, such an array is obtained upon filling the empty cylindrical pores with the desired magnetic

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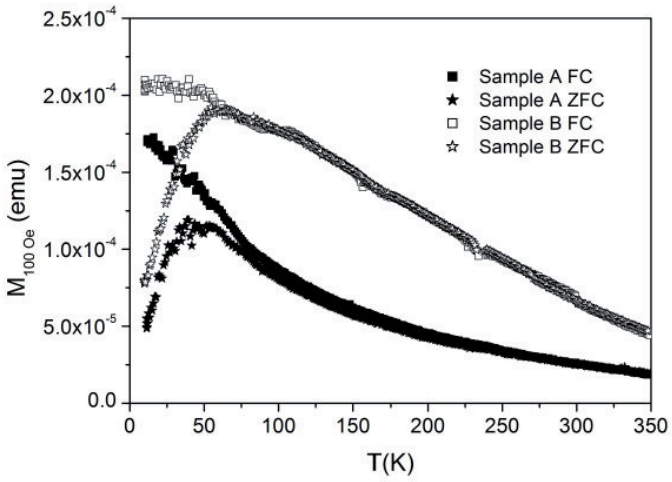
material (Co in the present exercise) producing a triangular array [1].
The starting point is the interaction energy for a pair of NCs [2]. We obtain the total energy of the system by adding the different pair contributions and then we normalize to the number of NCs in the orientated sector. We analyze sectors with different size and shape looking for the minimum energy per cylinder aiming for stable geometries to store meaningful information. We inscribe ferromagnetic sectors with basic geometric figures: circles, squares, triangles and hexagons, modifying their widths. No significant changes were observed. However when a small central sector with opposite magnetization is defined within the original ferromagnetic sector greater stability is achieved. Next we consider alphabet letters, numbers and other symbols also checked for stability.

[1] K. Nielsch et al., Adv. Eng. Mater. 7, 4 (2005).
[2] E. Cisternas, Y. Vásquez, and E.E. Vogel, J. Magn. Magn. Mat. 324, 1021 (2012).

11.30 – 11.45
Magnetic Properties of Jet-Printer Inks containing Dispersed Magnetite Nanoparticles
P. Tiberto [1], G. Barrera [1], M. Coisson [1], A. Chiolerio [2], P. Martino [3], P. Pandolfi [3], P. Allia [4]
(1) INRiM, Electromagnetism, 10135 Torino, Italy, (2) IIT, Corso Trento 21, 10129 Torino, Italy, (3) Politronica s.r.l., Corso Castelfidardo 30/A, 10129 Torino, Italy, (4) Politecnico di Torino, DISAT, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Two ferrofluid inks for jet-printing, containing magnetite nanoparticles of slightly different average radius (sample A: 6 nm; sample B: 8 nm) were prepared by adding a dispersion of magnetite nanopowders in n-hexane to an insulating ink based on polyvinylpyrrolidone (PVP), with a ratio 10:90.
Isothermal magnetization loops of inks were measured by means of a vibrating sample magnetometer in the temperature interval 5-300 K up to 70 kOe. The inks were then ejected at room temperature on standard paper by means of either a thermal ink jet head (TIJ; sample A) or a piezoelectric ink jet head (PIJ; sample B). Magnetic properties of prints on paper (FC/ZFC curves, shown below; isothermal magnetic loops and related hysteretic properties) were measured between 10 and 300 K using an alternating gradient force magnetometer up to 20 kOe.
The inks display a different magnetic behavior with respect to both prints. In particular, the dispersed nanoparticles are characterized by an effective radius (and ensuing magnetic interaction) larger than expected on the basis of the properties of the starting powders. Instead, the nanoparticle radii in both prints are closer to the starting values. This means that in the ferrofluid phase substantial nanoparticle aggregation takes place, while the process of ink ejection through both types of heads is able to disrupt such aggregates, although with a different effectiveness. The printed magnetic films show an almost perfect superparamagnetic (SP) response around room temperature; however, at temperatures lower than 100 K the SP scaling is not observed and both samples behave as interacting superparamagnetic (ISP) materials [1]. The evolution from the SP to the ISP regime is marked by a steady increase in the hysteretic properties of both samples.

[1] P. Allia and P. Tiberto, J. Nanoparticle Res. 13, 7277 (2011)



FC/ZFC curves of A, B prints on paper

11.45 – 12.00
Narrow Domain Wall Structures in Synthetic Antiferromagnetic Samples
R. Beacham [1], M.J. Benitez [1], S. Lepadatu [2], D. McGrouther [1], A. Whiteside [2], T. Moore [2], R.L. Stamps [1], J. Miguel [3], S. Dhesi [3], C.H. Marrows [2], S. Mcvitie [1]
(1) School of Physics and Astronomy, University of Glasgow, G12 8QQ, UK, (2) School of Physics and Astronomy, University of Leeds, LS2 9JT, UK, (3) Diamond Light Source Ltd, Rutherford Appleton Lab, OX11 0QX, UK

Magnetic domain walls (DWs) in nanowires have been studied extensively for their potential technological application. DWs in single layer thin film ferromagnetic (FM) Permalloy nanowires tend to be complex and have a width comparable to that of the wire. Here we focus on DWs in synthetic antiferromagnetic (SAF) multilayer structures; the DWs in SAF nanowires are expected to be much narrower with significantly reduced demagnetising fields at the wire edges. Previously such structures have been used as pinning layers in spin valve and magnetic tunnel junction arrangements; however investigation of the structure and behaviour of the DWs in these films has been limited [1].
In this study we have deposited SAF films with balanced and unbalanced FM layers. In these SAFs the FM layers are separated by a 7Å Ruthenium layer, corresponding to the peak of antiferromagnetic exchange inter-layer coupling [2]. The FM layer thicknesses are 100Å (balanced) and 133Å/67Å (unbalanced). The structure shown in *figure 1a* has been nanofabricated using electron beam lithography with an unbalanced wire connected to a DW injection pad [3].

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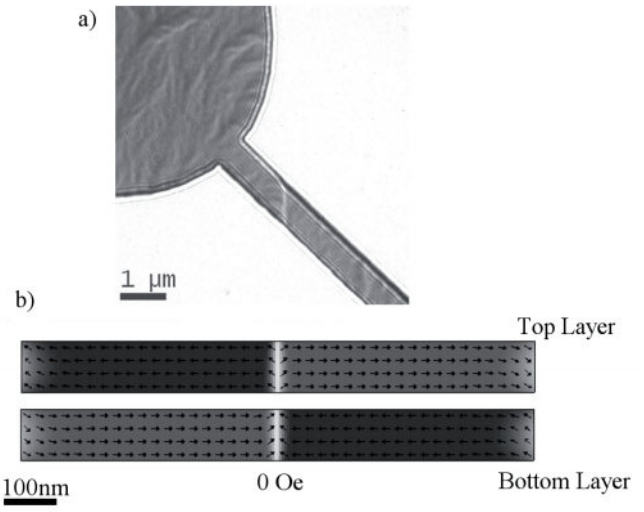
Simulations show that narrow coupled DWs are supported in the FM layers as indicated in *figure 1b*.
Initial results from Lorentz microscopy and magnetosresistance measurements indicate that DWs can be controllably injected and nucleated in the nanowires. We will present results from this study showing DWs being driven and manipulated using static and pulsed magnetic fields in addition to applied current pulses. Images from microscopic techniques (Lorentz and XMCD-PEEM) will be supported with transport measurements and simulations.

[1] B. Negulescu *et al. J. Appl. Phys.* **109** 10 (2011)
[2] S.S.P. Parkin *et al. Phys. Rev. Lett.* **64** 19 (1990)
[3] D McGrouther *et al. Appl. Phys. Lett.* **91** (2007)



(a) Lorentz TEM image and (b) OOMMF simulation of a narrow DW in an unbalanced SAF.

12.00 – 12.15
Magnetoresistance and ferromagnetic resonance in magnetite nanowires
O. Koplak [1], A. Dmitriev [2], R. Morgunov [2]
(1) Educational and Scientific Centre of T.Shevchenko Kiev National University and National Academy of Sciences, 01033, Kiev, Ukraine, (2) Institute of Problems of Chemical Physics, 142432, Russia

Enigma of the magnetite (Fe_3O_4) magnetic properties was refreshed by new experimental data concerning magnetite nanosized particles. In our work static and dynamical magnetic properties of the magnetite aligned nanowire arrays were studied. Suppression of the Verwey transition was observed in the magnetite nanowires due to size limitation. Ferromagnetic and paramagnetic resonances were studied in the ordered arrays of the magnetite nanowires (Fig.1). Contributions of individual Fe^{3+} ions and a ferromagnetic system to magnetization of nanowires were distinguished. Anisotropy field of nanowires was found by an order of value smaller than the shape anisotropy field.
Electrical properties of the nanowires were studied by microwave absorption technique. A phase inverted non-resonant line corresponding to magnetoresistance (MR) was identified in the spectra of electron spin resonance (see insert on the Fig.1). Inverted line was observed due to nonresonant electrical losses depending on magnetic field, i.e. magnetoresistance of the sample. Phase of the non-resonant line depends on the MR sign corresponding to negative MR in our experiments. The MR of magnetite was explained in the terms of the model assuming the decrease of the t_{2g} orbitals overlapping in the cation-anion pairs under magnetic field. This changes lead to partial delocalization of electrons and negative MR corresponding to interference of hopping electrons.

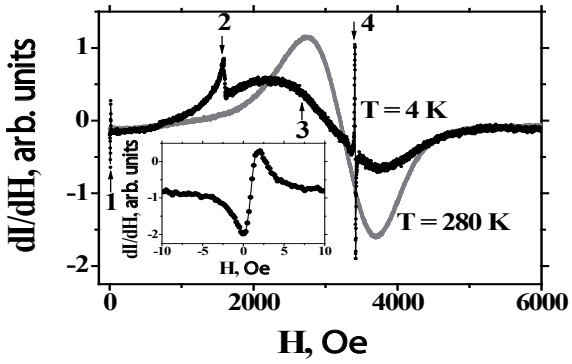


Fig.1. ESR spectra of the nanowires at T = 4 K (closed symbols) and 280 K (open symbols). Static magnetic field is directed along the axis of the Fe_3O_4 nanowires. Lines numeration is given in the picture. Phase inverted line 1 is shown in the insert.

12.15 – 12.30
Strain-induced magnetization reorientation in epitaxial Cu/Ni/Cu rings
E.C. Corredor [1], D. Coffey [2], J.I. Aranaudas [3], M. Ciria [2], C.A. Ross [4]
(1) INA-Dpt. Física Materia Condensada, Universidad de Zaragoza, 50009 Zaragoza, Spain, (2) ICMA-Dpt. Física Materia Condensada, CSIC-Univ. Zaragoza, 50009 Zaragoza, Spain, (3) INA-LMA-Dpt. Física Materia Condensada, Universidad de Zaragoza, 50009 Zaragoza, Spain, (4) Dept. Materials Science and Engineering, MIT Cambridge, USA 02139

Thin-film magnetic rings exhibit a variety of interesting magnetic states and have applications in memory, logic, or sensing devices; thereby, controlling the domain states is a fundamental issue [1]. In this work we explore the magnetic configurations in rings with competing anisotropies. Epitaxial Cu/Ni/Cu films show significant perpendicular magnetoelastic (ME) anisotropy because of the residual strain. Thus, Ni rings have been obtained by means of a subtractive process, which include electron-beam writing and ion-beam etching using a hard mask, on a 14 nm thick Ni film, a value with effective in-plane magnetic anisotropy. The ring diameters are 3 μm while the rings width is above 100 nm. MFM images taken on the rings 250 nm wide (see image) show a radial domain structure compatible with a magnetization vector pointing along the radial direction [2]. This fact is explained by the existence of transverse magnetoelastic anisotropy in patterned Ni films [3], due to a in-plane anisotropic relaxation of the strain existing in

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NANOSTRUCTURES 2
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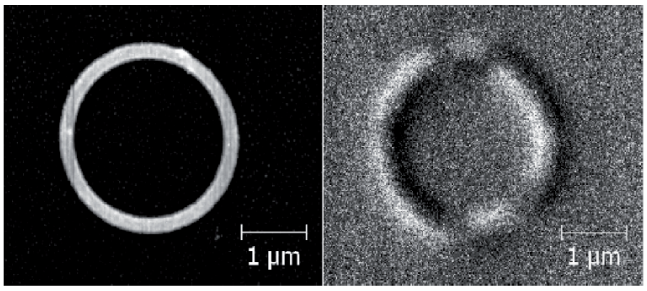
the continuous film. Rings with larger width show domains with out-of-the plane anisotropy, suggesting that the radial strain relaxation decreases as the ring width increases.

[1] C. Ross et al, J. Appl. Phys. 99, 08S501 (2006)
[2] D. Navas et al Phys Rev.B **81,** 224439 (2010)
[3] M.Ciria et al Phys Rev.B **80**, 094417 (2009)



Caption: AFM topographic (left) and MFM (right) images of a 14 nm thick Cu/Ni/Cu ring.

12.30 – 12.45
Magnetic domain walls in ferromagnetic wires with parabolic notches
P. Eib [1], V. Tshitoyan [1], A. Bischof [1], R. Allenspach [1]
(1) IBM Research - Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland

For the realization of magnetic domain wall-based memory devices it is important to understand the pinning and depinning behavior of magnetic domain walls. We report on the magnetic field-driven injection and propagation of magnetic domain walls in a ferromagnetic nanowire. The effect of applied AC currents is also investigated. Measurements are done on micrometer-wide $Ni_{80}Fe_{20}$ wires with parabolic notches structured by electron-beam lithography. Constrictions having a width of around 100 nm serve as pinning sites for the domain walls. We measure injection and depinning events electrically using the anisotropic magnetoresistance effect [1]. We attribute a continuous change of the wire resistance to the evolution of the domain wall state close to the constriction. Our analysis of resistance jumps suggests the existence of two distinct domain wall types in the vicinity of the constriction which we assign to the two di fferent chiralities of a vortex wall. The magnetic structure is determined by spin-SEM [2]. To complement the experimental findings we model the configurations by micromagnetic simulations and calculate the expected resistance. Applied AC electric currents are used to investigate domain wall resonance effects [3].

[1] M. Hayashi et al., Phys. Rev. Lett. 97, 207205 (2006)
[2] R. Allenspach, IBM J. Res. Develop. 44, 553 (2000)
[3] S. Lepadatu et al., Phys. Rev. B 81, 060402(R) (2010)

12.45 – 13.00
Micromagnetic configuration of modified individual nanowires
A. Ognev [1], A. Samardak [1], E. Sukovatitsina [1], M. Stebliy [1], L. Chebotkevich [1], F. Nasirpouri [2]
(1) Laboratory of Thin Film Technologies, Far Eastern Federal University, Vladivostok, Russia, (2) Department of Materials Engineering, Sahand University of Technology, Tabriz, Iran

Magnetic nanowires have deserved a high attention due to their potential applications in nanoelectronics. An highly demanding fabrication technique for magnetic nanowires is template electrodeposition. This includes electrochemically recued materials directly into the self-ordered nanopores of the template. Template is a nanoporous matrix such as anodic aluminium oxide (AAO). In this research, magnetic structure of individual Ni nanowires with a diameter D=40 nm and high aspect ratio [1] was studied.
Magnetic domain structure were investigated on the nanowires first released form AAO and then placed on a clean Si/SiO_2 substrate using magnetic force microscope (MFM) under variable magnetic field up to ±1000 Oe applied in plane of the substrate along the horizontal axis of nanowires.
We have investigated the magnetic configuration of nickel nanowires in two forms. Firstly, we investigated the straight nanowire with a length L=1.5um (Fig.1a,b). Only a single domain state with magnetic moments along nanowire could be observed at H=0.
After that we studied the modified nanowires. A non-contact cantilever was used to change the nanowire form (Fig.1c-e). In Fig.1f-h, the results obtained for a typical nanowire with L=3.5 um are presented. We have purposely chosen nanowire bended in the middle in order to pin the propagating domain walls. The dark and bright contrast in the MFM image (Fig.1g) arises from the magnetic volume charges located at the domain walls as seen in the vertical part of the nanowire at the field H=700 Oe. In the horizontal part of the nanowire an unusual zigzag-like domain pattern is observed (Fig.1h) at H=0. Novel magnetic configuration observed in the nanowires gives us a new challenge to understand the domain pattern formation at the nano-scale.

[1] A.S. Samardak, et al., Physics Procedia 22, 549 (2011).

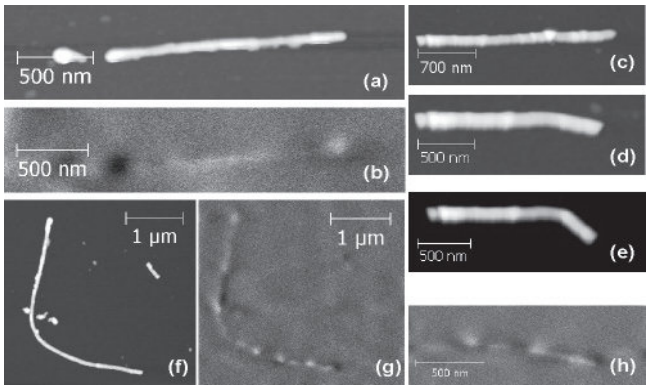


Fig.1. Images of individual magnetic nanowires with D = 40 nm and different lengths.

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

MAGNETIC IMAGING AND DOMAIN WALLS

Chair: D. Süss

10.30 – 11.00

Giant exchange-bias in Tb-Fe/(Co/Pt) systems *(invited)*

M.A. Marioni [1], S. Romer [1], K. Thorwarth [1], N.R. Joshi [1], S. Oezer [2], H.J. Hug [3]

(1) Empa, Swiss Federal Institute for Materials Testing and Research, CH-8600 Dübendorf, Switzerland, (2) University of Basel, CH-4056 Basel, Switzerland, (3) Empa, Swiss Federal Institute for Materials Testing and Research, CH-8600 Dübendorf, Switzerland, and University of Basel, CH-4056 Basel, Switzerland

In exchange-bias the magnetization of a ferromagnetic film is coupled to an antiferromagnet, which pins it. The bias is inherently small because the net coupling is weak, and because the coupled antiferromagnetic spins are not all pinned. Here we replace the antiferromagnet with a rare-earth based ferrimagnet. We fabricate $[Tb_{23}Fe_{77}]_{40nm}/(Co_{0.4nm}Pt_{0.7nm})_{\times n}$ (n = 1, 2, 5). The isolated ferrimagnet has a large coercivity, with $\mu_0 H$ exceeding 3 T below 280 K. In a bilayer with n = 5 shows an exchange-bias $\mu_0 H_{ex}$= 0.7 T at 280 K (Figure 1). Thinner ferromagnetic films (n = 1, 2) display a correspondingly larger bias ($\mu_0 H_{ex} \approx$ 3 T and 2 T respectively). This is indicative of a strong coupling between the ferrimagnetic and ferromagnetic layer in this system. A lower bound for the coupling energy can be estimated from the area between the vertical axis and the magnetization loop. For n = 5 it amounts to 6 mJ/m^2, and is thus comparable to values found for ferrimagnetic exchange coupled double layers [1]. This points to the absence of coupling frustration in this system.

[1] 12. C.-C. Lin, C.-H. Lai, R.-F. Jiang, H.-P.D. Shieh, J. Appl. Phys. 93, 6832 (2003).

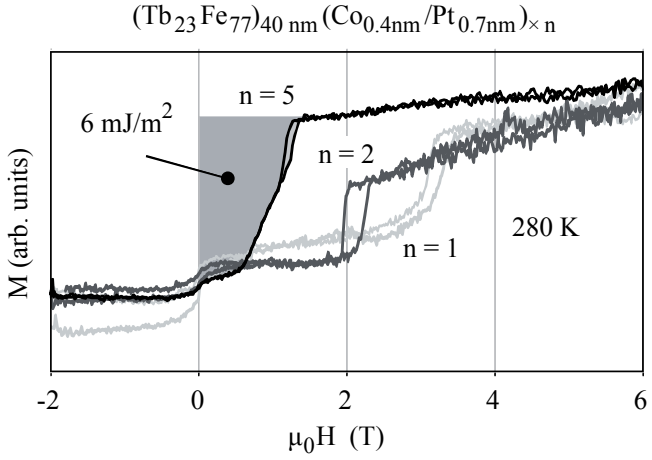


Fig. 1: hysteresis loops (left) for $[Tb_{23}Fe_{77}]_{40nm}/(Co_{0.4nm}Pt_{0.7nm})_{\times n}$.

11.00 – 11. 15

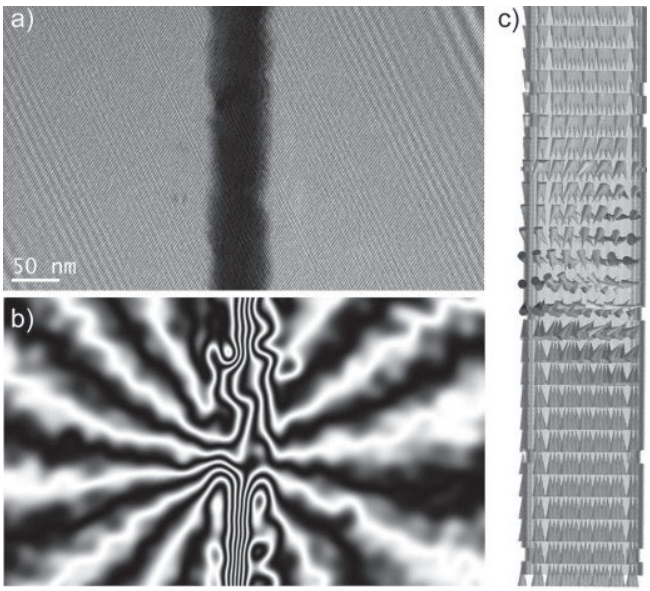
Electron Holography and Micromagnetic Simulations of a Domain wall in a Ni nano-cylinder

N. Biziere [1], R. Lassalle-Ballier [2], C. Gatel [1], M.C. Clochard [3], J.E. Wegrowe [3], J.M.D. Coey [2]

(1) CEMES-CNRS, 31055, Toulouse, France, (2) School of Physics and CRANN/Trinity College, Dublin 2, Ireland, (3) LSI/CEA/CNRS/Ecole Polytechnique, 91128 Palaiseau, France

Cylindrical magnetic nanowires are particularly interesting for technological applications since it is predicted that their particular symmetry allows propagation of domain walls (DW) with very high velocities. Up to now, most of the studies of the DW structure in nano-cylinders have been realized via micromagnetic modeling [1], and only few experiments have been performed mainly because of the complexity to grow isolated magnetic nanowires with diameter below 100 nm [2]. Moreover, no information have been obtained on the magnetic configuration inside the nanowire. In this work, the high spatial resolution and magnetic sensitivity of the TEM Electron holography experiments have been combined with 3D OOMMF micromagnetic modeling to study the DW structure in a single polycrystalline Ni nanowire of about 70 nm in diameter (Fig 1a) grown by template synthesis. The domain wall has been studied in the remanent state after saturation with a field of about 1.5T in the direction perpendicular to the nanowire axis.

To understand its internal structure, we have studied the field lines outside of the wire due to the stray field of the DW and the induction inside the nanowire. We have found a good agreement between the experiment (Fig 1b) and the simulation revealing a complex magnetic structure. Indeed, the DW presents some characteristic of a vortex wall, with the core axis shifted and tilted at about 45 degrees from the nanowire axis (Fig1c). We will present in detail the experimental results on the magnetic induction of these nanowires and the corresponding micromagnetic simulations.



Hologram (a) and induction lines (b) of a DW in a 70 nm cylindrical Ni nanowire. (c) micromagnetic simulation of the DW.

[1] Ming Yan et al. Phys. Rev. Lett. , 104, 057201, 2010.
[2] C. Beeli et al. Ultramicroscopy 67, 143, 1997.

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

MAGNETIC IMAGING AND DOMAIN WALLS

Chair: D. Süss

11. 15 – 11.30

Magnetisation dynamics in mesoscopic structures studied with x-ray microscopy

S.E. Stevenson [1], C. Moutafis [1], R.V. Chopdekar [1], G. Heldt [1], L.J. Heyderman [1], C. Quitmann [1], J. Raabe [1]
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Controlled manipulation of magnetisation dynamics is of interest for future data storage applications, and requires a fundamental understanding of micromagnetic behaviour of patterned magnetic elements. We report on the modification of the ground state domain configuration in $Ni_{81}Fe_{19}$ square islands due to RF excitation monitored by scanning transmission x-ray microscopy (STXM) at the PolLux beamline, Swiss Light Source. We excite the magnetisation of micrometer-sized structures with a sinusoidal continuous wave field applied via a stripline which is coplanar to the structures. With an increase in amplitude of the RF excitation, a breakup of the domain configuration into a complex metastable state occurs, as shown in the Figure below, and the metastable state returns to the ground state when the excitation is removed. Such indications of domain breakup have previously been reported [1], and our micromagnetic simulations confirm that the domain breakup nucleates from a high amplitude motion of the domain walls. Directly visualising such metastable states provides insight into the tailoring of RF excitations for vortex core reversal [2] and domain reorientation processes, and we will also report on the optimization of the shape of a low-power burst excitation to induce vortex switching.

[1] Buess, M. et al., Surf. Sci. 601, 5246 (2007)
[2] Van Waeyenberge, B. et al., Nature, 444, 461 (2008)

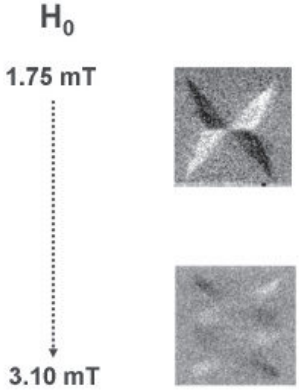

Figure: Dynamic STXM images indicate domain breakup with increasing field amplitude

11.30 – 11.45

Direct Observation of nearly Mass-less Domain Walls in Nanostripes with Perpendicular Magnetic Anisotropy

S. Pizzini [1], J. Vogel [1], M. Bonfim [2], O. Boulle [3], E. Jue [3], N. Rougemaille [1], I.M. Miron [3], A. Hrabec [1], G. Gaudin [3], J.C. Cezar [4], F. Sirotti [5]
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In spintronic devices based on spin transfer torque, domain walls (DW) should move reproducibly and react instantaneously to current pulses. Important inertial effects have been shown for DW in permalloy nanostripes [1]. These transient effects, giving rise to displacements up to 1.5μm after the end of the pulse, are caused by deformations of the DW internal structure under the action of the driving force [2]. We have used time-resolved photoemission electron microscopy combined with x-ray magnetic circular dichroism (XMCD-PEEM) to directly observe domain wall motion during the current pulse in Pt/Co/AlOx nanostripes with perpendicular anisotropy and Rashba spin-orbit coupling. We show that in these nanostripes the DWs move at constant speed since the beginning of the current pulse and inertial effects are much smaller than in permalloy nanostripes. For current density 7.7 x 10^{11} A/m^2 the delay of the linear motion with respect to the pulse is less than 1 ns and the transient motion is smaller than 30nm. Such domain walls therefore behave as nearly massless micromagnetic objects. The transient displacement δq depends of the change of generalized DW angle φ : $\delta q = -\Delta/\alpha\ \delta\varphi$ where Δ is the domain wall width at rest and α the damping parameter [2]. The negligible inertia in our system is accounted for by the narrow DW width (Δ = 5 nm) the large damping parameter (α=0.5) [3] and the small DW angle due to the presence of a transverse magnetic field due to Rashba effect. Such small inertial effects could be efficiently exploited in devices based on manipulation of domain walls.

[1] L. Thomas et al. Science 330, 1810 (2010).
[2] J.-Y. Chauleau et al, Phys. Rev. B 82, 214414 (2010).
[3] M. Miron et al. Nature Mater. 10, 419 (2011).

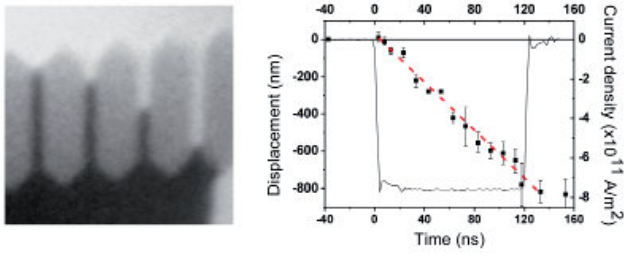

Figure 1: (*left*) : DW in 500 nm wide Pt/Co/AlOx nanostripes; (*right*) : DW position vs. time during current pulses.

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MAGNETIC IMAGING AND DOMAIN WALLS

Chair: D. Süss

11.45 – 12.00
Phase diagram of vortex versus transverse domain walls in spin valves

O. Fruchart [1], N. Rougemaille [1], Z. Ishaque [1], V. Uhlir [1], S. Pizzini [1], J. Vogel [1], J.C. Toussaint [1], A. Masseboeuf [2], A. Locatelli [3], T.O. Mentes [3], M. Urbánek [4], Z. Kassir-Bodon [1], P. Bayle-Guillemaud [2]
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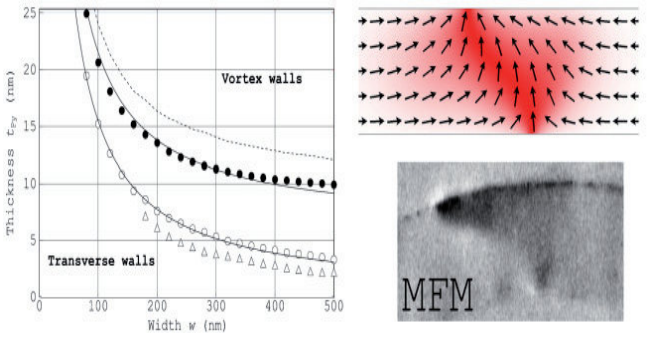
Most studies of domain-wall (DW) motion under spin-polarized current have considered single layers, such as permalloy (Py) for in-plane magnetization. Enhanced DW mobility have been reported in trilayer spin-valves such as Py/Cu/Co [1]. Tentative explanations point at either vertical spin currents [2], Oersted field, or magnetostatic interaction between Py and Co.
Related to the latter we investigated the transverse (TW) versus vortex (VW) phase diagram of head-to-head domain walls in Co/Cu/Py spin valve nanostripes in terms of stripe width and layers thicknesses, in which the Co layer is mostly single domain while the Py layer hosts the domain wall. We combined numerical and analytical micromagnetics with excellent correlation, and various magnetic imaging: MFM, layer-resolved XMCD-PEEM, and Lorentz. The range of stability (based on energy calculations) of the TW is shifted towards larger thickness of the Py layer, with respect to the well-established case of a single layer [3], by a value scaling with tCo*Mco/MPy. The shift is explained by Co acting as a magnetostatic mirror in response to the charges arising from the DW in Py.
In experiments TW are indeed observed in trilayers, for geometrical parameters where DW are already of vortex type in single layers. A very large asymmetry of TW is associated to their enhanced stability, and weak external flux (view from MFM) hinting at the flux closure. XMCD-PEEM confirms the Co mirroring effect, and Lorentz microscopy provides the real-time monitoring of DW propagation under field.

[1] V. Uhlír et al., Phys. Rev. B 81, 224418 (2010)
[2] A. V. Khvalkovskiy et al., Phys. Rev. Lett. 102, 067206 (2009).
[3] Y. Nakatani et al., J. Magn. Magn. Mater. 290-291, 750 (2005).



Phase diagram of DW in trilayers (single) layers, see full (open) dots, and asymmetry.

12.00 – 12.15
Field tuning of ferromagnetic domain walls on elastically coupled ferroelectric domain boundaries

K.J.A. Franke [1], T.H.E. Lahtinen [1], S. Van Dijken [1]
(1) NanoSpin, Department of Applied Physics, Aalto University School of Science, P.O. Box 15100, FI-00076 Aalto, Finland

Ferromagnetic and ferroelectric domain walls have been studied for many decades and their properties are still a topic of intense investigation. In ferromagnets, the domain wall width varies from a few nanometer in hard or geometrically constrained magnets to hundreds of nanometer in low anisotropy materials or thin films with uniform Néel walls. In ferroelectric materials domain walls are more abrupt. While the properties of ferromagnetic and ferroelectric domain walls in single ferroic systems are meanwhile understood, rigorous results on the structure and manipulation of coupled ferromagnetic-ferroelectric walls are scarce. Given the different nature and scaling of ferromagnetic and ferroelectric walls, strongly interacting systems are expected to display a rich variety of static and dynamic phenomena. Moreover, the realization of interferroic domain wall coupling opens up additional degrees of freedom to tune internal wall structures and to control domain wall motion [1]. We report on the evolution of ferromagnetic domain walls during magnetization reversal in elastically coupled ferromagnetic-ferroelectric heterostructures [2]. Using optical polarization microscopy and micromagnetic simulations, we demonstrate that the spin rotation and width of ferromagnetic domain walls can be controlled by the strength of the applied magnetic field if the ferromagnetic walls are pinned onto 90° ferroelectric domain boundaries. Moreover, reversible switching between magnetically charged and uncharged domain walls is initiated by magnetic field rotation. Switching between both wall types reverses the wall chirality and abruptly changes the width of the ferromagnetic walls by up to 1000% [3].

[1] T.H.E. Lahtinen, K.J.A. Franke, and S. van Dijken, Sci. Rep. 2, 258 (2012)
[2] T.H.E. Lahtinen, J.O. Tuomi, and S. van Dijken, Adv. Mater. 23, 3187 (2011), ibid IEEE Trans. Magn. 47, 3768 (2011)
[3] K.J.A. Franke, T.H.E. Lahtinen, and S. van Dijken, Phys. Rev. B 85, 094423 (2012)

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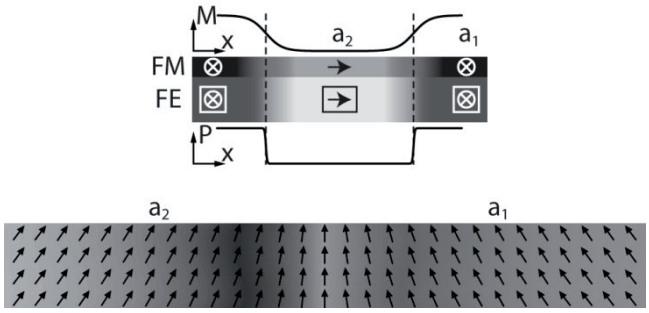

Broad ferromagnetic domain walls are pinned onto narrow ferroelectric boundaries

12.15 – 12.30

The role of disorder in the domain wall dynamics of magnetic nanostrips

B. Van De Wiele [1], L. Laurson [2], *G. Durin* [3]
(1) Department of Electrical Energy, Systems and Automation, Ghent University, B-9000 Ghent, Belgium, (2) Department of Applied Physics, Aalto University, Aalto 00076, Finland, (3) Ist. Nazionale di Ricerca Metrologica, 10135 Torino, Italy

We study the role of the disorder in the dynamics of the domain walls (DW) in nanostrips with in-plane magnetization. In contrast with previous works where the disorder is due to edge roughness, we consider the role of a random distribution of voids, thus simulating local changes of the magnetization saturation value. By making use of the high-speed computational capability of GPUs, and an ad-hoc micromagnetic code [1], we compute the speed of DWs under both applied field (0.5-15 mT), and spin-polarized currents (1-30 $A/\mu m^2$), for four different void densities. Field and currents are applied for 20 ns. We also consider both adiabatic and non-adiabatic spin-torque effects (β parameter equal 0 and 0.04, respectively). For all the cases, we repeat the simulation for 50 realizations of the void distributions. No thermal effects are considered.
Some results can be understood in the line of the models reported in the literature [2], while some others are more peculiar. For instance, we expect a lower value of the maximum DW speed. This actually occurs in the field driven case, but with a less dramatic drop at the Walker breakdown, due to the difficulty to nucleate an antivortex DW. When nucleated, it gets easily pinned, thus preventing its retrograde motion typical of disorder-free strips. In the case of non-adiabatic torque effects, any antivortex is immediately pushed back, so the dynamics is fully given by V-shape DW motion. This results in an *increased* value of the maximum speed available. Another important consequence of the disorder is that at low field/currents the depinning transition regions appear to be more rounded, *resembling* a creep behavior. This can have important consequences in the interpretation of experimental data.

[1] Mumax2, http://code.google.com/p/mumax2/
[2] O. Boulle at al., Mat. Sci. Eng: Reports, 752, 159 (2011)

12.30 – 12.45

Domain-wall manipulation in cobalt nanowires

L. Serrano-Ramón [1], A. Fernández-Pacheco [2], R. Córdoba [3], M.R. Ibarra [3], D. Petit [2], R. Cowburn [2], T. Tyliszczak [4], *J.M. De Teresa* [1]
(1) Instituto de Ciencia de Materiales de Aragón, Universidad de Zaragoza-CSIC, Spain, (2) TFM Group, Cavendish Laboratory, University of Cambridge, United Kingdom, (3) Laboratorio de Microscopías Avanzadas, Instituto de Nanociencia de Aragón, Universidad de Zaragoza, Spain, (4) Advanced Light Source, Lawrence Berkeley National Laboratory, USA

Focused-electron-beam-induced-deposition (FEBID) using Co_{2}(CO)_{8} gas precursor allows the direct writing of cobalt-based magnetic structures [1]. Interestingly, single domain-walls can be propagated along Co wires grown by FEBID, with potential applications in magnetic logic and storage [2]. Besides, it is possible to achieve the growth of Co structures tailored at the nanoscale, such as narrow high-cobalt-content nanowires (30 nm) and Hall sensors (100 nm) [3]. In this contribution, we will present recent results aiming for the manipulation of domain walls in Co nanowires by means of Ga irradiation. As studied by means of MOKE and STXM, irradiation with Ga{+} ions alters the transmission, propagation and nucleation fields of domain walls in the Co nanowires. As an example, figure 1 shows the effective pinning of a domain wall at the central position of the wire, previously irradiated with Ga{+} ions.

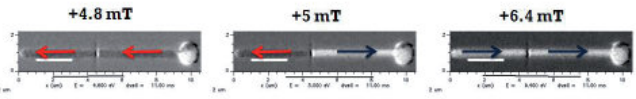

Figure 1. STXM images show the injection of a domain wall in the Co wire and its subsequent pinning at the irradiated point.

[1] A. Fernández-Pacheco et al, J.Phys. D: Appl. Phys. 42 055005 (2009)
[2] A. Fernández-Pacheco et al, Appl. Phys. Lett. 94 192509 (2009)
[3] L. Serrano-Ramón et al., ACSnano 5 7781 (2011)

12.45 – 13.00

Bimagnetic Microwires: high-frequency and temperature dependent behavior

R.E. Kammouni [1], G. Badini-Confalonieri [1], *V. Rodionova* [2], V. Samsonova [3], N. Perov [3], M. Vázquez [1]
(1) Instituto de Ciencia de Materiales de Madrid, 28049 Madrid, Spain, (2) Innovation Park, I.Kant Baltic Federal University, 236041 Kaliningrad, Russia; Dpto. Fisica de Materiales, UPV/EHU 20009 San Sebastian, Spain; Faculty of Physics, Lomonosov MSU, 119991 Moscow, Russia, (3) Faculty of Physics, Lomonosov Moscow State University, 119991 Moscow, Russia

Two-phase magnetic microwires are prepared by combined quenching & drawing and electroplating techniques and consist

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of a cylindrical magnetic core and an intermediate insulating layer surrounded by an external magnetic shell. Tailoring of the magnetic composition and thermal processing allows one to design soft/hard, hard/soft and soft/soft bimagnetic character where confirmed magnetoelastic and magnetostatic interactions between magnetic phases [1] have been used to design sensing elements for sensors [2].
In the present work, we introduce latest obtained results on the influence of the presence of a second external phase (soft NiFe and harder CoNi) asymmetrically grown along the soft (Fe. base and Co-base amorphous) microwire and its comparison with fully covered microwires [3]. The effect is measured at low (Vibrating Sample Magnetometer) and high-frequencies (ferromagnetic behaviour with a Network Analyser up to 14 GHz). In addition, the temperature dependent behavior is characterized for bimagnetic wires at increasing temperature up to 900ºC [4]. Thermal treatments induce significant structural changes in the magnetic phases leading to partial crystallization together with metallic elements inter-diffusion at the external shell interphase leading to shifted hysteresis loops.

[1] J. Torrejón, G. Badini, K. Pirota, M. Vázquez: Design of multilayer microwires with controllable magnetic properties. Magnetostatic and magnetoslastic coupling, Acta Materialia 55 (2007) 4271.
[2] M. Butta, P. Ripka, G. Infante, G.A. Badini-Confakmieri, M. Vazquez: Bi-metallic magnetic wire with insulating layer as core for orthogonal fluxgate. IEEE Trans Magn. 45 (2009) 4443.
[3] J. Torrejón, G.A. Badini-Confalonieri, M. Vázquez: Double-absorption ferromagnetic resonance in biphase magnetic microwires, J. Appl. Phys. 106 (2009) 0203913.
[4] V. Rodionova, A. Nikoshin, J. Torrejón, G.A. Badini-Confalonieri, N. Perov, M. Vazquez: Temperature-Dependent Magnetic Properties of Magnetically Biphase Microwires, IEEE Trans. Magn. 47 (2011) 3787.

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MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS...)

Chair: O. Gutfleisch

10.30 – 11.00
NdFeB thick films as model high performance magnets *(invited)*
N.M. Dempsey [1], Y. Zhang [1], G. Ciuta [1], D. Givord [1]
(1) Institut Néel, CNRS/UJF, 38042, Grenoble, France

NdFeB-based permanent magnets are used in applications that require magnets with very high energy densities. A domain of application of major and growing importance concerns the high performance motors used in hybrid electric vehicles and gearless wind turbines. Owing to the relatively high maximum working temperature (< 180°C) in such applications, part of the Nd is now replaced with Dy so as to increase the material's magnetocrystalline anisotropy and thus maintain a sufficiently high coercivity at elevated temperatures. However, the gain in magnetocrystalline anisotropy comes at the cost of reduced magnetization, since the Dy moment couples anti-parallel to the Fe moment. More importantly, significant concerns exist relating to the cost and availability of the heavy rare earth elements. For this reason, much effort is now going into reducing and ultimately eliminating the need for Dy. One of the most promising approaches concerns the controlled diffusion of Dy along the $Nd_2Fe_{14}B$ grain boundaries so as to selectively target the surface of the grain, from where magnetization reversal is thought to develop.
In this talk we will report on the use of NdFeB thick films as model systems for the study of coercivity in this technologically critical material. We have shown that coercivities as high as 2.7 T can be achieved in 5 micron thick heavy rare earth free films prepared by high rate triode sputtering [1]. We will discuss the influence of buffer/capping layer mediated stress on the development of coercivity in our films [2]. Analysis of magnetisation reversal within the Global Model [3] will be presented.

[1] N.M. Dempsey, T.G. Woodcock, H. Sepehri-Amin, Y. Zhang, H. Kennedy, D. Givord, K. Hono and O. Gutfleisch, in prep.
[2] Y. Zhang, D. Givord and N.M. Dempsey, accepted Acta Mater.
[3] D. Givord et al., J. Mag. Mag. Mat. 258–259, 1 (2003)

11.00 – 11.15
Magnetic water treatment; How could it possibly work?
J.M.D. Coey [1]
(1) School of Physics, Trinity College Dublin 2, Ireland

Claims that passing hard water through a magnetic field somehow influences the structure and morphology of the

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calcium carbonate that is precipitated when the water is subsequently heated, have been met with robust scepticism, largely because there was no plausible mechanism whereby water containing a very dilute solution of calcium carbonate could acquire a magnetically-imprinted memory lasting many hours! Nonetheless, there are credible reports in the literature that indicate there is something to explain, despite difficulties in replicating many of the results.
A way out of this dillemma is provided by recent work challenging classical nucleation theory, at least insofar as calcium carbonate is concerned, which has advanced the idea of prenucleation clusters of indeterminate shape that are thermodynamically-stable in calcium carbonate solutions [1]. These liquid-like nanometer-scale clusters, named DOLLOPS [2] may be the key to the solution; the possible influence on them of a magnetic field via Maxwell-like stress or singlet-triplet mixing of proton dimers leading to a long-lived change in charge or the number of ionic bonds in the DOLLOP is discussed [3]. A design criterion for a permanent magnet water treatment device is proposed.

[1] D Gebauer, H. Colfen Nano Today **6** 564 (2011)
[2] R Demichelis *et al* Nature Communications (2011) DOI 10.1038/ncomms1604
[3] J. M. D. Coey, Philos. Mag. In press (2012)

11.15 – 11.30
Mixed Magnetism for Refrigeration and Energy Conversion
E. Brück [1], N.H. Dung [1], R. De Groot [2]
(1) Fundamental Aspects of Materials and Energy, Faculty of Science, Delft University of Technology, 2629 JB Delft, The Netherlands, (2) Electronic Structure of Materials, Faculty of Science, Radboud University, 6525 AJ Nijmegen, The Netherlands

Modern society relies on readily available refrigeration. Magnetic refrigeration has three prominent advantages compared to compressor-based refrigeration. First there are no harmful gasses involved, second it may be built more compact as the working material is a solid and third magnetic refrigerators generate much less noise [1].
The efficient coupling between lattice degrees of freedom and spin degrees of freedom in magnetic materials can be used for refrigeration and energy conversion. This coupling is enhanced in materials exhibiting the giant magnetocaloric effect. First principle electronic structure calculations on hexagonal MnFe(P, Si) reveal a new form of magnetism: the coexistence of strong and weak magnetism in alternate atomic layers. The weak magnetism of Fe layers (disappearance of local magnetic moments at the Curie temperature) is responsible for a strong coupling with the crystal lattice while the strong magnetism in adjacent Mn-layers ensures Curie temperatures high enough to enable operation at and above room temperature [2]. Varying the composition on these magnetic sublattices gives a handle to tune the working temperature and to achieve a strong reduction of the undesired thermal hysteresis. In this way we design novel materials based on abundantly available elements with properties matched to the requirements of an efficient refrigeration or energy-conversion cycle.

[1] Brück E., J. Phys. D-Appl. Phys. 38(2005) R381-R391
[2] Dung NH, Ou ZQ, Caron L, Zhang L, Thanh DTC, de Wijs GA, de Groot RA, Buschow KHJ, Brück E. Adv. Energy Mat. 2011;1:1215.

11.30 – 11.45
Tomographic investigation of $SmCo_5$/Fe nanocomposites and correlation with magnetic properties
R. Lardé [1], J.M. Le Breton [1], A. Maitre [1], D. Ledue [1], O. Isnard [2], V. Pop [3], I. Chicinas [4], D. Givord [2]
(1) Groupe de Physique des Matériaux (GPM), UMR 6634 CNRS, Université et INSA de Rouen, Avenue de l'Université, B.P. 12, 76801 Saint Etienne du Rouvray, France, (2) Institut Néel, CNRS et Université Joseph Fourier, BP 16638042 Grenoble cedex 9, France, (3) Faculty of Physics, Babes-Bolyai University, 400084 Cluj-Napoca, Romania, (4) Materials Science and Technology Dept., Technical University of Cluj-Napoca, 103-105 Bd. Muncii. 400641 Cluj-Napoca, Romania

In the field of permanent magnets, the magnetic performances can be greatly improved by the exchange coupling between hard and soft phases. This coupling called exchange spring, can be only exploited through the elaboration of nanocomposite materials composed of nano-sized soft magnetic clusters embedded in a hard magnetic matrix. To obtain this kind of nanostructures we applied mechanical milling to synthesize $SmCo_5$/α-Fe nanocomposites starting from a mixture of $SmCo_5$ powder and 20 wt% of elemental iron. $SmCo_5$/Fe nanostructured alloys were thus investigated by X-ray diffraction, ^{57}Fe Mössbauer spectrometry, magnetic measurements and Atom Probe Tomography (APT). The APT is a 3D high resolution analytical microscope, which provides a 3D mapping at the atomic scale of the spatial distribution of atoms in the analyzed sample. It allowed investigating the nanostructure and the chemical nature of the hard/soft phase interfaces. The results show that during milling, Co/Fe interdiffusion occurs, leading both to the formation of Fe(Co) regions and to the presence of Fe in Sm-Co regions. Annealing leads to a structural refinement and promotes the introduction of both more Co in Fe-rich regions, and more Fe in Sm-Co regions. This induces the homogenisation of the α-Fe(Co) regions and the formation of a $Sm(Co,Fe)_5$ phase. Both coercivity and remanence depend upon the process conditions and can be improved by adjusting the milling and/or heat treatment parameters (time and temperature). Moreover, the strong observed Co/Fe interdiffusion may increase the exchange interactions between the hard $Sm(Co,Fe)_5$ and soft α-Fe(Co) phases. This assumption was confirmed by Monte Carlo simulations. So, our investigation confirms the benefit of the Co/Fe interdiffusion on the magnetic exchange.

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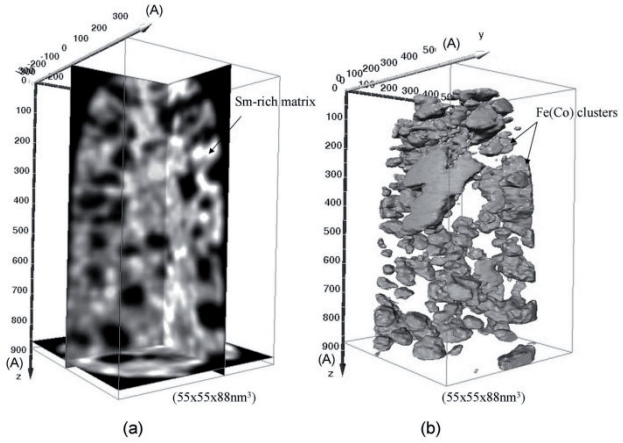

3D representation of the nanoscale morphology of the $SmCo_5$/Fe powder milled for 8h.

11.45 – 12.00

Approaching the critical point: Impact and potential benefits with regards to magnetocaloric applications

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The magnetocaloric effect (MCE) manifests as the change in temperature of a material in response to magnetic field - a consequence of conservation of entropy when a system undergoes a magnetic phase transition. For application, the ideal material should possess a tunable T_c, and large values of ΔS and ΔT; most easily achieved in systems that exhibit a first order phase transition.[1]

Initially interest revolved around magneto-structurally coupled materials where a giant MCE was observed, but which have significantly large hysteresis. In recent years several magneto-volume coupled systems have been investigated such as $La(Fe,Si)_{13}$[2] and $Mn_xFe_{1.95-x}P_{1-y}Si_y$.[3] The advantage of these systems is that they possess similarly large entropy changes but with significantly less hysteresis.

We will give a general overview of the characteristic features observed in magnetization data, heat capacity and latent heat data for several materials systems, including CoMnSi, $La(Fe,Si)_{13}$, $Gd_5Ge_2Si_2$, and $La_xCa_{1-x}MnO_3$. Emphasis will be placed on whether these materials fall into the local moment or itinerant model(s), how this relates to manifestation of the first order phase transition, and what we observe or might expect as the critical point is approached.

[1] K.A. Gschneidner and V.K. Pecharsky, Int. J. Refrig. 31, 945-961 (2008)
[2] O. Gutfleisch, M. Willard, E. Brück, C. Chen, S. Sankar and J. Liu, Adv. Mat. 23, 821-863 (2011)
[3] N.H. Dung, Z.Q. Ou, L. Caron, L. Zhang, D.T.C. Thanh, G.A. de Wijs, R.A. de Groot, K.H.J. Buschow and E. Brück, Adv. En. Mater. 1 (2011)

12.00 – 12.15

Enhanced Nucleation Fields due to Dipolar Interactions in Nanocomposite Magnets

J. Fischbacher [1], S. Bance [1], T. Schrefl [1]
(1) Industrial Simulation, St. Poelten University of Applied Sciences, 3100 St. Poelten, Austria

Most high performance magnets today are based on rare-earth elements like Neodymium or Dysprosium. These are both expensive and in short supply. One approach to construct even more powerful permanent magnets while using less rare-earth elements is to combine two different magnetic alloys at the nanometer scale and create so-called “nanocomposite” or “exchange spring” magnets. The idea behind this is to combine a hard magnetic material having a high coercive field with a soft magnetic material having a high saturation magnetization. If both materials are strongly coupled exchange forces will form a stable magnet with energy products as high as 1 MJ/m³, with low rare-earth content [1][2]. The enhancement of the remanence is generally achieved at the expense of the coercivity. But exchange interactions between soft and hard magnetic phases preserve a high coercivity, if the size of the magnetically soft region is smaller than twice the domain wall width of the hard magnetic phase [3].

We will use finite element micromagnetics simulations to optimize nanocomposite structures. In particular, we investigate the changing hysteresis properties for varying arrays of soft magnetic spheres in a hard magnetic body. Here we show that the anisotropy arising from dipolar interactions between soft spherical particles ($Fe_{65}Co_{35}$, diameter 8 nm) in a $Nd_2Fe_{14}B$ matrix can enhance the nucleation field by 8 %, rising with decreasing gap between the spheres. Using numerical optimization we search for the optimal microstructure for a given phase combination.

[1] G. Hadjipanayis and A. Gabay, “The Incredible Pull of Nanocomposite Magnets”, IEEE Spectrum, August 2011.
[2] R. Skomski and J. M. D. Coey, “Giant energy product in nanostructured two-phase magnets”, Am. Physical Soc. Phys. Rev. B 48, 15812-15816 (1993).
[3] T. Schrefl, H. Kronmueller, J. Fidler, “Exchange hardening in nano-structured two-phase permanent magnets”, JMMM 127, L273-L277 (1993).

12.15 – 12.30

Calorimetric study of the barocaloric and magnetocaloric effects in Ni-Co-Mn-Ga-In

S. Yuce [1], B. Emre [2], E. Stern [3], A. Planes [3], M. Barrio [4], J.L. Tamarit [4], F. Albertini [5], S. Fabbrici [6], L. Mañosa [3]
(1) Dept. ECM. Ftat. Física. Universitat de Barcelona, 08028 Barcelona, Catalonia.Ondokuz Mayis University, Faculty of Arts&Science, Dept. Phys., 55139 Samsun, Turkey., (2) Dept. ECM. Ftat. Física. Universitat de Barcelona, 08028 Barcelona, Catalonia. Ankara University, Faculty of Eng., Dept. of Eng. Phys., 06100 Ankara, Turkey., (3) Dept. ECM. Ftat. Física. Universitat

Wednesday, 12 September 2012
Otello Room

MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS...)
Chair: O. Gutfleisch

de Barcelona, 08028 Barcelona, Catalonia, (4) Grup de Caracterització de Materials, Dept. Física i Enginyeria Nuclear. ETSEIB. Universitat Politècnica de Catalunya, 08028 Barcelona, Catalonia., (5) IMEM. CNR., 43124 Parma, Italy., (6) IMEM. CNR., 43124 Parma, Italy. MIST-ER. Lab., 40129 Bologna, Italy.

Caloric effects are inherent to every material. They refer to the adiabatic temperature change or to the isothermal entropy change that occur when the external field is modified. The most studied caloric effect so far is the magnetocaloric effect. In addition to magnetocaloric materials, materials exhibiting caloric effects associated with external fields other than magnetic are also receiving increasing interest. Barocaloric effect is one of them, which is the heating or cooling of any material upon pressure variation. Ni-Mn-X (X=In, Ga, Sn) alloys were the subjects of intensive investigations due to interplay between structure and magnetism, which causes various properties: magnetic superelasticity, giant magnetocaloric effects, and giant magnetoresistance (Planes 2009). It was reported that some giant magnetocaloric materials would also show giant barocaloric effects (Mañosa 2010). In this study, differential scanning calorimetry under hydrostatic pressure has been used to determine pressure induced entropy changes on NiCoMnGa samples. In addition to that, differential scanning calorimetry under magnetic-field has also been used to determine field-induced entropy change. We have compared the results of both caloric effects. It is found that the barocaloric effect is conventional (heating with applying pressure) while the magnetocaloric effect is inverse (cooling on applying magnetic field).

[1] Planes A. et al., 2009, J. Phys.;Condens. Matter 21: 233201.
[2] Mañosa L. et al., 2010, Nature Matt. 9: 478-481.

12.30 – 12.45
Effect of Stabilization Heat Treatment on the Time-Dependent Polarization Losses in Sintered Nd-Fe-B Permanent Magnets
M. Haavisto [1], H. Kankaanpää [2], T. Santa-Nokki [1], S. Tuominen [1], M. Paju [1]
(1) Prizztech Oy, Magnet Technology Centre, Pori, Finland, (2) Neorem Magnets Oy, Ulvila, Finland

The utilization of sintered NdFeB permanent magnets in motor and generator applications has increased rapidly in recent years. The replacement of traditional induction technology with permanent magnet technology increases the efficiency of energy conversion in these applications. A general acceptance of the new technology requires, however, a verification of the stability of permanent magnets over time. Time-dependent demagnetization in sintered NdFeB magnets depends on the magnet material, temperature and reverse magnetic field [1-3]. To avoid the time-dependent demagnetization of sintered NdFeB magnets, some manufacturers have adopted a pre-ageing heat treatment in order to stabilize the magnets before assembly. The parameters of this stabilization heat treatment are mainly based on a rough estimate and not on any published research results. In this work we studied the effects of a pre-ageing treatment on the time-dependent polarization losses of two different types of commercial, sintered NdFeB magnets. The material showing the squarer J(H) curve did not benefit from the pre-ageing treatment, since it was stable anyway. Instead, the material showing a rounder J(H) curve did benefit from the treatment. After the stabilization treatment, the polarization of these magnets was found to be unchanged over a certain period of time. The length of this period depends on the temperature and duration of the pre-ageing treatment. In addition, our FEM analysis revealed that the stabilization heat treatments performed in open circuit conditions do not stabilize the magnets uniformly.

[1] M. Haavisto and M. Paju, IEEE Trans. Magn. 45, 3114 (2009)
[2] M. Haavisto et al., IEEE Trans. Magn. 46, 3582 (2010)
[3] M. Haavisto et al., IEEE Trans. Magn. 47, 170 (2011)

12.45 – 13.00
Hard magnetic nanoparticles and flakes prepared by surfactant assisted high energy ball milling
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(1) IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany, (2) T U Darmstadt, Petersenstr. 23, 64287 Darmstadt, Germany

Surfactant assisted high energy ball milling (SA-HEBM) has been shown to be an efficient method for the fabrication of anisotropic nanoparticles and flakes of Sm-Co and Nd-Fe-B. These anisotropic nanostructures are the potential precursor materials to be used as magnetic hard phase in combination with nanosized magnetically soft phase for the preparation of next generation textured exchange spring nanocomposite permanent magnets [1,2,3]. In this study, we discuss the effect of different milling parameters such as the type and concentration of surfactants, milling energy and milling time on the structural, morphological and magnetic properties of hard magnetic SmCo and NdFeB nanoparticles and flakes prepared by SA-HEBM. XRD patterns of magnetically oriented samples milled under different conditions show strong c-axis out-of-plane texture. The broadened and less intense peaks in case of 800 rpm as compared to that of 200 rpm milling indicate that higher milling energy in terms of rotational speed causes fast amorphization and reduction in grain size with milling time. TEM results of $SmCo_5$ flakes show that bigger flakes are single crystalline with c-axis out-of-plane whereas smaller flakes (<500 nm) are polycrystalline with grain size of around 10 nm. SAED pattern on a single flake shows six-fold symmetry with arcs and the absence of (001) diffraction indicates the presence of preferential c-axis out-of-plane texture. The as-milled samples of $SmCo_5$ show a maximum degree of texture of 88% and $(BH)_{max}$ of 24 MGOe and maximum coercivity of 2.3 tesla was obtained. The pronounced anisotropy and high coercivity of the nanoflakes should prove advantageous for the preparation of exchange spring magnets.

[1] E. F. Kneller, R. Hawig, IEEE Trans. Mag. MAG 27, (1991), 3588.
[2] R. Skomski, J. M. D. Coey, Phys. Rev. B 48, (1993), 15812.
[3] O. Gutfleisch et. al., Adv. Mater. 23 (2011), 821.

Wednesday, 12 September 2012
Macbeth Room

PEROVSKITES AND MULTIFERROICS
Chair: A. Gauzzi

10.30 – 11.00
Strain-driven imprinting of magnetic domains in perovskite manganite-titanate heterostructures *(invited)*
R.V. Chopdekar [1], J. Heidler [1], Y. Takamura [2], L.J. Heyderman [1], F. Nolting [1]
(1) Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland, (2) Dept. of Chemical Engineering and Materials Science, University of California at Davis, 95616 Davis CA, USA

Recent studies of artificial multiferroic epitaxial heterostructures consisting of ferromagnetic manganite and ferroelectric titanate layers have shown large structural, electronic and magnetic changes in the ferromagnetic layer induced by the ferroelectric layer, illustrating that such artificial systems can be a promising route to obtaining room temperature magneto-electric coupling in nanostructured systems.[1-2] In this work, we present a detailed angular dependent study on the strain-induced magnetic domain structure of a $(La,Sr)MnO_3$ thin film epitaxially grown on a $BaTiO_3$ substrate through the use of polarization-dependent x-ray photoemission electron microscopy. Angular-dependent measurements allow us to detect vector magnetization on a single-domain scale, and we relate the strain-induced changes in magnetic anisotropy of the ferromagnetic film to the ferroelectric domain structure of the underlying substrate with x-ray magnetic and x-ray linear dichroism spectro-microscopy.[3] Comparisons to measurements on a nearly strain free film of $(La,Sr)MnO_3$ grown on $(La,Sr)(Al,Ta)O_3$ illustrate that the $BaTiO_3$ ferroelectric domain structure imprints specific domain sizes and wall orientations in the $(La,Sr)MnO_3/BaTiO_3$ artificial multiferroic heterostructure.

[1] D. Dale, A. Fleet, J.D. Brock and Y. Suzuki, Appl. Phys. Lett., **82**, 3725 (2003).
[2] C. A. F. Vaz, J. Hoffman, C. Ahn and R. Ramesh, Adv. Mater **26-27** 2900 (2010).
[3] R.V. Chopdekar, V.K. Malik, A. Fraile Rodríguez, L. Le Guyader, Y. Takamura, A. Scholl, D. Stender, C.W. Schneider, C. Bernhard, F. Nolting, and L.J. Heyderman, in preparation.

11.00 – 11.15
Thermal and electrical control of perpendicular magnetization
M. Ghidini [1], F. Maccherozzi [2], J. Soussi [3], X. Moya [3], L. Phillips [3], W. Yan [3], N. Steinke [4], R. Mansell [4], C. Barnes [4], S. Dhesi [2], N. Mathur [3]
(1) 1 Materials Science, University of Cambridge, UK 2 Department of Physics, University of Parma, Italy, (2) Diamond Light source Ltd, Didcot, UK, (3) Materials Science, University of Cambridge, UK, (4) Cavendish Laboratory, University of Cambridge, UK

In magnetoelectric studies of magnetic thin films, electrical control of in plane magnetization has been demonstrated via changes in stress, exchange bias, carrier density and orbital occupation. However, electrical control of out of plane magnetization remains elusiveour. Here we show that the out of plane magnetization of strained 100 nm-thick magnetostrictive nickel films, which alternates in sign every 120 nm to yield regular stripe domains, can be controlled via stress from ferrolectric ferroelastic $BaTiO_3$ substrates. Photoemission electron microscopy with magnetic contrast from x-ray magnetic circular dichroism reveals that thermal cycling through structural phase transitions in the substrate switches the stripes on and off in a volatile manner, consistent with the unchanged ferroelectric-domain configurations observed indirectly via the magnetic imaging. By contrast, cycling the substrate in an applied electric field switches the stripes on and off in a non volatile manner due to 90° ferroelectric-domain switching, as revealed by magnetic force microscopy. This non-volatile electrical control of perpendicular magnetization, in the absence of an applied magnetic field, could inspire the design of electrically driven micromagnets, e.g. for electric-write magnetic-read in perpendicular recording media.

11.15 – 11.30
Magnetoelastic and magnetoelectric effects in composite multiferroic hybrid structures
S. Geprägs [1], M. Opel [1], S.T. Goennenwein [1], R. Gross [2]
(1) Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany, (2) Physik-Department, Technische Universität München, 85748 Garching, Germany

Multiferroic composite materials, in which ferromagnetic and ferroelectric compounds are artificially assembled, have attracted widespread interest over the last years. They allow for large and robust converse magnetoelectric effects at room temperature by exploiting the elastic coupling between the two constituents [1]. This extrinsic converse magnetoelectric coupling can be described phenomenologically by a product tensor property including both piezoelectric and magnetoelastic effects [2]. Thus, a detailed understanding of these effects and the elastic coupling across the interface is mandatory to predict magnetoelectric effects in novel multiferroic hybrid structures. Here, we present a detailed study of the magnetic properties of multiferroic hybrid systems consisting of $BaTiO_3$ as the ferroelectric and Ni or Fe_3O_4 as the ferromagnetic component. We report on the study of the modification of the magnetization caused by magnetoelastic effects exploiting the structural phase transitions of $BaTiO_3$. We demonstrate that for well-defined ferroelectric/ferroelastic domain states the observed magnetization changes in multiferroic hybrid structures can be predicted by first-principle simulation baseds on an effective Hamiltonian. Moreover, we investigate converse magnetoelectric effects at room temperature in $BaTiO_3$-based multiferroic hybrid structures. There, the magnetization behavior as a function of the applied electric field can be explained by the magnetic behavior of those parts of the ferromagnetic thin film clamped to *a*-domains of the $BaTiO_3$ substrate, while the magnetization of regions of the ferromagnetic thin film located on top of *c*-domains stays nearly unaffected. We show that the experimentally obtained converse magnetoelectric effects at room temperature in multiferroic hybrids are well described within this approach. Financial support by the German Excellence Initiative via the Nanosystems Initiative Munich (NIM) is gratefully acknowledged.

[1] W. Eerenstein *et al.*, Nat. Mater. **6**, 348 (2007); S. Geprägs *et al.*, Appl. Phys. Lett. **96**, 142509 (2010).
[2] C.-W. Nan, Phys. Rev. B **50**, 6082 (1994).

Wednesday, 12 September 2012
Macbeth Room

PEROVSKITES AND MULTIFERROICS
Chair: A. Gauzzi

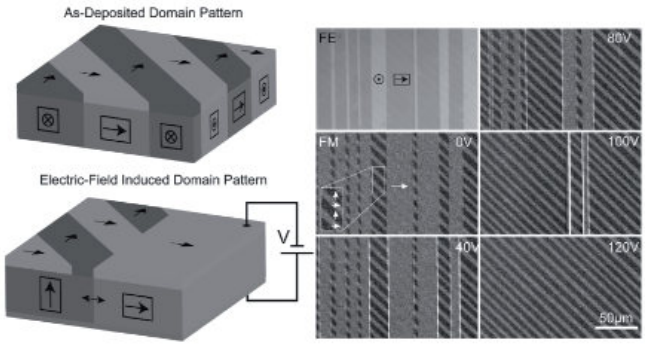
11.30 – 11.45

Electric-field control of magnetic domain wall motion and local magnetization reversal in multiferroic heterostructures

T.H.E. Lahtinen [1], K.J.A. Franke [1], S. Van Dijken [1]
(1) Department of Applied Physics, Aalto University School of Science, 00076, Finland

Spintronic devices currently rely on magnetic switching or controlled motion of domain walls by an external magnetic field or spin-polarized current. Achieving the same degree of magnetic controllability using an electric field has potential advantages including enhanced functionality and low power consumption. Here, an approach to electrically control local magnetic properties, including the writing and erasure of regular ferromagnetic domain patterns and the motion of magnetic domain walls is presented. The method is based on strain transfer from ferroelastic 90° stripe domains in ferroelectric $BaTiO_3$ substrates to continuous magnetostrictive CoFe films with negligible magnetocrystalline anisotropy. The dominance of magnetoelastic anisotropy in these multiferroic heterostructures causes full imprinting of the ferroelectric domain pattern into its ferromagnetic counterpart. Furthermore, strong pinning of magnetic domain walls onto the narrow ferroelastic boundaries is demonstrated in the as-deposited state [1]. Optical polarization microscopy of both the ferroelectric and ferromagnetic domain structures reveals that domain correlations and strong inter-ferroic domain wall pinning are maintained in an applied electric field [2]. This leads to unprecedented electric-field control over the formation of ferromagnetic domains and lateral motion of magnetic domain walls, an accomplishment that opens the way for electric-field driven spintronics.

[1] T.H.E. Lahtinen, J.O. Tuomi, and S. van Dijken, Adv. Mater. **23**, 3187 (2011), ibid IEEE Trans. Magn. **47**, 3768 (2011)
[2] T.H.E. Lahtinen, K.J.A. Franke, and S. van Dijken, Scientific Reports, **2**, 258 (2012)



Schematic and experimental data illustrating electric-field control of magnetic domains.

11.45 – 12.00

Magnetotransport and Hall effect studies of $SrRuO_3/SrTiO_3$ superlattices

F. Bern [1], M. Ziese [1], I. Vrejoiu [2], E. Pippel [3], D. Hesse [3]
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Good epitaxial growth characteristics make oxide heterostructures of the perovskite family a model system for the study of emerging phenomena at interfaces. Here we report on $SrRuO_3/SrTiO_3$ superlattices (SL) with individual layer thicknesses between two and 20 unit cells fabricated by pulsed laser deposition. Coherent growth of the interfaces was confirmed by X-Ray and HRTEM measurements. In this system an emerging magnetoelectric effect [1] as well as a magnetic 2DEG [2] have recently been theoretically predicted. Our magnetization and magnetotransport characterization are in agreement with results obtained earlier in similar systems [3]. Special attention is dedicated to the study of the normal and anomalous Hall effect (AHE). While SRO single layers as thin as three unit cells and SL with individual layer thicknesses above 4 unit cells show an AHE similar to the bulk and a constant high field Hall slope, the ultrathin SL show a temperature dependence in the high field Hall slope and opposite sign in the AHE. Additionally, angle dependent magnetotransport was used to obtain structural information.

[1] J.M. Rondinelli et al., Nat. Nano 3, 46 (2008)
[2] M. Verissimo-Alves et al. Phys. Rev. Lett. 108, 107003 (2012)
[3] M. Izumi et al., J. Phys. Soc. Jpn. 67, 651 (1997)

12.00 – 12.15

Optimal doping at $La_{2/3}Sr_{1/3}MnO_3/SrTiO_3(001)$ heterojunctions for spintronic applications: a first-principles study

C. Wang [1], *N. Stojic* [1], N. Binggeli [1]
(1) ICTP, The Abdus Salam Centre for Theoretical Physics, 34151 Trieste, Italy

Due to its large spin polarization and high Curie temperature, $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) is a promising candidate for spintronic applications, such as tunneling magnetoresistance and field-effect transistors [1]. With $SrTiO_3$ (STO) as insulating barrier, the resulting LSMO/STO/LSMO(001) magnetic tunneling junctions were found to give rise to an exceptionally large tunneling magnetoresistance (TMR) ratio at low temperatures. However, the TMR was found to depend strongly on interface effects and to vanish well below the LSMO Curie temperature. Previously, it was observed [2] that doping the SrO-terminated STO-LSMO, by depositing two unit layers of $LaMnO_3$ at the interface, strengthens the interface ferromagnetism and enhances the TMR ratio. However, the effect was not large enough to make the SrO-termination competitive with the TiO_2 termination [2].
We apply the first-principles density-functional-theory method to explore the effects of doping at the LSMO/STO(001) TiO_2-terminated interface. Both the generalized-gradient approximation (GGA) and the GGA plus on-site Coulomb interaction approach (GGA+U) are used. In our simulations, one unit layer of LSMO at the interface is replaced by $La_{1-x}Sr_xMnO_3$, with varying doping $0<x<1$. In particular, we are interested in the variations of the exchange energy [3], E_{AFM} - E_{FM} (energy difference

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PEROVSKITES AND MULTIFERROICS
Chair: A. Gauzzi

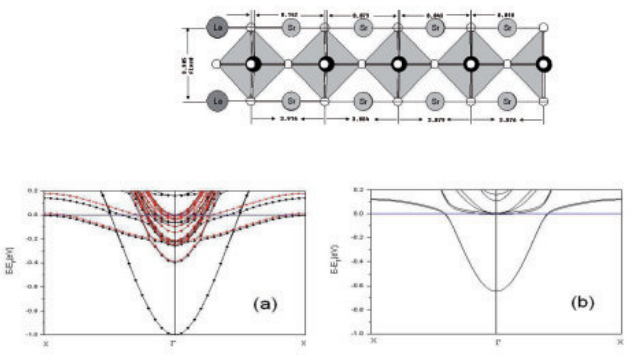
between antiferromagnetic and ferromagnetic alignment of the MnO_2-interface layer relative to bulk LSMO), as a measure of the robustness of the interface ferromagnetism for spintronic applications. The corresponding optimal doping is found to be very close to x=1/3, both in GGA and GGA+U. Furthermore, the doping has strong effects on the interface magnetic moments, which are also discussed in the talk.

[1] M. Bibes and A. Barthelemy, IEEE Trans. Electron. Devices 54, 1003 (2007); Kourkoutis et al., PNAS 107, 11682 (2010).
[2] H. Yamada et al, Science 305, 646 (2004).
[3] B. Zheng and N. Binggeli, Phys. Rev. B 82, 245311 (2010).

12.15 – 12.30
Ferromagnetic two-dimensional electron gas at the $LaAlO_3$/$SrTiO_3$ interface driven by ferroelectric-like $SrTiO_3$ distortion
J.C. Li [1], *M.C. Muñoz* [2]
(1) School of Physics, Shandong University, 250100 Jinan , Shandong, P.R. China, (2) Instituto de Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain

We address the origin of the ferromagnetic phase formed at the LaO/TiO2 interface in LaTiO3/SrTiO3 (001) heterostructures [1]. Using first-principles density functional calculations we show that the charge transfer to the Ti t2g conduction band (CB) induced by the polar mismatch at the interface, combined with the incipient ferroelectric character of the SrTiO3, lead to a substantial lattice deformation (see top of the figure). The ferroelectric-like distortion of the SrTiO3 slab generates the spontaneous spin-polarization of the lowest dxy orbital parallel to the interface and the emergence of a ferromagnetic ground state. Moreover, it yields differential occupation of the non-degenerated dxy and degenerated dxz-yz orbital states. We predict the existence of three different types of electrons, magnetic two-dimensional (2D) dxy electrons and non-magnetic higher-lying dxy and dxz-yz quasi-2D electrons. While the former, with a 2D-light effective mass (m*) parallel to the interface, are confined to the TiO2 interface plane, the non-spin polarized higher-lying dxy, also with a light m*, and the Bloch dxz-yz electrons spread over several SrTiO3 layers. Their different characteristics could explain the coexistence in the same sample of superconductivity and magnetism [2]. Furthermore, since ferroelectric distortions and orbital magnetism are coupled, the magnetic state can be controlled by an electric field.

[1] A. Brinkman, M. Huijben, M. van Zalk, et al., Nature Materials 6, 493 (2007).
[2] Ariando, X.Wang, et al., Nature Communications 2, 188 (2011); D. A. Dikin, et al., Phys. Rev. Lett. 107 (2011); L. Li, et al. Nature Physics 7, 762 (2011); J. A. Bert, et al., Nature Physics 7, 767 (2011).

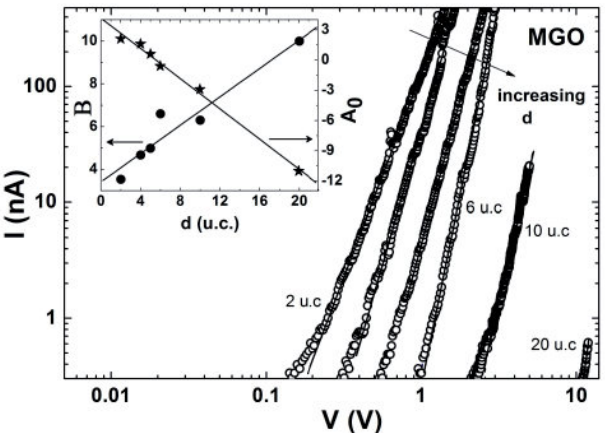


Lattice and CB with (a) and without (b) relaxation for the LAO*3.5*/STO*8.5* structure.

12.30 – 12.45
Substrate influence in the barrier quality of multiferroic tunnel junctions, model and experiments
M. Sirena [1], L. Avilés Félix [1], L.B. Steren [2]
(1) Lab. Resonancias Magneticas, Centro Atomico Bariloche, Inst. Balseiro - UNCuyo & CNEA, also at CONICET, (2) Centro Atómico Constituyentes, Av. Gral. Paz 1499, San Martín 1650, Buenos Aires- Argentina

In this work a phenomenological approach [1] is proposed to analyze the electrical transport through an insulating barrier in ferromagnetic (FM)/ferroelectric (FE) bilayers, using conductive atomic force microscopy (CAFM). We have found that I(V) = A _{0} . V ^{B} , where A _{0} and B depend linearly with the barrier thickness. The proposed model allows to obtain critical information for the development of magnetic tunnel junctions. Moreover, assuming a Gaussian distribution of the barrier thickness, it is possible to fit the measured current distribution and to study the thickness homogeneity of the barrier. The influence of the substrate in the electrical properties of the FE/FM bilayers was studied in the frame of this model. MgO substrates with higher roughness than SrTiO3 ones, were found to increase the barrier thickness distribution and to increase the attenuation length in the material, reducing the barrier quality for the developing of multiferroic tunnel junctions.

[1] M. Sirena, Journal of Applied Physics, 110, 063923 (2011).



I(V) curves for FM/FE bilayers with different barrier thicknesses grown over MgO.

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Macbeth Room

PEROVSKITES AND MULTIFERROICS
Chair: A. Gauzzi

12.45 – 13.00
Order-Disorder Mediated Ferroelectricity in Dominantly Ferromagnetic Hybrid Organic-Inorganic Perovskites
B. Kundys [1], *A. Lappas* [2], M. Viret [3], V. Kapustianyk [4], V. Rudyk [4], C. Simon [5]
(1) Institute de Physique et de Chemie des Matériaux de Strasbourg (IPCMS), UMR 7504 CNRS-ULP, 23 rue du Loess, F67034 Strasbourg Cedex 2, France, (2) Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Vassilika Vouton, 71110 Heraklion, Greece, (3) Service de Physique de l'Etat Condesé, DSM/IRAMIS/SPEC, CEA Saclay URA CNRS 2464, 91191 Gif-Sur-Yvette Cedex, France, (4) Scientific-Technical and Educational Center of Low-Temperature Studies, Ivan Franko National University of Lviv, Dragomanova str. 50, UA-79005 Lviv, Ukraine, (5) Laboratoire CRISMAT, CNRS UMR 6508, ENSICAEN, 6 Boulevard du Maréchal Juin, 14050 Caen Cedex, France

The constantly growing exploration for new multiferroic materials branches out to include the hybrid organic-inorganic family. Particularly rare are single-phase compositions with coexisting ferromagnetism and ferroelectricity in the same temperature and pressure region. It is postulated that order-disorder phase transitions, rather than displacive ones, intrinsic to the broad family of such hybrid compounds can act as a good alternative to engineer multiferroic behavior in previously unexplored systems. In a recent report [1] of ours we demonstrated their potential through a subclass of such materials, the family of organic-inorganic perovskites, with composition $(C_nH_{2n+1}NH_3)_2MCl_4$, where n is an integer and M is a divalent metal (M= Mn^{2+}, Cd^{2+}, Fe^{2+}, and Cu^{2+}). More specifically, the ethylammonium copper chloride, $(C_2H_5NH_3)_2CuCl_4$, magnetic system was shown to become ferroelectric. The magnetic state is stabilized below 9 K via dominant intra-plane ferromagnetic exchange interactions. This, in contrast to other metal-containing members of the family, is a consequence of the Jahn-Teller distortion, which allows for the e_g hole-orbital ordering on anti-ferrodistortively arranged $CuCl_6$-elongated octahedra in the bc-plane (Fig.1a and 1b). A dielectric anomaly is identified at 247 K (Fig.1c), followed by large spontaneous polarization (Fig.1d) below this temperature. The system is also ferroelectric with large remnant polarization that is comparable to classical ferroelectric compounds (Fig.1d inset). The results are attributed to a disorder-to-order transition, where a favorable orientational configuration is selected while the organo-cation motion freezes upon temperature lowering. In such hybrid perovskites the underlying hydrogen-bonding, of the easily tunable organic building blocks, in combination with the 3d transition-metal layers offers an emerging pathway to engineer multi-functional multiferroics.

[1] B. Kundys, A. Lappas, M. Viret, V. Kapustianyk, V. Rudyk, S. Semak, Ch. Simon, I. Bakaimi, Phys. Rev. B 81, 224434 (2010)

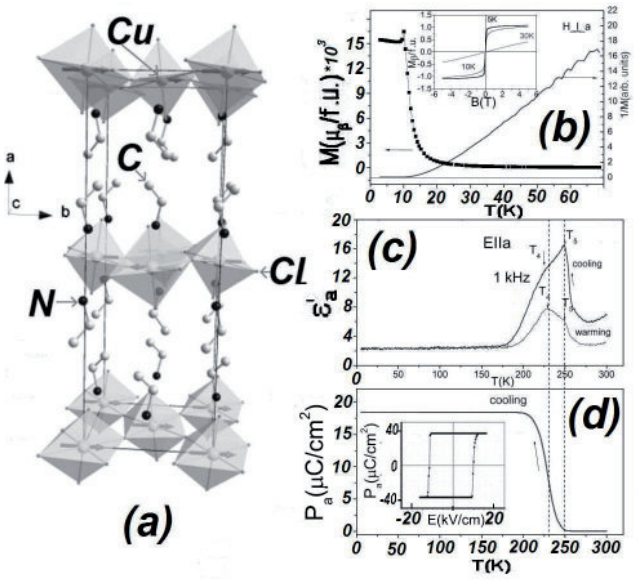

Figure 1. The structure (a), magnetization (b), permittivity (c) and polarization (d).

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Rigoletto Room

MAGNETISM AND SUPERCONDUCTIVITY
Chair: S. Sanna

10.30 – 11.00
Phase diagrams of Fe based superconductors *(invited)*
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Using a broad spectrum of experimental techniques, such as NMR, μSR, ARPES, magnetometry, thermodynamics, x-ray diffraction, and transport measurements, we have studied the interplay between magnetism and superconductivity in several classes of iron pnictide superconductors. In $LaO_{1-x}F_xAsFe$ and other 1111 type materials an intimate interplay between magnetism and electronic properties is evident. Moreover, measurements of the electrical field gradient by NQR yield clear-cut evidence for nanoscale order of charges and/or orbitals which are reminiscent to the famous stripe order found in cuprates. The phase diagram of Co doped NaFeAs is qualitatively very similar to that of the 1111 and 122 type pnictides. In contrast, LiFeAs, a second member of the 111 type pnictides shows quite different behaviour. From our measurements on pristine material as well as hole and electron doped compounds we do not find any evidence for strong antiferromagnetic correlations. Instead, measurements of NQR, μSR, magnetisation, and magnetic resonance reveal a weak ferromagnetic order in hole doped LiFeAs. Based on our determination of the phase diagram and the results from spectroscopic studies the possible relationship between this unusual ferromagnetic state and superconductivity in stoichiometric LiFeAs is discussed.

11.00 – 11.15
Interplay between magnetism and superconductivity in electron doped oxypnictides
P. Carretta [1], S. Sanna [1], R. De Renzi [2], P. Bonfà [2], G. Prando [1], G. Allodi [2], G. Lamura [3], A. Martinelli [4], M. Putti [3], Y. Kobayashi [5], M. Sato [5]
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The appearance of superconductivity (SC) close to the disruption of static magnetic order (M) is a general feature of the Fe-based superconductors. In the REFeAsO family (RE1111, with RE a rare earth) it is found that SC and M strongly compete and hardly coexist simultaneously [1,2], apart for Sm and Ce [3] where within a small doping range both order parameters are depressed. The competition between superconducting and magnetic ground states must be reconciled with the prevailing models of pairing mediated by spin fluctuations.
Here we show, by means of μSR and ^{75}As NQR, that magnetism is surprisingly still at play in optimally F-doped $REFe_{1-x}Ru_xAsO_{1-y}Fy$ [4] (with RE= Sm, Nd and La). The isoelectronic diamagnetic Fe:Ru substitution is found to deteriorate the superconducting state and to simultaneously to recover static magnetism within the FeAs layers, for $0.1< x < 0.6$. The two reduced order parameters coexist within nanometer-size domains in the FeAs layers and eventually disappear around a common critical threshold x_c around 0.6, the same threshold where magnetism tends to vanish in the parent $LaFe_{1-x}Ru_xAsO$ compound [5].
Superconductivity and magnetism in RE1111 are shown to be closely related to two distinct well-defined local electronic environments [4] and the two transition temperatures, tuned by Ru substitution, scale with the volume fraction of the corresponding environments. The results suggest that superconductivity cannot exist if magnetism is definitely suppressed by magnetic dilution, supporting a magnetic coupling mechanism for superconductivity.

[1] H. Luetkens et al., Nature Mater. 8, 305 (2009).
[2] R. Khasanov et al., Phys. Rev. B 84, 100501 (2011).
[3] S. Sanna, et al. Phys. Rev. B 80, 052503 (2009); ibid. Phys. Rev. B 82, 060508(R) (2010);
[4] S. Sanna et al. Phys. Rev. Letters 107, 227003 (2011)
[5] P. Bonfà et al. Phys. Rev. B 85, 054518 (2012) ;

11.15 – 11.30
Transition metal doping in 122 superconductor family
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New classes of materials have revived interest in superconductivity; among these, the pnictides presented many similarities and differences with high Tc cuprates and posed completely new issues as the interplay and possibly the coexistence between magnetism and superconductivity. As in cuprates, charge doping appears to be an effective tool to promote or suppress superconductivity: for example compounds of the 122 family such as BaFe2As2 and CaFe2As2 become superconductor upon K and Na doping. Substitution of the transition metal, which suppresses the antiferromagnetic phase, is also seen to help the onset of superconductivity as observed in BaFeCoAs2[1]. As the effect on the superconducting transition temperature is seen to linearly depend on the number of electrons introduced by doping, the occurrence of a "chemical scaling" relation has been proposed. However, this scaling relation has been recently questioned by experiments [2] showing that iso-electronic substitutions do not follow this rule. This is the case of Pt doping in CaFe2As2 which, being isovalent with Ni, should destroy the antiferromagnetic phase, and thus favour the onset of superconductivity, at a concentration value which is the same of Ni and half the one of Co. While the rule is obeyed for Co and Ni, Pt doping preserves the antiferromagnetic phase up to its solubility limit and thus suppresses the onset of superconductivity.
In this study we present first-principles calculations of Ni and Pt doping in Ca2Fe2As2 at different concentrations and analyse in detail the effects of doping on the structural and electronic properties in terms of states at the Fermi level and Fermi surface changes. Rigid band approximation and disorder effects are specifically addressed.
[1] A.S. Sefat et al. Phys. Rev. Lett. 101, 117004 (2008)
[2] K. Kudo et al., cond-mat 203.0822 (2012)

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11.30 - 11.45
Pressure effect on the magnetic and superconducting properties of $REFeAsO_{1-x}F_x$ (RE=Sm, Ce, La)
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Apart from chemical doping, the electronic properties of the Fe-based compounds can also be tuned by applying an external pressure (P). In particular, it has been shown that $LaFeAsO_{1-x}F_x$ (La1111) system, for $0<x<0.15$, displays a significant increase of T_c with P already at P<2 GPa [1]. Indeed, the T_c variation upon pressure for the RE1111 family is found to be RE dependent, showing a minor effect for the case of RE=Sm [2].
We report on the effect of external pressure on the magnetic properties of $REFeAsO_{1-x}F_x$ with RE=La, Ce, Sm. The microscopic magnetic behaviour of the undoped (x=0) and slightly doped (x~0.04-0.07) samples has been investigated up to P≈25 kbar by using the μSR technique.
The external pressure modifies the microscopic magnetic properties and the effect is generally rare earth dependent. Both the staggered magnetization M_s and T_N diminish vs. pressure for all the REFeAsO samples, but the slopes $-dM_s/dP$ and dM_s/dP decreases with the RE ionic radius, from La to Sm.
In particular, the interplay between magnetism and superconductivity in $LaFeAsO_{0.945}F_{0.055}$ was studied as a function of hydrostatic pressure up to P = 2.4 GPa by means of muon-spin rotation (μSR) and magnetization measurements [3]. The application of pressure leads to a substantial decrease of the magnetic ordering temperature, reduction of the magnetic phase volume and, at the same time, to a strong increase of the superconducting transition temperature and the diamagnetic susceptibility. From the volume-sensitive μSR measurements it can be concluded that the superconducting and the magnetic areas, coexisting in the same sample, are inclined toward spatial separation and compete for phase volume as a function of pressure.

[1] H.Okada et al., J.Phys.Soc.Jap. 77, 113712 (2008)
[2] Wei Yi et al., EPL 83, 57002 (2008)
[3] R. Khasanov et al., Phys. Rev. B 84, 100501(R) (2011)

11.45 – 12.15
HTS and magnets; magnetism and HTS *(invited)*
J. Tallon [1]
(1) MacDiarmid Institute, Industrial Research Ltd, POB 31310, Lower Hutt, New Zealand

This year marks a quarter of a century since the discovery of high-T_c superconductors (HTS) operating over the temperature of liquid nitrogen. Despite the fact that these materials are still not understood HTS are now being used in a wide range of magnet applications, including for synchrotrons, NMR, MRI, testing hard drives, and ion implantation. At the same time magnetism plays a central role in the puzzling physics of these mysterious materials. This talk will describe the recent developments in applications of HTS in magnets (including products from our spin-out company *HTS-110 Ltd*) and will highlight the role of magnetism in HTS – a role that is completely unexpected: superconductivity is found to anticorrelate with magnetic exchange interactions.

12.15 – 12.30
Negative magnetic relaxation in superconductors
E. Krasnoperov [1]
(1) Kurchatov Inst.,123182 Moscow, Russia

It was observed that the trapped magnetic field in high-temperature superconductors (HTS) tablets or annuli increases in time (negative relaxation) if they are not completely magnetized by a pulsed magnetic field [1,2]. It is shown, in the framework of the Bean critical-state model, that the radial temperature gradient appearing in discs or annuli during a pulsed field magnetization (PFM) can explain the negative relaxation of the magnetic in the superconductor.
The temperature gradient appearing in PFM strongly effects the current relaxation in the superconductor. The currents near the outer surface diminish slower than the internal currents, which vary in the opposite direction. This can lead to the negative relaxation of superconducting currents, that is to an increasing of the magnetic moment of the superconductor as a function of time. The logarithmic magnetic relaxation rate of thick-walled cylinder is calculated depending on the magnetization and the temperature gradient. Negative relaxation can be used to improve the time stability of the magnetic field in systems on basis melt grown HTS.

[1] A.A. Kartamyshev, E.P. Krasnoperov, Yu.D. Kuroedov, N.A. Nizhelskiy, O.L. Poluschenko, Physica C 469 (2009) 805–809
[2] E.P. Krasnoperov, A.A. Kartamyshev, D.I. Puzanov, O.L. Polushchenko,
N.A. Nizelskij, J Supercond Nov Magn (2010) 23: 1499–1501

12.30 – 12.45
Point Contact Andreev Reflection from Graphite in External Magnetic Field
P. Stamenov [1]
(1) CRANN and School of Physics, Trinity College, Dublin 2, Ireland
Highly Oriented Pyrolitic Graphite (HOPG) is a synthetic form of graphite which apart from its widespread use in crystal monochromators, has been utilised for fundamental investigations into the electronic transport and magnetic properties of semimetals.

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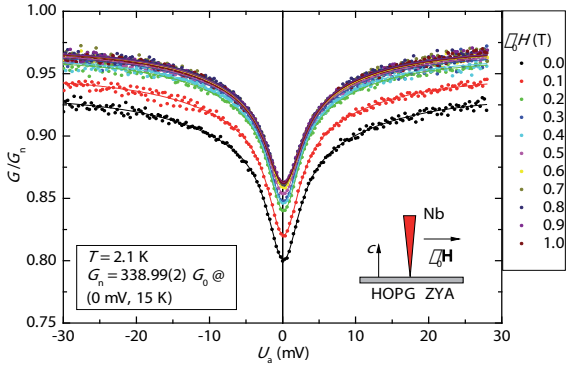
Here we report on an investigation of the suppression of the Andreev reflection and the modifications to the Density Of States (DOS) at low temperatures (T = 2.0 – 15.0 K), with an in-plane (perpendicular to the crystal c-axis) magnetic field of up to ($\mu_0 H$ = 1 T), in point contacts between ZYA-grade HOPG and polycrystalline niobium. The measurements are performed by a real-time Derivative Spectroscopy (DS) methodology, described elsewhere [1], permitting the acquisition of external magnetic field and temperature dependences, without the need to reform even unstable and short-lived point contacts.
The normal-state DS of the junctions (at T = 9.2 – 15.0 K) is relatively featureless, with a quasi-parabolic bias dependence of the differential conductance. At temperatures below the T_c = 9.2 K of the niobium tip used, a region of suppressed normalized differential conductivity appears, centred at zero bias, that is well-fitted by a superposition of two Lorentzian peaks with approximate widths of 5.3(1) and 28(1) mV, and amplitudes of -0.76(4) and -1.8(2), respectively. The two peaks are attributed to the superconducting gap of niobium (about 1.5 meV) and the offset of the Fermi level from the bottom of the c-band in HOPG (about 12 meV), modified by the thermal smearing and the vanishing gap in the DOS of HOPG (< 2 meV). The peaks' amplitudes, widths and the background conductivity, all exhibit nonlinear behaviour as functions of the in-plane external field, while the magnetoresistive contribution of the bulk HOPG is essentially linear. The same methodology should be applicable to other semimetals, such as bismuth.

[1] P. Stamenov, Journ. App. Phys., **111**, 07C519 (2012)



Andreev spectra of an HOPG/Nb junction, with in-plane magnetic field.

12.45 – 13.00
Hysteresis phenomenon and magnetic memory in FeNi/Nb hybrid films

L. Uspenskaya [1], A. Chugunov [2], V. Skidanov [3]
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Magnetic pinning in hybrid S/F structures as well as hysteresis phenomenon at magnetization reversal influences on the low temperature behavior of magnetoresistance and the value of effects. For example, it was shown recently that the value and the sign of magnetoresistance observed in FeNi/Nb depended on the thickness of magnetic layer. It was supposed that the change of sign was connected with the difference in the type of domain walls in permalloy. However, the variation of the type of the walls due to the Nb vicinity influence and distortion of stray fields, the asymmetry of the dependence of magnetoresistance upon the field were neglected in the consideration.
This study is devoted to direct observation of magnetization reversal process in hybrid films permalloy-niobium. We have found that magnetization reversal of permalloy in hybrids and in the free permalloy layers differes not only by the value of coercitivity, by the duration of time of domain wall nucleation and by the rate of magnetization reversal, but in a qualitative sense. Next, we have observed the dependence of kinetics of magnetization reversal upon the structures sizes and aspect ratios; smart rotational modes appear with the reduction of structure sizes below some critical size L. The surprise was not only the emergence of new modes of reversal, but the dimension of the structure under which the transition to new modes of reversal occurs; the critical size L was found much larger than the width of the domain wall in permalloy; it was of the order of several micrometers. We have seen that the coercitivity and the delay of magnetization reversal depend upon the size and shape of the structure. And finally, we have found the memory effect of the structure upon the magnetic state of permalloy which survive till heating sample over T_c^{Nb}

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MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

SPIN VALVES AND SPIN INJECTION

Chair: J.M. De Teresa

14.45 – 15.15

Coulomb Blockade and Single Electron Spintronics *(invited)*

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Coulomb blockade happens when a quantum dot is isolated from electrodes by a tunnelling barrier and the charging energy must be supplied to add an electron. Such systems may be useful for spintronics because the quantum dot may have a very long spin-flip lifetime and the quantised energy levels can act as a spin filter. These ideas are behind the current studies of imbedding particles in barriers, for example, in a conventional magnetic tunnel junction. Work so far has shown that there are a number of systems that can demonstrate Coulomb blockade and resonant conductance where the tuning of the dot energy by a gate can create conductance peaks as the dot energy aligns with the electrode Fermi energy. There is an interesting possibility to generate a very high magnetoresistance in a quantum dot system by using the magneto-Coulomb (MC) effect to change the dot energy and thus shift the conductance peaks. Applying an external field changes the Zeeman energy of the magnetic electrode which in turn has an effect on the dot that mimics a change in the gate voltage. We have fabricated carbon nanotube spin valves with sputtered permalloy contacts in which we have demonstrated this effect. Our samples are single-walled carbon nanotubes where the contact pads are made by electron-beam lithography in specially designed shapes to maximise the possibility that the tube is contacted by a single domain and that the switching is very sharp. As well as these large MR effects, in excess of 300%, we shall demonstrate features of the conductance of the quantum dot and its electrodes that are consistent with the present understanding of the MC effect and some that are new.

15.15 – 15.30

Unexpected spin polarized electron tunneling in BCC FeCo/MgO/FeCo(001) magnetic tunnel junctions

S. Andrieu [1], T. Hauet [1], F. Bonell [1], F. Montaigne [1], F. Bertran [2], P. Lefevre [2], A. Taleb [2], L. Calmels [3]
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In combining spin- and symmetry-resolved photoemission, magnetotransport measurements and ab- initio calculations, we detangled the electronic states involved in the electronic transport in Fe1-xCox(001) /MgO/ Fe1-xCox(001) magnetic tunnel junctions (MTJ) prepared by molecular beam epitaxy (MBE) [1]. Contrary to previous theoretical predictions [2], we observe a large reduction in TMR (from 530 to 200% at 20K) for Co content above 25% as well as anomalies in the conductance curves. To understand the tunneling in these MTJs, it is necessary to obtain information both spin and symmetry resolved. The CASSIOPEE beamline at SOLEIL synchrotron offers remarkable opportunities for this type of study: (i) spin resolution through the MOTT detector (ii) access to very low energy (from 10eV), where the Fe and Co cross sections are large, (iii) low angular aperture of the detector, allowing only looking at Δ symmetry, (iv) tunable light polarization allowing to distinguish between Δ1 et Δ5 state symmetry [3]. Thus, for p polarization of light, Δ1→Δ1 and Δ5→Δ1 transitions are allowed, whereas for s polarization, only Δ5→Δ1 transitions are allowed, due to symmetry reasons. We demonstrate that the magneto-transport behaviors in FeCo/MgO based MTJs originate from a minority spin states with Δ1 symmetry that exists below the Fermi level for high Co concentration. Using angle-resolved photoemission, this state is shown to be a two-dimensional state that occurs at both Fe1-xCox(001) free surface, and more importantly at the interface with MgO. The combination of this interface state with the density of empty states due to chemical disorder allows us to describe the complex conduction behavior in this system.

[1] F. Bonel et al, Phys. Rev. Lett., (2012), in press (april)
[2] X. G. Zhang & W. H. Butler, Phys. Rev. B **70**, 172407 (2004)
[3] N. Tong et al, Phys. Rev. B **77**, 064421 (2008)

15.30 – 15.45

Optical spin injection and spin filtering in Fe/MgO/Ge photodiodes: photon energy dependence

M. Cantoni [1], C. Rinaldi [1], M. Marangoni [2], G. Cerullo [2], R. Bertacco [1]
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In this contribution, the degree of spin polarization of electrons and holes photo-excited in Ge at room temperature is investigated by means of the spin filtering effect at the Fe/MgO interface. Spin-detection experiments have been performed by illuminating photodiodes, fabricated by optical lithography on epitaxial Fe/MgO/Ge(001) heterostructures [1], with circularly polarized light in a magnetic field applied parallel to the light helicity. Photo-generated carriers in Ge are spin-filtered by the MgO barrier depending on the relative orientation of the spin and of the magnetic field.
The degree of spin polarization (DSP) of photo-excited carriers in Ge is related to the percentage variation of the photocurrent due to full reversal of the light helicity (ΔI). The spin filtering (SF), defined as ΔI divided by the photocurrent, is reported in Figure as a function of the photon energy in the range 0.8 eV1.57 eV (1550 nm-823 nm). In order to explain the observed behaviour, we developed a theoretical model based on the Fert-Jaffrès theory [2] with the inclusion of a spin-dependent photo-generation term. In the frame of this model, the superposition of two effects, i.e. the DSP of photo-carriers [3] and the absorption coefficient of Ge vs. photon energy, are able to explain the experimental results, as proved by the good fitting between the experimental data (dots) and the model predictions (lines) reported in Figure. The device we presented is then suitable for integrated detection of light helicity at room

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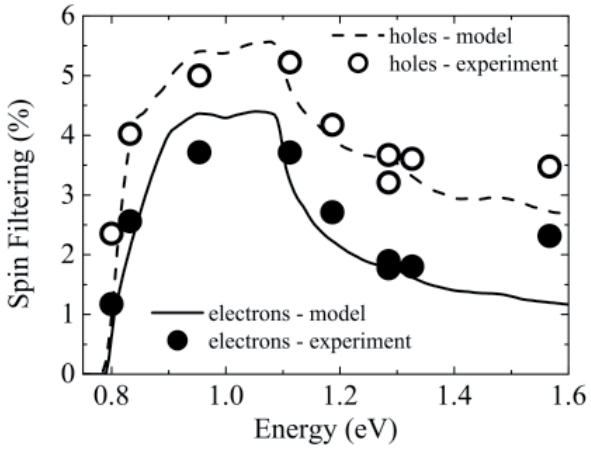
temperature in novel spin-optoelectronics systems working in the 0.95 eV-1.3 eV energy range.

[1] M. Cantoni et al., Appl. Phys. Lett. **98**, 032104 (2011).
[2] A. Fert and H. Jaffrès, Phys. Rev. B **64**, 184420 (2001).
[3] J. Rioux and J. E. Sipe, Phys. Rev. B **81**, 155215 (2010).



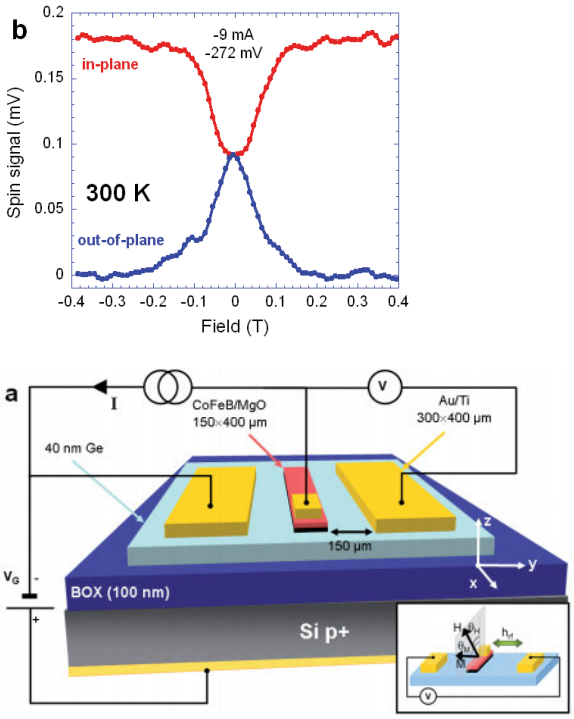
Room temperature Spin Filtering vs. photon energy

15.45 – 16.00
Transition from spin injection into interface states to the channel in n-Ge

A. Jain [1], J.C. Rojas Sanchez [1], M. Cubukcu [1], J. Peiro [2], J.C. Le Breton [2], C. Vergnaud [1], C. Portemont [3], C. Ducruet [3], *L. Vila* [1], J.P. Attané [1], E. Augendre [4], S. Gambarelli [5], H. Jaffrès [2], J.M. George [2], M. Jamet [1]
(1) INAC/SP2M, CEA-Grenoble and Université Joseph Fourier, 38054, Grenoble, France, (2) Unité Mixte de Physique, CNRS-Thalès, 91767, Palaiseau, France, (3) CROCUS-Technology, 38025, Grenoble, France, (4) LETI, Minatec Campus, CEA-Grenoble, 38054, Grenoble, France, (5) INAC/SCIB, CEA-Grenoble and Université Joseph Fourier, 38054, Grenoble, France

Spin injection into semiconductors is crucial for exploring spin physics and new spintronic devices. Unlike GaAs or Si, very few studies have dealt with spin injection in Ge [1,2]. This material is of great interest for high carrier mobility, long spin diffusion length and large spin-orbit coupling to perform electric field spin manipulation through Rashba interaction. However the exact role of interface states in spin injection mechanism in n-Ge has not been clarified yet and except in ref. [1] no clear evidence of spin accumulation in the channel has been given. In this paper, we show a clear transition from spin injection into interface states to the channel. For this purpose, we have grown CoFeB/MgO spin injector on GOI [2]. We observe spin signal amplification at low temperature due to spin accumulation into interface states. At 200 K, we observe a clear transition to spin injection in the channel up to room temperature: the spin signal is reduced to a value compatible with spin diffusion model and more interesting we could demonstrate spin signal modulation applying a back gate voltage and spin-pumping by the ferromagnetic resonance of the CoFeB layer which are clear manifestations of spin accumulated in the channel.

[1] Y. Zhou, W. Han, L.-T. Chang, F. Xiu, *et al., Phys. Rev. B* **84**, 125323 (2011).
[2] A. Jain, L. Louahadj, J. Peiro, J. C. Le Breton, C. Vergnaud, A. Barski, C. Beigné, L. Notin, A. Marty, V. Baltz, S. Auffret, E. Augendre, H. Jaffrès, J.-M. George, M. Jamet, *Appl. Phys. Lett.* **99**, 162102 (2011).



(a) Sketch of the multi-terminal device used for electrical spin injection/detection/manipulation and spin pumping (inset). (b) Spin signal at 300 K and zero gate voltage.

16.00 – 16.15
Tunneling processes in thin MgO magnetic tunnel junctions

J.M. Teixeira [1], J. Ventura [1], M.P. Fernández-García [1], J.P. Araujo [1], J.B. Sousa [1], P. Wisniowski [2], S. Cardoso [3], P.P. Freitas [3]
(1) IFIMUP and IN-Institute of Nanoscience and Nanotechnology and Departamento de Fisica, Faculdade de Ciencias, Universidade do Porto, Rua do Campo Alegre, 687, 4169-007 Porto, Portugal, (2) Department of Electronics, AGH University of Science and Technology, 30-059 Krakow, Poland/INESC-MN and IN-Institute of Nanoscience and Nanotechnology, Rua Alves Redol, 9-1, 1000-029 Lisbon, Portugal, (3) INESC-MN and IN-Institute of Nanoscience and Nanotechnology, Rua Alves Redol, 9-1, 1000-029 Lisbon, Portugal

Magnetic tunnel junctions (MTJs) with MgO barriers are a subject of great research interest due to their huge number of applications,

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such as forefront spin-transfer torque magnetic random access memories, read heads, and novel microwave devices. In this work, we probed the temperature (T) and the voltage (V) dependence of the tunnel conductance (G) and magnetoresistance (TMR) of sputtered CoFeB/MgO/CoFeB MTJs with different barrier (t_b=0.75–1.35 nm) and free layer (t_{fl}=1.55–3.0 nm) thicknesses. We observe the onset of pinholes for MTJs with 0.75 nm of MgO, with a transition to metallic-like transport. For $t_b \geq 0.85$ nm, the spin-polarized direct elastic tunneling is the dominant mechanism determining the T-dependence of G and TMR [1]. Moreover, tunneling spectroscopy [G(V) and dG/dV] measurements reveal that, beyond the standard magnon excitations, the electronic band structure of the electrodes plays a significant role on the low bias voltage window (0 <V< 0.4 V) of the TMR [2]. Furthermore, we have detected resonant electronic trapping within the barrier for voltages V > 0.15 V [3]. These trapping features are associated with defects in the barrier crystalline structure, as confirmed by high-resolution transmission electron microscopy images. Such defects are responsible for resonant tunneling due to energy levels that are formed in the barrier. A model was applied to determine the average location and energy level of the traps. Evidence of the influence of trapping on the voltage dependence of TMR is shown.

[1] J. M. Teixeira *et al.*, Appl. Phys. Lett. 96, 262506 (2010).
[2] J. M. Teixeira *et al.*, Appl. Phys. Lett. 100, 072406 (2012).
[3] J. M. Teixeira *et al.*, Phys. Rev. Lett. 106, 196601 (2011).

16.15 – 16.30
Magnetotransport in nanopatterned manganite nanowires
L. Marín Mercado [1], L. Morellón [2], P.A. Algarabel [3], L. Casado [4], J.M. De Teresa [5], M.R. Ibarra [6]
(1) INA / Dpto. Física de la Materia Condensada / ICMA, Universidad de Zaragoza, 50009, Spain, (2) INA / Dpto. Física de la Materia Condensada, Universidad de Zaragoza, 50009, Spain, (3) ICMA / Dpto. Física de la Materia Condensada, Universidad de Zaragoza, 50009, Spain, (4) LMA-INA, Universidad de Zaragoza, 50018, Spain, (5) ICMA / LMA-INA / Dpto. Física de la Materia Condensada, Universidad de Zaragoza, 50009, Spain, (6) INA / Dpto. Física Materia Condensada / LMA, Universidad de Zaragoza, 50009, Spain

Nanostructured materials have attracted an intense research interest over recent years, as they provide the critical building blocks for nanoscience and nanotechnology. A noteworthy potential in this field is related to the recent improvements in nanopatterning techniques, such as electron beam lithography and focused ion beam (FIB). Fundamentally, novel properties emerge as the sample size becomes comparable to or smaller than certain characteristic length scale [1]. Moreover, it has been observed that ion irradiation induces peculiar morphological changes, such as structural damage (amorphization). In manganites, structural and morphological changes have dramatic counterparts in magnetic and transport properties [2].

In this work, we have obtained wires from thin films of $La_{1-x}Ca_xMnO_3$ and $La_{1-x}Sr_xMnO_3$ manganites that maintain their physical properties such as the metal – insulator transition (MIT). We have succeeded in producing wires by optical lithography + FIB between 50 – 6 μm in length, 5 μm – 100 nm in width (with typical thickness ranging 20 – 80 nm). In our case, the MIT temperature increases when the wire width decreases (see fig. 1a). The electrical resistivity and magnetoresistance of the thin films, micro and nanowires (Fig. 1b) were measured in a standard four probe configuration with the current parallel to the wire, as a function of temperature between 10 K and 400 K, and in-plane magnetic field between ± 9 Teslas.

[1] J.I. Martín et al., J. Magn. Magn. Mater. 256, 449 (2003)
[2] I. Pallecchi et al., J. Magn. Magn. Mater. 320, 1945 (2008)

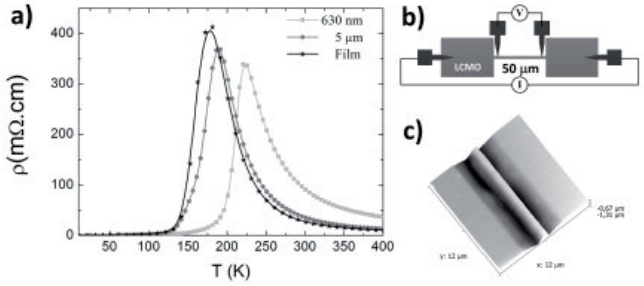

Figure 1. (a) Temperature dependence of the resistivity in $La_{2/3}Ca_{1/3}MnO_3$ (LCMO) thin film, microwire (5 μm width) and nanowire (630 nm width) configuration. (b) Schematically representation of the transport measurements. (c) AFM images on the nanowire.

16.30 – 16.45
Features of the magnetization reversal mechanisms in the magnetoresistive response of magnetic multilayers
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(1) IMDEA NANOSCIENCE, 28049 MADRID SPAIN, (2) Departamento de Fisica de la Materia Condensada, Universidad Autonoma de Madrid, 28049 Madrid, Spain, (3) Instituto de Fisica Aplicada, CSIC, 28049 Madrid, Spain, (4) ISOM, Universidad Politecnica de Madrid de Madrid, 28049 Madrid, Spain

The Giant-Magneto-Resistance effect found in multilayers composed by ferromagnetic (FM) layers separated by non-magnetic spacers consists in a significant change of the electrical resistance depending on the relative magnetization orientation of the FM layers [1]. Even though it is commonly assumed that the magnetoresistance (MR) depends on the magnetic anisotropy of multilayer structures, a comprehensive description of the magneto-resistive behavior related to the magnetization reversal is still lacking. Experiments just relies in either magnetization (usually parallel component) or MR curves measured independently for a given applied field angle,

normally close to the easy axis (e.a.) direction.
Here, we present a detailed study of the angular-dependence of both magneto-resistive and magnetization reversal properties in a exchange-biased spin-valve [2], by using a new experimental set-up that allows us to measure simultaneously magneto-resistance and vectorial-resolved Kerr [3] hysteresis loops, i.e., including MR and in-plane parallel and perpendicular magnetization components, at different applied field angles in the whole angular range. We advance towards a microscopic understanding of the MR properties by showing that their angular-dependence leaves distinct fingerprints directly related to their magnetization reversal processes. For instance, reversible (around h.a.) and irreversible (around e.a.) transitions are similar in both MR and vectorial-resolved magnetization curves. The MR-plateau-value decreases as the magnetic field is misaligned with respect to the e.a. and the MR-maximum decreases approaching the h.a. Our results directly show that the different magneto-resistive behaviors originate from the magnetic anisotropy of the structure, which ultimately depends on the relative magnetization orientation of the FM layers.

[1] M.N. Baibich, et al. Phys. Rev. Lett. 61, 2472 (1988); G. Binash, et al. Phys. Rev. B 39, 4828 (1989).
[2] B. Dieny, et al. Phys. Rev. B 43, 1297 (1991).
[3] D. Ecija, et al. Phys. Rev. B 77, 024426 (2008); P. Perna et al. *submitted* (2012).

14.45 – 15.15
Screened hybrid functionals applied to 3d, 4d, and 5d transition metal perovskites *(invited)*
C. Franchini [1]
(1) Computational Materials Physics, University of Vienna A-1090 Vienna, Austria

Despite their astonishing success, conventional density functional theory (DFT) approximations introduced to evaluate the exchange-correlation energy, such as the local and generalized gradient spin density approximations, are known to be inadequate to account for the electronic and magnetic structure of materials with partially filled *d* orbitals. Particularly problematic is the treatment of the coupling between lattice/spin/electron degrees of freedom and the description of metal-insulator (MI), structural and magnetic transitions.
The objective of this talk is to show that hybrid functionals, suitable admixture of density functional and Hartree-Fock theories, can systematically adjust the drawbacks of standard DFT and provide a satisfactory prediction of the physical properties of magnetic oxides, thus allowing for a much more accurate elucidation of the complex physical phenomena occurring in this class of systems.
After introducing the screened hybrid functional formalism and discussing the role and influence of the screening and mixing parameter we will present results on:
· 3*d* perovskites La*M*O3 (*M*=Sc to Cu).
· Band/Mott-Hubbard/charge-transfer insulators \& correlated metals.
· Pressure induced metal-insulator, AFM-FM, orthorhombic-cubic transitions in LaMnO3.
· 4*d* perovskites *R*TcO3 (*R*=Ca, Sr, Ba): exceptionally strong magnetism (TN > 750 K).
· 5*d* perovskite BaIrO3: Mott-SOC (spin-orbit coupling) insulator.

[1] A.D. Becke, J. Chem. Phys. 98, 1372 (1993)
[2] J. Heyd, G. E. Scuseria, and M. Ernzerhof, J. Chem. Phys. 118, 8207 (2003);
erratum: J. Chem. Phys. 124, 219906 (2006)
[3] The VASP project @ http://www.vasp.at

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ELECTRONIC STRUCTURE AND CORRELATION EFFECTS IN MAGNETIC SYSTEMS

Chair: A. Filippetti

15.15 – 15.30

Surface/interface effects in the electronic structure of CrN thin films and multilayers

A.S. Botana [1], V. Pardo [1], I. Conde-Leboran [1], D. Baldomir [1], P. Blaha [2]
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The manipulation of the electronic structure of a material by quantum confinement has focused much attention recently. The appearance of conducting surface states or the novel phenomena at the interface between oxides are two notorious examples.
As a bulk, CrN is a degenerate semiconductor with promising thermoelectric properties. It shows a magnetostructural phase transition at 286 K from a paramagnetic rocksalt structure to an antiferromagnetic orthorhombic one with a 25% lower bulk modulus [1]. By means of electronic structure calculations, we have first studied CrN as a bulk to elucidate its controversial properties and to control the computational parameters. Then, within the LDA+U formalism, we have studied thin CrN films and CrN/MgO multilayers, analyzing the evolution of the electronic structure with CrN thickness. For the CrN thin films, surface states arise due to the dangling bonds at the surface that reduce the symmetry of the octahedral crystal field around Cr. When the underlying lattice has rocksalt structure, a gap opens and the material remains semiconducting. However, when the positions are relaxed, the surface states drive the material towards metallicity. The role of these conducting surface states in a possible improvement of the thermoelectric properties of CrN has been analyzed. To see the changes in the electronic structure arising when the vacuum is substituted by a MgO barrier and to investigate the interface phenomena, multilayers of CrN/MgO have also been studied. When CrN films are sandwiched by MgO, no conducting surface states appear and a gap opens. Differences between the case of multilayers and thin films will be discussed.

[1] F. Rivadulla, M. Bañobre-Lopez, C.X. Quintela, A. Piñeiro, V. Pardo, D. Baldomir, M.A. López-Quintela, J. Rivas C. A. Ramos, H. Salva, J-S. Zhou and J. B. Goodenough. Nat. Mater. 8, 947 (2009)

15.30 – 15.45

Magnetoelasticity in ACr_2O_4 spinels with magnetic A-site ions

V. Kocsis [1], S. Bordács [1], A. Abouelsayed [2], C.A. Kuntscher [2], K. Ohgushi [3], Y. Tokura [4], K. Penc [5], I. Kezsmarki [1]
(1) Department of Physics, Budapest University of Technology and Economics, 1111 Budapest Hungary, (2) Experimentalphysik 2, Universität Augsburg, D-86135 Augsburg, Germany, (3) Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581, Japan, (4) Institute for Solid State Physics, University of Tokyo, Kashiwanoha, Kashiwa, Chiba 277-8581, Japan, (5) Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, P.O.B. 49, Hungary

Spin-lattice coupling plays a crucial role in lifting the degeneracy of the magnetic ground state in various frustrated spin systems including ACr_2O_4 spinel compounds with nonmagnetic A-site ions [1].
We study the lattice dynamics of ACr_2O_4 spinels, with spin (A=Mn, Co) and both spin and orbital degrees of freedom (A=Fe, Ni, and Cu) on the A site. For the latters, orbital degeneracy is lifted via cooperative Jahn-Teller effect, which reduces the originally cubic symmetry to tetragonal. Due to magnetic exchange between the Cr^{3+} ions forming a frustrated pyrochlore lattice and A^{2+} ions sitting on a diamond lattice, the spin frustration is released and each compound has magnetically ordered ground state.
We investigated the effect of magnetic ordering on the lattice symmetry by the analysis of the reflectivity spectra in the region of infrared active phonon modes from room temperature down to 10K. We calculated the optical conductivity spectra to allow a clear assignment of the phonon resonances.
Compounds with no orbital degeneracy preserve the cubic symmetry as we observed no splitting of phonon modes [2]. In contrast, those with orbital degeneracy exhibit strong magnetoelastic effects. The sequence of the phonon splitting shows that their symmetry is reduced to orthorhombic due to the spin ordering transition. Moreover, in $NiCr_2O_4$ the emergence of new infrared active modes was observed.
Our experimental results indicate that lowering of the lattice symmetry to tetragonal within the paramagnetic state is a criterion for magnetically induced structural distortion. Our theoretical model indeed show that the common energy scale of the spin-orbit coupling and the tetragonal splitting for the d-levels of the A-site ions has fundamental role in the magnetoelasticity in $FeCr_2O_4$, $NiCr_2O_4$, and $CuCr_2O_4$.

[1] O. Tchernyshyov *et al.*, Phys. Rev. Lett. **88**, 067203 (2002).
[2] S. Bordács *et al.*, Phys. Rev. Lett. **103**, 077205 (2009).

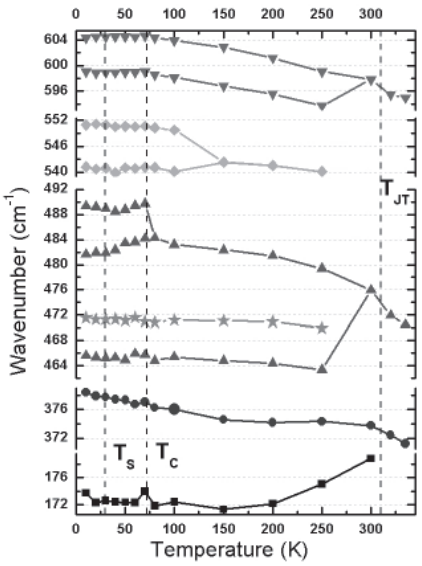

Figure: Sequence of the phonon mode splitting in $NiCr_2O_4$ across the Jahn-Teller and the magnetic transition at T_{JT}=310K and T_C=70K.

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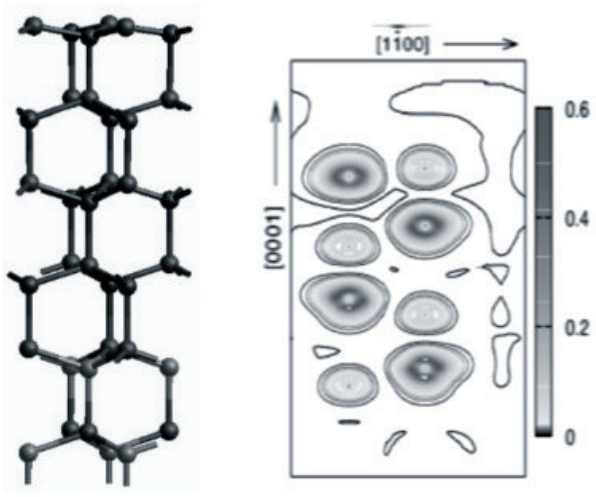
Chair: A. Filippetti

15.45 – 16.00
Ferromagnetic CoO in ultrathin wurtzite films
N. Sanchez [1], S. Gallego [2], M.C. Muñoz [2]
(1) Instituto de Magnetismo Aplicado, Univ. Complutense de Madrid, 28230 Las Rozas, Madrid, Spain, (2) Materials Science Institute of Madrid, CSIC, 28049 Cantoblanco, Madrid, Spain

CoO is a prototypical antiferromagnetic Mott insulator that crystallizes in the rocksalt lattice. Eventhough its apparent simple structure, it hosts complex electronic interactions that also manifest in a complex magnetic order. Furthermore, the recent ability to synthetize wurtzite-like CoO nanostructures with weak magnetism invokes the existence of a new phase diagram for CoO under reduced dimensions [1-3]. Based on ab initio calculations within density functional theory (DFT) including a local Hubbard on-site repulsion term (+U), we demonstrate that ultrathin CoO films with wurtzite structure can be stabilized under appropriate conditions, and that they exhibit robust ferromagnetism with high magnetic moments. We provide the clues to understand the mechanisms governing the exchange coupling, and the differences with respect to the bulk-like rocksalt structure.

[1] A.S. Risbud et al. Chem. Mater. 17, 834 (2005)
[2] J. Alaria et al., J. Phys. D: Appl. Phys. 41, 135004 (2008).
[3] H.L. Meyerheim et al., Phys. Rev. Lett. 102, 156102 (2009)



Structure and charge density distribution of ultrathin wurtzite CoO films.

16.00 – 16.15
Effects of interactions and high magnetic fields on a Lifshitz transition: Application to $CeIn_3$
P. Schlottmann [1]
(1) Department of Physics, Florida State University, Tallahassee, FL 32306, USA

The Néel ordered state of CeIn_3 is suppressed by a magnetic field of 61 T at ambient pressure. There is a second transition at ~45 T, which has been associated with a Lifshitz transition [1]. Skin depth measurements [1] indicate that the transition is discontinuous as T → 0 and weakly pressure dependent until it merges with the Néel transition. Motivated by this transition we study the effects of Landau quantization and interactions among carriers on a Lifshitz transition. The Landau quantization leads to quasi-one-dimensional properties for the direction parallel to the field. Repulsive Coulomb interactions give rise to strong coupling for the one-dimensional gas [2]. The density correlation function is calculated for a special long-ranged potential [3]. For the lowest Landau level the problem can be mapped onto the interacting one-dimensional electron gas. It is concluded that in CeIn_3 (a) an electron or hole pocket is being emptied as a function of field and (b) in the ground state the pocket is emptied in a discontinuous fashion. This discontinuity is gradually smeared by the temperature [3] in agreement with the skin depth experiments [1].
Work supported by the Department of Energy under grants DE-FG02-98ER45707.

[1] K.M. Purcell *et a*l, Phys. Rev. B **79**, 214428 (2009)
[2] R. Gerhardts and P. Schlottmann, Z. Phys. B **34**, 349 (1979); P. Schlottmann and R. Gerhardts, Z. Phys. B **34**, 363 (1979)
[3] P. Schlottmann, Phys. Rev. B **83**, 115133 (2011); J. Appl. Phys.**111**, 07E101 (2012)

16.15 – 16.30
The electronic and magnetic structure of I-Mn-V antiferromagnetic semiconductors
F. Maca [1], J. Masek [1], J. Zelezny [2], T. Jungwirth [3]
(1) Institute of Physics ASCR, 182 21 Praha 8, Czech Republic, (2) Institute of Physics ASCR, 162 53 Praha 6, Czech Republic, (3) Institute of Physics ASCR, 162 53 Praha 6, Czech Republic and School of Physics and Astronomy, University of Nottingham, United Kingdom

Recent observation of a large magnetoresistance in an antiferromagnet (AFM) based tunnel junction opens the prospect for utilizing AFMs in spintronics [1]. This motivates a search for new materials which may be suitable for spintronics and are room-temperature AFMs. The desired control of devices via electrical fields could be further exploited if the materials involved would be either semiconductors or semimetals with a low density of states at the Fermi energy [2]. We report on an ab-initio theoretical study of CuMn-V antiferromagnets based on the density functional theory. Previous works showed low-temperature antiferromagnetism and semimetal electronic structure of the semi-Heusler CuMnSb. We show that the transition to a semiconductor-like band structure upon introducing the lighter group-V elements is present in both the metastable semi-Heusler and the stable orthorhombic crystal structures [3]. We also predict a remarkable increase

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of the Néel temperature and a strong enhancement of magnetocrystalline anisotropy in the layered crystals of CuMnAs. The experimental results indeed indicate that the Néel temperature in CuMnAs is much higher than in CuMnSb. We discuss in detail the ground state of these compounds and the role of defects to stabilize it.

[1] B. G. Park et al., Nature Materials **10**, 347 (2011)
[2] T. Jungwirth et al., Phys. Rev. B **83**, 035321 (2011)
[3] F. Maca et al., J. Magn. Magn. Mater. **324**, 1606 (2012)

16.30 – 16.45
FP-LMTO investigation of the structural, electronic and magnetic properties of Heusler compounds Ru_2CrZ (Ge,Sn,Si)
S. Bahlouli [1], Z. Aarizou [1], *M. Elchikh* [1], N. Sekkal [2], G. Vergoten [3]
(1) Laboratoire de Physique des Matériaux et des Fluides, Département de Physique, Université des Sciences et de la Technologie d'Oran -Mohamed Boudiaf- BP 1505 Oran El Mnaouer, Algeria, (2) Ecole Normale d'Enseignement Technologique d'Oran, BP 1523 EL-M'naouer Oran 31000 ALGERIE, (3) Unité de Glycobiologie Structurelle et Fonctionnelle, UMR CNRS/USTL n° 8576-IFR 118, Université des Sciences et Technologies de Lille, Batiment C9, 59655 Villeneuve d'Ascq cedex, France

We report structural and magnetic properties as well as band structures and density of states (DOS) of full Heusler Ru_2CrGe, Ru_2CrSn and Ru_2CrSb. This was performed in the frame work of self consistent first principle calculations, using the Full-Potential Linearized Muffin Tin Orbital (FP-LMTO) method based on the Generalized Gradient Approximation (GGA). Experimentally, Okada et al. succeeded in synthesizing Ru2CrGe and Ru2CrSn, and found that Ru2CrGe is an antiferromagnet and Ru2CrSn shows a spin-glass-like behavior below Tg = 7 K [1,2]. Our results confirm that behavior and find that these compounds, along with Ru2CrSb, are semi-conductor.

[1] H. Okada, K. Koyama, K.Watanabe, Y. Kusakari, T. Kanomata and H. Nishihara, App. Phys. Letters. 92, 062502 (2008).
[2] H. Okada, Y. Kusakari, E. Matsuoka, H. Onodera, K. Koyama, K.Watanabe and T. Knomata, J. Phys. Conference Series 150 042153 (2009).

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MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: Z. Arnold

14.45 – 15.15
Parimagnetism and Short Range Correlations in RCo_2 *(invited)*
F. Bartolomé [1], C.M. Bonilla [1], J. Herrero [2], C. Castán-Guerrero [1], I. Calvo-Almazán [3], L.M. Garcia [1], A. Figueroa [1], J. Bartolome [1], E. Weschke [4], D. Schmitz [4], A. Stunault [3], J.A. Rodríguez-Velamazán [3], M. Carpenter [5], S.L. Driver [5]
(1) ICMA, Universidad de Zaragoza - CSIC, 50009 Zaragoza, Spain, (2) CUD, Academia General Militar - U. de Zaragoza, 50090 Zaragoza, Spain, (3) Institute Laue Langevin, 38042 Grenoble, France, (4) HZB, Albert-Einstein-Str. 15, 12489 Berlin, Germany, (5) Department of Earth Sciences, University of Cambridge, CB2 3EQ United Kingdom

A systematic experimental study our group has been carrying recently on the Laves phases RCo_2 (where R is a heavy rare earth ion Er, Ho, Dy, or Tm), reveals the occurrence of parimagnetism, i.e., the antiparallel arrangement between the net magnetic moments of the rare-earth and the cobalt sublattices in an extended temperature interval well above the critical temperature for magnetic ordering. The relationship of this unusual state with short-range magnetic correlations, which are present in the paramagnetic phase of this compounds up to temperatures as high as room temperature, appears from comparison between different experimental results.
The experimental techniques used range from macroscopic magnetometries, including ac longitudinal and rf transverse susceptibility, electric and thermal transport measurements to element specific magnetometries such as x-ray magnetic circular dichroism (XMCD), neutron diffraction (SANS and polarized ND), and muon relaxation spectroscopy. Additionally, Resonant Ultrasound Spectroscopy (RUS) studies have shown the presence of fluctuations in local strain, also described as ferroelastic clusters, above the magnetic ordering temperature. Comparing RUS and magnetic measurements sheds light on the interrelationship between ferroelastic and magnetic nanoclusters.
If a textbook paramagnet is an ideal gas of non-interactuating magnetic moments, it appears clearly that RCo_2 is a strongly correlated paramagnet, in which Co has a very strong tendency to form clusters, or "droplets", suggesting a liquid-like magnetic state, rather than an ideal gas. This tendency is reminiscent of the fact that amorphous $ErCo_2$ is a ferrimagnet due to the Co-Co interaction at temperatures as high as 470 K, one order of magnitude higher than the Tc of crystalline $ErCo_2$.

15.15 – 15.30
Pressure influence on parimagnetism in RCo_2 compounds
J. Prchal [1], J. Valenta [1], M. Míšek [1], D. Turčinková [1], L. Lapčák [1], M. Kratochvílová [1], J. Prokleška [1], V. Sechovský [1]
(1) Charles University in Prague/DCMP, Faculty of Mathematics and Physics, 121 16 Prague 2, Czech Republic

The RCo_2 (R = Dy, Ho, Er, Tm) compounds crystallize in the

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MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: Z. Arnold

cubic Laves phase structure. The rare-earth localized 4f-electron magnetic moments coexist together with the itinerant Co 3d moments, which appear on the verge of magnetism. Below T_C, the large exchange field due to the ferromagnetically ordered R moments polarizes the Co 3d-electron states and the emerged moments in the Co sublattice orient antiparallel to the R sublattice. Recent reports propose that weak Co moments survive rather far above T_C in Co magnetic clusters remaining coupled antiparallel to paramagnetic R moments forming a parimagnetic configuration in the paramagnetic phase [1,2]. The onset of his phenomenon causes an anomaly in the magnetic susceptibility at the "parimagnetic transition temperature" T_f.
The ordering temperature appears to be very sensitive to applied hydrostatic pressure. The same pressure coefficient has been found for T_f that indicates a common underlying mechanism of ferrimagnetism and parimagnetism. We will present variations of the transition temperatures T_C and T_f in compounds with R = Dy, Ho_2 and Er with applying hydrostatic pressures up to 3 GPa. The results will be discussed in term of suppressing the Co magnetic moments and varying the exchange and crystal-field interactions with applying the hydrostatic pressure.

[1] J. Herrero-Albillos et al., Phys.Rev.B **76** (2007) 094409.
[2] C.M. Bonila et al., J.Appl.Phys. **111** (2012) O7E315.

15.30 – 15.45
The $R_{11}Ni_4In_9$ phases: new compounds and their magnetic properties
A. Provino [1], Y. Mudryk [2], D. Paudyal [2], P. Manfrinetti [1], V.K. Pecharsky [2], K.A. Gschneidner Jr. [2]
(1) Department of Chemistry and Industrial Chemistry, University of Genova, 16146 Genova, Italy, (2) Ames Laboratory, U.S. Department of Energy, Division of Material Science and Engineering, Iowa State University, Ames, IA 50011, U.S.A.

The formation of new compounds in the $R_{11}Ni_4In_9$ (R = rare earth) series has been probed. The existence of the homologous phases for R = Dy, Ho, Er, Tm, Lu has been found [1,2]; these results prove the formation of the $R_{11}Ni_4In_9$ phases extends to all the R, but Sc. These compounds, with general formula $R_{m+n}M_{2n}X_m$, crystallize in the $Nd_{11}Pd_4In_9$-type (*oC*48, *Cmmm,* Z = 2) [3]. The crystal structure, formed by AlB_2 and CsCl fragments, is layered: it forms a sheet with long *a* and *b* axes and a very short *c* axis, where layers of R alternate with layers of Ni/In. Due to the crystal structure, the $R_{11}Ni_4In_9$ compounds show a peculiar fibrous microstructure, responsible of a very strong anisotropy in the physical and magnetic properties (Figure 1*a* and 1*b*). Moreover, five crystallographic sites are occupied by the rare earth atoms; this feature gives rise to complex magnetic interactions, due to the coupling of the R magnetic moments within the different sublattices.
None of the physical properties on any of the $R_{11}Ni_4In_9$ compounds has been reported so far. A ferromagnetic ground state is observed in all these compounds; after a first ferromagnetic transition, multiple magnetic anomalies appear at lower temperatures.

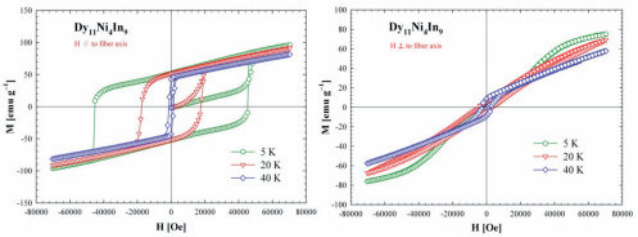


Figure 1*a* Figure 1*b*

[1] A. Provino, Y. Mudryk, P. Manfrinetti, D. Paudyal, V.K. Pecharsky, K.A. Gschneidner, Jr., *Rare Earth Research Conference 2011 (RERC11)*, Santa Fe (NM, U.S.A.), June 19-23, 2011.
[2] A. Provino, PhD. Thesis in *Chemical Sciences and Technologies*, University of Genova, Italy, 2012.
[3] L. Sojka, M. Manyako, R. Černý, M. Ivanyk, B. Belan, R. Gladyshevskii, Ya. Kalychak, *Intermetallics* 16, 625-628, 2008.

15.45 – 16.00
The efficiency of ultrafast demagnetization in $Gd_xFe_yCo_{100-x-y}$ alloys
R. Medapalli [1], I. Razdolski [1], M. Savoini [1], A.R. Khorsand [1], A.M. Kalashnikova [2], A. Tsukamoto [3], A. Itoh [3], A. Kirilyuk [1], A.V. Kimel [1], T. Rasing [1]
(1) Institute for Molecules and Materials, Radboud University Nijmegen, 6525 AJ, Nijmegen, The Netherlands, (2) Ioffe Technical Institute of the Russian Academy of Sciences, 194021 St. Petersburg, Russia, (3) College Science and Technology, Nihon University, 7-24-1 Funabashi, Chiba, Japan

Optical control of magnetism in rare-earth (RE)/transition-metal (TM) thin films has been an issue of immense interest [1]. Understanding such a phenomenon microscopically at the time scale of the exchange interaction [2] is a timely issue to push the current magnetic data storage technologies into the range of unprecedentedly high operational frequencies above 10 GHz. Using a time-resolved pump-probe experimental setup we studied the efficiency of ultrafast laser-induced demagnetization in multisublattice $Gd_xFe_yCo_{100-x-y}$ alloys. Our systematic studies of laser-induced ultrafast demagnetization as a function of Gd-concentration (x = 18, 22, 24, 30%, and y=9%), pump fluence, and sample temperature clearly show that the ultrafast demagnetization efficiency strongly depends on both Gd-concentration and the relative temperature of these ferrimagnets compared to their magnetization compensation point (T-T_M). For example, in $Gd_{24}Fe_{66.5}Co_{9.5}$ we observed efficient ultrafast demagnetization below the magnetization compensation point (T_M) and only a partial demagnetization (50%) above T_M for the same excitation laser pulse fluence of 10.7 mJ/cm^2 (see figure). Based on recent works [2, 3], we reveal that the ultrafast demagnetization in Fe is assisted by the angular momentum transfer from the spin reservoir of Fe to that of Gd. This is most efficient when the concentrations of Fe and Gd are balanced. In addition we show that the compensation point plays an important role in achieving the conditions for full demagnetization at the ultrafast time scale.

Wednesday, 12 September 2012
Otello Room

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: Z. Arnold

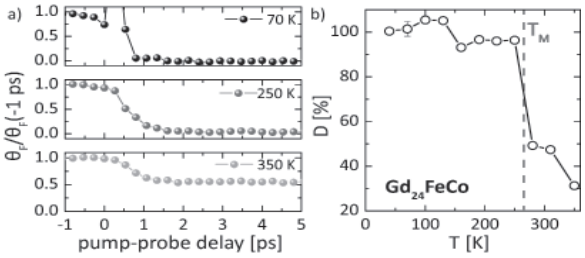


Figure: Time dependence and efficiency of ultrafast demagnetization in $Gd_{24}Fe_{66.5}Co_{9.5}$.

[1] K. Vahaplar *et. al.,* Phys. Rev. Lett. 103, 117201 (2009).
[2] I. Radu *et. al.*, Nature 472, 205 (2011).
[3] J. H. Mentink *et. al.*, Phys. Rev. Lett. 108, 057202 (2012).

16.00 – 16.15

Pressure and Magnetic field phase diagrams of Dy_5Si_3Ge intermetallic compound

N. Marcano [1], P.A. Algarabel [2], J. Rodríguez-Fernández [3], C. Magén [4], N. Singh [5], V.K. Pecharsky [5], K. Gschneidner [5], L. Morellón [6], M.R. Ibarra [6]
(1) Centro Universitario de la Defensa, 50090 Zaragoza, (2) ICMA, Universidad Zaragoza-CSIC, 50009 Zaragoza, Spain, (3) CITIMAC, Universidad de Cantabria, 39005 Santander, Spain, (4) Fundación ARAID, 50004 Zaragoza, Spain, (5) Ames Laboratory, Iowa State University, Ames, Iowa 500011-3020, USA, (6) INA, Universidad de Zaragoza, Zaragoza 50018, Spain

The discovery of the giant magnetocaloric effect in the $Gd_5Si_2Ge_2$ alloy has attracted a great interest in the study of other $R_5(SiGe)_4$–type (R=rare earth) compounds in order to understand the relationship between their structural and magnetic properties. One interesting example is Dy_5Si_3Ge, which experiences several magnetic and structural phase transitions [1]. At room temperature the Dy_5Si_3Ge crystallizes in the monoclinic $Gd_5Si_2Ge_2$-type structure (M). As temperature decreases this compound presents a magnetic transition from the paramagnetic to an antiferromagnetic (AF) state at T_N= 105 K followed by a transition to a ferromagnetic (FM) phase at T_C= 75K. At around T_S=60 K it shows a structural transition from the M state to an orthorhombic Gd_5Si_4-like [O(I)] crystallographic structure.
The hydrostatic pressure (P) produces a strong effect on both the structural and magnetic phase transitions of the $R_5(SiGe)_4$ alloys [2]. In this work we have performed a study of the pressure effect on the different phase transitions observed in Dy_5Si_3Ge by measuring the magnetization under different applied magnetic field protocols: zero-field cooling, field cooling and field warming. The magnetic measurements have been performed for 5<T<200 K under applied magnetic fields (H) up to 50 kOe and P up to 10 kbar. At low applied magnetic field (100 Oe) T_S strongly increases with increasing P, whereas T_N and T_C show a weak dependence on P. Such a different pressure dependence produces a coupling of the FM and structural transitions for P > 4kbar. At high magnetic field (10 kOe) the AF phase is quenched by H and the FM and structural transitions are coupled, showing T_C a strong dependence with P.

[1] R. Nirmala et al., Phys. Rev. B 76 104417 (2007).
[2] C. Magen et al., Advances in Solid State Physics, Vol. 46, pp. 241–253, Prof. R. Haug (Ed.), Springer (2007).

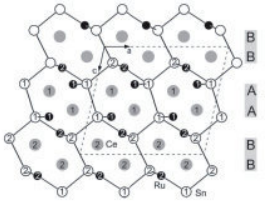
16.15 – 16.30

Complex charge ordering in CeRuSn

R. Feyerherm [1], E. Dudzik [2], S. Valencia [2], J.A. Mydosh [3], Y. Huang [4], W. Hermes [5], R. Poettgen [5], K. Prokes [1]
(1) Helmholtz-Zentrum Berlin fuer Materialien und Energie GmbH, BESSY, 14109 Berlin, Germany, (2) Helmholtz-Zentrum Berlin fuer Materialien und Energie GmbH, 14109 Berlin, Germany, (3) Kamerlingh Onnes Laboratory, Leiden University, 2300RA Leiden, The Netherlands, (4) Van der Waals-Zeeman Institute, University of Amsterdam, 1018XE Amsterdam, The Netherlands, (5) Institute for Inorganic and Analytical Chemistry, University of Muenster, 48149 Muenster, Germany

At 300K, CeRuSn exhibits coexistence of trivalent Ce3+ and intermediate valent Ce(4−δ)+ in a metallic environment. Charge ordering produces a doubling of the unit cell along the c axis with respect to the basic monoclinic CeCoAl-type structure. Below 2.7K antiferromagnetic long-range order occurs within one-half of the Ce sites, e.g., the magnetic entropy of the transition is ½Rln2. Neutron diffraction studies are under way in order to clarify to ordered spin structure. Below room temperature, a phase transition with very broad hysteresis is observed in various bulk properties like electrical resistivity, magnetic susceptibility, and specific heat. We present x-ray-diffraction results which show that at low temperatures the doubling of the CeCoAl type structure is replaced by an ill-defined modulated ground state. In this state, at least three different modulation periods compete, with the dominant mode close to a tripling of the basic cell. XANES data suggest that the average Ce valence remains constant, excluding any valence transition. We propose a qualitative structure model with modified stacking sequences of Ce^{3+} and $Ce^{(4-\delta)+}$ layers in the various modulated phases. In addition, we found that far below 100K the modulated state is sensitive to x-ray irradiation at photon fluxes available at a synchrotron. The modulated ground state can be destroyed on a time scale of minutes and the doubling of the CeCoAl cell observed at 300K is recovered. Heating the sample above 60K again leads to a recovery of the modulated state. Thus CeRuSn exhibits both thermally and x-ray induced reversible transformations of the $Ce^{3+}/Ce^{(4-\delta)+}$ charge-ordering pattern. Such a behavior is unique among any known intermetallic compound [1].

[1] R.Feyerherm *et al.* Physical Review B **85** (2012) 085120.



Crystal structure of CeRuSn at 300 K with $Ce^{(4-\delta)+}$ (A) and Ce^{3+} (B) charge ordering

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Otello Room

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: Z. Arnold

16.30 – 16.45
Effective magnetic Hamiltonians
V. Drchal [1], J. Kudrnovsky [1], I. Turek [2]
(1) Institute of Physics, Acad. Sci. Czech Republic, (2) Institute of Physics of Materials, Acad. Sci. Czech Republic

We employ the first-principles electronic-structure calculations to construct effective magnetic Hamiltonians that can be used to derive magnetic structure of solids and nanostructures. Such Hamiltonians consist of three parts: (i) The local exchange part that describes formation of local moments on individual atoms, this part is determined using the fixed spin moment method. (ii) The isotropic exchange interactions that describe interactions between spin moments on different atoms and are responsible for ordering of magnetic moments. These interactions have the form of a classical Heisenberg Hamiltonian and are calculated from the Liechtenstein formula. (iii) The anisotropic part which includes relativistic effects and dipole-dipole interactions. This part determines the orientation of magnetic moments with respect to crystallographic axes. Once the effective Hamiltonian is known, we can find the size and orientation of magnetic moments at T=0 and, using the methods of statistical mechanics, we can study the magnetic properties at T>0 such as the magnetic structure as a function of temperature, magnon spectra, the Curie/Néel temperature, transport properties, etc. of complex magnetic systems. The *ab initio* calculations can be done for a rather limited set of configurations of a magnetic system. The approach based on the effective Hamiltonians makes possible to study a wide set of magnetic configurations with the accuracy of *ab initio* methods. In order to illustrate the theory we will show (i) the construction of the effective magnetic Hamiltonians for 3d and 4d metals, (ii) the formation of induced magnetic moments, and (iii) the importance of anisotropic interactions for the magnetic structure of a magnetic monolayer on a non-magnetic substrate.

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Macbeth Room

SENSORS, MEMS AND MAGNETIC DEVICES

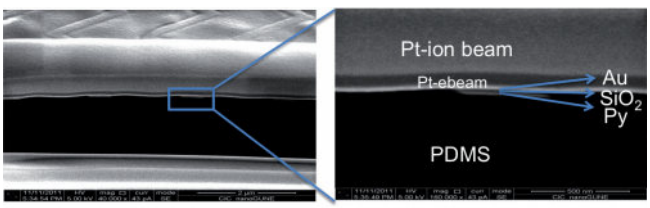
Chair: O. Cugat

14.45 - 15.15
Magnetic nanostructures embedded in a polymeric substrate
(invited)
M. Donolato [1], J.M. Porro [1], C. Tollan [1], A. Berger [1], P. Vavassori [1]
(1) CiC nanoGUNE Consolider, Tolosa Hiribidea 76, 20009 San Sebastian, Spain

Flexible devices realized on stretchable, nonplanar, and biocompatible substrates have been widely studied in the last few years because of their huge potential for applications [1, 2]. On the other hand, there has been limited work so far exploring the utilization of these new functional substrates for magnetic devices. Here, we present for the first time the integration of magnetic nanostructures on a flexible poly(dimethilsiloxilane) PDMS membrane. We will report the initial results obtained by patterning magnetic nanostructures directly on the PDMS membrane that showed that the magnetic properties are maintained in the free-standing devices[3]. However large area patterning of nanostructures directly on flexible substrates is far from being the optimal solution, due to the difficulties arising from the non-planar surface topography, heat treatments and the use of required solvents. For this reason we conceived, demonstrated and optimized a novel technique for transferring large arrays of magnetic nanostructures previously fabricated on a standard Si substrate to a polymeric substrate without using any solvent or chemical etchant. We monitored possible changes of their micromagnetic configurations both with scanning probe microscopy and with magneto-optical Kerr effect measurements. In addition, we studied the formation of wrinkles, potentially interesting for realizing stretchable magneto-electronic devices (see Fig.1). Finally, as an application, we transferred arrays of nanostructures for magnetic separation onto both sides a PDMS microfluidic channel. We acknowledge funding from the Basque Government under the Etortek Program IE11-304.

[1] J.A. Rogers, T. Someya, Y.Huang, Science, 327, 1606 (2010)
[2] T. Someya, Nat. Mater. 9, 879 (2010)
[3] M.Donolato, F.Lofink, S.Hankemeier, J.Porro, H.P.Oepen, and P.Vavassori J.Appl.Phys. 111, 07B336 (2012)

Electron beam microscopy image of the cross section of a PDMS substrate where Permalloy nanowires are embedded. The inset shows the profile of a single nanowire and the layers used to enhance the image quality.



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Macbeth Room

SENSORS, MEMS AND MAGNETIC DEVICES

Chair: O. Cugat

15.15 – 15.30
Holographic images reconstructed from GMR-based fringe pattern

D. Kato [1], K. Aoshima [1], K. Machida [1], A. Emoto [2], H. Kinjo [1], K. Kuga [1], H. Ono [3], T. Ishibashi [4], H. Kikuchi [1], N. Shimidzu [1]
(1) Science & Technology Research Laboratories, NHK, 157-8510, JAPAN, (2) National Institute of Advanced Industrial and Science Technology, 305-8561, JAPAN, (3) Department of Electrical Engineering, Nagaoka University of Technology, 940-2188, JAPAN, (4) Department of Materials Sciences and Technology, Nagaoka University of Technology, 940-2188, JAPAN

We have developed a magneto-optical spatial light modulator (MO-SLM) using giant magneto-resistance (GMR) structures for realizing a holographic three-dimensional display [1]. For practical applications, reconstruction image of hologram consisting of GMR-structures should be investigated in order to study the feasibility of the MO-SLM. In this study, we fabricated a hologram with GMR-based fringe-pattern (termed a GMR hologram) and demonstrated a reconstruction image.
A fringe-pattern convolving a double circle image was calculated by a conventional binary computer-generated hologram (CGH) technique. The CGH-pattern has 2,048 × 2,048 with 5 μm pixel pitch. The GMR stack consists of a Tb-Fe-Co(10 nm)/Co-Fe(1 nm) pinned-layer, a Ag(6 nm) spacer, a Gd-Fe(8.9 nm) free-layer for light modulation, and a Ru(3 nm) capping-layer, was deposited by dc-magnetron sputtering. The GMR hologram was formed using photo-lithography and Kr-ion milling processes, followed by the deposition of a Tb-Fe-Co reference-layer with large coercivity and the same Kerr-rotation angle compared to the free-layer, and a lift-off process.
The magnetization direction in the free-layer was exclusively switched by an external magnetic field. When the magnetization direction of the free and the reference layers are parallel configuration, the incident light with linear polarization (He-Ne laser, λ=632.8 nm) is reflected on the hologram, and cut at the analyzer (OFF-state). When the configuration is anti-parallel, the light is diffracted through the analyzer depending on the fringe-pattern, and reconstructs the image (ON-state). Figure 1 shows 1st-order reconstructed images from the GMR hologram. The hologram image of the ON-state was clearly observed and successfully distinguished from the OFF-state. These results indicate the possibility of realizing a holographic 3D display by the MO-SLM using the GMR structures.
This research was partly supported by the National Institute of Information and Communications Technology.

[1] K.Aoshima et al., J. Display Technology, 6, 374 (2010)

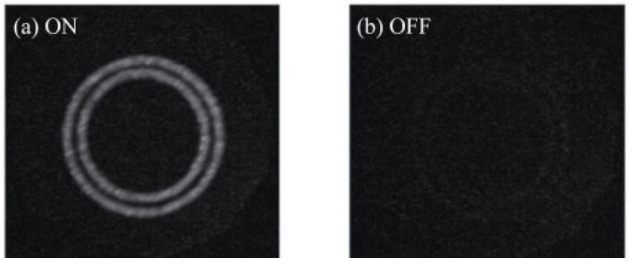

Fig.1 Reconstructed images.

15.30 – 15.45
Thick soft magnetic films for microsystems

D. Le Roy [1], F. Dumas-Bouchiat [1], N.M. Dempsey [1]
(1) Institut Néel, CNRS-UJF, Grenoble, France

Magnets have great potential for use in micro-systems. Indeed, as a magnet size is reduced the magnetic field gradient it produces scales up [1]. Micromagnets with high magnetic polarization can be achieved using hard or soft magnetic materials. Hard micromagnets made by topographic or thermomagnetic methods [2,3] have the advantage of being autonomous, but they produce a static stray field pattern. In contrast, micromagnets made with soft magnetic materials require an external magnetic field source but they can exert time variable magnetic forces and produce higher magnetic fields ($\mu_0 M_s$ up to 2.4 T for $Fe_{65}Co_{35}$). In particular, soft micromagnets allow on and off switching of the generated forces, which broadens the application fields. The magnetic performance of a soft micromagnet is essentially governed by its shape and its microstructure. We have prepared topographically patterned soft micromagnet arrays of $Fe_{65}Co_{35}$ and $Ni_{80}Fe_{20}$ with lateral sizes ranging from 5 to 100 μm and thicknesses varying from 5 to 30 μm. Their fabrication consists in thick layer deposition by triode sputtering on pre-patterned substrates. The shape dependence of the micromagnets' properties and the magnetostatic interactions will be discussed. The focus is on the hysteresis losses, the produced field gradient and the low frequency susceptibility. On-going works using these magnet arrays for biological studies will be presented.

[1] O. Cugat, J. Delamare, and G. Reyne, IEEE Trans. Magn. 39, 3608 (2003)
[2] A. Walther, C. Marcoux and B. Desloges, R. Grechishkin, D. Givord and N. M. Dempsey, J. Magn. Mag. Mat. 321, 590 (2009)
[3] F. Dumas-Bouchiat, L.F. Zanini, M. Kustov, N.M. Dempsey, R. Grechishkin, K. Hasselbach, J.C. Orlianges, C. Champeaux, A. Catherinot, D. Givord, Appl. Phys. Lett. 96, 102511 (2010).

15.45 – 16.00
Expanding the longitudinal magnetoimpedance sensor range by dc bias current

M. Ipatov [1], V. Zhukova [1], A. Zhukov [2], J. Gonzalez [1]
(1) Dpto. Fisica de Materiales, Fac. Quimicas, Universidad del País Vasco UPV/EHU, 20018 San Sebastian, Spain, (2) Dpto. Fisica de Materiales, Fac. Quimicas, Universidad del País Vasco UPV/EHU, 20018 San Sebastian, Spain; IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain

The magnetoimpedance (MI) effect has received much attention during the last two decade due to its potential for magnetic

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SENSORS, MEMS AND MAGNETIC DEVICES

Chair: O. Cugat

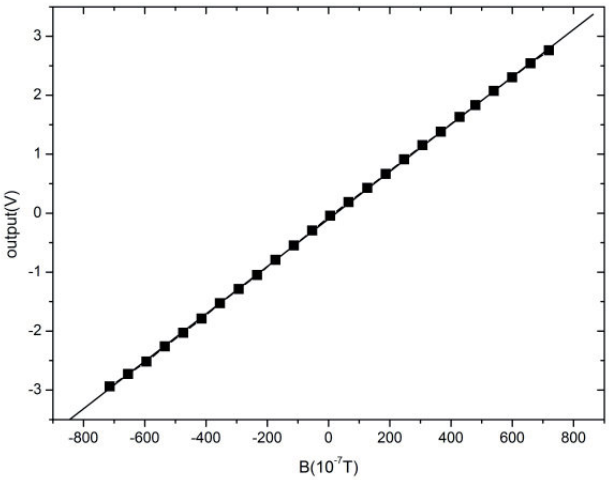
sensor applications. Sensors based on MI effect in amorphous microwires are now available on the market. In such microwires the impedance is of tensor form. The longitudinal impedance has appeared generally not to be suitable for magnetic sensors applications as it exhibits a symmetrical dependence on the magnetic field. Such dependence does not allow determination the direction of applied magnetic field. Moreover, the MI effect becomes very low approaching zero magnetic field. To overcome these serious drawbacks, the off-diagonal MI effect that appears due to the cross-magnetization process is used in commercially available MI sensors. Such an off-diagonal MI sensor allows the correct determination of both the magnitude and the sign of the external magnetic field in the field range below the anisotropy fields whilst in the case that the magnetic field exceeds this range, the sensor gives an erroneous reading. This drawback of off-diagonal MI sensors is very important for some applications.
Here we investigate a method that allows determination of the sign and magnitude of the magnetic field from the longitudinal impedance. The underlying physics is related to the static magnetization reversal process in the surface layer of the microwire with helical anisotropy and the effect of bias current on it [1-3]. We theoretically and experimentally demonstrate that a set of two measurements of longitudinal impedance with properly selected bias current allows unambiguous determination of both the magnitude and direction of the magnetic field up to fields much higher then the anisotropy field.

[1] M. Ipatov et al., Phys. Rev. B, 81 (2010), 134421
[2] M. Ipatov et al., Appl. Phys. Lett., 97 (2010), 252507.
[3] M. Ipatov et al., J. Appl. Phys. 110 (2011), 086105

16.00 – 16.15
Magnetic detector based on giant magnetoimpedance and its application to vehicle detection
Q. Zhang [1], *H. Gao* [2], Z. Zhao [1], U. Hartmann [2]
(1) Department of Physics, Engineering Research Center for Nanophotonics & Advanced Instrument, Ministry of Education, East China Normal University, Shanghai 200062, China, (2) Institute of Experimental Physics, Saarland University, P.O. Box 151150, D-66041 Saarbruecken, Germany

The giant magnetoimpedance (GMI) effect, which refers to the significant changes of impedance of a magnetic element with respect to an external magnetic field, has attracted much attention because of its potential applications in highly sensitive magnetic field sensors [1]. Compared to conventional magnetic sensors, GMI sensors have several advantages, such as high sensitivity, large sensing range and broad bandwidth.
Optimized traffic flow control and guidance systems based on adequate vehicle detection techniques are urgently needed for improving road traffic management. For this purpose, a magnetic detector system based on a GMI sensor was developed. The GMI sensor is made of a $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ microwire with a diameter of 16 μm and a length of 5 mm. A pick-up coil is wrapped around the microwire. The driving ac current through the wire induces an axial magnetization variation and thus a corresponding voltage in the pick-up coil. The field dependence of the second harmonics of this voltage is measured. The characteristics of the complete detector in terms of sensitivity, resolution, linearity and temperature behavior were acquired under laboratory conditions. A 100 pT magnetic field at a frequency of 40 Hz was detected. The output signal drift is lower than 5×10^{-4}/K in the working range of -40 ^{0}C to 85 ^{0}C. A first field test on vehicle detection is presented.

[1] K. Mohri, et l., Sens. Acta A 59, 1 (1997)



The Detector Output Signal Dependence on the External Field with a Sensitivity of 39 mV/μT and a Linearity Coefficient of 0.9999

16.15 – 16.30
Magnetically Enhanced Memristor
M. Prezioso [1], A. Riminucci [1], P. Graziosi [1], I. Bergenti [1], *A.V. Dediu* [1]
(1) Consiglio Nazionale delle Ricerche - Istituto per lo Studio dei Materiali Nanostrutturati (CNR-ISMN) via P. Gobetti 101, 40129 Bologna, Italy

We describe here an experimental achievement which adds conceptually new features to a standard GMR device. We show that electrically controlled magnetoresistance[1] can be achieved in organic devices by combining the GMR effect[2] with resistance switching effects eventually realizing a Magnetically Enhanced Memristor (MEM).
The devices consist of a 20 nm thick bottom LSMO electrode, on which a layer of Alq_3 (with thickness ranging between 3 nm and 250 nm) is evaporated. A top electrode of a 20 nm thick Co film, separated from the Alq_3 by a 2 nm thick AlO_x layer.
These devices show the typical voltage-driven memristor fingerprint known as the "pinched I-V hysteresis"[3]. In the negative branch, over -1V, the I-V features a well controllable NDR region which allows the selection of the memristance state of the device by reaching the necessary voltage and then come back to zero. The device can be reset with a positive bias (2-3V). The same devices, when operated at biases as low as -0.1 V,

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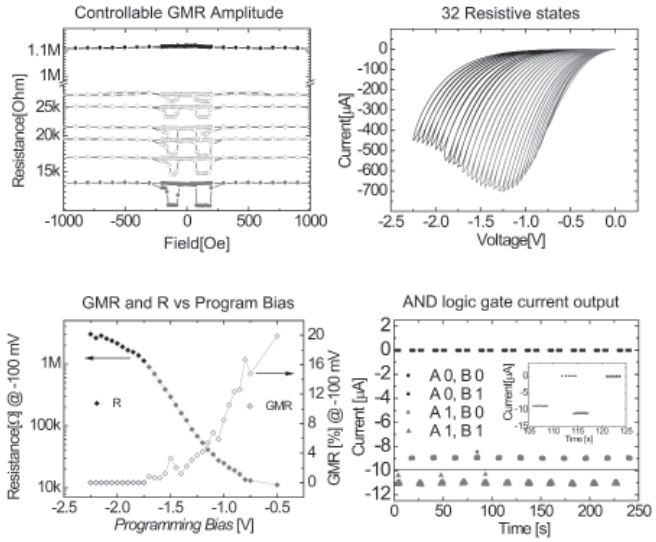
behaves also as a spin-valve and can show a GMR effect of up to 22% (at 100K).
The dependence of the GMR effect on the memresistance state is such that the higher is the resistance state the lower is the GMR amplitude. This, added to the possibility of selecting the memristance state, leads to a controllable amount of GMR effect. We experimentally demonstrate 32 different resistance states with their corresponding GMR amplitude.
Moreover we show that by using the programming voltage and the external magnetic field as inputs, it is possible to obtain an AND logic gate with only a single MEM device.



[1] M. Prezioso, et al., Adv. Mater., 23, 1371,(2011).
[2] V. A. Dediu, et al., Nat. Mater., 8, 707,(2009).
[3] L. Chua, Applied Physics a-Materials Science & Processing, 102, 765,(2011).
JEMS 2012 Joint European Magnetic Symposia

16.30 – 16.45
Hall Current Sensor IC with Integrated Magnetic Cobalt-based Alloy Thin Film

V. Palumbo [1], D. Paci [1], P. Iuliano [1], F. Toia [1], M. Marchesi [1], V. Chiesi [2], F. Casoli [2], P. Ranzieri [2], F. Albertini [2], M. Morelli [1]
(1) Smart Power Technology R&D, STMicroelectronics, Via C.Olivetti 2, 20041 Agrate Brianza (MB), Italy, (2) Institute of Materials for Electronics and Magnetism (IMEM), CNR, Parco Area delle Scienze 37/A, 43124 Parma, Italy

In recent years an increasing interest in hybrid and full electric vehicles, energy metering and consumer compass applications has pushed the development of integrated Hall magnetic sensors. In order to improve magnetic field sensitivity and signal/noise ratio, soft-magnetic concentrators coupled with Hall cells have been adopted [1,2]. In commercial devices the magnetic concentrator is generally a 10-100μm thick disc bonded on the Hall sensor IC surface. This work deals with a cobalt-based alloy thin film magnetic concentrator which is fully integrated on an Hall sensor IC developed in 8" silicon wafer 0.35 μm BCD[3] technology. An amorphous magnetic film with a thickness of 1.1μm, coercitive field H_c<10A/m and saturation magnetization ($\mu_0 M_S$) of 0.45T has been obtained (Fig.1a). Sputtering conditions and thermal treatments effects on morphological and magnetic properties have been investigated. The integrated magnetic concentrator shape and its alignment with respect to the Hall cells, that are generally critical for bonded concentrators, have been controlled with sub-micron tolerance lithographic and etch processes (Fig.1b). The compatibility of the magnetic film with silicon CMOS processes in terms of mechanical stress and metallic contamination has been proven. A current sensor IC prototype with eight symmetric Hall cells together with biasing and amplification circuitry has been carried out (Fig.1c). The obtained sensitivity to magnetic field at room temperature is 240V/AT without concentrator and 2550V/AT with concentrator, gaining a factor of 10.6. Such IC sensor mounted on a board in proximity of the metal strip flowed by the current to be measured has shown linear response in the range -50 to 50A (Fig.1d).

[1] R.S.Popovic et al., Sensors and Actuators A 91, 46-50 (2001)
[2] C.Schott et al., Sensors IEEE, 959-962 (2005)
[3] D.Riccardi et al., ISPSD Proceedings, 73-76 (2007)

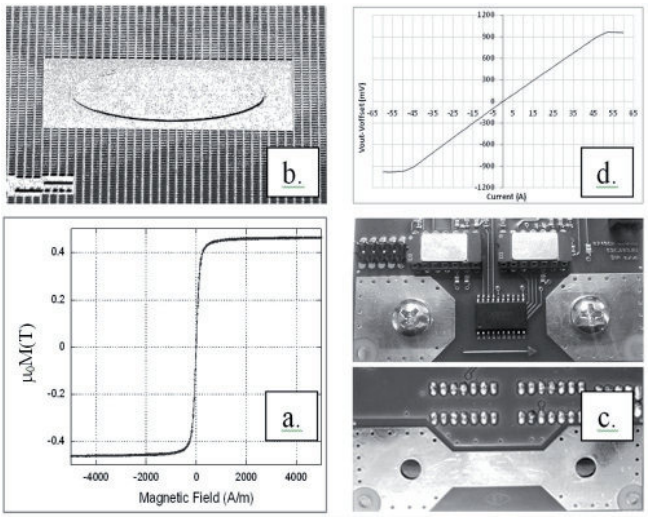


Fig.1 SEM image and hysteresis loop (a,b). The sensor and its output (c,d).

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Rigoletto Room

ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS

Chair: C. Dallera

14.45 – 15.15

Advances in magnetic soft X-ray microscopy *(invited)*

P. Fischer [1]
(1) CXRO/LBNL, Berkeley CA 94720 USA

Understanding and controlling the spins in magnetic materials is scientifically highly attractive and highly relevant for exploring new directions in key technologies. To characterize magnetic structures and their fast dynamics down to fundamental magnetic length and time scales with elemental sensitivity in emerging multi-element and nanostructured materials advanced imaging tools are highly desirable. Magnetic soft X-ray microscopy is a unique analytical technique combining X-ray magnetic circular dichroism (X-MCD) as element specific magnetic contrast mechanism with high spatial and temporal resolution. Our approach is to use Fresnel zone plates optics to provide a spatial resolution down to currently 10nm. Images can be recorded in external magnetic fields giving access to study magnetization reversal phenomena on the nanoscale and its stochastic character with elemental sensitivity. Utilizing the inherent time structure of current synchrotron sources fast magnetization dynamics such as vortex dynamics in ferromagnetic elements can be performed with a stroboscopic pump-probe scheme with 70ps time resolution. I will review the achievements of magnetic soft X-ray microscopy by selected examples from recent studies on magnetic vortices. We have observed a symmetry breaking effect in the nucleation of magnetic vortex structures [2] and studies with time resolved magnetic soft X-ray microscopy indicate that the dipolar coupling of magnetic vortices can be used as an energy efficient concept for novel logic devices [3].
At next generation high brilliant fsec X-ray sources snapshot images of nanoscale ultrafast spin dynamics become feasible with a spatial resolution approaching the <10nm regime.
Supported by the Director, Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division, of the U.S. Department of Energy under Contract No. DE-AC02-05-CH11231.

[1] P. Fischer, Materials Science & Engineeering R72 81-95 (2011)
[2] M.-Y. Im, et al. (2012) under review
[3] H. Jung, et al. NPG - Scientific Reports 1 59 (2011)

15.15 – 15.30

X-ray imaging of magnetic order in meander domain structures: role of lateral confinement

C. Spezzani [1], H. Popescu [2], N. Jaouen [2], M. Tortarolo [2], F. Fortuna [3], R. Delaunay [4], *M. Sacchi* [5]
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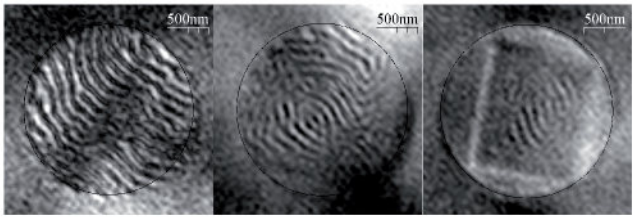
We have imaged local magnetic order in Co/Pd multilayers as a function of lateral confinement by x-ray Fourier transform holography (FTH) using synchrotron radiation.
Perpendicular magnetic anisotropy, one of the properties that are sought for when manufacturing artificially structured magnetic materials, is often accompanied by the formation of regular domain structures with sub-micron length scales. Knowledge of the response of the local magnetization to the action of a short magnetic pulse or laser pulse (ultra-fast local heating) is of fundamental importance for envisaging applications.
Element selective imaging of the magnetization by coherent scattering of polarized x-rays [1] takes advantage of all the most peculiar characteristics of advanced x-ray sources: high degree of coherence, high flux and short pulse duration.
X-ray imaging of the meander structure of perpendicular magnetic domains in $(Co_{0.4}/Pd_{0.8})_n$ multilayers was obtained at the SEXTANTS beamline of the SOLEIL synchrotron, using a new scattering chamber [2]. Coherent scattering was performed at the Co L_3 edge, using circular polarization of the x-rays.
Our work aims at three objectives, with either immediate or long term interest: i) image perpendicular magnetic domains with 50nm resolution; ii) investigate the influence of lateral confinement and of magnetic history on the formation and on the order of meander domains; and iii) acquire expertise and master FTH imaging of small magnetic objects in the perspective of more complex applications, notably time-dependent x-ray magnetic imaging at fs-pulsed x-ray sources.

[1]. S. Eisebitt et al., Nature, **432**, 885 (2004).
[2]. M.Sacchi, H. Popescu, N. Jaouen, M. Tortarolo, F. Fortuna, R. Delaunay, and C. Spezzani, Opt. Express (2012), to be published.



FTH images of perpendicular magnetic domains in a patterned $(Co_{0.4}/Pd_{0.8})_{30}$ multilayer.
Left: continuous film. Center: 2µm square. Right: 1.2µm square. Black circles define the 2µm circular field of view.

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Rigoletto Room

ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS

Chair: C. Dallera

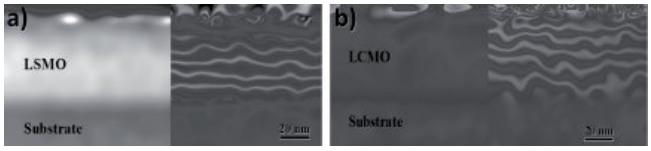
15.30 – 15.45

Cryo-Electron Holography magnetic characterization of manganite-based tunnel junctions

L.A. Rodríguez González [1], L. Marín Mercado [2], *C. Magén Dominguez* [3], I. Lucas [4], J.M. Teixeira [5], P.A. Algarabel [4], L. Morellón [2], E. Snoeck [6], J.M. De Teresa [7], M.R. Ibarra [1]
(1) LMA-INA and TALEM/Universidad de Zaragoza, 50018 Zaragoza, Spain, (2) INA/Universidad de Zaragoza, 50018 Zaragoza, Spain, (3) LMA-INA and ARAID/Universidad de Zaragoza, 50018 Zaragoza, Spain, (4) ICMA/Universidad de Zaragoza-CSIC, 50009 Zaragoza, Spain, (5) IFIMUP/INN/Depto. Fisica/Universidade do Porto, Porto, Portugal, (6) CEMES-CNRS 29/rue Jeanne Marvig, 94347 F-31055 Toulouse Cedex,France, (7) ICMA/ Universidad de Zaragoza-CSIC, 50009 Zaragoza, Spain

Magnetic tunnel junctions (MTJs) are key elements of spintronic devices for magnetic data storage and magnetic sensors [1,2], and the use of half-metallic ferromagnetic (FM) electrodes such as manganites is pursued to maximize magnetoresistance. Though great advances in the understanding of magnetotransport behaviour of MTJs have been made, direct visualization of magnetization switching process with high spatial resolution can provide valuable information of the physical processes involved. Local characterization of magnetization processes in nanostructures is possible using electron microscopy techniques such as Electron Holography (EH). This technique allows the quantitative imaging of the magnetization configurations of FM materials with nanometer-range resolution [3]. Furthermore, EH can be combined with the *in situ* application of external constraints such as magnetic, electric fields, temperature, etc. In this work magnetization switching of $La_xCa_{1-x}MnO_3$ (LCMO) and $La_xSr_{1-x}MnO_3$ (LSMO) thin films, and LCMO- and LSMO-based MTJs is studied by Cryo-Electron Holography. Cryogenic conditions (T>100 K) are required to have both electrodes in FM state (FM ordering of LCMO thin films is around 160 K). Hysteresis loops obtained by *in situ* cryo-EH applying in-plane magnetic fields by exciting the objective lens and tilting the sample have been carried out. The interlayer coupling/decoupling of magnetic electrodes is compared with respect to the switching fields of isolated thin films. Experimental data is supported with micromagnetic simulations.

[1] S. Yuasa *et al.*, Nature Materials 3, 868 (2004).
[2] S. S. P. Parkin *et al.*, Nature Materials 3, 862 (2004).
[3] R. E. Dunin-Borkowski and M. R. McCartney in "Magnetic Nanostructures", Ch. 7, (Ed. H. S. Nalwa, American Scientific Publishers, 2002).



Electrostatic phase shift of 40-nm-thick LSMO (a-left) and LCMO (b-left) thin films acquired at 100 K. Cosine of 20 (a-right) and 40 (b-right) times the magnetic phase shift showing the magnetic flux inside the LSMO and LCMO layers, respectively.

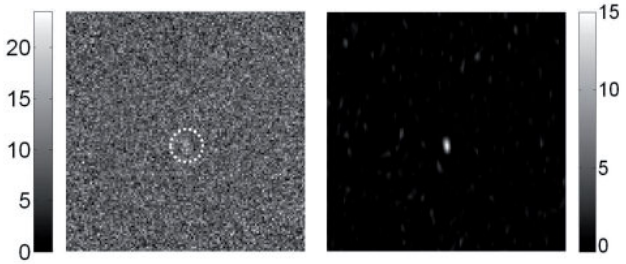
15.45 – 16.00

Neutron diffraction on thin films: what can we gain by using 2D detectors?

A. Bataille [1], A. Gukasov [1]
(1) Laboratoire Léon Brillouin, CEA Saclay, 91191 Gif-sur-Yvette, France

Antiferromagnetic thin films are now widely used in spintronic devices, in which they play a secondary role by altering the coercivity of ferromagnetic layers through exchange bias. Yet in very recent reports, antiferromagnets are cast in a more active role [1,2]. Among the very few techniques sensitive to the antiferromagnetic order, neutron diffraction has the advantage of providing direct information, both on the spin directions and the magnetic unit cell. However, this tool has been seldom used up to now in thin films studies, since signal is thought too small to be measurable. The aim of this paper is to expose how, by using image processing techniques, it is possible to push the limits of neutron diffraction to create new opportunities to study antiferromagnetic thin films.
The generalization of 2D Position Sensitive Detectors for single crystal neutron diffraction was originally aimed at facilitating bulk studies, yet these devices also offer advantages for measurements on epitaxial thin films. In particular, given the trade-off between resolution and flux made on the diffractometer, the signal is spread on many voxels of the datacube comprising a Bragg peak. Using Laplacian of Gaussian filters with parameters related to the resolution function of the diffractometer, the contrast can be enhanced by more than one order of magnitude (see figure). Proper integration of weak peaks and detection of very weak peaks (a few counts/minute at the peak maximum) then becomes possible.

[1] S. Urazhdin et al., Phys. Rev. Lett 99 046602 (2007)
[2] A.V. Kimel et al, Nat.Phys. 5 727 (2009)



Magnetic Bragg peak of a 200 nm Cr film. Left: raw image. Right: same image after filtering

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ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS

Chair: C. Dallera

16.00 – 16.15

Niobium nano-SQUIDs and their applications to magnetic nanoparticle characterization

R. Russo [1], C. Cannas [2], E. Esposito [1], D. Peddis [2], M. Russo [1], A. Vettoliere [1], C. Granata [1]

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We will report our recent results about the nano-SQUIDs having a loop area less than 0.5 μm^2 and their applications in nanomagnetism. The nano-SQUID are based on niobium Dayme Bridges fabricated by Electron Beam Lithography and lift-off. A suitable compensation circuit has been developed in order to increase the linear dynamical range when the nanoSQUID operates as a magnetic flux to critical current transducer.
The nano-SQUIDs have been employed to measure the magnetization of Fe_{3}O_{4} nanoparticles having a size between 4 and 8 nm. Measurements have been performed applying a magnetic field B// in the plane of the nano-SQUID. We will show the nanoparticle magnetization curves where it is evident the magnetic hysteresis of the nanoparticles indicating the ferromagnetic-like behavior of these nanoparticles at low temperature (at T=4.2 K) . The field has been provided by a normal conducting solenoid limiting the maximum magnetic fields to 100 mT. Nano-SQUIDs can be used also at higher magnetic fields (up to 2 Tesla) to obtain a complete saturation of the magnetization; on the other hand, the use a normal conducting solenoid allows to switch off the magnetic field in a very short time making accessible the measurement of magnetic relaxation with a small acquisition time. We will present data acquired using a custom electronic developed for Quantum Mechanic experiment which allows a maximum acquisition rate of about 1 Hz, however a new electronic will reduce the acquisition time well below one second. A measuring system equipped with both solenoid (superconducting for high magnetic field up to saturation and normal conducting solenoid for relaxation measurement) is under development.

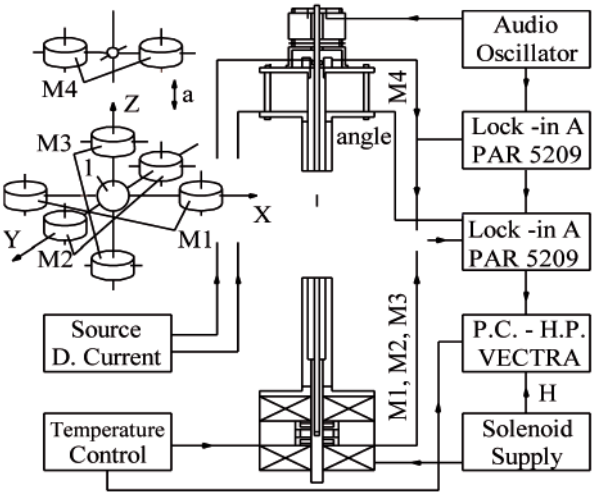
16.15 – 16.30

Exchange and Magnetic Anisotropic Interactions of Magnetic Ions in Antiferromagnetic Materials

A. Bazhan [1]

(1) P.L.Kapitza Institute for Physical Problems, RAS, 119334, Moscow, Russian Federation

Investigations of exchange and magnetic anisotropic interactions of magnetic ions in antiferromagnetic materials, based on theory of materials crystallographic and magnetic symmetry, which presents quadratic forms of thermodynamic potentials, invarianted with respect to operations of magnetic symmetry groups of materials and presented in irreducible representations of magnetic moments of interacting magnetic ions, are caring out using vector v.s.magnetometer, Fig.1, which can investigate separetely three perpendicular components of samples magnetic moments. Discussions, based on such theory, are presented in solvable forms introducing $\frac{1}{2}l^2\chi_{\perp}(1-\chi_{\shortparallel}/\chi_{\perp})(\gamma\mathbf{H})^2$ terms in thermodynamic potentials, where $\chi_{\shortparallel}$ and $\chi_{\perp}$ are parallel, $\mathbf{H} \shortparallel \gamma l$, and perpendicular, $\mathbf{H} \perp \gamma l$, magnetic susceptibilities with $\chi_{\shortparallel} << \chi_{\perp}$ and vectors γ – are unit antiferromagnetic vectors of interacting magnetic moments. Advantages of vector v.s. magnetometers are indicating in investigations of magnetic field dependencies of three, separate components of samples magnetic moments, that presents magnetic field dependencies of orientations of samples magnetic moments with respect to crystallographic axis and direct information about interactions of magnetic ions, especially with high electrons spin - orbit interactions. Investigations of antiferromagnetic orderings with weak ferromagnetic states and ferromagnetic moments, determined by interactions of second and higher orders in materials of tetragonal and rhombohedral structures such as NiF_2 and $NiCO_3$, are presented as examples. Spin Hamiltonians of second order symmetric, Anderson, and antisymmetric, Dzyaloshinskii - Moria, exchange interactions of magnetic ions, which are discussing in investigations of antiferromagnetic orderings, for some rhombohedral structures are presented as, $H_{ex}=\sum_{ij}J_{ij}(\mathbf{S}_i\mathbf{S}_j)-\sum_{ij}D_{ij,z}(\mathbf{S}_{ix}\mathbf{S}_{jy}-\mathbf{S}_{iy}\mathbf{S}_{jx})$, with $D_{ij,z}$ in abs-values.



16.30 – 16.45

Muon-fluorine entangled states in AgF_2

J.S. Moeller [1], D. Ceresoli [2], T. Lancaster [3], S.J. Blundell [1], N. Marzari [4], S.R. Giblin [5], J.F.C. Turner [6]

(1) Department of Physics, University of Oxford, Parks Road, Oxford, OX1 3PU, UK, (2) Istituto di Scienze e Tecnologie Molecolari CNR c/o Dipartimento di Chimica Fisica ed Elettrochimica Università degli studi di Milano, via Golgi 19, 20133 Milano, Italy, (3) Department of Physics, Durham University, South Road, Durham, DH1 3LE, UK, (4) Ecole Polytechnique Federale de Lausanne, STI IMX THEOS MXC 337 (Batiment MXC), Station 12, 1015 Lausanne, Switzerland, (5) ISIS facility, Rutherford Appleton Laboratory, Chilton, OX11 0QX, UK, (6) Department of Chemistry and Biochemistry, University of Sussex, Falmer, Brighton, BN1 9QJ, UK

Muon spin relaxation is a uniquely sensitive probe of magnetism [1]. The technique involves implanting spin-polarized positive

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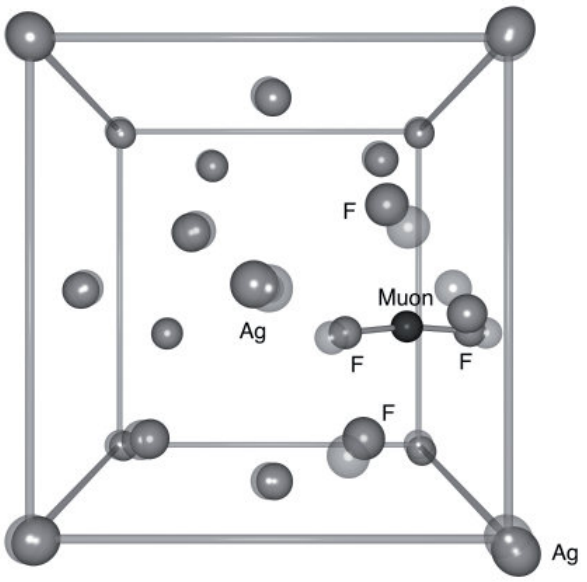
ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS

Chair: C. Dallera

muons in a sample, where they probe the local magnetic field. Despite its proven sensitivity, two concerns are frequently raised: first, the site of implantation is generally unknown, which can substantially hinder a successful interpretation of the data. Second, the extent to which the muon's own magnetic moment and charge perturb the sample is extremely poorly understood and has been ignored for a long time. This has been the cause for increased concern recently, since the technique is frequently employed to study magnetic systems at the verge of stability. We present a combination of ab initio and experimental studies for the weak ferromagnet AgF_2. We have studied the muon sites and the perturbation of the crystal and magnetic structure caused by the muon with density function theory (DFT). The presence of the signal of muon-fluorine entangled states in the experimental data as well as the magnetic signal observed below the transition allow an accurate verification of the results from DFT. To the best of our knowledge this is the first systematic study of this kind for diamagnetic muon states. We believe that our DFT approach is applicable to a large number of systems and hope that it will help to shed light on various issues that may affect muon spin relaxation experiments, such as understanding the nature of muon-induced bound magnetic polarons [2] and muon states in molecular magnets [3].

[1] F.L. Pratt et al., Nature 471, 612 (2011)
[2] V.G. Storchak et al, Phys. Rev. B. 80, 235203 (2009)
[3] T. Lancaster et al, Phys. Rev. B. 81, 140409(R) (2010)



Calculated muon site and perturbation of the crystal structure in AgF_2. Light shading represents unperturbed atomic positions.

Wednesday, 12 September 2012

Posters

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

DILUTED MAGNETIC SEMICONDUCTORS
Chair: R. Mantovan

WE-1
Magneto-Optical Effects in DMS Structures with 1-d Photonic Crystal
M. Koba [1], J. Suffczyński [1]
(1) Institute of Experimental Physics, University of Warsaw

We present a theoretical design and analysis of a 1D photonic crystal combined with a diluted magnetic semiconductor (DMS) layer. We show that this structure allows for an enhancement of the magneto-optical Kerr effect (MOKE) magnitude.
The designed structure consists of a single distributed Bragg reflector (DBR) and a DMS layer deposited on its top. We investigate representative cases of Mn-doped wurtzite III-V and zinc-blende II-VI structures, namely (Ga,Mn)N and (Cd,Mn)Te, respectively. The Mn ions concentration within DMS layer is assumed to be ~0.5%. The DBR mirror is fabricated of, correspondingly, $Al_{(1-x1)}Ga_{x1}N/Al_{(1-x2)}Ga_{x2}N$ or $Cd_{(1-y1)}Mg_{y1}Te/Cd_{(1-y2)}Mg_{y2}Te$, where x1, y1 amount typically to 0.05 and x2, y2 to 0.2. We base our calculations on the transfer matrix method, (e.g., Ref. 3) and take into account excitonic and unbound states contributions to the dielectric functions of respective layers. Parameters characterizing excitonic transitions and the electronic band structure are taken from the literature.
We analyse the impact of number of periods of DBR and the DMS layer thickness on MOKE. We demonstrate that even for relatively low contrast of refractive indices of the layers within the mirror, in both investigated cases, a strong influence of the stratified medium on MOKE is expected. In particular, about an order of magnitude enhancement of the Kerr rotation at certain ranges of DMS layer thicknesses is found.
The work was supported by FunDMS Advanced Grant of ERC and NCBiR project LIDER.

[1] H. Shimizu, and M. Tanaka, Physica E 13, 597 (2002)
[2] N. Qureshi et al., Appl. Phys. Lett. 85, 431 (2004)
[3] P. Yeh, Optical Waves in Layered Media (Wiley, New York,1988)

WE-2
Polarized photoreflectance spectroscopy of (Ga,Mn)As epitaxial layers
Ł. Gluba [1], O. Yastrubchak [1], J. Sadowski [2], T. Wosiński [2], J. Żuk [1]
(1) Institute of Physics, Maria Curie-Skłodowska University, 20-031 Lublin, Poland, (2) Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland

Diluted magnetic semiconductor gallium arsenide doped with manganese is the most promising material for future spintronics. Evolution of its band structure with increasing Mn concentration is still matter of controversy.
In our study we have investigated the polarization dependences of the (Ga,Mn)As photoreflectance (PR) spectra [1]. The polarization of the incidence light can affect the PR respond originated from the light and heavy holes. Ruff et al. [2] has shown in electric field modulated absorption experiment of LT-GaAs that heavy and light holes (lh and hh) are sensitive to polarization of light. Our polarized photoreflectance measurements have shown similar trend. Indeed, TM light mode (Transverse Magnetic) interacts only with the holes from the light hole subband and TE (Transverse Electric) interacts with both the light and heavy holes subbands. Photoreflectance spectra for low doped epitaxial (Ga,Mn)As contains mainly contribution from the heavy hole subband. On the other hand, PR spectra for high doped (Ga,Mn)As contains a mainly light hole subband contribution. Our results are in good agreement with the valence band hybridization model where the Fermi level is located below the valence band edge in high doped samples [3]. For our purposes we have used layers of (Ga,Mn)As (0.79% to 6% of Mn content) grown by low temperature (250^{o}C) molecular beam epitaxy method on GaAs (001) substrate.

[1] O. Yastrubchak et al., Phys. Rev. B 83, 245201 (2011)
[2] M. Ruff et al., Appl. Phys. Lett. 68, 2968 (1996)
[3] T. Dietl et al., Science 287, 5455 (2000)

WE-3
The electronic and magnetic properties of Mn-implanted 6H-SiC
M. Alazri [1], M. Elzain [1], K. Bouziane [2], S.M. Chérif [3], Y. Roussigné [3], A. Declémy [4], L. Thomé [5]
(1) Department of Physics, College of Science, Sultan Qaboos University, P.O. Box 36, Al-Khodh 123, Sultanate of Oman, (2) Pole Energies Renouvelables Environnement et Etudes Pétrolières, Université Internationale de Rabat, Parc Technopolis Rabat-Shore, 11100 Sala El Jadida, Morocco, (3) LSPM (CNRS-UPR 3407), Université Paris 13, 99 Av. J.B. Clément, 93430 Villetaneuse, France, (4) PhyMat, CNRS UMR 6630, Université de Poitiers, Boulevard Marie et Pierre Curie SP2MI - Téléport 2 - BP 30179, F-86962 Futuroscope Chasseneuil Cedex,France, (5) 5CSNSM-Orsay, Bât. 108, Université d'Orsay, F-91405 Orsay, France

The electronic and magnetic properties of 6H-SiC with Mn impurities have been calculated using GGA and LDA+U approximations. Various configurations of Mn sites and Si and C vacancies were considered. The magnetic coupling between two Mn atoms at substitutional and interstitials sites with and without vacancies is studied as a function of Mn atoms interatomic distance. It was found that the magnetic interaction energy decreases with increasing distance between the magnetic atoms for both strained and relaxed structure.
Furthermore, the energy levels appearing in the band gap due to vacancies and due to Mn impurities are determined. The calculated DOS's are used to analyze the nature of the exchange interaction between the impurities. The band coupling model based on the *p-d* and *d-d* level repulsions between Mn and SiC has been used to describe the magnetism observed in each configuration. Furthermore, the impacts of applying *U* to Mn-d orbital on the magnetic moment have also been investigated. The results are used to understand the experimental data obtained on Mn- 6H-SiC for various Mn concentrations.

WE-4

Domain structure near Curie temperature in (Ga,Mn)As

W. Stefanowicz [1], P. Mazalski [2], J. Sveklo [2], J. Sadowski [3], A. Maziewski [2], T. Dietl [4], M. Sawicki [5]

(1) Institut Néel, Centre National de la Recherche Scientifique, BP166, 38042 Grenoble, France; Institute of Physics, Polish Academy of Sciencies, al. Lotnikow, 02-668, Warszawa, Poland, (2) Faculty of Physics, University of Bialystok, Lipowa 41, 15-424 Bialystok, Poland, (3) MAX-IV laboratory, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden; Institute of Physics, Polish Academy of Sciencies, al. Lotnikow, 02-668, Warszawa, Poland, (4) Institute of Physics, Polish Academy of Sciencies, al. Lotnikow, 02-668, Warszawa, Poland; Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, 00-681 Warszawa, Poland, (5) Institute of Physics, Polish Academy of Sciencies, al. Lotnikow, 02-668, Warszawa, Poland

Diluted ferromagnetic semiconductor (Ga,Mn)As, in which Curie temperature does not exceeds 200 K, allows one to investigate the domain structure just below the paramagnetic to ferromagnetic phase transition.

We have studied, by SQUID magnetometry and magnetic force microscopy (MFM), micromagnetic properties of 50 nm thick (Ga,Mn)As layer grown by low temperature molecular beam epitaxy on a (Ga,In)As buffer layer and GaAs substrate. Such a buffer imposes a perpendicular-to-plane easy magnetization axis direction. According to thermoremanence SQUID measurements, Curie temperature T_C is 122 K.

We follow the well known procedure [1] in order to evaluate micromagnetic parameters, such as magnetic anisotropy and magnetic stiffness constant, from dependencies of magnetization on the magnetic field. By using these micromagnetic parameters we estimate the period of stripe domains just below T_C to be of the order of 400 nm. MFM images of domain structure were registered just below and above Curie temperature. Observed domain structure period value is the same order as calculated one. This period is close to a lower end of the values determined for annealed samples with similar magnitudes of T_C [1] and expected from the theory of magnetic stiffness [2]. Furthermore, our experiments imply that the remnant domain structure is not affected by pulses of in-plane magnetic field pulses or by cooling down through T_C in an applied in-plane magnetic field.

[1] S. Haghgoo et al., Phys. Rev. B 82, 041301(R) (2010).
[2] A. Werpachowska and T. Dietl, Phys. Rev. B 82, 085204 (2010).

WE-5

Magnetoelastic properties of (Ga,Mn)As investigated by SMFMR technique

R. Zuberek [1], K. Nesteruk [1], C. Śliwa [1], O. Proselkov [1], J. Sadowski [2], M. Sawicki [1], S. Piechota [1], H. Szymczak [1]

(1) Institute of Physics, Polish Academy of Sciences, PL 02-668 Warszawa, Poland, (2) Institute of Physics, Polish Academy of Sciences, PL 02-668 Warszawa, Poland, MAX-lab, Lund University, Lund, Sweden

We report results of magnetoelastic investigations of a 6% 15 nm and 11% 15 nm (Ga,Mn)As layers, deposited on (001)-oriented GaAs. The measurements were performed with in-plane magnetic field, in the temperature range between 10 K and 150 K by means of the ferromagnetic resonance and strain modulated ferromagnetic resonance (SMFMR). The novel experimental set-up for the measurement of magnetostriction [1] in the temperature range from 10 K up to the room temperature using the strain modulated ferromagnetic resonance phenomenon is presented.

For these films we assume the cubic symmetry; then, there are two magnetoelastic constants, b_1 (for strain in a cubic direction) and b_2 (for strain in a diagonal direction). The SMFMR measurements with DC magnetic field parallel to the [1 0 0] direction allow determination of the magnetoelastic constant b_1, whereas those with magnetic field parallel to the [1 1 0] direction – of the magnetoelastic constant b_2.

Numerical calculations within the standard mean-field theory predict values of b_1 and b_2 of the correct sign, but a few times smaller than observed. b_2 is larger that b_1 in both the experiment and calculations.

This work was supported by the Polish Ministry of Science and Higher Education under grant No 2048/B/H 03/2008/34

[1] K. Nesteruk, R. Zuberek, S. Piechota, H. Szymczak, 23rd General Conference of the Condensed Matter Division of the European Physical Society, 30 August – 3 September 2010, Warsaw, Poland

WE-6

Ferromagnetism and electronic transport in 2D structure GaAs/InGaAs/GaAs with remote Mn delta-layer

B. Aronzon [1], V. Rylkov [1], M. Pankov [1], V. Tripathi [2], K. Dhochak [2], A. Lashkul [3], E. Lahderanta [3]

(1) National Research Centre "Kurchatov institute", 123182 Moscow, Russia, (2) Department of Theoretical Physics, Tata Institute of Fundamental Research, Homi Bhabha Road, Navy Nagar, Mumbai 400005, India, (3) Lappeenranta University of Technology, Lappeenranta, Finland

We have studied GaAs/InGaAs/GaAs Quantum Wells (QW) with a Mn layer introduced into one of the GaAs layers and observed magnetic ordering and different manifestations of the spin polarization of the charge carriers. Mn layer and the conductive channel (the quantum well filled with charge carriers) are well separated from each other by the spacer of 1 – 5 nm thickness. That results in a relatively high mobility of the carriers (≥ 2000 $cm^2/V{\cdot}s$). As a consequence the hole spectrum is 2D, as it is witnessed by the observation of Shubnikov-de Haas oscillations and quantum Hall effect, alongside with ferromagnetic behavior. We have observed the anomalous Hall effect up to relatively high temperatures (100 K). Also the magnetic ordering was detected by the presence of a hump in the temperature dependence of the resistance which is typical for systems with ferromagnetic ordering as well as by direct magnetization measurements.

Experimental results on magnetization, Hall effect, resistance and resistance noise power spectrum as a function of various Mn concentration, depth of the quantum well and thickness of the spacer separating the Mn delta-layer and the QW are in agreement with theoretical calculations and shed a light on the mechanisms of exchange interaction leading to the ferromagnetic state in 2D systems with remote Mn layer.

WE-7

Observation of sign reversal of cubic anisotropy in (Ga,Mn)As

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(Ga,Mn)As, the main test-bed of semiconductor spintronics, has been known for its rich magnetic anisotropy. It has been demonstrated [1] that the uniaxial epitaxial-strain-induced in-plane/out-of-plane magnetic anisotropy can be remarkably well described on the ground of the *p-d* Zener model [2]. Furthermore, for non-broadened bands the model predicts <100> ⇔ <110> switching of the biaxial easy axes on temperature or hole concentration, which has not been reported to date for (Ga,Mn) As films.

In this contribution we present results of direct magnetometry of high quality 15nm thick $Ga_{0.89}Mn_{0.11}As$ film. We examine changes in the basic properties of the ferromagnetic state in response to sequential wet HCl etching and low temperature annealing (at 180°C). This procedure [3] has been suggested to enhance effectiveness of the post-growth processing for improving T_C. In fact we record additional 14 K increase of T_C to 167 K over single-step annealing, but only at the initial stages of the procedure. A prolonged annealing has a detrimental effects on M_S and T_C.

More importantly at the optimal conditions we unambiguously observe <100> ⇔ <110> switching of the biaxial in-plane easy axes on temperature. This effect is gradually washed away by subsequent thinning of the layer, ruling out a surface related origin of this switching. Moreover, since the rotation 'back' of the cubic easy exes to the commonly met <100> directions correlates with the reduction of T_C upon prolonged annealing we postulate an existence of an additional, detrimental to quality of (Ga,Mn)As process which switches in later, during extended annealing time. This process must therefore be characterized by a markedly higher activation energy than that which governs the Mn-interstitials diffusion in the (Ga,Mn)As lattice.

[1] W.Stefanowicz *et al.*, Phys.Rev.B **81**, 155203 (2010).
[2] T.Dietl, *et al*., Phys.Rev.B **63**, 195205 (2001).
[3] K.Olejnik *et al.*, Phys.Rev.B **78**, 054403 (2008).

WE-8

X-ray absorption spectroscopic study of ferromagnetic transparent conducting films

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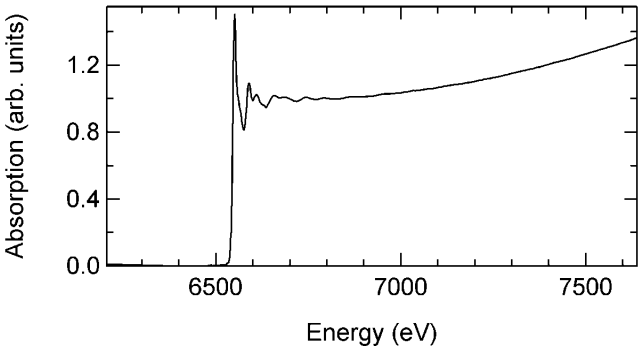
Diluted magnetic semiconductors (DMS) have gained much attention because of their potential applications to spintronic devices. It is a great advantage to use transparent conducting films such as indium tin oxide (ITO) as a host material because of their high conductivity and optical transparency. Integrating ITO into magneto-optoelectronic devices is straightforward, since there are several devices using its thin films in the market. In this work, we prepared Mn-doped ITO films on glass and polymer substrates by radio-frequency (rf) magnetron sputtering, and investigated not only magnetic, electroical, and optical properties of the films but also local structures surrounding Mn ions in the films by x-ray absorption spectroscopy.

The magnetization as a function of magnetic field showed hysteretic behavior at 300 K in the deposited Mn-doped ITO films. The films exhibited low electrical resistivity of the order of 10^{-4} Ωcm. The optical transmittance of the films ranged from 75 to 90 % in the wavelength region of 300-800 nm. The coexistence of ferromagnetism, high electrical conductivity, and high visible transparency in the Mn-doped ITO films is expected to be a desirable trait for spintronic devices.

The x-ray diffraction (XRD) patterns of the films were indexed based on a cubic bixbyite structure of In_2O_3. The local structures surrounding Mn ions were investigated using extended x-ray absorption fine structure (EXAFS) measurements. The Fourier transform of the EXAFS spectrum suggested that the Mn ions are incorporated into the In sites of the In_2O_3 lattice. The valence of Mn ions was evaluated to be almost +2 by the threshold energy obtained from the inflection point of the edge in the x-ray absorption near edge structure (XANES) spectrum. These x-ray absorption spectroscopic data are useful for revealing the origin of the magnetism of the Mn-doped ITO films.



Mn *K*-edge EXAFS spectrum of the deposited Mn-doped ITO film

WE-9

Properties of small TM aggregates in GaN and GaN:Si,Mg studied by first-principles calculations

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We present results of first-principles calculations in the framework of density functional theory for wzGaN doped with Mn and Fe, and simultaneously co-doped with Si or Mg. Our results confirm that Mn and Fe cations have a strong tendency to aggregate, *i.e.,* to form TM-rich nanocrystals [1,2]. For instance, the pairing energies for Mn, and Fe in wz-GaN are –672 and –161 meV, respectively [3]. We find, however, that at the (0001) wz-GaN gallium surface only Fe ions tend to aggregate while Mn ions repel each other [3]. Interestingly, Fe_{Ga} ions have a pairing energy equal to –125 meV at a ideal abrupt (without ad-layers) surface, and –232 meV at a surface wetted by one Ga monolayer [pseudo-(1x1), see Ref. 4]. To complete this picture, we demonstrate how co-doping with Si and Mg affects the formation of TM pairs and influences the magnetic coupling between TM ions [5,6]. Finally, we present a detailed comparison of our theoretical results with the experiment [3,5,6], which emphasizes that the TM aggregation occurs at the surface growth during the epitaxy process.

This opens possibilities for novel nanospintronics functionalities based on nanomagnetism originating in nanoscale aggregation of transition metals in the semiconductor matrix.

[1] A. Bonanni, and T. Dietl, *Chem. Soc. Rev.* 39, 528 (2010).
[2] K. Sato *et al., Rev. Mod. Phys.* 82, 1633 (2010).
[3] N. Gonzalez Szwacki, J. A. Majewski, and T. Dietl, *Phys. Rev. B* 83, 184417 (2011).
[4] Hao Zheng *et al., Phys. Rev. B* 75, 205310 (2007).
[5] A. Bonanni *et al., Phys. Rev. B* 84, 035206 (2011).
[6] A. Navarro-Quezada, N. Gonzalez Szwacki, W. Stefanowicz, Tian Li, A. Grois, T. Devillers, R. Jakieła, B. Faina, J. A. Majewski, M. Sawicki, T. Dietl, and A. Bonanni, *Phys. Rev. B* 84, 155321 (2011).

WE-10

Magnetic Circular Dichroism and sp-d interaction in (Ga,Fe)N

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Magnetic circular dichroism (MCD) is a standard method for the optical determination of magnetization in dilute magnetic semiconductors (DMSs) [1]. In wurtzite structure semiconductors, the valence band is split into three subbands, giving rise to three excitons (A, B and C) close in energy with exciton B exhibiting an opposite sign of giant Zeeman splitting. Therefore, the interpretation of the MCD magnitude and shape is no longer straightforward.
In this work we determine the relation between the magnitude of MCD signal and excitonic splitting in the representative case of (Ga,Fe)N, aiming at clarifying the meaning of MCD for a wide class of wurtzite structure DMSs. The MCD signal from a (Ga,Fe)N layer was determined from the reflectivity spectra measured in the Faraday configuration for both circular polarizations of the light. The reflectivity spectra are successfully fitted [2,3] as well as the excitonic Zeeman splittings resulting in the evaluation of the apparent s-d and p-d exchange energies: N0_alpha(app) = -0.05+/-0.1 eV and N0_beta(app) = +0.5+/-0.1 eV respectively, confirming previously reported values [2].
The amplitude of MCD and the integrated MCD are normalized and compared to the normalized splitting of the excitonic transitions and shown to be not linearly proportional to the splitting. The ratio of the excitonic line width to the difference between the excitonic energy positions is found to be a crucial parameter governing the relation between the MCD magnitude and the excitonic splitting. The obtained results show the limitations in the applications of MCD as a measure of magnetization for a class of wurtzite DMSs.
This work was supported by FunDMS Advanced Grant of ERC and NCBIR project LIDER

[1] K. Ando, Science 312, 5782 (2006).
[2] W. Pacuski et al. Phys. Rev. Lett. 100, 037204 (2008).
[3] J. Suffczyński et al. Phys. Rev.B 83, 094421 (2011).

WE-11

Magnetic and optical properties of Mn_2GeS_4 semiconductor compound

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Mn_2GeS_4, a material belonging to the II-IV_2-VI_4 family of semiconducting compounds has been synthesized by chemical transport method using I_2 as transporting agent. The X-ray powder diffraction analyses suggest that the compound crystallize in the orthorhombic structure with space group P3m1.
Low field magnetization measurements performed on Mn_2GeS_4 powders, shows irreversibility in the DC magnetization, as evidenced by field cooled and zero field cooled measurements below 23K as it is shown in figure 1. Moreover, the observed magnetic transition presents a strong dependence on the intensity of the applied magnetic field. An additional anomaly is present at 87 K which could be compare to the Néel temperature reported previously by K.Ohgushi et al.[1] In order to obtain the energy gap of the Mn_2GeS_4 compound, transmittance optical measurements were performed at room temperature by using an UV-vis spectrophotometer. The obtained results suggested that the compound behave as a direct energy gap semiconductor.

[1] K.Ohgushi and Ueda, Phys. Rev,. Lett. 95, 217202 (2005)

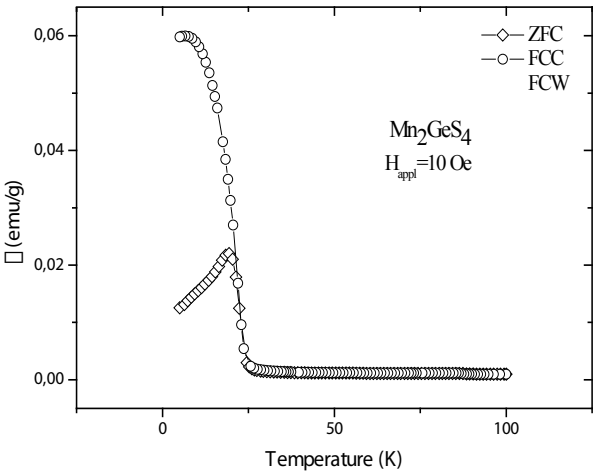

Figure 1: magnetization measurements as a function of temperature

WE-12

Magnetic properties of semiconductors $Yb_xMn_{1-x}S$

S. Aplesnin [1], A. Kharkov [1], O. Romanova [2], V. Sokolov [3], K. Yanushkevich [4]
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At present, much attention is focused on the materials with the strong correlation between magnetic and electrical properties.

The most intriguing are the materials containing variable-valence elements undergoing metal-insulator transitions and magnetic phase transformations including variations in magnetic properties at preservation of magnetic symmetry.
One might expect that upon cation substitution of a manganese ions by ytterbium ions will be induced a ferromagnetic exchange between the manganese ions located near boundary of ytterbium cluster. A competition between ferro- and antiferromagnetic interactions can give rise to a new magnetic structure. According to the data of the X-ray diffraction analysis, the YbxMn1-xS samples posses a NaCl-type face-centered cubic lattice. All measured lattice parameters well fit to the straight line. Magnetization of the samples in the field H = 0.86 T and specific magnetization versus field were measured in the temperature range of 80 K < T < 800 K. It is found the paramagnetic Cure temperature is decreased from θ=-550 K (x=0) to θ=-150 K (x=0.25) and Neel temperature falls in two time. The magnetization curve of solid solution are different from M(H) for MnS.

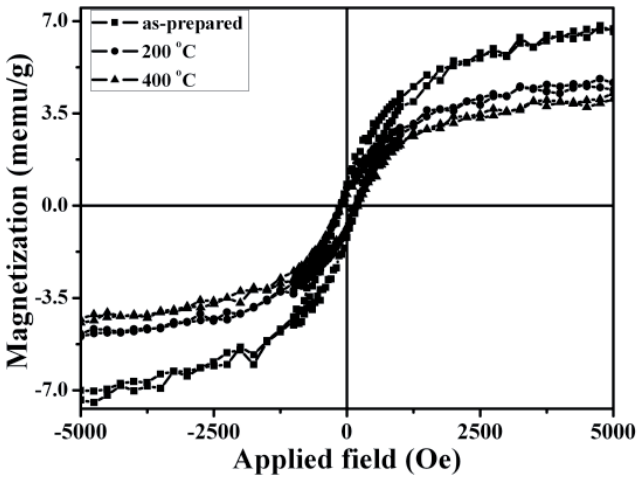

Fig. Magnetic hysteresis loops (M-H) of α-MoO_3 fibers measured at RT.

WE-13

Oxygen vacancy induced room temperature ferromagnetism in MoO_3 fibers

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(1) Department of Chemistry, Indian Institute of technology Kanpur-208016, India

The possibility of achieving ferromagnetic properties in semiconductor has resulted great intense interest for fundamental and scientific research for an emerging field of spintronics [1], which aim at using both spin and charge of the electron for promising spin based devices. To use semiconductors for practical spintronics devices, they must exhibit ferromagnetic ordering at temperature far above room temperature. Recently, the ferromagnetic properties obtained by doping of a small percentage of 3*d* transition-metal ions into ZnO, TiO_2, SnO_2, Cu_2O attracted wide attention due to its potential applications in spintronics. However, the origin of the observed room temperature ferromagnetism (RTFM) in these nanostructures is still controversial. Some experimental and theoretical works indicated the absence of RTFM in these systems, while other related studies showed that the nonintrinsic ferromagnetism is due to the formation of ferromagnetic clusters. An unexpected ferromagnetism was found in the undoped Single-crystalline α-MoO_3 fibers. These reports created great excitement in this new phenomenon, which is also known as d^0 magnetism.
Single-crystalline α-MoO_3 fibers with the diameter between 280–320 nm are prepared by a hydrothermal method. Magnetic measurements indicate that the as-prepared as well as air-annealed samples (200 °C and 400 °C) show clear ferromagnetic behavior at room-temperature. The saturation magnetizations of all air-annealed samples monotonically decrease with the increase of annealing temperature. Raman and X-ray photoelectron studies are employed to evidence the presence of oxygen vacancies in these samples. The origin of ferromagnetism may be the exchange interactions between localized electron spin moments resulting from oxygen vacancies at the surfaces of α-MoO_3 fibers. The decrease in saturation magnetization in higher air-annealing temperature are consistent with the reduction of oxygen vacancies at the surface of the α-MoO_3 fibers.

[1] S.A. Wolf et al., Science 294, 1488 (2001).

WE-14

Synthesis, Characterization and Discussion of Magnetic Properties of Undoped and Co Doped Tin Dioxide Obtained by Sol-Gel Method

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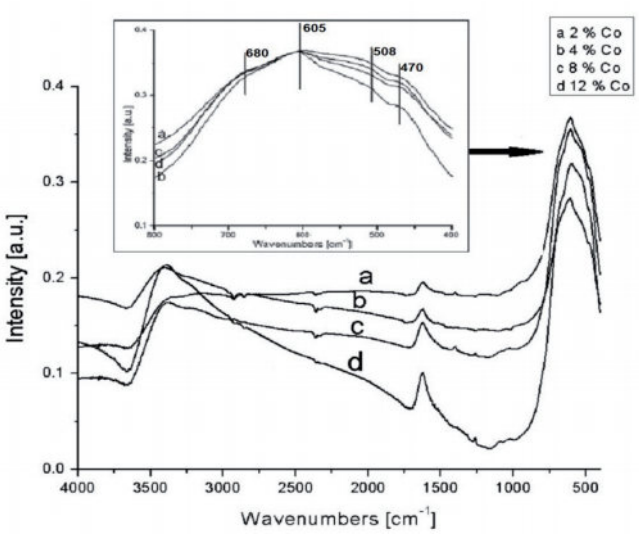
Tin dioxide is an n-type semiconductor that recently gained attention due to its doping potential with several transition metals like Co, Ni, Fe, Mn or with rare earth metals like Sm. The main purpose of the studies is to obtain room temperature ferromagnetism and to explain the mechanism of its occurrence. It is thought that the doping mechanism, combined with the presence of intrinsic defects (oxygen vacancies) is responsible for the ferromagnetic behavior of the material [1-3].
Our present work focuses on the synthesis and structural characterization of undoped and cobalt doped SnO_2 for potential applications as diluted magnetic semiconductor for spintronics. Several undoped and cobalt doped samples were obtained through an ethylene glycol assisted sol-gel synthesis.
The undoped samples were calcined at different temperatures in order to investigate their thermal treatment behavior. Their structural characteristics were determined by XRD diffraction, UV-VIS and fluorescence spectroscopy, TEM and HRTEM
Cobalt doped samples of precursor was investigated via TG/DSC analysis in order to determine the optimal thermal treatment temperature. The structural characteristics of the calcined samples were investigated with XRD diffraction, UV-VIS and IR spectroscopy, TEM.
Magnetic characterization of the Co doped SnO_2 nanoparticles was made using a vibrating sample magnetometer type *VSM Lake Shore.* The magnetization was measured vs magnetic field at 298 K.

[1] R. Parra, L.A. Ramajo , Materials Research Bulletin 43, 3202–3211 (2008)
[2] H. Bastami, E. Taheri-Nassaj , Journal of Alloys and Compounds 495, 121–125 (2010)
[3] R.N. Mariammal, N. Rajamanickam, J. Nano- Electron. Phys.3 , No1, P.92-100 (2011)



IR Spectra of Cobalt doped SnO_2 samples heat treated at 400 ˚C for 2 hours

WE-15

Atomic scale structural characterization and magnetic response in homogeneously Fe-doped ZnO nanoparticles

D. Ortega [1], J.C. Hernandez-Garrido [2], J.J. Saiz Garitaonandia [3]
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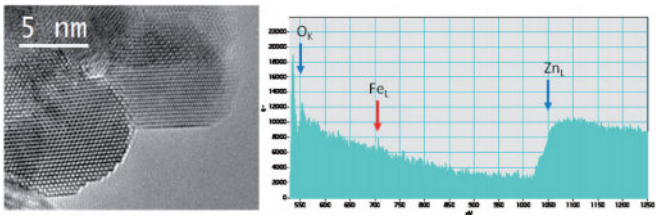
The plethora of reports accumulated during the last years on ferromagnetism in some diluted magnetic oxides still claims for a satisfactory explanation, as the well-established theories of ferromagnetic order are unable to provide a solid ground for it. Recently, a charge-transfer model has been proposed for Fe-doped TiO_2 thin films [1], whereas a wandering axis ferromagnet one appears to explain the ferromagnetic order in indium SnO_2 films, where the magnetization is considered to be confined at grain boundaries [2]. Although in many cases the appearance of a temperature-dependent hysteresis is usually linked to ferromagnetic impurities, in the case of Co-doped ZnO nanoparticles XMCD and EELS measurements clearly demonstrate an intrinsic ferromagnetic behaviour [3].
We report on the structural and magnetic characterization of ZnO nanoparticles doped with low concentrations of Fe (ca. 2% wt.) via chemical co-precipitation in alkaline media followed by a thermal treatment. HRTEM image analysis and EELS spectra acquired across the particle volume (energy resolution ~0.5 eV) let us conclude that nanoparticles are homogeneously doped showing no trace of phase segregation. Magnetization isotherms show a hysteretic feature at room temperature within the low field region superimposed to a paramagnetic signal. Further structural analysis and time-dependent magnetic measurements discard the possibility of a ferromagnetic impurity, which would show marked temperature dependence and evidences of relaxation processes given the length scales involved. The suitability of some recent models is discussed, where the relevance of an interparticle attachment promoted by thermal treatment and other defects are considered as possible sources of exchange coupling.

[1] J. M. D. Coey et al., New Journal of Physics, 12 (2010) 053025
[2] J. M. D. Coey et al., IEEE Transactions on Magnetics, 46 (2010) 2501
[3] Z. H. Zhang et al., Nature Nanotechnol., 4 (2009) 523



HRTEM image and EELS spectrum corresponding to the studied nanoparticles

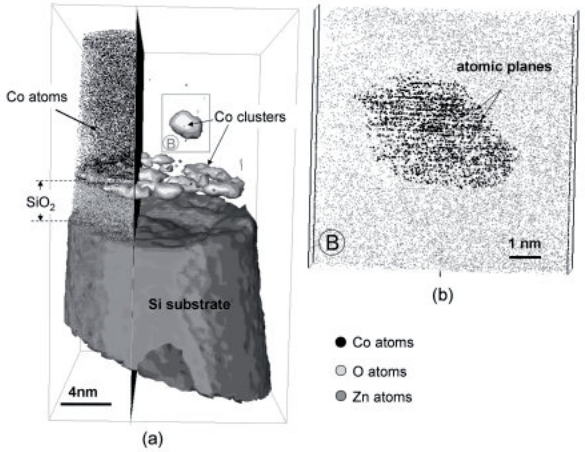
WE-16

Investigation of Co-doped ZnO by tomographic atom probe: Correlation between magnetic properties and Co spatial distribution

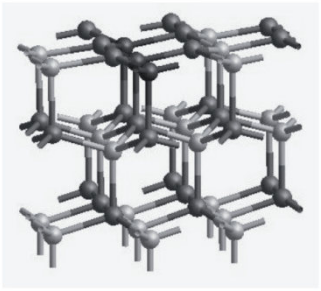
R. Lardé [1], I. Mouton [1], E. Talbot [1], P. Pareige [1], G. Schmerber [2], S. Colis [2], V. Pierron-Bohnes [2], A. Dinia [2]
(1) Groupe de Physique des Matériaux (GPM), UMR 6634 CNRS, Université et INSA de Rouen, Avenue de l'Université, B.P. 12, 76801 Saint Etienne du Rouvray, France, (2) Institut de Physique et Chimie des Matériaux (IPCMS), UMR 7504 CNRS –UDS, 23 rue du Loess, B.P. 43, 67034 Strasbourg Cedex 2, France

The development of magnetic diluted semiconductors with practical ordering temperatures could lead to new classes of spintronic devices and circuits. However, the large number of works performed on these systems, in particular Co doped ZnO, has clearly evidenced a large controversy on the nature (intrinsic or extrinsic) of the ferromagnetism on these systems. Several works attributed the room temperature ferromagnetism to impurity phases or Co clusters. In our study we have used the atom probe tomography in order to give an accurate 3D image of the spatial distribution of Co, Zn and O atoms in PLD grown ZnCoO films. Atom probe analyses show that the spatial distribution of Co atoms inside the Zn(Co)O layer is homogenous and there is no experimental evidence of the presence of any secondary phase. The most important result is the direct observation of nanosized Co clusters ($\varnothing \approx$ 3-4 nm) at the Zn(Co)O/Substrate interface. The size distribution of this Co cluster assembly is well correlated to the superparamagnetic relaxation evidenced by ZFC/FC magnetization measurements. Thus, the room temperature ferromagnetic properties of the sample studied in this paper can be attributed neither to the presence of secondary phases nor to the observed Co clusters which exhibit a superparamagnetic behavior at room temperature. In the present debate on the origin of the ferromagnetism in Co-doped ZnO thin film, our results give unambiguously more support to the defects-induced ferromagnetism.

[1] R. Lardé**, E. Talbot, P.** Pareige, H. Bieber, G. Schmerber, S. Colis, V. Pierron-Bohnes, and A. Dinia, J. Am. Chem. Soc. **133**, 1451 (2011).



3D image of the cluster decoration of the Zn(Co)O/substrate interface.



Substitutional Co chains at the O-ended ZnO(000-1) surface.

WE-17

Co aggregates at ZnO surfaces

N. Sanchez [1], *S. Gallego* [2], M.C. Muñoz [2]

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(Co,Zn)O is one of the most studied dilute magnetic oxides (DMO). Eventhough ferromagnetism has been measured on specific samples, it largely depends on the sample preparation and measurement conditions. After one decade of intense research, there is strong evidence that Co substitution in bulk ZnO produces short-ranged antiferromagnetic interactions, and only the formation of metallic clusters could provide a partial contribution to the measured ferromagnetic signal.

Here we will consider an often neglected aspect on the physics of DMO, that is the role of surfaces. It is known that ferromagnetism in DMO tends to be linked to interfaces and nanostructures, although the precise mechanisms remain yet to be completely understood [1,2]. Based on ab initio calculations, we will demonstrate first that substitutional Co impurities tend to approach ZnO surfaces. In addition, the tendency of the Co atoms to aggregate is completely different at different surfaces, and involves an energy scale one order of magnitude higher than in the bulk [3]. In particular, an inversion of the Co clustering trend exists at the O-ended ZnO(000-1) termination, where Co tends to disperse forming a planar $Zn_xCo_{1-x}O$ phase, leading to an ideal scenario to manipulate spinodal decomposition.

[1] S. Gallego, J.I. Beltrán, J. Cerdá, M.C. Muñoz, J. Phys.: Condens. Matter 17, L451 (2005); G. Fischer et al., Phys. Rev. B 84, 205306 (2011).
[2] N. Sanchez, S. Gallego, M.C. Muñoz, Phys. Rev. Lett. 101, 067206 (2008).
[3] N. Sanchez, S. Gallego, M.C. Muñoz, Appl. Phys. Lett. 99, 153102 (2011).

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

Chair: A. Di Bona

WE-19

Core-shell Fe/MgO nanoparticles for arsenic removal under alkaline environments

K. Simeonidis [1], S. Tresintsi [2], M. Tziomaki [1], N. Andritsos [1], M. Mitrakas [2], C. Martinez-Boubeta [3], L. Balcells [4], C. Monty [5], M. Angelakeris [6]

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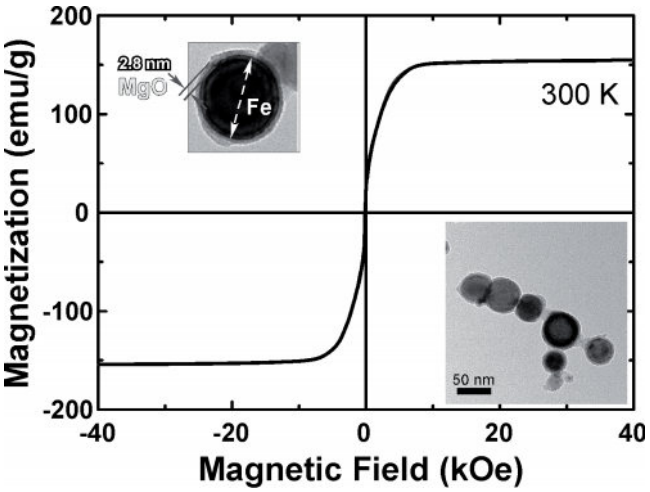
Nanoscale alkaline earth metal oxides are very promising materials for applications as decontaminating adsorbents of water due to their favourable electrostatic attraction mechanism, and the simplicity of their production from abundant natural minerals. Particularly, MgO has been reported to present a high uptake capability to remove arsenic species from water [1] with its performance being significantly promoted at high pH-values (>9). Such limited range of efficient operation for MgO adsorbents could be beneficiary exploited in the regeneration of conventional arsenic adsorbents. For instance, washing the saturated adsorbents by a strong alkaline solution not only could multiply the lifetime of consumables for arsenic treatment but also promote an innovative method to minimize toxicity of the arsenic enriched stream and recycle the alkaline solution, as well.

On the other hand, there is an increasing interest in the growth of high quality core-shell Fe/MgO nanoparticles because of their unique physical properties which allow for magnetically induced cancer therapies or catalytic splitting of water and hydrogen storage [2,3]. This work examines the efficacy of Fe/MgO nanoparticles in arsenic species adsorption from water in the pH-range 8-12. The incorporation of a magnetic core material facilitates to collect them after the adsorption step, by a simple magnetic separation stage. Core/shell Fe/MgO nanoparticles were synthesized by evaporating a pressed pellet (mixing Fe, MgO and Mg powders) using solar physical vapor deposition under inert atmosphere. Batch tests on arsenic containing solutions showed that As(III) and As(V) adsorption capacity of the nanoparticles reaches 10 μg/mg at high pH while residual arsenic could be minimized below 5 μg/L.

[1] X.-Y. Yu et al., J. Phys. Chem. C 115, 22242 (2011)
[2] C. Martinez-Boubeta et al., Nanomed. Nanotechnol. 6, 362 (2010)
[3] K. Zhu et al., Angew. Chem. 118, 7435 (2006)



Magnetic and morphological features of Fe/MgO core-shell nanparticles

WE-20

Microstructure, magnetism and catalytic synergetic effect in (Fe:Ni,Co)/Al2O3 nanocomposites

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Synergic improvement of activity in carbon nanotubes selective catalysis on metal-oxide composites in hydrocarbon pyrolysis is expected as with rising of system dispersivity as by using bi-metallic Fe:Co, Fe:Ni particles [1]. The optimal sizes of those active catalytic particles lies in the range of about 10-15 nm. These sizes correspond to the superparamagnetic single domains for Fe, Co and Ni. Present work deals with (50Fe:15Me)/35Al_2O_3 (Me: Ni or Co) nanocomposite catalysts synthesized via chemical technique [2-3] representing a hydrogen reduction of coprecipitated hydroxides systems at different temperatures. The samples microstructure was characterized by thermogravimetry, Mossbauer spectroscopy, X-ray diffraction and transmission electron microscopy. Fine particles magnetism have been researched by field and temperature dependences of magnetisation. In agreement with TEM observations, Mossbauer and magnetic study confirmed a distribution of the iron particles size, showing superposition of a ferromagnetic behaviour (larger particles) and a superparamagnetic behaviour (smaller particles). It was found that strong metal and alumina interaction occuring in the reduction process results in suppression of Fe reduction. Formation of interfacial antiferromagnetics phase $Fe_{1+x}Al_{2-x}O_4$ affects the particles coercive field and dissymetry of hysteresis loops. The greater interaction with dispersive component have been observed for Fe:Ni/Al_2O_3 leading to FeNi particles redistribution to smaller sizes at higher temperature. Fe and Co particles interactions in Fe-Co/Al_2O_3 during reduction process reveal their agglomeration with formation of larger alloyed particles. The quantity of superparamagnetic particles is considerably smaller than in the Fe-Ni/Al_2O_3 composition. It

was established that magnetic characteristics of the composites are in direct correlation with their microstructure and catalytic activity.

[1]Novakova A.A.,Kiseleva T.Yu et al. ISJAEE 2004, №3 (11) 37-43.
[2] Ryzhonkov D.I., Levina V.V. et al, J.Non- Ferrous Metals 2008, V49, №4, p.308-313.
[3] Kiseleva T.Yu., Novakova A.A., Levina V.V. et al. J. of Surface Investig. 2003, №3, p.61-66

WE-21

Synthesis of magnetic hybrid nanocomposites through controlled aggregation of nanoparticles using an autoclave system

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We propose a very well known solvothermal reaction taking place into an autoclave system for the production of magnetic hybrid nanocomposites. We suggest nanoparticles of materials with optical and magnetic properties for the very attractive resulting combination.
The controlled aggregation using an autoclave system is used to obtain nanoclusters built up using different transition metal ferrites nanoparticles. The chemistry involved permits to choose the size of the nanoparticles to aggregate and to control the size of the final nanocomposites, with the consequent ability to control the collective magnetic behavior. Accordingly, different ferrites can be produced just depending on the metal precursor that provides the necessary ions (Mn^{+2}, Zn^{+2}, Co^{+2}, etc.).
This method permits enriching combinations between ferrites and other materials, in such a way that the assembly helps to enhance the possible diversity of the ultimate functionalities of these complex nanomaterial systems, based on the interfaces established. This fascinating approach of artificial nanostructuring have allowed us the synthesis of mix multifunctional systems driving magnetite and gold nanoparticles that favor the acquisition of a characteristic surface plasmon band or magnetite and chromium oxide nanoparticles favoring a ferrimagnetic-antiferromagnetic interface.

[1] Chem. Mater. 2009, 21, 5079-5087
[2] Angew. Chem. Int. Ed. 2005, 44, 2782-2785

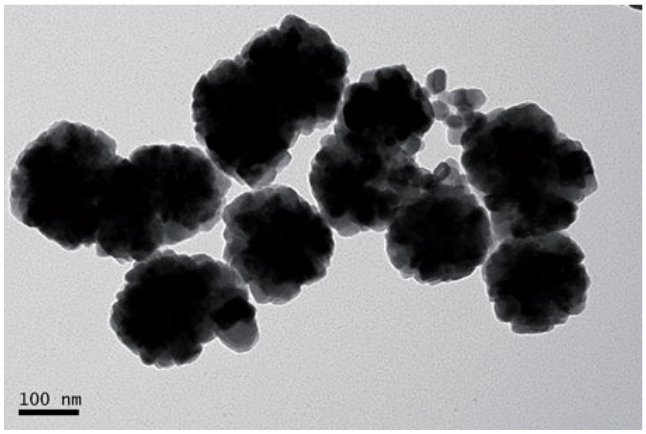

Figure 1. TEM images of Fe_3O_4-Cr_2O_3 hybrid nanocomposites.

WE-22

Development of a magnetic separator for biomedical and environmental applications

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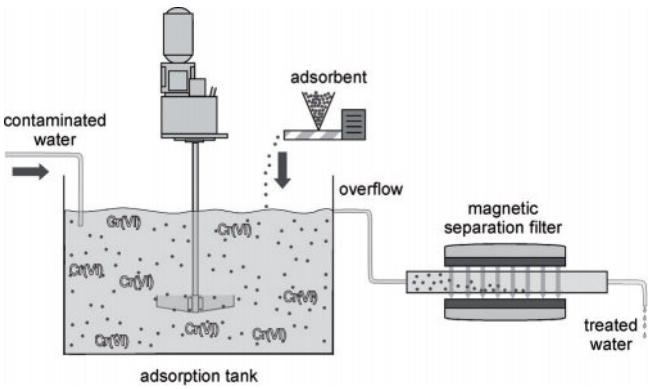
Magnetic separation of solids is a common method used in the traditional fields of mineral processing, industrial grading or more recently in biotechnology as well as wastewater and potable water treatment [1,2]. For instance, unceasing progress in the biomedical applicability of magnetic nanoparticles for drug delivery, cell detection and separation, hyperthermia treatment and detoxification technologies, requires the implementation of efficient magnetic separation systems for their extraction from the human body.
This work presents the development of an integrated pilot scale magnetic separation setup oriented to the continuous flow removal of magnetic nanoparticles dispersed in a flowing stream. In the simplified version a 1 L stirring tank with a 0.5-2 h retention time outflows in a 0.5 m horizontal tube which stands inside the homogeneous magnetic field produced by rectangular NdFeB permanent magnets. The design of the system was optimized by carrying out computational fluid dynamic simulations considering the magnetic field (strength and application length), the flow rate, the concentration and the magnetic properties of nanoparticles.
The constructed magnetic separation system was tested for the case of hexavalent chromium removal from water using magnetite nanoparticles. The goal was to supply a high enough retention time to allow adequate contact between the chromium-containing water and the nanostructured solid, while ensuring the complete capture of nanoparticles by the magnetic separator installed in the overflow of the tank. Currently, this system is examined as blood filtering system to mechanically collect and detoxify the blood stream from magnetic nanoparticles after they have achieved their biomedical goals.

[1] Q. Wang et al., Chem. Eng. J. 183, 339 (2012)
[2] K. Simeonidis et al., Chem. Eng. J.168, 1008 (2011)



Sketch of the developed magnetic separator

WE-23

Magnetic properties of iron nanoparticles coated with polyaniline

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Magnetic nanoparticles are useful in biomedical applications such as drug delivery, labelling or magnetic separation of biological materials. A problem in particular for iron nanoparticles, is their high chemical reactivity, specifically with water and oxygen. On the other hand, high chemical reactivity makes iron a good catalyst for reactions where the formation of new carbon-carbon bonds takes place, [1] or in the oxygen reduction reaction, ORR [2,3].
We have synthesised iron nanoparticles with or without a polyaniline (PANI) coating, using sodium borohydride as a reducing agent. We found that the polymer coating protects the iron nanoparticles from oxidation. When the particles are uncoated, they are rapidly oxidised in air to give a mixture of Fe, FeOOH and Fe_2O_3, with a magnetization of only 25 A m^2 kg^{-1}. However the PANI coating protects them from oxidation and they remain stable in air. The magnetization is 93 A m^2 kg^{-1}, about half that of bulk iron, and it is controlled by coating. We characterised the fresh, oxidised and coated particles by techniques including magnetic measurements, Transmission Electron Microscopy, X-Ray Diffraction and Mössbauer spectroscopy. Given their surface iron-nitrogen sites, they are potentially good candidates to catalyse the ORR.[2,3]

[1] G.P. Van der Laan, A.A.C.M. Beenackers, Catal. Rev. Sci. Eng., 41, 255 (1999)
[2] G. Wu, et al. Science, 332, 443 (2011)
[3] G.C.K. Liu, J.R. Dahn, Appl. Catal. A: Gen., 43, 347 (2008)

WE-24

Magnetically Assembled Nanochains in Polymers

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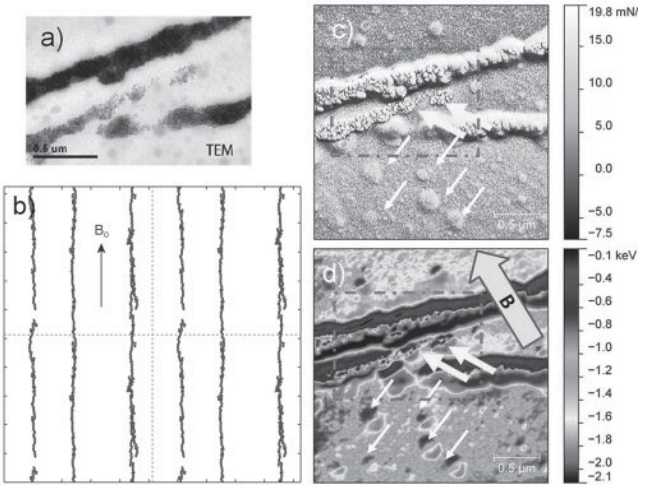
We present a microscopic study of magnetic aligned nanochains grown inside a polymer film by assembling nanometer size particles, producing possibly templates for novel plastic devices. To allow the assembling of the constituents (nanometer size γ-Fe_2O_3 particles) into the plastic film (an acrylate copolymer), a magnetic field was applied why drying the solution containing the polymer and the magnetic particles. 50-100 um thickness films are deposited on glass, and can be peeled off the substrate after drying [1].
In order to perform the microscopy analysis on the embedded structures, ultra-thin slices of the films were cut with an ultra-microtome. Thin cross-sectional slices were deposited on graphite substrates, to allow imaging of the wires inside the insulating polymer films by using SEM-BSE. The length and alignment of the wires in the film result to be dependent on the time application of the magnetic field upon evaporation of the polymer solvent, with aligned wires start forming at the surface of the film. This process can be understood considering the long-range magnetic interaction between the particles, and the short-range van der Waals attraction/repulsion mediated by the polymer matrix.
Moreover, the nanowires exhibit anisotropic magnetization, but maintaining the super- paramagnetic behavior of the constituent particles. The magnetic anisotropy can be predicted by simplified Monte Carlo (MC) simulations [2]. If the wires are exposed to the slice surface, MFM can be used to investigate the local magnetic response, down to the scale of few nanoparticles [3].
Similar nanocomposites could be used as magnetic sensors or shields, or to create multifunctional materials.

[1] D. Fragouli et al., ACS Nano 4, 1873 (2010)
[2] G. Bertoni et al., *J. Phys. Chem. C 115*, 7249 (2011)
[3] B. Torre et al., Sci. Rep. 1, 202 (2011)



Magnetic nanochains inside the polymer matrix (TEM, MC simulation, and MFM)

WE-25

A new, simple and inexpensive experimental set up designed for quality control of magnetic fluid preparation

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Key features of magnetic fluid (MF) samples include the average diameter (<*D*>), the diameter dispersion (<*S*>) and the average cluster size (<*Q*>) of the nanosized suspended magnetic units. Ultimately, we found in the technical literature a huge amount of reports describing the strong influence of these parameters on the final magnetic and magneto-optical properties of MF samples. Therefore, industrial and medical applications of MF samples, either as intermediate or final materials, require the correct choice of these features. Usually, the MF properties are assessed by traditional techniques, directly using high resolution microscopy (cryo-TEM for instance) or indirectly using magnetic hysteresis cycle (MHC) or static magnetic birefringence (SMB) [1-2]. This communication introduces and tests a new, simple and inexpensive experimental set up, able to provide quick information for <*D*>, <*S*> and <*Q*>, immediately after the MF preparation. The experimental set up includes on its design a computer driven precision laboratory scale and a permanent magnet. Furthermore, the experimental device herein described can be easily adapted as a nanoparticle size-sorter

system for size-dispersity control of as-produced MF samples. We used typical MF samples for testing the new experimental set up, collecting their <*D*>, <*S*> and <*Q*> characteristics and comparing the assessed data with the values obtained from TEM, MHC, and SMB. We found excellent agreement between the data collected from the new set up introduced in the present study and the data collected using the traditional experimental techniques.

[1] P.C. Fannin, C.N. Marin, V. Socoliuc, G.M. Istratuca, J. Magn. Magn. Mater. 284 (2004) 104–112;
[2] P.P. Gravina, A.F. Bakuzis, K. Skeff Neto, R.B. Azevedo, P.C. Morais, J. Magn. Magn. Mater. 289 (2005) 448–452.

WE-26

Influence of the spatial confinement at nanoscale on the structural surface charging in magnetic nanocolloids

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In this work, we survey the surface charging properties of core shell ferrite nanoparticles dispersed in water, namely the electric double layered magnetic fluids (EDL-MF). This structural charge results from the Brönsted acid-base behavior of the particles surface and is achieved through hydrolysis reactions at the surface. It can be modeled by considering identical charged sites behaving as weak diprotic acids. Then, electrochemical techniques can be applied in order to study the acid-base equilibrium between the particle surface and the bulk dispersion. Simultaneous potentio-conductimetric titrations are therefore performed in order to determine the thermodynamical constants of the pH-dependent protonation/deprotonation reactions and to obtain the surface charge density [1,2]. The results reveal that the saturation value of the structural charge vary as a function of the nanoparticle mean size. These variations are well fitted by a phenomenological law similar to that of photonic crystals based on 3D colloidal arrays, self assembled with polystyrene particles. This surface charge reduction is enlightened by considering both the particular environment of the nanoparticle surface and the lowered tunneling barrier in the small-sized *quantum dots* resulting from a large quantum confinement effect.

[1] A. F. C. Campos et. al., J. Magn. Magn. Mater. 310, 2847 (2007).
[2] A. F. C. Campos et al., Braz. J. Phys. 39, 230 (2009).

WE-27

Size-dependent electronic and magnetic properties of individual iron oxide-based nanocrystals

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Iron oxide-based nanoparticles (NP) have outstanding magnetic properties and promising applications for spin-filter devices, biomedicine, and catalysis. In addition to finite-size effects, a key issue for research is how the intrinsic magnetic properties of the individual particles are modified by their own electronic structure, chemistry, surface termination and crystallinity. In particular, the high-spin polarization predicted for Fe_3O_4 is limited experimentally by structural defects, cation and oxygen vacancies. For spinel ferrites such as $CoFe_2O_4$, the likely size-dependent cation distribution of the tetrahedral and octahedral sites in the close-packed oxygen structure may strongly affect the magnetic properties of the NP.
By combining x-ray magnetic circular dichroism with photoemission electron microscopy, we analyze the electronic structure, chemical bonding, and magnetic properties of individual, pseudo-spherical $Fe_{3-x}O_4$ and $CoFe_2O_4$ NP in the size range of 12 to 30 nm, synthesized by thermal decomposition of organometallic precursors [1] and deposited onto hydrophobic substrates. The $Fe_{3-x}O_4$ NP display high crystalline quality and macroscopic bulk-like magnetic properties down to 5 nm [2], while the $CoFe_2O_4$ NP show some crystallographic defects and in-volume domain boundaries. The unique spectral features of the individual particles, such as resonance heights, chemical shifts, oxidation states of the Fe atoms and density of states for the core-hole state, as well as their XMCD asymmetry profiles, are correlated to variations in either the stoichiometry or the lattice geometry of their Fe and Co ions. Our preliminary results show that the X-ray absorption spectra of single $Fe_{3-x}O_4$ NP cannot be fully superimposed to those of reference pure iron oxide species, suggesting the coexistence of different iron oxide phases with competing electronic configurations and magnetic orders within each NP.

[1] P. Guardia, N. Pérez, A. Labarta, and X. Batlle, Langmuir 26, 5843 (2010)
[2] X. Batlle et al, J. Appl. Phys. 109, 07B524 (2011)

WE-28

Temperature and size dependent spin dynamics in polymer-coated maghemite nanoparticles as probed by ^{1}H-NMR

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We present a study of the spin dynamics of a series of maghemite/polymer composite nanoparticle assemblies with variable magnetic core size, via ^{1}H-NMR spectra and relaxation. Each particle is composed of a γ-Fe_2O_3 core entrapped in a single folded PVP (Polyvinylpyridine) chain and an outer part composed of PEG (Polyethylenglycol) chains in radial disposition. Ferro- and ferri-magnetic nanoparticles have been extensively studied during the last fifty years because of the wide range of magnetic phenomena they show, such as superparamagnetic blocking, ageing phenomena, glass-like behavior and surface effects. The NMR study that we propose represents a novel approach and complementary to ESR and Mossbauer spectroscopy, the two main long-known techniques employed to perform the investigation of the dynamics in Iron-based nanoparticles. The quasi-local probing of the ferrite core dynamics has been made possible by the hyperfine coupling

of the Fe^{2+} and Fe^{3+} spins with the nuclear spin of hydrogen atoms inside the organic shell. We performed ^{1}H-NMR $1/T_1$ vs T experiments, collecting data in the range 4.5 K < T < 300 K and at magnetic fields H = 0.48 Tesla and H = 1.38 Tesla. For each sample, we observed two broad field-dependent peaks in the temperature dependence of the longitudinal relaxation rate of the nuclear magnetization. The two anomalies shift towards higher temperatures with the particle diameter. We relate the high-T dynamics with the onset of hyperfine field fluctuations near the superparamagnetic blocking temperature T_B; the low-T peak in $1/T_1$ can be tentatively interpreted by splitting the ferrite core in surface and core regions, so that a faster dynamics and a consequently lower temperature of spin freezing can be associated to a disordered magnetic layer on the surface of the particle, a scenario also envisioned in the past and recent literature.

WE-29

Interparticle interactions and spin-glass behaviour in colloidal maghemite nanocrystals clusters

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The synthesis of monodispersed magnetic nanocrystals (NCs) with controlled size and shape, and in particular their assembly has drawn rising interest due to cumulative properties arising from the proximity and coupling effects of the individual building blocks involved. Such assemblies can be developed directly in solution, on substrates or even by using appropriate templates.

Here we study colloidal nanocrystals clusters (CNCs), assemblies of superparamagnetic gamma-Fe_2O_3 NCs which were prepared directly in solution. The CNCs were grown via a high-temperature polyol process where primary NCs (PNCs) grow first and then they aggregate into size-tunable clusters (Fig. 1a) [1]. Both the PNCs and the final CNCs are covered by polyacrylic acid. The carboxylate capping groups bind on the surface of the inorganic nanoparticles and render them negatively charged and water dispersible.

Nanoclusters of 50 and 85 nm and their corresponding PNCs were characterized magnetically by ac SQUID magnetometry. M□ssbauer spectroscopy suggests that strong intra-cluster interactions are the main reason behind their ferrimagnetic behavior. The dissipative part of the temperature-dependent ac susceptibility (Fig. 1b) identifies two broad maxima, namely, one around 100 K and another narrower one in the range 20 – 75 K. These are likely associated with the particular nanoscale morphological characteristics of the nanoparticle assemblies, which sustain both blocked spins due to the cluster as a whole and spin-glass like features due to canted or frustrated moments entailing the non-fully coordinated nanocrystals at the near-surface of the clusters [2]. We discuss the influence of intra- and inter- cluster interactions in mediating such thermally assisted mechanisms (Fig. 1b, inset).

[1] A. Kostopoulou et al., Photon. Nanostruct.: Fundam. Appl. 9, 201 (2011)

[2] Nadeem et al., J. Appl. Phys. 109, 013912 (2011)

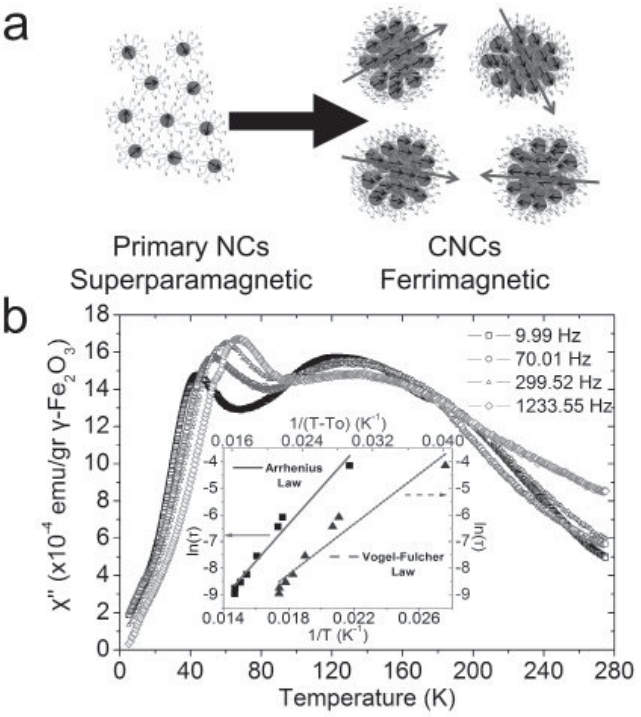

Figure 1. PNCs assembly into nanoclusters (a) and x´´(T) for CNCs of 50 nm (b).

WE-30

Monte Carlo simulation of pH-dependent nanoparticle agglomeration in ionic magnetic colloid

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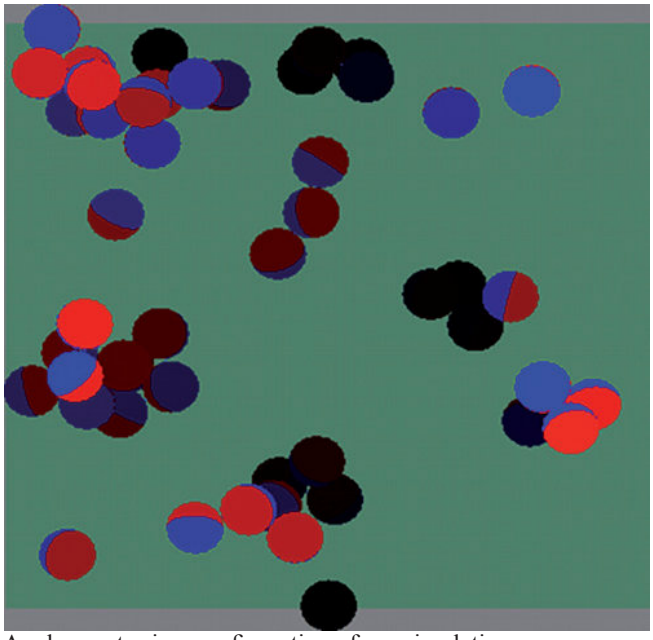
Magnetic colloids, also called magnetic fluids or ferrofluids, are composed of magnetic nanoparticles dispersed in liquid solvents [1]. The unique combination of fluidity and strong magnetism makes magnetic colloids very suitable for different types of applications. In the so-called ionic magnetic colloids, the charged surfaces of the nanoparticles attract ions from the solvent which, in their turn, attract other ions of opposite charge, forming an electrical double layer (EDL) around each nanoparticle. The repulsion between EDLs is essential to stabilize an ionic magnetic colloid, as attractive interactions (mainly van der Waals and magnetic dipolar) tend to make the nanoparticles agglomerate. Monte Carlo methods are characterized by the use of random number sequence to simulate statistical properties. Our simulations were performed by means of the Metropolis algorithm [2], a Monte Carlo method used to simulate systems that can be described by the Boltzmann distribution. The results of our simulations shows high increase of agglomeration at pH from 5 to 6 due to the strong decrease of ion concentration in the EDL. The value of average pair interaction energy turns to be negative around pH = 6 and its magnitude reaches several units of k_BT, while the average first neighbour distance strongly decreases in the same pH range. The computational result was compared to previous experimental observations that evidenced a phase transition from sol to gel on this pH range. Although high agglomeration

at pH = 7 is not desirable for some biomedical applications, the existence of phase transitions may be useful for other applications, such as sensors.

[1] R.E. Rosensweig, *Ferrohydrodynamics,* Dover, New York, (1997)
[2] M.P. Allen and T.J. Tildesley, *Computer Simulation of Liquids*, Oxford Science Publications, Oxford (2003).
[3] A. F. C. Campos et al., Braz. J. Phys. 39, 230 (2009).



Agglomerates in a configuration of our simulation.

WE-31

Exploring the effect of Co doping in fine maghemite nanoparticles

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Nanosized spinel ferrites are the subject of increasing interest due to their remarkable magnetic, catalytic, electric and optical properties, which, in most cases, make the material a fundamental building block for the fabrication of nanodevices to be employed in a large number of applications.
One of the most fascinating properties of spinels is their versatility: the physical properties can be easily tuned by modifying the composition while keeping intact the crystal structure. Cobalt ferrite represents one of the most notable examples: indeed, the replacement of Fe^{2+} with the more anisotropic Co^{2+} cation allows tuning the magneto-crystalline anisotropy from that of pristine magnetite up to very high values (ca. 20 times larger).
Here we present a study of the structural, magnetic and magneto-optical properties of a family of Co substituted ferrite nanoparticles, (NPs), prepared by thermal decomposition. The structural characterization, carried out by using TEM, XRD and XAS, showed all the samples are high crystalline, 5-6 nm spherical NPs with the cubic spinel structure typical of ferrites. The evolution of the lattice parameter with Co content suggests that the material is Co-substituted maghemite, also confirmed by XAS and Magneto-optical spectroscopy. The investigation of the magnetic and magneto-optical properties displays peculiar trends with the Co content, the main features being the large increase of the saturation magnetization and the anomalous dependence of magnetic anisotropy which reaches its maximum value for intermediate compositions.
On increasing the size of the NPs up to 12 nm while keeping constant the composition, a non trivial variation of the physical properties was observed, indicating the volume enhancement modifies important structural parameters such as cations and vacancies distribution.
The large tuneability of this material makes it possible to implement the performances of devices used in biomedical and sensing applications.

WE-32

Review of magnetic order in epsilon-Fe2O3

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In our work, we focused on re-investigation of the magnetic phase diagram of the ε-Fe_2O_3 phase by means of neutron scattering, X-ray magnetic circular dichroism (XMCD), in-field Mössbauer spectroscopy and frequency-dependent a.c. susceptibility. In this compound, the Fe^{3+} spins order below the Curie temperature, T_C = 480 K, entering the high-coercivity magnetic phase (MP). Below 100 K, an additional order-to-order magnetic phase transition (MPT) into a low-coercivity MP occurs. In contrast to previous work [1], we observed that the zero-field high-coercivity magnetic structure corresponds to a canted ferrimagnet. Moreover, the zero-field MP undergoes a field-induced MPT, as evidenced by virgin magnetization curves obtained by magnetization and XMCD measurements. The corresponding field-induced anomalies were complementarily detected by the field-dependent Mössbauer spectroscopy experiments. The unusual hard-to-soft MP crossover is also reflected by the inverse response of the frequency-dependent spin relaxation investigated by the a.c. susceptibility. The experimental results suggested significant re-consideration of the magnetic order scenario in the ε-Fe_2O_3 phase and they are discussed in the context of the first-principle calculations.

[1] M. Gich et al., Chem. Mater. **18**, 3889 (2006).

WE-33

Influence of surfactant on magnetic properties of magnetite nanoparticles produced by electrooxidation

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The development of novel metallic oxide nanoparticles has attracted great attention because their characteristics can be significantly different to those of the bulk materials. To date, several approaches have been employed to synthesiz magnetite nanoparticles [1-2].

We have used an electrooxidation method to producing magnetite (Fe_3O_4) nanoparticles in the presence of several different surfactants. The growth was carried out in a thermostatic electrochemical cell containing two iron electrodes and an appropriate aqueous solution [3]. The samples were analyzed by X-ray diffraction (XRD), scanning electron microscope (SEM), superconducting quantum interference device (SQUID) magnetometry, and Mössbauer spectrometry. The formation of the Fe_3O_4 spinel phase was confirmed by the XRD patterns. The SEM images confirmed that the nanoparticles'size in the range 5-100 nm critically depends on the type of surfactant used. Room temperature, the saturation magnetization of Fe_3O_4 nanoparticles range from 5– 86 Am^2kg^{-1}, again depending on the type of surfactant (Figure 1). Mössbauer spectra in transmission geometry were recorded at room temperature for all samples using a Co^{57} source. The spectra were well fitted by two magnetic sextets, corresponding to Fe^{3+} ions at A site and (Fe^{2+}:Fe^{3+}) ions at B site and a paramagnetic doublet. The relation between magnetic properties and the length and nature of surfactant molecules will be discussed.

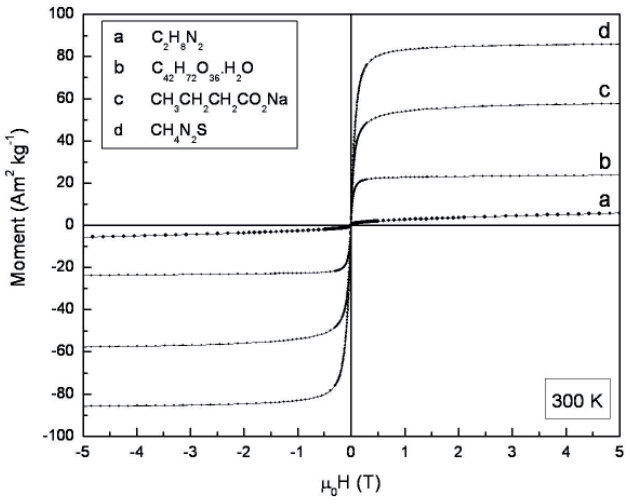

Fig. 1: Magnetization curves of Fe_3O_4 nanoparticles covered with different surfactants.

[1] W. Wu, Q. He, C. Jiang, Nanoscale Res. Lett. 3, 397 (2008).
[2] L. Cabrera, S. Gutierrez, N. Menendez, M. P. Morales, P. Herrasti, Electrochim. Acta. 53, 3436 (2008).
[3] I. Kazeminezhad, S. Mosivand and M. Farbod, Current Nanoscience. 7, 819 (2011).

WE-35

Nanoparticles of Antiferromagnetic and Ferrimagnetic Oxides as Magnetic Heterostructures

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Interfaces between different oxides in hybrid systems offer the perfect environment for manipulating the complex interplay between the electronic and lattice degrees of freedom and drawing out new functionalities by exploiting epitaxial strain, local symmetry breaking, frustration or charge transfer between the materials. Magnetic interfaces are highly relevant for technological applications and in most of them, exchange bias plays a key role.[1]

We intend to exploit oxide interfaces established in composite nanostructures synthesized by colloidal chemistry methods. The great advantage of using different types of inorganic nanostructures as building blocks comes from the fact that permits the design and fabrication of colloidal and supracolloidal assemblies knowing first their magnetic characteristics. As a proof of concept we have developed mixed systems, driving on the surface of AFM substrates (goethite nanorods or cobalt oxide octahedrons), cobalt ferrite nanoparticles or magnetite shells (the study of bimagnetic systems opens new degrees of freedom to tailor the overall properties and offers the Meiklejohn-Bean paradigm).[2],[3] Opposite structures driving the antiferromagnetic material on a ferrimagnetic substrates is also possible to attain.[4].

[1] M. Gibert, P. Zubko, R. Scherwitzl, J. Iñiguez, J. M. Triscone, Nature Materials, **11**, 195 (2012).
[2] R. Mariño-Fernández, S. H. Matsunaga, N. Fontaíña-Troitiño, M. P. Morales, J. Rivas, V. Salgueiriño, J. Phys. Chem. C **115**, 13991 (2011).
[3] Nerio Fontaíña-Troitiño, Beatriz Rivas, V. Salgueiriño, in preparation (2012).
[4] Sara Liébana-Viñas, R. Otero-Lorenzo, V. Salgueiriño, in preparation (2012).

WE-36

Evidence of core-shell interaction between magnetite core and hematite shell nanocomposite produced by mechanical attrition

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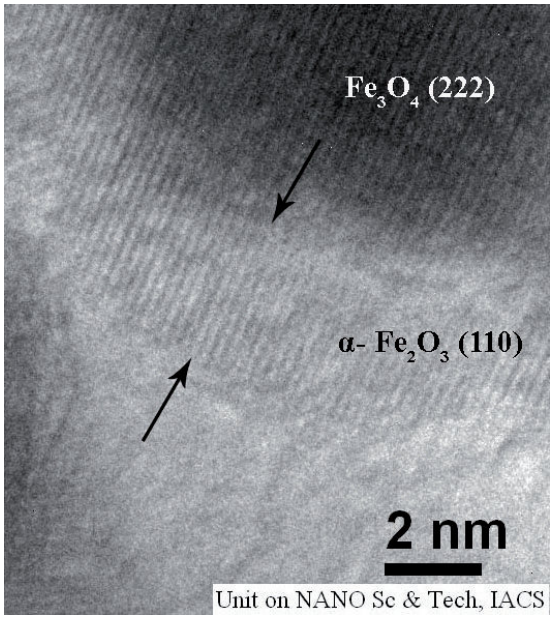
Magnetic nano particles (np) are of growing interest because of their potential application in ultra high-density recording and medicine [1]. Exchange coupling (exchange bias) induced at the interface between ferromagnetic and antiferromagnetic system can provide an extra source of anisotropy leading to magnetization stability [2]. Exchange bias (E_B) has been extensively studied in thin films with ferromagnet-antiferromagnet (FM-AFM) interfaces. E_B has been studied in np of metal (core) - Metal oxide (shell) structure of transition metal or their alloy. So far various experimental methods have been used to synthesize core (FM)-shell (AFM) interface structure to observe exchange bias, e.g. inert-gas-condensation, plasma-gas-condensation, vapour deposition

technique etc. These methods are expensive and not suitable for bulk production. On the other hand, mechanical attrition is an useful technique for making nano structural materials in bulk production. Our earlier work has shown that nanointerface between Fe based oxides can be generated by subjecting magnetite powder to mechanical grinding [3]. Nano particles comprising of magnetite (Fe_3O_4) core-hematite (α-Fe_2O_3) shell with mean diameter around 9 nm were synthesized by mechanical grinding of Fe_3O_4 powder. High resolution TEM (figure below) shows the formation of Fe_3O_4 core-α-Fe_2O_3 shell particles. Zero field cooled and field cooled magnetization and hysteresis loop were carried out over the temperature range 5 to 300 K. Exchange bias 140 to 10 Oe was observed. This is explained as arising due to ferrimagnetic-antiferromagnatic coupling at the nano interfaces between the two phases. Analysis of data shows a pronounced increase in the effective anisotropy constant as the milling time is increased.

[1] R .H. Kodama, J. Magn. Magn. Mater. 200, 359 (1999)
[2] K.Liu et al., Appl. Phys. Lett. 81, 4434 (2002)
[3] P. Brahma et al., J Magn. Magn. Mater, 288, 301 (2005)



High resolution micrograph for the Fe_3O_4 core - α-Fe_2O_3 shell particles.

WE-38

Nanocrystallization at severe plastic deformation and magnetic properties of $Fe_{78}Si_{13}B_9$ amorphous alloy

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Nanocrystallization of $Fe_{78}Si_{13}B_9$ metallic glass under severe plastic deformation was studied by X-ray diffraction, transmission electron microscopy and magnetic property measurement methods. SPD of amorphous $Fe_{78}Si_{13}B_9$ alloy samples causes nanocrystallization with formation of Fe (Si) nanocrystals. Volume fraction of the nanocrystalline phase increases with deformation degree constituting more than 50% of the sample after the highest deformation level. The average size of the nanocrystals is 6 nm. After the deformation, numerous nanocrystals are combined into extended zones where the nanocrystals exhibit dominant crystallographic orientation (texture). The degree of dominant nanocrystal orientation in different regions of the sample is not constant. The dominant orientation of the SPD-formed nanocrystals is likely to be due to the fact that nanocrystals grow in the stress field whose characteristics vary insignificantly within a single electron microscopy sample. The formation of a large fraction of the crystalline phase should lead to a change of the magnetic properties of the samples. The formation of SPD-induced nanocrystalline structure increases saturation magnetization by 40% without appreciable changes of the coercivity. The achieved level of saturation magnetization of such an amorphous crystalline sample exceeds essentially that of FINEMET alloy.

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WE-39

Development of iron-based nanoparticles for Cr(VI) removal from drinking water

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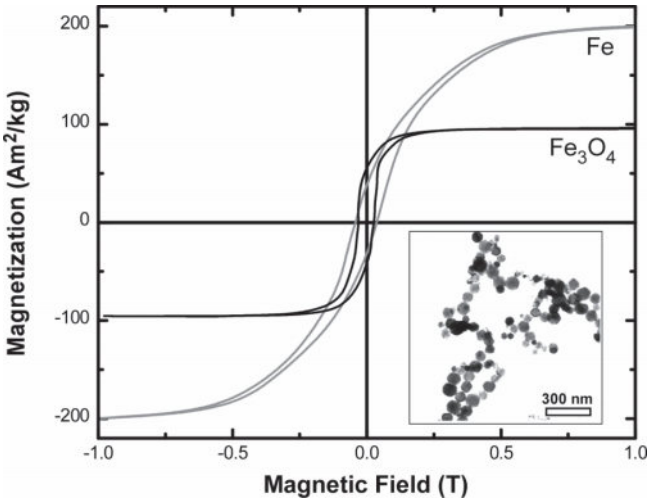
The presence of hexavalent chromium in aqueous systems has been recently become an intense problem due to the indications for harmful effects on human health and other life forms [1]. Adsorption on solid materials is considered as the simplest removal method in which chromium is loaded and generally strongly bonded on a compact adsorbent. The process can be alternatively take place by the reduction of a Cr(VI) and adsorption of Cr(III) specie. In this work, magnetic nanoparticles based on zero-valent iron (ZVI) and magnetite (Fe_3O_4) were tested as potential Cr(VI) adsorbents able to reduce Cr(VI) and subsequently immobilize the produced Cr(III) within their surface.
The studied samples were synthesized directly from the gas phase by using physical vapor deposition under inert atmosphere high vacuum conditions. This process has been developed at the PROMES facilities in Odeillo-Font Romeu using reactors working with concentrated sunlight (1 kW/m^2) in a solar furnace apparatus. The target was placed in the focus of the light concentrator and the evaporated fume was condensed in a nanoporous ceramic filter where the particles were collected. Structural analysis verified that the chemical composition of the target was preserved and spherical nanoparticles sized 50-80 nm were formed. The applicability of the nanoparticles as Cr(VI) adsorbents was evaluated by testing the hexavalent chromium removal potential under batch adsorption experiments in the concentration range 50-1000 μg/L Cr(VI). Eventually, due to the enhanced magnetic properties of the nanoparticles, their

effective recovery after water treatment by the application of a magnetic field was achieved.

[1] C.D. Palmer and P.R. Wittbrodt, Environ. Health Perspect. 92, 25 (1991)
[2] D. Mohan and C.U. Pittman Jr, J. Hazard. Mat. B137, 762 (2006)



Magnetic properties of iron-based magnetic nanoparticles prepared by solar physical vapor deposition

WE-40

Magnetic properties of C/Co/C/Co/C multilayers

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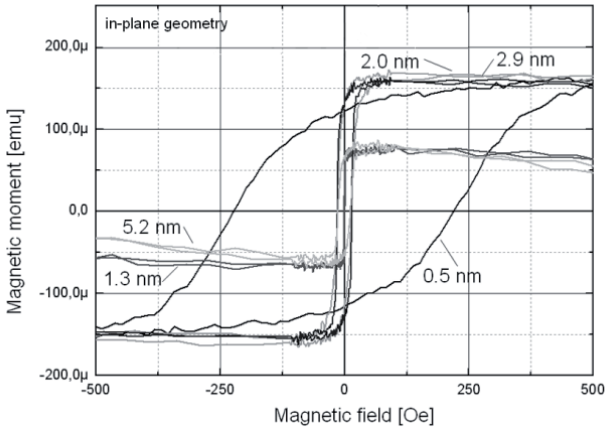
The cobalt-carbon multilayers are of a great practical interest, especially for soft X-ray range [1] as well as for novel applications [2]. Recently the important role of surface intermixing in ultrathin Co/C films and of Co-layer thickness was shown [3].
The magnetic properties of C/Co/C/Co/C multilayers (MLs) with various C and Colayers thickness have been studied by TKE spectrometry, SQUID and VSM magnetometry at 80300 K.
The MLs have been sputtered with DC magnetron, the thickness of Co layers was varied from 4 to 40 nm, and thickness of middle C layer was varied in the range 0.515 nm. The crucial role of C and Co layers thickness was revealed both for magnetic as well as for structural properties of MLs.
TEM, X-ray diffraction, and in-situ resistivity measurements revealed the metal layer being an amorphous cobalt-carbon alloy as a result of the layer intermixing for Co thickness < 5 nm. An avalanche crystallization of the amorphous alloy took place and monocrystalline hcpCo layers were formed for Co thickness > 5 nm.
Magnetic and magneto-optical properties of MLs have been studied in as-deposited state and after one hour annealing below crystallization temperature (250 °C). The one order increase of the coercitivity has been found for annealed samples in comparison with asdeposited films. The TKE spectra of the samples with Co thickness less than 5 nm have been found to be similar to the polycrystalline Co spectrum. Magnetic interaction between Co layers separated by amorphous carbon of different thickness is discussed.



M(H) curves at 300 K of C/Co/C/Co/C ML with various thickness of middle C layer

[1] I.A. Artyukov et al., Micron 41, 722 (2010)
[3] M. Gabureac et al., Nanotechnology 21, 115503 (2010)
[2] A. Zolotaryov et al., Phys. Status Solidi A 208, 1698 (2011)

WE-41

Creation of perpendicular magnetization state in Pt/Co/Pt nanostructures using femtosecond laser pulses

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Ultrathin cobalt layers exhibit a spin reorientation transition (SRT) – below a critical Co thickness the magnetization orientation changes from in-plane to out-of-plane. We present a possibility of creating a perpendicular magnetization state above the thickness of the SRT, by irradiating the Pt/Co/Pt sample with single femtosecond laser pulses. In the several-micrometers region limited by the size of the focused laser beam, the temperature rapidly increases, and due to diffusion and intermixing of Co and Pt atoms, CoPt alloy phases form with high magnetic anisotropy. This results in creation of an out-of-plane magnetization state. A similar effect has been recently reported for Pt/Co/Pt films irradiated by Ga+ ions [1].
We studied magnetic effects of such local laser annealing in detail, by means of magneto-optical Kerr effect (MOKE) microscopy. In this way we determined the magnetic remanence, coercivity and anisotropy field as a function of energy density deposited locally with the Gaussian-shape laser pulses.
Applying a simple model we estimated the temperature increase during the laser annealing process and we propose a qualitative description of laser-induced structural changes in the sample.

[1] A.Maziewski, et al. Phys. Rev. B 85, 054427 (2012)

WE-42

The Manipulation of Magnetostrictive Behaviour in Ni_xFe_{100-x} Multilayered Systems

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Many electrical devices require a form of magnetic shielding in order to redirect produced magnetic fields and avoid damage to components. One important application for shielding is in magnetic recording devices. Necessary for effective shielding, the material must have a high initial permeability, as well as a high saturation value. A close to zero magnetostriction is also desirable to avoid stress which may cause changes in the magnetic behaviour of the material. Ferromagnetic alloys, particularly NiFe, have been found to have good soft magnetic properties. Specific properties will reach an optimum depending on the Ni : Fe ratio in the composition. In an attempt to improve the magnetic properties, a multilayering technique with Ni_xFe_{100-x} is used. The multilayering technique is initially focused on interplay of positive and negative magnetostrictive compositions in an effort to achieve zero magnetostriction. Magnetostriction values of these films are determined through the use of magneto-optics by measuring the change in the anisotropy field as a result of applied strain.[1] Magnetostriction, compositional, magnetic and structural properties will be presented and results based on composition and thickness of layers will be analysed.

[1] M. P. Hollingworth and M. R. J. Gibbs, J. Appl. Phys. **94**, 7235 (2003)

WE-43

On the formation of magnetic nanocomposites and impurity complexes in GaN doped with Fe and Mn

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The control over the aggregation of magnetic ions in a non-magnetic semiconductor matrix constitutes a new way to realize semiconductor/ferromagnetic nanocomposites with hitherto unexplored but striking functionalities.

In this work we show, in the case of the model systems (Ga,Fe)N and (Ga,Mn)N, that there is a critical and systematic dependence of the crystalline structure, magnetic ion incorporation and macroscopic properties of these composite material systems on the fabrication conditions and co-doping with shallow impurities.

For phase-separated (Ga,Fe)N, we show that the controlled formation of various Fe-rich embedded nanocrystals with particular stoichiometry and magnetic properties, is responsible for the observed contributions to the overall magnetization of the layers, namely: (i) paramagnetic – due to dilute Fe^{3+}; (ii) ferromagnetic – stemming from FM ε-Fe_3N and γ'-Fe_4N; and (iii) a component linear in the magnetic field, associated with antiferromagnetic interactions – originating from Fe_xN ($x \leq 2$) [1]. Further, the effect of Mg co-doping and deposition mode on the Fe distribution is discussed, together with the ways to obtain a controlled and well-defined arrangement of single-phase Fe-rich nanocrystals embedded in the GaN host.

In the case of (Ga,Mn)N, we demonstrate that the co-doping with Mg allows to modify the charge – and spin-state of Mn via the formation of impurity complexes Mn-Mg_n, where *n* depends on the fabrication conditions. The significance of these results is discussed in view of prospects of embedded magnetic nanocrystals and impurity complexes for photonics and solotronics applications [2].

[1] A. Navarro-Quezada *et al.,* Phys. Rev. B. 84, 155321 (2011)
[2] P. Koenraad and M. Flatté, Nat. Mat. 10, 91-100 (2011)

WE-44

The influence of the anisotropic effect on the spin Hall effect studied using the effective mean-free-path model

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In presence of the spin Hall effect [1, 2], there exists the spin-dependent scattering, and also the spin accumulation. The resulting spin accumulation can be specified by the difference between the spin-up and the spin-down chemical potentials. The difference can be easily derived by using the effective mean-free-path model, which is equivalent to the Boltzmann transport equation model [3]. In this paper, a nonmagnetic thin film system both with the spin Hall effect and with the anisotropic effect is investigated by use of the effective mean-free-path model. The thin film has the mean free path λ and the width w along the y-axis. The parameter P is used to specify the spin accumulation along the y axis. Our theoretical results in Fig. 1 show that the spin accumulation will be localized near both side edges, when the thin film has a large ratio of w/ λ or has a large parameter a which is a measure for the anisotropy of the scattering.

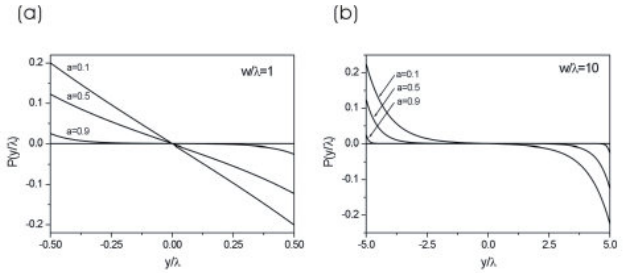

Figure 1: The relation of P(y/λ) versus a for (a) w/λ=1 and (b) w/λ=10.

[1] J. E. Hirsch, Phys. Rev. Lett. 83, 1834 (1999)
[2] Y. K. Kato, R. C. Myers, A. C. Gossard, and D. D. Awschalom, Science 306, 1910 (2004)
[3] S.-P. Chen and C.-R. Chang, Phys. Rev. B 72, 064445 (2005)

WE-45

Size dependence of the surface spin layer response in external applied field

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In our study we have focused on discrimination between the response of the core and the surface spins, respectively, in ensembles of monodispersed iron oxide (magnetite) nanoparticles under varying external magnetic field. The particle sizes ranging from 7 to 22 nm was found out to be nearly uniform (the particle size distribution below 0.2 nm) that gives an excellent opportunity to study the surface effects by means of the in-field Mössbauer spectroscopy at low temperatures.

In this case we can neglect the influence of the particle size distribution on the distribution of the hyperfine fields that causes the asymmetric broadening of the Mössbauer lines. Therefore; the varying external applied field from 0 to 6 T that led to the change of the Mössbauer line width (i.e. distribution of the hyperfine field) can be attributed to the relaxation of the surface spins into the direction of the external field. The effect was found to be more pronounced for the smaller particles, where the surface effects are more emphasized.

Moreover; the decreasing particle size causes the increasing oxidation of the surface layer to maghemite phase allowing better distinction of the surface-core contributions to the Mössbauer spectra. The surface effects were also supported by the non-saturation character of the magnetization isotherms.

WE-46

Fine structure of interface substrate-film transitional layer in RF-sputtered Bi-substituted iron-garnet films

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The RF-sputtered films of bismuth-substituted iron garnet are known to be the most promising magneto-optical (MO) material for applications in magneto-optical devices, magnetic photonic crystals, and photonics. The properties of substrate-film transitional layer determine the nanocrystalline structure and magnetic properties of all film volume because the crystallization processes begin in transitional layer.

In order to clarify this problem a set of RF-sputtered films of nominal composition $Bi_2Dy_1Fe_4Ga_1O_{12}$ and thicknesses of 1.7; 3.7; 10 and 50 nm were fabricated on $Gd_3Ga_5O_{12}$ (111) and glass (Corning 7059) substrates and characterized using magnetic circular dichroism (MCD) measurements over the spectral region 250-600 nm.

The as-deposited samples were subsequently crystallized through annealing for 1 hour at temperatures within an interval 540 - 580 °C. The measurements of MCD at room temperature revealed a small signal near 360 nm incompatible with MCD spectra of Bi-iron garnet for samples 1.7 and 3.7 nm thickness, and was typical for Bi-iron garnet MCD spectra for samples of 10 and 50 nm thickness when we used GGG substrates.

We didn't observe any MO activity in samples of thickness 1.7; 3.7 and 10 nm on glass substrates at room temperature and observed slightly changed MCD spectral dependence for film of 50 nm thickness.

Low-temperature (down to 8 K) MCD measurements on samples of thickness 3.7 nm revealed typical Bi-iron garnet MCD spectra in the temperature interval 150 – 8 K with Curie temperature near 180 K and independence of MCD value at peak position near 440 nm on temperature between 8 and 100 K. This means that most part of the film's volume had Ga content near 2.5 formula units.

[1]. A. K. Zvezdin, V. A. Kotov, "Modern Magnetooptics and Magnetooptical Materials", Institute of Physics Publishing. Bristol and Philadelphia. (IOP Publishing Ltd.) (pp. 386) 1997, ISBN 0 7503 0362 X.

WE-47

Growth of Ti doped half-metallic Fe_3O_4 thin films diposited on $SrTiO_3$, Al_2O_3, Si, and Float Glass substrates

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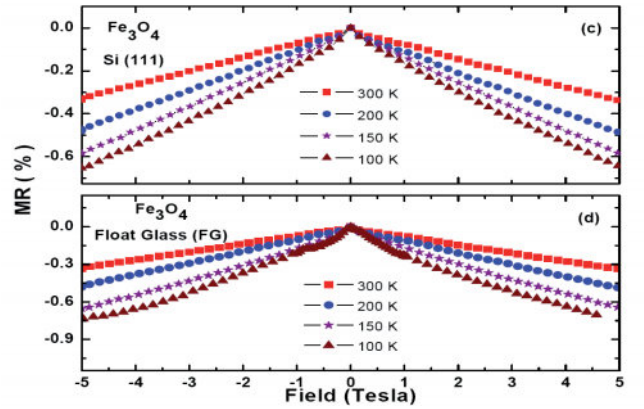
We investigate the effects of Ti doping on the structural and transport properties of half metallic Fe_3O_4 films grow on varying substrates [$SrTiO_3$ (100), Al_2O_3 (0001), Si (111), and Float Glass (FG)] by pulsed-laser deposition technique (PLD). The structural properties of Ti doped Fe_3O_4 are investigated through X-ray diffraction (XRD) pattern, which infers that parent and Ti doped magnetites are grown in single phase with (111) orientation for all the substrates. The doped films not exhibit a metal–insulator Verwey transition as compared to that of undoped Fe_3O_4 films. The Verwey transition temperature for Fe_3O_4 thin films are 121 K (Float Glass), 123 K ($SrTiO_3$), 123 K (Al_2O_3) and 120 K (Si). The transport properties of the doped films are markedly sensitive to the Ti doping concentration. Raman spectra infer the formation of magnetite phase through out all samples $Fe_{3-x}Ti_xO_4$ (x = 0 and 0.0206). Magnetoresistance (MR) curves show linear magnetic field dependence for the undoped films, while an increase in MR and departure from linear field dependence is observed for Ti-doped films. The Magnetoresistance (MR) curves show highest change in MR for doped and undoped films are in Al_2O_3 (0001) substrate. For parent Fe_3O_4 films MR is of -0.48% at room temperature which increases below the Verwey transition up to -1.12% at 100 K, while in Ti doped films MR is of -1.56% at room temperature which increases up to -3 %.

[1] Deepak Venkateshvaran, Matthias Althammer, Andrea Nielsen, Stephan Geprägs, M. S. Ramachandra Rao, Sebastian T. B. Goennenwein, Matthias Opel, and Rudolf Gross, *Phys. Rev. B* **79** 134405 (2009).



[2] S. B. Ogale, K. Ghosh, R. P. Sharma, R. L. Greene, R. Ramesh, and T. Venkatesan, *Phys. Rev. B* **57** 7823 (1998).

WE-48

Structure and magnetic properties of UO_2/Fe_3O_4 thin films

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Uranium compounds where the magnetism is determined by the state of 5*f* electrons are rather exotic and interesting objects of study [1]. Uranium dioxide UO_2 is an antiferromagnet with Néel temperature T_N = 30.8 K [2]. It plays an important role in science and technology, and investigation of its magnetic properties in a low-dimensional state is an attractive task. In the present work, the research is conducted on antiferromagnetic/ ferromagnetic UO2/Fe3O4 heterostructures separated by Au spacer with various thicknesses of the layers. The samples are grown by reactive sputter deposition and attested by X-Ray Photoelectron and micro Raman spectroscopy, HRXRD (High-Resolution X-ray Diffraction) and magnetic methods using a vibrating sample magnetometer and a SQUID magnetometer (Quantum Design). The exchange coupling mechanism was investigated by measuring the temperature evolution of the hysteresis loops under various cooling conditions. The magnetic properties of the $UO_2/Au/Fe_2O_4$ samples were compared to that of the UO_2/Fe_2O_4 bilayers in order to clear up the effects of a non-magnetic spacer layer on the exchange coupling mechanism.

[1] V. Sechovsky, L. Havela, in: Magnetic Materials, K.H.J. Buschow (Ed.), Elsevier, Amsterdam, 1998, Vol. 11, p. 1.
[2] P. Santini et al., Rev. Mod. Phys. 81, 807 (2009).

WE-49

Domain structure and the magnetization process in Ni/Cu multilayers studied by MFM

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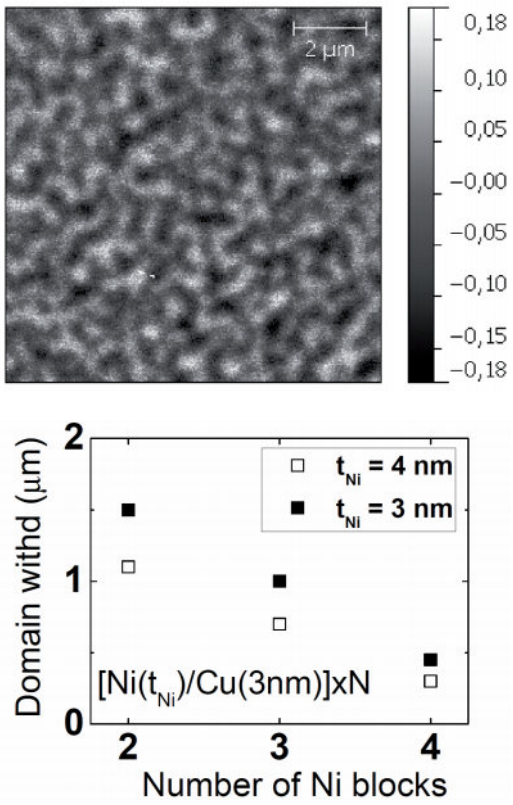
Structures with perpendicular magnetic anisotropy are involved in spintronic devices forming functional elements. These kind of systems show complex domain structures that control the magnetization process [1,2]. Thus, stripe or maze domain structures are found in Co/Pt multilayers with a large number of repeats [3] and in thick Ni films with effective in-plane anisotropy because of a weak perpendicular magnetic anisotropy induced by the residual stress in the Ni layer [2]. Here, we study epitaxial structures [Cu(3 nm)/Ni (t_{Ni})]xN, with t_{Ni} = 3 and 4 nm, and N ranging from 1 to 5. Single Ni films have a strong perpendicular anisotropy with large remanence and negative nucleation field. We show that as N increases, the remanence decreases, the nucleation field shifts to positive values and domain patterns change from an irregularly spotted structure to maze domain patterns, with values for the domain width that decrease linearly with N. The magnetization process, for H applied perpendicularly to the plane, takes place through the nucleation of a maze domain state, while if H is applied along the film plane the maze domain structure remains with minor changes up to field values as large as 1.2 kOe.

[1] Joseph E. Davieset al Phys rev B 70 224434 (2004)
[2] M. Marioni et al Phys. Rev. Lett. 97, 027201 (2006)
[3] O. Hellwig et al J. Mag. Mag. Mat. 13, 310 (2007)



Caption (Left)MFM image of a [Ni(4nm)/Cu(3nm)]x4.structure. (Right) Variation of the domain width with the number of Ni blocks.

WE-50

Magnetization processes in antiferromagnetic Ni/Cu/Ni(100) trilayers

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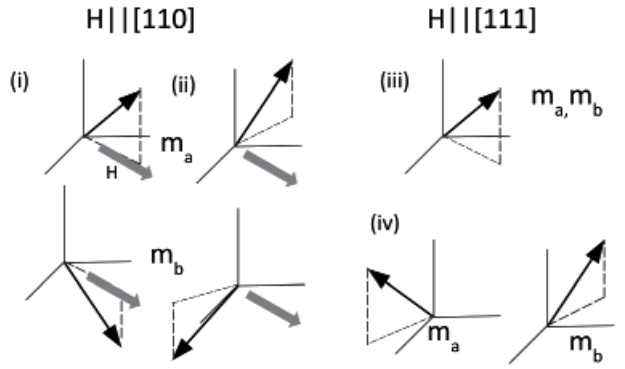
We present the analysis of the hysteresis loops in a (001) Ni(2nm)/Cu(1.1nm)/Ni(2nm) epitaxial structure. The nickel blocks thickness is set to a value for which the in-plane and out-of-the plane magnetic anisotropy contributions are balanced out ($K \approx 0$) [1] and the copper thickness corresponds to a value with large antiferromagnetic interlayer exchange coupling coefficient J [2]. The M-H loops taken along the in-plane [100] and [110] directions and the <111> axis show negligible remnant magnetization with transitions of M for H around 50 Oe that disappear if the angle between H and the film normal is below 40 degrees. Micromagnetic calculations of the M-H loops, with K = 0, J = - 5×10^{-6} J/m^2 and K_{cub} ≈ -10 kJ/m^3 (the magneto-crystalline cubic constant), show how the magnetization vector changes in each Ni block , $\mathbf{m}_a$ and $\mathbf{m}_b$. Thus, decreasing H from saturation, along the in-plane [110] or [100] directions, produces a remanent state consisting of collinear and anti-parallel $\mathbf{m}_a$ and $\mathbf{m}_b$ along a <111> direction (see figure). For H along [111] the observed jump is due to a reorientation of $\mathbf{m}_a$ and $\mathbf{m}_b$ along not collinear <111> directions: $\mathbf{m}_a$ and $\mathbf{m}_b$ || [111] move to $\mathbf{m}_a$|| [$\underline{1}$11] and $\mathbf{m}_b$ || [1$\underline{1}$1]. For H along the film normal, $\mathbf{m}_a$ and $\mathbf{m}_b$ rotate smoothly and symmetrically with respect to H.

[1] K. Ha et al, J. Appl. Phy, 85,2688 (1999)
[2] M. T. Johnson et al, Phys. Rev. Lett. 68, 2688 (1992).



Caption. Sketch of the spin configuration in each block ($\mathbf{m}_a$ and $\mathbf{m}_b$) for the field applied along the [110] and [111] directions: before, (i) and (iii), and after, (ii) and (iv), the field had induced a flip of M.

WE-51

Ga^+ ion-induced changes in magnetic anisotropy of Pt/Co/Pt thin films studied by x-ray magnetic circular dichroism

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Plenty of efforts have been made to realize perpendicular magnetic anisotropy (PMA) in thin films and multilayers, in view of the application to high-density magnetic recording media. Among them, the control of magnetic anisotropy by ion irradiation has attracted much interest in this decade, due to a possibility of nanostructure patterning by using a focused ion beam. In fact, a Ga^+ ion-induced spin reorientation transition to perpendicular magnetization from an in-plane magnetized Pt/Co/Pt thin film has been reported at medium ion doses in the 10^{14} ions/cm^2 region [1]. Although the film exhibits in-plane magnetization at higher doses, it has very recently revealed that PMA appears again at much higher ion doses in the 10^{15} ions/cm^2 regions [2].

In the present study, we performed x-ray magnetic circular dichroism (XMCD) experiments to clarify the origin of the Ga^+ ion irradiation-induced changes in magnetic anisotropy of aPt/Co/Pt thin films in a wide range of the ion dose. The XMCD analysis shows a larger orbital magnetic moment of Co in the out-of-plane direction compared with that in the in-plane direction at the first PMA region with medium ion doses. On the other hand, for the second PMA region with higher ion doses, no significant difference in the orbital moments is found, suggesting a different origin for the appearance of PMA.

[1] J. Jaworowicz, A. Maziewski, P. Mazalski, M. Kisielewski, I. Sveklo, M. Tekielak, V. Zablotskii, J. Ferre, N. Vernier, A. Mougin, A. Henschke, and J. Fassbender, Appl. Phys. Lett., **95**, 022502 (2009).
[2] A. Maziewski, P. Mazalski, Z. Kurant, M. O. Liedke, J. McCord, J. Fassbender, J. Ferre, A. Mougin, A. Wawro, L. T. Baczewski, A. Rogalev, F. Wilhelm, and T. Gemming, Phys. Rev. B **85**, 054427 (2012).

WE-52

Alteration of magnetic anisotropy of Pt/Co/Pt trilayers by FIB irradiation

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Investigation of the magnetic thin film structures with the out-of-plane magnetization are important for both fundamental research and applications. In nanostructures with decreasing magnetic film thickness an out-of-plane alignment of magnetization is frequently observed due to increasing contribution of surface anisotropy. It has been shown that ion beam irradiation modifies magnetic properties of such structures [1, 2]. With increasing irradiation dose D of such films the strength of perpendicular anisotropy is suppressed, magnetization rotates towards in-plane alignment or

ferromagnetic ordering is converted to the superparamagnetic state. Very recently an oscillatory behaviour of magnetic anisotropy between the in-plane and out-of-plane states driven by an increasing dose of 30 keV Ga^+ ion homogenous irradiation, has been observed in the molecular beam epitaxy (MBE) deposited Pt/(Co 3.3 nm)/Pt films [3].
The aim of this work is investigation of local modifications of magnetic properties in MBE grown Mo/Pt(20nm)/(Co3.3nm)/Pt(5nm) films by a focused ion beam (FIB). In the studied as deposited structure magnetization was aligned in the film plane. Numerous spots of the sample (squares 100x100μm^2 or 50x50μm^2) have been locally irradiated with Ga^+ ions with energy of 30 keV and different doses *D* ranging between $2{\cdot}10^{12}$ and $1{\cdot}10^{16}$ ions/cm^2. FIB irradiated spots were probed using polar/longitudinal Kerr effect magnetometry (sensitive to perpendicular/longitudinal magnetization component) and atomic/magnetic force microscopy techniques. Creation of the two out-of-plane magnetization branches upon increasing FIB irradiation dose *D* was observed, similarly to the effect reported for homogenous irradiation [3].
Presented results seem to be promising for new method for magnetic nanostructure patterning.

[1] C. Chappert et al., Science 280, 1919 (1998).
[2] J. Fassbender et al., J. Magn. Magn. Mat. 320, 579 (2008).
[3] A. Maziewski et al., Phys. Rev. B 85, 054427 (2012).

WE-53

Ga^+ ion-induced lattice distortion and magnetic anisotropy in Pt/Co/Pt thin film

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Plenty of efforts have been made to realize perpendicular magnetic anisotropy (PMA) in thin films and multilayers, in view of the application to high-density magnetic recording media. Among them, the control of magnetic anisotropy by ion irradiation has attracted much interest in this decade, due to a possibility of nanostructure patterning by using a focused ion beam. In fact, a Ga^+ ion irradiation-induced spin reorientation transition to perpendicular magnetization from in-plane magnetized Pt/Co/Pt thin films has recently been reported both at medium [1,2] and high [2] ion doses, which are in 10^{14} and 10^{15} ions/cm^2 regions, respectively.
In this contribution, we perform x-ray magnetic circular dichroism (XMCD) and extended x-ray absorption fine structure (EXAFS) experiments to investigate Ga^+ ion irradiation-induced changes in magnetic anisotropy and crystalline structure of a Pt/Co/Pt thin film. The XMCD analysis shows a large positive magnetic anisotropy energy (MAE), which corresponds to PMA, at moderate ion doses of $1.5*10^{14}$ ions/cm^2, while further doses decrease the MAE. The Co K-edge EXAFS analysis shows that enhancement of PMA is directly related to an in-plane lattice expansion caused by ion irradiation-induced elimination of Co atoms and/or Co-Pt intermixing, which results in a large lattice distortion. Further doses cause both in-plane and out-of-plane lattice expansions resulting in an isotropic structure, which would decrease PMA.

[1] J. Jaworowicz, A. Maziewski, P. Mazalski, M. Kisielewski, I. Sveklo, M. Tekielak, V. Zablotskii, J. Ferré, N. Vernier, A. Mougin, A. Henschke, and J. Fassbender, Appl. Phys. Lett. 95, 022502 (2009)
[2] A. Maziewski, P. Mazalski, Z. Kurant, M. O. Liedke, J. McCord, J. Fassbender, J. Ferré, A. Mougin, A. Wawro, L. T. Baczewski, A. Rogalev, F. Wilhelm, and T. Gemming, Phys. Rev. B 85, 054427 (2012)

WE-54

Perpendicular CoFeB/MgO/CoFeB-based magnetic tunnel junctions with [Co/Pd]n multilayer films

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The magnetic tunnel junctions with perpendicular magnetic anisotropy (pMTJs) are being of great interest due to they could have a high potencial for STT-MRAM with low critical curretn I_c and high thermal stability [1]. A promising candidate for PMA films in MgO-based pMTJ is using Co-based multilayer films, such as $[Co/Pt]_n$ or $[Co/Pd]_n$ [2]. Moreover, recently, PMA was reported in Ta/CoFeB/MgO/CoFeB-based MTJ [3], where Ta/CoFeB interface has substantial PMA and the Ta seed is essential for obtaining perpendicular films. In this work we have developed a CoFeB/MgO/CoFeB-based pMTJ using [Co/Pd] multilayer films. First, different thicknesses for Co and Pd are used [Fig. 1(a)], then, several alternation periods (n) of synthetic antiferromanetic coupled reference layer are studied [Fig. 1(b)], and finally, two annealing conditions are presented [Fig. 1(c)]. With all those studies, we found that the [Co 0.3nm/Pd 0.8nm]$_5$ multilayer is the best option for antiferromagnetic coupled reference layer. Then, a pMTJ stacking of SiO_2/seed layer/CoFeB/MgO/CoFeB/Ta/$[Co/Pd]_5$/Co/Ru/$[Co/Pd]_{12}$/top contact [4], was prepared by sputtering at room temperature. The AGM results of our pMTJ stack, where the magnetic fields were applied perpendicular to film plane, are shown in Fig. 1(d). Here it´s seen that all magnetic films including the CoFeB are perpendicularly magnetized. The transport properties (as determined by the CIPT technique) on pMTJ's were also investigated.

[1] T. Kishi et al., IEDM Tech. Dig., 309 (2008).
[2] K. Yakushiji, T. Saruya, H. Kubota, A. Fukushima, T. Nagahama, S. Yuasa, and K. Ando, Appl. Phys. Lett. 97, 232508 (2010).
[3] S. Ikeda, K. Miura, H. Yamamoto, K. Mizunuma, H. D. Gan, M. Endo, S. Kanai, J. Hayakawa, F. Matsukura, and H. Ohno, Nature Mater. 9,721 (2010).
[4] D. C. Worledge,a_ G. Hu, David W. Abraham, J. Z. Sun, P. L. Trouilloud, J. Nowak, S. Brown, M. C. Gaidis, E. J. O'Sullivan, and R. P. Robertazzi, Appl. Phys. Lett. 98, 022501(2011)

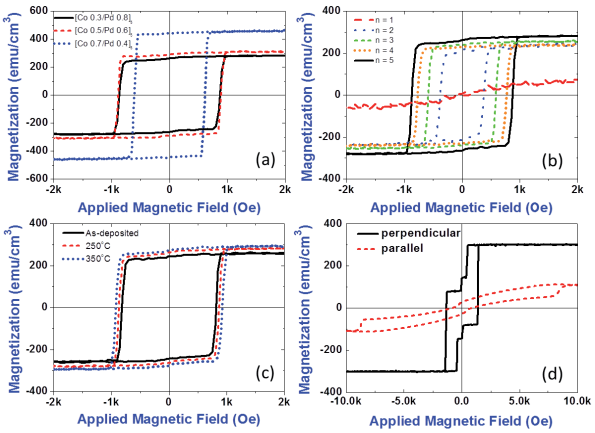

Fig. 1 M-H loops to optimize the $[Co/Pd]_n$ multilayer used as antiferromagnetic coupled reference layer in pMTJs. The stacking used for this study was SiO2/Seed/Pd 2/$[Co/Pd]_n$/Co 0.3/Ta 5. (a) Different thicknesses for Co and Pd at $[Co/Pd]_5$ multilayer are used. (b) Several alternation periods (n) in $[Co\ 0.3/Pd\ 0.8]_n$ multilayer. (c) Two annealing condition using $[Co0.3/Pd0.8]_5$. (d) M-H loop for CoFeB/MgO/CoFeB-based pMTJ using [Co0.3/Pd0.8] multilayer films. All the thicknesses are given in nm.

WE-55

Irradiation effect on anisotropy axis of bilayers

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A magnetization study of Fe/Co bilayers prepared by ion beam sputtering on Si substrate has been investigated in order to probe the effect of nitrogen ion irradiation at the interface. The in-plane remnant magnetization and coercivity for the pristine sample was found to exhibit two fold uniaxial symmetry as compare to irradiated sample indicating deviation from two fold symmetry suggesting modification of magnetic structure at the interface. The out of plane measurement has shown hysteresis loop in both the cases indicating the presence of some out of plane magnetization also, which get slightly modified by nitrogen irradiation with decrease in magnetization.

WE-56

Co/Au multilayers for possible spin transfer torque applications

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Spintronic devices based on spin transfer torque (STT) can be realized as double spin valves that consist of a polarizer, a free layer and a second polarizer that serves also as analyzer. Much attention is paid to spin valves with a polarizer that has a perpendicular anisotropy. Spin valves with perpendicularly magnetized polarizer can provide sub-nanosecond switching times [1].
We prepared a series of double spin valves with perpendicular anisotropy for possible applications in STT experiments. A single spin valve consists of several Co and Au layers that form the polarizer, the free layer and the analyzer. By varying thickness of Co and Au, we fabricated the structures in which polarizer has the perpendicular anisotropy, while the rest of the structure possesses in-plane anisotropy. A typical double spin valve consists of a (Co 0.8 nm/Au 0.5-2 nm)×3 multilayer as the polarizer and two Co layers (1.5-10 nm) with in-plane anisotropy.
We determined magnetic parameters like surface (0.4 erg/cm^2), bulk anisotropy (6×10^6 erg/cm^3) and FMR linewidth using broadband ferromagnetic resonance (VNA-FMR). We observed that FMR linewidth for in-plane Co layers does not depend on frequency. A Ti4/Au60/(Co0.8/Au1)×3/Au2/Co1.5/Au2/Co3/Au5 structure shows the best magnetic characteristics for possible applications in STT.

[1] A. D. Kent et al., Appl. Phys. Lett. 84, 3897 (2004)

WE-57

Investigation of in-plane magnetic anisotropy across the wedge-shaped Au/Co/Au heterostructure

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Magnetic anisotropy plays an important factor determining the applicability of ultrathin ferromagnetic films. The understanding of magnetic anisotropy and its relationship with film properties such as morphology and crystal structure, plays an important role in the description of the magnetic behavior of ultra-thin films. For purposes of this study, the in-plane magnetic anisotropy of ultra-thin Co wedge-shaped films, epitaxially grown on Au(111) and covered by a cap gold layer, was determined by means of ferromagnetic resonance measurements. Uniaxial and unidirectional contributions of the in plane anisotropy were extracted from the angular resonance-field dependence. It was found that: (i) the uniaxial component is dominant and (ii) the easy axis of magnetization vector is located in the Co layer with direction parallel to the wedge edge. A comparison of the obtained results with earlier data on Co anisotropy will be presented.

WE-58

Perpendicular magnetic anisotropy in MBE grown Co/Ni(111) superlattices

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Magnetization in Co/Ni (111) superlattices grown by Molecular Beam Epitaxy is perpendicular to the plane for a Co thickness range between 0.2 and 4 ML [1]. This system is particularly interesting to study spin transfer in devices since the critical currents are strongly decreased compared to devices with in-plane magnetization [2]. In this contribution, we make a review on the structural and magnetic properties of these Co/Ni(111) single-crystalline layers. First, the possibility of a magnetostrictive contribution is analysed by using both Transmission Electron Microscopy and X-Ray diffraction. The TEM strain analysis of

a (Co/Ni)/Au/(Co/Ni) (111) spin valve shows that the (Co/Ni) superlattices are not strained by gold (incommensurate growth), leading to a small magnetoelastic contribution. However, an interface magnetoelastic contribution cannot be excluded, since the interface magneto-elastic energy term is similar to the Neel type interface anisptropy term. Second, the atomic moments of both Co and Ni were determined by using XMCD experiments performed at ALS in Berkeley. The perpendicular anisotropy (PMA) is linked to an increase of the perpendicular orbital moment of Co, whereas no effect was observed for Ni. Moreover, we explain why the PMA is lower in sputtered films compared to MBE. Third, The spin polarization was also analysed by using spin polarized photoemission. The experiments were performed on the CASSIOPEE beamline at SOLEIL synchrotron. The samples were epitaxially grown in a MBE chamber coupled to the beamline. The polarization measured for the whole BZ is found to be around 65%. Finally, CIP and CPP magneto-transport measurements allow us to confirm that this system is a very good candidate for spin transfer torque devices.

[1] – S. Girod *& al*, Appl. Phys. Lett., 94, (2009), 262504
[2] – S. Mangin *& al,* Nature Mater. **5**, 210 (2006).
[3] – M. Gottwald *& al*, Materials Science and Engineering 12 (2010) 012018

WE-59

Structure evolution and magnetic properties of annealed nanoscale Gd/Ti multilayers

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The magnetic properties of nanostructured ferromagnetic materials show strong dependence on the microstructure [1]. This connection is important both in fundamental and applied science. For example, nanostructured Gd has different magnetocaloric behavior when compared with the bulk counterparts [2-3]. Magnetron sputtering deposition of the nanoscale Gd multilayeres is a simple way to get gadolinium in nanocrystalline state. Moreover, controlled heat treatment is an additional way to change of the structure of the samples toward a desired state.
In this work the structure and magnetic properties were comparatively analyzed for Gd/Ti multilayers prepared by dc magnetron sputtering. The thickness of the Gd layers was varying from 0.9 nm to 12 nm and the thickness of Ti spacers was changed in the interval of 0.5 nm to 2 nm. Heat treatments of the multilayers were carried out in a vacuum at temperatures up to 400 °C.
For all annealed samples X-ray diffraction data indicate an evolution of the structure, Gd nanocrystalline grain size increase and segregation process for the Gd and Ti phases as the annealing temperature grows up. The temperature dependence of magnetization (M) for as deposited Gd/Ti multilayes is characterized by flattened shape of the $M(T)$ curve comparing with $M(T)$ curve of the bulk Gd. Annealing changes the shape of the $M(T)$ curves making it more complex and causes an increase of the magnetic ordering temperature of multilayers.
We discuss the relations between structural features and magnetic properties of Gd/Ti nanoscale multilayers.

[1] F. Döbrich et al., Phys. Rev. B. Appl. Phys. 85, 094411 (2012)
[2] D.G. Neerinck et al., J. Appl. Phys. 107, 09A903 (2010)
[3] A.V. Svalov et al., Phys. Status Solidi A 208, 2273 (2011)

WE-60

Magnetoimpedance in multilayered $Ni_{81}Fe_{19}$/Cu films electrodeposited on Cu microwires

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Electrodeposited cylindrical magnetic films deposited on non-magnetic wires are good candidates to produce magnetoimpedance (MI) based devices as they allow to tailor the MI ratio as well the Z vs. H curves yet making use of the convenient cylindrical geometry. In this work, multilayered $Ni_{81}Fe_{19}$/Cu films were produced by electrodeposition on copper microwires with a diameter of 120um. The thickness of magnetic layers varies from 80 nm to 950 nm and copper thickness varies from 0.7 nm to 3.8 nm, while the number of bilayers was kept between 40 and 80. The static magnetic properties for these samples were investigated with a VSM magnetometer operating in a field range of -300 Oe to 300 Oe. The magnetization dynamics and magnetoimpedance were studied with a coaxial waveguide, where the sample plays the role of the inner conductor, using a Rohde & Schwarz ZVA24 Vector Network Analyzer, in the frequency range of 0.1 GHz to 7 GHz and fields from -300 Oe to 300 Oe. A de-embedding procedure was used for extract the sample impedance and remove the effects of the sample holder from the data. Magnetization measurements showed low coercive fields in all samples, in the order of 2 Oe. The shapes of the curves show an increase in the demagnetizing field with increasing thickness of $Ni_{81}Fe_{19}$ layers. The high-frequency measurements showed a strong dependence of the magnetoimpedance with skin effects and ferromagnetic resonance. It was measured magnetoimpedance ratios in the order of 125%. The linewidths obtained from ferromagnetic resonance spectra were large for all the samples, indicating a high anisotropy dispersion, which decreases with an increment of the $Ni_{81}Fe_{19}$ thickness. The increase of copper thickness resulted in a small increase in the linewidth, possible related to the increase of the roughness at permalloy/Cu interfaces.

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC SHAPE MEMORY, MAGNETOELASTIC AND MULTIFUNCTIONAL MATERIALS

Chair: S. Fähler

WE-61

Structural modulation in Ni-Mn-Ga ferromagnetic shape memory alloys: new aspects of martensitic transformation

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Ferromagnetic shape memory Ni-Mn-Ga Heusler alloys are frequently characterized by structural modulation in martensitic phases. Currently, modulated martensitic phases, showing the higher magnetic field induced strain (MFIS) performance, are the most promising candidates for novel actuation devices. The periodic length of modulation, associated to satellites spacing in diffraction patterns, depends from the Ni-Mn-Ga composition, as well as pressure and temperature conditions. Ni-Mn-Ga modulated martensitic structures have been observed and classified depending upon the corresponding ideal nM superstructures based on fundamental distorted lattices. So far, a series of different interpretative models of such complex crystal structures were suggested [1,2]. Conversely, it has been demonstrated that such structural modulation, consisting of shuffling of atomic layers along defined crystallographic directions, is incommensurate and the corresponding crystal structures have been fully determined by Rietveld refinement of powder diffraction data. The structural results converge to a unified crystallographic description of the modulated martensitic structures, where every different nM periodicity can be straightforwardly represented. On the other hand martensitic transformation is a complex process essentially involving two levels: lattice deformation with structural modulation and the occurrence of a typical microstructure associated to a diffuse multi-twinning. The mapping of the populations of twins and related boundaries can be accomplished if based on the detailed knowledge of the martensitic crystal structures. The extended study of martensitic microstructure allows to clarify some fundamental aspects related to the MFIS effect.

[1] J.Pons, V.A. Chernenko, R. Santamarta, E. Cesari, Acta Mater. 48, 3027 (2000)
[2] S. Kaufmann, U.K. Rößler, O. Heczko, M. Wutting, J. Buschbeck, L. Schltz , S. Fähler Phys. Rev. Lett. 104, 145702 (2010)

WE-62

Autonomous generator based on Ni-Mn-Ga microactuator as a frequency selective element

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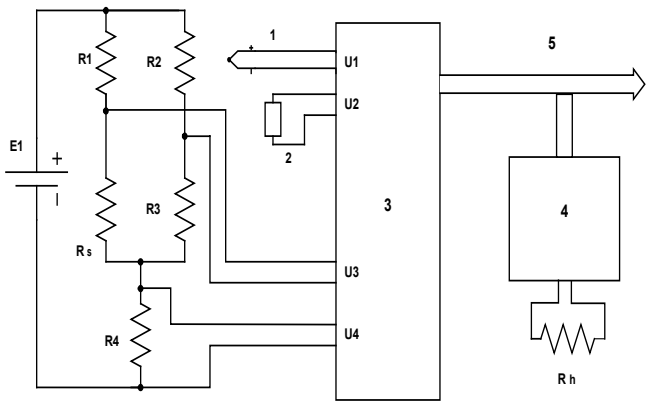
Ni-Mn-Ga alloys are multiferroics as they exhibit two types of the strongly correlated long-range order: ferroelasticity and ferromagnetism. The martensitic transformation (MT) exhibited by these materials is a core ingredient of their extraordinary properties and multifunctionality. Particularly, the magnetoelastic, ordinary shape memory, and magnetoresistance actuation mechanisms have been already implemented into the prototype devices [1].
In the present work, the N-shaped resistivity vs temperature change at MT in a polycrystalline $Ni_{52}Mn_{24}Ga_{24}/Al_2O_3$-5micron-thick film composite was utilized as an actuation mechanism for design of novel autonomous generator. Block diagram is shown in figure, where a Wheatstone bridge consisting of NiMnGa microactuator element (R_s) and resistors R1-R3, heater (R_h), thermocouple (1), thermometer (2), digital-analog conversion modules (3), relay (4) and the interface (5) are depicted. We set the working temperature range of R_s element corresponding to its MT temperatures: M_f=313.2K (the heater turns on) and A_f=323.3K (the heater turns off). Thermal cycling between these temperatures brings a device into the stable regime (amplitude, period and waveform). We found that the heating power tunes an output frequency. In the current work, for three values of heating power of 1.125 W, 0.91 W and 0.72 W, the signal frequency was measured to be equal to 0.008 Hz, 0.011Hz and 0.014 Hz, respectively. The oscillator characteristics can be controlled by the magnetic field and/or mechanical stress.

[1] D. Auernhammer et al., Smart Mater. Struct. 18,104016 (2009).



Block diagram of autonomous generator

WE-63

Theoretical study of twin boundary motion in Heusler Ni-Mn-Ga shape memory alloys using Monte Carlo method

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Ferromagnetic Heusler Ni-Mn-X (X=Ga, In, Sn, Sb) alloys

have attracted much attention in view of their unique properties such as the shape memory effect which can be controlled by an external magnetic field, giant magnetocaloric effect etc. [1-3]. In this work we study the twin boundary motion in Ni-Mn-Ga alloys. We propose the microscopic model in which the real tetragonal lattice of Heusler alloys is used. We consider two variants of the low temperature martensite which divided by twin boundary. We have chosen the Heisenberg model for description of magnetic subsystem and Blume-Emery-Griffiths model for description of structural subsystem with magnetostructural interaction between these subsystems and external magnetic field and anisotropy. The magnetic exchange constants were calculated by first principles. In the proposed model we have used the parameters for Ni_2MnGa alloy. The calculations were carried out by the Monte Carlo method. Our simulations have shown that the external magnetic field leads to moving of twin boundary at constant temperatures. The motion of twin boundary undergoes during transformation an unfavorable martensitic variant in another variant, which has the same direction as the external field. The transformation of the initial twin structure to the one tetragonal martensitic variant occurs at the magnetic field which closes to the experimental one. The velocity of twin motion depends on the temperature and magnetoelastic constants. Moreover it is shown the accounting of the magnetoelastic coupling leads to the synchronous and symmetrical behavior of spins and strains in the martensitic variants under an external field. It should be noted the theoretical motion of twin boundary has the same trend as experimental observations [1].

[1] A.A. Likhachev, K. Ullakko Phys. Lett. A 275 (2000) 142.
[2] P. Entel et. al. Mater. Sci. Forum 583 (2008) 21.
[3] T. Krenke et al. Phys. Rev. B 73 (2006) 174413.

WE-64

Surface study of electronic and structural properties of Ni-Mn-Ga(100) shape memory alloys

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In our work we address the preparation of high-quality surfaces of Ni-Mn-Ga single crystals as well as of epitaxial Ni-Mn-Ga films with different compositions in ultra-high vacuum (UHV) conditions by means of repeated cycles of Ne+-sputtering and annealing. The investigation of the (001)-oriented sample surface was carried out at different temperatures in both the austenitic and the martensitic phase. The surface structure down to the atomic scale was studied by variable temperature scanning tunnelling microscopy (VT-STM). Additionally the electronic structure was studied by means of ultraviolet photoemission spectroscopy (UPS) and scanning tunnelling spectroscopy (STS).
In the martensitic state the samples reveal on the nanometer scale a pronounced surface corrugation which was shown to arise from the modulated superstructure in martensites [1]. For off-stoichiometric samples with 7M martensitic phase varying modulation periodicities with a clear stacking profile were found. Atomically resolved pictures reveal atomic rows stacked in sequences with varying periods and occasional stacking faults. Additionally the UPS spectra show pronounced features near the Fermi level which are similar to those of the DOS calculated for the NM $L1_0$ structure [2]. This findings support the theory of adaptive martensites, which describes the modulated 7M phase as consisting of nanotwinned NM variants [3].
On the other hand the stoichiometric single crystal with the 5M modulated martensitic phase shows a very regular modulation periodicity without any stacking faults and a different shape of the modulation corrugation revealing a harmonic wave displacement of the atomic planes for this crystal structure.
This work was supported by the BMBF-Projects MSM-Sens 13N10061 and 13N10062.

[1] P. Leicht et al., New J. Phys. 13, 033021 (2011).
[2] P. Entel et al., Materials Science Forum Vol. 635, 3 (2010).
[3] S. Kaufmannet al., Phys. Rev. Lett. 104, 145702 (2010).

WE-65

Preparation and characterization of NiMnGa thin films

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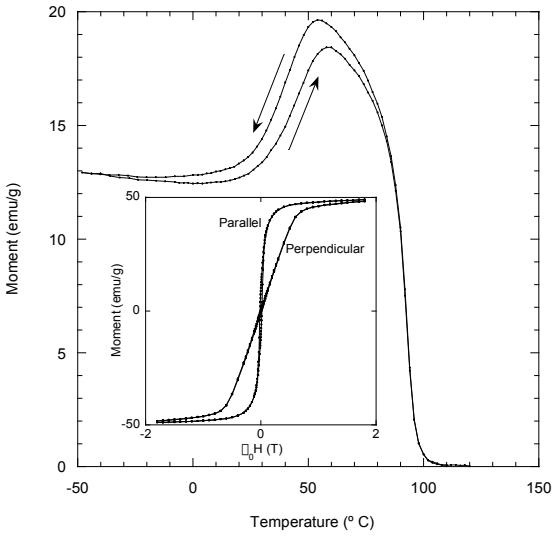
Ferromagnetic shape memory alloys (FSMAs), such as NiMnGa, show interesting physical properties related to their magneto-structural coupling and martensitic transformation. In martensitic phase, due to the twin variant reorientation, FSMAs can strain up to 10% under magnetic field in miliseconds, allowing high frequency applications. These features, together with the large energy to mass ratio, make FSMAs suitable for microscale actuation or sensing devices. For such dimensions, the thin film form of these alloys has revealed the expected functionality.
In this work, we use magnetron DC sputtering to manufacture thin films of NiMnGa onto heated single crystalline MgO and Si/SiO_2 substrates. Several sputtering targets were prepared using an induction furnace with composition chosen to obtain 5M modulated (tetragonal), 7M modulated (orthorhombic) martensites and cubic austenites in the films. Sputtering parameters like power, Ar pressure and substrate temperature were optimized to obtain the desired composition and crystallinity.
The film composition and crystal structure were studied by EDX and XRD. Magnetization loops, M(H), and thermomagnetization curves, M(T), were obtained revealing the martensitic transformation (see figure), further confirmed by resistivity measurements. Hysteresis loops agreed with this behaviour in terms of coercive field, with soft austenites and hard martensites. Curie temperatures of around 95º C were measured for most samples. The martensitic transformation temperature showed a decreasing trend with increasing Ar pressure, as confirmed through different deposition series. A noteworthy influence of substrate was found, since films grew epitaxially over MgO but they did in polycrystalline fiber-texture state over Si/SiO_2. The films were probed by AFM and SEM, that directly showed the twin variant structures, impacting the anisotropy fields.



M(T) curve for a 1.1 µm $Ni_{48.2}Mn_{30.7}Ga_{21.1}$ film on Si/SiO_2. Inset: M(H) loops at 20º C.

WE-68

Reversible magnetic field induced strain in Ni_2MnGa-polymer-composites

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We investigated particle-matrix interface, stiffness of polymer matrix and reversible magnetic field induced strain of $Ni_{50.9}Mn_{27.1}Ga_{22.0}$- and $Ni_{51.4}Mn_{26.9}Ga_{21.7}$-polymer composites. The $Ni_{50.9}Mn_{27.1}Ga_{22.0}$-particles, produced by gently crushing melt-extracted and subsequently annealed fibres have 5M martensitic structure and the $Ni_{51.4}Mn_{26.9}Ga_{21.7}$-particles are austenitic. These particles were embedded in stiff epoxy resin (E = 858 MPa) and in very soft polyurethane (E = 2 MPa). In response to an external applied magnetic field, the MSM particles are prone to relocation within the polyurethane due to its low Young's modulus, leading to a very small effect of magnetic field induced twin boundary motion. In $Ni_{50.9}Mn_{27.1}Ga_{22.0}$-epoxy-composites a magnetic field induced strain of 0.1 % was observed and resettable by rotating the magnetic field by 90°. Furthermore single fibre pull-out tests indicted significant improvements of the interfacial properties by using silane-coupling-agent treated fibres.

WE-69

Microactuator based on Ni-Mn-Ga FMSMA

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Recently a new layered composite with shape memory effect (SME) providing reversible strain using only "one-way" SME has been proposed [1]. The purpose of the present contribution is to propose a robust technology of production of composite microactuators based on Ni-Mn-Ga ferromagnetic shape memory alloy (FMSMA) and to prove their operation by controlling the martensitic transition by local heating.
A 54 µm thick melt -spun ribbon of FSMA $Ni_{53}Mn_{24}Ga_{23}$ with martensite-to-austenite transition temperature near 56 °C has been prepared by rapid quenching as described elsewhere [2]. The composite structure including 0.8 µm thick layer of FSMA and an elastic layer of Pt of approximately the same thickness have been produced by FIB milling. The overall dimensions of the actuator are 2x3x22 μm^3. The experimental study of thermally induced reversible bending strain of the microactuator has been done in the vacuum chamber of the FIB device. a A semiconductor laser was used as heating source.. Long-term operation of the microactuator with reversible bending strain up to 1.5 % has been demonstrated (see figure A and B) making them promising in a wide ramge of applications, comprinsing bio-MEMS technology.
Further work will also be done to prove the operation of the new composite microactuator in magnetic field taking advantage of new FMSMAs with improved magnetic-field sensitivity of martensitic transition.

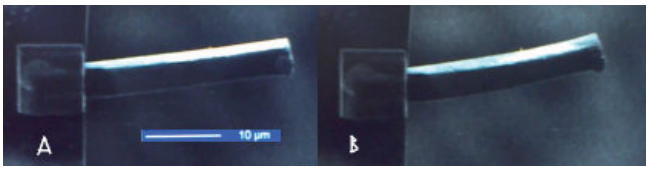

Figure. 1.5% bending of FMSMA Ni-Mn-Ga based microactuator by heating in the vacuum chamber of a FIB device. A: cold state (martensite), B: bent, hot state (austenite). See the video on the web: http://www.smwsm.org/ll/microactuator.html.

[1] Irzhak, A.V., Kalashnikov, V.S., Koledov, et al. Techn. Phys. Lett. 36 (2010) 329-332.
[2] Albertini, F., Algarabel, P.A., et al. Journ, Magn. Magn. Mater. 272-276 (2004) 2047-204.

WE-70

Magnetic field induced effects in Ni-Co-Fe-Ga melt spun ribbons

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The ferromagnetic shape-memory alloys receive great attention due to the huge magnetic field induced strain (MFIS) of the order of several percent, as evidenced by Ullakko on Ni2MnGa, seen as a the prototype. Ferromagnetic off-stoichiometric Heusler alloy Ni-Fe-Ga seems to be a good choice to replace the brittle Ni-Mn-Ga. The better ductility of Ni-Fe-Ga alloys was related to the presence of a secondary γ- face–centered cubic phase. Unfortunately, this secondary phase precipitates in various uncontrollable amounts, changing the main phase composition and causing a large spread of reported values, concerning all the properties influenced by the martensitic transition. Recent reported data on Ni-Fe-Ga ribbons [1], as well as our own results, have shown that rapidly quenching preparation techniques, like high velocity melt spinning, prevent

the formation of the secondary γ phase and offer an adequate frame to study the changes of the intrinsic properties during the martensite transformation. A small substitution of cobalt in Ni-Fe-Ga ribbons can be used in order to enhance the magneto-crystalline anisotropy of the martensite phase [2]. This work reports on the effect of removing the quenched-in strains in $Ni_{52}Co_2Fe_{20}Ga_{26}$ ribbons (usually retained in materials prepared by the melt spinning technique) via subsequent suitable thermal treatments. The influence of the thermal annealing on the atomic ordering process, martensitic transformation characteristic temperatures and linear thermal expansion and magnetostriction coefficients is also discussed.

[1] H.Okumura J. Appl. Phys 108, 043910 (2010)
[2] H. Morito, K. Oikawa, A. Fujita, K. Fukamichi, R. Kainuma, K. Ishida, T. Takagi, J. Mag. Mag Mat. 290-291, 850 (2005).

WE-71

Role of Ga substistution on the magneto-structural properties of Ni-Mn-In based alloys

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It has been reported that the ferromagnetic shape memory effect and the requisite thermoelastic martensitic transition (MT) in Mn excess Ni_{2}Mn_{1+x}In_{1-x} alloys exist only for x greater than or equal to 0.36 [1]. Here we studied an underdoped composition with x = 0.32 which does not show MT in its pure form. Our goal is to investigate the effect of Ga doping at the Indium site of this x = 0.32 composition through magnetization, transport and calorimetric measurements [2]. For that purpose we prepared and studied polycrystalline Ni_{2}Mn_{1.32}In_{0.68-y}Ga_{y} samples with y = 0.04, 0.08, 0.12, 0.16, 0.20, 0.24, 0.28 etc. All the doped samples are found to have ordered cubic L2_{1} phase at room temperature with lattice parameter varying linearly with y. Interestingly, for small Ga doping (y = 0.08), the MT reappears suddenly in the system around 180 K, although it is completely absent for smaller Ga concentration (y = 0.04). The y = 0.08 sample shows exotic kinetically arrested state, which is particularly evident on field cooling through MT [3]. All other samples with higher Ga concentrations (y greater than or equal to 0.08) show MT, however, the martensitic start temperature shows sluggish but steady increase with y. All the samples are found to be ferromagnetically ordered with their Curie point being close to room temperature. The present work clearly indicates the strong influence of Ga in inducing MT through some complex electronic processes, as Ga doping does not change the valence electron concentration of the system.

[1] T. Krenke et al., Phys. Rev. B 73, 174413 (2006)
[2] S. Chatterjee, S. Giri, S. K. De, S. Majumdar, Phys. Rev. B 81, 214441 (2010)
[3] S. Chatterjee, S. Giri, S. Majumdar, S. K. De, Phys. Rev. B 77, 224440 (2008)

WE-72

Kinetic arrest of martensitic transformation in as-quenched $Ni_{52.2}Mn_{34.3}In_{13.5}$ melt spun ribbons

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We report on the magnetic field-induced phase coexistence phenomena related to the first-order martensitic transformation (MT) in melt spun ribbons of a $Ni_{52.2}Mn_{34.3}In_{13.5}$ ferromagnetic shape memory alloy. Samples crystallize in a single-phase cubic austenite (AST) with B2-type structure of T_C^A=285 K. Decreasing the temperature AST transforms into a martensite (MST) with $T_C^M \approx$185 K. The measured transformation temperatures M_s =275 K, M_f=264 K and A_s =271 K and A_f=279 K. A progressive kinetic arrest of the AST to MST transformation was observed for magnetic field values from 10 to 90 kOe. A dc magnetization study of this unusual phenomenon was carried out, which in fact has been observed in several Ni-Mn-In alloys [1-4]. The metastable and glass-like character of the non-equilibrium field-cooled state was revealed by the decreasing behaviour shown by magnetization after a temperature cycling from 10 K to increasing temperature values up to 150 K (keeping H= 50 kOe). By measuring the thermo-remanent demagnetization isotherms followed by the subsequent recording of field-up and field-down isotherms, between 10 K and 200 K, it was observed that the fraction of AST frozen into the MST matrix, which is proportional to the magnetization difference ΔM between the ZFC and FC pathways of *M(T)* in the martensitic existence region, does not fully transform into MST when H is removed. The total magnetization difference ΔM shows irreversible and reversible components; the former decreases with the temperature decreasing.

[1] V.K. Sharma, et al., Phys. Rev. B 76, 140401R (2007);
[2] R.Y. Umetsu et al, Scripta Materialia 60 (2009) 25
[3] W. Ito et al., Appl. Phys. Lett. 92 (2008) 021908.
[4] J.L. Sánchez Llamazares et al., J. Appl. Phys., Vol. 107 (2010) 09A95.

WE-73

Interplay of thermal, magnetic and hydrostatic-pressure as external fields in $Ni_{49.26}Mn_{36.08}In_{14.66}$

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In the present work we report the effect of the interdependence between magnetic field and hydrostatic pressure on the Martensitic Transition and the Magnetocaloric Effect in a $Ni_{49.26}Mn_{36.08}In_{14.66}$ magnetic shape-memory alloy.

The ingot was prepared by arc melting technique under argon atmosphere, employing highly pure elements and its composition was determined by energy-dispersive X-Ray photoluminescence analysis. Magnetization as a function of temperature, magnetic-field and pressure has been measured with a Quantum Design MPMS-XL in the range of 250-340 K and up to 7 T applied field, and a hydrostatic-pressure up to 10 kbar. The measurements show that both transition temperature field-rate ($dT/d\mu_0H$) as well as transition temperature pressure-rate (dT/dP) show a monotonous increase as a function of pressure and magnetic field, respectively. According to that, it is observed that the magnetization jump at the transition decreases at higher applied pressure as the Curie point is approached.

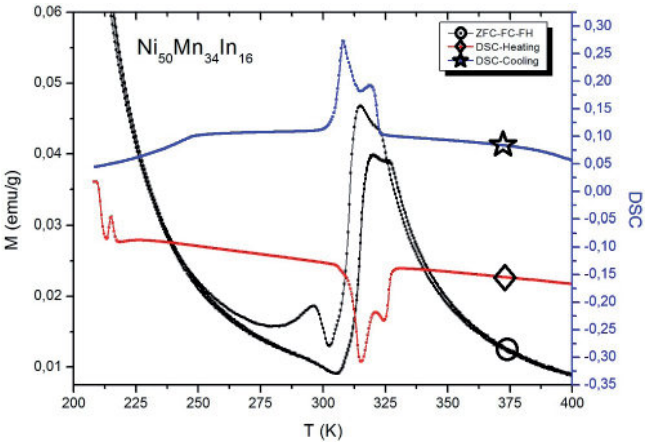

Figure. Thermal dependence of low field magnetic susceptibility and DSC of Ni50Mn34In16 Heusler alloy

WE-74

Two-step martensitic transition and shape memory effect in $Ni_{50}Mn_{34}In_{16}$ Heusler alloy

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The polycrystalline Heusler alloy Ni50Mn34In16 have been prepared by arc-melting technique. Its magnetic and structural transitions have been studied by magnetization, electric resistivity measurements and differential scanning calorimetry (DSC). The signatures for the two-step transition are clearly visible in the magnetization data measured at 50 Oe as well as zero field DSC measurement (see Figure).

For the first stage (A→M1) start and finish temperatures are TSA→M1 = 320 K, TFA→M1 = 318 K, TSM1→A = 330 K, TFM1→A = 332 K. While for the second stage (M2→M1), start and finish temperatures of transition are determined as TSM1→M2 = 311 K, TFM1→M2 = 309 K, TSM2→M1 = 317 K, TFM2→M1 = 320 K. Direct strain-temperature-stress measurements of the sample have shown the clear shape memory effect (SME). Pseudoplastic deformation in the region of martensitic transition also show two-step behavior. The merging of martensitic transition and Curie point has been observed by magnetic measurements in the fields up to 3 T. An additional pick on temperature dependence of low magnetic susceptibility at cooling in the sample has also been observed below the temperature of martensitic transition.

The two-step martensitic transition and observation of additional peak near martensitic transition have been previously reported in the samples of Ni-Mn-In family but have not been explained theoretically yet [1]. Possible origin of the additional peak below the transition lies in the complex kinetics of the martensitic transition, where residual austenite phase experiences negative pressure due to the growing martensitic fraction and thereby shows a second satellite transition at lower temperature.

[1]. Y. Sutou, Y. Imano, N. Koeda, et. al. ,Appl. Phys. Lett. 85 (2004) pp. 4358 - 4360.

WE-75

Magnetoresistance in magnetic shape memory Ni-Mn-Sn films

J. Dubowik [1], *I. Gościańska* [2], K. Załęski [1], H. Głowiński [1], A. Ehresmann [3]

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Large magnetoresistance (MR) observed in some magnetic shape-memory Heusler alloys (HA) has been generating much interest. In particular, MR in some Ni-Mn-In may be as high as 60%. Here, we report on magnetotransport of Ni_{50} Mn_{35}Sn_{15} epitaxial films studied as a function of temperature T and magnetic field H. The large negative MR extends over martensitic transformation with maximum of -22 % at 110 K. In martensitic and austenitic phase the MR is -3% and -5%, respectively. We show that the MR is governed mainly by magnetization paraprocess at high magnetic fields. The MR in Ni_{50}Mn_{35}Sn_{15} films is consistently analyzed both in the framework of a frequently applied functional relationship [1] and a phenomenological model originated from microscopic spin disorder theory [2]. It is found that MR scales as the square of magnetization m(H, T)^{2}. We show that the MR can be consistently explained in the framework of a phenomenological approach involving magnetization changes, which are connected with the presence of AFM interactions [3].

[1] S. Singh and C. Biswas, Appl. Phys. Lett. 98, 2112101 (2011).
[2] T. Kasuya, Prog. Theor. Phys. 16, 58 (1956); P. G. de Gennes and J. Friedel, J. Phys. Chem. Solids 4, 71 (1958); T. van Peski-Tinbergen and A. J. Dekker, Physica 29, 917
(1963); M. Kataoka, Phys. Rev B 63, 134435 (2001).
[3] J. Dubowik et al. submitted to Appl. Phys. Lett.

WE-76

Magnetic properties of Ni-Mn-Sn-Fe melt spun ribbons

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(1) Instituto Potosino de Investigación Científica y Tecnológica, Camino a la Presa San José 2055 Col. Lomas 4a, San Luis Potosí, S.L.P. 78216, México, (2) Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México,Cd. Universitaria A.P. 70-360, 04510 México D.F., México, (3) Centro de Investigaci´on en Materiales Avanzados, S.C. Miguel de Cervantes 120, Complejo Industrial Chihuahua, 31109 Chihuahua, M´exico

Recent work on caloric effects shows that alloys of Ni-Mn-Sn system are promising as a material for solid state refrigeration systems. In this study we present results on the effect of 6, 7 and 8 atomic percent of Fe on a Ni-Mn-Sn alloy Ribbons. The ribbon alloys were elaborated by rapid solidification on a Melt spinner apparatus. Results of magnetization measurements, microstructure, and transformation temperatures from as quenched and heat treated ribbons are presented. Magnetization versus temperature cycles were performed in a Physical Properties Measurement System (PPMS), for each composition and heat treatment in order to obtain Curie and martensitic transformation temperatures. The Magnetocaloric effect and RCP due to magnetic and transformation transitions is measured and compared for different Fe contents. Also the Transformation Temperatures decrease with iron contents.

WE-77

Effect of electron density on the martensitic transition in Ge doped Ni-Mn-Sb alloys

R.L. Wang [1], L.S. Xu [1], X. Chen [2], Z.G. Sun [2], H. Gong [3], D.W. Shi [1], *C.P. Yang [1]*

(1) Faculty of Physics & Electronic Technology, Hubei University, Wuhan, 430062, People's Republic of China, (2) tate Key Lab of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan 430070, People's Republic of China, (3) Hubei Quanyang magnetic materials manufacture Co. Ltd, Yichang, 443007, People's Republic of China

Ni–Mn-X (X= In, Sn, Sb) ferromagnetic shape memory alloys (FSMAs) have attracted increasing attention due to their multifunctional properties in the vicinity of martensitic transition. Therefore, tuning the MT temperature and enlarging the working-temperature interval are of great importance. The the martensite start temperature M_s usually increases with the increase of valence electron concentration (e/a). Recently, many reports indicate that substitution X with smaller radius element would result in the increase of M_s. In the present work, we investigated the effect of Ge doping on the MT in $Ni_{50}Mn_{36}Sb_{14-x}Ge_x$ (x = 0, 1, 2, and 3) alloys. The results showed that though Ge has smaller radius compared to Sb, decreases with the increase of Ge, which can be attributed to the decrease of electron density (electrons per unit volume).

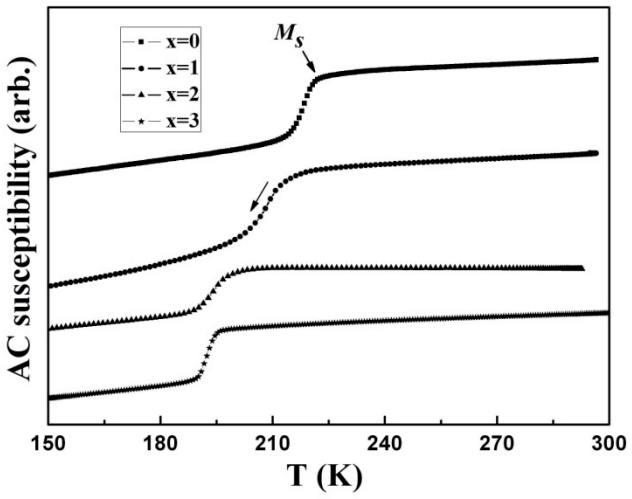

Fig. 1 Temperature dependence of the AC magnetic susceptibility for the $Ni_{50}Mn_{36}Sb_{14-x}Ge_x$ (x = 0, 1, 2, and 3) alloys

[1] Y. Sutou, Y. Imano, N. Koeda, T. Omori, R. Kainuma, K. Ishida, and K. Oikawa, Appl. Phys. Lett. 85, 4358 (2004).
[2] R. Sahoo, A. K. Nayak, K. G. Suresh, and A. K. Nigam, J. Appl. Phys. 109, 07A921 (2011).

WE-78

Structural and magnetic properties of melt spun NiCoAl alloy ribbons

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Recently, NiCoAl alloys have been developed as new ferromagnetic shape memory alloys (FSMAs) [1], showing interesting functionalities associated to the thermally induced martensitic transformation. Previous studies have shown that these FSMAs can be also produced as single-phase materials by rapid solidification using melt spinning technique [2]. This fast cooling method can effectively minimize the homogenization annealing time usually spent to form the equilibrium phase when the alloys are produced in bulk form by conventional methods. In this work we focus on the effect of chemical composition and thermal annealing on both structural and magnetic properties of as-quenched ribbons with nominal composition $Ni_{37-x}Co_{35+x}Al_{28}$ ($0 \leq x \leq 4$). Polycrystalline alloy ribbons flakes were prepared by rapid solidification using melt spinning technique at a high wheel speed of 35 ms^{-1}. In the case of $Ni_{37-x}Co_{35+x}Al_{28}$ ($3 \leq x \leq 4$) the abrupt change in magnetization upon cooling evidences the occurrence of a first-order martensitic transformation around 250 K. XRD patterns confirm that the structural transition occurs from a magnetically soft cubic B2 austenitic phase to a magnetically hard tetragonal $L1_0$ martensite structure. The effect of vacuum annealing was studied at 823 K, 923 K and 1023 K during 2 hours resulting in; (a) the disappearance of the austenite-martensite transition, b) the precipitation of a Ni_5Al_3 phase upon 823 K annealing as observed in XRD

analysis and (c) a large increment in the coercive field at 300 K from 5 Oe to 1500 Oe when annealed up to 823 K is observed, such an increase is followed by a continuous decrease of the coercive field when annealed at higher temperatures (923 K and 1023 K).

[1] K. Oikawa et al., Appl. Phys. Lett., **79**, 20 (2001)
[2] T. Saito, J. Appl. Phys., 100, 053916 (2006)

WE-80

Magnetic domains structure in ferromagnetic martensites

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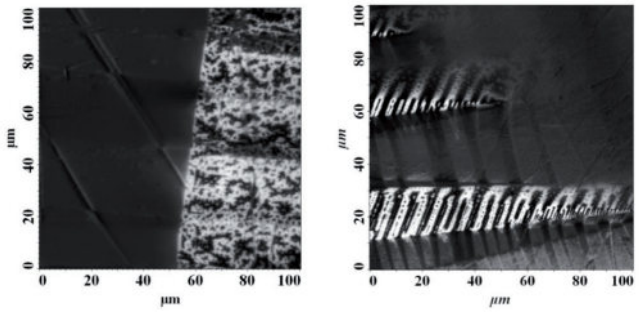
To obtain magnetic shape memory (MSM) also called magnetic field induced reorientation (MIR) the twinning interface has to be very mobile. Recently the mobile twinned interfaces with two different magnitude of twinning stress about 1 MPa and 0.1 MPa were reported in Ni-Mn-Ga 10M martensite, a prototype of MSM alloy. As microstructural analysis showed these mobile twinned interface can be ascribed to be Type I and Type II macrotwin boundaries when using monoclinic approximation [1,2]. The structure relief due to martensite interfaces (ferroelastic domains) and corresponding magnetic domains structure in the vicinity of these interfaces was studied by AFM and MFM. In addition to the Ni-Mn-Ga martensite also the domain morphology of ferromagnetic shape memory alloy CoNiAl with no MSM effect was studied. The figure shows the magnetic domains in both materials. The comparison of magnetic domain structures may facilitate the understanding of MSM effect.

[1] L. Straka, O. Heczko, H. Seiner, N. Lanska, et al. Acta Mat. 59 (2011) 7450.
[2] O. Heczko, L. Straka, J. Drahokoupil, H. Seiner, submitted to Acta Mat. (2012).



Magnetic domains in the vicinity on the twinning interfaces. Left - 10M Ni-Mn-Ga martensite (mobile macrotwin interface – approximately vertical). Right - Co-Ni-Al martensite needle (horizontal).

WE-81

Phenomenological parameterization of the magnetoelastic resonance

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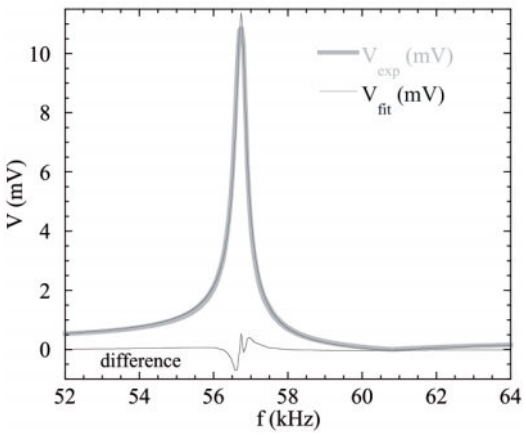
The magnetoelastic resonance effect occurs in magnetostrictive materials when stationary mechanical waves, compatible with sample dimensions, are excited through the magnetoelastic coupling by an alternating magnetic field of suitable frequency. The phenomenon is well known [1] and extensively used, for example, in anti-shoplifting acoustic labels.
In this work we use a phenomenological approach to describe the frequency response of a magnetostrictive ribbon, which is characterized by a sharp maximum at the resonance followed by a null minimum at the antiresonance (see Figure). Using the formalism of linear systems, an analytical expression for the transference function can be readily written: the resonance imposes a couple of complex conjugated poles in the denominator, and the antiresonance is described with a couple of complex conjugated zeros in the numerator. The transference function is then

$$G(s) = \frac{\omega_r^2}{\omega_a^2} \times \frac{s^2 + 2\delta_a\omega_a s + \omega_a^2}{s^2 + 2\delta_r\omega_r s + \omega_r^2}$$

where ω_r is the value of the resonance frequency, ω_a the antiresonance, and $\delta_a$and δ_r are damping parameters. In this formalism $s=j\omega$, where ω is a real frequency and $j=\sqrt{-1}$.
Using this extremely simple analytical expression, the resonance curve can be described by only five parameters: ω_r, ω_a, δ_r, $\delta_a$and an additional scale factor that accounts for the amplitude. Experimentally measured curves can be fitted to this expression with only three independent parameters (plus two more for a linear baseline), since the resonance and antiresonance frequencies are unequivocally determined from the maxima and the minima of the measured curve. The figure shows the excellent agreement found by a least squares fit for the resonance curve measured in a 37 mm long, 6 mm wide VITROVAC ribbon.
This fitting procedure would allow to easily quantify the influence of the measured quantity (humidity, viscosity, etc) in sensors based in the magnetoelastic resonance.

[1] C.A. Grimes *et al*. Sensors **11** (21011) 2809-2844



Experimentally measured resonance curve, best fit and difference between them.

WE-82

Magneto-elasticity and metamagnetism of Fe_2P-based alloys

Z. Gercsi [1], K.G. Sandeman [1]
(1) Imperial College London

Fe_2P is a weakly itinerant magnetic compound with a peculiar magnetic structure: there are very large magnetic moments of about Fe_{II}=2.4μB on the 3g site and smaller Fe_I=0.8μB moments on the 3f site [1]. The alloy exhibits a first order ferro- to para-magnetic (FM-PM, Curie) transition at around 212 K without a change in the crystal symmetry. The physical origin of this unusual arrangement of the magnetic moments lies in the hexagonal symmetry (189) of the lattice. Partial replacement of phosphorus with other p-block elements (B, Si or As) increases its Curie (T_c) temperature sharply while simultaneously changing the Curie transition from first order to second order [2]. The Curie temperature increases drastically with even a small amount of doping: 10% replacement of P by B leads to ~120% change in T_c, while the same amount of Si and As substitution also results in a ~70% or ~60% increase in T_c, respectively. Further, partial replacement of the 3d element (Fe) by Mn results in a significant increase of the saturation magnetisation value of the alloys. Interestingly, the metamagnetic transition is preserved and it yields a large magnetocaloric effect around room temperature [3]. In this work, we will present detailed density functional theory (DFT) combined with recent results from high resolution neutron diffraction (HRPD) experiment on selected Fe_2P-based compositions to reveal the exchange striction mechanism in these magnetocaloric alloys (Fig.1).

[1] Yamada H and Terao K., Phase Transitions, 75, 231 (2002)
[2] Chandra R et al. J. Sol. State Chem. 34, 389 (1980)
[3] Dung, NH et al. Advanced Energy Materials 1, 1215 (2011)

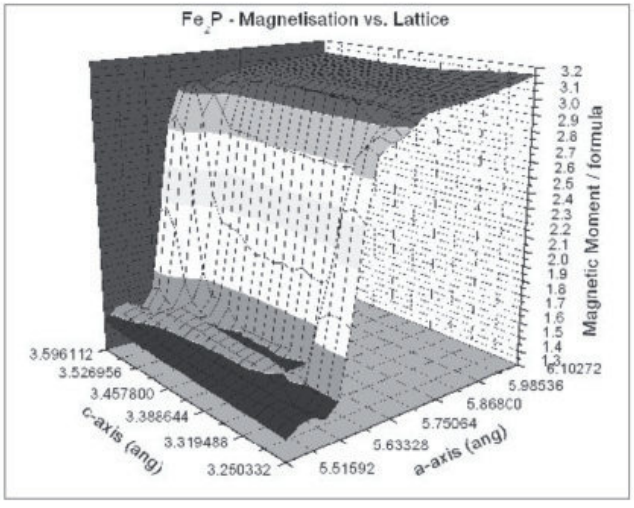


Fig.1. Calculated change in magnetization as a function of lattice parameters in Fe_2P from first principle.

WE-83

Magnetic and structural investigation of growth induced magnetic anisotropies in $Fe_{50}Co_{50}$ thin films

M. Tamisari [1], G. Ausanio [2], V. Guidi [1], V. Iannotti [2], I. Neri [1], F. Spizzo [1], P. Vavassori [3]
(1) Department of Physics and CNISM, University of Ferrara, 44122 Ferrara, Italy, (2) CNR-SPIN and Department of Physical Science, Federico II University, 80125 Naples, Italy, (3) Department of Physics and CNISM, University of Ferrara, 44122 Ferrara, Italy; CIG nanoGUNE consolider, Tolosa Hiribidea, 76 E-20018 Donostia, San Sebastian, Spain

Thin $Fe_{50}Co_{50}$ (FeCo) films are highly magnetostrictive and have recently attracted great attention due to their possible application in magnetic devices. The growth conditions may highly affect the FeCo films magnetization reversal process as they may induce compressive or tensile stress and additional magnetic anisotropies, accordingly [1].
We present FeCo layers, with thickness, t, ranging from 5 up to 100 nm, grown by dc-magnetron sputtering on Si substrates in Ar atmosphere. RT magnetization data were collected using a SQUID magnetometer and a MOKE apparatus, using both an in-plane and an out-of-plane magnetic field. Magnetoresistance (MR) measurements were collected using the Van der Pauw method. The structural characterization was performed with a high resolution X-Ray diffractometer and an optical profilometer.
For $t \leq 20$ nm, the shape of the in-plane M loops is squared and coercivity increases with t, possibly due to the grain size growth induced by the thickness increase. The MR response is anisotropic in character. For $t > 20$ nm, coercivity smoothly decreases and the shape of the loops changes, the approach to saturation gets slower and the shape of the whole loop gets less and less squared. The MR effect becomes almost isotropic and its intensity increases of about one order of magnitude. These results suggest that the magnetization reorientation process changes for $t > 20$ nm, and are in agreement with the progressive development of an out-of-plane easy axis [2]. This hypothesis is substantiated by profilometric analysis that reveals an increase in samples curvature with t, thus confirming a change in the degree of in-plane tensile stress. Diffraction data collected for different t values will be presented and discussed, as well.

[1] W. Yu et al., J. Appl. Phys. 99 (2006) 08B706.
[2] G. Ausanio et al., Thin Solid Films 519 (2011) 5420.

WE-84

Electric field tuneability of ferromagnetic resonance in FeGa via a piezoelectric substrate

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Modification of magnetisation and magnetocrystalline anisotropy by electric fields is promising for data storage, spintronic and magnonic applications. Removing the requirement of an electric current to generate a magnetic field or spin-polarised current to control the magnetisation avoids the problems associated with energy dissipation and stray fields. Following the demonstration of reversible, non-volatile electric field control of magnetisation in an FeGa/PZT composite device [1], we now investigate the effect of strain-induced anisotropy on the dynamic response. An epitaxial FeGa thin film grown on GaAs(001) and cemented to a piezoelectric transducer is mounted on a coplanar waveguide that is connected to a vector network analyser. By measuring the microwave transmission

losses whilst sweeping the microwave frequency as a function of bias field and angle we obtain angular dependent ferromagnetic resonance spectra (FMR).
We present voltage controlled FMR shifts of ($\Delta B_{res}/B_{res}$ =) 20% with the maximum shift obtained along the azimuth normal to the strain axis. The strain effect gives an additional uniaxial anisotropy component that rotates the easy axes of the FeGa film by ~2°. Line shape analysis of the FMR spectra also reveals a modification of the damping. Our results demonstrate strong magnetoelectric coupling at microwave frequencies in, and demonstrate the feasibility of voltage control in FeGa-based microwave devices.

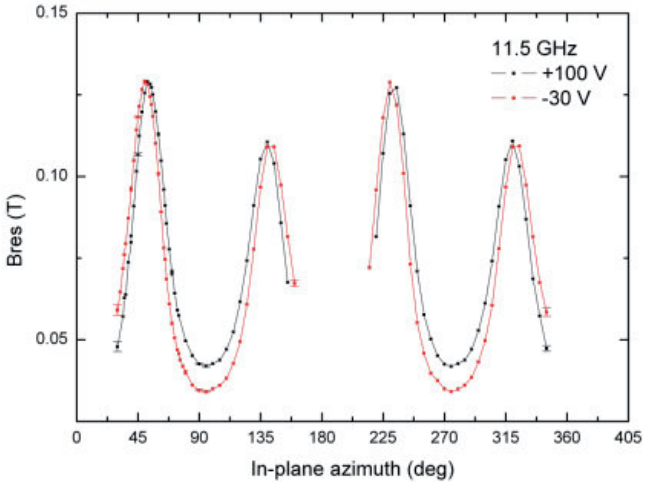

Figure 1 – FMR anisotropy of FeGa-PZT recorded at 11.5 GHz, for PZT bias of +100 V (black curve) and -30 V (red curve). The strain axis is parallel with the 0, 180° azimuth.

[1] D.E. Parkes, S. A. Cavill *et al*. submitted to Advanced Materials.

WE-85

Ultrasonic triggering of giant magnetocaloric effect in MnAs thin films

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(1) Institut des NanoSciences de Paris, UPMC-CNRS UMR 7588, 4 place Jussieu, 75252 Paris Cedex 5, France., (2) VeDeCom- Université de Versailles Saint-Quentin en Yvelines - 55, Av. de Paris - Versailles 78035 Versailles Cedex - France.R 7588, 4 place Jussieu, 75252 Paris Cedex 5, France.

Mechanical control of magnetic properties in magnetostrictive thin films offers the unexplored opportunity to employ surface wave acoustics to trigger dynamic magnetic effects. Here, we report about the opportunity to employ surface wave acoustics to trigger the magnetic properties of a well-known giant magnetocaloric [1] and giant magnetoelastic material [2]: MnAs. We show the possibility to dynamically modulate magnetocaloric effect by Surface Acoustic Waves technology (170 MHz) in magnetostrictive thin films, i.e. MnAs(200nm)/ GaAs(001) thin films, a spintronic relevant ferromagnetic/ semiconductor hybrid system [3] .
During the MnAs magnetostructural phase transition, in an interval range around room temperature (0°C – 60°C), ultrasonic waves (170 MHz) are strongly attenuated by the phase coexistence (up to 150 dB/cm). We show that the giant magnetocaloric effect of MnAs is responsible of the observed phenomenon. By a simple anelastic model we describe the temperature and the external magnetic field dependence of the observed ultrasound attenuation. Our explanation of the observed acoustic attenuation is based on an attenuation process enhanced by the entangled magnetoelastic and magnetocaloric properties of MnAs. Acoustic stresses induce magnetic entropy change in MnAs. To restore equilibrium, a heat flow sets up leading to anelastic ultrasound propagation. We will show how strain-manipulation of the magnetocaloric effect could be a further interesting route for dynamic and static caloritronics and spintronics applications in semiconductor technology.

[1] D. H. Mosca, F. Vidal, and V. H. Etgens, Phys. Rev. Lett. 101, 125503 (2008)
[2] V. Chernenko, L. Wee, P. McCormick, and R. Street, J. Appl. Phys. 85, 7833 (1999)
[3] I. Zutic, J. Fabian, S. Das Sarma Rev. Mod. Phys. 76, 323

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

Chair: I. Bergenti

WE-86

Detection of magnetization reversal in nanostructures using magnon magnetoresistance

V.D. Nguyen [1], L. Vila [1], P. Laczkowski [1], A. Marty [1], C. Beigné [1], L. Notin [1], W. Savero Torres [1], M. Jamet [1], *J.P. Attané* [1]
(1) INAC/ CEA Grenoble and University of Joseph Fourier, Grenoble, France

We present a new magnetoresistance (MR) effect based on the contribution of the magnons to the resistivity, i.e., Magnon Magnetoresistance (MMR). We show that the MMR can be used to study the magnetization reversal in systems with either perpendicular (FePt) or in-plane anisotropy (NiFe).
MMR measurement exhibits a linear dependence of the resistivity on the applied field, originating from electron-magnon scattering (cf. Fig.1a). The drop of resistivity, due to the abrupt change of magnon density, corresponds to the magnetization switching. As shown in fig.1, MMR measurement allows detecting precisely the position of a DW along a FePt nanowire and following the dynamic of DW motion [1] (as in CIP–GMR measurements [2]).
In system with in-plane magnetization as NiFe nanowires, we show that the enhancement of the shape anisotropy in the narrowest widths leads to the disappearance of the AMR signal, the remaining contribution to the MR being that of the MMR [3]. Additionally, we also show that the MMR signal can give access to the position of the DW along the NiFe wire.
We emphasize that the observation of MMR in in-plane anisotropy nanowires can provide a change of paradigm in the study of in-plane magnetized nanowires: for certain field directions the magnon contribution dominates the MR, clearly overcoming the AMR.

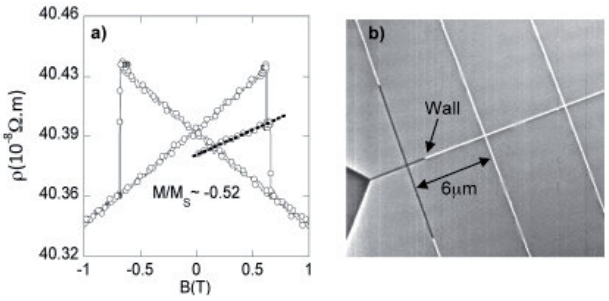

Fig. 1. (a) MMR major and minor loop. (b) MFM image shows DW position as MMR measurement [1].

[1] V. D. Nguyen *et al*., Phys. Rev. Lett. **107**, 136605 (2011)
[2] C. Burrowes *et al.*, Nat. Phys. **6**, 17 (2010)
[3] V. D. Nguyen *et al*., Appl. Phys. Lett. **99**, 262504 (2011)

WE-87

Thermal conductivity of anisotropic spin ladders

H. Rezania [1]
(1) Physics Department, Razi university/Iran

We have studied the thermal conductivity of anisotropic spin ladder model with antiferromagnetic coupling constants between spins on the both rung and ladder directions. Kubo formalism has been applied to study temperature dependency of thermal conductivity of this model hamilltonian. The bond operator formalism is used to transform the spin model to a hard core bosonic gas. We have used the green's function approach to obtain the temperature dependence of spin excitation spectrum. We have found the temperature dependence of the thermal conductivity for various exchange coupling constants and anisotropies in both coupling strengths. We have obtained the increase of coupling constant along ladder direction leads to decrease of thermal conductivity. Furthermore the effect of local anisotropy anisotropy on the thermal conductivity has more significant in comparison with other one.

In Fig.(1), we show temperature dependence of static thermal conductivity along perpendicular to
the rung direction for various onsite exchange coupling. The monotonic decrease of thermal
conductivity versus temperature is obvious for all values of onsite exchange coupling constants and
anisotropy parameters in Figs.(1,2,3). The effect of onsite anisotropic parameter on the temperature
behavior in the specific value for coupling constants is shown in Fig.(2). The values of thermal
conductivity decreases with the onsite anisotropy for each temperature.

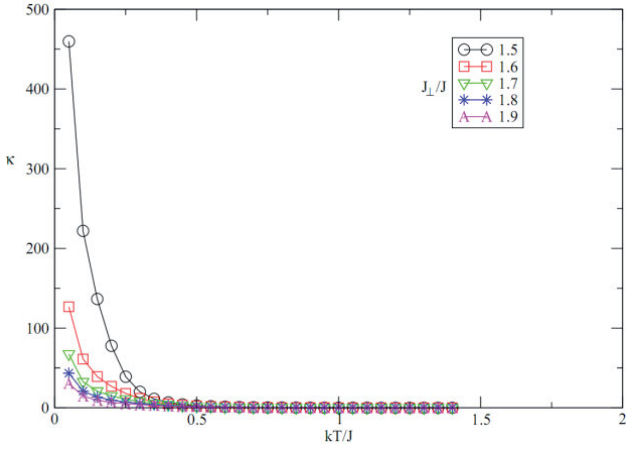

Fig.(1): Thermal conductivity as a function of temperature for various coupling constants

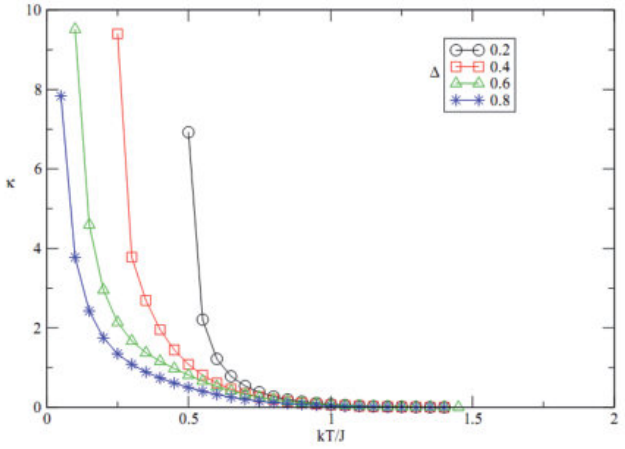

Fig.(2): Thermal conductivity as a function of temperature for various onsite anisotropies

[1] E. Dagootto and T. M. Rice, Science 271, 618 (1996)
[2] A. Klumper and D. C. Johnston, Phys. Rev. Lett, 84, 4701 (2000)
[3] A. V. Sologubenko and K. Gianno, H. R. Ott, U. Ammerahl and A. Revolevschi, Phys. Rev. Lett, 84, 2714(2000)

WE-88

Spin dynamics in GaMnAs heterostructures containing quantum well

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Heterostructures containing a quantum well and a thin layer of a diluted magnetic semiconductor (DMS) like GaAs:Mn have attracted great attention due to their possible application for injecting spin-polarized carriers in light emitting diodes [1]. The implantation of Mn into the quantum well leads to low mobility of charge carriers and suppresses radiative recombination [2]. The spatial separation of charge carriers and the GaAs:Mn layer results in a considerable increase in the mobility of charge carriers and the luminescence quantum yield. This combination of optically and magnetically active structures appears promising for controlling optical properties by spin-dependent magnetic field control over the luminescence. Ferromagetic resonance and magnetoresistance was studied by ESR spectrometer in vicinal and singular samples (Fig.1). Here, we present results on the ferromagnetic GaAs:Mn layer contribution to the magnetic moment of the samples, the effect of the GaAs:Mn layer magnetization on the polarization of the photoluminescence of the InGaAs quantum well, the effect of different GaAs substrate orientations on the type of magnetic ordering, exchange parameters, magneto-optical properties and spin dynamics in the GaAs-based heterostructures with a InGaAs quantum well and a GaAs:Mn layer.

[1] Y.Ohno, D.K.Young, B.Beschoten F.Matsukura, H.Ohno, and D.D. Awschalom, Nature 402, 790(1999).
[2] M.Poggio, R.C.Myers, N.P.Stern, A.C.Gossard, and D.D.Awschalom, Phys. Rev. B 72, 235313(2005) .

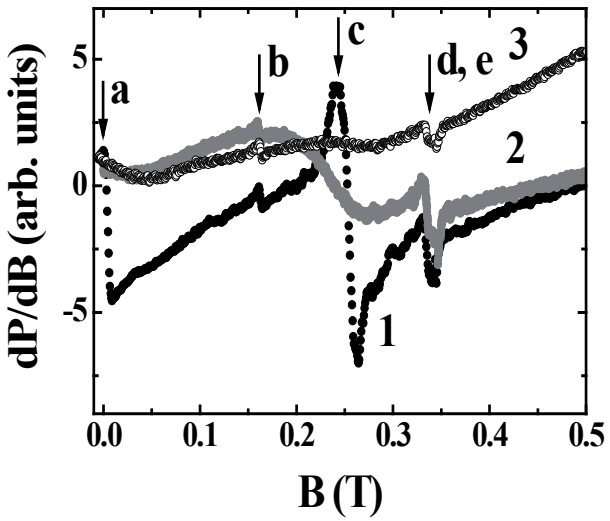

Figure 1. ESR spectra in the singular (1) and vicinal (2) heterostructure with the GaAs:Mn layer and the reference heterostructure without GaAs:Mn layer (3) at T = 4 K. The dc magnetic field was applied in the (001) heterostructures plane.

WE-89

Spin polarization of Bloch states and Hall currents in GaAs quantum wells

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The description of carrier properties in semiconductors is usually based on the extended Kane model [1] which capture most of the semiconductor properties. A key ingredient of the model is the spin-orbit interaction. Spin orientation of carriers is then established by the use of the effective medium Hamiltonian which depends on the wave vector $\boldsymbol{k}$, but it is independent of spatial coordinates. However, since eigenfunctions of electron states in crystalline solids are of the Bloch form their spin orientation given by expectation values of the spin operator are mostly determined by the periodic part of Bloch functions. We have used empirical pseudopotential method to establish spin polarization of Bloch states in GaAs crystals. The obtained spin orientation differs significantly from that obtained by the use of the effective medium Hamiltonian [1].
Knowledge of Bloch eigenfunctions allowed us to establish not only their spin orientation, but also the real-space spin distribution. In the case of the equilibrium occupation of states the total spin vanishes at any real space point, which is the consequence of the Kramer's theorem. However, a non-equilibrium distribution induced by the applied current can lead to a local spin polarization. It is accompanied by a Hall current densities and their non-zero spin polarization. Both quantities oscillate in accord with the lattice periodicity. As expected the total Hall current vanishes. At some cases the strong tendency to transfer spins of the different orientation in opposite directions have been found.

[1] R. Winkler: *Spin-Orbit Coupling Effects in Two-Dimensional Electron and Hole Systems*, in Springer Tracts in Modern Physics, Vol. 191 (Springer-Verlag Berlin Heidelberg, 2003).

WE-90

Stark effect and spin dynamics in coherently coupled quantum dots

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We show that spin entanglement can be controlled by an external electric field in a system of three coherently coupled quantum dots with a linear and triangular geometry. The studies are performed within the Hubbard model (and its canonical transformation to an effective Heisenberg Hamiltonian) which takes into account electron and spin correlations. The electric field modifies super-exchange couplings, shifts many-electron levels (the linear and quadratic Stark effect) as well as changes spin correlations. We use the spin-spin correlation function as well as the concurrence as measure of entanglement. These quantities depend on the strength of the electric field and its orientation with respect to the system axes. For a specific conditions one can find a dark spin state, the state which is biseparable. Here we show how a scheme for universal quantum computations proposed by Di Vincenzo *et al.* [1] can be realized for a spin system with exchange interactions in three quantum dots with logical qubits encoded in the doublet subspace. Moreover we show that the spin Stark effect manifest itself in spin dynamics when a time dependent electric field induces Landau-Zener passages. The spin dynamics can be controlled by rotation of the electric field and a proper preparation of initial entangled states. Our studies suggest that recent experiments [2,3] on coherent spin manipulation in semiconducting quantum dots can be modified using the spin Stark effect.

This work was supported by Ministry of Science and Higher Education (Poland) and by the EU project Marie Curie ITN NanoCTM.

[1] D. P. Di Vincenzo et al., Nature 408, 339 (2000).
[2] E. A. Laird et al., Phys. Rev. B 82, 075403 (2010).
[3] L. Gaudreau et al., Nature Phys. 8, 54 (2012).

WE-91

Nonlocal transport properties via crossed Andreev reflections in a double quantum-dot system

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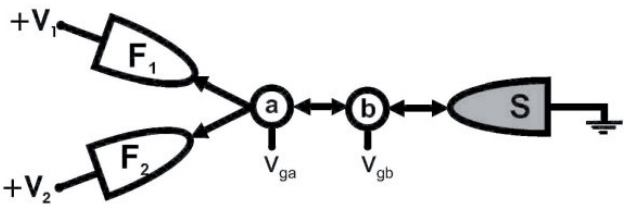
We study the transport properties of a hybrid nanostructure composed of two ferromagnets (F_{1}, F_{2}), two quantum dots (a,b), and a grounded superconductor (S) connected in series (see the figure below). By using the non-equilibrium Green's function approach developed in Ref. [1], we have calculated the electric current, the differential conductance, the transmittance and the magnetoresistance. For energy scales within the superconductor gap, electric conduction is only allowed by Andreev reflection processes. Due to the presence of two ferromagnetic leads, non-local crossed Andreev reflections are possible, if the distance between the two ferromagnets is smaller than the superconducting coherence length. Those processes dominate the transport when the ferromagnets are completely polarized, and the current in one of the ferromagnets can be controlled through the potential applied to the second one (transistor-like effect). In addition, the magnetoresistance sign can be changed by tuning the external potential applied to the ferromagnets. Intradot electronic correlations are included, and their influence is studied through a mean field approximation. Gate voltages are applied at each quantum dot and their interplay with the intradot interactions are fully analyzed. The interaction reduces the current amplitudes with respect to the non-interacting case, but the transistor-like behavior remains as a manifestation of quantum coherence within scales of the order of the superconductor coherence length.

[1] E. C. Siqueira and G. G. Cabrera, Phys. Rev. B 81, 094526 (2010)



V_{1} and V_{2} are external potentials and V_{ga} and V_{gb}are gate voltages

WE-92

Magnetization Reversal and Dynamics in Co antidot lattices

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We have systematically investigated the static and dynamic behaviour of Co(*t* nm)/CoO(5 nm)/Cu(2 nm) antidot square lattices [Ref. 1] as a function of Co thickness *t* in the range from 25 nm to 100 nm. The effects of hole diameter on the magnetization reversal mechanism by fixing the centre-to-centre spacing *p* = 415 nm and varying the hole diameter from 145 nm to 265 nm was investigated. The orientation (θ) dependence of saturation field (H_s) and coercivity were measured using MOKE. The $H_s(\theta)$ dependences show weak anisotropy in *t* = 25 nm compared to a quasi-8-fold symmetry observed for *t* =50nm, with the easy axes along the <01> and <11> directions as shown in Fig.1 (upper panel). The polar component of the spin-precession measured using time-resolved MOKE with optical pumping for 25 and 50 nm samples (and *d* = 185 nm) exhibits time periods of 26 and 17 ps, respectively.
We attempt to explain the thickness and hole-diameter dependence of the magnetization reversal behaviour using micromagnetic simulations. We observe surface dynamics induced by optical pumping in the presence of the quasi-8-fold anisotropy and weak anisotropy and compare it to the collective dynamics observed using Ferromagnetic Resonance spectroscopy.

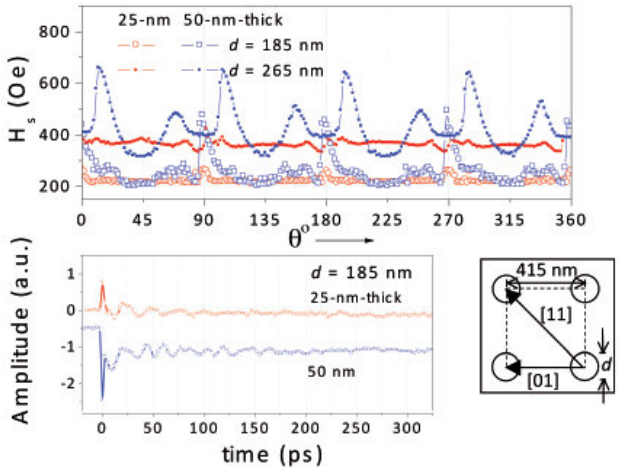

Fig: (upper panel) Orientation dependence of the saturation field (H_s) for 25 and 50 nm thick antidots with d = 185 and 265 nm (where θ = 0° is the [01] direction); (lower left) time dependence of Kerr rotation after optical pumping for d = 185 nm; (lower right) sketch of the antidot lattice geometry.

[1] C C Wang *et al* 2006 *Nanotechnology* **17** 1629 (2006)

WE-93

Spin transport and magnetization dynamics in dual spin valves with perpendicular and in-plane polarizers: numerical analysis

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We have analyzed current-induced magnetization dynamics in a metallic spin valve consisting of a free magnetic layer and two polarizers separated from the free layer by nonmagnetic spacers. One of the polarizers plays the role of an analyzing layer with in-plane magnetization, while the second one consists of several thin magnetic films with out-of-plane anisotropy and hence with magnetization perpendicular to the layer's plane. When electric current flows through such a structure, the spin-transfer torque (STT) acts on the free layer and gives rise to magnetization dynamics.
The spin transport through the spin valve has been studied in the diffusive transport regime [1]. The complex out-of-plane polarizer has been modeled as one magnetic layer with effective parameters calculated from first-principles using wave-function matching scheme [2,3]. The dynamics of the free layer's magnetization has been modeled in the single-domain approximation by the Landau-Lifshitz-Gilbert equation with both in-plane and out-of-plane STT components [2] included. In the simulations we have focused on the magnetization switching induced by a rectangular current pulse. We have studied the switching probability as a function of pulse length and current density. In accord with experiment [4], an enhancement of the switching probability for short sub-nanosecond pulses has been found.

[1] J. Barnaś et al, Phys. Rev. B 72, 024426 (2005).
[2] M. Zwierzycki et al, Phys. Stat. Sol (b) 245, 623 (2008).
[3] Xia et al, Phys. Rev. B 73, 064420 (2006).
[4] O. J. Lee et al, Appl. Phys. Lett. 95, 012506 (2009).

WE-94

Complex switching resistance induced by contact-point spin transfer torque

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In this work we have investigated spin transfer torque phenomena [1,2] by spin polarized current injected by contacts point on continuous films. The tips where produced by electrochemical etching of tungsten wires resulting in points with diameters around 200nm. Spin valves nanostructures IrMn(10nm)/Co(15nm)/Cu(t_{Cu})/Co(15nm), with t_{Cu} = 2, 5, 8 and 11nm, were produced by magnetron sputtering on n-Si (100) substrates with magnetic field of 130Oe applied in plane of film during deposition. The IrMn was used to pin the ferromagnetic cobalt layer (FM1) in order to spin-polarize the injected current. Different copper spacer thicknesses were used in order to investigate the role of the coupling between ferromagnetic layers on spin transfer effect. The structural and morphological characterization of the nanostructures was made by X-ray diffraction and X-ray reflectivity. Magnetic characterization of the spin valves were performed with a VSM magnetometer and magnetoresistance measures. Spin transfer torque phenomena was investigated by current voltage measurements using the tungsten tips produced.
The electrical measurements shows complex response with characteristic switching resistance associated to magnetic reorientation, characterizing a noisily current dependent response, suggesting successive transitions among dynamical and/or static magnetic states.

[1] M. Tsoi et al. Phys Rev. Lett. 19, 4281 (1998)
[2] Mark D. Stiles and Jaques Miltat, Spin Dinamics in confined magnetic structures III. Springer-Verlag Berlin Heildelberg 2006.

WE-95

Spin motive force driven by the dynamics of topological nanomagnets

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The current-induced magnetization dynamics realized in spintronics devices involve both of charge and spin degrees of freedom. Recently, it has been pointed out that the magnetization dynamics induces an effective electric field acting on the conduction electrons through the spin Berry phase.[1-3] The effective electric field, or a «spin motive electric field», was investigated for a simple one-dimensional domain wall. It is difficult to estimate analytically this effective electric field in actual systems, because the magnetization dynamics obeys the non-linear Landau-Lifshitz equation. In this report, we investigate the the spin motive force due to the dynamics of the magnetic structrue with a topological number. We calculate the dynamics of the magnetic vortex [3] and a skyrmion lattice in the presence of the AC magnetic field. We propose that the phase transition of the magnetic structure can be measured by the electrical measurement, such as a local voltage probe, induced by the spin motive force.

[1] S. E. Barnes and S. Maekawa, Phys. Rev. Lett. 98, 246601(2007).
[2] J. Ohe and S. Maekawa, J. Appl. Phys. 105, 07C706 (2009).
[3] K. Tanabe et. al., Nature Communications (2012) in press

WE-96

Intrinsic spin Hall and spin Nernst effects in silicene

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Silicene, a two-dimensional silicon lattice, has been synthesized recently and attracts much attention theoretically as well as experimentally. The silicene is a material with linear electron energy spectrum near the Fermi level, but opposite to graphene this spectrum reveals a sizable energy gap due to the presence of large spin-orbit interaction. This feature, as well as compatibility with silicon-based conventional electronics, makes the silicene a promising material for future spin electronics.

Here, we consider theoretically intrinsic spin Hall as well as spin Nernst effects. The spin Hall effect (SHE) offers a possibility of spin manipulation with electric field only. The SHE is due to the spin-orbit coupling and may be either of intrinsic or extrinsic origin. The extrinsic SHE is associated with scattering mechanisms on impurities and other defects (skew scattering and/or side jump), while the intrinsic SHE is a consequence of a nontrivial trajectory of charge carriers in the momentum space due to the spin-orbit contribution of a perfect crystal lattice to the corresponding band structure. The transverse spin current may be also generated by a temperature gradient. This is so-called spin Nernst effect or thermally induced spin Hall effect. Using Green function formalism and Kubo formula both spin Hall and spin Nernst conductivities have been determined analytically. We have shown, that when Fermi level is inside the energy gap, spin Hall effect is nonzero but the value of the conductivity is not quantized. The influence of a bias voltage between the two atomic sublattices will be also discussed. This voltage can lead to a phase transition between the spin Hall insulator state at low voltages to the conventional insulator phase at higher voltages. This transition resembles recently reported phase transition in a bilayer graphene.

WE-97

Anomalous Hall Effect in epitaxial Ni thin films

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Since its discovery in 1879, the Hall Effect has been extensively studied giving rise to several applications based on this effect. Among the family of possible Hall Effects, the Anomalous Hall Effect (AHE) remains maybe the most controversial one [1]. Depending on its origin, different dependences between ρ_{xy} (anomalous part) and the longitudinal resistivity ρ_{xx}, have been proposed and experimentally claimed in various materials [1]. Identifying and quantifying the intrinsic and extrinsic mechanisms of the AHE is one of the challenges to understand this effect. In a recent work [2], a new theory describing the AHE has been proposed including both extrinsic and intrinsic contributions, and interesting predictions were proposed and experimentally confirmed [3, 4].

In this work, we report AHE measurements of Ni thin films of thickness ranging from 1 to 18 nm, epitaxially grown on MgO (100) and (111) substrates by molecular beam epitaxy (MBE). *In-situ* reflection high-energy electron diffraction (RHEED) has been used during deposition to control the epitaxial growth. Our results have been interpreted in terms of the former unified theory of AHE [2]. The application of a recently proposed new scaling for the AHE will be discussed [5]. Anomalous Hall conductivity σ_{xy} versus longitudinal conductivity σ_{xx} is reported to show a crossover from the intrinsic intermediate regime of conductivities to the dirty regime ($\sigma_{xx} < 10^4$ S/cm) for thickness values lower than 3 nm.

[1] N. Nagaosa, et al., Rev. Mod. Phys. **82**, 1539 (2010)
[2] S. Onoda et al., Phy. Rev. Lett. **97**,126602 (2006)
[3] A. Fernández-Pacheco et al., Phys. Rev. B **77**, 100403(R) (2008)
[4] S. Sangiao et al., . Phys. Rev. B **79**, 014431 (2009)
[5] Y. Tian et al., Phys. Rev. Lett. **103**, 087206 (2009)

WE-98

Inverse Spin Hall Effect on Ge by spin pumping in CoFeB/MgO/Ge based-device

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The first challenging requirement to develop semiconductor (SC) spintronics consists in injecting spin polarized electrons in the conduction band of a SC at room temperature.

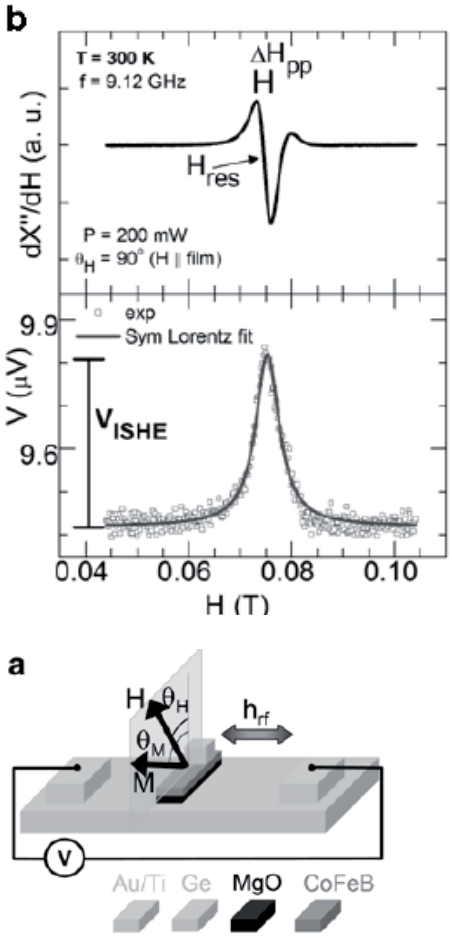
In this work, we have inserted a thin MgO tunnel barrier between Ge and the CoFeB ferromagnetic electrode in order to: i) circumvent the conductivity mismatch and (ii) partly alleviate Fermi level pinning by strongly reducing the interface states density which leads to a modest Schottky barrier height at the MgO/n-Ge interface. We have then investigated spin injection mechanisms using the socalled three-terminal device [1].

The spin-Hall angle (θ_{SHE}, ratio between the transverse spin current density and the longitudinal charge current density) [2] qualifies a material for its utility in new kinds of devices based on the spin-Hall effect (SHE), generation of spin currents from charge currents via the spin-orbit interaction, or the inverse spin-Hall effect (ISHE).

We will show a complete study of electromotive force generation under microwave excitation into a resonant cavity on the following systems: Ta(5nm)/CoFeB(5nm)/MgO(3nm)//SiO2 which exhibits only AMR voltage with symmetrical and asymmetrical components. Ta(5nm)/CoFeB(5nm)/Ge(40nm) device which exhibits also an AMR contribution. In contrast the Ta(5nm)/CoFeB(5nm)/MgO(3nm)/Ge(40nm) device exhibits a voltage with pure symmetrical contribution due to ISHE by spin pumping-ferromagnetic resonance (SP-FMR). We have extracted all the parameters from the same device in order to measure the spin-Hall angle, θ_{SHE}, of Ge at room temperature which results to be 0.002 [3].

[1] A. Jain et al. Appl. Phys. Lett. 99, 162102 (2011). A. Jain, J.C. Rojas Sánchez et al. Submitted to Phys. Rev. Lett.
[2] L. Vila, T. Kimura, and Y. Otani, Phys. Rev. Lett. 99, 226604 (2007)

[3] J.C. Rojas Sánchez et al. To be submitted.



(a) Sketch of the Ta(5nm)/CoFeB(5nm)/MgO(3nm)/Ge(40nm) device along with the angles definition. (b) FMR (top) and ISHE voltage simultaneously measured.

WE-99

Enhancing the spin hall effect with gold based alloys

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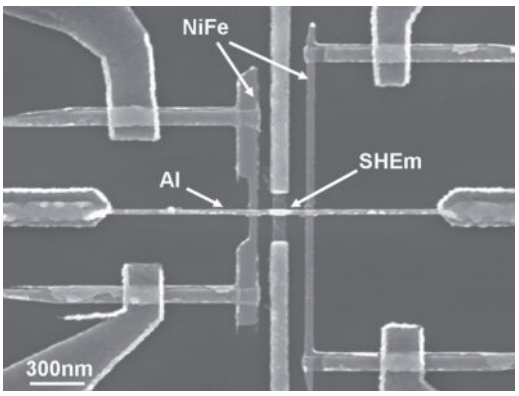
The Spin Hall Effect (SHE) [1] is currently attracting much attention as it allows generating pure spin currents, i.e., flow of spin angular momentum without charge current, in non magnetic materials. However, the spin Hall angles–characterizing the spin/charge current conversion, are still weak, even for materials with strong spin-orbit coupling such as Pt. The development of new materials with high spin Hall angles is thus required to promote the emergence of a SHE-based spintronics, avoiding requirement for ferromagnet or external magnetic field. In this context, quantifying the SHE angle remains a challenge. Here, we combine two different approaches to measure the spin Hall angle in Au based alloys: ferromagnetic resonance [2], and electrical detection in Lateral Spin-Valves [3].

In this work, we measured the voltage generated by a microwave excitation on bilayers associating a thin film of NiFe (permalloy) and another one of Au doped with nonmagnetic impurities. This method allows extracting the contribution coming from the inverse spin Hall effect, and calculating the spin hall angle.

We also used electrical detection to measure spin Hall angles, developing lateral NiFe/Al spin-valves with high spin signal amplitudes. When a wire of Pt, or Au based doped materials, is inserted in-between the NiFe electrodes, the spin current is partly absorbed. The spin signal amplitude consequently decreases, allowing the extraction the spin diffusion length. Using devices with Au based alloys, we then show that we could generate and detect spin currents with a much higher efficiency than in Pt.

[1] S. Takahashi, S. Maekawa, *Journal of the Physics society of Japan*, 77:3, 2008
[2] K. Ando *et al*, J. Appl. Phys. 109,103913 (2011)
[3]L. Vila *et al,* Phys. Rev. Lett. 99,226604 (2007)



SEM image of the LSV with insertion of a wire for SHE experiments (SHEm)

WE-100

Manipulation of spin precession in metallic lateral spin valves

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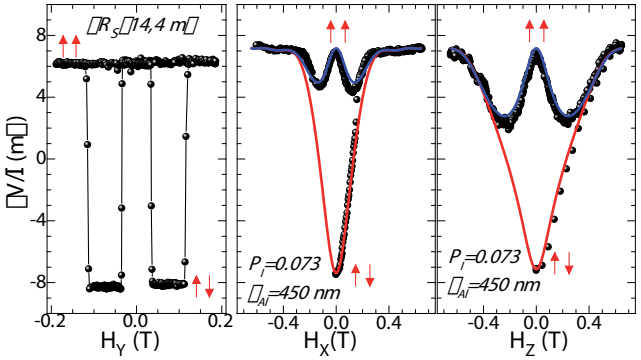
Lateral Spin Valves (LSV) consist of two parallel ferromagnetic nanowires (FM) connected by a non-magnetic transverse nanowire (NM). LSV allow generating pure spin current into the NM channel to study fundamental spin-dependent transport properties in various materials as well as for their exploitation in spintronic [1].

LSV with transparent contacts can be obtained by depositing directly the NM wire on top of the FM wires, but the resulting spin signal amplitude, Rs, is relatively small. In contrast by inserting a tunnel barrier or a highly resistive contact at FM/NM interface leads to greatly increased Rs. We added a natural Al oxide between

the interface of Py and Al and we achieved spin signals above 150 mΩ at 77 K instead of 24mΩ with transparent contacts [2].
When the magnetic field H is applied perpendicularly to the LSV plane, the injected spins in the channel precess around an axe parallel to H, leading to oscillations of the spin signal as well as Hanle effect [3]. We show that it is also possible to carry out such measurements by applying H parallel to the NM channel, the precessing spins getting in this case an out-of-plane component. We adapted Fukuma-Otani and Jedema [3] models to fit our Hanle curves. We will discuss the possibility of new experiments to exploit this new degree of freedom.

[1] L. Vila, T. Kimura, and Y. Otani, Phys. Rev. Lett. 99, 226604 (2007)
[2] P. Laczkowski, L. Vila et al., Appl. Phys. Exp. 4, 063007 (2011).
[3] Y. Fukuma et al., Nature Mat. 10, 527 (2011). F.J. Jedema et al., Nature 416, 713 (2002).



Non-local spin signal on LSV obtained by sweeping H parallel to: FM wires (a), NM channel (b), and perpendicular to the LSV plane (c). There is spin precession in (b) and (c).

WE-101

Study of spin transport in noble metals using Lateral Spin Valves

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Finding the means to generate, manipulate and detect spin currents is one of the main challenges in spintronics. Spin currents can be obtained, among other methods, by using ferromagnetic (FM) / nonmagnetic (NM) lateral spin valves (LSV). In these devices, a spin-polarized current is injected from a FM electrode to a NM channel, creating a spin accumulation at the interface, which diffuses in the NM channel and it is detected by measuring the non-local voltage in a second FM electrode [1,2].
In this work, LSV devices have been fabricated using permalloy ($Ni_{80}Fe_{20}$) for the FM electrodes and gold and silver for the NM channel. The spin signal is measured at different lengths so that the injected spin polarization of the FM electrode and the spin diffusion length for both NM metals are obtained. The spin transport behavior has also been studied performing measurements at different temperatures. These results show the crucial role of the FM/NM interface for an optimal spin injection. We also observe that the growing conditions of the noble metals influence their spin transport properties.
The authors acknowledge funding from the Spanish MICINN, the Basque Government and the European Commission. M.I. and E.V. thank the Basque Government for Ph.D. fellowships.

[1] F.J. Jedema, A.T. Filip, B.J. van Wees, Nature **410**, 345 (2001)
[2] F. Casanova, A. Sharoni, M. Erekhinsky and I.K. Schuller, Phys. Rev. B **79**, 184415 (2009)

WE-102

Magnetostatic interaction between continuous and granular layers in multilayered nanowires for current-induced domain wall motion

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Multilayered nanowire (ML-NW) for achieving high density bit based on current-induced domain wall motion (CIDWM) was proposed [1]. It is expected that magnetostatic interaction between continuous layer (CL) and granular layer (GL) in ML-NWs plays a very important role for CIDWM. However, the effect of the magnetostatic iteraction in ML-NWs has not been discussed yet in detail. In this study, the effect of the magnetostatic iteraction in ML-NWs with various saturation magnetizations on CIDWM has been investigated by using micromagnetic calculation.
Fig. 1 shows schematic calculation model of ML-NW in this study. The calculation parameters are also shown in Fig. 1. The grain size is 8×8×5 nm^3. The intragrain exchange constant in each layer was set to 2.0×10^{-7} erg/cm. The saturation magnetization M_s^g in GL was varied. The u_c is generally estimated from the hard-axis anisotropy energy $K_{h.a.}$, which is defined as the energy difference between two extreme values in total energy E_{tot} as a function of magnetization angle Θ_w at the domain wall. In order to estimate $K_{h.a.}$ in ML-NWs, the energy difference in E_{tot} was calculated by varying Θ_w.
In M_s^g of 10 emu/cm^3, the difference between energies in Bloch and Néel walls corresponds to $K_{h.a.}$, and is 0.012 perg. On the other hand, in M_s^g of 100 emu/cm^3, the difference between energies in two Néel walls with the opposite directions corresponds to $K_{h.a.}$, and is 0.14. It was found that the difference in E_{tot} increased with increasing M_s^g because the magnetostatic field from GL increases with increasing M_s^g. Therefore, it is expected that u_c increases with increasing M_s^g. We will also discuss the CIDWM in these systems.

[1] T. Komine, A. Ooba, and R. Sugita, J. Appl. Phys. 111, 07D314 (2012)

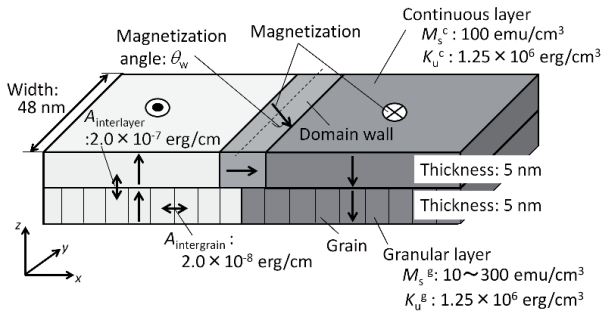

Fig. 1 Schematic calculation model of ML-NW in this study.

WE-103

Current driven domain wall motion in rare-earth transition metal alloys with perpendicular anisotropy

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Rare earth transition metal (R-TM) alloys such as TbFeCo, DyFeCo films exhibits perpendicular magnetic anisotropy. The 4f electrons of Tb and 3d electrons are antiferromagnetically coupled. Both saturation magnetization and anisotropy field of those films can be manipulated in a wide range by controlling the film composition. It is well know that different heavy rare earth metals have different spin and orbit moment. Hence it is possible to manipulate the spin polarization in those R-TM ferrimaganet. R-TM alloys normally have very sharp domain wall due to the large magnetic anisotropy and relatively low saturation magnetization. Such properties make R-TM alloys prominent candidates for the domain wall memories. In the present work, we have prepared TbFeCo, DyFeCo wires with width of about 8 micrometer and thickness of about 10 nm. As convinced by magnetooptical Kerr effect, the wires show perpendicular magnetic anisotropy. The coercivities, which is depended on the film composition, are ranging from 0.5 kOe to 5 kOe. The current-driven domain wall motion has been directly observed by a Kerr microscope. The critical current density J_c is depended on the composition of the wire. The critical current of around $1.5x10^6$ A/cm^2, which is 2 orders smaller than the critical current density in NiFe nanowires, was found for a film with composition of $Tb_{24}Fe_{64}Co_{12}$.[1]
Our experimental results show that TbFeCo, DyFeCo with perpendicular magnetic anisotropy has low critical current density. Such properties are suitable for the applications of race track memory.
The spin torque transfer efficiency, velocity of current driven domain wall motion, and domain wall magnetoresistance [2] in those R-TM alloys will also be reported.

[1] S. Li, H. Nakamura, T. Kanazawa, X. Liu, A. Morisako, IEEE Trans. Mag. 46, 1695 (2010).
[2] S. Li, T. Amagai, X. Liu, A. Morisako, Appl. Phys. Lett. 99, 122501 (2011).

WE-104

Electric conductance in nanowires with a domain wall

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The electric conductance of ferromagnetic nanowires exhibiting a domain wall is investigated within the Landauer formalism. Calculations are carried out for different sets of material parameters and in each case the dependence of the conductance on the wall thickness is investigated. For weak ferromagnetic materials, contributions to the wire conductance associated with spin-flip and non-spin-flip processes are separately analyzed. Two regimes are clearly identified, one corresponding to thick walls, in which transport is dominated by the spin-flip process, and the other to thin walls, in which case the non-spin-flip process dominates. For strong ferromagnetic materials, a single regime is found and conductance is determined just by spin-flip process. In all cases under consideration, the signature of quantum interference effects, which are not present in the description of the phenomenon based semi-classical approaches, is highlighted.

WE-105

Current-induced magnetic domain wall motion below intrinsic threshold triggered by Walker breakdown

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Controlling the position of a magnetic domain wall (DW) by electric currents is a prospective method for information processing in new types of magnetic non-volatile memory and logic devices. A key to realizing such devices is to reduce the threshold current density for DW motion. One of the proposed mechanisms for the threshold current density is the intrinsic pinning due to magnetic anisotropy [1], which has been recently confirmed experimentally in perpendicularly magnetized Co/Ni nanowires [2]. Because of its intrinsic nature, it seems impossible to drive a DW by a current below the intrinsic threshold J_{th}^0. In this contribution, we show that, contrary to this intuition, the DW motion can be induced below J_{th}^0 when an external magnetic field larger than a pinning field of a DW is applied. We show prove that this counterintuitive phenomenon is triggered by the Walker breakdown and that a current of 4×10^{11} A/m^2, smaller than J_{th}^0, can drive a DW against a magnetic field as huge as 2000 Oe. Detailed experiments reveal that the competition between current-induced DW velocity, v_J, and field-induced DW velocity, v_H, determines the direction of DW motion. The experimentally confirmed additivity of v_J and v_H gives a unique and ideal way for simultaneously determining of the spin polarization of current and the Gilbert damping constant.

[1] G. Tatara and H. Kohno, *Phys. Rev. Lett*. **92**, 086601 (2004)
[2] T. Koyama *et al*., *Nature Mater.* **10**, 194 (2011)

WE-106

Linewidths of Spin Transfer Driven Vortex Self-oscillations

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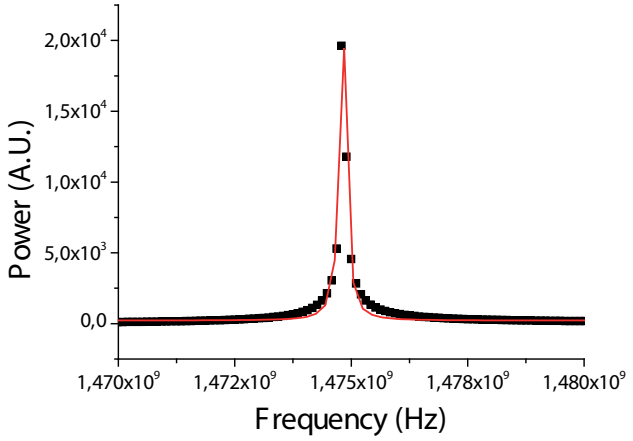
In a previous work [1] we describe by means of micromagnetic simulations the spin transfer driven vortex self-oscillations found experimentally in Py/Cu/Py Spin Valves of elliptical cross sectional (160 nm x 75 nm) [2]. The experimental linewidths range from 0.3 MHz to 60 MHz so that, as we stated in [1], "the linewidth computed numerically cannot be compared to the experimental data because the 50 ns simulation time limits the resolution to 20 MHz". In this paper we take the advantages of using GPU micromagnetic code GPmagnet [3] to perform very long micromagnetic simulations of 10 microseconds (10^{-5} s) allowing spectral resolution of 100 KHz. The simulation

is carried out in a standard GPU in around 60 hours so that systematic analysis can be achieved using a server with several GPUs. The variation of the linewidth with the current applied to the spin valve is analyzed with and without taking into account thermal activation. In the figure, the lorentzian fitting of the linewidth for an applied current of 1.0 10^{8} A/cm^2 with a perpendicular applied field of 160 mT is shown (no thermal activation), the linewidth is 174 KHz.

[1] G. Finocchio, V.S. Pribiag, L. Torres et al. Appl. Phys. Lett. 96, 102508 (2010)
[2] V. S. Pribiag, I. N. Krivorotov, G. D. Fuchs, et al. Nat. Phys. 3, 498 (2007)
[3] www.goparallel.net



WE-107

Brillouin light scattering investigation of magnetic normal modes in rhombic antidot lattice from Permalloy

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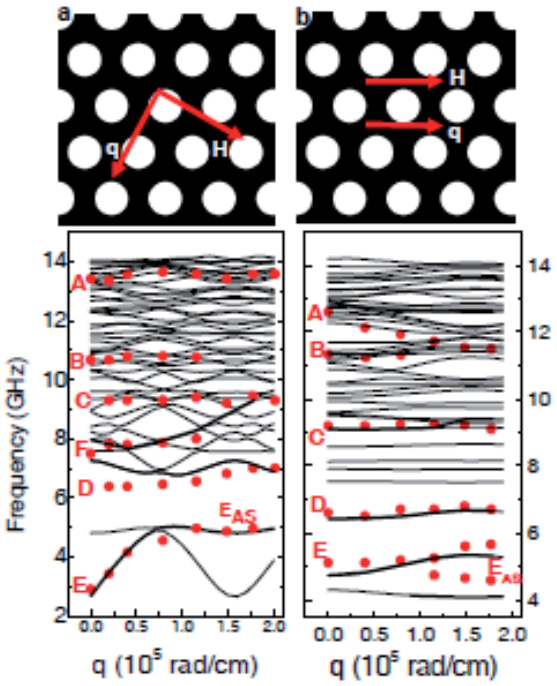
We investigate by Brillouin light scattering (BLS) spectroscopy the spin wave dispersion (frequency vs wave vector) in an antidot (AD) lattice fabricated from a 30 nm thick $Ni_{80}Fe_{20}$ film. The antidot array, fabricated using optical lithography at 248 nm exposure wavelength [1], has circular holes with diameter of 250 nm which are arranged in a rhombic unit cell with a lattice constant of 400 nm. BLS experiments have been performed in the magnetostatic surface spin waves (panel a) and magnetostatic backward volume waves (panel b) geometries with wave vectors ranging up to 2.0×10^5 rad/cm and the magnetic field H applied along high symmetry directions of the AD lattice. Only specific modes are observed to exhibit a significant dispersion for propagation along high symmetry direction of the AD lattice. In particular, propagation is found to occur for coherently coupled edge modes (labeled as E and E_{AS} in the Figure), characterized by having a large spin precession amplitude close to the hole edges and confined into sub-100 nm wide channels. A satisfactory interpretation of the BLS data is achieved by performing analytical calculations based on the plane wave method and micromagnetic simulations. Evidence is provided for the existence of allowed minibands and forbidden frequency gaps, exhibiting a periodic dispersion relation in reciprocal space. These findings are relevant for basic research on magnonic crystals [2]. Authors acknowledge the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°228673 (MAGNONICS) and the German Excellence Cluster NIM.

[1] C. C.Wang et al., Nanotechnology **17**, 1629 (2006).
[2] G. Gubbiotti et al, J. Phys. D: Appl. Phys. **43**, 264003 (2010)



Spin wave frequencies measured by BLS (points) at $\mu_0 H = 90$ mT, as a function of the exchanged wave vector *q*, in two different scattering geometries, illustrated in the upper panels. The lines are the dispersion curves calculated by the plane wave method.

WE-108

Ferromagnetic Resonance Investigation in Permalloy Magnetic Antidot Arrays on Alumina Nanoporous Membranes

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Patterned nanomagnets systems have been the object of intense interest in recent years due to their potential applications. Among these systems, magnetic antidot arrays consisting of periodically

arranged holes in continuous magnetic films have been proposed for high-density storage media. The presence of ordered nonmagnetic holes, induces a demagnetization field distribution, which can dramatically affect both, the static and dynamic properties of the magnetic system. From the static point of view it has been observed that the presence of holes affects the magnetization reversal, the coercive field and the intrinsic magnetic anisotropy of the film. From the dynamical point of view it has observed the presence of resonance modes whose frequencies can be tuned by varying the holes dimensions, symmetry of the lattice and external magnetic field [1]. Here, using the ferromagnetic resonance (FMR) technique we investigate the magnetic properties of $Ni_{80}Fe_{20}$ nanometric antidot arrays with hole diameters of 15 nm and 70 nm fabricated using porous anodic aluminum oxide (AAO) membrane as template. We study the effect of the increase in the hole diameter and the presence of defects on the angular dependence of the FMR field and show that although the SEM images reveal a quite regular hexagonal arrangement of the pores, the angular dependence of the FMR field () do not exhibits the six-fold symmetry expected. Instead of that, the azimuthal dependence of shows a clear two-fold anisotropy .To explain the experimental results, micromagnetic simulations performed on a perfect hexagonal lattice was compared with those made on a real system taken from a SEM image. The simulations qualitatively agree with the experimental findings and indicate that in samples with defects, the micromagnetic simulations must be performed on images extracted from the real systems.

[1] V. N. Krivoruchko, and I. Marchenko, J. Appl. Phys. **109**, 083912 (2011).

WE-110

FMR in Permalloy-Cobalt Magnonic Crystals

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Artificial periodical bicomponent structures (BCS) composed from alternating areas of cobalt (Co) and Permalloy (Py) films are attractive because of possible application for microwave signal processing [1]. In this work we study features of the ferromagnetic resonance (FMR) spectrum for 1D and 2D Co-Py magnonic crystals.

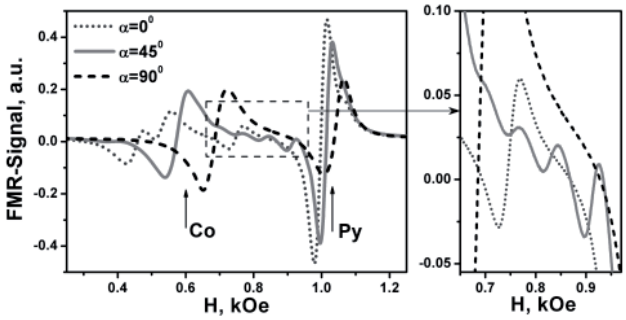
BCSs were fabricated using magnetron sputtering, photolithography, ion etching. FMR spectrum was measured for various angles α between the external in-plane magnetic field and symmetry axis for periodic structure at 9.8 GHz.

The presence of additional responses between strong ones corresponding to the quasiuniform FMR in Co and Py elements was observed in FMR spectrum (Figure.). These responses can be attributed to the formation of the standing spin-wave (SW) resonances across the lateral dimensions of BCS elements similar to those observed for the separate magnetic elements [2]. In geometry of the magnetostatic surface wave (MSSW) the formation of the standing SW for Py elements occurred because above the uniform FMR field for Co MSSW can propagate only in Py so that MSSW is reflected from boundaries between Co and Py elements and localized in Py. In contrast, in the geometry of the backward volume magnetostatic wave the localization of SW is possible in Co elements.

This work was supported by RFBR (grants No. 11-07-12081, 11-07-00233), Federal Grant-in-Aid Program "Human Capital for Science and Education in Innovative Russia" (contracts No. П 485, 14.740.11.0077), the Grant from Government of Russian Federation for Support of Scientific Research in the Russian Universities Under the Guidance of Leading Scientists (project No. 11.G34.31.0030) and European Community's 7th Framework Programme under Grant Agreement No 247556 (NoWaPhen).

[1] A. Adeyeye, *IEEE Trans. on Mag*., **47**, 1639 (2011).
[2] S. Vysotskii, *JETP Lett*., **88**, 461 (2008).

Figure. FMR results for bicomponent striped structure



WE-111

DC voltage generation by a propagating spin wave

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We report on a measurement of spin motive force generated by a propagating spin wave in a ferromagnetic FeNi wire. The sample has a rectangular shape with a length of 850 um and a width of 10 um. By exciting a propagating spin wave with a microwave coplanar waveguide (CPW), a voltage distribution in the wire was measured. It is found that (i) DC voltage is generated at the resonance frequency of magnetostatic surface spin wave, and that (ii) its magnitude diminishes as a function of distance from the CPW (spin-wave propagation distance), consistent with a picture of spin-wave attenuation. These two facts strongly support that the signal is due to the propagating spin wave. Since spin waves provide a well-characterized space-time variation of magnetization, spin waves are expected to be an ideal phenomenon to study the relation between spin dynamics and spin motive force. The observed DC voltage is well reproduced by simulations based on the theory of spin motive force.

This research was supported by PRESTO-JST, T. O. acknowledges the financial support from MEXT.

[1] S. E. Barnes and S. Maekawa, Phys. Rev. Lett. 98, 246601(2007).
[2] J. Ohe and S. Maekawa, J. Appl. Phys. 105, 07C706 (2009).
[3] K. Sekiguchi et. al., Phys. Rev. Lett. 108, 017201(2012).

WE-112

Interplay between magnonics and spintronics in spin-motive force generation devices

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We use micromagnetic simulations to explore the role of spin waves in the generation of the "spin-motive" force, a spin analogue of the electromotive force, and therefore to bridge magnonics - the study of spin waves - and spintronics – the study of spin currents.
In Ref. 1, ferromagnetic resonance (FMR) and OOMMF micromagnetic simulations were used to investigate continuous generation of the spin-motive force in a Permalloy comb structure obtained by periodic repetition (vertically in the plane of the Figure) of the building block shown below. The analysis from Ref. 1 assumed uniform precession of the magnetisation in either pad or stripe region of the comb structure. This is in contrast to earlier experiments [2] that demonstrated that, due to a dispersion mismatch at boundaries between the pad and the stripes, the excitation of such combs by uniform microwaves at the FMR frequency of the pad should launch magnetostatic spin waves into the stripes. Equally, the resonant excitation of the stripes can launch spin waves into the pads.
Firstly, we use simulations to confirm that the same mechanisms of spin wave generation are active in Permalloy structures studied in Ref. 1. Secondly, we demonstrate that adding a second pad on the opposite side of the comb enables the use of the spin-motive force to detect standing modes formed by counter-propagating spin waves. Thirdly, we discuss designs of microwave driven magnonic logic devices that are based on such structures and use the spin-motive force as their electrical output.
The research leading to these results has received funding from the EC's FP7/2007-2013 (GA 228673, MAGNONICS) and EPSRC.

[1] Yamane *et al.,* Phys. Rev. Lett. **107**, 236602 (2011)
[2] Au *et al.,* Appl. Phys. Lett. **92**, 022505 (2011)

Spin waves excited by microwaves in one period of the comb structure are shown.

WE-113
Topological transport of magnons in magnonic crystals
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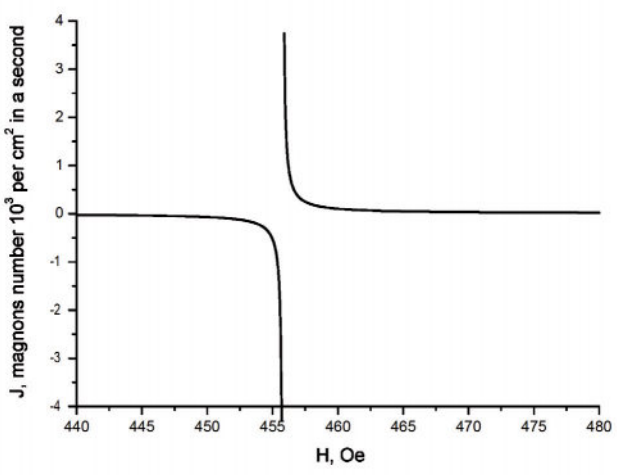
Topological transport of forward volume magnetostatic waves (magnons) in inhomogeneous isotropic medium is studied. Due to analogy drawn to the topological transport of photons [1] or phonons [2], theory of magnon transport is built under the Hamiltonian approach. By diagonalizing the magnon kinetic energy in the Walker's equation, we derive the gauge potential in the momentum space. The origin of such potential in case of absence of spin-orbital interaction is demagnetizing energy. This leads to the appearance of the Berry phase and to an additional anomalous velocity term in the equations of motion. The anomalous velocity has the form of the `Lorentz force' caused by the Berry gauge field in the momentum space and gives rise to the transverse transport of spin waves in opposite directions because of opposite helicities. Semiclassical equations of motion of magnon wavepacket are obtained; trajectories of the wave packet in two-dimensional and one-dimensional periodic structures (magnonic crystals [3]) were calculated. Tremendous increasing of the magnon cross current near the band gap edges is shown, what can be used for spintronics applications. Also the existence of anomalous Hall effect of non-charged particles, namely, magnons is shown.

[1] K. Yu. Bliokh and V. D. Freilikher, "Topological spin transport of photons: Magnetic monopole gauge field in Maxwell's equations and polarization splitting of rays in periodically inhomogeneous media", Phys. Rev. B 72, 035108, 2005;
[2] K.Yu. Bliokh, V.D. Freilikher,"Polarization Transport of Transverse Acoustic Waves: Berry Phase and Spin Hall Effect of Phonons", Phys.Rev.B 74, 174302, 2006.
[3] S. A. Nikitov, Ph. Tailhades, C. S. Tsai, "Spin waves in periodic magnetic structures.magnonic crystals", J. Magn. Magn. Mater., Vol. 236, 320, 2001.



Magnon cross current dependence on the external field (anomalous Hall effect)

WE-114
Peculiarities of spin-wave propagation in magnonic waveguides
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A demand of miniaturization in nanoelectronics leads to a size reduction of the ferromagnetic elements used in microwave devices. It is well-known that the conditions for the wave propagation in confined waveguiding structures differ drastically from the infinite plane ones. In the magnetic finite-width waveguides a lot of new effects appear due to the strong confinement of propagating spin waves [1, 2]. From these perspectives, commonly used approximate theoretical methods cannot exhaustively meet all the demands of the theoretical analysis of obtained experimental data.
Here we report a normal-mode theory for the description of spin-wave propagation in a finit-width anisotropic ferromagnetic waveguide. The dipole-exchange spectrum of spin waves is obtained analytically using the method of tensorial Green's function together with the spin-wave mode approach elaborated in our previous works [3]. A finite width of the waveguiding structure

is taken into account simultaneously with the magnetocrystalline anisotropy of uniaxial type. The problem of the determination of the internal static magnetic field in the confined structure is solved for an arbitrary direction of the external bias magnetic field.
To illustrate the presented theoretical approach, the numerical calculations were done for the most common case of uniaxial anisotropy perpendicular to the film plane and for perpendicularly magnetized waveguiding structure. It is demonstarted that the approximate methods, which were widely used for accounting of the finite-size effects in ferromagnetic waveguides, give a large discrepancy for micron-size samples.

[1] V.E. Demidov et al., J. Phys. D: Appl. Phys. 41, 164012 (2008)
[2] A.V. Chumak et al., Appl. Phys. Lett. 95, 262508 (2009)
[3] N.Yu. Grigorieva et al., In *Handbook of Artificial Materials*, ed.by F. Capolino, Vol. I, pp. 34-1-68. 2009. Taylor and Francis Group, Oxford, UK.

WE-115

Spin-wave dynamics in lateral periodic and quasiperiodic magnetic micro- and nanostructures-magnonic crystals

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Magnetic periodically structured ferromagnetic films being a microwave analog of photonic and phononic crystals have created a revival interest of spin waves (SW) investigations in periodically micro- and nanostructured magnetic media, which are called magnonic crystals (MC). However SW propagation in such structures has some specific properties untypical for both optic and elastic waves. Namely, they possess strong nonlinearity, anisotropic and nonreciprical propagation characteristics even for the case of wave propagation in isotropic materials. Besides that, ferromagnetic films being a base for MC with strong magnetostriction due to resonance interaction between excitations of magnetic and elastic subsystems lead to a new unusual effects. Such peculiarities of SW propagation in MC are interesting and important both from fundamental and practical points of view as they can be important for microwave signal processing on the basis of magnonic crystals. In this paper we review the recent results of propagating and localized spin-waves excitations in magnetic thin film structures with micro- or nanosize features arranged in lateral one- (1D) or two-dimension (2D) periodic arrays. Such fundamental phenomena as anisotropic Bragg scattering
and quantization of SW are discussed as well opportunities to control the magnonic crystals parameters due to metal screening and nonlinearity of magnetic system. Some attention will be paid to magnetoelastic interaction in epitaxial yttrium iron garnet/ gadolinium iron garnet (YIG/GGG) structures with microstructured surface of ferromagnetic YIG film. We also review results of ferromagnetic resonance (FMR) investigations of localized SW modes in MC crystals based on metallic ferromagnetic films: permalloy (Py) films sputtered on B patterned nonmagnetic substrate, bicomponent (Py and Co) MC and antidote lattices.

WE-116

Collective vortex mode dynamics and bandwidth tunability in a magnonic crystal

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Magnonic crystals are artificial materials with periodic variation of their magnetic properties. They are promising candidates for advanced devices in which tuning an external field H can modulate the allowed/forbidden bands, and slow down even to zero speed the information carriers ("magnons") turning a waveguide (or a filter) into a memory (and vice-versa). In the saturated case, the band diagram has been extensively investigated also experimentally [1], while only a few studies on collective vortex dynamics have been reported [2]. Employing the dynamical matrix method (DMM) [3], we performed calculations on a square lattice of small disks in the vortex state, varying the inplane wavevector components to investigate the first Brillouin zone. Interdot coupling in the vortex configuration is not simply dipolar: in DMM, higher order terms in the multipole expansion are actually considered through the full calculation of the demagnetizing tensor of the system. We computed the dispersion relations for gyrotropic, azimuthal and radial modes at H=0 (Fig-1) and also at H≠0. We found that the profile of a given mode (and its circular polarization) depends on the Bloch wavevector k, and can dramatically differ from the case k=0 (mode conversion). We found that application of an external field can significantly reduce or enhance the gyrotropic mode bandwidth and propagation speed. This work was supported by the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°233552 (DYNAMAG).

[1] S. Tacchi et al., Physical Review Letters, in **107**, 127204 (2011).
[2] A. Yu. Galkin, B. A. Ivanov and C. E. Zaspel, Physical Review B, **74**, 144419 (2006).
[3] L. Giovannini, F. Montoncello, and F. Nizzoli, Physical Review B **75**, 024416 (2007).

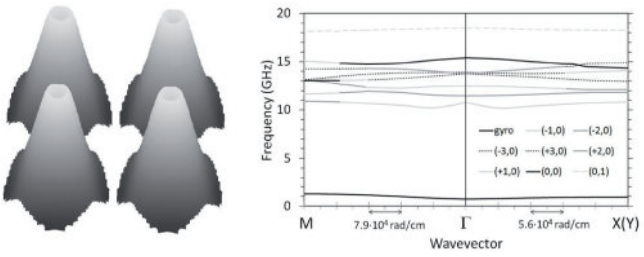

Fig. 1 (left panel) Radial mode with one node; (right panel) band diagram at H=0.

WE-117

Forward Volume Magnetostatic Spin Wave Propagation in a Local Resonant Magnonic Crystal

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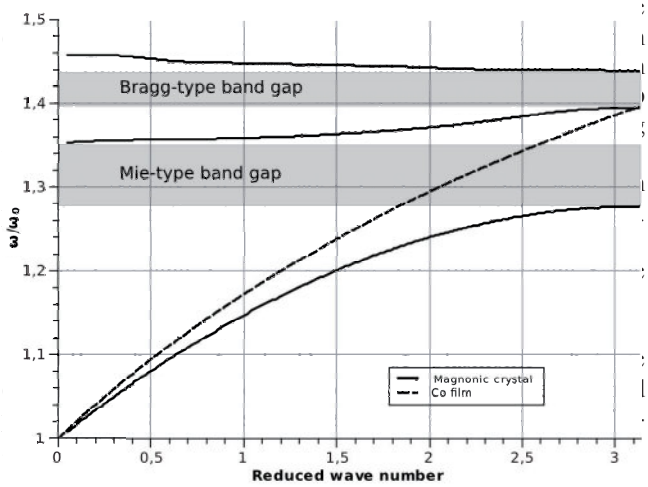
Wave propagation in nanostructured materials with space modulated constitutive parameters has drawing attention for last

decades [1]. Special attractive case of artificial materials is quasi-isotropic composites with embedded resonators [2,3]. Propagation of magnetostatic spin waves in this type of composite media is less covered to date. In present work we provide investigation of Forward Volume Magnetostatic Spin Wave (FVMSW) propagation in two-dimensional magnonic crystal (MC) [1], considered as a ferromagnetic film with nano-sized cylindrical inclusions in a matrix and placed in a periodic lattice.
Two types of resonances could occur in such structure: Bragg-type resonance from the periodical arrangement of inclusions and Mie-like local resonances inside inclusions. The resonance regime and destructive interference may open a band gap in FVMSW spectrum. We report a theoretical analysis of band gap behavior in two-fold composites with Yittrium-Iron-Garnet, Ni, Co and Fe fractions, depending on a filling fraction, a film width and an external magnetic field. It is shown, that local resonances may dramatically change the band structure of MC. As an



Band structure of Forward Volume Magnetostatic Spin Wave in Co/Py MC.

WE-118

Magneto-optical Properties of (Pt/Co)/X/IZO (X = Ta, Au, Pt, Ru and Ag) structures for Magneto-optical Spatial Light Modulators

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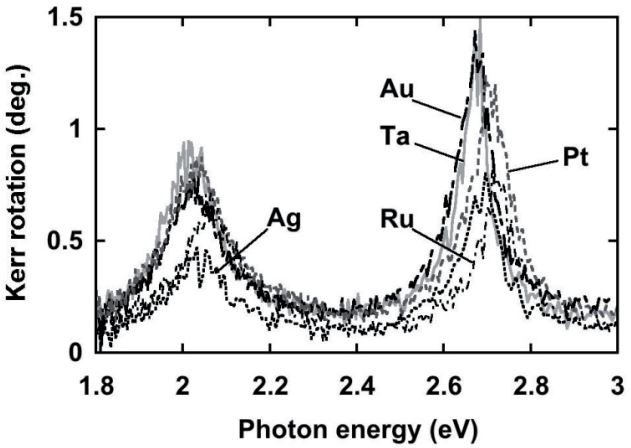
Magneto-opitcal spatial light modulator (MO-SLM) using giant magneto-resistive (GMR) device is promising as a holographic three-dimensional (3D) display[1]. For practical applications, MO properties of GMR devices should be investigated[2]. We studied an enhancement of Kerr rotation of GMR structure by a top transparent electrode and a capping layer deposited on a free layer. MO layer/capping layer/transparent electrode structures were fabricated on a Cu/Ta electrode deposited on Si substrates by a DC magnetron sputtering technique. The Pt/Co multilayer with a thickness of 6.64 nm and Indium Zinc oxide (IZO) with 350 nm were used as a MO free layer and a transparent top-electrode, respectively. Capping layers consisting of Ta, Au, Pt, Ru or Ag, with a thickness of 3 nm were deposited on Pt/Co multilayers. Kerr rotation spectra and reflectivity spectra were measured for a visible region, 400 - 700 nm in wavelength. We also studied those spectra by a simulation using the virtual optical constant method.
A large enhancement of Kerr rotation was found at approximately 2 and 2.7 eV in photon energy and reflectance decreased at the same energies for all samples prepared in this study. The Kerr rotation reaches 0.7 - 0.9 degrees at 2 eV and 1.2 - 1.5 degrees at 2.7 eV for samples with Ta, Au or Pt capping layer, while samples with Ru or Ag capping layer had relatively small Kerr rotation. Our simulation reproduced well that there are two peaks and that lager Kerr rotation can be obtained for Ta or Au capping layer.
This research was partly supported by the National Institute of Information and Communications Technology (NICT).

[1] K. Aoshima et al., J. Display Tech., 6, 374 (2010)
[2] T. Ishibashi et al., J. Magn. Soc. Jpn., 36, 70 (2012)



Kerr rotation spectra of Si sub./(Cu/Ta)/(Pt/Co)/X/IZO (X = Ta, Au, Pt, Ru and Ag).

WE-119

Magnon-phononic crystal based on epitaxial YIG/GGG structure

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In this work we study magnetoelastic waves (MEW) propagation in normally magnetized yttrium iron garnet (YIG) film on gadolinium gallium garnet (GGG) substrate with periodic array of grooves in YIG film. We show that both magnonic and phononic gaps can appear in such structure due to Bragg resonance so that the structure can be qualified as a phonon-magnonic crystal (PMC).
PMC was made in the form of 1D grating of grooves with depth of $\delta d \approx 0.4\mu m$, width of $w \approx 52\mu m$ and period of $\Lambda \approx 100\mu m$ etched in YIG film with thickness of $d \approx 3.8\mu m$, see figure. PMC was placed on the microstrip tranducers for excitation and detection of forward volume magnetostatic waves (FVMSW) and S_{21} was measured versus frequency f arround 500 MHz where YIG film acts as a half wavelength magnetostrictive transducer for transverse elastic wave (TEW).
The equidistant ($\Delta f \approx 3.5$MHz) oscillations was observed in $S_{21}(f)$ with frequencies corresponding to theoretical prediction for TEW resonances in GGG substrate: $fN \approx NV/(2L)$, where $V \approx 3.57 \cdot 105$cm/s and $L \approx 596\mu m$ are TEW velocity and thickness for GGG substrate, and number N = 148-197. In addition to

these features which well coincide with earlier found in plain YIG/GGG structures for MEW excitations [1], we observed the frequency gap in the range of 500-520 MHz corresponding to the first Bragg resonance for the wavenumber k≈π/Λ≈300cm−1 where the transmitted signal amplitude dropped down to the level of the direct electromagnetic leakage between transducers for both cases FVMSW and MEW.

This work was supported by RFBR grants 11-07-12081, 11-07-00233, the Grant for Support of Scientific Research in the Russian Universities Under the Guidance of Leading Scientists (No. 11.G34.31.0030) and EC 7th Framework Programme under Grant Agreement No 247556 (NoWaPhen).

[1] Gulyaev Yu.V., et. al. JETP Lett., **34**, 500 (1981).

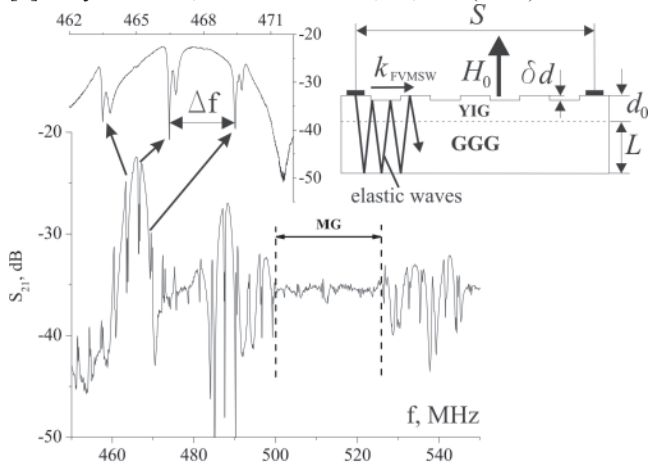

Figure. $S_{21}(f)$ for FVMSW in YIG/GGG based PMC.

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

Chair: O. Fruchart

WE-121

Influence of perturbations on the out-of-plane precession of an in-plane magnetized free layer with a perpendicular polarizer

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In-plane magnetic tunnel junctions with perpendicular polarizer are of great interest for applications in MRAM and nano-oscillators. The spin torque coming from the perpendicular polariser compensates the damping term coming from the demagnetizing field, giving rise to out-of-plane precessions (OPP) of the magnetization on a subnanosecond time-scale [1]. The magnetization dynamics are well described in a first approximation by the macrospin LLGS equation. In general this equation cannot be solved analytically. However in the simplified case of a thin free layer subject to the demagnetizing field and the spin-transfer torque coming from the perpendicular polarizer only, we can deduce an analytical expression [2]. The solution is a periodic cycle describing the out-of-plane precession at a constant out-of-plane angle. In the more complex case, with uniaxial anisotropy, applied field or spin-torque of the in-plane reference layer, LLGS equation can only be solved numerically. However an analytical expression can be approximated by using perturbation theory. We compare it with numerical simulations and define a range of validity for the approximation. Critical currents and frequency changes are also computed. This approach gives an insight of the solution and of the influence of each parameter without numerically integrating LLGS equation, in particular the influence of the spin-torque of the reference layer on the out-of-plane precession.

[1] U. Ebels et al., Phys. Rev . B 78, 024436 (2008)
[2] T.J. Silva et al., IEEE Transactions on Magnetics, Vol. 46, no 9 (2010)

WE-122

Nonlinear dynamics of the domain walls in real magnetics

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One line in theoretical investigations of the influence of defects on magnetic inhomogeneity is considering the possibility of a spatial dependence of the parameters of the materials under study. Since microscopic calculation is generally quite difficult, we have to model the functions describing the parameters of inhomogeneous material.

Approximation of a defect in the form of a flat magnetic inclusion, either infinitely thin or having a finite thickness is often used for ferromagnets. The effect of flat magnetic inclusions on the static and certain dynamic properties of magnetic inhomogeneities has been studied both analytically and using numerical methods [1].
In this work we have investigated the origin and evolution of the dynamic magnetic inhomogeneities, appearing after the passage of a DW through a defect. In the one-dimensional modulation of the magnetic parameters this is a weakly damped breather and a soliton, in the two-dimensional modulation of the magnetic parameters this is a pulson and 2D soliton. The evolution of a DW is trapped in the defect has been considered. The translational and pulsation modes of the DW have been calculated. We have investigated for the case of 2D magnetic inhomogeneity the dynamic of solitary deflection waves, which appear on the DW crossing of defect. It's shown that the solitary deflection wave appears as "kink on kink". Dependences of maximum amplitude solitary deflection waves on DW speed and on inhomogeneity magnetic parameters in case of DW motion in an external magnetic field was found. In the presence of the magnetic field it was obtained the dependence of the speed and acceleration of the DW on the amplitude and duration of pulsed magnetic field. We have compared these results with known analytical, numerical and experimental data.
[1] E.G. Ekomasov et al., The Physics of Metals and Metallography 112, 213 (2011)

WE-123

Micromagnetic study of the domain wall dynamics along square cross section wires: the role of the Oersted field

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The static configuration of head-to-head DWs in Permalloy-wires of square cross section with sides L from 10 to 100nm (Fig. 1(a)), and its subsequent dynamics driven by electric currents along the wire axis, have been studied by means of systematic micromagnetic simulations [1]. Depending on L, two equilibrium states are obtained: (i) Transverse DW (Fig. 1(b)) for L<40nm, and (ii) Bloch-point DW (Fig. 1(c)) for L>40nm.

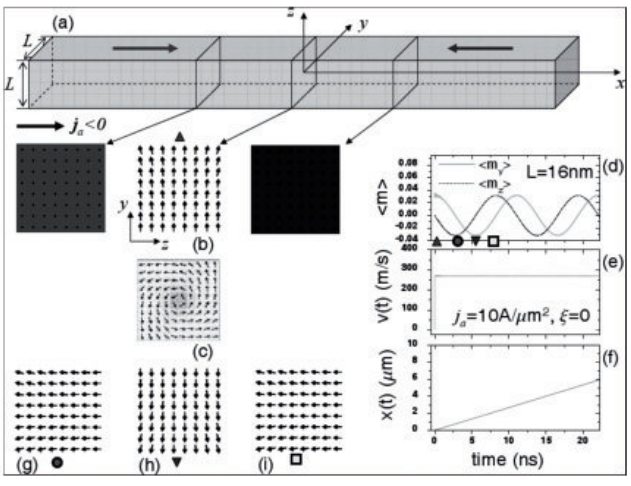

Figure 1. (a)Schematic view of the square wires. Central section of Transverse DW (b) and Bloch-point DW(c). Temporal evolution of the $<m_x>$ and $<m_y>$ (d), the DW velocity (e)and the DW position (f) under $\boldsymbol{j}_a$=10A/mm$^2\boldsymbol{u}_x$ in the perfect adiabatic case for a L=16nm wire.

The current-driven DW dynamics have been studied by considering several values of the non-adiabatic parameter, from x=0 to x=4α, being α the damping. For instance, the temporal evolution of the volume average transversal magnetization components ($<m_x>$ and $<m_y>$), the DW velocity(v) and the DW position(x) are depicted in Fig.1(d)-(f) respectively in the perfect adiabatic case (x=0) under a density current of $\boldsymbol{j}_a$=10A/mm$^2\boldsymbol{u}_x$. For a current, the DW reaches a steady DW velocity, but the transverse DW displaces along the x-axis (see Fig.1(g)-(i))[2]. Although the current is high above than the Walker breakdown(0.2A/mm^2), it was confirmed that the Oersted field induced by the current does not modify this transverse DW motion. However, the Oersted field plays a significant role in other cases, as for example for transverse DWs when x=α, or in wider wires, where the DW adopts a Bloch-point configuration.

[1] E. Martinez et al. Phys.Rev.B**77**,174409(2008)
[2] J. H. Ai et al. J.Appl.Phys.110,093913(2011)

WE-124

Domain wall dynamics in CoFeB-MgO films with perpendicular anisotropy

C. Burrowes [1], J.P. Adam [1], N. Vernier [1], N. Nguyen [1], S. Ahn [1], G. Agnus [1], S. Eimer [1], J. Kim [1], T. Devolder [1], B. Ockert [2], D. Ravelosona [1]

(1) Institut d'Electronique Fondamentale, Université Paris Sud, CNRS UMR 8622, 91405 Orsay, France, (2) Singulus technology AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

One crucial breakthrough in spin electronics has recently been achieved regarding the possibility to move magnetic domain walls (DWs) in magnetic tracks using the sole action of an electrical current instead of a conventional magnetic field. This important discovery has opened a perspective for a paradigm shift in mass storage design. However, one crucial issue is the distribution of intrinsic pinning defects that induces stochastic domain wall motion and high threshold currents to move domain wall, in particular in films with perpendicular magnetic anisotropy (PMA). Here, we will present measurements by Kerr microscopy of DW dynamics obtained in CoFeB-MgO films with PMA. As shown in Figure 1(a), the shape of magnetic domains is perfectly round and DWs propagate at ultra-low propagation fields below 1 mT at 300 K. This is a very important result, indicating an ultra low density of pinning defects in CoFeB-MgO films. For comparison, similar measurements for Co/Ni or Co/Pt films show propagation fields above15 mT. To go further, DW velocity under field was investigated from the creep regime (nm/s) to the high velocity regime (few m/s). Below Hp a creep regime is found, typical for DWs interacting with a distribution of weak defects. Above Hp, a very peculiar feature is revealed. We observe two linear regimes, one up to 6mT with a high DW mobility and the other one with only a slight increase of DW velocity up to 24 mT. No evidence of DW instabilities (Walker breakdown) is found between these two regimes. In light of micromagnetic simulations, we will discuss these results.

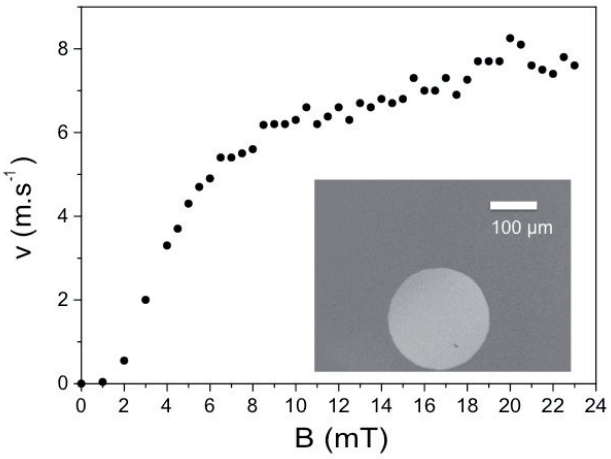

Fig. 1: Typical image of a magnetic domain in CoFeB-MgO films. Insert: DW velocity versus applied magnetic field indicating two different flow regimes at high fields.

WE-125

Spin dynamics of ferromagnetic nickel excited in the mid infrared

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Using ultrashort laser pulses to study and control the magnetization dynamics of materials has triggered a new field of research called Femtomagnetism [1]. Such studies are of great interest for applications using ultrafast magnetic devices controlled by light pulses. In that context, we will show how the ultrafast demagnetization and the subsequent rapid re-magnetization occur when exciting a ferromagnetic material with low energy infrared pulses. We have used mid-infrared femtosecond laser pulses (λ= [3-10 µm]) to excite thin films of nickel. The magneto-optical response is then probed in the visible (λ = 798nm). Our results show that even though only intraband transitions occur, the demagnetization process and its subsequent relaxation to the lattice and to the environment are still the dominant processes involved in the magnetization dynamics. We also show that the material band structure is important to interpret the thermalization dynamics of the spins that occur before the heating of the lattice. For specific experimental configurations, we show that it is possible to induce a motion of precession of the magnetization around the effective magnetic field and observe it while it is damped. The magnetization dynamics induced at 6.5 µm in nickel shows an oscillatory behaviour with a period of 2 ps. We attribute this result to the excitation of a two-magnons mode on the NiO by an acoustic mode generated in nickel [2].

[1] E. Beaurepaire, J. –C. Merle, A. Daunois and J. –Y. Bigot, Phys. Rev. Rev. Lett.76, 4250 (1996)
[2] R. E. Dietz, G. I. Parisot and A. E. Meixner, Phys. Rev. B, 4, 7 (1971)

WE-126

Pinned Layer dynamics and its influence in nanocontact vortex oscillators

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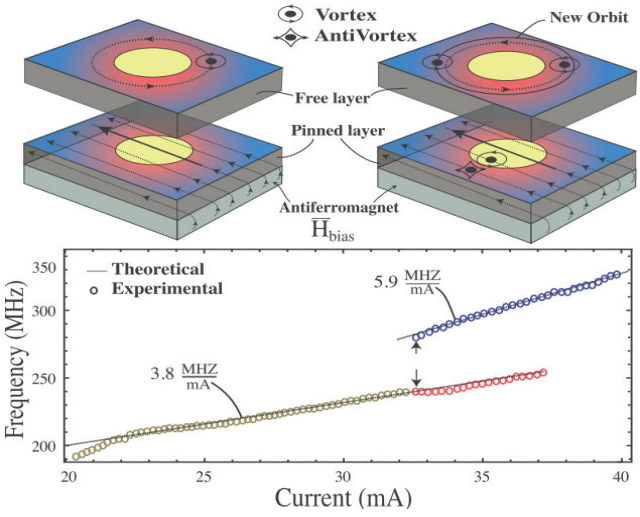
The phenomenon of spin transfer torque provides a method to manipulate magnetization under different geometries without using any external magnetic field [1]. In the case of nanocontact geometry the current passes through a small contact area (~ 60 nm radius) and is injected into a magnetic multilayer with the following composition: Py(3nm)/IrMn(6nm)/$Co_{90}Fe_{10}$(4.5nm)/Cu(3.5nm)/Py (4nm)/Pt(3nm). The Oersted-Ampere field associated with this current can nucleate a vortex under certain conditions [2]. Although the key features of the nucleation process in the free layer have been reported [3], the role of the current on the exchange biased pinned layer remains unknown. We provide conclusive evidence that the pinned layer posseses a vortex-antivortex pair under the nanocontact above certain value of the current. We find that the role of the exchange bias is to confine the pair below the nanocontact. The nucleation of the pair leads to a distinct jump in the frequency of the free layer oscillation mode and a different current tunability (Figure). The coexistence of the two branches indicates the existence of the pair is intermittent, which suggests a thermally-activated phenomenon. Good agreement is found with micromagnetic simulations.

[1] M. R. Pufall et al., Phys. Rev. B 75, 140404 (2007)
[2] Q. Mistral et al., Phys. Rev. Lett. 100, 257201 (2008)
[3] T. Devolder et al., Appl. Phys. Lett. 97, 072512 (2010)
[4] Joo-Von Kim et al., arXiv : 10073859v1 (2010)



Vortex oscillation frequency as a function of the injected current. Nucleation of vortex-antivortex pair results as a jump (at 33mA) in the oscillation frequency of the vortex in the free layer.

WE-127

Finite Element based self-consistent treatment of magnetization dynamics caused by spin transfer effects

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Up to now the spin transfer effects were introduced in micromagnetism by means of two local contributions called adiabatic term and non-adiabatic term related to phenomenological constant whose value is open to debate. Besides, the theoretical models were applied for simple geometries with homogeneous current flow. In order to design realistic spintronic devices with strong current and magnetization gradients imposed by system properties or geometry the additional length scales as well as self-consistent interaction between transport and dynamics equations should be considered.
We present an advanced model which couples Landau-Lifshitz-Gilbert equation (LLG) for magnetization dynamics with the diffusive transport equations introduced in [1]. In this self-consistent treatment all non-linear diffusive terms are taken into account. The implementation was realized as an add-on module to our micromagnetic finite element (FE) software FEELLGOOD which faithfully describes any complex geometry (nanoconstrictions, circular cross-sections etc.). To overcome the problem of magnetization renormalization (proper to most of existing FE software) and to treat correctly the magnetization dynamics for realistic damping factors we choose to deal with vector test functions belonging to the tangent plane to the local magnetization [2]. At each time step the local torque is determined from the spin accumulation distribution and then injected into the LLG equation.
By choosing different types of domain walls moving in a nanostrip under the action of homogeneous or non-homogeneous spin-polarized current we present a comparative study between simplified and coupled models. We show that spin diffusion terms are not negligible contrary to the hypotheses made in the basic model [1]. We discuss how these terms and current distribution affect the wall motion and its velocity.

[1] S. Zhang, P.M. Levy, A. Fert, Phys. Rev. Lett. 88, 236601 (2002)
[2] F. Alouges, E. Kritsikis, J.C. Toussaint, Physica B 407, 1345 (2012)

WE-128

Vortex core magnetization dynamics induced by spin current and heat

T.S. Machado [1], T.G. Rappoport [2], *L.C. Sampaio [1]*
(1) Centro Brasileiro de Pesquisas Físicas, 22.290-180, Rio de Janeiro, Brazil, (2) Universidade Federal do Rio de Janeiro, 21.941-972, Rio de Janeiro, Brazil

The control and manipulation of the magnetization in magnetic materials is one of the most interesting challenges in the field. In the last 10 years it has been shown that besides magnetic field, spin polarized current, light, electric field and heat can be used to modify a magnetic state, providing new opportunities for technological applications.
Depending on their length and thickness, microsized disks made by magnetic materials like Permalloy (Py) can exhibit a vortex in its center. Under excitation such as a pulsed field, the vortex core moves around the center of the disk and depending on the excitation intensity the core magnetization can be even reversed.

We investigate the effect of the spin polarized current [1] and the temperature [2] on the dynamic properties of magnetic vortices in small disks. Our calculations use a stochastic version of the Landau-Lifshitz-Gilbert (LLG) equation, valid for finite temperatures well below the Curie critical temperature. We show that a finite temperature induces a vortex precession around the center of the disk, even in the absence of other excitation sources. We discuss the origin and implications of the appearance of this new dynamics. We also show that a temperature gradient plays a role similar to that of a small constant magnetic field.

[1] T. S. Machado, M. A. de Menezes, T. G. Rappoport, and L. C. Sampaio, J. Appl. Phys. 109, 093904 (2011).
[2] T. S. Machado, T. G. Rappoport, and L. C. Sampaio, Appl. Phys. Lett. 100, 112404 (2012).

WE-129

Thermostated spin dynamics in an extended phase space.

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The use of lower than femtosecond laser sources has pushed limits down to time scale where the physical processes underlying the response of the magnetization on this very short time is complicated and far from being understood. This involves the out of equilibrium interaction of more than spins together including electronic and lattice excitations. Such extreme conditions suggest that the magnetic relaxation processes, occurring on this time, may be remarkably different from those typical for dynamics at longer time scales.
To get insights, when isothermal ensembles with a constant number of spins are considered, two methods are commonly reported to describe finite temperature effects for the coupling between classical particles and spins: the stochastic and the deterministic methods in which their corresponding merits are discussed. One shows that the temperature dependence of magnetic properties of nano materials is demonstrated by a dynamical system composed of interacting vector spins coupled together and additional friction variables. A set of coupled variables is formed according to the conservation of the extended phase space probability [1]. The whole system is integrated simultaneously in time domain following the Baker-Campbell-Hausdorf formula for each evolution operators. A spin temperature expression is found and followed in time. The analysis of the time behavior of the space-average magnetization is performed and compared to conventional stochastic spin dynamics. To make the deterministic spin dynamics more ergodic, an increase of the size of the phase space is formulated by means of a chain of thermostats. Analogies are formulated by comparison with an extended Miyazaki-Seki multi-spins dynamics and are investigated.

[1] Thibaudeau P. and Beaujouan D. , Physica A, 391, 1963–1971, (2012)

WE-130

Investigation of vortex dynamics in coupled trilayer systems

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Magnetic vortices are of great interest for storage media since quite some time. Different control methods are used to manipulate them [1]. We now use scanning transmission X-ray microscopy (STXM) to image the magnetic configurations within the different layers of a trilayer system of a Co/Cu/FeNi disc. Inside the hard and soft magnetic layers with a thickness of 25 nm vortices are formed. They couple depending on the interlayer. The dominant coupling mechanisms here are the magneto-dipolar interaction and interlayer exchange coupling [2]. The setup allows to drive a current perpendicularly through the disc. The corresponding behaviors of the magnetization configurations with a DC-current, in a static magnetic field, as well as in an oscillating magnetic field, are investigated. The emerging movement of the core can be tuned with the amplitude and frequency of the field. The interactions of the two cores and their individually movements are studied. The movement of the cores affected by an external magnetic field applied in-plane is shown in Fig. 1. This implies the corresponding resistance changes within different configurations at different magnetic fields and currents as well as the shifting of the core.

[1] N. Locatelli et al., Appl. Phys. Lett. 98, 062501 (2011)
[2] S. Wintz et al., Appl. Phys. Lett. 98, 232511 (2011)

WE-131

Equation for stochastic magnetization dynamics at elevated temperatures

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The magnitude of magnetization is preserved by the Landau-Lifshitz equation for magnetization dynamics. This restriction is justified well below the Curie temperature, where local exchange interactions dominate with respect to thermal fluctuations, but not at elevated temperatures, a fact that may have significant implications in such applications as thermally-assisted magnetic recording or all-optical magnetization switching [1]. For this reason, it is desirable to develop generalizations of the Landau-Lifshitz equation, which will be applicable when magnetization magnitude is not conserved. In this paper, one such generalization is discussed, which is based on the idea of describing thermal-bath effects by a jump-noise process. The value of this approach has been stressed in previous recent papers [2]. Variable magnetization magnitude naturally emerges when one makes the simplest assumptions for the structure of the jump-noise process. On the other hand, changes in magnetization magnitude are naturally reflected by the presence of additional terms in the system free energy and effective field. The result is a differential equation in which both longitudinal and transverse damping terms are present. In this sense, the obtained equation is similar to the so-called Landau-Lifshitz-Bloch equation [3]. The unique feature of the proposed approach is that longitudinal and transverse damping terms directly emerge from the structure of the jump-noise process. Moreover, explicit formulas can be derived for their dependence on magnetization.

[1] Z. Zhang and I. D. Mayergoyz, J. Appl. Phys. 103, 07F510 (2008); C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007).
[2] I. D. Mayergoyz et al., Phys. Rev. B 83, 020402(R) (2011); I. D. Mayergoyz et al., J. Appl. Phys. 111, 07D501 (2012).
[3] D. A. Garanin, Phys. Rev. B 55, 3050 (1997).

WE-132

Out-of-plane angular dependence of dynamical magnetization pinning for circular dot

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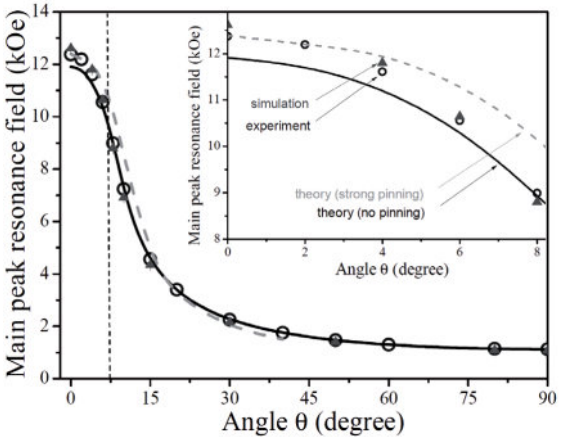
Array of Permalloy circular dots was fabricated on a silicon wafer using electron beam (EB) lithography and lift-off techniques. A double layer resist spin coating and highly directional EB evaporation were used to obtain the dots with sharp edges. Dots with the diameter of 1 μm and thickness of 50 nm were arranged into square array with the lattice period of 2.5 μm to avoid dipolar interdot interactions. The dot dimensions were confirmed by atomic force microscopy (AFM) and scanning electron microscopy (SEM). The surface roughness of dots was found to be only 3 nm by AFM. SEM images demonstrated almost perfect sharpness of the dot edges.

Sample was probed by continuous-wave Ferromagnetic resonance at 10 GHz. Out-of-plane angular dependence of the main resonance peak was measured in the whole range of the angles between external magnetic field and normal to the wafer surface $0^o \leq \theta \leq 90^o$. In spite of the main eigenmode spatial distribution is strongly non-uniform due to dot non-ellipsoidal shape, the Kittel's equation assuming uniform dynamic magnetization (no pinning at the dot lateral edges) describes the peak position with good accuracy for all the angles above 7º. For the field orientation around perpendicular to the dot plane ($\theta=0^o$) another approximation involving zero-order Bessel functions and strong pinning at the dot edges can be applied. Micromagnetic simulations confirmed the gradual evolution of the main mode profile and a smooth transition from the strong to small pinning conditions with the change of external magnetic field angle.



FMR fields for the different angles of the applied dc magnetic field

WE-133

Peculiarities of Dynamic Remagnetization Process in Ferrite-Garnet Plates

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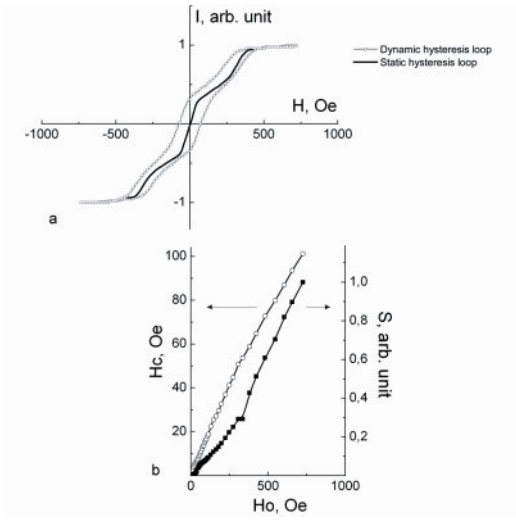
We report results of simultaneous study of domain structure (DS) restructuring and magnetooptic hysteresis loops for frequencies and amplitudes of oscillating magnetic field, for which domain walls drift is observed [1]. Magnetic field H=Ho sin 2πft with frequecy f (25-1000 Hz) and amplitude Ho up to 750 Oe was applied perpendicular to –(111) sample plate of ferrite-garnet single crystal $(TbErGd)_3Fe_5O_{12}$ 50 mkm thick. Magnetic anisotropy was characterized by cubic, induced uniaxial and orthorhombic components. Domain structure was revealed by means of magnetooptic Faraday effect and was captured by high-speed camera at 2000 fps. Static and dynamic hysteresis loops are shown on Fig.1a. Dynamic hysteresis loop was measured at f = 250 Hz and Ho = 720 Oe. Fig. 1b shows dependencies of dynamic hysteresis loops area (S) and of coercitive force (Hc) from amplitude of oscillating field. Peculiarity of static and dynamic hysteresic loops is their two-step form, which we explain by nature of restructuring of DS in different ranges of magnetic fields. Direct observaions of DS restructuring in oscillating magnetic field that changes along hysteresis loop show that hysteresis is caused by two factors: 1) delay of nucleation and growth of new magnetic phase in oscillating magnetic field; 2) sharp increase in the number of magnetic dislocations [1] with increase of amplitude of oscillating magnetic field.

[1] L. A. Pamyatnykh et al., Bull. of the Rus. Acad. of Sciences: Phys. 74, 1417 (2010)



a - static and dynamic magnetic hysteresis loops, b - Hc and S from field amplitude.

WE-134

Magnetostatic interaction of moving vortices in a pair of magnetic dots

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Arrays of magnetic dots in the vortex state attract considerable interest due to their possible applications as patterned recording media, logic operation devices, and magnonic crystals. A pair of magnetic dots can serve as a model system for understanding the vortex dynamics in dot arrays. In the pair of laterally separated dots the excitation of the vortex gyrotropic motion in one dot results in the vortex movement in the second dot due to the interdot magnetostatic interaction [1]. Such coupled vortices are considered as the promising candidates for spin-torque nano-oscillators emitting microwaves or transferring a microwave signal in magnonic crystals.

For a dot pair in the vortex state we calculate the interdot interaction energy as the Coulomb energy between magnetic charges within a model, which assumes no magnetic side surface charges induced by the moving vortex. We have found the vortex eigenfrequencies and their splitting. This splitting depends on both the geometrical parameters of the dots and interaction between them [2]. Our results are in a good agreement with the experimental observations [1, 3]. The time of the oscillation energy transfer from one dot to the other one is inversely proportional to the frequency splitting and can be therefore calculated from our theory.

To understand dependence of the interaction on the interdot distance we utilize the multipole expansion of the interaction energy. This expansion shows significant role of the dipole-dipole, dipole-octupole and octupole-octupole interdot interactions. The dipole-octupole interaction is found to be important and has to be taken into account considering the interaction between moving vortices, while the quadrupolar interaction can be neglected for thin dots.

[1] S. Sugimoto et al., Phys. Rev. Lett. **106**, 197203 (2011).
[2] O. Sukhostavets et al., Appl. Phys. Express 4, 065003 (2011).
[3] K. Arai et al., Japan J. Appl. Phys. 50, 053001 (2011).

WE-135

Simulations of vortex core reversal via inclusion of temperature effects

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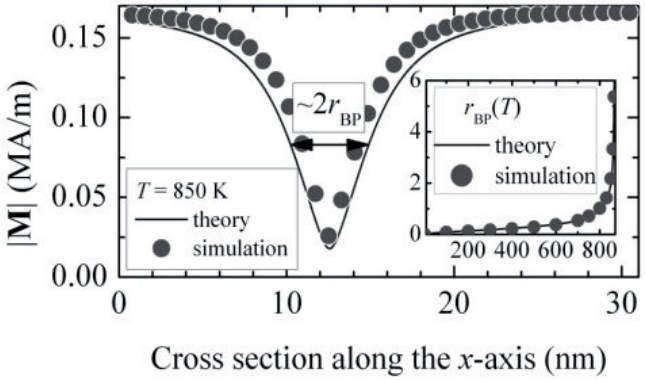
Magnetic vortices attract much interest recently, especially the switching properties of the vortex core. This phenomenon is, however, difficult to evaluate experimentally as it happens on a very short time scale. On the other hand the micromagnetic simulations done so far have been lacking completeness since the vortex core reversal is mediated by a Bloch point (BP), a discontinuous object [1], while classical micromagnetism is a *continuum* theory.

Our way to solve this discrepancy is to include a finite temperature, T, into the simulations via the Landau-Lifshitz-Bloch equation [2]. For $T > 0$ it is namely expected that the BP is a continuous object with magnetization magnitude smoothly dropping to zero at its center [3]. Our approach, being actually a generalization of the Landau-Lifshitz-Gilbert dynamics for $T > 0$, allows for the first time to perform self-consistent

modeling of Bloch point-related phenomena, like for instance vortex core reversal.
We have focused our attention on permalloy and conducted studies in the full temperature range. The revealed internal structure of the BP will be compared with analytical theories, and an improved phenomenological theory will be proposed. The dependence on temperature will be shown for BP properties (like the BP radius shown on the Figure below) and for the resulting vortex core reversal in the case of quasi-static perpendicular magnetic field application. Critical issues that can potentially influence the simulation procedure will be discussed.

[1] S. Gliga et al., J. Phys.: Conf. Ser. **303**, 012005 (2011).
[2] D. A. Garanin, Phys. Rev. B **55**, 3050 (1997).
[3] E. G. Galkina et al., J. Magn. Magn. Mater. **118**, 373 (1993).



Magnetization drop in the vicinity of the BP. The inset: the BP radius (nm) vs. *T* (K).

WE-136
Parametric excitation in spin-transfer vortex oscillators
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Parametric excitation is a physical phenomena existing in many linear and non-linear system. A general definition is that it exists when one of its energy-storing parameters is modulated periodically with time. Classical examples are the dynamics of a playground swing or of an oscillatory circuit with a variable parameter, either a capacitor or an inductance [1]. In all systems, the largest output power is obtained when the excitation frequency is twice the resonance frequency of the system. In this work, the studied system is a MgO tunnel junction with a magnetic vortex as remanent configuration in one of the magnetic layers [2, 3] (STVO). Large amplitude vortex core oscillations induced by spin-transfer torque can be observed at frequency f_0 for dc-currents larger than a critical value I_c. However, if one injects a rf-current at $2f_0$, hence the system can be forced into oscillation even in the subcritical regime. The excitation characteristics are similar to the one obtained in case of uniform magnetization [4]. The main difference is that, in our case, when the power of the rf-current is further increased, the signal characteristics, and notably the spectral linewidth, are significantly improved by two orders of magnitude. We claim that such behavior is a consequence of the nature of the parametric excitation itself and it was not observed for uniform cases due to their large non-linearities. In order to clarify such difference, we will compare our experimental results with a new analytical development.
Support from ANR VOICE-PNANO, ANR SPINNOVA-P2N and EU MASTER NMP-FP7-212257 and CANON-ANELVA for MTJ film are acknowledged.

[1] E. Butikov, *Eur. J. Phys.* 25 535 (2004)
[2] A. Dussaux et al., *Nat. Comm.* **1** 1 (2010)
[3] A.V. Khvalkovskiy et al, *Phys. Rev. B* **80** 140401(R) (2009)
[4] S. Urazhdin et al., *Phys. Rev. Lett.* **105**, 237204 (2010)

WE-137
Magnetostatic interactions and domain-wall propagation in cylindrical magnetic nanowires
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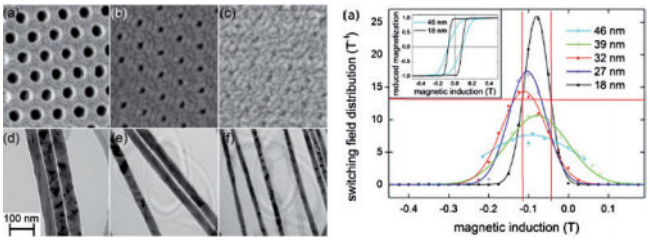
Propagation of domain walls (DWs) in one-dimensional structures under the stimulus of magnetic field or spin-polarized current has been a very active topic in the past decade. Theory and micromagnetic simulation predict dramatic differences between the case of nano-stripes (very anisotropic cross-section) and nano-wires (circular cross-section). In the former the propagation scheme differs below and above a so-called Walker field[1] and gives rise to a DW inertia, related to the stripe lateral demagnetizing field. In contrast, for the latter propagation is inertia-less[2]. Whereas numerous experiments have been reported for the former, none has come yet for the latter.
We performed experiments of nucleation and propagation of DWs in dense arrays and in isolated nanowires. The wires are obtained by electroplating self-organized anodized alumina membranes, later dissolved for single-wire investigations. In arrays we characterized the effect of the collective demagnetization field for both nucleation and propagation and domain walls. We used atomic layer deposition to decrease the wires' diameter and dramatically reduce the interactions, a prerequisite for the their potential use as a 3d memory[]. For isolated wires we evidenced propagation fields lower than 5mT for Ni wires. Experiments are under way in Permalloy wires (reducing the magnetostriction with respect to Ni) and in diameter-modulated wires to create pinning sites.

[1] A. Thiaville et al., Europhys. Lett. 69, 990 (2005).
[2] M. Yan et al., Phys. Rev. Lett. 104, 057201 (2010)
[3] S. Da Col et al., Appl. Phys. Lett. 98, 112501 (2011)



Decrease of wire diameter at constant pitch; resulting decrease of switching distribution.

WE-138

Effects of interaction on the dynamics of a magnetic dimer

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A magnetic dimer (MD) is a system formed by two magnetic layers separated by a non magnetic layer. Owing to the GMR effect the MD can be used as a bit in an MRAM device, and this is why such systems are interesting. We investigate the dynamics of an MD with the inter-layer coupling being either the exchange, dipole-dipole, or Dzyalozhinski-Moriya interaction. Using the kinetic theory of Langer, we provide (semi-)analytical expressions for the switching rate and compare the switching mechanisms and switching rates corresponding to the three couplings. We find that the dipole-dipole coupling leads to the slowest magnetic dimer, as far as the switching of its net magnetic moment is concerned.
We also study the variation of the magnetization of one layer due to a change in that of the other layer, and how they are affected by the different interactions. To understand this, we first expand each layer into a multispin vertical array coupled by intra-layer exchange interaction, and we investigate how the applied field and the three interactions at the interface act on the deviation of the magnetic moments in the static regime. We find that the system has an asymptotic behavior for high values of the three interactions and for a sufficient number of spins on either side of the interface. A comparison between the interactions with typical values shows a dependence mainly due to the exchange, while the other two interactions only induce slight in-plane or out-of-plane deviations.

WE-139

Chirality switching and ultra-fast vortex domain wall motion in ferromagnetic nanotubes

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We study the effects of electric currents and magnetic field pulses on the domain wall motion of a ferromagnetic nanotube. We show that proper interplay between the spin torque and the Oersted field from the current flowing along the nanotube, can be used to manipulate the position, velocity and chirality of a vortex domain wall. Also, by applying magnetic field pulses, it is found that the chiral state of the vortex wall can be switched [1] provided that (i) the field amplitude is between two critical values, the so-called chiral field and the well-known Walker field, and (ii) the pulse duration is longer than a critical time, which is the time that the wall needs in order to overcome a local energy barrier [2]. Moreover, the classical Oersted field, which more than frequently is ignored over spin-transfer effects, suppresses the precessional motion, leading to domain wall propagation at ultra-fast velocities, of the order of several thousands meters per second for experimentally accessible electric currents [3]. The suppression of the precessional domain wall motion may be also observed in others systems, as spin valve nanostripes, provided that magnetization reversal is mediated by transverse domain wall propagation.

[1] J. A. Otálora, J. A. López-López, P. Vargas, and P. Landeros, Appl. Phys. Lett. 100, 072407 (2012)
[2] P. Landeros and A. S. Núñez, J. Appl. Phys. 108, 033917 (2010)
[3] J. A. Otálora, P. Landeros, and A. S. Núñez, unpublished.

WE-140

Experimental measurement of the magnetisation dependence of domain wall mobility

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The domain wall mobility relates the velocity of a domain wall to the amplitude of the applied magnetic field. Different mobility regimes such as the thermally activated creep and viscous flow regimes [1] are usually experimentally evidenced. Using a classical ferromagnet such as FeNi or Co, the experimental mobility can be compared to predictions where temperature and magnetisation are key parameters. We used ferrimagnetic intermetallic films such as Gd(1-x)Co(x) [2] and TbCo with varying compositions to study independently the respective rôles of magnetisation and temperature. Thin films have been grown using the sputtering technique in an off-axis geometry. The deposition technique induces a perpendicular magnetic anisotropy leading to spontaneous perpendicular magnetisation. The average film composition x=0.80 was chosen to be close to the compensation composition (Ms=0) at 300 K. The film composition varies laterally with a 0.1%/mm gradient. UV lithography has been used to define identical patterned lines parallel to the gradient, allowing for a statistical study of domain wall propagation using polar Kerr microscopy. The static coercive field varies as a function of the inverse magnetisation, diverging at the magnetic compensation. Domain wall mobility has been measured as a function of short (ns-long) magnetic field pulses at different positions along the composition gradient, which allowed to compare it to the usual creep and flow mobility models.

[1] P. J. Metaxas et al. Phys. Rev. Lett. 99, 217208 (2007)
[2] A. Hrabec, N. T. Nam, S. Pizzini, L. Ranno, Appl. Phys. Lett. 99(5), 052507 (2011)

WE-141

Fast field induced domain wall dynamics in MnAs/GaAs films

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The possibility of storing information in magnetic domains separated by domain walls (DW) moving along domain tracks has stimulated a renewed interest in DW propagation in in-plane magnetized materials for spintronics [1]. Most studies are performed on Permalloy where high DW velocities (up to 1000 m s^{-1}) can be achieved. However it is well known that MnAs is a promising candidate for spintronics applications as it can be grown on different semiconductors. Even though the domain wall (DW) dynamics in ferromagnetic films has been intensively studied during the last decades DW propagation in MnAs was studied only recently, and has been limited to the creep regime of the DW dynamics (velocity ≈ 30 μm s^{-1}) under application of a magnetic field close to the coercive field [2].

Using longitudinal Kerr microscopy and a field pulse technique [3], we have investigated the DW dynamics in MnAs/GaAs over a wide range of magnetic field and temperature, below and within the coexistence regime of the (ferromagnetic) α phase and (non-ferromagnetic) β phase. The DW reversal in the studied temperature range shows wedge-shaped magnetic domains (Fig. 1). The analysis of the velocity curves leads to the identification of different dynamical regimes given by the interplay of the depinning field and the Walker field. A maximum DW velocity of 940 m s^{-1} is measured at 200K. Remarkably it is still as high as 500 m s^{-1} at 290 K within the coexistence regime.

[1] S. S. P. Parkin, M. Hayashi, and L. Thomas, *Science* **320**, 190 (2008).
[2] K. S. Ryu, H. Akinaga, and C. S. Shin, *Nat. Phys*. **3**, 547 (2007).
[3] L. Thevenard et al., Phys. Rev. B **85**, 064419 (2012).

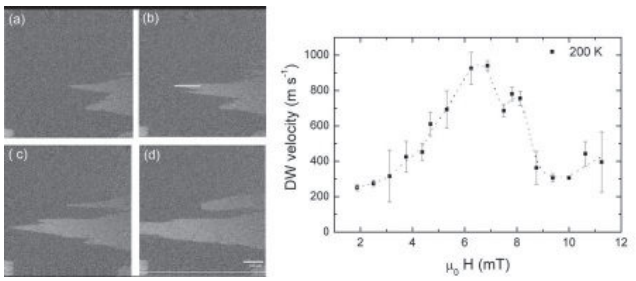

Figure 1: DW propagation at 270 K: snapshots taken after successive magnetic field pulses (40 G, 600 ns) and DW velocity curve.

WE-142

Scattering of spin waves in curved magnonic waveguides

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Despite the recent burst of research activity, the field of magnonics [1] is still in its infancy. Within the context of magnonic devices, the majority of studies have been focussed on the propagation of spin waves in straight waveguides. Little attention however has been paid to curved waveguides, which would be critical for the construction of, for example, magnonic interferometers and other elements of magnonic logic.
We use analytical and OOMMF numerical calculations to investigate spin wave propagation in a circularly curved region within a Permalloy waveguide nanostructure shown below. The structure is magnetised using a bias magnetic field applied vertically downwards in plane of the picture. First, the dominant resonant mode of the wide pad region of the structure is identified. Then, a microwave magnetic field at the identified frequency is used to launch spin waves into the stripe waveguide, through making use of a dispersion mismatch between the pad and the stripe. The simulations are repeated for different magnetic ground states of the structure, in particular for the cases of uniform magnetisation and of the magnetisation following the curvature of the waveguide. The dependence of the ability of excited spin waves to follow the curvature of the waveguide upon the magnetic ground state is then studied in detail. The results are compared against predictions of an analytical theory developed for the case of infinitely thin magnonic waveguides. The ability of spin waves to follow curved magnonic waveguides observed in most cases provides an encouraging start for the future development of magnonic devices containing such curved waveguides.
The research leading to these results has received funding from the EC's FP7/2007-2013 (GA 228673, MAGNONICS and GA 247556, NoWaPhen) and EPSRC.

[1] Kruglyak et al., J. Phys. D 43, 264001 (2010)

WE-143

Competition between local and non-local magnetic interactions in the domain wall dynamics of thin films

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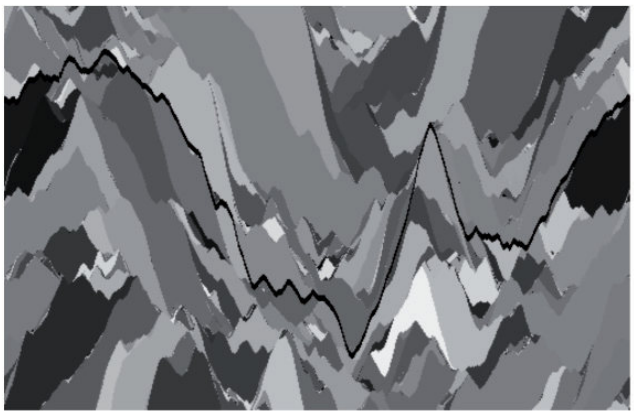
We study theoretically and numerically a line-based model of a domain wall moving in a disordered ferromagnetic thin film with in-plane head-to-head domains. The competition between the local domain wall surface tension and the non-local dipolar interactions leads to a characteristic zigzag morphology of the domain wall, and induces a crossover scale separating two universality classes of the Barkhausen noise or the jerky avalanche dynamics of the domain wall, in agreement with experimental observations [1]. For short length scales the local surface tension is important, leading to a power law distribution of avalanche sizes with an exponent close to 1.1, while above a crossover length scale the non-local dipolar interactions dominate, resulting in a larger avalanche size exponent around 1.3. We investigate this crossover scaling and the nature of the universality class dominated by the dipolar interactions, and compare our results with earlier experimental observations [1].

[1] K.-S. Ryu, H. Akinaga, and S.-C. Shin, Nature Physics 3, 547 (2007).



Dynamics of in-plane head-to-head domain wall, giving the sequence of magnetic avalanches of different sizes (different gray levels). The thick line is the position of the front at a given time, and show the competition between local (rugged front) and non-local interactions (large zig-zag structures)

WE-144

Dynamics of the domain walls in magnetic with modulation of the parameter of the magnetic anisotropy

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It is known that in real magnetics the appearance of magnetic parameters local changes happens due to structural and chemical non-homogeneities and local influence (mechanical, thermal or solar). It results in considerable complication of Landau-Lifshitz equation for the magnetization. Although the task of excitation and distribution of the magnetization waves, under certain conditions, is reduced to the studies of the modified sine-Gordon equation with floating factor [1,2]. The investigation of the big perturbations influence on the solution of the modified sine-Gordon equation in general case can be investigated only with the help of numerical methods [3].

This research considers our studies of the domain walls (DW) dynamics in ferromagnetics with an optional size one dimensional modulation of the magnetic anisotropy constant in terms of stimulation and radiation of the nonlinear waves. In the presence of the nonhomogeneity of the constant magnetic anisotropy (NCMA) was obtained a reflection of the DW from the NCMA region. It was connected with the DW resonant interaction with the magnetic nonhomogeneity of the breather type, stimulated in the NCMA region. We have shown the possibility of the DW quasitunneling involving several NCMA regions (i.e. when the particle crosses the barrier with the speed below ultimate). We have also shown the origin of the magnetic nonhomogeneities of the multi-pulson type in the form of kink and breather bound state cophased and antiphased with the oscillating breathers.

The work was supported by Russian Foundation for Basic Research (project 10-02-00594-a).

[1] M.A. Shamsutdinov and other, Ferro- and antiferromagnitodynamic. Nonlinear oscillations, waves and solitons, Moscow:Nauka, 456 (2009)
[2] Ekomasov E.G., Azamatov Sh.A., Murtazin R.R., The Physics of Metals and Metallography, 105(4), 313 (2008)
[3] Ekomasov E.G., Azamatov Sh.A., Murtazin R.R., The Physics of Metals and Metallography, 108(6), 532 (2009)

WE-145

Effect of the Oersted field on the domain wall dynamics

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The magnetic domain wall motion is an important issue not only because of its potential technological application in several magnetic devices, but also due to the possibility of understanding the fundamental physics associated with the dynamical processes. In this work, we determine the domain wall velocity in the low field region and study the domain dynamics in Joule-heated amorphous glass-covered microwires with positive magnetostriction. As a result of the combination of magnetoelastic and shape anisotropy, this kind of material presents a domain structure composed by a large axially oriented domain and a closure one near the extreme of the sample. This domain structure is responsible by the magnetic bi-stability, meaning that the magnetization process in the axial direction runs through the single domain-wall propagation under the influence of the applied magnetic field. The domain wall dynamics was studied using the Sixtus–Tonks like modified method, where the domain wall velocity is determined by the time of flight of the domain wall between two sensing coils, separated by a known distance. In order to study the influence of an orthogonal magnetic field on the domain wall dynamics, an electrical current was applied to the wire simultaneously to the driving magnetic field. Without applied current the domain wall moves in an adiabatic regime verified by a power-law dependence of the domain wall velocity with the driving field, with the critical exponent around 0.5. When the DC current is applied to the sample, a change on the domain wall velocity is verified, depending on the current direction. These results are discussed in terms of a change of domain wall length during its displacement on the wire.

WE-146

Travelling spin wave generated by gyrotropic magnetic vortex core motion under AC magnetic field

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Travelling spin wave generated by gyrotropic magnetic vortex core motion under AC magnetic field

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We have investigated a spin wave behavior when the magnetic vortex core is excited by an AC magnetic field by means of micromagnetic simulation[1]. The core motion under AC field is analytically understandable but the spin wave generated by the vortex structure excitation under AC field is not explored fully yet. In this work, we report that there exists a spin wave mode rotating in a sense reverse to the core gyration, which should not be neglected in practical AC operation of spintronic devices based on the magnetic vortex structure. The travelling spin wave rotating opposite to the core motion seems to arise from the change of M_z distribution over the disk structure and thus, from the decrease of the effective gyrovector[2]. The amplitude of AC field is varied from 1 to 2.5 mT. The AC field frequency was varied around the core gyration resonance frequency about 120 MHz. The radius of permalloy disk is 250 nm and the thickness is 5 nm.

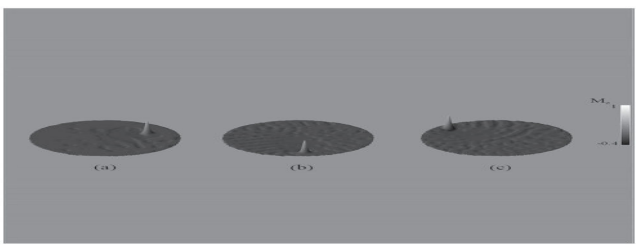

Figure 1: Snap shot of the vortex core motion under AC magnetic field (the amplitude is 2mT, and the frequency is 120 mT) at time t = 26.4 (a), 31.9 (b), and 36.3 ns(c).

[1] M. J. Donahue and D. G. Porter, OOMMF User's Guide, from http://math.nist.gov/oommf (2002).
[2] J. -H. Shim, H. -G. Piao , S. -H. Lee, S. -K. Oh, S. -C. Yu, S. -K. Han and D. –H. Kim, Appl. Phys. Lett. 99, 142505 (2011).

WE-147

Initial dynamics of vortex core reversal under a short burst of magnetic field

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It has been known that when a magnetic vortex core is reversed, a pair of vortex and antivortex are generated and the annihilation between the old vortex core and the newly generated antivortex completes the core switching process[1]. In this work, we have carefully explored the very initial process of a vortex core excitation and the vortex/antivortex pair generation under a short burst magnetic pulse field by means of micromagnetic simulation [2]. The short burst magnetic pulse field temporarily generates a magnetic dip and hill at each side of the ferromagnetic disk due to the strong Oersted field pulse, as illustrated in the figure. The vortex core dynamics on the dip/hill of the disk under the short burst magnetic field pulse was systematically investigated. The amplitude of the pulse field is varied from 20 to 40mT and the pulse width was varied from 60 to 120 ps, where the full details of the vortex core switching phenomenon under such a strong burst field pulse were revealed.

Figure 1: Spiral motion of a magnetic dip distribution generated by short burst pulse field. The pulse field strength is 40 mT and the width is 120 ps. The snapshot of the Mz distribution at t = 59.86 ps.

[1] K. -S. Lee, K. Y. Guslienko, J.-Y. Lee, and S. –K. Kim, Phys. Rev. B. 76, 174410 (2007).
[2] M. J. Donahue and D. G. Porter, *OOMMF User's Guide*, from http://math.nist.gov/oommf (2002).

WE-148

Phase sensitive spin-wave mode conversion in a two-dimensional system

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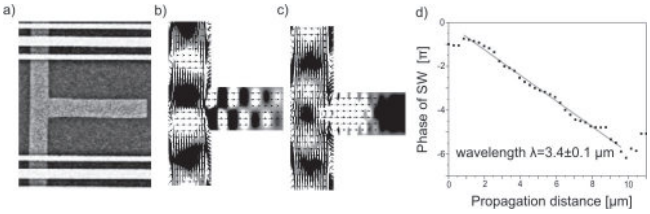
The investigation of propagating dipole-exchange spin waves (SW) in micro-sized metallic ferromagnetic structures has been the subject of experimental studies and micro-magnetic simulations due to their potential application in microwave signal processing devices and next-generation logic circuits [1]. However, due to the strong anisotropy of the dispersion of these waves, most of the experiments have been restricted to one-dimensional structures.
In a recent survey [2], we showed that breaking of symmetry in a two-dimensional structure can lead to the mode conversion of the incoming propagating modes. By combining this result with the interference of SW [3] and with the help of the demagnetizing fields in micro-structures, we created a structure that allows for a 90° change of the propagation direction via mode conversion. In addition, this conversion process is sensitive to the relative phase of the incoming SW, allowing us to switch between different outgoing modes.
Using Brillouin light scattering microscopy, analytical theory and numerical simulations to investigate this structure, we exemplify the excitation, propagation, interference and mode conversion in a two dimensional system. To model our experiments in real scale, our micro-magnetic simulations are carried out by Mumax, a high performance GPU based code. Our studies show a way to manipulate the characteristics of SW which is promising for two dimensional spin-wave logic circuits working with the phase and amplitude as information carriers.

[1] A Khitun et al., IEEE Trans. on Mag. 44 (9), 2141-2152 (2008)
[2] P. Clausen et al., Appl. Phys. Lett. 99, 162505 (2011)
[3] P. Pirro et al., Phys. Status Solidi B, 1–5 (2011)



a) SEM image, b), c) micromagnetic simulations with different input phases, d) Brillouin light scattering measurement of propagating spin waves

WE-149

High frequency magnetization dynamics of CoFeB/(Cu,Ag,Ta) magnetic multylayers: experiment and numerical calculation

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In this work, we investigate the magnetization dynamics of multilayered $(Co_{40}Fe_{40}B_{20}/NM) \times 50$ thin films produced by magnetron sputtering, with 9 nm thick ferromagnetic layers and 2 nm thick nom-magnetic layers (NM), where NM = Ta, Ag or Cu. The dynamical magnetic behaviour is studied through magnetoimpedance (MI) effect measurements obtained in a wide range of frequency, from 10 MHz up to 1800 MHz. The MI results are interpreted in terms of the structural and magnetostrictive properties of the samples, obtained respectively by analysing x-ray reflectivity patterns and magnetostriction curves, measured using a cantilever system. The results indicate a strong dependence of the MI with the quality of the layers, magnetostriction values, and spacer material. In order to obtain further information on the magnetization dynamics, we compare the MI experiment results with numerical calculus performed using an approach that considers a magnetic transverse susceptibility model for planar systems and an appropriate magnetoimpedance model for a multilayer system together. The results show remarkably good agreement between numerical calculus and experimental measurements. Thus, we discuss the experimental results in terms of different mechanisms that

govern the MI changes observed in distinct frequency range and provide experimental support to confirm the validity of the theoretical approach.

WE-150

Tuning maximum attainable domain velocities through magneto-crystalline anisotropy engineering

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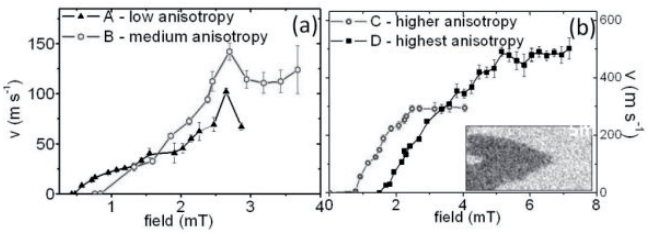
Novel shift-register memories based on magnetic domain wall propagation (DWP) require an excellent knowledge of the physics governing the DW velocity and structure, via the micromagnetic parameters of the material. This work uses the tuning of the magneto-crystalline anisotropy to modify the DWP, an original route that has been rarely explored in metals due to the difficulty to tune it over a broad range in these materials. This is not the case for dilute magnetic semiconductors such as GaMnAs, where the magnetic anisotropy can be finely tuned through phosphorus co-doping. So far, DWP studies on in-plane magnetized GaMnAs layers have been limited to observations of the magnetic after-effect in the creep regime, and transport measurements in stripes [1]. In this geometry, the intricate interplay between magnetic anisotropies and DWP could not be studied.

Field-induced domain wall (DW) propagation was evidenced in unpatterned layers of in-plane magnetized (Ga,Mn)(As,P) using Kerr microscopy and a field pulse technique[2]. Both stationary and precessional regimes were observed, and domain wall velocities of up to 500 m s−1 were measured, of the order of magnitude of those observed on in-plane magnetized metals. Taking advantage of the strain-dependent magneto-crystalline anisotropy in this dilute magnetic semiconductor, both out-of-plane and in-plane anisotropies were adjusted by varying the manganese and phosphorus concentrations. We demonstrate that these anisotropies are a critical parameter to obtain large velocities [2]. These results are interpreted in the framework of the one-dimensional model for domain wall propagation [3].

[1] H. Tang et al., Phys. Rev. B **74**, 041310(R) (2006).
[2] L. Thevenard et al., Phys. Rev. B **85**, 064419 (2012)
[3] A. Thiaville and Y. Nakatani, Spin Dynamics in Confined Magnetic Structures III, Springer, NY (2006).



Domain wall velocity versus applied field [inset] Wedge shape of the domains.

WE-151

Controlling the stochasticity of domain wall depinning and spin transfer torque in ferromagnetic nanowires

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We show dynamic measurements of domain wall (DW) depinning from a single defect, in nanowires with either perpendicular (FePt) or in-plane anisotropy (NiFe). Statistical analysis reveals that the DW depinning is stochastic, and that this stochasticity has two origins [1, 2]. The first one is thermal activation, which helps the wall to cross the energy barrier associated to the defect. The second one originates from the ability of the DW to get pinned randomly along different configurations, each one corresponding to a given depinning fields.

We further study the influence of different constriction types on the stochasticity of DW depinning, using GMR measurements in spin-valve-based FePt nanowires and MMR [3] in NiFe nanowires. The probability function is found to exhibit very different behaviors, which clearly depend on the types of constriction. For a "smooth" constriction (cf. fig.1b), there exist sequential pinning events: the DW has to cross several barriers in series. Using a "sharp" constriction (cf. fig. 1c), it is found that the depinning probability functions obey a single exponential function, as expected for a single barrier. These results emphasize that it is partially possible to control the stochastic behavior of DW depinning by tuning the shape of constrictions, i.e. by reducing the DW configuration degeneracy. Additionally, we showed that the probability function of DWdepinning can be modified using a spin transfer torque instead of a magnetic field, the effect on the thermal and configurational stochasticitiesbeing very similar in both case. Finally, these results allow comparing the spin transfer torque efficiency in FePt and NiFe.

[1] C. Burrowes *et al.*, Nat. Phys. **6**, 17 (2010)
[2] Mihai *et al*., Phys. Rev. B **84**, 014411 **(**2011)
[3] V. D. Nguyen *et al*., Phys. Rev. Lett. **107**, 136605 (2011)

WE-152

Barkhausen noise in Permalloy films: statistical properties and driving field rate effects

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Barkhausen noise (BN) corresponds to the voltage pulses induced in a sensing coil wound around a ferromagnetic material submitted to a variable magnetic field. BN can provide important information on magnetization dynamics and domain wall motion in soft magnetic systems, however, the effect has attracted growing interest as an example of system exhibiting crackling noise, becoming an excellent area for investigating scaling phenomena. For bulk materials there is a well established interpretation of the noise statistics and of functions such as jump sizes and durations distributions, average size vs. duration and power spectrum, which follow power laws with exponents $\boldsymbol{\tau}$, $\boldsymbol{\alpha}$, $1/(\boldsymbol{\sigma\nu z})$ and $\boldsymbol{\upsilon}$, respectively. For thin films, noise properties

are not completely understood due to various experimental difficulties. Most of published results, based on magneto-optical measurements, show exponents smaller than those obtained for bulk samples, indicating a possible two-dimensional magnetic behavior, as expected [1]. Here, we report an experimental study of the BN, obtained for different driving field rates with the inductive method, in polycrystalline ferromagnetic films, with nominal composition $Ni_{81}Fe_{19}$ and thickness between 100 and 1000nm. The exponents for all considered films are found to be $\boldsymbol{\tau}$~1.5, $\boldsymbol{\alpha}$~2;0 and $1/(\boldsymbol{\sigma\nu z})$~$\boldsymbol{\upsilon}$~2.0, obtained for the smallest magnetic field rate, despite striking differences in the hysteresis loops, although rate-dependent exponents and the crossover in average size vs. duration are also observed. By considering this wide statistical analysis, the agreement between experimental results and well-known predictions for bulk polycrystalline magnets [2] indicates that these films present a typical three-dimensional magnetic behavior with predominant long-range interactions [3]. We discuss all results in terms of the predictions of theoretical models for domain wall motion.

[1] K.-S. Ryu et al., Nature Phys. 3, 547 (2007)
[2] G. Durin, S. Zapperi, Phys. Rev. Lett. 84, 4705 (2000)
[3] S. Papanikolaou et al., Nature Phys. 7, 316 (2011)

WE-153

Domain wall motion by current in a perpendicularly magnetized Co/Ni nanowire under in-plane magnetic fields

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Current-induced domain wall motion (CIDWM) has been studied because of its potential applications for high-density magnetic storage devices. Highly stable information retention and the capability of CIDWM against external magnetic field as well as thermal disturbances are necessary to ensure device reliability. We have investigated the CIDWM in a perpendicularly magnetized Co/Ni nano-wire. In our previous work, we found that the DW velocity was almost independent of perpendicular (easy-axis) external magnetic field, H_z, in the range of ±50 Oe [1]. In this work, we report the effect of in-plane (hard-axis) external magnetic fields, H_x and H_y, on the DW velocity, where H_x and H_y are the in-plane magnetic fields applied along parallel and normal to the longitudinal direction of the wire, respectively (see the illustration in inset of Figure). Dependences of the DW velocity on H_x, H_y, and H_z are shown in the figure. Regardless of the direction of the fields, the DW velocity was confirmed to be almost flat within the range of ±50 Oe. The result shows that reliable device operation against any directions of external magnetic field disturbance is expected to be achievable in the present system.

This work was partly supported by a Grant-in-Aid for Scientific Research (S) from the Japan Society for the Promotion of Science (JSPS), by the Collaborative Research Program of the Institute for Chemical Research, Kyoto University, and by JSPS through its "Funding program for world-leading innovative R & D on science and technology" (FIRST program).

[1] T. Koyama, *et al*., *Appl. Phys. Lett.* **98**, 192509 (2011).

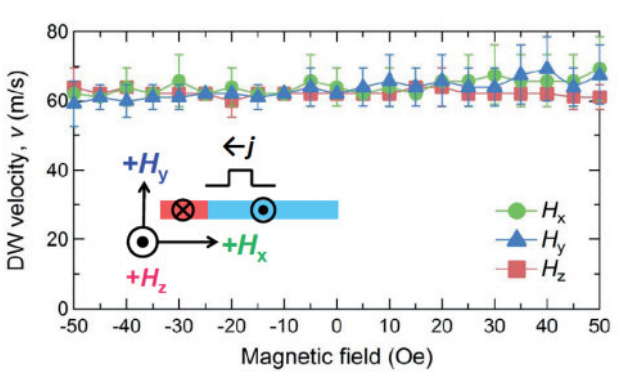

Figure Dependence of the DW velocity on the external magnetic fields H_x, H_y, and H_z.

WE-154

Influence of fabrication defects on the magnetization dynamics of magnetic tunnel junctions

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The fabrication process of magnetic tunnel junctions generates shape defects or apparition of hotspots or pinholes within the tunnel barrier that can affects their magnetoresistive response. We performed static and dynamic micromagnetic simulations in order to investigate first, the influence of shape defects on the hysteresis loops of the storage layer in a magnetic tunnel junction and second, the magnetization dynamics of a spintorque oscillator under perpendicular spin polarized current in the presence of pinholes. The studies were carried out by solving the Landau-Lifshitz-Gilbert equation enhanced by the Slonczewski's spintorque term at 0K temperature. From the simulation point of view we have considered the defect as a non-magnetic zone placed on the edge or inside of the ferromagnetic body. Generally, edge defects with small area ($\leq$100nm^2) have small influence on the hysteresis loops. The simulations indicate that increasing the area of the edge defect (to about 400nm^2) gives rise to a deformation of the hysteresis loop leading to an enhancement of the coercive field. A more drastical impact on the switching behavior is observed when the defect is placed inside the nanomagnet. Regardless of defect size, two domain walls form near the boards of the defect and the coercive field is largely increased.

Another type of defect characteristic for magnetic tunnel junctions concerns the quality of the tunneling barrier, namely the presence of nanometric conduction channels, so called pinholes. These pinholes affect locally the configuration of the magnetization implying for spin torque oscillators a reduction of the oscillation frequency. Moreover, under certain conditions it

can even cause the formation of a vortex which stabilizes in the pinhole zone suppressing the precession of the magnetization.
Acknowledgements: I. Firastrau wish to acknowledgement the assistance and support of CNCSIS- UEFISCDI from Romania by the project PNII-RU-TE, COD77, number 85/2010.

WE-155

Magnetic vortex core at elevated temperatures - simulations

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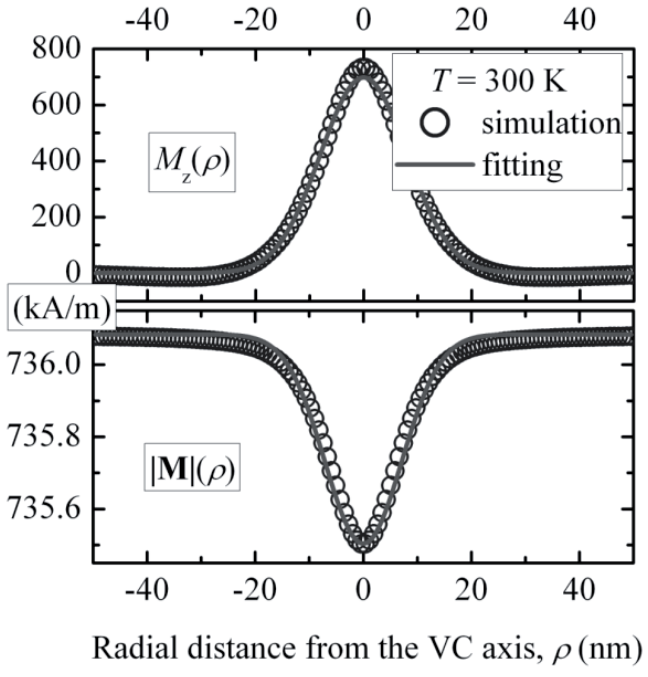
When simulating ferromagnetic structures at elevated temperatures—using the recently proposed Landau-Lifshitz-Bloch equation [1]—new phenomena can appear. Mostly the magnitude of the magnetization vector can deviate locally (in space and/or in time) from its equilibrium value. This effect has been already described in the past (see Ref. 2), where magnetization squeezing in the middle of a domain wall was investigated.
In our present study we focus our attention on the same effect in the one-dimensional Bloch line. For that we have simulated a circular island with material parameters resembling permalloy and a vortex domain structure inside. We investigate the full range of temperatures, *T*. Vortex core properties, like width and height of the out-of-plane magnetization component (see top part of the Figure) have been analyzed. The squeezing of the magnetization magnitude, if plotted against the radial distance from the vortex core axis, seems to have Gaussian-like shape as well—see bottom part of the Figure. We analyze the parameters of this squeezing effect as a function of temperature.

[1] D. A. Garanin, Phys. Rev. B **55**, 3050 (1997).
[2] D. Hinzke et al., Phys. Rev. B **77**, 094407 (2008).



Magnetization magnitude (bottom) and its out-of-plane component (top).

WE-156

Non stationary synchronization of spin-torque oscillators to a microwave source

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We studied the dynamical behavior of exchange bias spin-valves composed by IrMn(8nm)/Py(10nm) (polarizer)/ Cu(10nm)/Py(4nm) (free layer) with elliptical cross sectional area (120nm x 60nm). First of all, we characterized the STO in the free running regime. We observe dynamical regime in a wide range of current density for bias field larger than 180 mT. We systematically studied the locking to the first harmonic, in particular, we found that the non-autonomous dynamics in presence of both microwave current and field at the same frequency can exhibit complex non-isochronous effect.[1] The most interesting from fundamental point of view is the non-stationary hopping between Q (quasi-stationary) and P (periodic) mode.[2] The measured power spectrum is characterized by two modes with amplitude of the same order, one at the frequency of the microwave source and one near the frequency of the self-oscillation mode. A wavelet based analysis has been used for the time domain characterization of the mode hopping. Our results can stimulate future experimental studies of the non-isochronisms behavior of STOs.

[1] A. Slavin and V. Tiberkevich, IEEE Trans. Magn. 45, 1875 (2009).
[2] R. Bonin, G. Bertotti, C. Serpico, I.D. Mayergoyz, M. d'Aquino, Eur. Phys. J. B 68, 221 (2009).

WE-157

Numerical analysis on the output frequency and power of a spin-torque nano-contact oscillator

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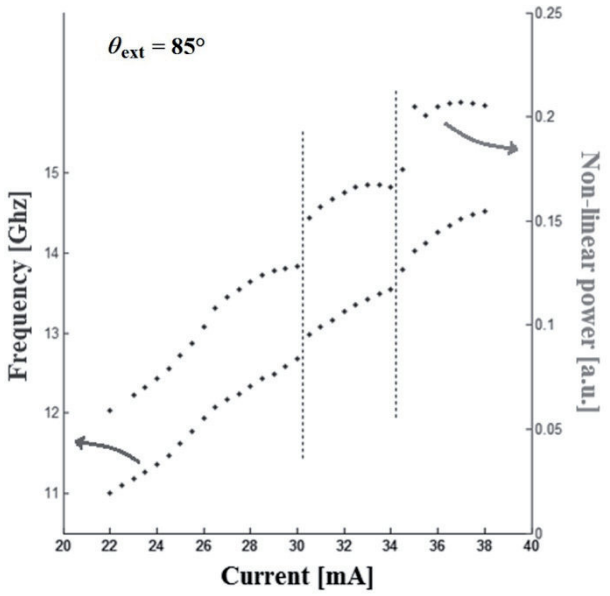
Spin-torque nano-contact oscillators (STNOs) are nowadays the focus of much research, as they include fundamental physics and promising applications [1-3]. Among others, some studies noticed the occurrence of jumps in the output frequency of the STNO as the applied current or the external magnetic field is varied [1,2]. This behavior was ascribed to the magnetization precession in the thicker fixed layer of the device [1] or to the hopping between propagating and evanescent modes [2], nevertheless it cannot be considered fully explained.
Here, we provide a different viewpoint on this topic through a micromagnetic numerical analysis. The object under investigation is an STNO whose contact has a radius of 65nm, that can be considered quite large with respect to the usual dimensions [1,2]. The frequency vs. current curves, obtained for different out-of-plane orientations of the external field (Θ_{ext}=55°, 65°, 75°, 85°), show some jumps or, more often, cusp points where the curve slope abruptly changes. It is interesting that these points appear ordered as the external field is rotated. We also evaluate the output power by using the definition of the non-linear oscillation power [3]. The resulting curves show once again cusp points at the same values of the applied current (see figure). The same behavior is showed by

the perpendicular-to-plane component of the precession axis. This combined result can indicate that frequency jumps in STNOs are mainly due to changes in the energy profile, associated with non-linear changes of the precession axis inclination. These non-linear behaviors could be further emphasized by the large contact area.

[1] W.H. Rippard, et al. Phys. Rev. B 70, 100406(R) (2004)
[2] G. Consolo, et al., Phys. Rev. B 78, 014420 (2008)
[3] S. Bonetti, et. al., arXiv:1203.3244 (2012)



STNO frequency and power as functions of the applied current for an out-of-plane field.

WE-158

Probing the magnetization processes in FEBID Co nanowires by in situ Lorentz Microscopy

L.A. Rodriguez [1], *C. Magén* [2], E. Snoeck [3], L. Serrano-Ramón [4], C. Gatel [3], R. Córdoba [1], J.M. De Teresa [4], M.R. Ibarra [1]
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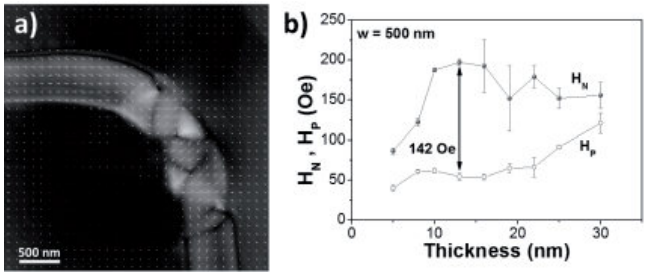
Magnetic memory devices using domain walls (DWs) in magnetic nanowires (NWs) to carry the information bits require the tuning of the magnetic configurations by applying either magnetic fields or electric currents [1]. For this purpose, quantitative imaging of the morphology and dynamics of the DWs configurations is essential.
High-resolution imaging techniques such as Lorentz Microscopy (LM) in combination with the Transport-of-Intensity Equation (TIE) formalism allow the quantitative mapping of the magnetic states with nanometer-range resolution. Furthermore, the *in situ* application of magnetic fields by exciting the objective lens makes LM an extraordinary technique to probe magnetization processes.
In situ LM characterization and magnetic-field manipulation of DWs of cobalt NW have been performed in a FEI Titan equipped with a Lorentz lens. High-purity NWs (>90%) [2] have been grown on Si_3N_4 membranes by focused-electron-beam-induced deposition (FEBID), presenting physical properties close to bulk [3]. Nucleation and propagation fields have been determined *in situ* by direct LM observation of L-shape cobalt NW with varying width (w=125-1000 nm) and thickness (t=5-30 nm) upon magnetic field. Mapping of the magnetic induction has been performed by applying TIE to focal series of LM images. The nucleation process gives rise to transverse DW in the thinner NWs (t < 13 nm for w = 500 nm), whereas vortexes are nucleated in thicker NWs, the best DW conduction taking place for the physical dimensions of this crossover.

[1] D. Allwood et al., Science 309, 168 (2005); S. Parkin et al., Science 320, 190 (2008)
[2] A. Fernandez-Pacheco et al., J. Phys. D: Appl. Phys. 42, 055005 (2009)
[3] L. Serrano-Ramón et al., ACS Nano 5, 7781 (2011)



a) TIE magnetic induction mapping of a Co NW, w=500 nm, t=30 nm; b) thickness dependence of the nucleation (H_N) and propagation fields (H_P) in a 500-nm-wide NW.

WE-159

Ferromagnetic and Magnetisation studies of Fe implanted nanoparticles into Single crystal Yttria-Stabilized Zirconia (100)(YSZ)

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In recent years, ion implantation has been used to create Ferromagnetic nanoscale composites consisting of Fe, Ni precipitates embedded in the near-surface region of a substrate such as SiO_2 or YSZ[1–3]. Fe ions have been implanted into single crystal Yttria-Stabilized Zirconia (YSZ) with implant energy of 45 keV, and an ion fluence of 5.0×10^{17} ions/cm^2. After implantation, magnetization dynamics was measured using Vibrating Sample Magnetometer (VSM) and Ferromagnetic Resonance (FMR) methods. XPS measurement was carried out, than it is observed that Fe and Fe compounds are present in samples.
Ferromagnetic Resonance investigation represents that there is a major distinction between H||n (hard direction) and H ⊥ n (easy direction) where n is the normal of implanted sample surface. We have simulated both the experimental spectra and angular dependence of resonance field to deduce anisotropy and other magnetic parameters. Study of Field Cooling (FC)

Zero Field Cooling (ZFC) magnetisation measurements indicates that Fe implanted YSZ has a combination of both superparamagnetic and ferromagnetic nano particles.

In conclusion, the results of FMR and magnetization measurements show the interaction between the particles related to magnetostatic interactions. A typical magnetic hysteresis loops taken at various temperatures. The magnetic field is oriented parallel to the sample surface.The sample shows clear ferromagnetic behavior assuming that all the Fe atoms contribute to the magnetization.The coercive field was found to be 260 Oe at low temperature and 70 Oe at room temperature. These results make that materials have attractive potential sensor materials for high speed magnetic sensors.
This work was partially supported by DPT (State Planning Organization of Turkey) through the project No 2009K120730, DFG through SFB 491 and BAPKO project of Marmara University.

[1] A. Meldrum et al.,Adv. Mater. 13, 1431, (2001)
[2] S. Honda et al., Mat.Res. Symp. Proc. 581, 71(2000)
[3] E. Cattaruzza et al., Appl. Phys. Lett. 73, 1176(1998)

WE-160
Domain walls nucleation of super paramagnetic Cobalt nano-wire on Pt(111) by Magnetic Molecular Dynamics simulations
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The understanding of the magnetization dynamics at an atomic level becomes essential with the miniaturization of magnetic materials devices. For example in the super-paramagnetic regime, magnetization reversal is intrinsically a dynamical phenomenon with spin-waves excitations [1]. However, micromagnetic simulations are no longer suitable for nano-objects smaller than the typical wall length. Atomic Spin Dynamics (ASD) simulations are performed to describe properly their magnetization dynamics **[2,3].**
The closeness of Molecular Dynamics (MD) and ASD timescales suggest that the time evolution of spin and atoms are intimately connected [4]. We have developed a Magnetic Molecular Dynamics model in which positions, impulsions and spins evolve simultaneously in time. The energy of the system is a sum of a mechanical part and magnetic terms combining Heisenberg isotropic exchange, pseudo-dipolar and quadrupolar anisotropy. The magneto-elastic coupling is described by a radial dependence of exchange and anisotropy functions, leading to the existence of atomic magnetic. With the use of an enhanced spin-pair model, we were also able to reproduce the four magnetostrictive constants of an hcp Cobalt. This model agrees well with *ab-initio* calculations of magneto-crystalline anisotropy performed on an isolated wire of Cobalt.
I will finally present an investigation of thermally induced spin and lattice dynamics of varying sizes nanowires of Cobalt on (111)Pt substrate (see Fig1) that exhibits a crossover in the activation energy between a single domain regime and many domain walls nucleation.

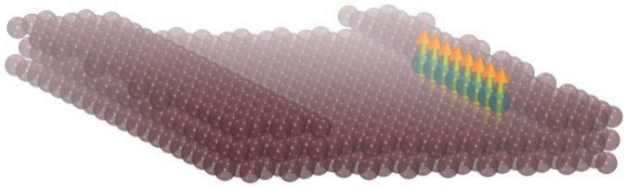

Fig1: Wire of 8 Co-atoms on Pt(111) substrate

[1] L. Néel, Ann. Geophys. 5, 99 (1949), W.F. Brown, Phys. Rev, 130, 1677 (1963).
[2] D. Hinzke and U. Nowak, Phys Rev B, 61, 6734 (2000) .
[3] D. Beaujouan, P. Thibaudeau and C. Barreteau, J. Appl. Phys. 111, 07D126 (2012).
[4] Pui-Wai Ma, C.H. Woo and S.L. Dudarev, Phys. Rev B, 78, 024434 (2008).

WE-162
Interactions of domain walls in ferromagnetic wires and stripes
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Domain walls (DWs) in ferromagnetic wires are of the Bloch or Ising types while DWs in soft-ferromagnetic stripes are of the transverse or vortex types. Complexity of internal structure of the DWs in quasi-1D systems includes degeneration of their states with respect to chirality and/or polarity (DWs in stripes), which enables variety of dynamical behaviors of the DW pairs observed in micromagnetic simulations. Creation of complete picture of these behaviors in absence and presence of an external magnetic field directed along the domain magnetization is the aim of the present work. Analytically solving the Landau-Lifshitz-Gilbert equation, stability of all types of the complexes of two DWs in magnetic wires and stripes is studied (including development of a perturbation calculus for soliton interactions [1]).
In magnetic wires, two DWs of the Bloch (Neel) type create the so called (by analogy to relevant 2D objects) soft bubble [1]. The DWs of such a pair attract or repeal depending on their chiralities (the magnetization orientation in the DW centers) which can be like or opposite ones. Hence, stabilization of such a bubble demands using an external magnetic field. In absence of external field, one Bloch DW and one Neel DW do not interact, however, such a pair is unstable with respect to fluctuation-induced Bloch-Neel transformation inside one of the DW. Upon application of the filed, they can collide and create a hard 1D bubble [2].
In magnetic stripes, two transverse (vortex) DWs create a kind of soft or hard bubble. The presence or lack and character of their interaction (attraction, repulsion) are determined by both; polarity (orientation of magnetization in the wall center) and chirality (direction of magnetization rotation in the stripe plane) [3].

[1] A. Janutka, arXiv 1201.0596
[2] A. Janutka, Phys. Rev. E 83, 056607 (2011)
[3] A. Janutka, arXiv 1201.5760

WE-163

Ferromagnetic resonance frequency and line broadening of a ferromagnetic $Fe_{33}Co_{43}Hf_{10}N_{14}$ film by high-frequency field perturbation

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Soft ferromagnetic $Fe_{33}Co_{43}Hf_{10}N_{14}$ films, produced by reactive r.f. magnetron sputtering, are useful to study the ferromagnetic resonance (FMR) by means of permeability measurements up to the GHz range. These films exhibit a saturation polarisation J_s of around 1.35 T and an in-plane uniaxial anisotropy ($\mu_0 H_u \approx$ 4.4 mT), and are consequently considered as being uniformly magnetised after annealing them at 400 °C in a static magnetic field for 1 hour. Being exposed to a high-frequency field, the precession of magnetic moments lead to a marked frequency-dependent permeability plot with a sharp Lorentzian shaped imaginary part at around 2.3 GHz (natural resonance peak), which is in a very good agreement with the modified Landau-Lifschitz-Gilbert (LLG) [1]- Maxwell theory [2,3]. In the following, a slightly increased FMR and an clear increase in the resonance line broadening due to the variation of the high-frequency amplitude, considered as an additional perturbation of the precessing system of magnetic moments, was experimentally determined. By calculating the homogenous LLG, it can be shown that the high-frequency field perturbation impacts the resonance peak location f_{FMR} and line broadening Δf_{FMR} characterised by a completed damping parameter $\alpha = \alpha_{eff} + \Delta\alpha$. Finally, the increase in f_{FMR} and decrease in lifetime of the excited level of magnetic moments associated with Δf_{FMR}, similar to a spin ½ particle in a static magnetic field, was theoretically elaborated as well as compared with experimental data.

[1] T.L. Gilbert, IEEE Trans. Mag. 40, 3443 (2004)
[2] K. Seemann, H. Leiste, V. Bekker, J. Magn. Magn. Mater. 278, 200 (2004)
[3] K. Seemann, H. Leiste, K. Krüger, J. Magn. Magn. Mater. 321, 3149 (2012)

WE-164

High frequency permeability spectra performed in Co_xO_y / CoFeB / Co_xO_y trilayers

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Microwave applications such as broadband skin antennas, microwave filters, noise suppressors and planar inductors require the development of soft magnetic thin layers with high permeability levels at elevated frequencies. One way for achieving such materials is to fabricate multilayers like AF/F [1] or F/NM [2] with (NM=Cu, Ta…) systems. The main drawback is the reduction of the effective permeability induced by Eddy currents. Replacing the conductive layer by an oxide may be a promising way. Co_xO_y / CoFeB / Co_xO_y trilayers have been realized in order to evaluate their potentiality as microwave material.

Samples were sputter-deposited on 9 mm x 9 mm flat glass substrates. The amorphous CoFeB layer was deposited by DC sputtering. The Co_xO_y layer was fabricated by DC pulsed reactive magnetron sputtering from a pure cobalt target in a Ar/O_2 reactive atmosphere. Static and dynamic magnetic properties have been performed at room temperature.

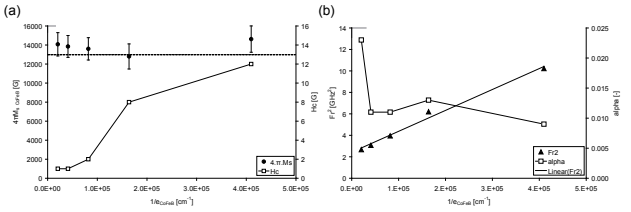
Single CoFeB layer exhibits a coercive field Hc lower than 1Oe. Its resonance frequency equals to 1.5GHz. Co_xO_y thickness was then fixed to 80nm while the CoFeB layer thickness was tuned in the 24-488nm range. Anisotropy and coercive fields increase while the CoFeB layer decreases. The maximum resonance frequency Fr, achieved is 3.2GHz.

One can observe that Fr^2 follows a law in $1/t_{CoFeB}$ which suggests an interfacial coupling. Let us assume that an uniaxial anisotropy is induced by an interfacial coupling. The calculated interfacial coupling energy J is 4.10^{-2} erg.cm^{-2}.

$$Fr = \bar{\gamma}\sqrt{4\pi M_s \cdot H_{eff}} \quad \text{and} \quad H_{eff} = H_{k0} + 2.\frac{2 \cdot J}{M_s . t_{CoFeB}}$$

Let us consider the Co_xO_y(12-600nm)/CoFeB(60nm)/Co_xO_y (12-600nm) system. CoFeB coercive field increases from 1.5Oe to 74Oe with Co_xO_y layer thickness. Fr^2 follows a t_{CoxOy}^{β} law with β=0.36.

[1] B. Viala, G. Visentin and P. Gaud, IEEE Trans. Mag. 40, 1996 (2004)
[2] G. Chai, Z. Wang, W. Sui and D. Xue IEEE Trans. Mag 47, 3115 (2011)



WE-165

FMR linewidth and the crystallization processes in Co-based amorphous microwires

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(1) Instituto de Física, UFRGS, 91501-970, Porto Alegre,Brazil, (2) Departamento de Física, UFSM, 97105-900, Santa Maria, Brazil

The Ferromagnetic Resonance technique has been used for many years as a tool to characterize the dynamic magnetic properties of bulk, thin film magnetic materials and microwires. It is well known that FMR linewidth is associated to dissipative processes involved on the magnetization dynamics. On the other hand, the complete understanding of the different channels leading to the precessional magnetization damping is still an open problem. The dissipative channels that promote the magnetization relaxation may be separated in two groups: intrinsic and extrinsic ones. While the first one is related mainly to the Landau-Lifshitz and eddy-currents damping mechanisms, the second one take in to account contributions coming from the inhomogeneities. Each one of these relaxation processes contributes to the FMR linewidth in a different frequency and/or magnetic field range and they can be separated by an appropriate FMR linewidth measurement. In this work we present FMR measurements, by the impedance method, ranging from 100 KHz to 1.8 GHz, in Joule annealed Co-based amorphous microwires. It is shown that the crystallization process can be followed by evaluating the contributions from inhomogeneities in the FMR linewidth. From the fitting of models which consider LL damping, Anisotropy Dispersion and Magnon Scattering to

the experimental data, three ranges of annealing temperatures can be distinguished: Annealing Temperatures lower than the Curie temperature, between the Curie and the Crystallization temperature, and above the Crystallization temperature.

WE-166

Propagation of spin waves excited by a microwave current: a combined phase-sensitive micro-focused BLS and micromagnetic study

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(1) CNISM-Unità di Perugia and Dipartimento di Fisica, Università di Perugia, Italy, (2) Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, München, Germany, (3) Istituto Officina dei Materiali del CNR (CNR-IOM), Unità di Perugia, Dipartimento di Fisica, Università di Perugia, Italy

The excitation and the propagation of spin waves on both a continuous NiFe film and a two dimensional magnonic crystal (Co dots deposited on top of a Nife antidot lattice) is investigated both experimentally and numerically. The spin waves have been excited by a microwave current injected into a coplanar waveguide (CPW) with finite-width ground lines, which is lithographically defined on top of the sample. Phase sensitive, micro-focused Brillouin Light Scattering (μ-BLS) has been employed to reveal the spatial profile of the propagating spin waves in the magnetostatic surface wave (MSSW) geometry (Fig.1). This allowed us to measure both the wavelength of the emitted spin waves as well as their attenuation as a function of the distance from the exciting antenna.

The experimental results have been satisfactorily reproduced by means of micromagnetic simulations performed with the open source micromagnetic code OOMMF. The exciting microwave field used in this simulation has the spatial profile defined by the CPW. To this aim we employed user-defined periodic boundary conditions in order to simulate an extended system. The resulting space and time dependent evolution of the magnetization has been analyzed by means of one and two dimensional fast Fourier transform algorithm (FFT) in order to obtain the spatial profile (Fig.1, inset) and the frequency spectrum of the excited spin waves as well as their dispersion relations. Evidence is given to asymmetric emission from the two sides of the CPW due to the symmetry breaking related to the sense of precession of the dynamical magnetization, as well as to the near-field effects of the extended SW emitter.

Funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement No. 228673 (MAGNONICS) is gratefully acknowledged.

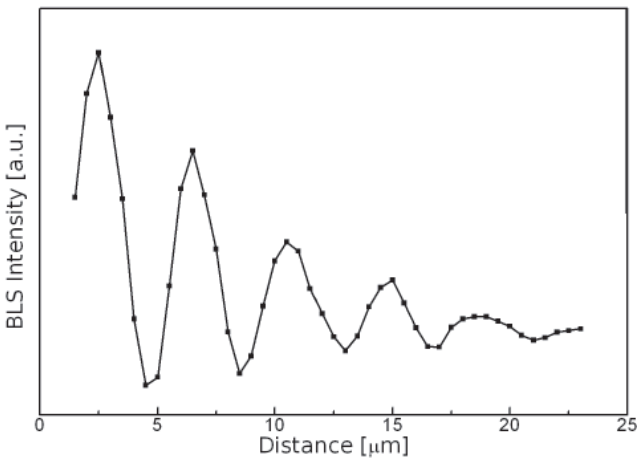

Fig.1 Phase-resolved μ-BLS measurement as a function of the distance from the CPW. (inset) simulated spin wave spatial profile.

WE-167

Field-induced domain wall propagation: beyond the one dimensional model

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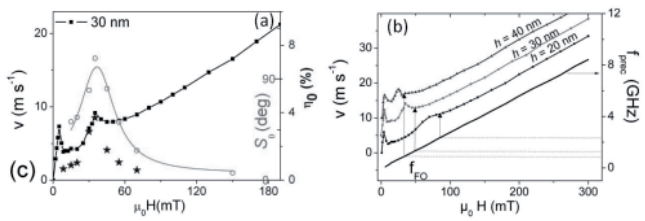
Many experimental studies focusing on field-induced domain wall (DW) propagation are finding only partial agreement with the general one-dimensional (1D) model theory for the behavior of the velocity versus field, v(H) [1]. In particular, kinks have repeatedly been observed in the precessional regime. Using numerical simulations to analyze the 3D configuration of the DW, we show that the torsion of the magnetization within the DW (twist) and the elongation of the DW are both maximum at the v(H) kinks. Using a 3D analytical v(H) model, we evidence that it is then the torque of the stray field emanating from the domains surrounding the DW upon the twisted magnetization that yields a velocity increase. The kinks are very clearly shown to occur when the precession frequency approaches the DW's flexural mode frequency, thus explaining how their positions shift with layer thickness and micromagnetic parameters. Finally, this approach is tested against experimental data on the dilute magnetic semiconductor alloys (Ga,Mn)As and (Ga,Mn)(As,P) of varying thickness, exchange constant and magnetic anisotropy, giving satisfying explanation of some of the observed kinks [2].

[1] R. Moriya, M. Hayashi, L. Thomas, C. Rettner, and S. S. P. Parkin, Appl. Phys. Lett. 97, 142506 (2010)

[2] L. Thevenard, C. Gourdon, S. Haghgoo, J-P. Adam, H. J. von Bardeleben, A. Lemaître, W. Schoch, and A. Thiaville Physical Review B 83,245211 (2011)



(a) Micromagnetic simulation of the DW velocity versus applied field for a 30nm perpendicularly magnetized layer (squares). A notable kink in the precessional regime coincides with the resonance of the twisting of the magnetization (S_0, open circles) and the flexion of the domain wall (eta_0, stars). (b) The field at which the velocity anomaly occurs is such that the precession frequency of the domain wall (solid line) is then close to its free oscillating frequency (FO).

WE-168

Suppression of Walker breakdown by spin waves in edge modulated planar NiFe nanowires

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Interest in the dynamics of domain walls in magnetic nanowires has increased rapidly in recent years, largely due to their potential in novel spintronic applications. Domain wall dynamics are key to device operation speeds, which are ultimately limited by the domain wall velocity.

Typically, domain wall velocity increases linearly with applied field up to the Walker field. This field marks the onset of Walker breakdown, after which a dramatic reduction in the time-averaged velocity occurs due to the nucleation of a vortex core originating from a structural instability in the wall. Further increase in the applied field leads to a gradual increase in velocity interrupted by further breakdown events. Walker breakdown can be suppressed with the application of transverse fields, which shifts breakdown to higher fields [1]. Edge roughness can also suppress Walker breakdown by dissipation of wall energy preventing vortex core formation, but by its nature this is hard to control [2]. Subsequent theoretical work has shown modulation of the edges modifies the energy landscape and thus affects wall propagation [3].

Here, a detailed systematic micromagnetic analysis of small amplitude periodically modulated nanowires has been performed. The periodicity dependence shows how energy dissipation via spin wave emission from domain walls can reduce the structural instability of the wall. Edge modulated nanowires can be tuned to match the period of vortex nucleation giving rise to a regime where fast, constant domain wall motion can be achieved at fields above that usually resulting in Walker breakdown.

[1] M.T. Bryan et.al., J. Appl. Phys. **103**, 073906 (2008).
[2] Y. Nakatani et.al., Nature Materials **2**, 521 (2003).
[3] J. Ieda et.al., J. Magn. Magn. Mater. **322**, 1363 (2010).

WE-169

Influence of Substrate Temperature on the Dynamic Magnetic Properties of $Fe_{70}Co_{30}$(001) Single-Crystal Thin Films

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Crystallographic defects and imperfections in magnetic thin films influence the dynamic magnetic properties like FMR line-width etc. [1]. However, there are very few fundamental studies on the effects of extrinsic property using well-defined single-crystal magnetic thin films [2]. In the present study, broadband FMR measurements [3] have been applied to $Fe_{70}Co_{30}$(001) single-crystal thin films prepared at different substrate temperatures to investigate the influence of film deposition temperature on the dynamic magnetic properties.

Single-crystal films with 40 nm thickness were deposited on MgO(001) single-crystal substrates using an UHV RF magnetron sputtering system at substrate temperatures from RT to 600 ºC. RHEED measurements confirmed the epitaxial growth of $Fe_{70}Co_{30}$ thin films with bcc(001) structure. Inductance measurements were carried out under static magnetic fields applied along [100] and [110**] in** the single-crystal film. Fig. 1 shows the complex permeability characteristics of the films deposited at RT, 200 ºC, and 400 ºC, respectively measured under a static field of 536 Oe along [110]. The FMR line-width spreads out and the resonant frequency shifts to lower frequency with increasing the film deposition temperature. The surface roughness, R_a, increases from 0.25 to 2.14 nm with increasing the temperature from RT to 400 ºC. Magnetic anisotropic energy also increases from 3,000 to 15,000 J/m^3 with increasing the temperature. The influence of extrinsic factors, such as surface roughness and crystallographic imperfections, on the dynamic magnetic property will be discussed.

[1] A. Azevedo *et al.*, Phys. Rev. B 62, 5331 (2000).
[2] F. Schreiber *et al.*, Solid State Commun. 93, 965 (1995).
[3] S. Takeda and H. Suzuki, J. Magn. Soc. Jpn., 33, 171 (2009).

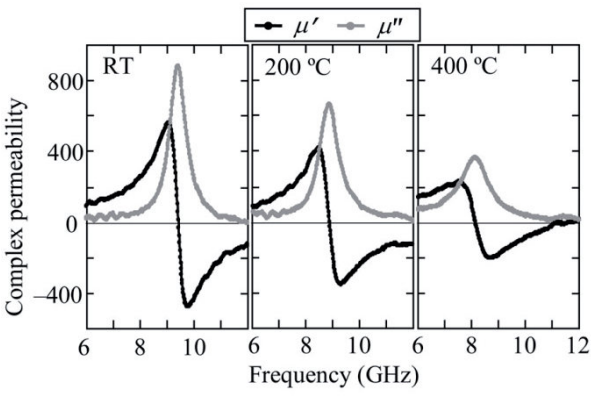

Fig. 1 Complex permeability characteristics of $Fe_{70}Co_{30}$(100) single-crystal films.

Wednesday, 12 September 2012
Poster Area, 17.00 – 19.00

SPIN EXCITATIONS AND ULTRAFAST DYNAMICS
Chair: G. Gubbiotti

WE-170
Low frequency spin dynamics in unsaturated YIG films: correlation with magnetic domain structures
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Yttrium iron garnet (YIG) is a well-known and studied magnetic material, having a number of high frequency applications. In this work we describe low frequency spin dynamics in thick films of single crystal YIG. The room temperature low frequency (0 – 4 GHz) spin dynamics were studied systematically using a vector network analyzer (VNA) at low applied magnetic fields. In order to assist the analysis of VNA data, we have performed Kerr microscopy and SQUID magnetometry on the samples in the same field configurations as the VNA measurements. In the saturated state we observe the expected uniform mode ferromagnetic resonance (FMR) line. However, for fields below saturation we register a strong deviation from uniform FMR behaviour, where various additional features are present and dependent on differing sample orientations. In particular, we note two specific field regimes below saturation, which correlate with the domain patterns (as observed using Kerr microscopy). For very low fields this corresponds to zig-zag domains, while for intermediate field strengths we observe a stripe domain structure. In the former, there is a strong absorption feature, which appears to be virtually frequency independent, persisting up to about 1 mT. An abrupt transition between the zig-zag and stripe domain patterns corresponds perfectly with the sharp changes observed in the frequency – field characteristics noted from the VNA measurements. In the region between 1 and 3.5 mT, the field at which saturation is almost complete, the frequency – field characteristics show several lines, which appear to be related to domain wall motion and resonance conditions in the different aligned domains. SQUID hysteresis loops support these findings.

WE-171
Nonlinear propagation and damping of short-wavelength spin waves in YIG and Ga,La-substituted YIG films
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Investigation of nonlinear effects and spin-wave damping are of great importance for creation of spin-wave devices with improved functional properties such as low-loss filters and broad-band delay lines. Frequency band broadening of spin-wave devices leads us to employ short wavelength spin waves propagating in magnetic films. We investigate nonlinear processes and damping of surface (Damon-Eshbach) spin waves in yttrium-iron-garnet (YIG) and Ga,La-substituted YIG films of the thicknesses 2.38 – 14.33 mkm. Magnetizations of films are in the range 1116 – 1788 Oe. Spin waves are generated by the microstrip antenna and the maximum of the spin-wave wavevector (q_{max} = 2.1 10^3 cm^{-1}) is determined by the microstrip width. To measure the two dimensional spin wave amplitude distribution in garnet films, the Brillouin light scattering (BLS) technique was used. It was found that the spin-wave intensity is proportional to exp(-l/d), where l is the distance from the generating antenna to the light spot and d is the damping length, which is the function of the wavevector, magnetization and the film thickness. The damping length decreases with the wavevector growth and with the decrease of the magnetization and the thickness. It changes the spectrum of propagating spin waves (Fig.1). Due to nonlinear processes, intensity of short-wavelength spin waves (q > 400 cm^{-1}) strongly depends on the microwave input power. Threshold of nonlinear processes decreases with the wavevector growth and depends on the magnetization. The minimum threshold (1.9 dBm) is observed for spin waves in YIG:Ga films.

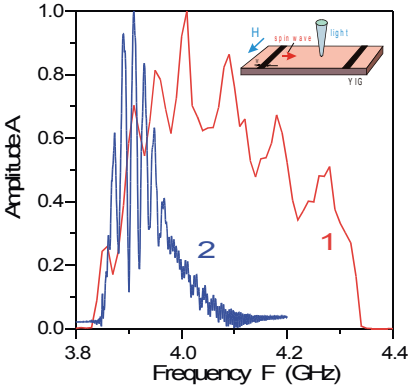

Fig.1. Spectrum of surface spin waves propagating in YIG film of the thickness 2.38 mkm at the magnetic field H = 736 Oe (1) near the edge of the microstrip antenna and (2) in the receiving antenna at the distance of 4 mm from the spin-wave generation. Amplitudes are normalized by their maximum values.

WE-172
Low relaxation of spin waves in thin magnetic films
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Spin excitations and spin-wave relaxation in thin magnetic films (in two-dimensional magnetic monolayer and bilayer lattices) and in thick films are studied in the Heisenberg model with magnetic dipole and exchange interactions by the spin operator diagram technique [1-2]. It is found that dispersion relations of spin waves in monolayers and bilayers, which are determined by poles of effective Green functions, differ from spin-wave

dispersion relations in thick magnetic films.
Spin-wave relaxation processes are different in thick and thin films. In thick films the relaxation is determined by diagrams in the one-loop approximation for a diagram expansion of the Green functions, which correspond to three-spin-wave processes and are accompanied by transitions between thermal excited spin-wave modes. It is found that the magnetic dipole interaction makes a major contribution to the relaxation of long-wavelength spin waves in thick magnetic films. Decreasing film thickness results in appearance a region of low relaxation of long-wavelength spin waves (Fig.1). In thin films with the thickness below a certain value the energy of spin waves in the low-relaxation region is less than energy gaps between spin-wave modes, three-spin-wave processes are forbidden, and four-spin-wave processes take place. It is found that the damping of spin waves propagating in magnetic monolayers has the form of the quadratic dependence on the temperature and for spin waves with small wavevectors is essentially lower in comparison with spin-wave damping in thick films.
This work was supported by the Russian Foundation for Basic Research, grant 10-02-00516.

[1] L.V. Lutsev, J. Phys.: Condens. Matter 17, 6057 (2005).
[2] L.V. Lutsev, Mathematical Physics Research Developments, Editor: Morris B. Levy, 141-188 (Nova Science Publishers, New York, 2008).

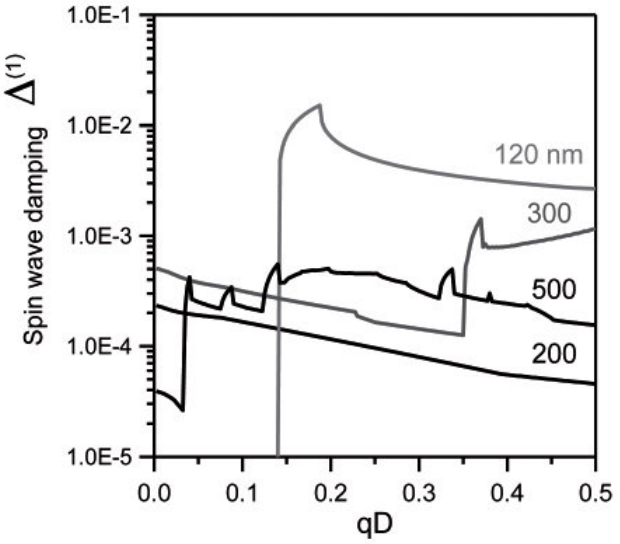

Fig.1. Spin wave damping of the first mode in normal magnetized YIG film at H = 3.0 kOe, 300 K at different film thickness D.

WE-173

Role of Gd in laser-pulse-induced demagnetization dynamics in amorphous ferrimagnetic $Gd_{1-x}Co_x$ alloys

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Ultrafast laser-induced magnetization dynamics is very intriguing; double so in multi-sublattice systems [1, 2]. Here we report 100 fs optical-laser-pulse-induced demagnetization dynamics in $Gd_{1-x}Co_x$ ferrimagnetic thin films by means of a time-resolved magneto-optical Kerr effect. Two-types of demagnetization processes, which are typical for Gd, have been observed. These are a partial ultrafast demagnetization process, which occurs on a subpicosecond time scale followed by a dominant slower demagnetization with a time constant of hundreds of picoseconds. Additionally there is a re-magnetization process within a few picoseconds immediately after the ultrafast one. Here we show that although the magnetism of Gd is not directly accessible with magneto-optical measurements, its fingerprint is clearly visible on the demagnetization dynamics of Co. The experimental observations are supported by a phenomenological four-temperature model that considers the interactions of electrons, lattice, and two spin heat reservoirs of Gd and Co, respectively.

[1] A. Mekonnen et al., Phys. Rev. Lett. **107**, 117202 (2011)
[2] J. H. Mentink et al., Phys. Rev. Lett. **108**, 057202 (2012)

WE-174

Laser-Induced Spin Dynamics in NdFeCo

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Rare-earth transition metal (RE-TM) alloys provide a wide playground for investigating magnetization dynamics at ultrafast timescales. Recently, a number of fascinating results have been reported for GdFeCo alloys with an anti-parallel alignment of the two spin subsystems [1]. From the physical point of view, magnetization dynamics in NdFeCo is of special interest because of an unusually complex configuration of the magnetic moments of the Nd and FeCo sublattices. Although the spins of both TM and Nd couple antiferromagnetically, the system is ferromagnetic due to the large orbital moment of Nd dominating the RE magnetization [2]. NdFeCo amorphous thin films with Nd concentrations of 20%, 30% and 50% were studied by means of a time-resolved pump-probe technique. The samples had an in-plane magnetic anisotropy and were probed with the help of the longitudinal Kerr effect. Static measurements confirmed the increase of magnetization with temperature as reported in [2]. All samples showed an ultrafast laser-induced demagnetization on a sub-picosecond timescale. We observed an increase in the efficiency of demagnetization in Nd50 upon cooling (Figure 1a), while for the Nd20 sample the trend is the opposite (Figure 1b). An increase of the relaxation time with increasing Nd concentration is also noticeable, becoming more pronounced at low temperatures. The obtained results are analyzed using a phenomenological model of ultrafast spin dynamics in multisublattice magnets [3].

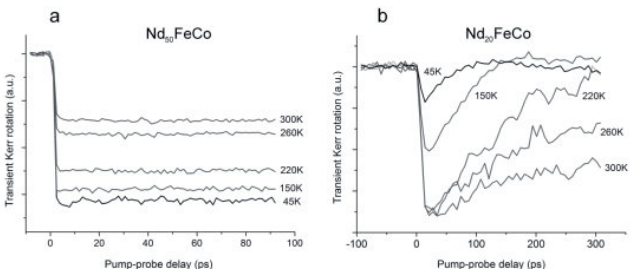

Figure 1: Magnetization dynamics of (a) Nd50FeCo and (b) Nd20FeCo.

[1] I. Radu et al., Nature 472, 205 (2011).
[2] R.J. Gambino and T.R. McGuire. J. Appl. Phys. 57, 3906 (1985)
[3] J. H. Mentink et al., Phys. Rev. Lett. 108, 057202 (2012)

WE-175

Theoretical study of magnetic precessions induced by ultrafast laser pulses

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Ultrafast optical control of a magnetic state of a medium is one of the most intensively studied topics in modern magnetism. Many fascinating experiments have been done to understand processes that take place in a material due to the excitation by subpicosecond laser pulses. However, the full picture of the light induced magnetization dynamics remains a puzzle. The ultrafast inverse Faraday effect (IFE) [1] is one of several magneto-optical effects, which are studied intensively and requires much deeper understanding.
In order to get insight into this effect, we study theoretically the interaction of a circularly polarized laser pulse with a magnetic system on subpicosecond timescales [2]. We describe the mechanism of the excitation of magnetic precessions due to the ultrafast IFE via the stimulated Raman scattering process [3]. We study the magnetization dynamics of the systems of atoms coupled via the exchange interaction in a crystal field environment due to this process. We calculate the time evolution of magnetization of the systems during and after the action of light.
We are thankful for the support by the FANTOMAS project.

[1] A. Kimel et al., Nature 435, 655 (2005).
[2] D. Popova, A. Bringer, S. Blügel, Phys. Rev. B 84, 214421 (2011).
[3] D. Popova, A. Bringer, S. Blügel, Phys. Rev. B 85, 094419 (2012).

WE-176

Angle dependence of ferromagnetic resonance peak widths in $Fe_{1-x}Co_x$ single crystal thin films

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Fe-Co based alloy thin films have been used for magnetic recording heads and magnetically soft underlayers(SUL) in the media. Gilbert's damping constant α of the head and SUL materials is an important factor to develop high frequency perpendicular magnetic recording system, as well as that of magnetic recording layers in the media. The α has been evaluated by ferromagnetic resonance (FMR) peak widths in thin films. In this work, magnetic properties of $Fe_{1-x}Co_x(001)$ single crystal thin films, epitaxially deposited on MgO(001) single crystal substrates by a rf magnetron sputtering system, were investigated by FMR spectroscopy in terms of crystal structure. As shown in Fig. 1, in-plane angle dependence of the resonance field H_r for the $Fe_{1-x}Co_x(001)$ specimens showed four-fold magnetic anisotropy. Magnetization easy and hard axes of the $Fe_{0.88}Co_{0.12}$ and $Fe_{0.79}Co_{0.21}$ specimens were parallel to the $<100>_{bcc}$ and $<110>_{bcc}$ directions, respectively. The orientation of the easy and the hard axes of the $Fe_{0.69}Co_{0.31}$, $Fe_{0.62}Co_{0.38}$, and $Fe_{0.49}Co_{0.51}$ specimens was changed to the $<110>_{bcc}$ and $<100>_{bcc}$ directions, respectively. This is a result of a sign change of the cubic anisotropy constant K_1[1]. The FMR peak width ΔH was also four-fold symmetrically varied. The maximum and the minimum α values of the $Fe_{0.69}Co_{0.31}$ specimen were estimated to be 0.04 and 0.017 from the ΔH values. The ΔH, or α, of all the specimens had the maximum and minimum values at the $<110>_{bcc}$ and the $<100>_{bcc}$ directions of the bcc crystal structure, respectively. These results show that the α does not depend on the magnetic anisotropy.

[1] Th. Muhge et al., J. Appl. Phys., 77, 1055 (1995)

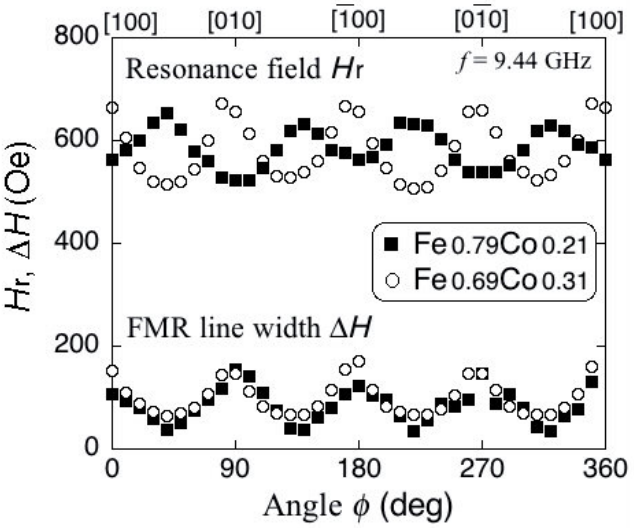

Fig. 1 In-plane angle dependence of resonance field H_r and ΔH for $Fe_{0.79}Co_{0.21}(001)$ and $Fe_{0.79}Co_{0.21}(001)$ specimens.

WE-177

Broadband ferromagnetic resonance studies in NiFe/Cu and NiFe/Ag multilayers

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Acoustic and optical ferromagnetic resonant modes were measured in NiFe/Ag and NiFe/Cu multilayered films using Vector network analyzer FMR (VNA-FMR). Our samples with NiFe thickness of 10nm and varying metal spacer thickness from 0.5nm to 2.5nm were produced by magnetron sputtering. All samples exhibited an unixial induced anisotropy after production. The dispersion relations of these samples were extracted from the measured resonance spectra in the range of 0.1 GHz to 7 GHz and fields up to +/-300 Oe. Static magnetization curves were also obtained in the same field range by VSM. Depending on the spacer thickness, two resonant peaks for a given field were observed, a behavior previously detected in magnetoimpedance measurements performed at 1.8 GHz in this kind of samples [1]. In this work this multiple peak structure is ascribed to acoustic and optical resonant modes of the coupled

magnetic layers. A relatively high intensity is observed in the optical resonant mode. Angular dependence of the resonances is also studied. The experimental data are compared to numerical calculations obtained from a simple model of FM–FM coupled layers including bilinear and biquadratic coupling interactions [2]. Our numerical calculations show good agreement with experimental measurements.

[1] A.M.H. de Andrade, R.B. Da Silva, M.A. Correa, A.D.C. Viegas, A.M. Severino, and R.L. Sommer, J. Magn. Magn. Mater 272, 1846 (2004)
[2] S.M. Rezende, C. Chesman, M.A. Lucena, A. Azevedo, F.M. de Aguilar and S.S.P. Parkin, J. Appl. Phys. 84, 958 (1998)

WE-178

Calculation of Gilbert damping in ferromagnetic films

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The Gilbert damping constant, entering the phenomenological Landau-Lifshitz-Gilbert (LLG) equation describing the magnetization dynamics, is calculated for ferromagnetic metallic films of Fe, Co, Ni and ferromagnet/nonmagnet bilayers within a realistic nine-band tight-binding model. The calculations of the Gilbert damping constant are based on the Kambersky formula presently re-derived [1,2] by comparing the frequencies of the long-wavelength spin-wave solutions of the LLG equation with the spin-wave energies obtained with the spin-orbit coupling treated as a perturbation. The efficiency of these calculations is remarkably improved by introducing finite temperature into the electronic occupation factors and subsequent summation over the Matsubara frequencies. The obtained dependence of the Gilbert damping constant on scattering rate for bulk Fe, Co, and Ni is in good agreement with the results of previous ab-initio calculations [3]. The dependence of this constant on the film thickness and the effect of the nonmagnetic cap overlayers of Ag, Au, Cu, Pd, Pt are studied for various scattering rates and compared with recent experiments.

[1] D. M. Edwards and O. Wessely, J. Phys.: Condens. Matter **21**, 146002 (2009)
[2] E. Barati, M. Cinal, D. M. Edwards and A. Umerski, in preparation (2012)
[3] K. Gilmore, Y. U. Idzerda, and M. D. Stiles, Phys. Rev. Lett. **99**, 027204 (2007)

WE-179

Magnetic properties of Co_2MnSi films: Ferromagnetic resonance, transverse bias initial inverse susceptibility and torque studies

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Full-Heusler alloys are currently attracting great interest since their possible use in spintronics applications due to their predicted 100% spin-polarization [1] and their high Curie temperature largely exceeding the room temperature [2]. We therefore studied the magnetic properties of Co_2MnSi thin films of 20 nm and 50 nm in thickness grown by radio frequency (RF) sputtering on a-plane sapphire substrates. X-ray diffraction (XRD) revealed the cubic <110> Co_2MnSi axis is normal to the substrate and that well defined preferential in-plane orientations are present. The static magnetic properties were studied at room temperature by conventional magneto-optical Kerr effect (MOKE) and by transverse bias initial inverse susceptibility and torque (TBIIST) MOKE. The dynamic magnetic properties were investigated by micro-strip ferromagnetic resonance (MS-FMR) at room temperature within the 2-18 GHz frequency domain sweeping. The resonance and TBIIST measurements versus the direction of the in-plane applied magnetic field reveal that the in-plane anisotropy results from the superposition of a two-fold and a four-fold symmetry. The directions of the principal axes of the twofold anisotropy are sample dependent. The angular dependence of remanent normalized magnetizations and coercive fields, studied by MOKE are analyzed within the frame of a coherent rotation model. A good agreement is observed between the field anisotropy values obtained from MS-FMR and from TBIIST data. The measured high value of the damping coefficient ($\alpha = 0.0285$), which lays in the range of previously reported ones in polycrystalline Co_2MnSi thin films [3], confirms the polycrystalline nature of our samples deduced from our XRD observations.

[1] H. C. Kandpal, G. H. Fecher, and C. Felser, J. Phys. D 40, 1507 (2007).
[2] S. Trudel, O. Gaier, J. Hamrle, and B. Hillebrands, J. Phys. D 43, 193001 (2010).
[3] R. Yilgin, M. Oogane, Y. Ando and T. Miyazaki, J. Magn. Magn. Mat. 310, 2223 (2007)

WE-180

Ultrafast switching of ferrimagnets

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Recently it was demonstrated that a linearly polarized laser pulse is able to reverse the magnetization in ferrimagnetic GdFeCo on a ps time scale [1]. In contrast to the former known opto-magnetic switching with an 80 fs, circularly polarised laser pulse [2], where a short magnetic field pulse induced by the inverse Faraday effect is assumed to play a crucial role, the switching here is on a purly thermal basis.
Opto-magnetic switching is only obtained in the ferrimagnetic materials like GdFeCo, so it is assumed that the antiferromagnetic coupling of the two different sub-lattices in these materials play a role, but the general mechanisms are still up for debate. For example the switching is mediated by a transient ferromagnetic-like state which is against the antiferromagnetic coupling and so a highly non equilibrium state.
To reach such a state the substantially different demagnetization times of the different sub-lattices seems to be crucial. These are a result of the different magnetic moments but probably also of the general different ultrafast laser-induced demagnetization dynamics of 3d transition metals and Gd [3].

To understand this new type of dynamics we perform atomistic spin model simulations of ferrimagnets, where we distinguish between the different demagnetization mechanisms in the sub-lattices and investigate the switching of the magnetization in detail.

[1] I. Radu et al., Nature 472, 205 (2011)
[2] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007)
[3] B. Koopmans et al., Nat. Mat. 9, 259 (2009)

WE-181

Ultrafast processes in magnetic strongly correlated materials

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Unique properties of strongly correlated materials arise from the exclusive interplay between orbital, electronic, spin and lattice degrees of freedom. Static spectroscopies cannot easily disentangle their individual contributions thus non-equilibrium optical techniques are here proposed. We performed pump and probe experiments with energy and temporal femtosecond resolution on different samples, ranging from metallic to more complex manganites and Rashba-type semiconductors. $La_{1-x}Sr_xMnO_3$ systems are characterized by strong orbital and magnetic ordering giving rise to the giant magneto resistance effect. On the other hand Rashba semiconductors like BiTeI, show a large band splitting because of the spin-orbit effect. Here the interactions between spins, electrons and orbitals induce a spin polarization of the involved bands making these materials good candidates for novel spintronic and magnetoelectric devices.
We measured the reflectivity response and the magneto-optical Kerr signal as a function of temperature, exciting laser energy and external magnetic field. Looking at the ultrafast timescale it is possible to clarify the behaviour and the role of single degrees of freedom and eventually highlight their interactions. We will show our results for BiTeI, different $La_{1-x}Sr_xMnO_3$ stoichiometries and superlattices compounds involving building blocks of manganites and cuprate superconductors.
Concerning iron metallic samples we studied the pump induced demagnetization as a function of temperature to further elucidate the role of phonons in the femtosecond regime [1].

[1] E. Carpene, E. Mancini, C. Dallera, M. Brenna, E. Puppin, and S. De Silvestri, Phys. Rev. B 78, 174422 (2008)

WE-182

Time-domain simulations of spin dynamics in molecules from first principles

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The classical Heisenberg spin model is based on the high-spin limit of the Heisenberg exchange Hamiltonian and has been used successfully to describe macroscopic, statistical properties of magnetic materials. Typically, *ab initio* methods for extracting Heisenberg exchange parameters (HEP) are based on spin density-functional theory (SDFT) and require a pair of self-consistent-field total energy calculations. Alternatively, *ab initio* HEP can be calculated from perturbation theory. For instance, in a recently proposed non-collinear constrained-SDFT method [1], the exchange couplings in two-centre magnetic molecular complexes (TCMMC) are extracted from the total energy at small angles of spin misalignment.
We propose a method for the calculation of HEP for TCMMC, rooted in the time-dependent (TD) non-collinear SDFT. This also provides a verification for the suitability of the Heisenberg model to describe dynamic spin interactions in the system of interest. Technically, our method is based on fitting the calculated from TD-SDFT trajectories of the local-spin expectation values to the analytical solution of the two-spin classical Heisenberg dynamics. The core of our computational scheme is provided by the open-source TD-SDFT code Octopus [2] with an in-house developed functionality of spatially-inhomogeneous fempto-second magnetic pulses. We compare our results to the results of Ref. [1] and discuss additional insights accessible only through the time-dependent method.

[1] J.E. Peralta and V. Barone, J. Chem. Phys. 129, 194107 (2008)
[2] A. Castro, H. Appel, Micael Oliveira, C.A. Rozzi, X. Andrade, F. Lorenzen, M.A.L. Marques, and E.K.U. Gross, Phys. Stat. Sol. B 243, 2465 (2006)

WE-183

Collective spin excitations driven by enhanced spin-orbit field in a quantum well

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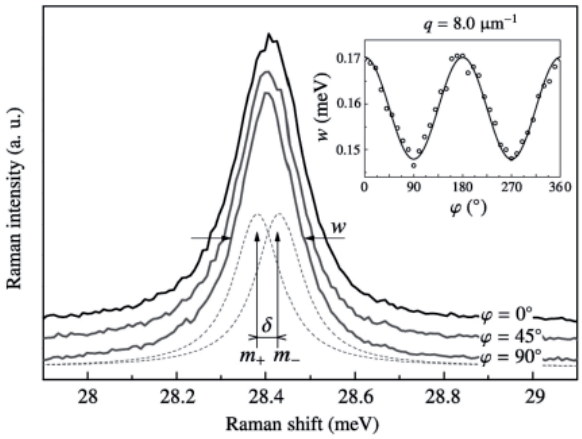
Spin-orbit coupling provides many avenues to detect and manipulate the electronic spin in paramagnetic semiconductors [1], as well as the magnetization of domains in ferromagnetic semiconductors [2], by purely electrical means. However, this mechanism also acts as a source of undesired dissipation (D'yakonov-Perel' mechanism). Numerous efforts have been made in recent years to overcome these limitations. All rely, in one form or another, on tuning the system parameters to restore the spin rotational symmetry, initially broken by spin-orbit coupling. In contrast with these studies, where the macroscopic spin is carried by individual electrons, we address a situation where, owing to Coulomb interaction, the macroscopic spin dynamics is coherent and has a collective character. Our focus is on inter-subband spin plasmons in a quantum well. Here, as we show, the suppression of spin-orbit induced dissipation does not necessitate specific parameter tuning, but arises in a fully generic manner from many-body effects alone. We demonstrate, for the first time, the existence of a collective spin-orbit magnetic field, which governs the coherent precession of the ensemble of spins. This magnetic field induces the fine structure of the spin plasmons, a quantizing phenomenon analogous to what happens in atoms. Using inelastic light scattering [3] on an asymmetric GaAs quantum well, we characterize this fine structure. We measure the anisotropic spin-orbit induced splitting (Fig. 1), and map the collective spin-orbit field associated with the spin plasmon. The latter field is found tenfold higher than the magnetic field acting on individual electrons, revealing novel opportunities for magnetization control through collective spin-orbit fields.

[1] V. Sih et al, Nature Phys. 1, 31 (2005)
[2] A. Chernyshov et al, Nature Phys. 5, 656 (2009)
[3] F. Perez et al., Phys. Rev. Lett. 99, 026403 (2007)



Raman spectra of the inter-subband spin plasmons, showing anisotropic splitting (inset).

WE-184

Significance of Nutation in Magnetization Dynamics of Nanostructures

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The dynamics of magnetic moments in nanostructures is closely linked to that of gyroscopes. The Landau-Lifshitz-Gilbert equation describes precession and relaxation but does not include nutation. Both precession and relaxation have been observed in experiments, in contrast to nutation.
We have extended the atomistic Landau-Lifshitz-Gilbert equation by a nutation term.
This allows us to study the significance of nutation in magnetization dynamics of nanostructures: for a single magnetic moment, a chain of Fe atoms, and Co islands on Cu(111). We find that nutation is significant at low-coordination sites and on the timescale of about 100fs; its observation challenges todays experimental techniques.

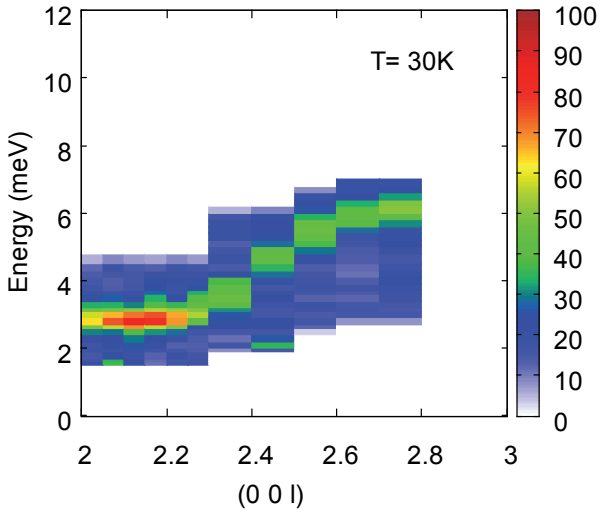
WE-185

Magnetic excitations in rare earth based nanosystems

K. Dumesnil [1], C. Dufour [1], S. Petit [2], *A. Bataille* [2]

(1) Institut Jean Lamour, Université Henri Poincaré, 54506 Vandoeuvre, France, (2) Laboratoire Léon Brillouin, CEA Saclay, 91191 Gif-sur-Yvette, France

Spins waves in magnetic films and superlattices are of great interest to understand fundamental properties in nanostructures, especially their dynamic response to an external perturbation. Technical improvements in Inelastic Neutron Scattering (INS) and the synthesis of high quality samples enable us to perform a pioneering study and address fundamental issues: the effect of (i) reduced dimensions (ii) lattice strains (iii) magnetic coupling, on magnetic excitations.
A reference 3μm thick Dy film exhibits bulk-like dispersion curves, with the appearance of an energy gap, related to crystal field and magneto-elastic anisotropies. In Dy/Lu superlattices with 5nm thick Dy individual layers, epitaxial strains lead to the stabilization of the Dy ferromagnetic phase which is either confined or coupled through non magnetic Lu, depending on the Lu thickness. The superlattices dispersion curves exhibit significant differences compared to bulk Dy (i) reduction of the energy gap (ii) modification of the shape of the dispersion curve in the vicinity of Q=(002). Those features are attributed to the influence of epitaxial strains on both anisotropy and exchange contributions. Specific effects have been also observed: Brillouin Zone Folding in the case of long range magnetic order and possibly discrete energy levels when the ferromagnetic order is confined.



Dispersion of magnetic excitations along the c-axis in a 3μm thick Dy sample

WE-186

Magnon softening in tetragonal FeCo alloys from ab-initio many-body perturbation theory

E. Sasioglu [1], C. Friedrich [1], S. Blügel [1]

(1) Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425, Jülich, Germany

Recently, tetragonal FeCo alloys received considerable attention for perpendicular magnetic recording applications due to their large uniaxial magnetic anisotropy energy K_u and large saturation magnetization M_s [1], which allows to further increase the recording density in hard disk drives. Besides large K_u and M_s values, another very important issue in device applications is the magnetization reversal processes i.e., magnetic switching time, which impose physical limits on areal recording densities. Currently the switching speeds have reached the point that dynamical effects are becoming important. This means that the magnetic switching speed is limited by the dissipation of the magnon energies. Using a recently developed Green-function method in combination with the multiple-scattering T-matrix approach [2] within the full-potential linearized augmented plane-wave framework [3], we have studied the magnon dynamics in tetragonal CsCl-type FeCo alloys considering three different experimental c/a ratios [1], i.e., FeCo grown on Pd, Ir, and Rh with c/a = 1.13, 1.18, and 1.24, respectively. As there are two atoms in the unit cell, the calculated magnon dispersions possess two branches: an acoustic branch and an optical one. The former branch

persists throughout the Brillouin zone indicating a localized nature of magnetism in FeCo alloys. On the other hand, the optical branch is heavily damped due to the coupling to single-particle Stoner excitations. We find that the tetragonal distortion gives rise to significant magnon softening. The magnon stiffness constant *D* decreases almost by a factor of two from FeCo/Pd to FeCo/Rh, which is a desired feature to decrease the switching times in devices. The combination of soft magnons and large magnetic anisotropy suggests the FeCo alloy grown on Rh to be a promising material for the perpendicular magnetic recording applications.

[1] F. Yildiz *et al*., Phys. Rev. B **80**, 064415 (2009)
[2] E. Şaşıoğlu *et al*., Phys. Rev. B **81**, 054434 (2010)
[3] http://www.flapw.de

WE-187

Coupled electromagnetic-spin-acoustic waves in magnetic having ferromagnetic spiral

I. Bychkov [1], V.D. Buchelnikov [1], D. Kuzmin [1], V. Shavrov [2]
(1) Chelyabinsk State University, 454001, Chelyabinsk, Russia, (2) Institution of Russian Academy of Sciences, Institute of Radio-engineering and Electronics, 125009, Moscow, Russia

Recently, spiral (helicoidal) magnetic materials have attracted researchers' attention for their unusual physical properties. The spiral magnetic structures contribute a number of features in the spectrum and dynamics of spin excitation in magnetic materials: zone structure is observed, the principle of nonreciprocity is manifested, i.e. difference between the velocity of wave transmission along and against the spiral axis. The coupled electromagnetic-spin, electromagnetic-spin-acoustic waves in the magnetic structure „simple spiral" had been investigated earlier [1, 2]. However, the spectrum and dynamic properties of magnets in a phase «ferromagnetic spiral» are not studied enough. In the present work the spectrum of the coupled spin, acoustic and electromagnetic waves in spiral magnetic structure of type «ferromagnetic spiral» is investigated. Also the reflection of electromagnetic waves from a layer of magnetic having the ferromagnetic spiral is considered. We use approach L >> a, where L - the spiral period, a - the lattice constant. Studies on the electromagnetic-spin-acoustic waves in magnetic materials with a helical magnetic structure in the phase of «ferromagnetic spiral», showed that the spectrum of the coupled waves has band structure. The band gap depends on the angle of the ferromagnetic spiral, and hence on the external magnetic field. The frequency dependence of the reflection coefficient of electromagnetic waves from the plate of the magnetic with a ferromagnetic spiral at different angles of the helix has been calculated. As the angle increases the opacity region broadens and shifts to higher frequencies. Thickening of the plate also leads to broadening of the opacity region.

[1] I.V. Manzhos, I.E. Chupis Phys. Low Temp., 14, 600 (1988) (rus).
[2] V.D. Buchelnikov, I.V. Bychkov, V.G. Shavrov JMMM, 117, 703 (1992).

WE-188

Full Phase Diagram of Spin Torque Oscillators with Perpendicular Polariser

A.S. Jenkins [1], J.F. Sierra [1], M. Quinsat [1], B. Rodmacq [1], B. Delaet [2], B. Dieny [1], M.C. Cyrille [2], U. Ebels [1]
(1) SPINTEC, UMR(8191) CEA/CNRS/UJF/Grenoble INP ;INAC, 17 rue des Martyrs, 38054 Grenoble, France, (2) CEA-LETI, MINATEC, 17 Rue des Martyrs, 38054 Grenoble, France

Spin torque nano-oscillators (STNOs) provide a promising alternative to existing technologies to realize frequency tunable nanoscale microwave oscillators. Spin torque driven excitations have been shown for a variety of magnetic configurations, including magnetic free layers with quasi-single domain or vortex type magnetization configurations [1], as well as for in-plane and out-of-plane magnetized polarizing layers.
Enhancing output power is a crucial issue for applications. This can be achieved by maximising the precession amplitude using vortex type oscillations [1] or out-of-plane (OPP) precession modes [2], realized by combining an out-of-plane polarizer with an in-plane free layer. In agreement with micromagnetic simulations [3], two OPP branches exist. A macrospin OPP branch is present at low current densities, which develops into an 'onion' or 'C' distortion branch with increasing current. Simulations reveal that upon further increasing the current the system evolves into a vortex state.
The experimental studies presented here on perpendicular polarizer spin valve structures, explore high current excitation spectra, that are characterized by low frequency (1-2 GHz), low linewidth (~10MHz) oscillations with multiple harmonic signals. These oscillations are indicative of the vortex oscillations predicted by our simulations.
Analysis of the linewidth and power of the 2nd and 3rd harmonics suggest two dynamic vortex states, related to damped resonant and steady state oscillations. It is noted that these vortex oscillations correspond to a dynamic state that is stabilised through the perpendicular spin polarized current. This is in contrast to vortex oscillations stabilised by the Oested field [1] or developing from a vortex ground state [1].

1. M. R. Pufall, Phys. Rev. B 75, (2007), V. S. Pribiag, Nature Phys. 498, (2007)
2. D. Houssameddine et al, Nature Mat., 6, (2007).
3. I. Firastrau et al, Phys. Rev. B 78, (2008).

Thursday, 13 September 2012

Oral Communications

Thursday, 13 September 2012
Aida Room

PLENARY
Chair: J.M.D. Coey

08.30 - 09.15
Novel electronic properties of graphene
F. Guinea [1]
(1) Instituto de Ciencia de Materiales de Madrid, CSIC, 280049 Madrid, Spain

Graphene is a two dimensional semimetal with vanishing density of states at the neutrality point. Weakly localized states can be induced near defects and edges. These states can lead to the formation of magnetic moments, even in the absence of magnetic dopants.
The control and manipulation of local moments in graphene is nowadays a very active research topic. Experimental and theoretical studies of these states, and of the induced magnetic properties of graphene, will be reviewed.

Thursday, 13 September 2012
Aida Room

SEMIPLENARY
Chair: C. Felser

09.15 – 10.00
Interplay between ferroelectricity and magnetism: a theorist's approach
S. Picozzi [1]
(1) Consiglio Nazionale delle Ricerche, CNR-SPIN, 67100 L'Aquila

Ferroelectricity - a long range switchable order of dipole moments - and magnetism - a long range switchable order of magnetic moments - couple in the so-called multiferroics (materials where spontaneous ferroelectricity and magnetism coexist) and magnetoelectrics (materials where a magnetic (electric) field can control or tune or switch ferroelectric (magnetic) properties). Multiferroics and magnetoelectrics represent emerging classes of multifunctional materials well-suited for applications in electrically-controlled spintronic devices. Compounds, where these peculiar phenomena occur, range from transition metal oxides to organic crystals to organic-inorganic hybrids. I will discuss several examples from a theoretical point of view, focusing in particular on the coupling between structural and electronic (charge-spin-orbital) degrees of freedom. Recent, unexplored and promising avenues connecting magnetism and ferroelectricity will be presented in the last part of the talk.

Thursday, 13 September 2012
Nabucco Room

SEMIPLENARY
Chair: G. Bertotti

09.15 – 10.00
Optimization of Exchange Bias in Polycrystalline Thin Films
K. O'Grady [1], G. Vallejo-Fernandez [1], N.P. Aley [1]
(1) University of York, Heslington, York YO10 5DD, UK

In the recent past there has been a paradigm shift in our understanding of exchange bias in polycrystalline thin films. What has come to be known as the York Model shows that exchange bias in such granular thin films depends upon the degree of order in the antiferromagnetic (AF) layers. [1] Generally films for technological application use IrMn as the AF which has a high anisotropy but in thin film form cannot be set above T_N. This can lead to the larger grains in the film not being aligned by the original setting process. Also at normal temperatures smaller grains in the distribution can have their orientation disordered due to the effects of thermal energy. This leads to the exchange bias being critically dependent on the exact form of the grain size distribution.
This understanding has made it possible to measure the anisotropy constant of the AF grains. This allows studies to be undertaken of those factors which give rise to the optimum value of exchange bias for a given application. In this paper the method by which the anisotropy constant can be measured will be reviewed together with the resulting correlation to the grain volume distribution in the films. Factors controlling the anisotropy such as the crystallinity of the IrMn grains and particularly the use of seed layers will also be discussed. Data will be presented showing that values of the AF anisotropy constant as high as $4x10^7$ergs/cc have been achieved. We also show that with control of the interfaces values of exchange bias as high as 3.6kOe have been achieved which is a world record for a polycrystalline film at this time. [1]

[1] K O'Grady et al, J. Magn. Magn. Mater. 322 (2010) p883

Thursday, 13 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 2

Chair: P. Tiberto

10.30 – 10.45

Effects of deposition induced and post-deposition thermally activated intermixing on the exchange bias of [Pt/Co]/(Pt)/IrMn films

F. Letellier [1], *L. Lechevallier* [1], R. Lardé [1], J.M. Le Breton [1], V. Baltz [2], B. Rodmacq [2], B. Dieny [2], J.F. Jacquot [3]
(1) GPM UMR(6634), CNRS / Université de Rouen, avenue de l'Université, BP 12, 76801 St Etienne du Rouvray, France, (2) SPINTEC, UMR CEA / CNRS / UJF-Grenoble 1 / Grenoble-INP, INAC, Grenoble, F-38054, France, (3) INAC SCIB, F-38054 Grenoble 9, France

The effects of deposition induced and post-deposition thermally activated layer intermixing on the exchange bias properties of $[Pt/Co]_{x3}/Pt(t_{Pt})/IrMn$ with out-of-plane anisotropy and deposited under a perpendicular magnetic field have been investigated. The consequences of these effects on the magnetic properties are analyzed and correlated to atom probe structural investigations. Atom probe tomography measurements allow the characterization at the nanoscale of the spatial repartition within the stack of the various species of atoms [1]. We show that Co-Mn and Co-Pt intermixing is already present in the as-deposited state. This intermixing is much more pronounced for Pt on Co (about 50% intermixing within the topmost 0.6 nm of Co) than for Mn on Co (about 5% intermixing). This can be ascribed to physical reasons (kinetic energy of incident atoms during the sputtering deposition) and/or to chemical reasons (affinity between elements and tendency to form compounds). Upon annealing up to 200°C, it is observed that the annealing does not result in further Co-Mn intermixing whereas it significantly accentuates the Co-Pt initial intermixing. This enhanced intermixing upon annealing leads to a 40% reduction the exchange bias field. We observed that it is not primarily due to changes in effective perpendicular anisotropy or to changes in saturation magnetization. This is predominantly ascribed to a reduction of the mean interfacial moment and Co-Mn exchange stiffness both due to reduction of the Co content at the interface and to a subsequent reduction of the amount of Co-Mn exchange-bonds [2].

[1] L. Lechevallier et al, Phys. Rev. B 79, 174434 (2009).
[2] F. Letellier et al, submitted (2012).

10.45 – 11.15

Ultrafast optical control of magnetism: from fundamentals to submicron dynamics *(invited)*

A.V. Kimel [1]
(1) Radboud University Nijmegen.

Usually magnetization dynamics are studied by observing the collective response of exchange-coupled spins, that is, spin resonances, after an external perturbation by a pulse of magnetic field, current or light [1]. The periods of the corresponding resonances range from one nanosecond for ferromagnets down to one picosecond for antiferromagnets. However, virtually nothing is known about the behavior of spins in a magnetic material after being excited on a timescale of the fastest spin excitation in a medium i.e. a magnon at the edge of the Brillouin zone with the period 10-100 fs [2]. Such an excitation perturbs the system in a non-adiabatic way bringing it into a strongly non-equilibrium state in which conventional description of magnetic phenomena in terms of equilibrium thermodynamics is no longer valid. Here we will discuss the results of experimental studies showing that mechanisms of magnetic switching triggered by such an excitation can be very counterintuitive [3,4]. For example, until now it has been generally assumed that heating alone, not represented as a vector at all, cannot result in a deterministic reversal of magnetization, although it may assist this process. Here we will demonstrate a novel mechanism of deterministic magnetization reversal in a ferrimagnet driven by an ultrafast heating of the medium without the presence of a magnetic field [4]. The mechanism is demonstrated for continuous films as well as for microstructures with in-plane and out-of-plane magnetic anisotropy. Peculiarities of ultrafast optical control of magnetism with submicron spatial resolution will be discussed.

[1]] J. Stöhr, H. C. Siegmann, *Magnetism: from fundamentals to nanoscale dynamics* (Springer, Berlin, 2006).
[2] A. Kirilyuk, A. V. Kimel & Th. Rasing, *Rev. Mod. Phys.* **82**, 2731 (2010).
[3] J. de Jong *et al Physical Review Letters* (in press).
[4] T. A. Ostler *et al Nature-Communications* **3** 666 (2012).

11.15 – 11.30

Exchange Bias in $IrMn_3$/Co Bilayers

R. Yanes [1], J. Jackson [2], L. Udvardi [3], L. Szunyogh [3], U. Nowak [1]
(1) Fachberich Physisk, Universität Konstanz, 78457, Konstanz, Germany, (2) Max-Planck Institut für Festkörperfurschung, 70569 Stuttgart, Germany, (3) Department of Theoretical Physics, Budapest University of Technology and Economics, H1111 Budapest, Hungary

The antiferromagnetic $IrMn_3$ exhibits a strong second order effective anisotropy, a non-collinear magnetic ground state within a [111] magnetic easy plane [1] and a high Néel temperature. When it is capped by a Co layer, sizeable Dzyaloshinskii-Moriya (DM) interactions arise owing to the breaking of symmetry at the interface [2]. These properties make the $IrMn_3$/Co bilayer a promising prototype for a exchange bias (EB) system. We studied the magnetic properties of a bilayer of $IrMn_3$/Co using a multiscale modeling,from ab-initio to localized spin model simulations.
Numerical calculations of the hysteresis loops of $IrMn_3$/Co were carried out for different values of the thickness of the Co capping (t_{Co}). Figure 1 shows the out-of-plane hysteresis loops of an $IrMn_3$/Co bilayer for 3 different values of t_{Co}, and it clearly demonstrates that $IrMn_3$/Co displays a strong perpendicular EB and high coercive field which decay as increasing the Co thickness.
To elucidate the microscopic origin of the exchange bias in the system, we evaluated the hysteresis loops taking into account different relativistic contributions to the exchange interaction. Based on these investigations we conclude that the main origin of the perpendicular exchange bias is the DM interaction at the interface.

[1] L. Szunyogh, et. al., Phys. Rev. B 79, 020403(R) (2009)
[2] L. Szunyogh, et. al., Phys. Rev. B 83, 024401 (2011)

Thursday, 13 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 2

Chair: P. Tiberto

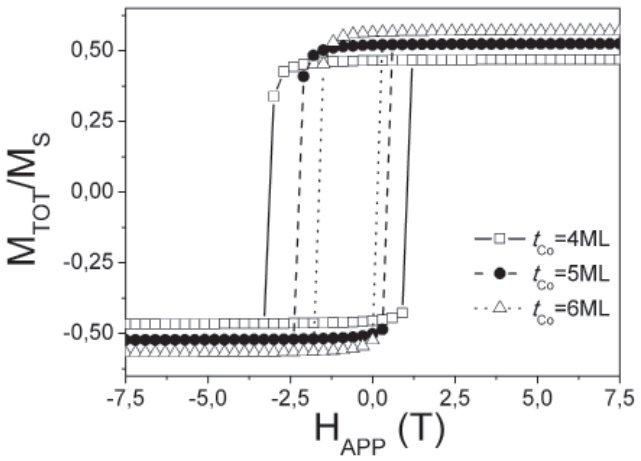


Fig1. Out of plane

11.30 – 11.45

F-AF-F coupling - A novel coupling mechanism through antiferromagnetic spacers

T. Kosub [1], D. Makarov [1], L. Han [1], R. Streubel [1], R. Abrudan [2], F. Radu [3], O.G. Schmidt [1]

(1) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany, (2) Condensed Matter Physics, Ruhr-University Bochum, 44780 Bochum, Germany, (3) BESSY II, Helmholtz-Zentrum Berlin, 12489 Berlin, Germany

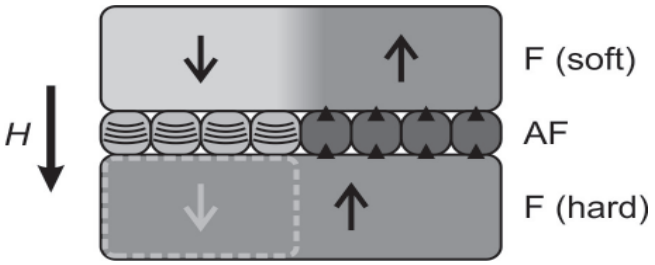
We recently discovered a novel coupling mechanism between two ferromagnetic (F) layers through an antiferromagnetic (AF) spacer in a layer stack exhibiting perpendicular magnetic anisotropy [1]. The model suggested so far relates the coupling to the presence of antiferromagnetic grains with a frozen spin structure. Due to the magnetization reversal of the softer F layer, the AF spin structure is collectively excited leading to a coupled reversal process of the complete F-AF-F system.

The key requirement for this type of magnetic coupling is a sufficiently defect-free antiferromagnet with a strong magnetic anisotropy as spin waves can propagate with low damping in these materials [2]. The two ferromagnets on either side of the AF grain lead to two F-AF subsystems which both show the exchange bias (EB) effect, i.e. a loop shift and increased coercivity [3]. As shown in Figure 1, when the softer ferromagnet nucleates reverse domains, the exerted spin wave disturbs the EB effect associated with the adjacent AF grains which can lower the required coercive force of the harder ferromagnet [1]. This allows for a joint reversal of both F layers.

Here, we present an in-depth analysis of the novel coupling mechanism by investigating the layer specific magnetization reversal in a [Pt/Co]/IrMn/[Ni/Pt] trilayer stack by x-ray magnetic circular dichroism (XMCD). We demonstrate that the two interfaces of the AF layer behave magnetically independent and but still give rise to F-AF-F coupling.

This effect is of great interest for spintronic applications in which antiferromagnets could take the role of conductors for pure spin currents.

[1] T. Kosub et al., Phys. Rev. B 84, 214440 (2011)
[2] K. H. Michel and F. Schwabl, Z. Physik 238, 264 (1970)
[3] T. Kosub et al., J. Phys. D: Appl. Phys. 44, 015002 (2011)



F-AF-F coupling leads to reversal of the dashed domain.

11.45 – 12.00

Exchange bias in Fe/CoO(001) and Fe/CoO(111) bilayers

E. Młyńczak [1], J. Gurgul [1], N. Spiridis [1], J. Korecki [2]

(1) Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Niezapominajek 8, 30-239 Krakow, Poland, (2) Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, al.Mickiewicza 30, 30-059 Krakow, Poland

CoO is an antiferromagnetic oxide having a rocksalt structure. Magnetic moments of Co atoms are aligned ferromagnetically in {111} planes, while adjacent {111} planes are coupled antiferromagnetically [1]. As a result, {001} planes of a perfect CoO crystal are magnetically compensated, in contrast to the {111} planes, which have a net magnetization corresponding to Co spins. In this contribution we will discuss the role of CoO crystal orientation on the magnetic properties of Fe/CoO bilayers. CoO films were grown layer-by-layer on MgO substrates, (001) and (111) oriented, by evaporation of single Co atomic layers and their subsequent oxidation. Oxygen exposure during growth was optimized to assure the stoichiometry of the CoO films (as checked by XPS). The thickness of the resulting CoO films was approximately 20 Å. LEED showed that the growth of CoO films was epitaxial for both crystal orientations. Iron layers were grown by the molecular beam epitaxy. Two-monolayer thick (app. 3 Å) ^{57}Fe probes were deposited directly on the oxide films and covered with ^{56}Fe to the total thickness of 50 Å to allow the analysis of the interface chemical and magnetic structure using Mössbauer spectroscopy. The occurrence of exchange bias effect was checked using MOKE and related to the amount of the uncompensated spins present at the Fe/CoO interface, as well as to the interfacial chemical structure.

[1] W.L Roth, Phys. Rev. 110, 6 1958

This work was supported in part by the Polish Ministry of Science and Higher Education and by the MPD Program of the Foundation for Polish Science co- financed by the EU Regional Development Fund

Thursday, 13 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES
SURFACES/INTERFACES 2
Chair: P. Tiberto

12.00 – 12.15
Contributions of freezing interfacial spin structure to exchange bias in NiO-Permalloy thin films
J. McCord [1], S. Mangin [2]
(1) Institute for Materials Science, Christian-Albrechts-University Kiel, D-24143 Kiel, Germany, (2) Institute Jean Lamour, University of Lorraine , F-54506 Vandoeuvre lès Nancy FRANCE

Exchange-coupled magnetic thin films consisting of an antiferromagnetic (AF) and an adjacent ferromagnetic (F) layer are an essential part of today's spin-electronic applications. This is based on the possibility of using F/AF systems for the magnetic stabilization of the F layer relative to external magnetic fields. The stabilization is based on the phenomenon of exchange bias (EB), manifesting itself in a magnetic loop shift.
We have studied the dependence of EB and coercivity in as-deposited $Ni_{81}Fe_{19}$/NiO films with varying field cooling history from room temperature, below the blocking temperature and with stabile EB, down to 4 K by SQUID magnetometry. By positive, negative, and by alternating field cooling procedures, we were able to distinguish between the two different contributions of EB. Zero field cooling accompanied by low temperature magneto-optical domain observation and local hysteresis measurements was performed. Dependent of the cooling procedure a strong increase, but also controlled reversal of sign of EB at lower temperatures is found. From comparison with measurements of magnetization dynamics at room temperature, the volume contributions, which are resulting from the instability of the AF grains, are separated from the influence of the freezing interfacial spin structure at low temperatures.
Our data clearly proofs the existence of two independent contributions to EB. By adjusting the field cooling procedure, we were able to control the amplitude and sign of EB. Moreover, the occurrence and origin of higher order exchange anisotropy terms, the coercivity dependence, and training effects will be discussed.

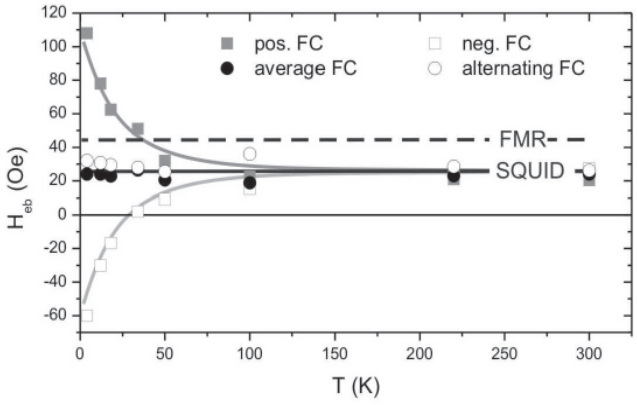


Fig. 1 Change of EB field H_{eb} with T for different field cooling (FC) procedures together with dynamic H_{eb} field at room temperature.

[1] J. McCord et al., Phys. Rev. B 75, 134418 (2007)
[2] L.E. Fernandez-Outon et al., J. Appl. Phys. 104, 093907 (2008)
[3] V. Baltz et al., Phys. Rev. B 81, 052404 (2010)

12.15 – 12.45
New magnetic relaxation process in ferromagnet/normal metal bilayers *(invited)*
S.M. Rezende [1], R.L. Rodríguez-Súarez [2], M.M. Soares [1], L.H. Vilela-Leão [1], A. Azevedo [1]
(1) Departamento de Física, Universidade Federal de Pernambuco, 50670-901, Recife, PE, Brasil, (2) Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago, Chile

In very thin ferromagnetic films and multilayers there are physical mechanisms for magnetic relaxation which are not present in bulk materials, such as two-magnon scattering at the surfaces or interfaces [1,2] and spin pumping [3]. These mechanisms produce relaxation rates that vary inversely to the magnetic film thickness and thus become important in ultra-thin films. Here we show that another relaxation mechanism is present in bilayers of a ferromagnetic (FM) material with a non magnetic metal (NM), namely, the transferred relaxation due to the coupling of the precessing magnetization in the FM layer with the heavily damped motion of the conduction-electron spins in the NM layer. This process is present in FM metallic or insulating films and is independent of the spin-pumping mechanism [3], although both originate in the spin coupling at the interface. While the spin-pumping mechanism is due to the flow of angular momentum out of the FM layer into the NM layer and relaxes the longitudinal component of the magnetization, the new mechanism relaxes the transverse components of the magnetization. The spin-pumping damping does not depend on the conduction electron spin-flip relaxation rate η_{sf} and varies inversely with the thickness of the FM layer, whereas the transferred damping is proportional to η_{sf} and is independent of the FM layer thickness. The proposed relaxation mechanism explains experimental observations of the ferromagnetic resonance linewidth broadening in thick films of yttrium iron garnet after deposition of a Pt layer and in thin permalloy/Pt bilayers.

[1] R. Arias and D.L. Mills, Phys. Rev. B **60**, 7395 (1999).
[2] S. M. Rezende, A. Azevedo, M. A. Lucena, and F. M. Aguiar, Phys. Rev. B**63,** 214416 (2001).
[3] Y. Tserkovnyak *et al*., Rev. Mod. Phys. **77**, 1375 (2005).

12.45 – 13.00
Antiferromagnetic coupling at the interface of two ferromagnetic layers: $LaSr0MnO_3$ and $SrRuO_3$
A. Solignac [1], R. Guerrero [1], P. Gogol [2], T. Maroutian [2], F. Ott [3], P. Lecoeur [2], C. Fermon [1], M. Pannetier-Lecoeur [1]
(1) DSM/IRAMIS/SPEC- CNRS URA 2464, CEA Saclay, 91191 Gif sur Yvette Cedex France, (2) Institut d'Electronique Fondamentale, Université Paris-Sud, CNRS, 91405 Orsay, France, (3) Laboratoire Léon Brillouin CEA/CNRS, CEA Saclay, F-91191 Gif sur Yvette Cedex, France

$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $SrRuO_3$ (SRO) are two ferromagnetic materials with Curie temperatures of respectively 350K and 150K. A positive exchange bias has been observed in bilayers and superlattices of LSMO/SRO [1,2,3] which

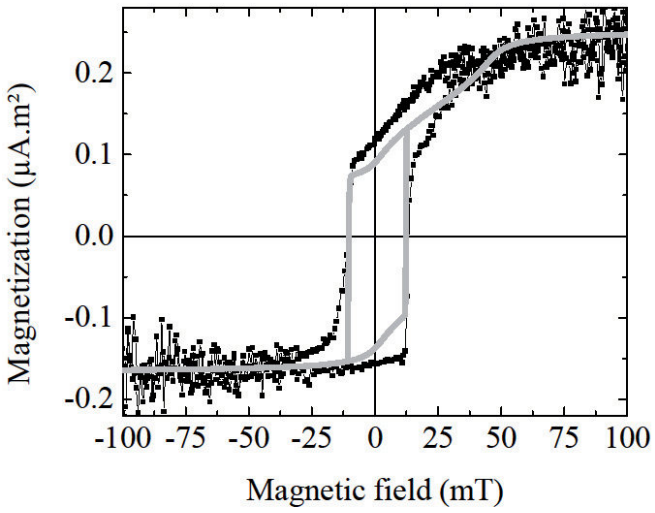
Thursday, 13 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 2

Chair: P. Tiberto

originates from an antiferromagnetic coupling at the interface between these two materials. This phenomenon is of particular interest to obtain a hard layer for magnetic oxide junctions where the stabilization of a reference layer is a crucial point.
LSMO/SRO bilayers have been grown epitaxially by pulsed laser deposition on $SrTiO_3$ (STO) substrate oriented (100). The layers grow in a 2D growth mode. XR diffraction and AFM characterization show the good crystalline quality of the deposition.
By combining magnetometry and Polarized Neutrons Reflectivity (PNR) measurements, we studied how the magnetization of both layers is rotating in the plane. We observed an asymmetry in the LSMO hysteresis loop that we attribute to the presence of two different exchange coupling strengths at the interface between LSMO and SRO. This model is verified by simulations based on an extended Stoner-Wohlfarth model. The simulations are in good agreement with the experimental data.
[1] X. Ke, M. S. Rzchowski, L. J. Belenky and C. B. Eom, Appl. Phys. Lett. **84**, 5458 (2004)
[2] P. Padhan, W. Prellier and R. C. Budhani, Appl. Phys. Lett. **88**, 192509 (2006)
[3]M. Ziese, I. Vrejoiu, E. Pippel, P. Esquinazi, D. Hesse, C. Etz, J. Henk, A. Ernst, I.V. Maznichenko, W. Hergert and I. Mertig , Phys. Rev. Lett. 104, 167203 (2010)



Magnetometry measurement (black dots) and simulation using a Stoner-Wohlfarth model (grey line) of a LSMO/SRO bilayer minor loop at 10K and after a 5T field cooled procedure. This minor loop corresponds to the LSMO magnetization switching, while the magnetization of the SRO layer is blocked because of its high coercive field.

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

MAGNETIC VORTICES AND SPIN TORQUE

Chair: M.A. Marioni

10.30 – 10.45
Switching dynamics of Co nanodots with perpendicular anisotropy by in-plane current injection
A. Hrabec [1], *S. Pizzini* [1], V. Stsefanovich [1], M. Bonfim [2], J. Vogel [1], I.M. Miron [3], G. Gaudin [3], O. Boulle [3], P. Gambardella [4], F. Sirotti [5], T.O. Mentes [6], A. Locatelli [6]
(1) Institut Néel, CNRS, Grenoble, France, (2) Departamento de Engenharia Eletrica, Universidade do Parana, Curitiba, Brazil, (3) SPINTEC, CEA/CNRS/UJF/GINP, INAC, Grenoble, France, (4) Catalan Institute of Nanotechnology (ICN-CIN2),Barcelona, Spain, (5) Synchrotron SOLEIL, Gif-sur-Yvette, France, (6) ELETTRA, Sincrotrone Trieste, Basovizza, Trieste, Italy

Materials with perpendicular magnetization and large coercivity are ideal for data storage, because they can retain information for long times. Reversing magnetization in nanosized magnets remains however a major technological challenge. Using transport measurements, some of us have found that the magnetization of Co nanodots in Pt/Co/AlOx structures can be reversibly switched by applying positive/negative in-plane current pulses parallel to a static magnetic field [1]. This system constitutes the first prototype of bi-stable magnetic switch working with in-plane current pulses. Our measurements on Pt/Co/AlOx system, showing that the non-centro-symmetric structure is at the origin of new torques – possibly related to Rashba effect and SHE in Pt [1,2] - have stimulated a large amount of experimental and theoretical work. The aim of this contribution is to show our advances in the understanding of the dynamics of magnetisation reversal in such Co nanodots. Experiments were carried out on both 1μm and 500nm large Co dots shown in the figure (a). The current flows in the underlying Pt nanostripe and the in-plane magnetic field is created by the embedded Co nanomagnets. While magnetic microscopy measurements (XMCD-PEEM) give direct evidence of the bi-stable magnetic switching (figure b-c), details of the switching mode, governed by nucleation and propagation of domain walls, are revealed by high resolution imaging. Time-resolved Kerr measurements show reversal times of the order of 1ns or less, which can be directly related to the reversal process.

[1] I.M. Miron et al. Nature 476 189 (2011).
[2] I. M. Miron et al., Nature Mater. 10 419 (2011).
[3] V. Uhlir et al. Phys. Rev. B 83, 020406(R) (2011).

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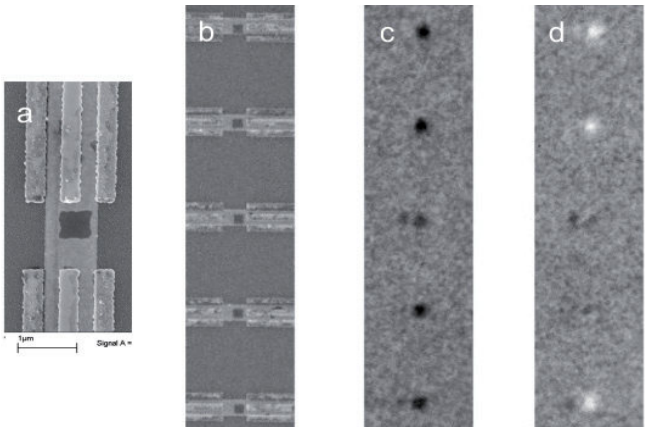
MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

MAGNETIC VORTICES AND SPIN TORQUE

Chair: M.A. Marioni

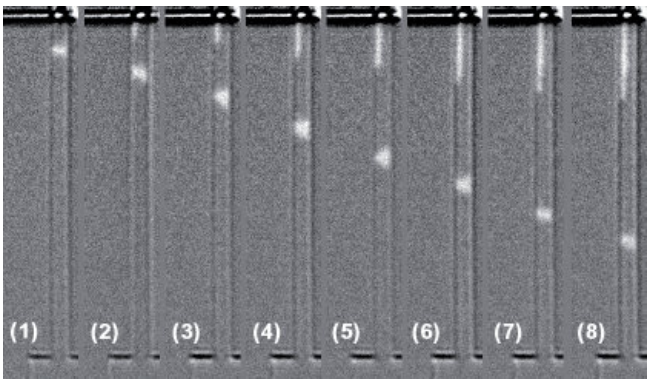


(a-b) SEM and PEEM image of the Pt/Co/AlOx device with Co magnets. (c-d): magnetic contrast obtained for the Co dots after application of opposite current pulses, obtained with XMCD-PEEM.

10.45 – 11.00
When magnetic domain shape changes domain wall propagation induced by spin polarized current
N. Vernier [1], J.P. Adam [1], J. Ferre [2], A. Thiaville [2], A. Lemaître [3], G. Faini [3]
(1) Institut d›électronique fondamentale, bât. 220, Université Paris-Sud, 91405 Orsay, France, (2) Laboratoire de Physique des Solides, bât. 510, Université Paris-Sud, 91405 Orsay, France, (3) Laboratoire de Photonique et de Nanostructures, CNRS, route de Nozay, 91460 Marcoussis, France

Recently, many ideas have appeared to use magnetic domain walls for memories. Several of them are using spin polarized current to move the domain walls [1,2]. However, this process to move domain walls is far from being fully understood. One important question remains : what is really happening to the domain? Most of the experiments are using global probes, and cannot determine the real shape of the domain after propagation. We present here a work about domain wall movement induced by spin polarized current in a track of GaMnAs with perpendicular anisotropy. The shape of the magnetic domains were checked using Kerr imaging. GaMnAs is a good model system to study this problem, as domains are large and can be viewed with optical resolution [3], contrary to the case of usual ferromagnetic metals, for which there can be multidomains at a scale smaller than the optical resolution.
Our experiments show that the shape of the magnetic domain can be tricky. For example, as shown on the figure below, the domain wall can extend on the whole section of the wire or only on half of the section. Depending on this, the velocity of the domain wall changes. This result can be explained by a demagnetizing effect, and one should be careful about it to create new type memories.

[1] Parkin et al, Science **320**, 190 (2008)
[2] Burrowes et al, Nat. Phys. **6**, 17 (2010)
[3] Adam et al, Phys. Rev. **B 80**, 193204 (2009)



Sequence of 8 Kerr pictures, between each picture a current pulse of 7x10^8 A/m and 15µs was sent in the sample

11.00 – 11.15
Transfering magnetic vortices between many spin torque oscillators
M. Manfrini [1], J. Kim [2], S. Petit-Watelot [2], R.M. Otxoa [2], W. Van Roy [1], J. Kittl [1], L. Altimime [1], L. Lagae [1], *T. Devolder* [2]
(1) IMEC, Kapeldreef 75, B-3001 Leuven, Belgium, (2) Institut d›Electronique Fondamentale, CNRS, UMR 8622, Orsay, France and Univ. Paris-Sud, 91405 Orsay, France

«Vortexonics» is the art of manipulating of magnetic vortices. A model playground for vortexonics is a metallic nanoscale contact injecting electrical current into a multilayer. Indeed the magnetic field associated with the charge flow can prepare a vortex on demand, which is subsequently set into planetary revolution about the nanocontact by the spin flow and the related transfer of angular momentum between the layers› magnetizations. Through the magneto-resistance, the spinning vortex induces an oscillation of the nanocontact resistance, with foreseen applications to compact microwave sources of exceptional agility, instant-on capability, low phase noise and multi-octave frequency coverage. When instead of a single nanocontact, chains or complicated patterns comprising multiple nanocontacts sharing the same multilayer are used (Fig. 1) and addressed with independent currents, this yields an even richer vortex dynamics. The peculiarly of the non parabolic attracting potentials supplied by the charge flow and non conservative forces supplied by the spin flow in the set of nanocontacts ensures the presence of a single spinning vortex in the system. Playing with the adjustable attracting potentials of neighbouring nanocontacts, we show experimentally and model theoretically that the vortex can be ordered to swap position between the neighbouring nanocontacts, as proven from the microwave signals radiated by each of the nanocontacts. Time-resolved experiments show that this relocation of the vortex can be faster than 5 ns, in agreement with micromagnetic modeling.
In high current conditions, the vortex can also orbit along a path that surround several nanocontacts. This opens routes for the coherent guiding of a single magnetic vortex in interconnected chains of nanocontacts, and to manipulate the vortex and have it interact with other high energy magnetic pseudo-objects.

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MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

MAGNETIC VORTICES AND SPIN TORQUE

Chair: M.A. Marioni

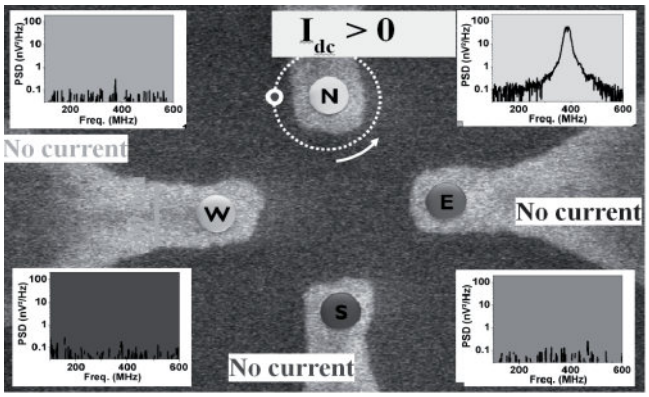

Figure1: Voltage spectra recorded on each nanocontact of a cross configuration.

11.15 – 11.30

Current driven vortex core reversal in nanocontact systems

R. M. Otxoa [1], S. Petit-Watelot [1], M. Manfrini [2], J. Kim [1], T. Devolder [1]
(1) Institut d'Electronic Fondamentale, Université Paris-Sud, 91405 Orsay, France, (2) IMEC, Kapeldreef 75, B-3001 Leuven, Belgium

Magnetic vortices represent a significant example of a small object with a high structural stability in nano-magnetism. Study the stability of the vortex core (soliton part of the vortex) is an important issue to exploit the potential application of these objects into data storage. Recent studies have shown that under certain conditions the vortex core polarization can be switch either by magnetic fields, spin polarized currents or spin waves [1,2,3]. The physical origin of the core reversal has been associated to an internal magnetic field generated by the dynamics of the vortex [4]. In this study it is stated that the key parameter to avoid (or promote) the vortex core reversal is the linear velocity of the vortex. Instead, we will show theoretically and by simulation that in presence of in-plane torques in a nanocontact geometry the switching mechanism it does not only depend on the vortex dynamics, certainly it is necessary to account for the influence of these torques in to the media in which relies the vortex. Geometrical aspects of the vortex orbit need to take into account in order to explain the dependence of the critical velocity as a function of applied in-plane torques.

[1] B. Van Waeyenberge et al., Nature 444, 461-464 (2006)
[2] Sang-Koog Kim et al., Appl. Phys. Lett 92, 022509 (2008)
[3] Kammerer, M. et al., Nat. Commun. 2 :279 doi : 10.1038/ncomms1277 (2011)
[4] Konstantin Yu. Guslienko et al., Phys. Rev. Lett 100, 027203 (2008)

11.30 – 11.45

Switching vortex chirality in patterned magnetic nanodisks by nanosecond field pulses

V. Uhlir [1], *M. Urbánek* [2], L. Hladik [3], J. Spousta [3], P. Fischer [4], M. Im [4], E. Fullerton [1], T. Šikola [2]
(1) Center for Magnetic Recording Research, University of California, San Diego, CA 92093-0401 La Jolla, USA, (2) CEITEC BUT, Brno University of Technology, Technická 10, 616 00 Brno, Czech Republic, (3) Institute of Physical Engineering, Brno University of Technology, Technická 2, 616 69 Brno, Czech Republic, (4) Center for X-ray Optics, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, CA 94720 Berkeley, USA

A magnetic vortex is a curling magnetic structure formed in a sufficiently small magnetic disk in which the demagnetizing and exchange energy are minimized. The magnetization configuration of a vortex is described by two binary characteristics. The chirality, representing either a clockwise or counterclockwise sense of curling, and the polarity of the vortex core, where the magnetization points either up or down. The possibility of controlling these two binary states independently is promising for the realization of a quaternary memory cell.
Fast, subnanosecond switching of the vortex polarity has already been demonstrated. We focused on switching the vortex chirality at a comparable time scale. We present the results of time-resolved imaging of the switching and relaxation of a vortex chirality in a chain of permalloy disks with a radius of 120 nm and thickness of 50 nm during the application of a field pulse. The experiments were performed using the XM-1 full field soft x-ray transmission microscope located at the beamline 6.1.2 at the Advanced Light Source (Berkeley, CA), magnetic contrast is obtained by the X-ray Magnetic Circular Dichroism (XMCD).
The images were obtained with 25 nm spatial and 50 ps temporal resolution and clearly demonstrate that the vortex chirality can be switched back and forth by bipolar field pulses with an amplitude of 20 mT and a duration longer then 0.9 ns.

11.45 – 12.00

Magnetic Vortex Core Reversal Based on the Interaction between Azimuthal Spin Waves and the Vortex Gyromode

M. Sproll [1], M. Noske [1], M. Kammerer [1], M. Weigand [1], G. Dieterle [1], A. Gangwar [2], G. Woltersdorf [2], H. Stoll [1], G. Schuetz [1]
(1) Max Planck Institute for Intelligent Systems (formerly: MPI for Metals Research), Stuttgart, Germany, (2) Department of Physics, University of Regensburg, Regensburg, Germany

Essential progress in understanding magnetic vortex dynamics was achieved when low-field vortex core reversal was discovered by exciting the (sub-GHz) vortex gyromode [1]. Recently we have demonstrated a much faster vortex core reversal process by excitation of azimuthal spin waves with rotating multi-GHz magnetic fields [2, 3].
Here we report on experiments and micromagnetic simulations with simultaneous excitation of both the sub-GHz gyromode and multi-GHz spin waves. This combined excitation allows investigations on the interaction between the vortex gyromode and spin waves in this highly non-linear system.
Results of micromagnetic simulations for Permalloy discs (vortex polarity up, 1.6 µm in diameter, 50 nm thick) are presented in the figure below. The threshold amplitude of clockwise (cw) rotating GHz excitation needed for vortex core reversal is plotted vs. the applied frequency for four different gyromode amplitudes (linear excitation at 240 MHz). Surprising effects are found in this way:

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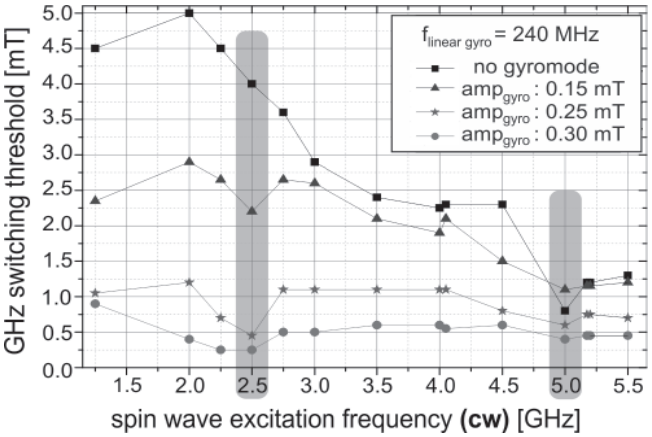
(i) Beside the well-known azimuthal spin wave mode (n = 1, m = -1) at 5 GHz an additional resonance appears at 2.5 GHz, but only if the vortex gyromode is excited simultaneously. This 2.5 GHz resonance shows a strong dependence on the amplitude of the gyromode excitation.
(ii) Our experiments and simulations (see figure) reveal a significant reduction of the switching threshold depending on the amplitude of the simultaneous linear gyromode excitation.
A possible explanation for the observed reduction in the switching threshold is basing on a superposition of the two 'dips' (i.e. magnetizations opposite to the initial vortex core) which are found for both, vortex gyromode [1] as well as spin wave excitation [2, 3].

[1] B. Van Waeyenberge et al., Nature **444**, 461 (2006)
[2] M. Kammerer et al., Nature Communications **2**, 279 (2011).
[3] M. Kammerer et al., http://arxiv.org/abs/1112.1903

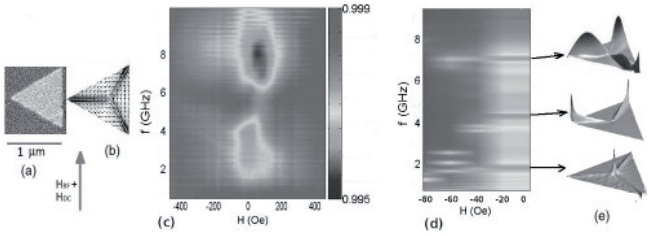


Simulated switching thresholds for combined gyromode and spin wave excitation.

12.00 – 12.15
Winter magnons in circular and triangular vortex state Permalloy dots
A. Lara [1], A. Awad [1], *F. Aliev* [1], K. Guslienko [2], V. Metlushko [3]
(1) Dpto. Fisica Materia Condensada C03, Universidad Autonoma de Madrid, 28049, Madrid, Spain, (2) Dpto. Física de Materiales, Universidad del País Vasco, 20018 San Sebastian, Spain & IKERBASQUE, The Basque Foundation for Science, 48011 Bilbao, Spain, (3) Dept. Electrical & Computer Engineering, University of Illinois at Chicago, Chicago, 60607 IL, USA

We present an investigation of the magnetization dynamics in circular Permalloy (Py) dots in the single vortex (SV) or double magnetic vortex (DV) states and in triangular Py dots in SV state by means of broadband ferromagnetic resonance and micromagnetic simulations. The oscillating magnetic field is applied in the dot plane. In the metastable DV configuration we have observed a new type of quasi 1D spin waves excited along the domain walls connecting the vortices and edge half-antivortices [1]. We have also detected several spin excitation modes of the same kind in 25 nm thick Py triangles (Figure). In this case, the domain walls naturally appear in the SV ground state, connecting the vortex core and the vertices of the triangle. These spin waves are analogous to the displacement waves of elastic strings and could be excited in a wide class of magnetic nanostructures possessing domain walls.

[1] F. G. Aliev, et al., Physical Review **B84**, 144406 (2011).



(a) SEM (b) DC simulation (c) measurements (d) AC simulations (e) main modes.

12.15 – 12.30
Influence of vortex parameters on spin transfer nonlinear vortex dynamics
E. Grimaldi [1], A. Dussaux [1], B. Salles [2], J. Grollier [1], A. Fukushima [2], H. Kubota [2], K. Yakushiji [2], S. Yuasa [2], V. Cros [1], A. Fert [1]
(1) Unité Mixte de Physique CNRS/Thales, 1 Av Fresnel, Palaiseau, and Université Paris-Sud, Orsay, France, (2) National Institute of Advanced Industrial Science and Technology (AIST), Spintronics Research Center, Tsukuba, Japan

A novel type of nano-oscillators based on spin transfer torque promising for telecommunication applications given that key features such amplitude of emitted power and spectral coherence can be improved. A solution would be to synchronize an ensemble of STNOs. A precise analysis of the main features of spin transfer dynamics (frequency and linewidth) as a function of injected current is a major issue [1].
Here we study vortex based STNOs and notably the possibility to control the dynamics of gyrotropic motion (frequency and linewidth) induced by spin transfer torque through the modification of the vortex parameters (vortex chirality and core polarity).
The studied devices are circular nanojunctions made of NiFe (10nm) / MgO (1.1nm) / SAF which presents a vortex at remanence. This sample exhibits large emitted signal with large coherence when an external out-of-plane field to generate sufficient spin polarization is applied [2]. Using rf measurements, we study the evolution of frequency, power and linewidth with external applied out-of-plane field and injected current. We observe that the emitted signal behavior strongly depends on the chirality configuration if it is identical or opposed to Oersted field symmetry.
Moreover, we analyze our experimental results in the frame of our non linear model for vortex dynamics that considers non linearities

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Chair: M.A. Marioni

of the damping force and confining force[3]. This new model predicts evolution of frequency and linewidth with current. Both model and experiments qualitatively agree and show the large impact of vortex configuration on gyrotropic motion of the vortex core.

We thank CANON ANELVA for preparing the MTJ films, the ANR VOICE and SPINNOVA grant and MASTER grant and E.G. acknowledge financial support from CNES and DGA.

[1] A. N. Slavin and V. S Tiberkevich, PRB, 72 (2005)
[2] A. Dussaux *et al.,* Nat. Comm. 1, 8 (2010)
[3] A. Dussaux et al. (2012)

12.30 – 12.45

Spin torque driven excitations in synthetic antiferromagnets

E. Monteblanco [1], D. Gusakova [1], F. Garcia Sanchez [1], L.D. Buda-Prejbeanu [1], A.S. Jenkins [1], U. Ebels [1], M.C. Cyrille [2], B. Dieny [1]
(1) SPINTEC, UMR CEA / CNRS / UJF-Grenoble 1/ Grenoble-INP, INAC, Grenoble, F-38054, France, (2) CEA-LETI/ MINATEC/38054 Grenoble, France

Spin torque driven excitations provide a unique means to investigate large angle magnetization dynamics and the associated non-linear properties in nanoscale magneto-resistive devices. To mention in particular is the non-linear coupling between amplitude and frequency, that allows frequency tuning, enhances phase-locking ranges and plays a crucial role in linewidth broadening [1]. All these phenomena have been studied in the past for single free layers. For read-head and magnetic random access memory applications (MRAM), it has been proposed to use synthetic antiferromagnets (SAF), where two ferromagnetic layers are strongly coupled by exchange interaction across a non-magnetic spacer layer. Our previous experimental study [2] indicates that the linewidth in a SAF can be lower than in a single free layer. Therefore it is also of interest for spin torque driven excitations. In order to understand this result, it is important to analyze in detail the various aspects of non-linear magnetization dynamics for coupled magnetic layer structures.

We have established the zero temperature excitation spectrum using macrospin simulations of spin torque driven excitations in AF/SAF structures. Here the SAF is exchange biased by an antiferromagnet AF. Going beyond our previous results [3], we present here the current-field state diagram of the excitations and the corresponding current and applied bias field dependencies of the frequency, as a function of the exchange coupling strength. We can identify conditions that are more suited for magnetic switching and MRAM applications or more suited for microwave applications. Furthermore, we can explain the transition of a red-shifted in-plane-precession (IPP) mode to a blue-shifted IPP mode in terms of the dynamic interlayer exchange coupling.

[1] A. N. Slavin and V. Tiberkevich, IEEE Trans. Magn. 45, 1875 (2009)
[2] D. Houssameddine et al., Appl. Phys. Lett 96, 072511 (2010)
[3] D. Gusakova et al., Phys. Rev. B 79, 104406 (2009)

12.45 – 13.00

Evaluation of the local Joule heating in nanocontact devices

S. Petit-Watelot [1], R.M. Otxoa [1], M. Manfrini [2], J. Kim [1], *T. Devolder* [1]
(1) Institut d'Electronique Fondamentale, Université Paris-Sud, 91405 Orsay, France, (2) Laboratorium voor Vaste-Stoffysica en Magnetism, K. U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

We present an experimental study coupled with thermal diffusive simulations in magnetic noncontact devices, to evaluate the local increase of temperature due to Joule heating where the magnetization dynamics take place. Since electronic transport and magnetic properties are temperature dependent, the evaluation of this parameter is a key issue for applications as RF oscillators.

We experimentally studied a 60 nm gold nanocontact taken on top of an extended spin-valve stack. We performed differential resistance measurements for different applied temperature and DC polarization current (II). We find a residual resistance $R_0 = 4.3 R_0 = 4.3$ Ω at 0 K and a differential resistance variation with $I^2 I^2$ due to local Joule heating of $0.030.03$ mΩ/mA², independent of the applied temperature. We interpret this result by the presence of an interfacial resistance between the nanocontact and the spin-valve stack, where the current density is maximum. From a previous study [1], we find an interfacial RA product about $2\,10^{-2} 2\,10^{-2}$ Ω.µm², which represents 60% of the residual resistance.

We performed thermal simulations taking into account this interfacial resistance, to access to the maximum local temperature due to joule heating: $\delta T_{NC} \delta T_{NC}$. At the same time, we used an original method based on the possibility to nucleate a vortex in such structure. It has already been demonstrated that the nucleation of the vortex implies a thermally activated process [2]. Studying the nucleation probability for different DC current and applied temperature allows extracting the local temperature where the vortex nucleation takes places, below the nanocontact. The interest of this method is that no assumption is required. We find a good agreement between simulations and this method: for a DC applied current $I = 48\ I = 48$ mA we find from simulation $\delta T_{NC} = 160\ \delta T_{NC} = 160$ K and from this method $\delta T_{NC} = 147\ \delta T_{NC} = 147$ K.

[1] R. Otxoa et al., physica status solidi (b), 248(7), 1615 (2011)
[2] T. Devolder, et al., IEEE Trans. Mag. 47(6), 1595 (2011)

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Otello Room

PEROVSKITES AND MULTIFERROICS
Chair: A. Bombardi

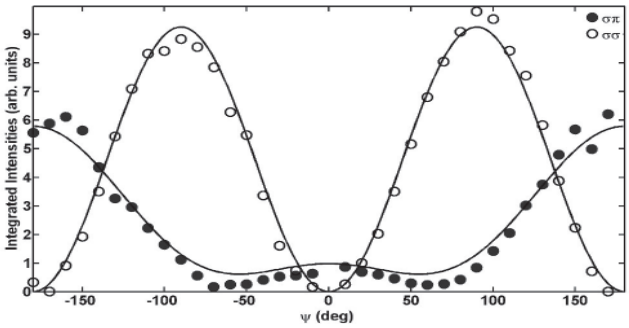
10.30 – 11.00

The magnetic structure of $GdMn_2O_5$ multiferroic determined by x-ray magnetic scattering *(invited)*

C. Vecchini [1], A. Bombardi [1], L. Chapon [2], P. Radaelli [3], N. Lee [4], S. Cheong [4]

(1) Diamond Light Source Ltd, UK, (2) Institut Laue-Langevin, Grenoble, France, (3) Oxford Physics, Clarendon Laboratory, Oxford, UK, (4) Rutgers Center for Emergent Materials and Department of Physics & Astronomy, Rutgers University, USA

Significant fraction of the current research on multiferroic materials is focused on magnetism driven ferroelectrics, where the presence of competing magnetic interactions induces a magnetic order with broken inversion symmetry that allows for spontaneous electric polarization to develop. The $REMn_2O_5$ (with RE=Ho, Tb, Bi, Y) multiferroics are improper ferroelectrics, which exibits a complex sequence of incommensurate (ICM)-commensurate (CM)-ICM transitions with propagation vectors close to the commensurate value k=(0.5,0,0.25). The CM phase coincides with the onset of ferroelectricity along the b crystallographic direction. The complex antiferromagnetic (AFM/CM) structures are always characterized by almost collinear Mn^{3+}-Mn^{4+} zig-zag chains running along the a-axis. The role of the rare earth with respect to polarization properties has been regarded as marginal due to the fact that the RE properly orders only below 10K where P is vanishing. Until now, the contribution of the x-ray magnetic scattering (XMS) to the multiferroic field has been limited to gain insights in structures determined using neutron diffraction. In this work, the full magnetic phase diagram of the $GdMn_2O_5$ multiferroic compound has been experimentally determined by single crystal hard XMS. Temperature dependence of magnetic Bragg reflections show an initial ICM ordering appearing at T=40K which condenses at T=33K in a CM, uncommon for RMn_2O_5 compounds, wave vector k=(0.5,0,0). Unlikely the other parent compounds, no further transitions have been detected. The CM and ICM phases of multiferroic $GdMn_2O_5$ were studied both off resonance and in resonant conditions at the Gd L3 edge. In the CM phase Gd^{3+} ions appear to order spontaneously at the same temperature as Mn ions. Azimuthal scans allowed for the first time the precise determination of the orientation and magnitude of the Gd^{3+} magnetic moments which surprisingly strongly contribute to the observed large total polarization.



Azimuthal dependence of the (2.5,3,0) reflection in non resonant condition at 6.4keV

11.00 – 11.15

Resonant Elastic X-ray Scattering investigation of Magneto-Electric phases in Multiferroic materials

C. Mazzoli [1], S. Partzsch [2], J. Hamann-Borrero [2], R.D. Johnson [3]

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Strongly Correlated Electron Systems are the solid state realm of electronic orderings and interactions. Depending on symmetries, intrinsic electronic degrees of freedom may compete; a high susceptibility of the electronic state is expected, resulting in rich phase diagrams and exotic phases. Among the latters, the ones presenting electric and magnetic sublattice polarizations are appealing, in particular Magneto-Electrics (MEs), which are the subset characterized by electric and magnetic interplay.
Over the last ten years the scientific community has produced a considerable effort to understand in details the mechanisms at play and the electronic states involved in MEs.
In this respect, Resonant Elastic X-ray Scattering (REXS) is a perfectly suited technique to access long range electronic ordering (charge, spin and orbital) in this class of materials.
I will present some recent REXS investigations of ME phases, ranging from manganites [1-2] to ferroborates [3]. Some interesting possibilities offered by alternative compounds will be discussed, based on recent structural and magnetic refinements.

[1] R. D. Johnson et al., Phys. Rev. B 78 (2008) 104407
[2] R. D. Johnson et al., Phys. Rev. B 83 (2011) 054438
[3] J.E. Hamann-Borrero et al, Phys. Rev. B 82 (2010) 094411 and S. Partzsch et al., in preparation

11.15 – 11.30

Giant Directional Optical Anisotropies at Spin-Wave Excitations of the Multiferroic $Ba_2CoGe_2O_7$

D. Szaller [1], S. Bordacs [2], I. Kezsmarki [1], L. Demko [3], H. Murakawa [2], T. Room [4], U. Nagel [4], H. Engelkamp [5], S. Miyahara [3], N. Furukawa [6], Y. Tokura [3]

(1) Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary, (2) Quantum-Phase Electronics Center, Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan, (3) Multiferroics Project, ERATO, Japan Science and Technology Agency (JST), Japan c/o The University of Tokyo, Tokyo 113-8656, Japan, (4) National Institute of Chemical Physics and Biophysics, 12618 Tallinn, Estonia, (5) High Field Magnet Laboratory, Institute for Molecules and Materials, Radboud University, 6525 ED Nijmegen, The Netherlands, (6) Department of Physics and Mathematics, Aoyama Gakuin University, 5-10-1 Fuchinobe, Chuo-ku, Sagamihara, Kanagawa 252-5258, Japan

In materials simultaneously breaking time-reversal and spatial inversion symmetries the strength of absorption for two counter-propagating light beams can be different irrespective of the polarization state of light [1]. This effect is termed as non-reciprocal directional dichroism and can be realized in the following two configurations.
The optical magnetoelectric effect (OME) arises in polar materials when the light propagates along or opposite to the cross product of the static magnetization and electric polarization (the so-called toroidal moment) of the material. The other directional effect, magneto-chiral dichroism (MChD) appears in chiral systems for light beams propagating parallel and antiparallel to an external magnetic field. Until recent experiments on multiferroic materials [2] these effects were generally found to be weak.

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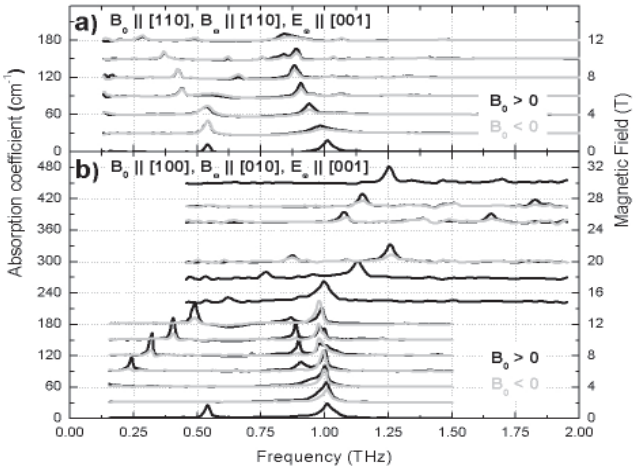
Both directional phenomena, OME and MChD, were investigated in the multiferroic phase of the non-centrosymmetric crystal $Ba_2CoGe_2O_7$ up to 12 and 30 Tesla fields, respectively. The spin-wave excitations of $Ba_2CoGe_2O_7$ located in the sub-THz spectral range show enormous directional dichroism close to 100 % for MChD. These spin resonances are both electric and magnetic dipole active (electromagnons) with matrix elements of comparable magnitude leading to strong magnetoelectric cross effects also responsible for the directional dichroism. The chirality necessary to the MChD is induced in $Ba_2CoGe_2O_7$ by the applied magnetic field and can be switched by a 90° rotation of the field [3].
Our results imply that due to the coupled spin-polarization dynamics significant directional dichroism can be present in a wide variety of multiferroic materials.

[1] W.F. Brown, Jr. S. Shtrikman, and D. Treves, J. Appl. Phys. **34**, 1233 (1963)
[2] M. Saito et al., Phys. Rev. Lett. **101**, 117402 (2008)
[3] S. Bordacs et al., to be published



a) Optical magnetoelectric effect and b) magneto-chiral dichroism in the spin excitations of $Ba_2CoGe_2O_7$

11.30 – 11.45
Crystal structure, magnetic ordering and physical properties of CMR and multiferroic manganites
A. Kurbakov [1]
(1) Petersburg Nuclear Physics Institute, 188300, Gatchina, Leningrad district, Russia

High-resolution neutron diffraction study of the temperature evolutions of the crystal and magnetic structures of the manganites with unique physical properties are presented. We construct the electronic, magnetic and structural phase diagram of colossal magnetoresistive hole-doped $Sm_{1-x}Sr_xMnO_3$ ($0.16 \le x \le 0.67$) perovskite manganites on the basis of their systematic studies by neutron powder diffraction and magnetic and transport measurements. It is shown that the actual pattern of the physical phenomena occurring in Sm–Sr manganites is significantly richer than it follows from macroscopic measurements. The tendency for the system under study to form ordered phase-separated states on crystallographic and, even to a greater extent, on a magnetic level is demonstrated.
Neutron diffraction study of the temperature evolutions of the crystal and magnetic structures of the complex multi-phase doped manganites-multiferroics on the example of $Yb_{1-x}Sr_xMnO_3$ ($x = 0.1, 0.4$) compounds are presented as well. The partial hole doping allows to pass a range of so-called "geometric" ferroelectrics $YMnO_3$-type to "magnetic" ferroelectrics $TbMnO_3$-type. The crystal structure of the investigated compounds corresponds a mixture of orthorhombic *Pbnm* (enclosing J-T Mn^{3+} ions) and hexagonal $P6_3cm$ (JT ions free) phases. Magnetic structure of hexagonal $P6_3cm$ phase represents canted-spin ordering of Mn magnetic moments in plane of *Γ2*-type. Mn ions form a well-separated triangular layers parallel to (*ab*) plane, with antiferromagnetic exchange interaction between the spins of the most nearest neighbors, which make Mn spin subsystem of low-dimensional and frustrated. In orthorhombic *Pbnm* phase with the *C*-type magnetic structure presumably is formed.
Finally it is demonstrated that the interpretation of physical processes in complex strongly correlated manganite systems based only on the results of macroscopic measurements (without using adequate structural data) can be insufficiently deep.

11.45 – 12.15
Disordered Multiferroics *(invited)*
W. Kleemann [1], P. Borisov [2], V.V. Shvartsman [3]
(1) Applied Physics, University Duisburg-Essen, 47048 Duisburg, Germany, (2) Department of Chemistry, University of Liverpool, L69 7ZD Liverpool, UK, (3) Institute for Materials Science, University Duisburg-Essen, 45141 Essen, Germany

Disordered multiferroic materials ('*type-III multiferroics*') escape the conventional schematics of *type-I* and *type-II* multiferroics, where two types of ferroic long-range order are expected to coexist under different interdependences and promise to attain a maximized bilinear (α or *EH*) *magnetoelectric* (ME) effect under special symmetry conditions. Nevertheless sizable higher order *ME* response occur also in disordered systems such as in the simultaneous *dipolar* and *spin glasses* ('*multiglass*') $Sr_{0.98}Mn_{0.02}TiO_3$ [1] and $K_{0.94}Mn_{0.03}TaO_3$, the *quantum paraelectric antiferromagnet* $EuTiO_3$ (ETO), the *spin cluster glass* (SG) and *antiferromagnetic* (AF) *relaxor ferroelectric* $PbFe_{0.5}Nb_{0.5}O_3$ (PFN, Fig. 1 [2]), and the *antiferroelectric antiferromagnetic dipole glass* $CuCr_{1-x}In_xP_2S_6$[3]. They have in common to show large quadratic magneto-capacitance effects, $\Delta\varepsilon \propto H^2$, which are related to dominating third-order E^2H^2 terms in their free energies, and do not require special symmetry conditions. The polarization controlled exchange coupling can achieve giant fluctuation-enhanced values in the vicinity of critical magnetic fields as observed *e.g.* on $EuTiO_3$. Exceptionally, even the first-order *EH*-type *ME* effect is observed whenever metastable homogeneous order parameters are induced by field cooling as in ETO or in the spin glass phase of the relaxor multiferroic PFN at $T < T_g = 10.6$ K.

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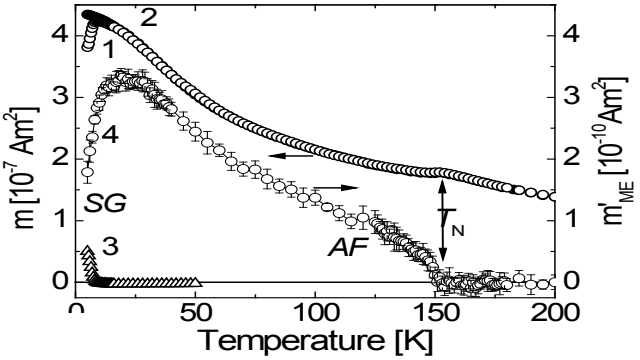


Magnetic and *ME* moments *m* and *m'*$_{ME}$ vs. *T* of PFN upon *ZFC*/*FH* (1, 4) and *FC* (2)/*ZFH* (3)

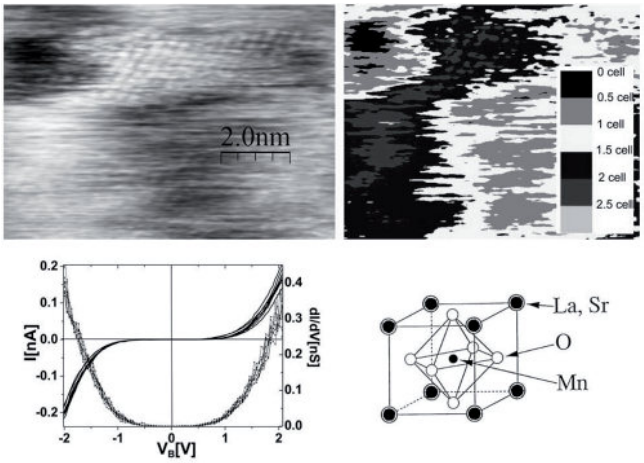
[1] V. V. Shvartsman, S. Bedanta, P. Borisov, W. Kleemann, A. Tkach, and P. M. Vilarinho. Phys. Rev. Lett. 101, 165704 (2008)
[2] W. Kleemann, V. V. Shvartsman, P. Borisov, and A. Kania, Phys. Rev. Lett.105, 257202 (2010)
[3] W. Kleemann, V. V. Shvartsman, P. Borisov, J. Banys, and Yu. M. Vysochanskii, Phys. Rev. B 84, 094411 (2011)

12.15 – 12.30
Half Unit Cell steps: Special Defects at the surface of ultrathin manganite films

A. Gambardella [1], P. Graziosi [1], I. Bergenti [1], M. Prezioso [1], F. Biscarini [1], A.V. Dediu [1]
(1) Consiglio Nazionale delle Ricerche - Istituto per lo Studio dei Materiali Nanostrutturati (CNR-ISMN) via P. Gobetti 101, 40129 Bologna, Italy

Nanoscale investigation of hole-doped manganites is strongly motivated by exotic properties arising from short scale effects in these highly correlated systems [1]. The recent development of the deposition techniques and the achieved control in the fabrication of surfaces and interfaces [2], allow nowadays to obtain high quality samples featuring intriguing low dimensionality physics.
Ultrathin $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) films grown by Channel Spark Ablation (CSA) were studied by Scanning Tunnelling Microscopy and Spectroscopy techniques at atomic scales. We show that sample surfaces are atomically flat up to several square microns large areas, while constituted of small grains, a few tens of nanometers large. Spectroscopic behaviour detected across the film surfaces has resulted as quite homogeneous. Noteworthy, the surface include regions where atomic resolution is clearly visible. These regions expand about 10 nm square and are characterized by half unit cell steps featuring in addition a distinct distortion with respect to normal LSMO topology.
It is well accepted that atomic contrast visualization by STM is strongly impeded on manganite surfaces by their metallicity and hence screening effects [3]. Previously detected visualizations were explained via trapped polarons [3] providing a local relieve of the charge surface density, or just by the vicinity to a defect leading to similar relieve. Our data indicate a different and simpler explanation, limiting the atomic resolution only to areas characterized by half unit cell growth. These regions indeed constitute a special type of defects, in which the deviation from standard unit cell is naturally explained by stoichiometry issues.

[1] E. Dagotto, T. Hotta and A. Moreo, Phys. Rep. 344, Issue 1-3, p. 1-153 (2001)
[2] P.Graziosi et al., Thin Solid Films (2012), submitted
[3] H. M. RØnnow et al., Nature (London) 440, 1025 (2006)



Half termination of an atomically resolved region and homogenous spectra

12.30 – 12.45
Metal-insulator transition in $Pr_{0.5}Ca_{0.5}CoO_3$ and related cobaltites

J. Hejtmánek [1], Z. Jirák [1], K. Knížek [1], K. Nitta [2], T. Naito [3], H. Fujishiro [3]
(1) Fyzikální ústav AV ČR, v. v. i. , dpt. of Magnetics and Superconductors, Cukrovarnická 10/112 162 00 Praha 6, Czech Republic, (2) Japan Synchrotron Radiation Research Institute, Sayo, Hyogo 679-5198, Japanoka 020-8551, Japan, (3) Faculty of Engineering, Iwate University, 4-3-5 Ueda, Morioka 020-8551, Japan

We have performed an extensive investigation (magnetic, electric, and thermal properties, neutron diffraction and X-ray absorption spectroscopy) of $Pr_{0.5}Ca_{0.5}CoO_3$ and $(Pr_{1-y}Y_y)_{0.7}Ca_{0.3}CoO_3$ (y = 0.05 - 0.15) perovskites, in which a peculiar metal-insulator (M-I) transition, accompanied with a pronounced structural and magnetic anomaly, occurs at 76 K and 40 - 132 K, respectively [1]. Though the transition bears characteristics of common spin-state crossover on cobalt sites, it appears that inherent part of the process is a significant valence shift from Co^{3+}/Co^{4+} toward Co^{3+}, enabled by closeness in energy of the Pr^{4+} and Pr^{3+} states. This scenario was originally suggested theoretically using GGA+U electronic structure calculations [2] and was supported later experimentally, in particular by observation of Schottky peak in the low temperature specific heat [3]. The peak, related to Zeeman splitting of the ground-state doublet of Kramers ions Pr^{4+}, proves the existence of internal magnetic field acting on Pr sites, even in the absence of applied field. However, no long-range magnetic order of the Co sublattice is detected by neutron diffraction down to 0.2 K. In

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new experiments, the M-I transition has been inspected directly using the XANES data of Pr L_3-edge an Co K-edge. The spectra clearly indicate the presence of Pr^{4+} ions at low temperatures and the change of Co spin state/valency on crossing the M-I transition. The study definitively confirms that the electron transfer between Pr^{3+} and Co^{3+}/Co^{4+} is decisive factor for the occurrence of the M-I transition.

[1] S. Tsubouchi, T. Kyômen, M. Itoh, *et al.*, Phys. Rev. B 66, 052418 (2002).
[2] K. Knížek, J. Hejtmánek, P. Novák, and Z. Jirák, Phys. Rev. B 81, 155113 (2010).
[3] J. Hejtmánek, E. Šantavá, K. Knížek, *et al.*, Phys. Rev. B 82, 165107 (2010

12.45 – 13.00
Non-linear conductivity of resistive oxides: facts and artifacts
B. Fisher [1], J. Genossar [1], L. Patlagan [1], G.M. Reisner [1]
(1) Physics Department, Technion, Haifa 32000, Israel

Our attention was drawn to this field by reports on striking non-linear conductivity effects induced by surprisingly low electric-fields in poly- and single-crystals of charge-ordered manganites, nickelates and one multiferroic. These were identified variously as dielectric breakdown, charge-order collapse, depinning of charge-density-waves or other electronic effects. Here we review our results on pulsed and d.c. I-V measurements on many resistive oxides, including some systems mentioned above. Our results show that non-linear conductivity of electronic origin at low electric-fields is a rare phenomenon. A recent example of such a rare case is discussed.[1] However, in the majority of cases[1,2] we detected no deviations from linearity in pulsed I-V characteristics under fields up to E about 500 V/cm. Current-controlled negative-differential-resistance (ndr) and hysteresis were found in d.c. measurements at fields that decrease with increasing temperatures. It is easily shown that such behavior is typical of Joule heating effects in materials with negative-temperature-coefficient of resistivity.[3] For the d.c. I-V characteristics of our samples exhibiting ndr, we found a rather unexpected correlation between $\rho(E_m)$ - the resistivity at maximum field (at the onset of ndr) and ρ_o - the resistivity at zero field. The data points for $\rho(E_m)$ versus ρ_o obtained from the d.c. I-V characteristics of 13 samples (8 manganites, 4 nickelates and one multiferroic) at various ambient temperatures, plotted together on a log-log scale, follow closely a linear dependence with slope one that spans over more than five orders of magnitude. This dependence was reproduced by calculations for several simple models.

[1]B. Fisher et al, J. Appl. Phys. **111**, 023712 (2012)
[2]B. Fisher et al, J. Appl. Phys. **109**, 84111 (2011) and references therein
[3]D. M. Kroll, Phys. Rev. B **9**, 1669 (1974); S. Mercone et al, J. Appl. Phys. **98**, 23911 (2005)

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10.30 – 11.00
Frustration in heavy fermions systems: local versus intersite screening *(invited)*
C. Lacroix [1]
(1) Institut Néel, CNRS et Université Joseph Fourier,BP 166, F-38042 Grenoble Cedex 9, France

In itinerant systems, the consequences of geometrical frustration are different from localized spin systems, but they have been shown to be present in many different systems [1]. Among them, several heavy fermions compounds exhibit unusual behavior due to frustration: we have shown that frustration may lead to an ordered ground state with magnetic and non-magnetic sites, as observed experimentally in CePdAl for example. More recently, we have studied the competition between two different types of non-magnetic ground states in these systems where Kondo effect and intersite exchange are present: If Kondo effect dominates, the ground state is a collective Kondo state in which screening is local; on the other hand if Kondo effect is small, the ground state can be a spin liquid due to frustration of intersite interactions. We have studied a model which shows explicitly this competition on the Shastry-Sutherland lattice [2]; this model can be applied to some Yb compounds such as Yb_2Pd_2Sn which have a structure topologically equivalent to a Shastry-Sutherland lattice. Extension of this model to the Kagome structure could apply to compounds with kagome-like crystal structure (YbAgGe and similar compounds). We propose that, even in compounds where geometrical frustration is not present, like URu_2Si_2 [3], such a competition between local and intersite screening has to be taken into account.

[1] C. Lacroix, J. Phys. Soc. Jpn, 79, 011008 (2010).
[2] B.H. Bernhard, B. Coqblin and C. Lacroix, Phys. Rev. B 83, 214427 (2011)
[3 C. Pépin, M.R. Norman, S. Burdin and A. Ferraz, Phys. Rev Lett 106, 106601 (2011)

11.00 - 11.15
Dynamic gapless spin liquid state on an fcc lattice in Ba_2YMoO_6.
M. De Vries [1], J. Piatek [2], H.M. Rønnow [2], J. Bos [3]
(1) School of Chemistry, The University of Edinburgh, Edinburgh EH9 3JJ, UK, (2) Laboratory for Quantum Magnetism, Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, (3) Department of Chemistry - EPS, Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom

The long search for geometrically frustrated magnetic insulators with spin-liquid ground states has yielded a number of compounds with quantum-disorderd magnetic ground states with strong quantum fluctuations. Arguably, the best characterised examples are the kagome systems $SrCr_8Ga_4O_{19}$,

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$ZnCu_3(OH)_6Cl_2$ (herbertsmithite) and the pyrochlore $Tb_2Ti_2O_7$. However, all known contenders exhibit imperfections that complicate a straightforward interpretation of the available experimental data. Here we show, using muon spin relaxation spectroscopy and ac magnetic susceptibility, that for the B-site ordered double perovskite Ba_2YMoO_6 a particularly clear-cut case can be made for a dynamical, gapless spin-liquid state as the ground state of a disorder-free geometrically frustrated magnet.

The B-site Y^{3+} and Mo^{5+} ($4d^1$ ^{2}T) cations order in a rocksalt structure, giving rise to antiferromagnetically coupled S = ½ spins on an fcc lattice. The spin liquid state in this system is best described as a valence bond glass (VBG) [1,2]. This is a dynamical, out-of-equilibrium effective ground state that has been predicted to arise even in the absence of quenched disorder, due to kinetic constraints in the fcc antiferromagnet impeding equilibration to the true topologically-ordered spin-liquid ground state [2]. A signature of the VBG is a small fraction of (emergent) relatively isolated spins in a background of random spin-singlet valence bonds. We observe a glassy "freezing" of these residual unpaired spins. While this emergent spin-glass gives rise to an increased muon relaxation for less than half of the implanted muons, the dynamics in this fraction of "glassy" spins is still faster than in all other geometrically frustrated antiferromagnets, with the exception of herbertsmithite [3].

[1] M. A. de Vries, A. C. Mclaughlin, and J.-W. G. Bos, Phys. Rev. Lett. 104, 177202 (2010).
[2] C. Chamon, Phys. Rev. Lett. 94, 040402 (2005).
[3] P. Mendels *et al.*, Phys. Rev. Lett. **98**, 077204 (2007).

11.15 – 11.30

Quantum Spin Liquid Properties of $Ba_3CuSb_2O_9$

F. Pratt [1], P.J. Baker [1], S.J. Blundell [2], T. Lancaster [3], J.S. Moeller [2], D. Prabhakaran [2], C. Baines [4]
(1) ISIS Facility, OX11 0QX Didcot, UK, (2) Department of Physics, Oxford University, OX1 3PU Oxford, UK, (3) Centre for Materials Physics, University of Durham, DH1 3LE Durham, UK, (4) Paul Scherrer Institute, 5232 Villigen PSI, Switzerland

Muon spin relaxation (μSR) has proven to be an extremely sensitive experimental probe of the subtle properties of quantum spin liquid systems [1]. We report μSR studies of the S=1/2 triangular lattice system $Ba_3CuSb_2O_9$ [2] that show many similarities to the previous results on the molecular system κ-$(ET)_2Cu(CN)_3$ [1]. Transverse field (TF) measurements show field induced transitions (Fig.1) that are indicative of a state with a very small but finite magnetic energy gap at low applied fields. Further studies using longitudinal fields show properties ascribable to 2D diffusive spin excitations, as well as localised spin defects.

[1] F. L. Pratt et al, Nature 471, 612 (2011)
[2] H. D. Zhou et al, Phys. Rev. Lett. 106, 147204 (2011)

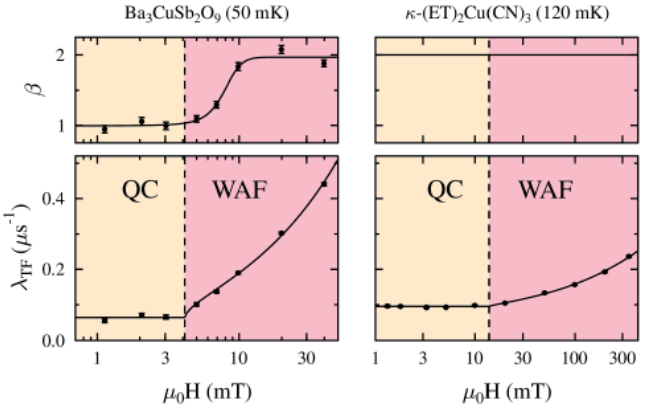

Fig.1. Field-induced magnetic transition revealed from TF μSR line width. The transition observed in $Ba_3CuSb_2O_9$ mirrors that previously seen in κ-$(ET)_2Cu(CN)_3$ [1].

11.30 – 11.45

Study of the correlation length of the two-dimensional frustrated square-lattice compound $BaCdVO(PO_4)_2$

B. Roy [1], Y. Furukawa [1], R. Nath [1], D.C. Johnston [1], *L. Bossoni* [2], P. Carretta [3]
(1) Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA, (2) Università di Roma TRE-CNISM, (3) Università degli Studi di Pavia

Geometrical frustration is the source of a variety of fascinating phenomena. Recently, thanks to the discovery of iron-pnictides, much attention has been given to the study of the frustrated S = ½ square lattice (FSL)[1], also known as the $J1$- $J2$ model, where the frustration is caused by a next-nearest-neighbor exchange interaction $J2$, along the diagonal of the square, competing with the nearest-neighbor exchange interaction $J1$, along the side of the square. The vanadium phosphate $BaCdVO(PO_4)_2$ is considered a prototype of the J_1-J_2 model. The compound has a layered crystal structure with square-like arrangements of V^{4+} ($3d^1$, S = ½) cations. The exchange interactions J_1 and J_2 between V^{4+} spins were reported to be J_1 = − 3.6 K (ferromagnetic) and J_2 = 3.2 K (antiferromagnetic) from magnetic susceptibility and magnetization measurements. A long-range antiferromagnetic (AFM) ordering at T ~ 1 K is reported from specific heat, magnetization [1,2] and muon spin resonance measurements [3]. Based on the ratio J_2/J_1 ~ − 0.9, the system is considered close to the phase boundary between the collinear antiferromagnet (CAF) and the gapless nematic phase. We report ^{31}P nuclear magnetic resonance (NMR) measurements, from which it is possible to extract the 2D correlation length, by means of a one-to-one correspondence. In the light of previous μSR data, it is possible to obtain a clearer picture of the correlations taking place before the CAF order is established. The correlation length versus the temperature seems to show a 1D behaviour, in agreement with the expected nematic critical region.

[1] L. Bossoni et *al.*, Phys. Rev. B **83**, 014412 (2011)
[2] R. Nath et al., Phys. Rev. B **78,** 064422 (2008)
[3] A. A. Tsirlin et al., Phys. Rev. B **80,** (2009)
[4] P. Carretta et *al.*, Phys. Rev. B **79**, 132407 224432 (2009)

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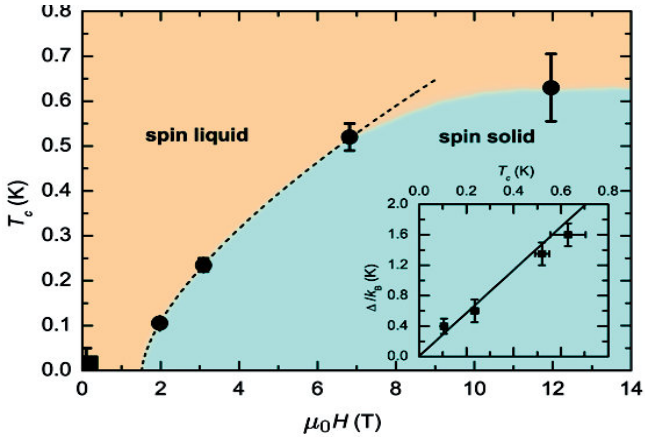
11.45 – 12.15
Spin liquid state in the quantum kagome antiferromagnets *(invited)*
F. Bert [1], M. Jeong [1], J. Quilliam [1], P. Mendels [1]
(1) Laboratoire de Physique des Solides, Université Paris Sud 11, UMR CNRS 8502, F-91405 Orsay, France

The frustration of antiferromagnetic interactions on the loosely connected kagome lattice associated to the enhancement of quantum fluctuations for S=1/2 spins was acknowledged long ago as a key combination to stabilize novel ground states of magnetic matter of the spin-liquid type. Only in 2005, a model quantum kagome compound, the Herbersmithite $ZnCu_3(OH)_6Cl_2$, could be synthesized. Among the salient achievements [1] in the study of this material are the absence of any kind of spin freezing down to at least 50 mK through μSR experiments, a featureless excitation spectrum and a gapless susceptibility evidenced through ^{17}O NMR[1].
By extending further the ^{17}O NMR down to 45 mK and in magnetic fields ranging from 2 to 12T, we uncovered an instability toward a spin-solid phase at sub-kelvin temperature induced by the applied magnetic field [2]. The latter phase shows largely suppressed moments $<0.1\mu_B$ and gapped excitations. We discuss this finding in light of the perturbative Dzyaloshinskii-Moriya interaction which was theoretically proposed to sustain a quantum critical regime. To address further the question of the criticality and stability of the kagome Heisenberg model, we will compare to the case of Vesignieite, $BaCu_3V_2O_8(OH)_2$, one of the very few new recent candidate kagome materials. While Dzyaloshinskii-Moriya interaction is relevant in both compounds, we propose that it is large enough in Vesignieite to drive the system through a quantum critical point [3] and towards a magnetic phase.

[1] For a review, see P. Mendels and F.Bert, *J. Phys. Soc. Jpn* 1, 011001 (2010)
[2] M .Jeong *et al*, Phys. Rev. Lett. 107, 237201 (2011)
[3] J.A. Quilliam *et al*, Phys. Rev. B 84, 180401(R) (2011)



H-T phase diagram of the quantum kagome Herbertsmithite

12.15 – 12.30
Magnetic interactions in the quasi 2D triangular Heisenberg antiferromagnets of the series alpha-ACr_2O_4 (A=Ca, Sr, Ba)
V. Hardy [1], C. Martin [2], F. Damay [3], G. André [3]
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We carried out a comparative study of three compounds of the series α-ACr_2O_4 (A = Ca, Sr, Ba), a family of layered oxides whose structure consists of sheets of edge sharing CrO_6 octahedra separated by A^{2+} cations.
From a magnetic viewpoint, these compounds can be classified as quasi 2D triangular Heisenberg antiferromagnets (2DTHAF), involving S=3/2 spins associated to Cr^{3+}.
A peculiarity of the α-ACr_2O_4 family is a sizeable distortion in the triangular topology of the spin layers. It turns out that this departure from the ideal triangular configuration can be progressively decreased by increasing the size of A^{2+}, while both the intraplane and interplane spacings are increased.
Neutron diffraction showed that the three compounds (A=Ca, Sr and Ba) exhibit the same type of incommensurate helical magnetic structure, a feature indicating the persistence of an effect of geometrical frustration over the whole series.
On the basis of magnetization and heat capacity measurements, the variations of three basic quantities (antiferromagnetic transition T_N, intraplane coupling J, and interplane coupling J') have been determined. While the evolution of J can be well accounted for on the basis of usual models, the variations of T_N and J' within this α-ACr_2O_4 series are more puzzling.
The results are discussed by taking into account not only the mean values of the intraplane and interplane distances between nearest-neighbouring spins, but also the degree of distortion from the triangular arrangement and the presence of a small easy-axis anisotropy of magnetocrystalline origin.
Are included in our analysis three other families of compounds known to be "reference" systems for 2D triangular Heisenberg antiferromagnets with S=3/2, i.e., the delafossites $MCrO_2$ (M=Cu, Ag, Pd), the ordered rock-salt structures $ACrO_2$ (A=Li, Na) and the vanadium halides VX_2 (X=Cl, Br).

12.30 – 12.45
Influence of frustration, disorder and high magnetic fields in a S = 1/2 spin ladder
T. Shiroka [1], F. Casola [1], S. Wang [2], C. Rüegg [3], H. Rønnow [2], M. Grbic [4], M. Horvatic [4], S. Krämer [4], S. Mukhopadhyay [4], C. Berthier [4], H. Ott [1], J. Mesot [3]
(1) Laboratorium für Festkörperphysik, ETH Hönggerberg, CH-8093 Zürich, Switzerland, (2) Laboratory for Quantum Magnetism, EPFL CH-1015 Lausanne, Switzerland, (3) Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland, (4) LNCMI - CNRS (UPR3228), UJF, UPS and INSA, BP 166, 38042 Grenoble Cedex 9, France

Characterized by a strong spatial confinement and by enhanced quantum fluctuations, low-dimensional systems represent unique laboratories for advancing our understanding of strongly-correlated electron systems [1]. In $BiCu_2PO_6$, a well-known model compound for studying the effects of frustration in spin ladders, the substitution of Cu with Zn induces non-magnetic defects and

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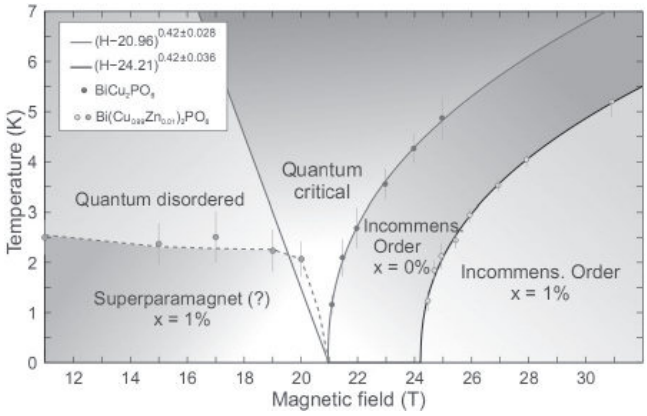
DISORDERED AND FRUSTRATED MAGNETIC SYSTEMS
Chair: G. Amoretti

corresponding local magnetization clouds [2]. Maps of *H-T* phase diagrams were obtained from data of low-temperature ^{31}P NMR studies in magnetic fields between 11 and 32 T on single crystals of pure, $x = 0$, and $x = 0.01$ doped samples.
In the pure case experiments show the onset of a field-induced magnetic ordering (FIO) at $H_c = 21$ T, with a phase boundary $T_c \sim (H–H_c)^{0.42}$. In the doped ($x = 0.01$) case, the site disorder mimics tunable ladder leg lengths. Here the low-temperature, *defect-induced* ordering (IIO) is first suppressed by a moderate field of 4 T. Successively, a *field-induced* order sets in below an analogous phase boundary as for $x = 0$, but with $H_c = 24.2$ T. Results of a low-field study of hyperfine interactions and the analysis of NMR line shapes in the ordered regime were used to identify details of the ordered structure.

[1] T. Giamarchi, Quantum Physics in One Dimension (OUP, Oxford, 2004)
[2] F. Casola, T. Shiroka, S. Wang, K. Conder, E. Pomjakushina, J. Mesot, and H.-R. Ott, Phys. Rev. Lett. 105, 067203 (2010)



Phase diagram for the pure and the Zn-doped $Bi(Cu_{1-x}Zn_x)_2PO_6$ as from T_1^{-1} NMR data

12.45 – 13.00
Soliton-magnon crossover in spin-1/2 Heisenberg AFM chains
S.A. Zvyagin [1], M. Ozerov [1], J. Wosnitza [1], E. Čižmár [2], R. Feyerherm [3], S. Manmana [4], F. Mila [5]
(1) Dresden High Magnetic Field Laboratory, HZ Dresden-Rossendorf, 01314 Dresden, Germany, (2) Centre of Low Temperature Physics, P.J. Šafárik University, SK-041 54 Košice, Slovakia, (3) HZ Berlin für Materialien und Energie, 14109 Berlin, Germany, (4) JILA, Dept. of Physics, University of Colorado, Boulder, CO 80309, USA and Inst. of Theor. Physics, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland, (5) Inst. of Theor. Physics, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Copper pyrimidine dinitrate ($[PM\text{-}Cu(NO_3)_2(H_2O)_2]_n$, PM = pyrimidine) is a spin-1/2 antiferromagnetic chain material with alternating *g*-tensor and Dzyaloshinskii-Moriya interactions, whose spin dynamics can be described using the effective sine-Gordon model. Due to the presense of alternating staggered magnetization, this material exhibits a field-induced spin gap, formed by first breather. Here, we report on electron spin resonance (ESR) studies of this material in magnetic fields up to 64 T. In particular, a minimum of the gap in the vicinity of the saturation field $H_{sat} = 48.5$ T associated with a transition from the quantum disordered sine-Gordon (with soliton-breather elementary excitations in the magnetic excitation spectrum) to a spin-polarized state (with excitation spectrum formed by magnons) has been observed. This interpretation is fully confirmed by the quantitative agreement over the entire field range of the experimental data with the DMRG calculations for spin-1/2 Heisenberg chain with a staggered transverse field [1]. Such a behavior appears to be a general feature of the high-field excitation spectrum of quantum spin-1/2 chain systems with alternating *g*-tensor and/or Dzyaloshonskii-Moriya interactions.
This work was partly supported by DFG and EuroMagNET II.
[1] S.A. Zvyagin, E. Čizmár, M. Ozerov, J. Wosnitza, R. Feyerherm, S.R. Manmana, and F. Mila, Phys. Rev. B **83**(R) (2011) 060409.

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Rigoletto Room

SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

Chair: M. Coisson

10.30 – 11.00

Multiscale modelling of classical losses in granular soft magnetic materials *(invited)*

A. Manzin [1], O. Bottauscio [1], M. Chiampi [2]
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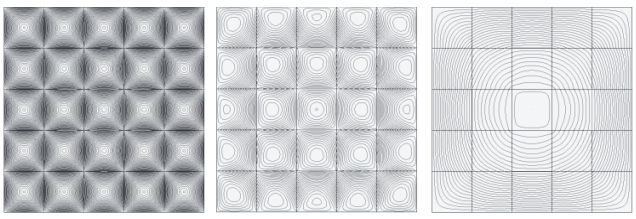
Granular soft magnetic materials are widely adopted in many engineering applications to reduce eddy current losses produced by harmonics and high frequency working conditions [1]. Soft ferrites are employed in power electronics for transformers and inductor cores, while soft magnetic composites are promising for high speed electrical machines. They both present a granular microstructure with magnetic grains separated by insulating layers, resulting in a high macroscopic resistivity that enables the attenuation of electromagnetic induction effects. However, the increase of frequency can lead to macroscopic eddy current circulation with a consequent loss increment affecting device performances.
The prediction of classical losses in a wide spectrum of working conditions is a fundamental topic in the research field on granular magnetic materials. An accurate modeling approach should be able to consider the interaction between macroscopic and microscopic scales, determined by sample and grain sizes, respectively. The use of standard numerical techniques is generally not feasible, due to the huge number of involved unknowns. This criticality can be faced by adopting multiscale techniques, which enable the problem decomposition into different spatial scales, preserving the reciprocal influence.
We present a panorama of multiscale numerical techniques [2], e.g. the Variational Multiscale Method (VMS) and an homogenization approach with second order correctors, focusing on the study of eddy current phenomena in granular magnetic materials. Advantages and drawbacks of the different techniques are discussed, giving hints for the accurate prediction of energy losses of ferrites and composite materials in a wide frequency range.



Current density isolevel lines, calculated with VMS, for a sample with a limited number of grains. The eddy current pattern is confined into each grain at low frequencies, distributing over the entire cross section at high frequencies.

[1] H. Shokrollahi and K. Janghorban, J. Mater. Process. Tech. 189, 1-12 (2007)
[2] W. E et al., Commun. Comput. Phys. 2, 367-450 (2007)

11.00 – 11.15

RF Shielding Effectiveness of CoZrNb film to countermeasure radiated emission on LTE-class RFIC

M. Yamaguchi [1], Y. Endo [1], R. Okuta [1], M. Nagata [2], N. Azuma [2], S. Takahashi [3], K. Hori [4], M. Murakami [4]
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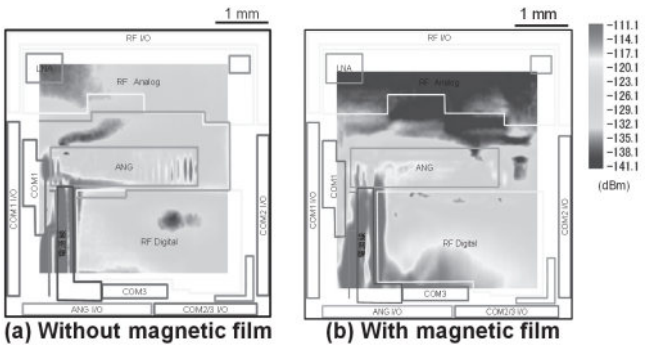
RF magnetic shielding effectiveness of $Co_{85}Zr_3Nb_{12}$ thin-film was studied on a LTE[1]-class RF frontend circuit for cell phone handset, in order to countermeasure digital-to-analogue noise attack problem. The CoZrNb film is with Ms=1.0T, Hk=1.0 kA/m, electric resistivity $\rho=1.2\times10^{-8}\Omega$m, FMR frequency f_r=1.2GHz, and integrated by RF sputtering onto the surface of a test element group chip (TEG chip, hereafter) developed for this particular study.
The TEG chip receives the analogue LTE signal from either of antenna or oscillator (equivalent signal as antenna) and outputs analogue I/Q signal. The I/Q signal will be subjected to analogue-to-digital converter and digital demodulator in the case of real RFIC chip. The major RF analogue circuit on the TEG chip consists of low noise amplifiers (LNA), mixer, voltage controlled oscillator, gain programmable amplifier, and low pass filter, and implemented in CMOS 65nm technology[2]. Arbitrary noise generator(ANG) and on-chip substrate voltage monitors(OCM) are also implemented in the TEG chip. Details of the circuit design and performance will be published elsewhere.
The figure (a) shows magnetic near field image at 2158MHz, which is in the LTE Band 1(2110-2170MHz, for downlink), measured by a planar shielded-loop type magnetic field probe[3] having 60μm-square coil we newly developed for this particular measurements. It is clear that the radiated emission from the chip is weak on the RF analogue circuits located at the top quarter area of the TEG chip, and lather high on the digital circuits(RF Digital and ANG) . The 1μm-thick CoZrNb film well suppressed the radiated emission by 15dB at most, as shown by the figure (b).
Supported in part by the Radio Use, MIC, Japan.

[1]3GPP, TS 36.101 V8.14.0 (2011).
[2]M. Yamaguchi, et al, IEEE Trans. Magn., **43**, 2370 (2007)
[3]S. Tanaka, IC chip level low noise technology workshop, CEWS-1-5, (2011, in Japanese)



Magnetic near field image w/ and w/o CoZrNb film at 2158MHz (LTE Band 1)

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SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

Chair: M. Coisson

11.15 – 11.30

A Soft Magnetic Material for Power Supply System of High Energy Physics Experiments

S. Baccaro [1], P. Cova [2], N. Delmonte [2], *E. Ghisolfi* [3], A. Lanza [4]
(1) UTT-MATT Casaccia Res. Centre, ENEA, via Anguillarese 301, 00060 Santa Maria di Galeria (Rome), Italy, (2) Dipartimento di Ingegneria dell'Informazione, University of Parma, viale G.P. Usberti 181/A, 43124 Parma, Italy, (3) FN SpA Nuove Tecnologie e Servizi Avanzati, Strada per Crescentino 41, 13040 Saluggia (VC), Italy, (4) Istituto Nazionale di Fisica Nucleare- Sezione di Pavia, via A. Bassi 6, 27100 Pavia, Italy

Most of the high energy physics experiments require their detectors to be embedded in a high intensity magnetic field. In particular the biggest of them, ATLAS [1], running in the CERN Large Hadron Collider (LHC) particle accelerator, generates a field of 2 T by means of a gigantic solenoidal magnet working in open air. Its future phase 2 upgrade plans to move the DC/DC power supplies from the present positions on the external balconies directly on the detectors, where the field is of the order of 1 T. This presentation describes the production and tests of samples made of special magnetic material for building cores for inductors suitable to work in such an environment.
Starting from an iron-silicon [2] powder, at FN plant a plastic forming process, based on powder extrusion, injection moulding and sintering, was developed. To get the best compromise between the forming process requirements (good coupling among the metallic powder and the organic components to assure the right mouldability) and the debinding and sintering conditions, several mixtures (with different percentages and kind of organic additives) were experimented.
In order to make the magnetic characterization of the material as specified in IEC 60404-04 using a DC permeameter, a proper mould was designed and realized to get torous-shaped prototypes through powder injection moulding.
To get the final density and the magnetic characteristics, a sintering process is necessary; inside this research activity an alternative way to flush out the binder and to sinter using microwaves was investigated.
The results of the physical-microstructural and magnetic characterization performed on the first prototypes (Fig. 1) made will be shown.

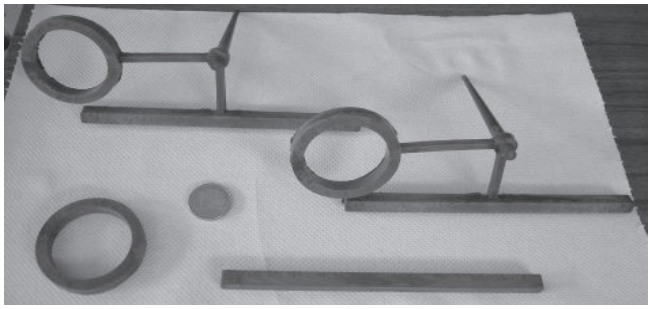

Fig. 1. Early prototypes fabricated

[1] The ATLAS Collaboration, Journ. Of Instr. 3 S08003 (2008)
[2] H. Gavrila and V. Ionita, J. Of Optoelect. Adv. Mat. 4, 173-192 (2002)

11.30 – 11.45

Local structure of spinel-type nanocrystals of ferrofluids: non equilibrium cation distributions

J. Depeyrot [1], J. A. Gomes [1], F.H. Martins [1], F.L. O.Paula [1], G. M. Azevedo [2], F.A. Tourinho [1], R. Aquino [1], J. Mestnik Filho [3], A. Abou Hassan [4], R. Perzynski [4]
(1) Complex Fluids Group, Universidade de Brasília, Brasília, Brazil, (2) Universidade Federal do Rio Grande do Sul, Instituto de Física, Porto Alegre, Brazil, (3) Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo, Brazil, (4) Laboratoire PECSA, Université Pierre et Marie Curie, Paris, France

Magnetic nanocolloids constitute a very attractive and promising class of nanomaterials as they may be confined, displaced, deformed and controlled by an external magnetic field. These unique and striking features make them suited for a quite large number of applications, from engineering to biomedicals. We are currently working on the synthesis of magnetic nanoparticles based on composites of metal oxides (ferrites) and on their dispersion in acidic and neutral media or in more complex systems like clays or liquid crystals. A core-shell strategy has been developed to protect the stoichiometric ferrite nanocore by a maghemite shell [1]. In this work, we explore the local structure of magnetic nanocrystals based on Zn-, Ni- and Mn-ferrite core. Measurements of neutron diffraction realized at Laboratoire Léon Brillouin (LLB-Saclay/France), of X-ray absorption spectroscopy (XAS) and X-ray Diffraction performed at the Brazilian Synchrotron Light Laboratory (LNLS) are undertaken to investigate the cations distribution, their valence state and coordination. The combined analysis suggest in all samples, a non equilibrium cation distribution among interstitial sites of the spinel-type nanocrystals structure. As an example, this cation inversion is responsible for the observed enhancement of the magnetic response of Zn-ferrite nanoparticles [2]. In Mn-ferrite nanoparticles, Rietveld refinement of neutron diffraction patterns shows that more than 50 % of Mn ions are located at octahedral sites. Moreover, the oxidation state of the manganese ions is 3+, a result different from bulk ferrite. Then, the presence of a shoulder before the main absorption peak may be attributed to Mn^{3+} ions in octahedral environment and the expected Jahn-Teller distortions.
Acknowledgment: CNPq, CAPES-COFECUB, FAP/DF.

[1] J. A. Gomes et al, J. Phys. Chem C 112, 6220 (2008).
[2] J. A. Gomes et al, J. Magn. Magn. Mater. 323, 1203 (2011).

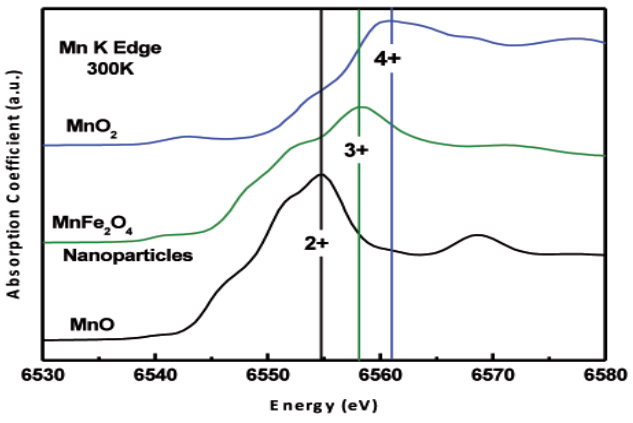

Fig. 1: XANES spectra and valence state of Mn ions.

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SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

Chair: M. Coisson

11.45 – 12.00

$ZnFe_2O_4$/Fe soft magnetic nanocomposite powders obtained by mechanical milling

I. Chicinas [1], T.F. Marinca [1], O. Isnard [2], V. Pop [3], F. Popa [1], B.V. Neamtu [1]

(1) Department of Materials Science and Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, 400641 Cluj-Napoca, Romania, (2) Institut Néel, CNRS / University J. Fourier, BP166, 38042 Grenoble, Cédex 9, France, (3) Faculty of Physics, Babes-Bolyai University, 1 Kogălniceanu, 400084 Cluj-Napoca, Romania

$ZnFe_2O_4$/α-Fe nanocomposite was synthesized by high energy mechanical milling technique using as starting materials nanocrystalline zinc ferrite ($ZnFe_2O_4$) obtained by reactive milling and commercial α-Fe powders. The magnetisation of the nanocomposite $ZnFe_2O_4$/Fe powder is smaller than the magnetisation of the ($ZnFe_2O_4$+Fe) un-milled mixture. The magnetisation decrease is attributed to the structural changes and to the magnetic disorder induced by milling process in the nanocomposite phases on the one hand and on the other hand to the magnetic coupling of the nanocomposite phases. The magnetic coupling was found, from magnetic measurements, to be antiparallel one between the B magnetic sublattice (octahedral sites) of zinc ferrite and iron. The increased coercive field and remanence suggest also the magnetic coupling between the nanocomposite phases. The FC and ZFC measurements revealed that the magnetic coupling between the $ZnFe_2O_4$ and Fe nanocomposite phases is of exchange-bias type. The hysteresis loop recorded in the FC mode is shifted to the negative values of H, the exchange-bias field is $H_E = 2$ mT. A decrease of the measurement temperature induces an increase of the magnetisation of the nanocomposite as well as modifications of the coercivity and remanence. The spontaneous magnetization at 3 K is 40 % larger than the one recorded at 300 K and 265 % larger than the one recorded at 550 K. This behaviour is associated with the changes of the zinc ferrite spinel magnetisation. By increasing the measurement temperature, the magnetic interaction in $ZnFe_2O_4$ is weaker. Also, it is assumed that a partial cations redistribution occurs at 550 K in the spinel structure. The electrical resistivity of the nanocomposite powder is larger than 10^7 Ω·cm and suggests potential applications of the nanocomposite material at high frequencies.

12.00 – 12.15

Formation of Metastable bcc Co, Ni, and NiFe Thin Films on GaAs(100) Substrates and Phase Transformation from bcc to fcc

M. Ohtake [1], M. Futamoto [1], N. Inaba [2]

(1) Faculty of Science and Engineering, Chuo University, 112-8551, Japan, (2) Department of Electrical and Electronic Engineering, Yamagata University, 992-8510, Japan

3*d* ferromagnetic transition metal thin films with metastable bcc structure have attracted much attention to MTJ applications. Metastable bcc-Co and bcc-Ni films have been prepared on GaAs(100) substrates [1,2]. However, the metastable structure is reported to transform into stable structure with increasing the film thickness. There are very few works on the detailed structure analysis. In the present study, Co, Ni, and $Ni_{80}Fe_{20}$ (at. %) films were deposited on GaAs(100) substrates at RT by UHV RF magnetron sputtering. The influence of film thickness on the structure was investigated. Figs. 1(a-1)–(c-1) show the RHEED patterns observed for 1-nm-thick Co, Ni, and NiFe films grown on GaAs(100) substrates. Clear diffraction patterns corresponding to bcc(100) texture are observed for all the films. Co, Ni, and NiFe single-crystal films with metastable bcc structure are formed in the orientation relationship of bcc(100)[001]//GaAs(100)[001]. With increasing the thickness, diffraction patterns of fcc start to overlap with those of bcc, as shown in Figs. 1(a-2)–(c-2). This result indicates phase transformation from metastable bcc to stable fcc structure. The transformation orientation relationships are determined by RHEED, pole figure XRD, and cross-sectional TEM to be fcc(100)[011]//bcc(100)[001], fcc(110)[001]//bcc(100)[001], and fcc(110)[1-10]//bcc(100)[001], where the bcc{100} planes are parallel to the fcc{100} or fcc{110} planes. Fig. 1(d) shows the cross-sectional HR-TEM image of Ni/GaAs interface. A bcc-Ni crystal is formed near the substrate. The metastable bcc structure seems to be stable at least in a thickness below 1.5 nm for the Ni, Co and NiFe thin films. The magnetic properties of 1-nm-thick Co, Ni, and NiFe films grown on GaAs(100) substrates investigated by high-sensitivity VSM and FMR will be presented at the conference.

[1] S.J. Blundell *et al.*: JAP, **73**, 5948 (1993).
[2] C.S. Tian *et al.*: PRL, **94**, 137210 (2005).

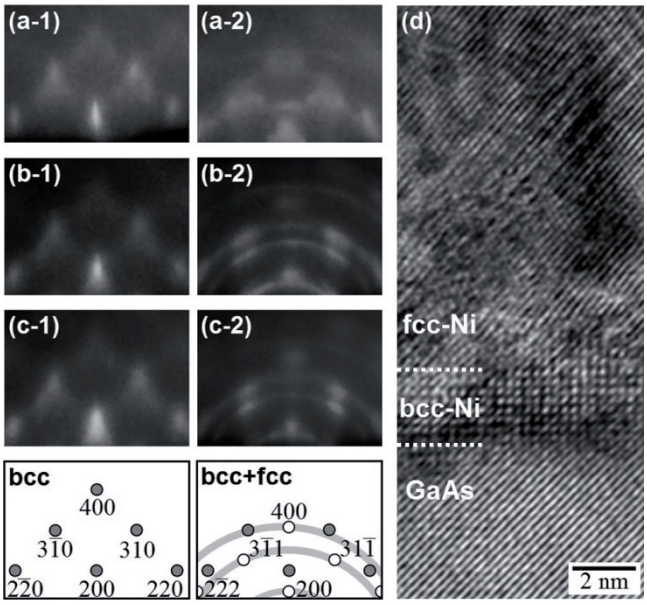

Fig. 1 (a)–(c) RHEED patterns. (d) Cross-sectional HR-TEM image.

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SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

Chair: M. Coisson

12.15 – 12.30

Effect of VC inhibitors in combination with unconventional dynamical heat treatment on the magnetic properties of GO steel

F. Kováč [1], *I. Petryshynets* [1], I. Škorvánek [2], L. Falat [1], J. Marcin [2]
(1) Institute of Materials Research, Slovak Academy of Sciences, 04001 Košice, Slovakia, (2) Institute of Experimental Physics, Slovak Academy of Sciences, 04001 Košice, Slovakia

Grain oriented (GO) steels are widely used for power and distribution transformer cores and characterized by sharp (110)[001] or so called Goss texture presence in final material. Magnetic properties of the product are closely related to sharpness of the (110)[001] texture. Strong Goss texture is a result of technological rout proposed in 1934 by Goss [1], which has been not significantly changed from those times. In order to obtain the Goss texture, the inhibitors such as MnS, AlN and MnS+AlN play an important role in controlling the grain growth of the first and the secondary recrystallizations.
Some new approaches of grain-oriented steels processes have been used in the present work. The suggested approach combines an application of nano - particles VC in combination with dynamic continuous annealing for the secondary recrystallization in the investigated steel. Such a dynamical (fast heating) annealing and VC particles was applied to the grain-oriented steels in order to obtain abnormal grain growth with Goss crystallographic orientation development during secondary recrystallization. This abnormal grain growth led to evolution of sufficiently sharp {110}<001> Goss texture which is equal to that obtained in conventionally treated GO steels. Moreover, the steels treated by the newly developed method showed similar magnetic properties as the material passed the long-time heat treatment. The coercive field value of our steels reached ~ 11 A/m. This means that the proposed heat treatment in combination with VC nano – particles lead to development equal material's quality at significantly shortened time of heat treatment in comparison to the conventional process of the GO steel production.

[1] N.P. Goss, U.S. Patent 1,965,559, (1934).

12.30 – 12.45

Bentonite/iron oxide composites studied by hyperfine methods

P. Křišťan [1], V. Chlan [1], H. Štěpánková [1], R. Řezníček [1], K. Kouřil [1], K. Poláková [2], V. Procházka [2], J. Čuda [2], I. Medřík [2]
(1) Faculty of Mathematics and Physics, Charles University in Prague, V Holešovičkách 2, 18000 Prague 8, Czech Republic, (2) Regional Centre of Advanced Technologies and Materials, Palacky University Šlechtitelů 11, 783 71 Olomouc, Czech Republic

Magnetic iron oxide particles of submicron and nanoscale dimensions are successfully applied in biomedical and bioengineering applications. Although they are applied also as MRI contrast agents, these materials have been studied rarely by NMR. Namely maghemite (γ - Fe2O3) attached to the surface of the bentonite clay forms an efficient negative oral contrast agent for MRI diagnostics in gastroenterology. From this point of view, we study the iron oxide system incorporated in bentonite matrix. Series of composite samples was prepared by isothermal calcination of bentonite powder composed and precursor containing ferric acetate. This chemical procedure enables us to obtain directly the composite samples without aggregation of iron oxide system (i.e. maghemite, hematite) in bentonite matrix.
The series were characterized by ^{57}Fe NMR method. The spectra were recorded at 4.2 K and at room temperature in the zero external magnetic field. We focused our attention on the spectral region corresponding to ^{57}Fe NMR resonance in maghemite and its evolution of calcination temperature T_{calc} running from 320 to 520°C. One of the main findings is that the spectral features of maghemite become more distinct with increasing T_{calc} up to ~420°C. This is most likely connected with higher degree of atomic/vacancy ordering in maghemite spinel structure. For higher T_{calc} we observed a ^{57}Fe NMR signal from hematite at room temperature which corresponds to the decrease of maghemite phase in the studied system. This observation follows the results obtained by Mössbauer spectroscopy.

12.45 – 13.00

Nonlinear Inductance Simulation by a Method of Summation

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Considering climate protection requirements and rapidly rising energy prices, energy saving technology has become essential to realize the ecological and economical objectives. Improving the power efficiency is now a permanent challenge of research and development in power electronics. Here, the focus is put especially on AC/DC drives for motor control, due to the fact that in 2011 electric motors consumed ~45% of the global electricity. A survey of power electronic circuits shows that further optimization has to be based on the passives and particularly on the inductive components like power inductors and transformers.
This paper focuses on power inductors. To be able to find an optimized design, the nonlinear inductance curve has to be predicted depending on the magnetic material and the geometry as well. For this purpose, a nonlinear model was developed based on a method of summation [1]. The description of the magnetic field strength

$$\vec{\mathbf{H}}(\vec{\mathbf{r}}) = \vec{\mathbf{H}}_0(\vec{\mathbf{r}}) + \sum_{i=1}^{N} \mathbf{N}_i(\vec{\mathbf{r}}_i)\vec{\mathbf{M}}_i(\vec{\mathbf{r}}_i) = \frac{1}{\chi_{\mathrm{M}}}\vec{\mathbf{M}}(\vec{\mathbf{r}}) \qquad (1)$$

in tensor notation leads to unique full matrix solution systems and can be transferred to the nonlinear case.
To describe the saturation behavior of the material, ring core specimens were grinded out carefully from the available core material and the *BH*-curves and differential permeabilities were measured considering different temperatures. For inter- and

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SOFT MAGNETIC MATERIALS AND RELATED APPLICATIONS

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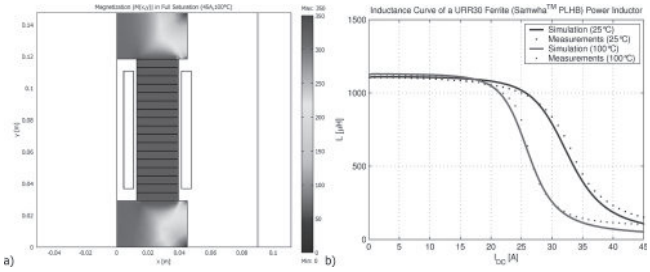
extrapolation of measured data, the rational expression

$$B = \mu_0(H+M) = \mu_0\left(H + \frac{a_1 H + a_2 H^2}{1 + b_1 H + b_2 H^2}\right) \qquad (2)$$

was applied as a description of the magnetization curve [2]. The pictures below give a first impression of the achieved accuracy. The full mathematical derivation will be shown in the final paper together with various simulation results.

[1] D. Fränkel, R. Nuscheler, Tridimensional Numerical Calculation of Magnetic Fields by a Method of Summation, Electrical Engineering 62 (1980)
[2] J. Rivas, J. M. Zamarro, E. Martin, Simple Approximation for Magnetization Curves and Hysteresis Loops, IEEE Trans. on Mag. 17, 4 (1981)



Core Magnetization (a) and Inductance Curve of a Ferrite Power Inductor (b)

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MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

NANOPARTICLES/NANOCLUSTERS

Chair: A. Lascialfari

14.45 – 15.00

Spin coupling, orbital angular momentum quenching, and electron localization in size-selected free transition metal clusters

J.T. Lau [1], K. Hirsch [2], V. Zamudio-Bayer [1], A. Langenberg [1], M. Niemeyer [1], M. Kossick [1], B. Langbehn [1], A. Terasaki [3], T. Möller [2], B. Von Issendorff [4]
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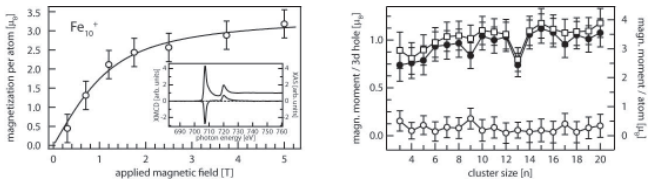
Magnetic spin and orbital moments of size-selected free iron and cobalt cluster ions have been determined via x-ray magnetic circular dichroism spectroscopy in a linear cryogenic ion trap situated in a superconducting 5 T solenoid [1]. Magnetization curves recorded for unperturbed free particles allow the determination of saturation magnetic moments and ion temperature with high precision.
For iron, all atoms within the clusters exhibit ferromagnetic coupling except for Fe_{13}^+, where the central atom is coupled antiferromagnetically to the atoms in the surrounding shell [1,2]. A counterintuitive decrease of the spin magnetic moment is observed for the smallest clusters and can be explained by a reduction of the interatomic distances.
Even in very small clusters, the orbital magnetic moment is strongly quenched and reduced to 5%–25% of its atomic value while the spin magnetic moment remains at 60%–90%. This demonstrates that the formation of bonds quenches orbital angular momenta in homonuclear iron and cobalt clusters already for coordination numbers much smaller than those of the bulk.

[1] M. Niemeyer et al., Phys. Rev. Lett. 108, 057201 (2012)
[2] P. Bobadova-Parvanova, et al., Phys. Rev. B 66, 195402 (2002).



Left: Magnetization curve of free Fe_{10}^+ clusters at 13 K; the inset shows the XMCD spectrum at 5 T. **Right:** Spin and orbital magnetic moments of size-selected free Fe_n^+ clusters. The reduced average spin magnetic moment of Fe_{13}^+ is due to antiferromagnetic alignment of the central atom in the icosahedron [1,2]

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15.00 – 15.30
Strain-mediated initial oxidation of Fe/Fe oxide core-shell nanoparticles *(invited)*
A. Pratt [1], A. Shah [2], L. Lari [3], C. Woffinden [3], S.P. Tear [3], C. Binns [4], R. Kröger [3]
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The initial oxidation of Fe nanoparticles is of central importance to their application in a variety of technological and environmental settings from clean fuel processing, high-density data storage and catalysis to ground-water remediation, targeted drug delivery and cancer therapy [1,2]. Exposure of a pure Fe^0 nanoparticle to ambient conditions results in the rapid formation of an Fe oxide layer that is approximately 2-3 nm thick. The oxidation state, crystallinity and structural order of this oxide all strongly affect the overall behaviour of the core-shell nanoparticle with significant consequences in terms of biocompatibility, chemical reactivity and toxicity. Additionally, geometry and confinement effects may lead to pronounced modifications to electronic, magnetic, and optical properties, particularly through the introduction of strain at the nanoscale [3]. Here we report a detailed study of the initial oxidation of core-shell Fe/Fe oxide nanoparticles using aberration-corrected scanning transmission electron microscopy (STEM) and geometric phase analysis. It is shown that strain induced by lattice mismatch at the core-shell interface and competing growth on different crystallographic Fe^0 planes leads to the formation of oxide domain boundaries. Disorder at these boundaries and at core edges promotes oxide formation through the enhanced outward diffusion of Fe cations to surface-adsorbed oxygen (Cabrera-Mott oxidation). This has important consequences for the development of the oxide, a process critical to many applications, and also to the shape evolution of the nanoparticle. We present results which allow significant new insights into nanoparticle structure and oxide formation, arising from the unprecedented resolution afforded by state-of-the-art STEM imaging.

[1] C. Wang, D. R. Baer, J. E. Amonette, M. H. Engelhard, J. Antony, and Y. Qiang, J. Am. Chem. Soc. 131, 8824 (2009).
[2] F. Ye, J. Qin, M. S. Toprak, and M. Muhammed, J. Nanopart. Res. 13, 6157 (2011).
[3] A. Pratt, C. Woffinden, R. Kröger, S. P. Tear, and C. Binns, IEEE Trans. Mag., 46, 1660 (2010).

15.30 – 15.45
Magnetic microstructure of Ni/NiO nanogranular samples studied by magnetoresistance measurements
L. Del Bianco [1], F. Spizzo [2], M. Tamisari [2], M. Calbucci [1], P. Allia [3]
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The main issue in the magnetism of nanoparticles is to gain a fundamental understanding of the magnetic interaction and/or aggregation mechanisms with increasing their volume concentration.
In this work, the study of the magnetotransport properties, in the 5-250 K temperature range, has been used to get information on the magnetic microstructure of two Ni/NiO samples consisting of Ni nanocrystallites (mean size of the order of 10 nm) embedded in a NiO matrix and differing for the Ni amount, ~ 33 and ~ 61 vol. %. They exhibit a metallic-type conduction mechanism indicating that the Ni content is above the percolation threshold for electric conductivity, even if the electric resistivity is definitely smaller in the sample with higher Ni fraction (10^{-5} Ωm against 10^{-3} Ωm).
The magnetoresistive response measured in the sample with lower Ni content appears to be GMR-like, i.e. negative, isotropic, unsaturating (up to 50 kOe) and is presumed to be generated by spin-dependent scattering mechanisms; on the other hand, both isotropic and anisotropic magnetoresistance phenomena coexist in the other case. The study of these behaviors, coupled to magnetization loop measurements and to the analysis of the exchange bias effect observed in both samples, allows one to draw a picture for their magnetic configuration. In the sample with lower Ni content, neither the physical percolation of the Ni nanocrystallites nor the magnetic percolation (i.e., formation of a homogeneous ferromagnetic network associated with a magnetic-domain pattern) are achieved; in the other sample physical percolation is reached while magnetic percolation is still absent. In both descriptions, a key role is played by the NiO matrix that brings about a magnetic nanocrystallite/matrix interface exchange energy term and rules the direct magnetic exchange interaction among the Ni nanocrystallites and, consequently, the magneto-transport properties of both materials.

15.45 – 16.00
Specific local relaxation and magnetism in mass-selected $L1_0$ CoPt nanoparticles
V. Dupuis [1], N. Blanc [2], L. Diaz [3], A. Hillion [1], A. Tamion [1], F. Tournus [1], G. Pastor [3]
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In this paper, we report the non-trivial structure and magnetic properties obtained on mass-selected CoPt nano-clusters prepared by low energy cluster beam deposition (LECBD) co-deposited in inert carbon matrix. For as-prepared samples, we have put into evidence from HRTEM the transition from a chemically disordered fcc A1 phase to a chemically ordered $L1_0$ tetragonal phase upon annealing under vacuum without particles coalescence. From x ray magnetic circular dichroism

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(XMCD) measurements at the Co and Pt $L_{2,3}$ edge, we found a significant increase of both magnetic moments while SQUID magnetometry measurements and our accurate "triple fit" method revealed a magnetic anisotropy energy (MAE) increase in the ordered phase but not in the same proportion that what is expected for bulk CoPt alloys [1, 2]. In order to obtain new insights on the correlation between magnetic properties and short-range chemical order in nanoalloys, we report the refined quantitative local structure on CoPt samples studied from extended x-ray absorption fine structure (EXAFS) experiments. From simulations, we found a contracted lattice parameter for the as-prepared nanoparticles in the whole sizes range while upon annealing an c/a ratio greater than 1 (resp. lower than 1) at Co K-edge (resp. at Pt L-edge) for the $L1_0$ nanoalloys phase which tend to converge to an unique bulk c/a ratio as the clusters diameter increases. Spin-polarized density-functionnal calculations were carried on using the Vienna ab initio simulation package (VASP) to perform first principles electronic, magnetic and structural optimizations. The calculations fully confirm the experimental trends thus providing a detailed account of the element specific local relaxations which bring back together the EXAFS experimental results [3].

[1] F. Tournus et al, J. Mag. Mag. Mat. 323, 1868 (2011)
[2] V. Dupuis et al, IEEE Trans. Magn. 47, 3358 (2011)
[3] N. Blanc et al, Phys. Rev. Lett. (2012)

16.00 – 16.15
Magnetic Properties of Spinel iron oxide nanoparticles
G. Muscas [1], F. Orrù [2], N. Yaacoub [3], J.M. Greneche [3], A. Musinu [2], C. Cannas [2], A. Ardu [2], G. Piccaluga [2], D. Rinaldi [4], G. Concas [1], D. Fiorani [5], D. Peddis [2]
(1) Dipartimento di Fisica, Università agli Studi di Cagliari, Cittadella Universitaria di Monserrato, 09042 Cagliari, Italy, (2) Dipartimento di Scienze Chimiche e Geologiche, Università agli Studi di Cagliari, Cittadella Universitaria di Monserrato, 09042 Cagliari, Italy, (3) LUNAM, Université du Maine, Institut des Molécules et Matériaux du Mans CNRS UMR-6283, Avenue Messiaen, 72085 Le Mans, France, (4) Dipartimento di Fisica e Ingegneria dei Materiali e del Territorio, Università Politecnica delle Marche, via Brecce Bianche 60131, Ancona, Italy, (5) Istituto di Struttura della Materia, Area della Ricerca di Roma, CNR, Via Salaria km 29.500, CP 10-00016 Monterotondo Stazione, Rome, Italy

During the last decade, there have been extensive interests focused on spinel ferrite nanoparticles due to the large potential in biological, diagnostic and medical applications.
The magnetic behaviour of an assembly of monodomain nanoparticles is determined by their magnetic anisotropy energy and the interparticle interactions The anisotropy energy depends mainly on the structure and chemical composition of the material. In addition, reducing particle size under 10 nm, the high surface to volume ratio can bring surface anisotropy contribution to overcome the bulk magnetocrystalline one. The interaction between molecules and surface atoms of nanoparticles can induce modification on surface anisotropy [1]. This communication focus on the magnetic properties of spinel iron oxide nanoparticles coated by oleic acid and their evolution with size in the range 4 – 13 nm. Four samples of magnetite nanoparticle coated by oleic acid were synthesized by high thermal decomposition of metal-organic precursor. Both Transmission Electron Microscopy and X-Ray Diffraction characterization indicate the presence of uniform, crystalline and isolated particles. In addition to the discrimination of maghemite and magnetite phases, the magnetic structure of the nanoparticles were investigated by ^{57}Fe Mössbauer spectrometry under intense magnetic field (8T), indicating the presence of a fraction of non-collinear spin that decreases with increasing particle size. This trend suggests the presence of spin canting localized at the particle surface, as confirmed by the observation of interface exchange coupling at low temperature [2]. Magnetic investigation indicates an increase of magnetic anisotropy (i.e., coercive field and anisotropy constant) with particle size, suggesting that in these systems magnetic anisotropy is governed mainly by its magnetocrystalline component [3].

[1] S. Bedanta and W. Kleemann, *J. Phys. D: Appl. Phys. 42,* 1(**2009**)
[2] D. Peddis et al., Nanotechnology, 21, 12, 125705 (**2009**)
[3] D. Peddis et al., *Chem. Mater.,* 26, 6, 1062-1071, (**2012**)

16.15 – 16.30
Tailoring MFe_2O_4 (M = Mn, Co, Fe) nanoparticles for hyperthermia applications
M.P. Fernández-García [1], C. Pereira [2], A.M. Pereira [1], J.M. Greneche [3], C. Fernandes [2], M. Rocha [2], T.E. Torres [4], M.P. Calatayud [4], G.F. Goya [4], M.R. Ibarra [4], C. Freire [2], J.P. Araujo [1]
(1) Institute of Nanoscience and Nanotechnology (IN) and Institute of Materials of the University of Porto (IFIMUP), Porto University, PORTUGAL, (2) REQUIMTE, Department of Chemistry and Biochemistry, Porto University, PORTUGAL, (3) LUNAM Université du Maine, Institut des Molécules et Materiaux du Mans, UMR CNRS 6283 FRANCE, (4) Instituto de Nanociencia de Aragón (INA), Zaragoza, SPAIN

The large variety of magnetic scenarios displayed by nanoparticle (NP) systems is mainly governed by the reduced size and/or miscellaneous morphologies of the NPs, because surface, interface or finite-size effects play an important role [1-2]. The complete understanding of the correlation between microstructure, morphology and magnetic behavior is an important issue for the functionalization of NPs and applications in hyperthermia.
In this study MFe_2O_4 (M = Fe, Co, Mn) NPs were obtained by a new one-step aqueous methodology based on the use of novel alkanolamines bases to induce the NP precipitation [3]. The nanomaterials exhibited at room temperature superparamagnetic properties and when directly compared with NPs synthesized with common inorganic NaOH bases, out of the ordinary findings were discovered: *i)* NP sizes 6 times smaller; *ii)* saturation magnetization (M_s) values up to 1.3 times larger and, *iii)* rearrangement of the surface with smaller dead layer thickness (see Figure below). We will review these features by

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detailed in-field Mössbauer spectroscopy measurements.
It is well established that this combination of tuned NP size, superparamagnetic response and enhanced M_s value, is crucial for improving the heating efficiency of the NPs in magnetic hyperthermia. We will present the hyperthermic response of $MnFe_2O_4$ NPs with specific power absorption and intrinsic loss power values of 140 W/g and 0.43 nH·m^2/kg respectively (studies done on 10 nm-$MnFe_2O_4$ NPs at f = 580 kHz and H_{appl} < 300 G).

[1] M. P. Fernández-García *et al.* **Phys. Rev. B** 81, 094418 (2010)
[2] M. P. Fernández-García *et al.* **J. Phys. Chem. C** 115, 5294 (2011)
[3] C. Pereira *et al.* **Chem. Mater.** (2012) dx.doi.org/10.1021/cm300301c

16.30 – 16.45
Quantitative analysis of magnetic phases in nanogranular layers by low-field magnetometry
G. Kakazei [1], A. García-García [1], Y. Pogorelov [1], S. Cardoso [2], P.P. Freitas [2]
(1) IFIMUP and IN–Institute of Nanoscience and Nanotechnology, Departamento de Física, Universidade do Porto, 4169-007-Porto, Portugal, (2) INESC-MN, 1000-029 Lisbon, Portugal

Superferromagnetism (SFM), or dipolar ferromagnetism, was recently discovered in granular layers of ferromagnetic metal in the insulating matrix [1]. By measuring hysteresis loops at different temperatures, it was demonstrated that for rather high concentrations of granules magnetization behavior change from typical paramagnetic to ferromagnetic with decrease of temperature. These studies are quite complicated due to the fact that part of the granules is in superparamagnetic (SPM) state. They experience freezing below blocking temperature that is comparable with the SPM-SFM transition temperature. Also, SFM should be distinguished from usual ferromagnetism (FM) that appear in the granules having size bigger than single-domain limit (usually ~ 10 nm for 3d ferromagnets).
Here we apply SQUID magnetometry to discriminate all major fractions (SPM, SFM and FM) in granular layers. The system under study is a set of discontinuous CoFe (t)/Al_2O_3 (4 nm) metal-insulator multilayers with nominal thickness t varying in the 0.8 – 1.8 nm range. Here it is crucial to fix a real zero of applied magnetic field within to 0.1 Oe. Than each sample is cooled down to 10 K the fields +0.5 Oe and -0.5 Oe and magnetic moment $m(T)$ is recorded in the fields +0.1 Oe and -0.1 Oe respectively within 10-380 K range. Such small fields are sufficient to switch the orientation of SFM phase, but not sufficient to reorient the FM phase and do not affect SPM phase. Thus, we can very accurately detect:
1) nominal thickness t where SFM appear,
2) amount and Curie temperature of SFM fraction for each t,
3) amount of FM fraction for higher t

[1] W. Kleemann et al., Phys. Rev. **B** 63, 134423 (2001).

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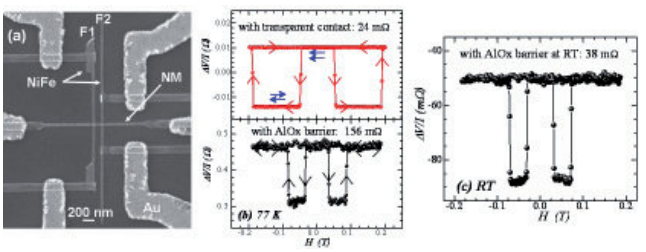
MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS
SPIN CURRENTS AND SPIN-TRANSFER TORQUE
Chair: A. Continenza

14.45 – 15.15
Generation and enhancement of spin currents in metal based lateral nanostructures *(invited)*
P. Laczkowski [1], J.C. Rojas Sanchez [1], W. Savero Torres [1], M. Cubukcu [1], V.D. Nguyen [1], C. Beigné [1], L. Notin [1], C. Vergnaud [1], M. Jamet [1], A. Marty [1], J.P. Attané [1], *L. Vila* [1]
(1) Institut Nanosciences et Cryogénie, CEA, and Université Joseph Fourier, Grenoble, France

Lateral Spin-Valves (LSV) devices are attracting an increasing attention. This interest towards non-local transport measurements is driven by its efficiency to measure fundamental spin-dependent transport properties in various materials. The non local geometry allows also separating charge and spin currents. The switching of ferromagnetic nanoparticles by a pure spin current [1], based on the spin torque effect, underlined the great interest of controlling spin currents. Moreover, recent experiments using the spin Hall effect opened new paths toward the generation and detection of spin current, without requiring neither magnetic materials nor magnetic fields.
We will present several ways to optimize the spin signal of lateral spin valves, especially using a technique to form and connect nanowires in a single evaporation sequence in vacuum, avoiding interface contamination and oxidation. We have studied the influence of the non-magnetic metal used to carry the spin current by processing Au, Al and Cu-based devices [2], and how confinement of the spin accumulation in the channel can lead to a significant increase of the spin signal. Another way to increase the spin signal amplitude is to insert a barrier at the F/NM interface, thus limiting the spin relaxation in the F material. Finally, these optimized LSV can be applied to the characterization of the spin Hall effect. For that purpose a wire made out of material with high spin-orbit coupling is inserted in the lateral spin valve, allowing the quantitative determination of its spin Hall angle [3].

[1] T. Yang, T. Kimura, Y. Otani, Nat. Phys. **4**, 851-854 (2008).
[2] P. Laczkowski *et al.*, Appl. Phys. Exp. **4**, 063007 (2011).
[3] L. Vila, T. Kimura, Y. Otani, Phys. Rev. Lett. **99**, 226604 (2007).



(a) SEM image of a LSV. Spin signals measured at (b) 77 K and (c) room temperature.

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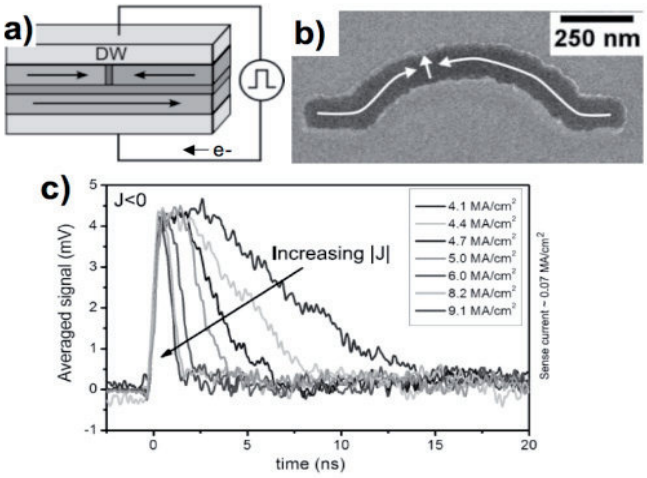
SPIN CURRENTS AND SPIN-TRANSFER TORQUE

Chair: A. Continenza

15.15 – 15.30
High speed, perpendicular current-induced domain wall motion in magnetic tunnel junctions
J. Sampaio [1], P. Metaxas [2], R. Matsumoto [3], S. Lequeux [1], A. Chanthbouala [1], V. Cros [1], A. Anane [1], J. Grollier [1], A. Fert [1], K. Zvezdin [4], A. Fukushima [3], S. Yuasa [3]
(1) Unite Mixte de Recherche CNRS/Thales, Palaiseau, France, (2) School of Physics, University of Western Australia, Crawley, Australia, (3) National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan, (4) Istituto P.M. s.r.l., Turin, Italy

The spin transfer effect allows the manipulation of magnetic domain walls (DWs) in ferromagnetic wires by injection of dc currents, which has led in recent years to the proposal of a number of potentially revolutionary devices [1,2]. In most of these systems, the current is injected along the direction of DW propagation, and the current density required to move the DW has generally remained prohibitively high for applications. Recently, it was predicted [3] that higher efficiency could be obtained by using vertical current injection through multilayer devices, specifically in magnetic tunnel junctions (MTJ). Our group has experimentally verified the higher efficiency DW motion with perpendicularly injected dc currents in MTJs, which was attributed to the out-of-plane spin transfer torque and the Oersted field [4]. We now present time-resolved measurements of DW motion under vertically injected pulsed currents, and demonstrate that DW speeds in excess of 500 m/s can be attained using current densities that are up to 2 orders of magnitude less than those required in devices that use lateral current injection. As such, this work represents an important advance in the race towards energy-efficient, high speed domain wall devices.



Driving DW motion with current pulses. (a) Perpendicular current injection geometry. **(b)** SEM image (top view). The white arrows represent the magnetisation within the free layer of the MTJ containing the DW. **(c)** Averaged voltage traces resulting from resistance changes induced by DW motion during the current pulse.

[1] S.S.P. Parkin et al., Science **320**, 190-194 (2008)
[2] X. Wang et al., IEEE Elec. Dev. Lett. **30**, 294-297 (2009)
[3] A.V. Khvalkovskiy et al., Phys. Rev. Lett. **102**, 067206 (2009)
[4] A. Chanthbouala et al., Nat. Phys. **7**, 626-630 (2011)

15.30 – 15.45
Spinmotive force in patterned nanowires with perpendicular magnetic anisotropy
J. Ieda [1], Y. Yamane [1], S. Maekawa [1]
(1) Advanced Science Research Center, Japan Atomic Energy Agency, 319-1195 Tokai, Japan

Spinmotive force produced by a domain wall (DW) motion in a wedged nanowire with perpendicular magnetic anisotropy (PMA) is theoretically investigated. The spinmotive force reflects the conversion of magnetic energy of a ferromagnet into electric energy of conduction electrons via the spin exchange interaction. This offers a new functionality for future spintronics applications such as magnetic sensors and read-heads.
To produce the spinmotive force it is required that the magnetization depends both on time and space. A field-induced DW motion in a uniform nanowire satisfies this condition, in which the moving DW releases its Zeeman energy into conduction electrons resulting in a finite voltage across the DW [1].
On the other hand, it has been suggested that a DW motion can be induced solely by a shape effect [2]. In addition to the Zeeman energy a DW has a surface-tension-like intrinsic energy due to the exchange and magnetic anisotropic energies. Thus in a nonuniformly patterned nanowire a DW spontaneously tends to move to narrower regions giving rise to a spinmotive force without any external field. Recently we have also reported that using high PMA materials can stabilize the spinmotive force output signal [3].
In this study these two progresses: spinmotive force due to the shape-effect and its high stability in PMA materials, are combined to design efficient conversion from the intrinsic magnetic energy stored in a DW to conduction electrons. AC-DC conversion of spinmotive force using patterned nanowires is also discussed.

[1] M. Hayashi, J. Ieda, Y. Yamane et al., Phys. Rev. Lett. (in press)
[2] Y. Yamane, J. Ieda, and S. Maekawa, Appl. Phys. Express 4, 093003 (2011)
[3] Y. Yamane, J. Ieda, and S. Maekawa, Appl. Phys. Lett. (in press)

15.45 – 16.00
Bias-dependence of the Spin-Transfer Torques in MgO-based Magnetic Tunnel Junctions
S. Boyn [1], R. Matsumoto [1], V. Cros [1], J. Grollier [1], A. Fukushima [2], H. Kubota [2], K. Yakushiji [2], S. Yuasa [2]
(1) Unité Mixte de Physique CNRS/Thales, France, (2) National Institute of Advanced Industrial Science and Technology, Japan

Understanding the bias dependence of the two spin-transfer torques (IP in-plane and OOP out-of-plane) in Magnetic Tunnel Junctions (MTJs) is important from the fundamental point of view and for applications. For example, back-hopping

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SPIN CURRENTS AND SPIN-TRANSFER TORQUE

Chair: A. Continenza

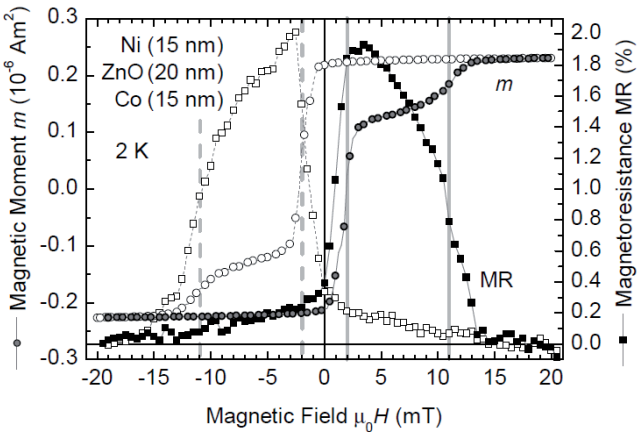
phenomena at large bias, unwelcome for MRAM applications, have been ascribed to a competition between IP and OOP torques [1]. There is still a debate on the expected bias dependence of both torques. In symmetric tunnel junctions (same thickness and composition for both ferromagnetic electrodes), some results report a OOP torque linear with bias [2], and others quadratic [2]. It has also been shown that by voluntarily introducing an asymmetry in the MTJ, it was possible to control the sign of the linear part of the OOP torque [3].
The presented work is a systematic study of the bias-dependence of the two torques in MTJs with different compositions for the electrodes, ranging from symmetric CoFeB/MgO/CoFeB to asymmetric CoFeB/MgO/NiFe MTJs. We will present the switching phase diagrams of the different MTJs measured as well at room as at low temperatures. From these we infer the evolution of the two torques by comparing our experimental results to numerical simulations.

[1] J.Z. Sun et al., J. Appl. Phys. 105, 07D109 (2009)
[2] O. Heinonen et al., Phys. Rev. Lett. 105, 066602 (2010); H. Kubota et al., Nature Phys. 4, 37 (2007) and J. Sankey, Nature Phys. 4, 67 (2007)
[3] S.-C. Oh et al., Nature Phys. 5, 898 (2009) and A. Chanthbouala et al., Nature Phys. 7, 626 (2011)

16.00 – 16.15
Spin valves for spin transport experiments in ZnO
M. Althammer [1], E. Karrer-Müller [1], S.T. Goennenwein [1], *M. Opel* [1], R. Gross [1]
(1) Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany

The wide bandgap semiconductor ZnO is interesting for semiconductor spintronics because of its small spin-orbit coupling implying a large spin coherence length. While other semiconductors have been studied extensively, only very few publications on the spin coherence in ZnO exist. Reports on electrical spin injection are rare [1] and mainly focus on technical aspects.
We investigate the injection, transport, and detection of spin-polarized carriers in ZnO utilizing all-electrical, vertical spin valve devices. We fabricated epitaxial multilayers of TiN/Co/ZnO/Ni/Au on (0001)-oriented Al_2O_3 substrates with different thicknesses of the ZnO layer and patterned them into vertical mesa structures. Magnetotransport (MR) measurements show a spin valve behavior (Fig). The switching fields correspond to the coercive fields of the ferromagnetic layers (Fig). For a ZnO thickness of 20 nm, the MR increases from 0.8% (200 K) to 8.5% (2 K) (Fig). We systematically analyse the maximum MR as a function of the ZnO thickness in the framework of a two spin channel model with a spin-dependent interface resistance [2]. From fits, we obtain a spin diffusion length of 12.3 nm at 2 K, corresponding to a spin dephasing time of 110 ns. This value exceeds previously published data determined from optical experiments [3]. In summary, we electrically create and detect a spin-polarized ensemble of electrons and demonstrate the transport of the spin information across several nm in ZnO.
This work was supported by the DFG via SPP 1285 (project no. GR 1132/14).

[1] Y. Chen *et al.*, Phys. Lett. A **303**, 91 (2002); K. Shimazawa *et al.*, IEEE Trans. Mag. **46**, 1487 (2010).
[2] T. Valet and A. Fert, Phys. Rev. B **48**, 7099 (1993); A. Fert and H. Jaffres, Phys. Rev. B **64**, 184420 (2001).
[3] S. Ghosh *et al.*, Appl. Phys. Lett. **86**, 232507 (2005).



Magnetic moment (left) and magnetoresistance (right) of a Co/ZnO/Ni spin valve

16.15 – 16.30
Finite bias spin-transfer torque from first principles
M. Stamenova [1], I. Popov [1], I. Rungger [1], S. Sanvito [1]
(1) School of Physics and CRANN, Trinity College Dublin, Dublin 2, Ireland

Spin-transfer torques (STT) are in general present any time a spin-polarized current flows through a magnetic system: a ferromagnetic conductor, a magnetic tunnel junction (MTJ), a molecular junction or in an atomically-precise scanning tunnelling microscope (STM) experiment. Because of the complexity the typical STT problem poses, as a non-equilibrium open-boundary many-body quantum problem, microscopic theories of STT are still in their infancy. There seems to be a need for a compromise between the level of description of the electronic structure and the ability to extend the theory beyond the linear response limit (LRL) for the transport.
We have adopted the scheme for *ab initio* STT calculation, conceptually developed in Ref. [1] for the LRL. This is based on an adiabatic approximation to the time-dependent spin-density functional theory (TDSDFT), where the steady-state electron transport is treated with the non-equilibrium Green's function (NEGF) method. We have implemented the method in our versatile *ab initio* SDFT+NEGF transport code SMEAGOL [2] and generalised the original formulation to finite-bias steady-state transport. This allows us to calculate atom- and orbital-resolved STT from first principles for nano-devices.

Thursday, 13 September 2012
Nabucco Room

MAGNETO-TRANSPORT, SPIN ELECTRONICS AND MAGNONIC CRYSTALS

SPIN CURRENTS AND SPIN-TRANSFER TORQUE

Chair: A. Continenza

Our results converge with the atom-resolved STT in a Co-Cu-Co-Cu spin-valve structure, calculated in Ref. [1] in the LRL, and we demonstrate that our finite-bias extension satisfactorily meets the criteria of the perturbative STT theory of Ref. [1]. We report results for the finite-bias STT in a few systems of interest, ranging from MTJ to magnetic point contacts and single magnetic adatoms on surfaces in STM geometry [3].

[1] P.M. Haney et al., Phys. Rev. B 76, 024404 (2007)
[2] A.R. Rocha et al., Phys. Rev. B 73, 085414 (2006)
[3] I. Rungger et al., Phys. Rev. B 79, 094414 (2009); K. Tao et al., Phys. Rev. Lett. 103, 057202 (2009); M. Persson, Phys. Rev. Lett. 103, 050801 (2009)

16.30 – 16.45
Hopping magnetotransport via nonzero orbital momentum states and organic magnetoresistance
V. Kabanov [1], A. Alexandrov [2], A.V. Dediu [3]
(1) Josef Stefan Institute, Ljubljana, Slovenia, (2) Department of Physics, Loughborough University, Loughborough, UK, (3) ISMN-CNR, Via Gobetti 101, 40129 Bologna, Italy

In hopping magnetoresistance (MR) of doped insulators, an applied magnetic field shrinks the electron (hole) s-wave function of a donor or an acceptor and this reduces the overlap between hopping sites resulting in the positive magnetoresistance quadratic in a weak magnetic field, B. We have developed the theory of hopping magnetoresistance via states with nonzero orbital momenta [1]. Different from s-states, a weak magnetic field expands the electron (hole) wave functions with positive magnetic quantum numbers, $m > 0$, and shrinks the states with negative m in a wide region outside the point defect. This together with a magnetic-field dependence of injection/ionization rates results in a negative weak-field magnetoresistance, which is linear in B when the orbital degeneracy is lifted. The theory provides a possible explanation of a large low-field magnetoresistance in disordered pi-conjugated organic materials (OMAR).

[1]] A. S. Alexandrov, V. A. Dediu and V. V. Kabanov, Phys. Rev. Lett. (2012, to appear).

Thursday, 13 September 2012
Otello Room

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: F. Bartolomé

14.45 – 15.15
High-field magnetisation studies of ferrimagnetic 3d-4f intermetallics *(invited)*
M. Kuzmin [1]
(1) Germany

Magnetic anisotropy brings a great diversity in the high-field behaviour of ferrimagnets. The models describing this behaviour are well established but insufficiently investigated. The reason is the large number of parameters and the impossibility of a general analytical solution. At the same time, magnetisation measurements in strong ($\sim 10^2$ T) long-pulse ($\tau \sim 10^{-2}$ s) magnetic fields have become a standard tool for characterisation of heavy-lanthanide-iron (or -cobalt) intermetallics. The still outstanding tasks for theoreticians include (i) finding analytical expressions for the magnetisation curves, (ii) devising techniques for direct determination of model parameters from experimental data, (iii) providing an exhaustive description of all possible shapes of magnetisation curves.
Certain advances along these lines have been achieved [1-3], albeit no definitive solution is in view as yet. Thus, the inter-sublattice exchange parameter can be found – independently of the anisotropy constants – from the position of the so-called orthogonality point in the magnetisation curve [1]. If a transition into the forced ferromagnetic field can be induced, the critical field yields unambiguously the first anisotropy constant [1]. The second anisotropy constant is then obtainable from the differential susceptibility left of the transition point [2]. If the sublattice anisotropy energies of a ferrimagnet are of second order ($\mu \sin^2 \vartheta$), its low-temperature magnetisation curve is presentable in parametric form [3].

[1] M.D. Kuz'min, Phys. Rev. B 79, 212405 (2009)
[2] M.D. Kuz'min, J. Magn. Magn. Mater. 323, 1068 (2011)
[3] M.D. Kuz'min, J. Appl. Phys. 111, 043904 (2012)

15.15 – 15.30
Designed Metamagnetism in $CoMnGe_{1-x}P_x$
Z. Gercsi [1], K.G. Sandeman [1]
(1) Imperial College London

The orthorhombic CoMnSi exhibits a complex non-collinear magnetic structure and strong magnetoelastic coupling over its metamagnetic transition. Our recent experimental findings based on neutron experiment (HRPD) shed light on the criticality of the closest Mn-Mn separations in such orthorhombic, MnP-type (Pnma, 62) structures [1]. The thermal evolution of the helimagnetic state in CoMnSi is accompanied by a change in interatomic distances of up to 2%, the largest ever found in a metallic magnet. Our results and the picture of competing exchange and strongly anisotropic thermal expansion that we use to understand them sheds light on a new mechanism for large magnetoelastic effects that does not require large spin-orbit coupling.

Thursday, 13 September 2012
Otello Room

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: F. Bartolomé

We further investigated the structural conditions for metamagnetism in MnP and related materials using Density Functional Theory. We found that a particular Mn-Mn separation plays the dominant role in determining the change from antiferromagnetic to ferromagnetic order in such systems and an excellent correlation between our calculations and structural and magnetic data from the literature is established [2]. Based on our calculations, we designed and synthesized a series of alloys, $CoMnGe_{1-x}P_x$, to experimentally demonstrate the validity of the model (Fig. 1). Unusually, we predict and prepare several metamagnets from two ferromagnetic end-members, thus demonstrating a new example of how to vary crystal structure, within the Pnma symmetry group, to provide highly tunable metamagnetism [3].

[1] Barcza A, Gercsi Z, Knight, KS, and Sandeman KG, Phys. Rev. Lett. 104. 247202 (2010)
[2] Gercsi Z and Sandeman KG , Phys. Rev. B 81, 224426 (2010)
[3] Gercsi Z, Hono K and Sandeman KG, Phys. Rev. B 83: 174403 (2011)

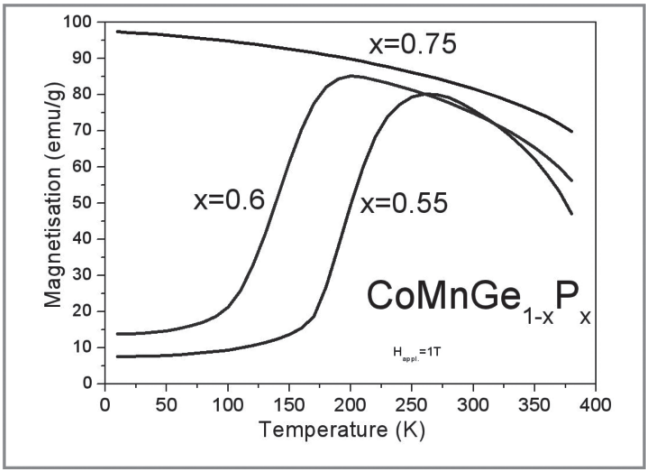


Fig1. We observe metamagnetism in samples with x=0.4-0.6, in line with DFT predictions.

15.30 – 15.45
Suppression of ferromagnetic ground state on $Hf_{0.825}Ta_{0.175}Fe_2$ intermetallic compound
L.V.B. Diop [1], Z. Arnold [2], O. Isnard [1], J. Kaštil [2], J. Kamarád [2]
(1) Institut Néel, CNRS / Université Joseph Fourier, BP 166, 38042 Grenoble, Cédex 9, France, (2) Institute of Physics AS CR v.v.i., Na Slovance 2, 182 21 Prague 8, Czech Republic

The effect of hydrostatic pressure up to 10 kbar on the magnetic properties of $Hf_{0.825}Ta_{0.175}Fe_2$ intermetallic compound has been studied. The present specimen shows successive magnetic transitions from ferromagnetism (F) to paramagnetism (P) via antiferromagnetism (AF) with increasing temperature. At ambient pressure the transition temperature $T_{F\text{-}AF}$ = 202 K is strongly affected by an applied magnetic field and applied pressure. In addition to the temperature-induced magnetic transitions, this compound exhibits metamagnetic transition at temperatures $T>T_{F\text{-}AF}$, the ferromagnetic state can be restored by application of an external magnetic field and $T_{F\text{-}AF}$ shifts to higher temperatures as the magnetic field is increased. The magnetic transition temperature $T_{F\text{-}AF}$ decreases strongly non-linearly with increasing pressure. The initial value of the pressure slope is very high, $dT_{F\text{-}AF}/dP$ = -11 K kbar^{-1}. Moreover the absolute value of pressure coefficient increases with increasing pressure and at critical pressure of P_C = 8 kbar the F-AF transition disappears, ferromagnetic phase is suppressed and the ground state is antiferromagnetic. The application of an external pressure leads also to the progressive decrease of T_N = 322 K with a moderate slope of dT_N/dP = -1.8 K kbar^{-1}. The critical magnetic field (H_C) of the metamagnetic transition AF – F at a given temperature rapidly increases with increasing pressure, as expected due to the large negative pressure-induced shift of the transition temperature $T_{F\text{-}AF}$. In this case the effect of pressure is opposite to the action of the magnetic field.

15.45 – 16.00
Iron, nickel and cobalt nitrides produced by N+ ion implantation
A.R.G. Costa [1], R.C. Da Silva [1], L.P. Ferreira [2], M. Pires [3], N. Franco [1], M. Godinho [3], M.M. Cruz [3]
(1) LFI, Instituto Tecnológico e Nuclear, Instituto Superior Técnico, Universidade Técnica de Lisboa, 2686-953 Sacavém, Portugal, (2) Dep. Física, Faculdade Ciências e Tecnologia, Universidade de Coimbra, 3004-516 Coimbra, Portugal, (3) CFMC/Dep. Física, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal

Transition metal magnetic nitrides have attracted considerable attention as potential candidates to incorporate new magnetic structures, since they display good chemical stability, high saturation magnetization values and can provide good interfaces with the corresponding transition metals. In this work, iron, cobalt and nickel single crystals were implanted with nitrogen at room temperature with a fluence of 5×10^{17} cm^{-2} and 50 keV energy to study the influence of the metallic structure in the formation of the nitrides. In the as-implanted state, Fe_2N, Co_2N and Ni_2N phases could be identified in iron, cobalt and nickel samples respectively. The stability and evolution of the nitride phases and diffusion of the implanted nitrogen were studied as a function of different annealing treatments in vacuum at 250 ºC. The structural and composition modifications induced were followed using Rutherford Backscattering Spectrometry with ion beam channelling (RBS/C). The nitrogen depth profile and effective implanted fluence were determined using elastic nuclear reaction $^{14}N(p,p)^{14}N$. The identification of the nitride phases was carried out using X-Ray Diffraction (XRD) in the Bragg-Brentano geometry and Grazing Incidence at 1.5º (GIXRD), and with Conversion Electron Mössbauer Spectroscopy (CEMS) in the case of iron samples. The magnetic properties of the implanted surfaces were characterized using Magneto-Optical Kerr Effect (MOKE).
A comparison is made with similar implantations in polycrystalline samples.
This work was supported by Portuguese funds through FCT-*Fundação para a Ciência e a Tecnologia* project PTDC/FIS/102270/2008.

Thursday, 13 September 2012
Otello Room

MAGNETISM IN METALS, ALLOYS AND INTERMETALLICS

Chair: F. Bartolomé

16.00 – 16.15

Magneto-optics for uniaxial solids: an application on FeCo strained lattice

F. Ricci [1], F. D'Orazio [2], A. Continenza [2], F. Lucari [3], A.J. Freeman [4]

(1) Dipartimento di Fisica, Università degli Studi dell'Aquila, Via Vetoio 10, 67010 Coppito (AQ) and CNR-SPIN, (2) Dipartimento di Fisica, Università degli Studi dell'Aquila, Via Vetoio 10, 67010 Coppito (AQ) and CNISM, (3) Dipartimento di Fisica, Università degli Studi dell'Aquila, Via Vetoio 10, 67010 Coppito (AQ), (4) Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60208, USA

The Magneto-Optical Kerr Effect (MOKE) is a powerful tool to probe the magnetic properties of materials strictly depending on lattice structure and geometry. On the basis of the existing approach [1], aimed to calculate the MOKE for cubic or isotropic systems starting from the optical conductivity tensor, we developed a theory extending the calculation method to uniaxial (anisotropic) lattices. As an example, we will describe results for the cubic-strained $Fe_{0.5}Co_{0.5}$ assuming a pseudomorphic growth on different substrates: Ni, Pd, Pt, Si, Fe. We will show and discuss the spectra dependence on the strain, magnetization direction, angle of incidence and polarization of the electromagnetic radiation.

[1] J. Zak *et al.*, Phys. Rev. B 43, 6423 (1991).

16.15 – 16.30

Tailoring of the bcc structures based on iron

A. Go [1]

(1) Faculty of Physics, University of Bialystok, 15-424 Bialystok, Poland

Bcc multicomponent alloys based on Fe are interesting from both, applied and basic physics. Their ordering processes result in formation of large class of Heusler-type alloys, some of them having extreme characteristics [1 and references therein]. For example, large negative magnetoresistance was found in polycrystalline Heusler alloys like as Fe_2VAl and quenched $Co_2Cr_{0.6}Fe_{0.4}Al$. The semi-magnetic properties, predicted first by de Groot for ferromagnetic NiMnSb, consisting of formation of an energy gap in one of spin sub-bands is still another example of the peculiarity of these alloys. Interesting transport properties were found in ordered Fe_2TiAl and Fe_2VAl. Moreover, the latter alloy exhibits semiconductor-like temperature dependence of the resistivity. The differences between Fe_2TiAl and Fe_2VAl were attributed to formation of a pseudogap on the Fermi level in Fe_2VAl.

Ab-initio calculations provide very useful tool for designing new materials with desirable properties. Assuming particular concentrations of component chemical elements we can predict electronic and magnetic properties of the alloy.

The aim of this study is systematic theoretical investigation of the systems with bcc structure built of Fe, V, Cr, Al and Si, covering *inter alia* some Heusler alloys based on Fe bcc. Band structure calculations of the investigated alloys were carried out within the framework of the local spin-density approximation, using TB-LMTO-ASA method. By varying concentrations of Fe, V, Cr, Al and Si, for some systems, total compensation of magnetic moments, a pseudogap at the Fermi level as well as half-metallic character of the alloys were obtained. Some theoretical predictions have been already confirmed experimentically [1]. Further experimental studies are still in progress.

[1] K. Perzyńska, K. Szymański, M. Biernacka, A. Go, W. Olszewski, D. Oleszak, K. Rećko, J. Waliszewski, P. Zaleski, L. Dobrzyński, JPSJ (2012) in press

16.30 – 16.45

Crystal Chemistry, Bonding Analysis and Magnetism of MRh6B3 Phases: Experimental and Theoretical Investigations

B. Fokwa [1]

(1) Inorganic Chemistry/RWTH Aachen University/52074, Aachen, Germany

In recent years, we have been studying ternary boride phases adopting the Th_7Fe_3 structure type, focusing on their crystal chemistry and magnetism. In structure of the ternary phase $FeRh_6B_3$,[1a] iron was found (together with rhodium) at only one of the three available rhodium positions, whereas in $Fe_xRh_{7-x}B_3$ ($1 < x \leq 1.5$)[1b] and in $M_{0.5}Ru_{6.5}B_3$ (M = Cr, Mn, Fe, Co, Ni)[1c] the magnetically active elements are present in two of the three rhodium or ruthenium sites. The $M_{0.5}Ru_{6.5}B_3$ (M = Cr, Mn, Co, Ni) phases were found to be either Pauli paramagnets (M = Cr, Co, Ni) or a normal paramagnet ($Mn_{0.5}Ru_{6.5}B_3$), and no hint of magnetic ordering down to 4 K was observed.

We have now successfully synthesized and characterized single phase samples of the MRh_6B_3 (M = Fe, Co) phases, which represent the first itinerant ferromagnetic borides crystallizing with the aforementioned structure type.[5] A tridimensional network of rhodium and iron atoms is identified by *first-principles* DFT calculations (GGA, GGA+U) to be responsible for the long range magnetic ordering below 240 K (for $FeRh_6B_3$) and 150 K (for $CoRh_6B_3$). Furthermore these calculations predict paramagnetism for the phases MRh_6B_3 (M = Cr, Ni) as found experimentally[3] as well as ferromagnetism for $MnRh_6B_3$ phase,[4] yet to be synthesized.

[1] a) B.P.T. Fokwa et al. *Z. Anorg. Allg. Chem*. **2005**, *631*, 2478; b) B.P.T. Fokwa et al. *J. Alloys Compd.* **2007**, *428*, 84; c) P.R.N. Misse et al. *Z. Anorg. Allg. Chem*. **2010**, *636*, 1013.
[2] B.P.T. Fokwa et al. *Inorg. Chem*. **2011**, *50*, 10303.
[3] P.R.N. Misse et al. *Z. Natuforsch. B*. **2011**, In press.
[4] I.M. Ndassa and B.P.T. Fokwa, in preparation.

Thursday, 13 September 2012
Macbeth Room

DILUTED MAGNETICS SEMICONDUCTORS

Chair: P. Torelli

14.45 – 15.15

Controlling ferromagnetism in dilute magnetic nitrides *(invited)*

A. Bonanni [1]
(1) Institut für Halbleiter- und Festkörperphysik, Johannes Kepler University, 4040 Linz, Austria

We summarise our recent work on controlling and elucidating magnetism and exchange interactions in GaN-based systems grown by MOVPE and doped with either Fe [1] or Mn [2] and co-doped with acceptors (Mg) or donors (Si). In particular, we show by combined experimental and ab initio studies that a significant contribution of d orbitals to the bonding leads to the self-organized aggregation of Fe cations driving the material systems to the state of condensed magnetic semiconductor (CMS), i.e., to a semiconducting matrix with nanoscale chemical or crystallographic phase separations [3]. The correlation between the presence of different Fe-rich phases with peculiar and well-defined magnetic behaviour is highlighted together with the ways for the realisation of a single-phase CMS. Furthermore, we demonstrate, by employing a range of nanocharacterisation tools, that Mn in GaN occupies random cation positions at least up to x = 3%. Moreover, we determine the strength of the superexchange coupling between Mn ions in GaN [2].

[1] A. Navarro-Quezada et al. Phys. Rev. B 84, 155321 (2011).
[2] A. Bonanni et al. Phys. Rev. B 84, 035206 (2011).
[3] A. Bonanni and T. Dietl Chem. Soc. Rev. 39, 528 (2010).

15.15 – 15.30

(Zn,Mn)Te/(Zn,Mg)Te Nanowires Studied by Magneto-Photoluminescence

K. Gałkowski [1], J. Suffczyński [1], J. Papierska [1], T. Kazimierczuk [1], P. Kossacki [1], P. Wojnar [2], E. Janik [2], T. Wojtowicz [2]
(1) Institute of Experimental Physics, University of Warsaw, 00-681 Warsaw, Poland, (2) Institute of Physics, PAS, 02-668 Warsaw, Poland

The polarization properties and dynamics of excitonic emission from individual ZnMnTe/ZnMgTe core/shell, MBE grown nanowires are studied. The set of results provides information on the radiative and non-radiative channels of excitonic decay. We measure micro-Photoluminescence (PL) spectra at T = 1.5 K, as a function of magnetic field up to 10 T, polarization of excitation and detection. We analyze also temporal profiles of the PL after pulsed excitation. Exciting beam (442 nm or 410 nm) is focused to 3 μm spot on the sample surface. The emerging signal is detected by the CCD or a streak camera. Near-band emission at about 2.35 eV is observed, with individual emission lines attributed to single nanowires. Degree of linear polarization of nanowires emission at B= 0 T remains in the range from 30 to 50 % and is proportional to the excitonic linewidth. This is expected since both quantities are inversely proportional to the nanowire diameter. With the increasing magnetic field, the energy of the nanowire excitonic emission decreases, while its magnitude increases by a factor of five, and saturates at about B= 5 T. Both show Brillouin-like dependence. This indicates that efficiency of non-radiative decay of exciton population decreases with the magnetic field, and that quenching of these processes is directly linked to Mn ions. This observation remains in qualitative agreement with the results of previous studies on bulk [1] and low dimensional [2] Mn-doped structures. The time resolved measurements provide a strong confirmation of the above findings. The exciton decay time increases from τ= 50±5 ps at B= 0 T to τ= 90±5 ps at B= 10 T. The work was supported by FunDMS Advanced Grant of ERC, NCBiR project LIDER and by ERDF EU grant POIG.01.01.02-00-008/08.

[1]W.Pacuski et al., PRB 84, 035214(2011).
[2]S.Lee et al., PRB 72, 075320(2005).

15.30 – 15.45

On-line Mössbauer investigation of ZnO

R. Mantovan [1], H.P. Gunnlaugsson [2], D. Naidoo [3], H. Masenda [3], T. Mølholt [4], S. Ólafsson [4], K. Johnston [5], K. Bharuth-Ram [6], M. Fanciulli [1], H. Gíslason [4], G. Langouche [7], M. Madsen [8], R. Sielemann [9], G. Weyer [2], The Isolde Collaboration [5]
(1) Laboratorio MDM, IMM-CNR, Via Olivetti 2, 20864 Agrate Brianza (MB), Italy, (2) Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark, (3) School of Physics, University of the Witwatersrand, South Africa, (4) Science Institute, University of Iceland, Dunhaga 3, IS-107 Reykjavík, Iceland, (5) PH Dept, ISOLDE/CERN, 1211 Geneva 23, Switzerland, (6) School of Physics, University of KwaZulu-Natal, Durban 4001, South Africa, (7) Instituut voor Kern-en Stralings fysika, University of Leuven, B-3001 Leuven, Belgium, (8) Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark, (9) Helmholtz-Zentrum Berlin für Materialien und Energie, D-14109 Berlin, Germany

The prediction of a Curie temperature above room temperature (RT) in Mn-doped ZnO initiated considerable experimental efforts with the aim to observe, understand, and control the magnetism in ZnO single-crystals and thin films doped with 3d elements. At present, a full understanding of the nature and origin of the magnetism in 3d-doped ZnO is still unclear. Ferromagnetism (FM) has been observed even in undoped ZnO thin films at RT, which was explained in terms of magnetic ordering induced by polarized lattice defects. We performed emission Mössbauer spectroscopy (MS) measurements following the implantation of radioactive ^{57}Mn (T½=1.5 min.), which decay into the Mössbauer state of ^{57}Fe (T½=98.1 ns) [1]. A special feature of this approach is that total implantation fluence is very low (10^{10-12} ions/cm^2) corresponding to a concentration of 10^{-4}–10^{-3} at.%. This assures the absence of spin-spin relaxations between probe Fe atoms and rules out any prospect of Mn/Fe precipitation. The initially favoured FM coupling between Fe^{3+} and neighbouring implantation-induced defects (mainly V_{Zn}) has been ruled out following MS experiments in a 0.6 T applied magnetic field [2]. Following Mn/Fe implantation, both Fe^{3+} and Fe^{2+} are observed, with paramagnetic Fe^{3+} displaying unusually long spin-lattice relaxation (~10^{-5} sec at RT) [2,3]. The Fe^{3+}/Fe^{2+} ratio is found

Thursday, 13 September 2012
Macbeth Room

DILUTED MAGNETICS SEMICONDUCTORS

Chair: P. Torelli

to increases with fluence of both $^{57}Mn/^{57}Fe$ and ^{23}Na implanted ions, demonstrating that the build up of long-lived Fe^{3+} in ZnO is not related to the specific chemical nature of implanted atoms. Our results exclude the possibility of achieving FM in ZnO as due to diluted Fe impurities.

[1] G. Weyer *et al.*, J. Appl. Phys. **102**, 113915 (2007)
[2] H. P. Gunnlaugsson *et al.*, Appl. Phys. Lett. **97**, 142501 (2010)
[3] T. E. Molholt *et al.,* Physca Scripta **T148,** 014006 (2012)

15.45 – 16.00
Magnetic switching of Co doped CeO_2 nanoparticles induced by deoxygenation
J. Sacanell [1], M.A. Paulin [1], A.G. Leyva [1], V. Ferrari [1]
(1) Departamento de Física de la Materia Condensada, Gerencia de Investigacion y Aplicaciones, Centro Atomico Constituyentes, CNEA. Buenos Aires, Argentina

The development of spintronics has promoted the study of materials with strong coupling between their electric and magnetic properties. For that kind of applications, the materials should have a high spin polarization and also present structural compatibility with existing semiconductors. Among materials that meet these requirements are the diluted magnetic oxides such as Co doped CeO_2. The pure compound is a diamagnetic insulator, but on doping with magnetic ions like, the system can become paramagnetic or ferromagnetic. The great capability to accomodate oxygen vacancies in its structure seems to be the responsible for this particular behavior. In this work we investigated the reversible ferromagnetic (FM) behavior of pure and Co doped CeO_2 nanopowders. The as-sintered samples displayed an increasing paramagnetic contribution upon Co doping. Room temperature FM is obtained simply by performing thermal treatments in vacuum at temperatures as low as 500ºC and it can be switched off by performing thermal treatments in oxidizing conditions. The FM contribution is enhanced as we increase the time of the thermal treatment in vacuum. Those systematic experiments establish a direct relation between ferromagnetism and oxygen vacancies and opens a new path for developing new materials with tailored properties.

16.00 – 16.15
d^0 Ferromagnetism in Oxide Nanowires: Role of Intrinsic Defects
S. Ghosh [1], G.G. Khan [1], *K. Mandal* [1]
(1) Department of Condensed Matter Physics & Materials Science, S. N. Bose National Centre for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700 098, India

The research of defect-induced d^0 ferromagnetism in oxides [1-3] semiconductors recently catches great attention of the scientists for preparing a new class of magnetic semiconductors for spintronic application. Here, we have studied the role of structural defects in inducing magnetism in K-doped ZnO and pure SnO_2 nanowires (NWs). Both the ZnO and SnO_2 NWs show room temperature ferromagnetism (RTFM). But, interestingly, two completely different kinds of defects are found to be responsible for observed FM in ZnO and SnO_2 NWs. Photoluminescence (PL) spectroscopic measurements showed the presence of large amount of cation vacancies (Zn vacancies, here) (V_{Zn}) whereas in case of SnO_2 NWs, singly ionized oxygen vacancies (V_O^+) (F centre) are detected. Ferromagnetic signature was found to enhance upto a certain critical K-concentration (4 at.%) then decreased on further K doping. A good correlation is observed between the PL green emission intensity (I_G) and the ferromagnetic saturation moment (M_S) which suggests Zn vacancy-induced FM in pristine and nonmagnetic K doped ZnO NWs. On the other hand, correlating the PL study with electron paramagnetic resonance (EPR) analysis in SnO_2 NWs, it is suggested that V_O^+ is the origin of FM in pristine SnO_2 NWs. This study demonstrates that the careful control of these types of structural defects can be an important tool to stabilize and tune FM in such oxides.
Keywords: Oxide semiconductor, Intrinsic defects, Ferromagnetism

[1] J. B. Yi et al., Phys. Rev. Lett. **104**, 137201 (2010).
[2] R. Podila et al., Nano Lett. **10,** 1383 (2010).
[3] S. Ghosh, D. De Munshi, and K. Mandal, J. Appl. Phys. **107**, 123919 (2010).

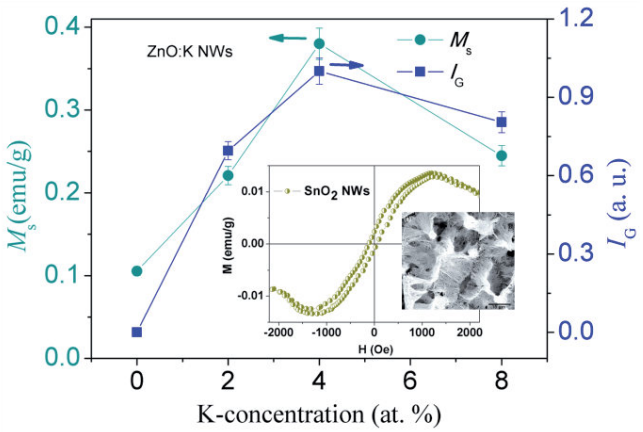


Fig.1 Saturation Magnetization (M_S) and PL green intensity (I_G) as a function of K-concentration in ZnO NWs. Inset: M-H loops and FESEM for pure SnO2 NWs.

16.15 – 16.30
Complex magnetic response of (Zn,Co)O layers
M. Sawicki [1], *D. Sztenkiel* [1], O. Proselkov [1], W. Stefanowicz [1], T. Dietl [1]
(1) Institute of Physics, Polish Academy of Sciences, PL-02-668 Warszawa, Poland

In this work, we present results of magnetic studies carried out on $Zn_{1-x}Co_xO$ layers grown by atomic layer deposition [1] and thoroughly analyzed by set of experimental methods, including XRD, HRTEM, XPS and EXAFS. All magnetic results have been obtained with conventional SQUID magnetometer. The structures deposited at 160 °C show magnetic properties specific to dilute magnetic semiconductors (DMSs) with localized spins S = 3/2 coupled by short range antiferromagnetic interactions. The presence of positional disorder within the spin system leads to low temperature spin-glass freezing, not observed earlier in (Zn,Co)O. We have found a good correspondence between the

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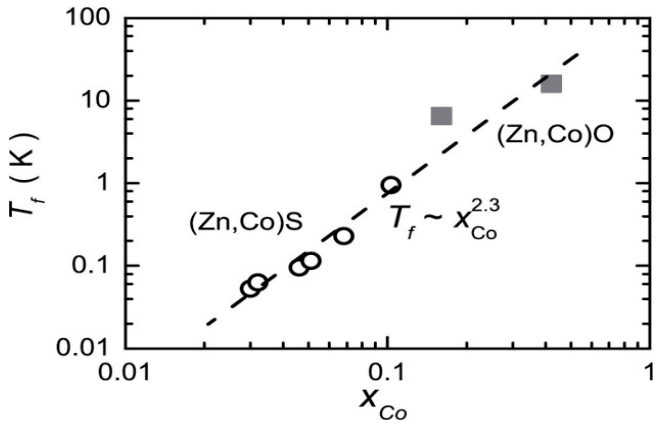
observed here freezing temperatures (T_f) with those reported for similar systems. For our samples T_f follows the already established power law, $T_f \propto x^{\alpha}$, with $\alpha = 2.1 \pm 0.4$ for bulk (II,Co) VI compounds ($\alpha \simeq 2$ for the other legacy DMSs).
Furthermore, when the growth temperature is risen to 200 °C or above the ferromagnetic-like response appears and is associated with metallic Co granules aggregated between the substrate and the (Zn,Co)O layer. Moreover, anomalous magnetic response is seen in the form of a superparamagnetic-like behavior, pointing to the presence of nanoparticles magnetized internally up to above room temperature.
The work was supported by FunDMS Advanced Grant of ERC within the Ideas 7th FP of EC and InTechFun (Grant No. POIG.01.03.01-00-159/08)

[1] M. Sawicki, E. Guziewicz, M. Łukasiewicz, Proselkov, I. Kowalik, W. Lisowski, P. Dłużewski, A. Wittlin, M. Jaworski, A. Wolska, W. Paszkowicz, R. Jakieła, B. S. Witkowski, L. Wachnicki, M. T. Klepka, F. J. Luque, D. Arvanitis, J. W. Sobczak, M. Krawczyk, A. Jablonski, W. Stefanowicz, D. Sztenkiel, M. Godlewski and T. Dietl, *arXiv:1201.5268*.

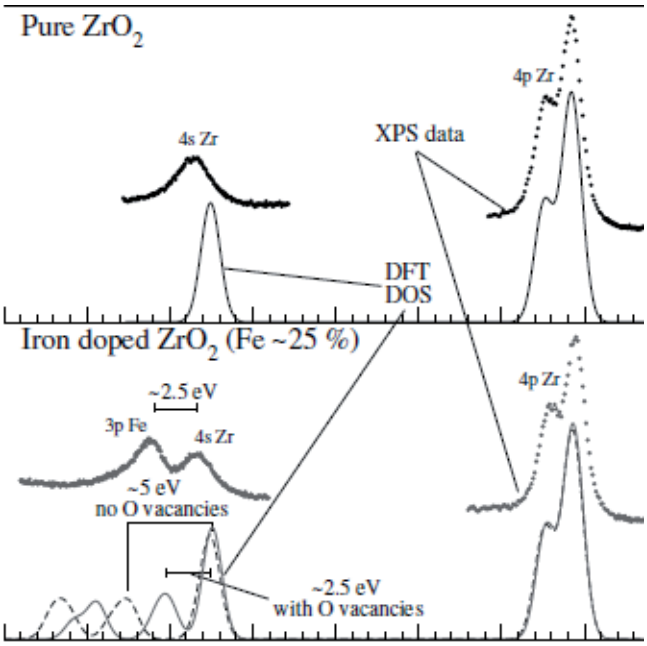


T_f dependence on the Co content x_{Co} in (Zn,Co)S (open circles) and in (Zn,Co)O (closed squares, this study).

16.30 – 16.45
Exploiting Fe doping in Zirconia: from first-principles simulations to the experimental growth and characterization of thin films
D. Sangalli [1], E. Cianci [1], A. Lamperti [1], R. Ciprian [1], M. Perego [1], F. Albertini [2], F. Casoli [2], P. Lupo [2], L. Nasi [2], M. Campanini [2], L. Lazzarini [2], A. Debernardi [1]
(1) Laboratorio MDM, IMM-CNR, Via C. Olivetti 2, 20864, Agrate Brianza (MB), Italy, (2) IMEM-CNR, Parco delle Scienze 37/A – 43124, Parma, Italy

Ferromagnetic doped ZrO_2 is a potential candidate material for the fabrication of alternative magnetic memory devices in view of innovative spin–electronic applications [1, 2]. In this study we explore, both from theoretical and experimental side, the effect of Fe doping in ZrO2 (ZrO_2:Fe). Density Functional Theory (DFT) simulations show that Fe doping induces a monoclinic to tetragonal/cubic phase transition; tuning the Fe atomic content at 12%, the tetragonal phase tends to stabilize. Moreover we find that Fe doping induces the formation of oxygen vacancies [3], which play a key role in determining the electronic and magnetic properties of ZrO_2:Fe. Thin films (~20 nm) of both pure ZrO2 and ZrO_2:Fe, are deposited by atomic layer deposition (ALD). We provide experimental evidence that Fe is uniformly distributed in the ZrO2 both in-plane, by TEM, and in the growth direction, by ToF–SIMS. XRD evidences the presence of the monoclinic phase only in films of pure ZrO_2 confirming that Fe-doping favours the tetragonal/cubic phase. XPS measurements of core levels suggest that Fe atoms are in the 3+ oxidation state. Moreover both the shape of the valence band and the position of the semi-core levels are in good agreement with the DFT energy values providing a confirmation of the model used in the simulations accounting for substitutional Fe doping and induced oxygen vacancies (see Figure). Preliminary results by AGFM suggest the possibility of ferromagnetic interaction at room temperature.

[1] Ostanin, et al. PRL 98, 016101 (2007)
[2] Kriventsova, et al. Nuclear Instruments and Methods in Physics Research A 470, 341 (2001)
[3] Hong, et al. APL 89, 042503 (2006)



XPS and DFT electronic levels of ZrO_2 and ZrO_2:Fe films

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Chair: C. Bernhard

14.45 – 15.15

Competition between charge and superconducting orders in underdoped YBCO *(invited)*

M. Julien [1]

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We report nuclear magnetic resonance measurements (NMR) showing that high magnetic fields induce a static, unidirectional, modulation of the charge density in the CuO_2 planes of underdoped $YBa_2Cu_3O_y$ [1]. The appearance of the charge order coincides with the Fermi surface reconstruction inferred from quantum oscillation and other transport measurements. This charge order appears to be most probably the same 4*a*-periodic stripe modulation as in La-214 cuprates. That it develops only when superconductivity fades away (no charge order is observed under strong fields parallel to the planes) and near the same 1/8 hole doping as in La-214 suggests that charge order, although visibly pinned by CuO chains in $YBa_2Cu_3O_y$, is an intrinsic propensity of the superconducting planes of high-Tc copper oxides. Since field induced stripe order is also compatible with neutron scattering data in La-214 and with STM data in Bi-2212, charge order could be a generic competitor of high Tc superconductivity.

This work was performed with T. Wu, H. Mayaffre, S. Krämer, M. Horvatic, C. Berthier (LNCMI Grenoble), W.N. Hardy, R. Liang, D.A. Bonn (University of British Columbia, Vancouver)

[1] T. Wu et al., Nature 477, 191 (2011)

15.15 – 15.30

Stripe dynamics in $La_{2-x}Sr_xCoO_4$ layered cobaltates by ^{59}Co and ^{139}La NMR

G. Allodi [1], M. Mazzani [1], S. Bordignon [1], R. De Renzi [1], T. Lancaster [2], S.J. Blundell [3], A.T. Boothroyd [3]

(1) Dipartimento di Fisica, Università di Parma, I-43100 Parma, Italy, (2) Department of Physics, Durham University, Durham DH1 3LE, United Kingdom, (3) Clarendon Laboratory, University of Oxford, Oxford OX1 3PU,United Kingdom

Hole doped lanthanum cobaltates $La_{2-x}Sr_xCoO_4$ are layered, magnetic compounds isostructural with the '214' copper oxide family $La_{2-x}Sr_xCuO_4$. They seemingly exhibit similar physics if one excepts the presence of a superconductive phase in cuprates, which is missing in cobaltates. Localized holes, inducing a spinless Co^{3+} state [1], tend to self-organize into arrays of charged stripes. The latter behave as antiphase domain walls in the AF spin structure, and give rise to a magnetic superstructure similar to the ones observed in cuprates [2]. Recently, inelastic neutron scattering on $La_{5/3}Sr_{1/3}CoO_4$ has revealed a peculiar "hour-glass"-shaped dispersion branch in the magnetic excitations of the system [3]. The same hour-glass dispersion was also observed in several cuprates, both with and without static stripe order. The presence of similar dispersion features in both classes of compounds suggests that the underlying excitations arise from stripes (either static or fluctuating) in all cases.

We present an investigation on a series of $La_{2-x}Sr_xCoO_4$ crystals (x = 0.25-0.9) by ^{139}La and ^{59}Co NMR. The magnetic ordering below $T_N \approx 40$K is signaled by broad featureless ^{139}La and ^{59}Co spectra, as opposed to the well-resolved quadrupolar patterns detected by both nuclei well above T_N. Evidence for very slow dynamical excitations, ascribed to the collective motion of the stripes, is provided by the partial or total loss of the NMR signal (wipeout), due to short and inhomogeneous T_2 times. Two wipeout regimes are detected over distinct temperature intervals, above 100K and in the 10-40K range. Comparison with μSR experiments, scheduled by the date of the conference, will help elucidating the predominant nature - either spin or charge - of the slow stripe dynamics, thanks to the insensitivity of muons (S_μ=1/2) to charge excitations.

[1] L.M. Helme *et al.*, Phys. Rev. B 80, 134414 (2009)
[2] J.M. Tranquada *et al.*, Nature 375, 561 (1995).
[3] A.T. Boothroyd *et al.*, Nature 471, 341 (2011).

15.30 – 15.45

The magnetic depth profile of $YBa_2Cu_3O_7/La_{0.66}Ca_{0.33}MnO_3$ superlattices from polarized neutron reflectometry

M.A. Uribe Laverde [1], D.K. Satapathy [1], I. Marozau [1], S. Das [1], V. Malik [1], C. Marcelot [2], J. Stahn [2], A. Rühm [3], J. Kim [4], A. Devishvili [5], B. Toperverg [5], C. Bernhard [1]

(1) University of Fribourg, Department of Physics and Fribourg Centre for Nanomaterials, Switzerland, (2) Laboratory for Neutron Scattering Paul Scherrer Institut, Switzerland, (3) Max-Planck-Institut fur Intelligente Systeme, Germany, (4) Max-Planck-Institut fur Festkörperforschung, Germany, (5) Institute of Solid State Physics, Ruhr-Universität Bochum, Germany

Using polarized neutron reflectometry (PNR) we have investigated the magnetic depth profile in $[YBa_2Cu_3O_7$(YBCO)/$La_{2/3}Ca_{1/3}MnO_3$ (LCMO)$]_{x10}$ superconductor/ferromagnet superlattices (SLs) as a function of temperature and applied magnetic field. Our high quality pulsed laser deposition grown SLs allowed us to measure up to the 4th order SL Bragg peak and thus investigate in detail the mismatch between the magnetic and the chemical potential noticed in previous PNR studies due to the appearance of the structurally forbidden 2nd order SL Bragg peak. However, due to the limited range of the measured SL Bragg peaks, an unambiguous determination of the magnetic profile had not been possible [1]. In this work we identify the relevant features of the magnetic profile and show that they involve the formation of a depleted ferromagnetic layer on the LCMO side of the interface [2]. We also provide evidence that this depleted layer (with a reduced ferromagnetic Mn moment) should not be mistaken with a "magnetically dead" layer but instead is likely to host an oscillatory magnetic order that plays a key role in mediating the interaction between magnetism and superconductivity in these superlattices. Our PNR data provide indeed evidence

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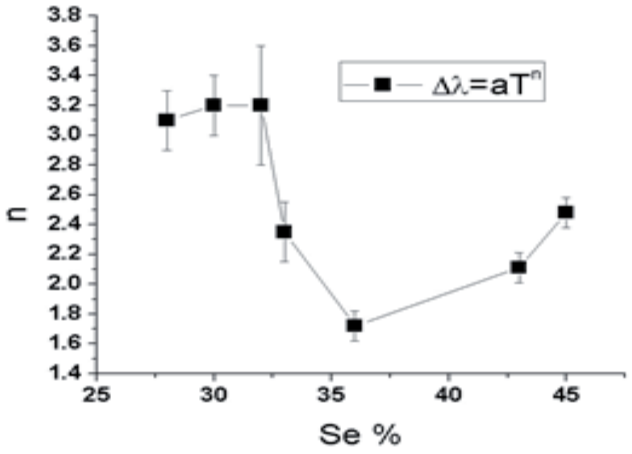
for an anomalous superconductivity-induced change of the ferromagnetic profile below the T_c of YBCO. Additional x-ray magnetic circular dichroism measurements also show that a ferromagnetic Cu moment is induced on the YBCO side of the interface. Furthermore, we find that the thickness of the depleted layer in LCMO and the strength of the induced Cu moment in YBCO strongly depend on the doping level of the manganite layers. Notably, the value of the induced Cu moment appears to increase with the thickness of the depleted layers [2].

[1] J. Stahn et al., Phys. Rev. B **71**, 140509 (2005).
[3] D.K. Satapathy et al., Phys. Rev. Let. accepted for publication (2012).

15.45 – 16.00
Doping evolution of the pairing state in $Fe_{1.02}(Te_{1-x}Se_x)$ as determined from penetration depth measurements
A. Diaconu [1], J. Hu [2], B. Qian [2], Z. Mao [2], *L. Spinu* [1]
(1) Advanced Materials Research Institute & Physics Deparment, University of New Orleans, New Orleans, USA, (2) Department of Physics, Tulane University, New Orleans, USA

A systematic investigation of transport, magnetic and superconducting properties in various regions of the phase diagram of $Fe_{1.02}(Te_{1-x}Se_x)$ single crystals is described in [1]. Our work focuses on the properties of the bulk superconductive region as derived from the in-plane penetration depth measurements as a function of temperature. The London penetration depth is one of the most important characteristic parameter in type II superconductors as its temperature dependence can give information about the pairing mechanism.
Precise measurements of the in-plane penetration depth λ_ab as a function of temperature using a tunnel diode oscillator technique [2] where performed in a dilution refrigerator down to a temperature of 50mK. By using a set of two mutually coupled planar inductors the uniform probing ac field is along the c axis making the variation in susceptibility solely due to supercurrents flowing in the ab crystallographic plane. The measurements performed in seven samples with Se concentration spanning form 28% to 45% revealed a power law dependence of the penetration depth with temperature. We found that, the samples with Se concentrations below 32% show a high power exponent behavior while for the samples close to optimum doping, the exponent increases with Se concentration from 1.7 for the 36% concentration to a value of 2.4 for optimum doping.

[1] T. J. Liu, Nature Materials 9, 718–72 (2010)
[2] R. Prozorov, Phys. Rev. B 62, 115–118 (2000)



16.00 - 16.15
t-J model for strongly correlated electrons: Coexistence of antiferromagnetism and unconventional superconductivity
J. Spalek [1], J. Kaczmarczyk [1]
(1) Marian Smoluchowski Institute of Physics/Jagiellonian University/Reymonta 4, 30-059 Kraków, Poland

The coexistence of antiferromagnetism with superconductivity is studied theoretically within the *t-J* model with the Zeeman term included. The strong electron correlations are accounted for by means of the extended Gutzwiller-Fukushima projection method within a statistically consistent approach proposed by us recently [1]. The phase diagram on the band filling-magnetic field plane is shown in Fig. 1. In this regime, the results reflect principal qualitative features observed recently in selected heavy-fermion systems, namely, (i) with the increasing magnetic field the system evolves from coexisting antiferromagnetic-superconducting phase through antiferromagnetic phase toward polarized paramagnetic state and (ii) the onset of superconducting order suppresses partly the staggered moment. The superconducting gap has both the spin-singlet and the staggered-triplet components, a direct consequence of the coexistence of the superconducting state with antiferromagnetism [2].

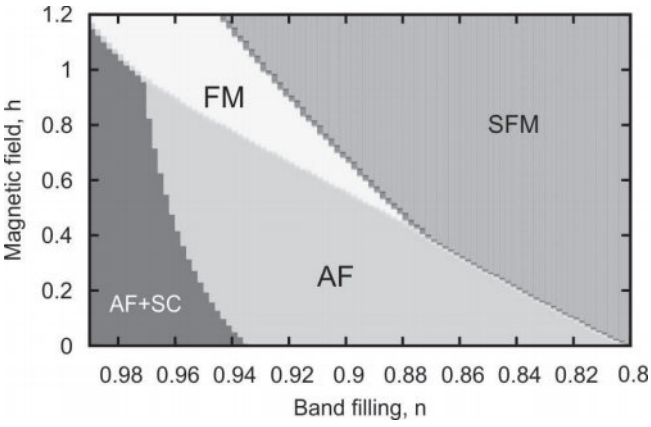


Fig. 1. Phases: antiferromagnetic (AF), superconducting (SC), and spin-polarized (PP, SFM).

[1] cf. J. Jędrak, J. Kaczmarczyk, and J. Spałek, arXiv: 1008.0021; J. Spałek, arXiv: 1202.2833 [cond-mat. str. – el.]
[2] J. Kaczmarczyk and J. Spałek, Phys. Rev. B **84**, 125140, pp. 1-10 (2011)

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MAGNETISM AND SUPERCONDUCTIVITY

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16.15 – 16.30

Magnetic behavior of a new heavy fermion compound Ce_2PtIn_8: a single crystal study.

M. Kratochvílová [1], K. Uhlířová [2], J. Prokleška [1], J. Prchal [1], I. Císařová [3], J. Custers [1], V. Sechovský [1]

(1) Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic, (2) Department of Condensed Matter Physics, Faculteit Wis- en Natuurkunde, Leiden University, Netherlands, (3) Department of Inorganic Chemistry, Faculty of Science, Charles University in Prague, Czech Republic

The $Ce_nT_mIn_{3n+2m}$ (n=1, 2; m=1; T=transition metal) type compounds are subject of intense interest in the condensed-matter community. By adding an additional $CeIn_3$-stacking layer in the tetragonal crystal structure the dimensionality changes from 3D to more 2D. While selecting the proper transition metal, the compound might either order antiferromagnetically or becomes superconducting. It has been shown, that the superconducting state is closely linked to the presence of a quantum critical point. Thence, the group of $Ce_nT_mIn_{3n+2m}$ compounds is predestined to investigate the interplay between magnetism and superconductivity.

Recently, two new compounds from the $Ce_nT_mIn_{3n+2m}$ heavy fermion family have been found. Ce_2PdIn_8 is an ambient pressure superconductor while $CePt_2In_7$ orders antiferromagnetically.

Here, we report on the existence of a new heavy fermion (γ~370 mJ/molCe.K^2) compound Ce_2PtIn_8. Similar to Ce_2PdIn_8, the synthesis of Ce_2PtIn_8 is rather complicated. However, from our recent studies of solution growth of Ce_2PdIn_8 supported by differential thermal analysis optimal conditions for growing Ce_2PtIn_8, single crystals could be deduced. Single crystal X-ray diffraction confirmed that Ce_2PtIn_8 crystallizes in Ho_2CoGa_8-type structure with lattice parameters a=4.699 Å and c=12.185 Å.

We will present specific heat, resistivity (ambient and under hydrostatic pressure) and magnetization measurements. Ce_2PtIn_8 orders magnetically at 2.1 K. An order-to-order transition is observed just below at 2 K. Contrary to Ce_2RhIn_8, the two transitions merge at magnetic field around 4 T and split again in higher magnetic fields pointing on a different character of magnetic ordering. The magnetic field-temperature phase diagram will be discussed in the context of superconductivity and magnetism evolution in related compounds.

16.30 – 16.45

Spin Exciton Formation Inside the Hidden Order Phase of CeB_6

P. Thalmeier [1], A. Akbari [1]

(1) Max Planck Institute for Chemical Physics of Solids

The heavy fermion metal CeB_6 exhibits hidden order of antiferroquadrupolar (AFQ) type below T_Q=3.2 K and subsequent antiferromagnetic (AFM) order at T_N=2.3 K. It was interpreted as ordering of the quadrupole and dipole moments of a Γ_8 quartet of localised Ce 4f electrons. This established picture has been profoundly shaken by recent inelastic neutron scattering [1] that found the evolution of a feedback spin exciton resonance within the hidden order phase at the AFQ wave vector appears and is stabilized by the AFM order. We develop an alternative theory [2] based on a fourfold degenerate Anderson lattice model, including both order parameters as particle-hole condensates of itinerant heavy quasiparticles. This explains in a natural way the appearance of the spin exciton resonance and the momentum dependence of its spectral weight, in particular around the AFQ vector and its rapid disappearance in the disordered phase. Analogies to the feedback effect in small gap Kondo semiconductors such as YbB_{12} and unconventional superconductors like $CeCoIn_5$ are pointed out.

[1] G. Friemel et al, arXiv:1111.4151
[2] A. Akbari and P. Thalmeier, arXiv:1202.4291

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Nabucco Room

IEEE Magnetics Society Italian Chapter – JEMS2012 Special lecture
Chair: E. Cardelli

17.15 – 18-15

Soft Magnetic Thin Film Applications at Radio Frequencies

Masahiro Yamaguchi [1]
(1) IEEE2012 Magnetic Society Distinguished Lecturer
Department of Electrical and Communication Engineering, Tohoku University

Development of new passive component technologies will enable a "More-than-Moore" paradigm leading to innovative application-specific compact systems [1]. Ferromagnetic thin film materials, having high permeability at (and above) radio frequencies, are candidate materials for use in inductive passive components that are available in the forms of vacuum-deposited and electro-deposited metallic alloys, chemically synthesized nano-particulate composites, and traditional oxides, among others. Using these materials, the development of CMOS integrated inductors and integrated electromagnetic noise suppressors for Long Term Evolution, or 3.9th Generation, cell phone RFIC and Point-of-Load one-chip DC-DC converters, is attracting great interest from both academic and industrial communities.

This lecture begins with a review of new soft magnetic thin film applications at radio frequencies for future system-in-package (SiP) and system-on-chip (SoC) technologies. Proposed in late 1970s, these thin film soft magnet applications have evolved from inductive read/write recording head technology to the frontiers of GHz frequency device applications. Discussions covered in this lecture include: (1) Development of international cross measurements of RF permeameters [2] to evaluate RF permeability and related FMR profiles of magnetic films; (2) small signal high permeable low loss applications to CMOS integrated inductors [3]; (3) small signal lossy application to CMOS integrated electromagnetic noise suppressor [4]; (4) small to medium signal applications as new metal/ferromagnetic multi-stack "conductors" to suppress skin effect utilizing negative permeability beyond the FMR frequency [$\mu r' < 0$, $\mu r'' \approx 0$][5]; and, (5) large current permeable application to Point-of-Load type one-chip DC-DC converters. The lecture will conclude with an outlook that provides a perspective on the future of on-chip RF magnetics.

[1] John P. Kent, and Jagdish Prasad, "Microelectronics for the Real World: 'Moore' versus 'More than Moore'," IEEE 2008 Custom Integrated Circuits Conference, 15-4-1 (2008).
[2] M. Yamaguchi, Y. Miyazawa, K. Kaminishi and K.I. Arai, "A New 1 MHz-9 GHz Thin-Film Permeameter Using a Side-Open TEM Cell and a Planar Shielded-Loop Coil," Trans. Magnetic Society of Japan, 3, 137-140 (2003).
[3] Masahiro Yamaguchi, Keiju Yamada, Ki Hyeon Kim, "Slit Design Consideration on the Ferromagnetic RF Integrated Inductor," IEEE Transactions on Magnetics, 42, 3341-3343 (2006)
[4] Sho Muroga, Yasushi Endo, Wataru Kodate, Yoshiaki Sasaki, Kumpei Yoshikawa, Yuta Sasaki, Makoto Nagata Masahiro Yamaguchi, "Evaluation of Thin Film Noise Suppressor Applied to Noise Emulator Chip Implemented in 65nm CMOS technology," IEEE Transaction on Magnetics, 48, 4485 - 4488 (2011).
[5] Masahiro Yamaguchi, Yutaka Shimada, Takayoshi Inagaki and Behzad Rejaei, "Skin Effect Suppression in RF Devices Using a Multilayer of Conductor and Ferromagnetic Thin Film with Negative Permeability," Microwave Workshop and Exhibition 2008 (MWE 2008), WS08-03 (Yokohama, 2008).

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Posters

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Poster Area, 17.00 – 19.00

ADVANCED EXPERIMENTAL TECHNIQUES FOR MAGNETIC MATERIALS

Chair: P. Fischer

TH-1

Magnetic force microscopy on permanent magnets. Specific aspects concerning cantilever choice and image analysis

G. Ciuta [1], F. Dumas-Bouchiat [1], N.M. Dempsey [1], D. Givord [1], O. Fruchart [1]
(1) Néel,CNRS,Grenoble,France

Magnetic force microscopy (MFM) is a powerful tool for the study of the domain structures of magnetic materials. Imaging hard magnetic materials requires specific considerations for cantilever and tip, three of which we address here.
Firstly, for usual magnetic samples cantilevers with stiffness of the order of 1 N/m are used. This is a tradeoff between the ability to image topography and achieving a good S/N ratio for the magnetic signal. We show that, due to the strong field gradients arising from permanent magnets, this choice may lead to: 1/ artifacts in topography 2/ non-linearities in magnetic images. Choosing a stiffness of 10-40 N/m allowed us to correct these pitfalls.
Secondly, it is known that a hard magnetic coating needs to be used to avoid switching of the tip magnetization during measurement. We show that this results in a non-negligible in-plane component of the tip magnetization. This brings sensitivity to the z-gradient of an in-plane component of the sample stray field, leading to asymmetric phase contrasts.
Thirdly, MFM contrast is usually discussed in terms of first or second z-derivatives of the stray field, related to a monopole or dipole approximation for the tip. We show that the long range of stray fields in permanent magnets may bring sensitivity to the field itself, related to sensing the long-range conical shape of the tip.
Consideration of these aspects should contribute to the development of quantitative analysis of MFM images.

TH-2

Preparation of High-Resolution Magnetic Force Microscope Tips Coated with Fe, Fe-Co, and Co Films

T. Hagami [1], K. Soneta [1], M. Ohtake [1], M. Futamoto [1]
(1) Faculty of Science and Engineering, Chuo University, Tokyo 112-8551, Japan

MFM spatial resolution better than 10 nm is required for observations of magnetic bits recorded at areal densities exceeding 1 Tb/in^2. MFM resolution is influenced by the sharpness and the signal detection sensitivity of MFM tip [1]. MFM tips are prepared by coating magnetic materials on non-magnetic sharp tips made of W, carbon nanotube, Si, etc. Fe, Fe-Co alloys and Co are high magnetic moment materials which seem desirable for coating non-magnetic tips to fabricate high sensitivity MFM tips. In the present study, MFM tips were prepared by coating Si tips of 3 nm radius with Fe, Fe-Co, and Co films by varying the thickness from 10 to 30 nm. The MFM tip radius (r) varied in relation to the film deposition thickness (t) as $r = 0.4\,t + 9$ (nm). The remanent magnetization (M_r) of Co film was larger than that of Fe film with a same thickness when deposited on Si substrate, though the saturation magnetization of Fe film is 20% larger than that of Co film. Fig. 1 shows the MFM images of a perpendicular medium recorded at 1200–1700 kFCI observed by using MFM tips coated with 20-nm-thick Fe and Co films and the power spectra of MFM intensity measured along the 1200 kFCI track direction. Clearer bit images are observed with the Co-coated tip. The power spectrum analysis indicates that the spatial resolution of Co-coated tip (7.5 nm) is better than that of Fe-coated tip (8.6 nm), which seems to be related with the larger M_rt value of Co-coated tip. The relationship between Fe/Co composition and MFM resolution will also be discussed at the conference.

[1] K. Nagano *et al.*: *J. Phys. Conf. Ser.*, **303**, 012014 (2011).

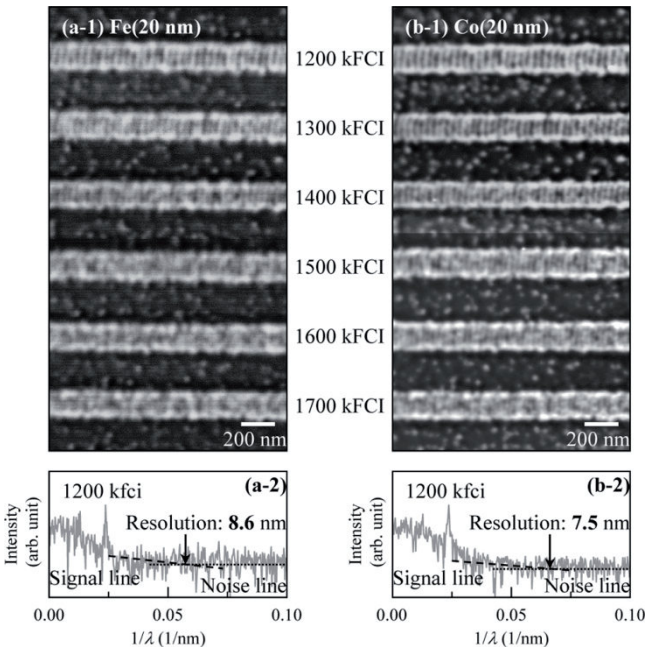

Fig. 1 MFM images and power spectra.

TH-3

Study of the domain wall dynamic in rapidly quenced submicron amorphous wires

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Two well known techniques Magneto-Optic Kerr Effect and Sixtus-Tonks, were combined in this work in the same experiment. In this way we obtained interesting information about shape and velocity of the domain wall during propagation in submicron wires. The effect of wire dimension on the wall shape and velocity is studied in conjunction with their magnetic behavior. The as-prepared wires have the nominal compositions $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ and $Fe_{77.5}Si_{7.5}B_{15}$. Their metallic nucleus diameter was ranging between 130 and 950 nm, while the glass coating thickness was between 13 and 15 μm. We combined two techniques in one experiment by adding a small detection coil system to our Magneto-optic Kerr effect setup (Fig.1).

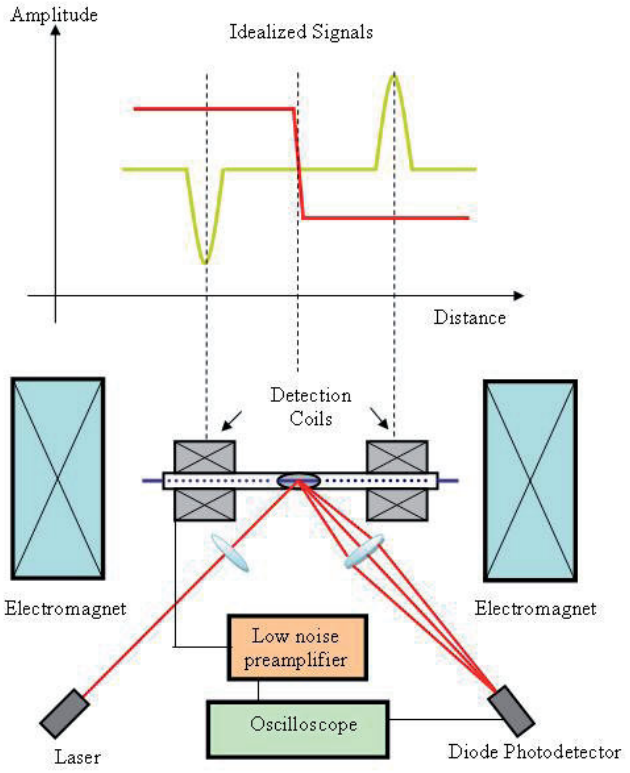

Fig.1. Experimental setup

Magneto-optic Kerr effect provide us information about domain wall propagation at the surface in the same time Sixtus-Tonks techniques give information about wall dynamics in the entire volume of the probe. Both signals the Kerr signal coming from the diode photo-detector and the amplified Sixtus-Tonks signal coming from the detection coils are captured on the oscilloscope screen and analyzed. Now if we consider a domain wall that is passing along the wire we will see on the oscilloscope the two signals and we can study their synchronization. Looking at the acquired signals for our probes and paying attention to the synchronization between the two signals we observe different phase shifts between the signals. Further more the phase shifts between the signals gradually decrease by decreasing the diameter of the measured samples. The effect of wire dimension on the wall shape and velocity are explained in conjunction with their magnetic behavior, and types of anisotropy that determine specific domain structure in glass covered amorphous wires

TH-4

Optimization of distribution functions for the Inverse Preisach Model by Genetic Algorithms

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(1) Scientific and Technical Research center in welding and control (CSC) Cheraga, Algiers, Algeria

In the Non Destructive Testing "NDT" procedure is very important to be informed about modification happened on structure in particular Inspection in Service "ISI" in the prediction life must be studied in the future by using the inverse problem. In our study an efficient method, called the inverse distribution function, for calculating the magnetic field strength H from the flux density B through the Preisach model is developed. According to this technique, H can be obtained from B by determining the parameters of the proposed distribution function using genetic algorithms. In this work various distributions functions will be studied to determine which function gives the best distribution for modeling the hysteresis loop and give maximum information with minimum error on what happened in the microstructure

Keywords: Hysteresis curve; Ferromagnetic material; Preisach model; inverse distribution function. Genetic Algorithms.

TH-5

Identification parameters with neural network for Preisach hysteresis model

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The description of hysteresis is one of the classical problems in magnetic materials. The progress in its solution determines the reliability of modeling and the quality of design of a wide range of devices, The proposed approach has been applied to model the behavior of many samples and the results show the robustness and efficiency of Neural Network to model the phenomenon of hysteresis loop The goal of this study is to optimize the parameters of hysteresis Loop by Preisach model with the Neural Network, the method developed is based on an analysis of two distribution functions. The modified Lorentz function and Gauss function have been analyzed. The implemented software and performances of the distributions are presented.

Keywords: Hysteresis loop, Preisach Model, Lorentzian distribution, Gaussian distribution, Neural Network.

TH-6

Dispersed nanomaterials studied with superparamagnetic resonance: Theory and practice

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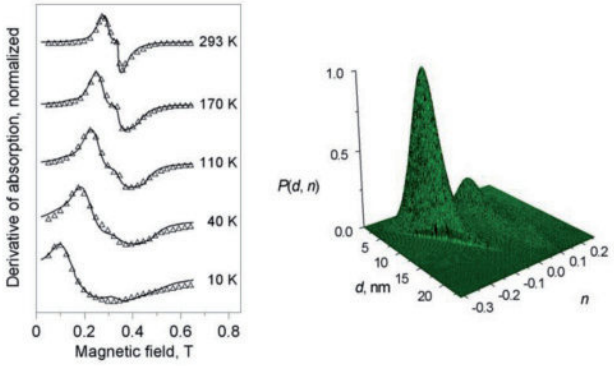
Due to its sensitivity to both the magnetic nature and morphological characteristics, the electron magnetic resonance (EMR) provides a powerful tool for studying physical properties of magnetically ordered particles dispersed in diamagnetic matrices.

Magnetic nanoparticles give rise to a special type of EMR called superparamagnetic resonance (SPR) [1]. We outline the formalism of computer-assisted SPR spectroscopy, in particular, the calculation of resonance magnetic fields and lineshapes, taking into account the nanoparticle size and shape distributions as well as superparamagnetic narrowing.

The application of the theoretical formalism is exemplified by a compendium of recent studies of borate glasses, where magnetic nanoparticles are formed at very low paramagnetic dopant contents. These glasses possess properties of magnetically ordered substances while remaining transparent in a part of visible and near IR range ("transparent magnets") [2]. Such materials are promising for magnetooptical data storage and spin electronics devices.

[1] J. Kliava, in: Magnetic Nanoparticles, S. Gubin, ed., Wiley-VCH, p. 255 (2009).
[2] J. Kliava, I. Edelman et al., J. Magn. Magn. Mater. 323, 451 (2011).



SPR of nanoparticles in borate glass. Left: experimental (full lines) and computer generated spectra (triangles). Right: distribution of morphological parameters extracted from the simulations

TH-7

3D Modelling of Bird Cage Coil By a Hybrid Method For a Magnetic Resonance Imaging System.

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(1) Department of Electrical Engineering,University Mohamed Khider of Biskra,07000 Biskra, Algeria, (2) Department of Electrotechnical, University Mentouri, 25000 Constantine, Algeria

Radio frequency (RF) coils, are key components in a magnetic resonance imaging (MRI) system. They serve two purposes. The first is to generated RF pulse at the Larmor frequency to excite the nuclei in the object to be imaged. The second is to pick RF signals emitted by the nuclei at the same frequency. To obtain high quality MRI images, RF coils must be able to produce a homogeneous B_1 field in the volume of interest at the Lamor frequency so that the nuclei can be excited uniformly.
Over three decade, ago, bird cage resonators (fig. 1) are most popular because they generate a very homogeneous field over a large volume within the coils.
There are many computational methods which have been published for calculating the magnetic field of the birdcage resonator. These cases have been treated by evaluating the magnetic field analytically in terms of functions such as complete or incomplete elliptic integrals of first and second types.
So in this paper we propose a hybrid method to compute the magnetic field which the sum of all magnetic fields produced by conductors coils.
The idea of this work consist to meshing the study area and calculate the magnetic fields produced by the high end ring, law end ring and legs of the birdcage resonator at each point of the numerical mesh, where the magnetic fields, are the sum of the magnetic fields created by the infinitesimal element located on the high end ring, law end ring and legs, respectively in the three dimension study area using the analytical formula (Biot-Savart)

[1] J. Jin, Electromagnetic Analysis and Design in Magnetic Resonance Imaging, CRC press: 1999.
[2] Eriksson, O. and P. Kjäll "Interaction between the RF-field and a stereotactic frame during MRI, a 3D study," Proceedings of COMSOL Multiphysics User's, Stockholm, Dane mark, 2005.

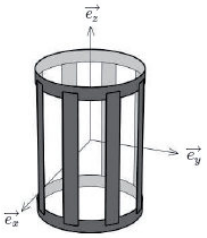

Fig. 1 Illustration of Birdcage coil.

TH-8

A new technique to obtain permittivity and permeability in microwave region

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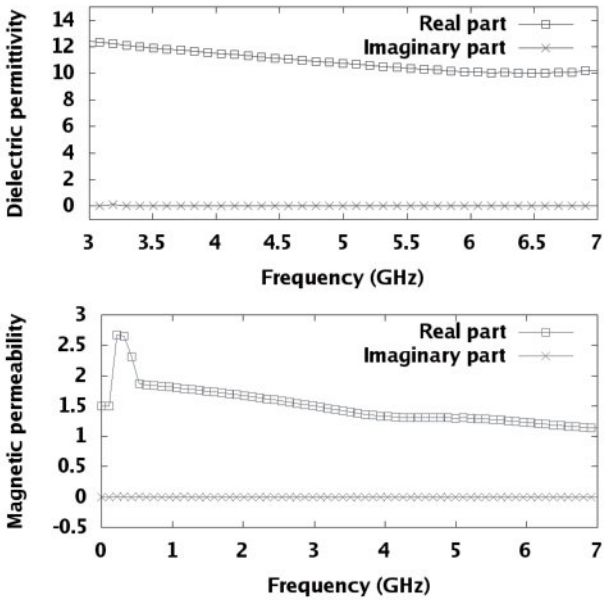
In this work we present a new technique for measuring permeability and permittivity of magnetic materials in a wide microwave frequency range. The most widely used method to obtain such parameters from the characterization of the propagation of microwaves through the material is the Transmission/Reflection method [1], in which both the reflection and the transmission coefficients are measured at once. However, system calibration and experimental setup are rather problematical. As an alternative technique, short-circuited lines, where only the reflection coefficient is measured, have been proposed [2]. Nevertheless, the sample has to be manipulated between measurements, leading to large experimental errors.
Our experimental setup is based on reflection measurements over a short-circuited transmission line combined with the application of a sufficiently high uniform magnetostatic field. As a consequence, the effective permeability of the saturated sample equals the permeability of the free space, without modifying its electrical properties. Therefore, two measurements are then required, with and without external magnetostatic applied field, in order to obtain both the permittivity and the permeability, respectively. As the major advantage, this configuration allows the obtaining of experimental data in just one sweep, without modifying the geometrical characteristics of the sample holder, so that the measurement process can be easily automated and the experimental errors due to sample manipulation are overcome. In addition, 1-port measurements require sample holders that are easy to be designed, so that the calibration process turns out to be much simpler. The system has been succesfully tested in PTFE and magnetite powders in the microwave range up to 7 GHz.
Acknowledgement: Junta de Castilla y León, project VA230A11-2

[1] A.N. Yusoff, M.H. Abdullah, J. Magn. Magn. Mater. 269, (2004)
[2] J. Baker-Jarvis, M.D. Janezic, J.H. Jr. Grasvenor and R.G. Geyer, NIST Technical Note 1355- R. Colorado (1993)



Permittivity and Permeability of magnetite powders

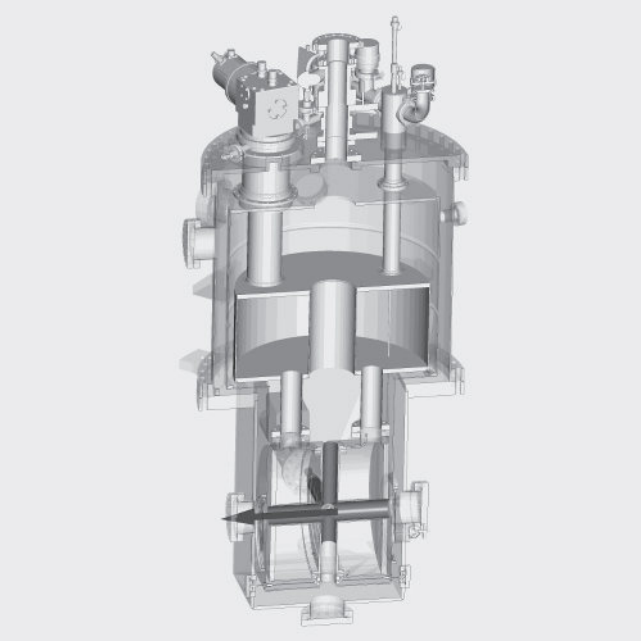


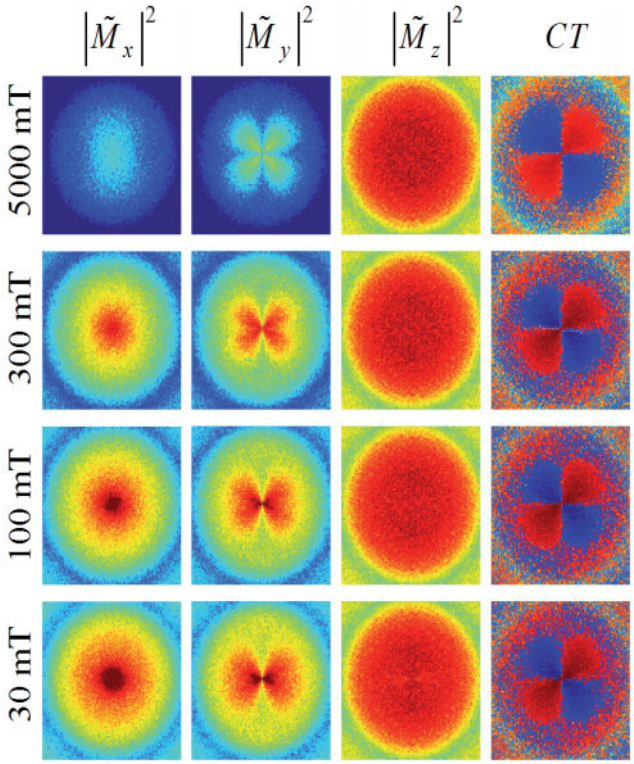
Figure 1: A section through the 14T magnet.

TH-10
14 T Cryo-Magnet for X-ray Magnetic Circular Dichroism
P. Bencok [1], A. Dobrynin [1], P. Steadman [1]
(1) Diamond Light Source, OX11 0DE Didcot, UK

We describe the design, construction and performance of a 14 T cryo-magnet for x-ray magnetic circular dichroism. This end station has been installed on the Beamline for Advanced Dichroism Experiments (BLADE) at the Diamond Light Source. A magnetic field along the horizontal direction is delivered by a superconducting split pair coil. The field vector is aligned with the propagation vector of the incoming soft x-ray beam.
The field polarity can be fully reversed between ±14 T within 1 hour. The magnet vessel and sample is kept in ultra-high vacuum (UHV) at a base pressure of $2x10^{-10}$ mbar. The main cryostat is equipped with two pulse tubes which insure He re-condensing during full operation of the system.
The sample is connected to the variable temperature insert (VTI) which allows the control of the temperature within the range of 3 - 420 K. A vertically mounted insert is coupled to the system through a drive allowing vertical translation and rotation around a vertical axis. The VTI can be replaced by a ^{3}He "Heliox" insert. The sample temperature range accessible with the Heliox insert will be 0.5 – 350 K.
Three detectors are available for signal recording. In-line and side diodes can detect total fluorescent yield (depending on sample orientation). Sample drain current measurement provides the measurement of the total electron yield.
The magnet system has been successfully tested and used during the first user experiment in March 2012.
In future, the magnet system will be extended with a UHV preparation chamber equipped with a nanocluster deposition source with a quadrupole mass filter. This chamber will be available for in-situ preparation of magnetic nanostructures.

TH-11
Magnetic neutron scattering on nanocomposites: Decrypting cross-section images using micromagnetic simulations
S. Erokhin [1], D. Berkov [1], N. Gorn [1], *A. Michels* [2]
(1) INNOVENT Technology Development, Jena, Germany, (2) Laboratory for the Physics of Advanced Materials, University of Luxembourg
We have used numerical micromagnetics for the calculation of the magnetic (small-angle) neutron scattering cross section Σ_M of nanocomposites. In contrast to neutron experiments, in which one generally measures only a weighted sum of the Fourier components of the magnetization, our approach allows one to study the behavior of the individual contributions to Σ_M. The procedure furnishes unique and fundamental information regarding the magnetic microstructure and corresponding magnetic scattering from nanomagnets. In particular, our simulations explain the recent observation of magnetodipolar correlations in two-phase nanocomposites and, moreover, suggest their relevance for a wide range of magnetic materials such as nanocomposites, nanoporous magnets, single-phase magnets with random anisotropy, or magnetic recording media.

[1] S. Erokhin, D. Berkov, N. Gorn, and A. Michels, IEEE Trans. Mag. 47, 3044 (2011).
[2] S. Erokhin, D. Berkov, N. Gorn, and A. Michels, Phys. Rev. B 85, 024410 (2012).
[3] S. Erokhin, D. Berkov, N. Gorn, and A. Michels, Phys. Rev. B 85, in press (2012).



Results of the micromagnetic simulations for the Fourier coefficients of the magnetization.

TH-12

Determination of material constants of magneto-optical crystals using Faraday effect

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(1) National Technical University, "Kyiv. Politekh. Inst." Kyiv 03056, Ukraine

It is theoretically substantiated and experimentally proven by the example of yttrium garnet ferrite that, in ferro- and ferrimagnetic crystals subjected to a constant bias and an additional alternating magnetic fields, magnetostriction phenomena result in additional changes of the variable magnetization component in a vicinity of the alternating-field frequencies close to the resonance frequencies of natural magneto-mechanical oscillations of the crystal. It is shown that these changes can be revealed by measuring the variable component of a turn of the polarization plane of light that passes through the crystal. A mathematical model of mechanical stresses distribution along unfixed pin-type rod under the influence of magnetostriction phenomena is proposed. A technique for the determination of the material constants of a crystal is proposed also.

It is proposed measuring methodology which helped to obtain numerical values of Young's modulus (136.4 GPa) and piezomagtetic constant along magnetic bias field m =1060 T for yttrium ferrite-garnet material [1].

[1]. I.V.Linchevskiy, O.N.Petrischev, V.A.Trohimets, UJP, 55, 947 (2010)

TH-13

The effect of magnetic training on the reversal mechanism in an exchange-biased NiFe/Fe_2O_3 bilayer

D. Cortie [1], F. Klose [1], S. Brueck [1], H. Fritzsche [2], C. Shueh [3], K. Lin [3]

(1) Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW 2234, Australia, (2) National Research Council Canada, Canadian Neutron Beam Centre,Chalk River Laboratories, Bldg. 459, Chalk River, ON, K0J 1J0, Canada, (3) Department of Materials Science and Engineering,National Chung Hsing University, Taichung 402, Taiwan

Polarised neutron reflectometry provides unique experimental insights into the magnetic depth profile and magnetization reversal processes of ferromagnetic/antiferromagnetic bilayer thin films, allowing for better characterization of systems showing the exchange bias effect. By uncovering the depth profile of the magnetic vector at different applied fields, such a measurement reveals specific details for testing the predictions of the growing number of models that aim to explain exchange bias [1,2,3]. We made use of the new Platypus polarized neutron reflectometer at the OPAL research reactor, Sydney, to investigate the impact of magnetic training on the reversal of a hematite a-Fe2O3/$Ni_{80}Fe_{20}$ bilayer film that showed a pronounced exchange bias effect. The field dependence of the neutron spin-flip signal and spin asymmetry was analysed in the biased state, and the first and second magnetic reversal were found to occur by asymmetric mechanisms. For the fully trained permalloy loop, the ferromagnetic reversal occurred symmetrically at both coercive fields by an in-plane spin rotation of ferromagnetic domains in agreement with the previous theoretical prediction made for the $Ni_{80}Fe_{20}$ /a-Fe_2O_3 system[1]. This reversal mechanism is similar to that of the Co/CoO system [2] but entirely different to the case known for MnF_2/Fe [3]. This difference can be explained on the basis of numerical simulations considering the symmetry of the respective antiferromagnet interface structures.

[1] J. Dho, C. W. Leung, Z. H. Barber, and M. G. Blamire, Phys. Rev. B 71, 180402 (2005).
[2] F. Radu, M. Etzkorn, R. Siebrecht, T. Schmitte, K. Westerholt, and H. Zabel, Phys. Rev. B. 67, 134409 (2003).
[3] M. R. Fitzsimmons, P. Yashar, C. Leighton, I. K. Schuller, J. Nogues, C. F. Majkrzak, and J. A. Dura, Phys. Rev. Lett. 84, 3986 (2000).

TH-15

Measurement of the Structural Unit in Magnetic Dispersions

T. Mercer [1], P. Bissell [2]

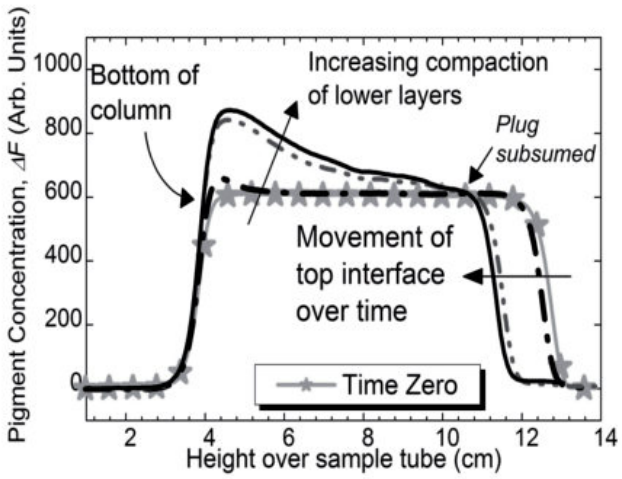
(1) Magnetic Materials Research Group, Institute of Nanotechnology & Bioengineering, University of Central Lancashire, PRESTON PR1 2HE, UK, (2) Centre for Materials Science, University of Central Lancashire, PRESTON PR1 2HE, UK

The characterisation of magnetic dispersions is an important field of study with a wide range of applications that includes advanced digital linear recording media at one end and an increasing interest [1] in nanoparticulate suspensions for potential biomedical treatments at the other.

In general, it is known that concentrated and complex suspensions consist of Structural Units (SUs) involving multi-particle structures that contain trapped fluid [2]. In the work reported here, the equilibrium state structure has been investigated

on a model system (based on a commercial recording media formulation) using a Scanning Column Magnetometer (SCM) and cone and plate rheometry techniques. SCM plots of magnetic particle concentration as a function of suspension column height are shown in the figure over time. The profiles show sedimentation indicative of a hindered settling system where a 'plug' of constant particle concentration falls 'en-bloc' at an initially constant rate into the lower compression layers. From the subsequent hindered settling analysis, in combination with evaluation of the complex viscosity of the liquid phase that is 'free' to flow up and around the SUs during the sedimentation process (free-fluid), a large volume fraction of 84% for the liquid trapped inside the SU was estimated that yielded an equivalent Stokes' particle diameter, d, of ($5.2 \leq d \leq 8.2$) microns. This compares well with computer simulations based on hindered settling theory that require correspondingly large trapped-liquid fractions in order to obtain concentration profiles similar to those of the figure and gives confidence in the SU size (particle plus trapped-liquid) obtained being approximately 22 times bigger than the ferric oxide particles of our formulation.

[1] T. Sen *et al.*, RSC Advances (in press)
[2] D. Quemada, European Physical Journal-Applied Physics 1, 119 (1998)



SCM magnetic particle concentration profiles of a sedimenting dispersion.

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS…)

Chair: J. Amaral

TH-16

Toward optimal magnetocaloric materials with first order transition: study of adiabatic temperature change

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(1) Leibniz Institute for Solid State and Materials Research (IFW),D-01171 Dresden, Germany, (2) National University of Science and Technology MISiS, Moscow 119049, Russia, (3) Fachbereich Material- und Geowissenschaften, Technische Universität Darmstadt, D-64287 Darmstadt, Germany

Compounds with first-order ferromagnetic-paramagnetic phase transitions are very promising for utilizing in magnetic cooling devises due to very high values of the magnetic entropy change ΔS_m [1]. However, the high value of ΔS_m is though indispensable but not sufficient for a magnetic material to be regarded as suitable for using in magnetic refrigeration technology. For practical application in the magnetic cooling, the adiabatic temperature change ΔT_{ad} is the critical quantity which should be maximized [2,3].
Using isothermal and adiabatic *M-H* loops, the magnetic entropy change ΔS_m, the adiabatic temperature change ΔT_{ad}, and the heat capacity c_p a comprehensive study of magnetocaloric properties of bulk $La(Fe,Si)_{13}$, Ni-Mn-Ga, and Ni-Mn-Sn alloys undergoing a first-order magnetic transition has been carried out. Based on the experimentally measured *M(T) M(H)* and $c_p(T)_H$ dependencies, *H-T* and *S-T* diagrams were constructed and used to explain the shape of $\Delta T_{ad}(H)$ dependencies. A relation between optimum operational parameters of a magnetic refrigerant and the maximum available field has been obtained for an idealized first-order transition.
In this work, we performed numerical simulation using our ΔT_{ad} and c_p data and determined the maximum possible cooling power for reversible refrigeration cycles with $La(FeSi)_{13}$ and Ni-Mn-Sn alloys. The results clearly demonstrate the functional ranges of these refrigerants.

[1] O. Gutfleisch, M. A. Willard, E. Bruck, C. H. Chen, S. G. Sankar, and J. P. Liu, Adv. Mater. 23, 821 (2011)
[2] V. V. Khovaylo, K. P. Skokov, O. Gutfleisch, H. Miki, R. Kainuma, and T. Kanomata, Appl. Phys. Lett. 97, 052503 (2010)
[3] K. P. Skokov, V. V. Khovaylo, K.-H. Müller, J. D. Moore, J. Liu, and O. Gutfleisch, J. Appl. Phys. 111, 07A910 (2012)

TH-17

Kinetics of the first order magneto-structural phase transition of MnBi

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(1) Istituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, Torino, I-10135, Italy

The α-MnBi intermetallic compound (hexagonal NiAs-type) is an interesting material for rare-earth free high temperature permanent magnets, because it has a uniaxial magnetic anisotropy along the *c*-axis increasing with temperature and maximum value $2.2x10^6$ Jm^{-3} around 500 K [1,2]. MnBi undergoes a first order magneto-structural phase transition at 628 K where the ferromagnetic α-phase transforms into the paramagnetic β-phase with a change of the *c*/*a* ratio of the cell and the diffusion of Mn atoms from the octahedral sites into trigonal bypiramidal holes of the Bi layers. Further understanding of the microscopic feature of the transition may hopefully lead to development of Mn-based alloys with optimized magnetic properties. In this paper we investigate the kinetics of the α-β phase transformation in polycrystalline samples. The alloy has been prepared by rapid quenching followed by annealing [2]. SEM, XRD and DSC analyses show that the prepared alloy contains α-MnBi (86 wt%) together with small Mn grains (9 wt%) and a residual Bi-rich interface (5 wt%). By changing the DSC temperature scan rate and taking into account the thermal contact resistance, we find that the α®β transition is almost rate independent while the β®α transition temperature T_c has a logarithmic rate dependence which is typical of thermal activated processes. The kinetics is interpreted in terms of the energy barriers for the α-β first order phase transition.

[1] J. M. D. Coey, *Magnetism and magnetic materials*, Cambridge University Press, Cambridge (2009).
[2] T. Chen T and E. Stutius, IEEE Trans. Magn. **10**, 581 (1974).

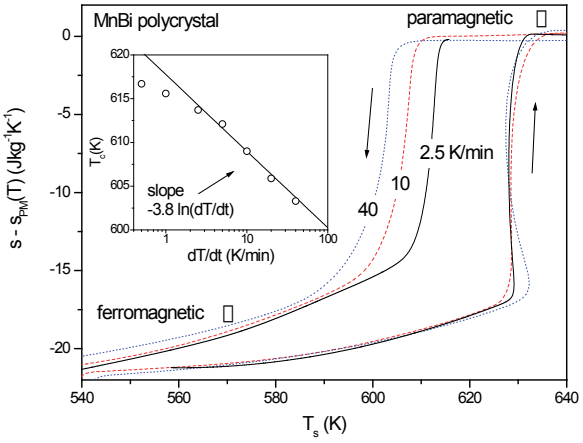

Fig.1 Rate dependent hysteresis of the entropy of MnBi (Tds_{PM}/dT = 220 $Jkg^{-1}K^{-1}$)

TH-18

Magnetism and Large Magnetocaloric Effect in $HoFe_{2-x}Al_x$

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The structural, magnetic and magnetocaloric properties of several $HoFe_{2-x}Al_x$ compounds were investigated. The compounds in the Fe-rich region ($0.36 < x < 0.4$) crystallize in the cubic $MgCu_2$ (C15) structure, while for the ones in the intermediate region ($0.75 < x < 1.125$) the hexagonal $MgZn_2$ (C14) structure was observed. All of the compounds display ferrimagnetic order, the Ho and Fe moments being antiparallelly oriented. For hexagonal $HoFe_{2-x}Al_x$, the Fe magnetic moments at 5 K increase from 1.04 μ_B/atom (x = 0.75) to 1.64 μ_B/atom (x = 1.125), whereas for the cubic compounds they decrease from 1.30 μ_B/atom (x = 0.36) to 1.15 μ_B/atom (x = 0.4). The Curie temperatures were found to decrease with increasing Al content. For the Fe-rich compounds, these are close to room temperature, while for the compounds in the intermediate region, transition temperatures are well below 300 K. All of the investigated compounds undergo a second-order magnetic phase transition at the Curie temperature. A maximum magnetic entropy change value of 7.6 J/kgK was obtained for the sample with x = 1.125, all of the studied samples displaying rather large RCP values. These are mainly attributed to the large δT_{FWHM} values of the $\Delta S_M(T)$ curves. No magnetic hysteresis was found around the Curie temperature for applied fields of up to 4 T. Due to their high magnetocaloric parameters and low hysteresis losses, the potential application of these materials in magnetic refrigeration devices is discussed. The authors would like to acknowledge support from project POSDRU/88/1.5/S/60185-"Innovative doctoral studies in a knowledge based society".

TH-19

Specific heat and magnetocaloric effect in the doped Dy-Ho-Co_2 solid solutions

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Polycrystalline samples of $DyCo_2$, $HoCo_2$ and their solid solutions $Dy_{1-x}Ho_xCo_2$ with x = 0.1-0.5 have been studied using X-ray diffraction analysis and heat capacity measurements. These compounds were synthesized using high-purity rare earth metals and cobalt. The X-ray diffraction performed at room temperature allowed us to reveal that the $DyCo_2$, $HoCo_2$ and their solid solutions solidify with the formation of the C15 cubic Laves phase structure corresponding to the Fd3m space group. The heat capacity was measured using Quantum Design PPMS 14 Heat Capacity System in a temperature range of 2-295 K without the magnetic field and in a magnetic field of 0.5, 1 and 2 T. $DyCo_2$, $HoCo_2$ and their solid solutions $Dy_{1-x}Ho_xCo_2$ with x = 0.1-0.5 are typical rare earth ferrimagnets and are magnetically ordered at temperature below 140 K. Their Curie temperatures decrease from 138 K for $Dy_{0.9}Ho_{0.1}Co_2$ to 118 K for $Dy_{0.5}Ho_{0.5}Co_2$. In the case of starting compounds T_C~140 K for $DyCo_2$ [1] and 76 K for $HoCo_2$ [2]. The magnetocaloric effect has been estimated from specific heat measurements for all solid solutions in magnetic fields up to 2 T.
The theoretical calculations performed by Oliveira suggest that composite materials made up of several samples of the doped compounds $Dy_{1-x}Ho_xCo_2$ can be very useful to work as magnetic refrigerant in the range of temperature 110-130 K [3]. In the present work we want to respond to above results. The influence of the partial replacement of Dy by Ho in $Dy_{1-x}Ho_xCo_2$ solid solutions on the phase structure, magnetic properties (T_C, phase transition) and MCE has been studied experimentally.

[1] D.H. Wang, S.L. Tang, H.D. Liu, W.L. Gao, Y.W. Du, Intermetallics 10, 819 (2002)
[2] G. Srinivas, S. Ramaprabhu , J. Alloys Compd. 497, 28 (2010)
[3] N.A.Oliveira,), Eur. Phys. J. B 65, 207 (2008)

TH-20

Improvement of magnetic refrigerant capacity by nanocrystallization of Gd-Fe-Al-B amorphous ribbons

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The magnetocaloric effect (MCE) has attracted a great deal of scientific interest because it is a basis of the environmentally friendly magnetic refrigeration technology. In this work, we report on the beneficial effect of partial crystallization on the MCE response of melt-spun $Gd_{65}Fe_{20}Al_{10}B_5$ alloys. The magnetic entropy changes, ΔS_m, were calculated from the M(H) dependences measured in the temperature range from 5 to 390 K. The value of the maximum magnetic entropy change under 5 T for the as-cast amorphous $Gd_{65}Fe_{20}Al_{10}B_5$ ribbon reached 5.01 J/kg K at 185 K. The corresponding value of the refrigerant capacity (RC) determined as the area below the ΔS_m peak with the integration limits at its half maximum is 647 J/kg. We have found that the RC value can be enhanced by suitable heat treatment leading to a formation of hexagonal Gd nanoparticles embedded in a residual amorphous matrix. The annealing induced partial crystallization leads to an appearance of a bimodal ΔS_M behavior. The major peak of the ΔS_m dependence that corresponds to Gd-nanocrystals is placed at 290 K while the peak related to the amorphous matrix phase is gradually shifted with the progressive crystallization towards the lower temperatures. Consequently, the magnetic refrigerant capacity of the partially crystallized alloys is higher than that of original amorphous precursor. Refrigerant capacity can be further enhanced by using the composite systems based on the parallel utilization of two ribbons containing different amount of nanocrystalline particles. This approach allowed us to reach the RC values, which are ~ 20 % larger than that of parent amorphous alloy.

TH-21

Magnetothermal properties of $Gd_{75}M_{25}$ (M = Co, Ni) alloys improved by amorphization

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Gadolinium-based materials are prospective for applications in magnetic refrigeration cycles at various temperature ranges. The amorphous $Gd_{75}Co_{25}$ and $Gd_{75}Ni_{25}$ samples were prepared by a melt-spinning technique and also by ball milling in an evacuated brass mortar. The specific heat measurements were performed for melt-spun amorphous samples for the first time. The amorphous $Gd_{75}Co_{25}$ and $Gd_{75}Ni_{25}$ alloys are found to exhibit a ferromagnetic (F) behavior unlike antiferromagnetic (AF) ordering in the crystalline compounds which show the AF-F phase transition under application of the magnetic field [1]. Moreover, a substantial growth of the magnetic ordering temperature up to 172 K has been observed in the melt-spun $Gd_{75}Co_{25}$ in comparison with T_N=130 K for the crystalline Gd_3Co compound, which is associated with the appearance of a magnetic moment on Co atoms. The presence of a Co magnetic moment induced by amorphization in $Gd_{75}Co_{25}$ is confirmed by NMR studies For the liquid quenched and ball-milled $Gd_{75}Ni_{25}$ alloys, the calculated values of the isothermal magnetic entropy (ΔS_M) change are estimated to be -3.6 and -4 J kg^{-1} K^{-1}, respectively, at a field change of 20 kOe in comparison with $\Delta S_M \approx$ -0.4 J kg^{-1} K^{-1} for the crystalline Gd_3Ni compound. Amorphous samples exhibit much higher refrigerant capacities in comparison with their crystalline counterparts. Our results have shown that the amorphization substantially changes the magnetic state and enhances the magnetothermal properties of Gd_3M (M = Co, Ni).

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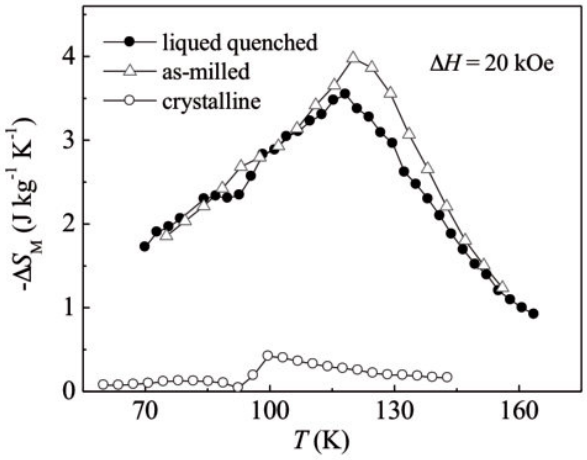

The ΔS_M versus T at a field change of 20 kOe for the amorphous $Gd_{75}Ni_{25}$ alloys in comparison with crystalline Gd_3Ni.

[1] G.J. Primavesi and K.N.R. Taylor, Phys. F: Metal. Phys. **2**, 761 (1972).

TH-22

Tailoring the Magnetism of $Tb_5Si_2Ge_2$ Magnetocaloric Compound by La Substitution

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The most promising magnetocaloric materials have been those which display a first order transition that usually combines both magnetic and structural components, particularly those belonging to the R_5(Si,Ge)_4 system [1]. This system attracts much attention due to its intriguing properties: magnetic and structural coupling, competition between ferro and

antiferromagnetic order. The chemical substitution, because of its effects on the structural and magnetic orders, emerges as an excellent tool to probe and study this system [2].
In order to study the crystal structure, magnetic properties and the corresponding magnetocaloric effect of the system Tb_{5-x}La_xSi_2Ge_2, a series of polycrystalline samples with compositions ranging from x=0 up to x=5 have been synthesized and thoroughly characterized [3]. At room temperature, two crystallographic structures have been detected: Monoclinic ($0 \leq x < 1$) and Tetragonal ($x > 1$) compounds. The unit cell volume increases linearly with La concentration, but with two different slopes: ~ 18 Å^3/ x and ~ 33 Å^3/ x, for $0 \leq x < 1$ (M) and $x > 1$ (T), respectively. In the Monoclinic region, an increase of T_C was observed, reaching a maximum value of T_C ~ 154K, at the x=0.75 composition. The samples that crystallize in the Tetragonal structure, exhibit a linear decrease of T_C(x) with a slope of $\partial T_C / \partial x = -38$ K/x . A magnetic and structural x-T phase diagram of Tb_{5-x}La_xSi_2Ge_2 system in the temperature range 2-300 K is proposed.

[1] Pecharsky V.K. and Gschneidner Jr. K.A Pure Appl. Chem., 79 (8), (2007).
[2] S. Misra,and G. J. Miller, J. Am. Chem. Soc. 130, 13900-13911 (2008).
[3] Belo J. H., Pereira A. M., de La Cruz C., dos Santos A. M., Morellon L., Magen C., Algarabel P.A., Ibarra M. R. and Araújo J. P. , submitted to Phys. Rev. B.

TH-23
Improvement of magnetocaloric properties of Gd-Ge-Si alloys by alloying with iron
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Gd-Ge-Si alloys exhibit very interesting magnetocaloric properties at the near-room temperature range. Measured MCE characteristic values are quite large. Also the temperature range of the effect may be tuned by little variations of chemical composition, usually changing Ge and Si proportion.
In this work, iron addition after arc melting are used to modify the properties of $Gd_5Ge_2Si_2$ alloys. Here, $Gd_5Ge_2Si_2Fe_x$ (x = 0-1) alloys were arc molten. The structure was assessed with XRD, and magnetocaloric properties were evaluated with VSM option on PPMS (Quantum Design), from which the entropy change, ΔS_M, was calculated. Additionally calorimetric measurement were performed in the temperature range 213K – 313K, using DSC method.
The results of the study showed that the dope of 0.2 mol Fe only negligibly changes the properties. Further addition of iron significantly increases the magnitude of entropy change in the arc molten alloys, leading to the values of -6 J/kgK, as compared to -3.5 J/kgK for the generic alloy (all values measured for 0 - 2 T field change).
The lattice parameter of the Fe-doped alloys slightly drops compared to the $Gd_5Ge_2Si_2$ alloy. The increase of iron content beyond x = 0.4 does not improve much the properties, but still reduces the temperature of ΔS_M maximum. DSC results showed some correlation between calorimetric curves and phase transitions observed in investigated materials.
The results of this study indicate that the minor addition of iron to Gd-Ge-Si alloys may be useful in improving the materials' magnetocaloric properties.

TH-24
Microstructure analysis of ageing on magnetocaloric materials
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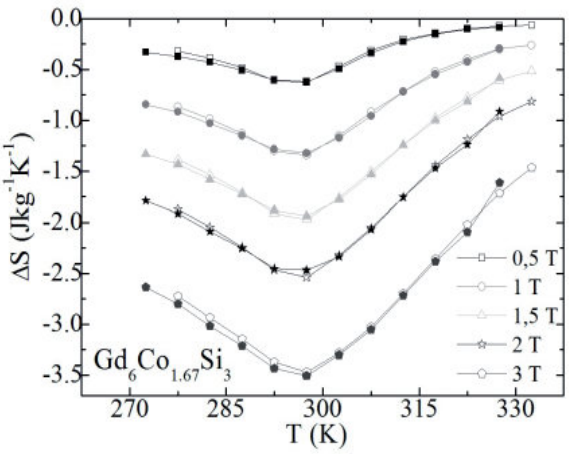
In recent years there was great quest for search of magnetocaloric materials for applications in ambient temperature cooling-refrigeration [1]. They are preferred over conventional vapor refrigerators as they are more power efficient, environmentally friendly and low noisy. Magnetocaloric materials have been successfully tested in cryogenic refrigeration and lot of prototypes has been proposed for near room temperature domestic applications. It is worthy to investigate ageing effect of these materials in order to know the reliability, durability and improve their performance [2].

$Gd_6Co_{1.67}Si_3$ was recently explored for its room temperature magnetocaloric effect (MCE) [3]. Here we will present x-ray diffraction and microstructural analysis of experimental results during ageing of $Gd_6Co_{1.67}Si_3$. To artificially stimulate ageing, $Gd_6Co_{1.67}Si_3$ was treated continuously with constant flux of water and surface properties were studied in defined interval of time. Based on our experimental investigations we will propose a model to explain the ageing process. Interestingly, no change in the bulk magnetocaloric performance are observed even after 3 month of ageing.

[1] K. A. Gschneidner et al., Rep. on Prog. Phys. 68, 1479 (2005); E. Brück et al., Nature 415, 150 (2002)
[2] F. Canepa et al., J. Phys. D Appl. Phys. 41, 155004 (2008)
[3] B. Chevalier et al., Chem. Mater. 20, 2972 (2008)



Entropy change for starting (solid symbol) and 3 month aged sample (open symbol)

TH-25
Correlation of Heat Treatment, Structure and Properties of $La(Fe,Si)_{13}$ Alloys for Magnetocaloric Cooling
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In this work, $La(Fe_{1-x}Si_x)_{13}$ alloys (x = 0.13, 0.15 and 0.20) were investigated to optimise the chemical composition and

manufacturing process in order to obtain the material that would exhibit good magnetocaloric properties. The alloys were arc molten and annealed at 1250°C for 5 hours with different cooling rate. The structure was investigated with x-ray diffractometry (XRD), scanning electron microscopy (SEM) and differential thermal analysis (DTA). Magnetocaloric properties (entropy change from 0 to 2 T) were derived from thermomagnetic curves, measured with a vibrating sample magnetometer. It was found that arc molten alloys contained 36 - 40% of bcc-iron, and this amount was reduced to 10 - 17% if annealing was followed by water quenching. In comparison to arc molten alloys, free air cooling after annealing enhanced the entropy change for x = 0.13 similarly to water quenching, but had insignificant effect for x = 0.15. Water cooling after annealing increased the entropy change from 1.3 J/kgK (arc molten state) to 2.6 (x = 0.13) and 3.5 J/kgK (x = 0.15). SEM images with chemical composition analysis revealed inhomogeneities in the samples, and that mainly two phases were present in the alloys: $La(Fe,Si)_{13}$ and probably LaFeSi, with no evidence of bcc-Fe presence. Contrary to this, in the XRD patterns, peaks from bcc-Fe were seen. SEM images showed that annealing and water quenching increased the volume fraction of $La(Fe_{1-x}Si_x)_{13}$ phase as well as changed its morphology. DTA measurements revealed that water quenching results in a single reaction upon heating around 1410°C, meaning one dominant phase present in the structure of the alloys, while the thermograms of slowly cooled samples exhibited two reactions. The above results indicated that water quenching after annealing stabilised the $La(Fe,Si)_{13}$ phase. Among the investigated alloys, $La(Fe_{0.85}Si_{0.15})_{13}$ exhibited the largest entropy change.

TH-26

Rate dependence of the magnetocaloric effect in La-Fe-Si compounds

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In magnetic refrigeration the magnetocaloric material is subjected to magnetic field and temperature cycling at moderate frequencies. If the magnetic refrigerant material exhibits a first order magneto-structural transition, in a dynamic regime the cooling efficiency may be reduced due to hysteresis and rate dependence. La-Fe-Si compounds are promising for magnetic refrigeration since they are produced by conventional powder metallurgical routes and the transition temperature can be easily tuned by substitution and/or hydrogenation. Recently, kinetic effects have been studied on $LaFe_{11.44}Si_{1.56}$ (temperature induced transition) [1] and of $LaFe_{11.7}Si_{1.3}$ (field induced) [2] and explained in the framework of thermal activation by using the Johnson-Mehl-Avrami model. However, it was pointed out by [3] that also non-isothermal measurement conditions lead to similar rate dependencies.

In the presented paper we analyse the dynamics of the field and temperature induced transition in La-Fe-Si compounds. A Peltier Differential Scanning calorimeter [4], working in the temperature range from 77-300K, was employed. The calorimeter dynamic was optimized using fast micro-Peltier heat flux sensors (heat diffusion time constant 0.24s). We measure specific heat and isothermal entropy change at various rates, and relaxation at constant field. In Fig.1, it is shown that the observed rate dependencies are strongly correlated to the thermal contact between sample and heat sensor, which was optimized by using silver-paste as contact medium. The transition kinetics was then analyzed in the framework of thermal activation by using the Arrhenius law, correcting the measurement data for the residual thermal contacts in the setup as described in [4].

[1] A. Fujita and H. Yako, J. All. Comp. In Press
[2] H. Zhang et al., Phys. Rev. B, 70, 212402 (2004)
[3] J.D. Moore et al., Appl. Phys. Lett. 95, 252504 (2009)
[4] V. Basso et al., Rev. Sci. Instr. 81, 113904 (2010)

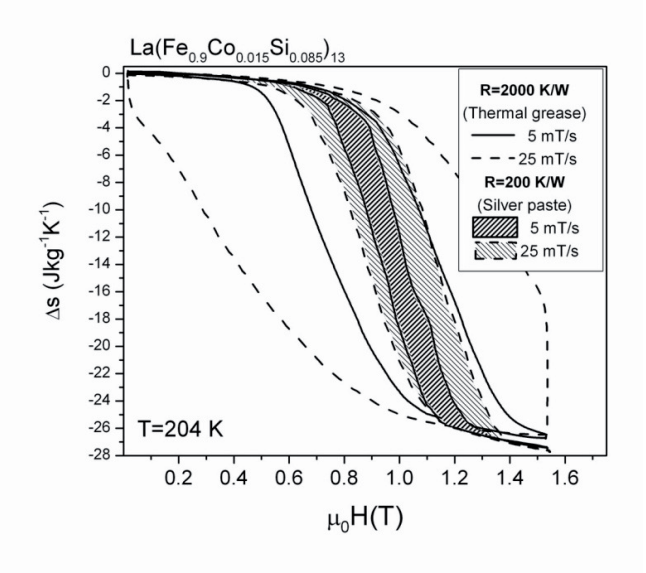

Fig.1 Rate dependent hysteresis of Δs(H).

TH-27

Phase constitution, magnetic ordering and microstructure of the $LaFe_{11.0}Co_{0.8}Si_{1.2}$ alloy

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Large magnetocaloric effect at around room temperature and relatively low costs of the $La(Fe,Si)_{13}$-type alloys of the cubic $NaZn_{13}$-type structure coursed their intensive studies over the last few years. For the $La(Fe,Si)_{13}$ alloy, magnetic entropy change reaches about 30 J kg^{-1} K^{-1}, under external magnetic field change of 5T, however this occurs at relatively low temperature of ~200K. Appropriate admixture of this alloy allows to obtain magnetocaloric effect near room temperature. The $La(Fe,Si)_{13}$-type alloys are intensively studied due to the possibility of application as an active elements in magnetic refrigerators. In the present work master alloy was prepared by arc-melting of the high purity elements under the Ar atmosphere. Ribbons were obtained using controlled atmosphere melt-spinning technique Subsequently the samples were annealed at 1323K for 24 hours (in case of ribbons) and 28 days (in case of bulk specimens). The phase composition of the samples was studied by X-ray diffraction and mössbauer spectroscopy. The microstructure and chemical composition of the alloy in as-cart state and subjected to annealing was performed using EDX incorporated to the SEM.

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TH-28

Phase transition and magnetocaloric effect in the $La(Fe,Co,Si)_{13}$-type alloys

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Comparative studies of the $LaFe_{11.0}Co_{0.8}Si_{1.2}$ and $LaFe_{11.0}Co_{0.8}(Si_{0.4}Al_{0.6})_{1.2}$ alloys produced by arc-melting followed by long time annealing at 1323K were performed. The phase analysis revealed almost single phase composition of the annealed samples. The high intensity synchrotron radiation was used for studying the thermal evolution of lattice constant of the $La(Fe,Co,Si)_{13}$ phase. Furthermore, calculations of temperature dependences of Landau coefficients were use to reveal changes in the character of phase transformation at around the Curie point. Furthermore it was shown that differences in the phase transition order for $LaFe_{11.0}Co_{0.8}Si_{1.2}$ and $LaFe_{11.0}Co_{0.8}(Si_{0.4}Al_{0.6})_{1.2}$ alloys has also an effect in their maximum entropy change values.

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TH-29

Magnetocaloric effect of $Mn_5Ge_{3-x}Sn_x$ and $Mn_3Sn_{2-x}Ge_x$ ternary alloys

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Recently manganese based alloys proved to be promising magnetocaloric materials. MnAs is the material with the highest magnetocaloric effect (MCE) in the whole family of manganese based compounds. As the elements from the 15 group of periodic table are highly toxic (As,P,Sb), other manganese alloys are extensively studied. We have performed research on two binary alloys i.e. Mn_3Sn_2 (orthorhombic structure) and Mn_5Ge_3 (hexagonal structure). Both compounds have second order transition near the room temperature. As the adiabatic temperature change is relatively small in those alloys (~ 1K at magnetic field 1.7 T), we have checked the effect of exchange Ge in Mn_5Ge_3 on Sn and Pb and the effect of exchange Sn in Mn_3Sn_2 on Ge and Pb on MCE strength. The most interesting are the ternary alloys $Mn_5Ge_{3-x}Sn_x$ and $Mn_3Sn_{2-x}Ge_x$ with x characteristic for the ratio for which initial phase becomes unstable. At certain x the crystallographic structure is changing which is connected with the significant drop in manganese magnetic moment. We have checked if the magnetic field (0-1.7 T) is able to reverse structural transition in these compounds, which in consequence could result in the significant increase of MCE.

TH-30

The crystal and magnetic structure of the magneto-caloric compounds $Mn_{0.66}Fe_{1.29}P_{1-x}Six$ (x = 0.34, 0.37 and 0.42)

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The magneto-caloric effect (MCE) is the thermal response of a magnetic material to an applied magnetic field, results in a change of temperature.[1,2] The MCE can be employed in a thermal cycle to achieve cooling, i.e. magnetic refrigeration. $(Mn,Fe)_2(P,Si)$ compounds are best known for their potential for room-temperature magnetic refrigeration, due to large MCE and tunable working temperatures, cheap and abundant raw materials.[3]

The single phase compounds $Mn_{0.66}Fe_{1.29}P_{1-x}Si_x$ (x = 0.34, 0.37 and 0.42) have been synthesized and the magnetic properties and magneto-caloric effect have been investigated. The crystal and magnetic structure have been investigated by means of neutron and X-ray powder diffraction. The refinement shows the compounds crystallize in the hexagonal Fe_2P-type structure (P-62m). It is found that the 3f site is nearly completely occupied by Fe atoms; the 3g site is occupied by Mn atoms and the excess Fe atoms, while the P and Si are randomly mixed. It is shown that, for the compound with x = 0.34, the total magnetic moment is 4.47 μ_B/f.u., which is in a good agreement with the value (4.56 μ_B/f.u.) obtained from magnetic measurement. The average magnetic moment in the 3g site is larger (2.65 μ_B) than in the 3f site (1.82 μ_B), The alignment of the magnetic moment has changed from almost c-direction to the a-b plane with increasing Si content from x = 0.34 to x = 0.42. The compounds show a strong magnetic field induced transition, small magnetic hysteresis and large magnetic entropy changes.

[1] V.K. Pecharsky and K.A. Gschneidner, Phys. Rev. Lett. 78, 4494 (1997).
[2] E. Brück, J. Phys D: Appl. Phys. 38, p. R381-R391 (2005).
[3] D. T. Cam Thanh, E. Brück, N. T. Trung, J. C. P. Klaasse, K. H. J. Buschow, Z.Q. Ou, O. Tegus and L. Caron, J. Appl. Phys. 103, 07B318 (2008)

TH-31

Influence of compositional tuning on the transition temperature of Iron rich $(Mn,Fe)_2(P,Ge)$

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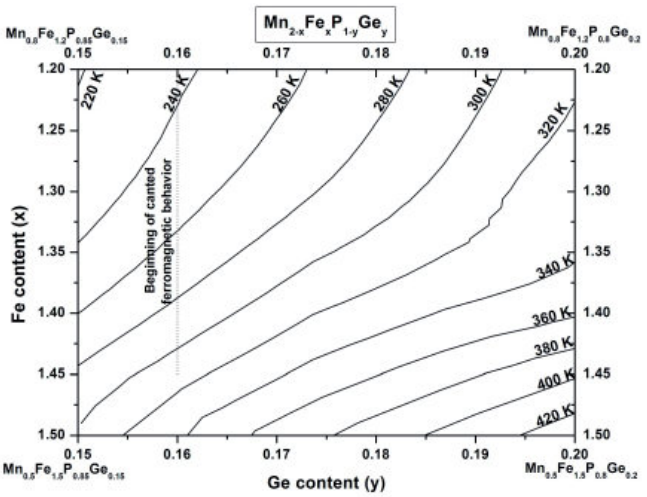
The magnetocaloric effect has gained increasing relevance as a cheap and "green" alternative to current vapor cycle refrigeration. Although this effect is known since the late 1920s [1], it is still to be applied to a viable commercial cooling device. As such, there has been a constant search for more effective, cheap and non-toxic working materials that may open the possibility for such a refrigerator.

In this context, the (Mn,Fe)_{2}(P,Ge) system is very promising for magnetocaloric application, having a highly tunable

transition temperature (T_{C}), thermal hysteresis and high magnetization [2].
However, it has the drawback of being relatively expensive due to the use of Germanium, jeopardizing its use in a commercial refrigerator.
Still, results presented by Trung et al. [2], and Dung et al. [3], on the similar (Mn,Fe)_{1.95}(P,Si) system, reveal that increasing Fe composition triggers an increase in T_{C}, which may be compensated by decreasing Ge or Si, respectively.
This suggests that if Fe composition is raised enough in the (Mn,Fe)_{2}(P,Ge) system, Ge composition may be significantly reduced making this system commercially viable.
Thus, Fe rich samples belonging to the (Mn,Fe)_{2}(P,Ge) system, with 0.15<Ge<0.2, were produced so their structure and T_{C} could be monitored.
Our results confirm our hypothesis, with T_{C} being easily manipulated with Fe content, allowing a significant decrease in Ge content. However, T_{C} does not seem to change linearly with compositional tuning, and furthermore, in samples with Ge compositions of 0.16 or 0.15 a complex canted ferromagnetic behavior becomes evident, this behavior, however, seems to gradually disappear is large Fe concentrations.

[1] P. Debye, Ann. Phys. 81, 1154 (1926)
[2] N. T. Trung et al., Appl. Phys. Lett., 94, 102513 (2009)
[3] N. H. Dung et al., Appl. Phys. Lett., 99, 092511 (2011)



T_{C} dependence with Fe and Ge concentration in the (Mn,Fe)_{2}(P,Ge) system

TH-32

Theoretical studies on the Curie temperature dependency of the magnetocaloric effect

J.H. Belo [1], J.S. Amaral [2], A.M. Pereira [1], S. Das [3], V.S. Amaral [3], *J.P. Araujo [1]*
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For the past fifteen years, a very devoted effort has been made into the optimization of the magnetocaloric effect in several different alloy families [1]. Such effort is of crucial importance for the applicability and commercialization of magnetic refrigeration technology.
The most conventional way to characterize the MCE of a given magnetic material is through the temperature dependence curve of its magnetic entropy change (ΔSm(T)), namely through its peak value (ΔSm_{MAX}), T_C and the refrigerant capacity [1].
A considerable effort has been made on applying various theoretical models to the study of the MCE, from phenomenological theories ([2], [3]), to microscopic models. Nevertheless, there is a notable lack of direct relations between the MCE and microscopic magnetic parameters.
Herein, we have performed theoretical simulations in order to study the dependency of the ΔSm(T) curves on a set of magnetic parameters such as: Curie temperature (TC), spin number (J) and applied magnetic field (H). The simulated ΔSm(T) curves for both first and second order magnetic transitions were obtained within the framework of the molecular mean field model and by including the Bean-Rodbell volume dependency of the exchange [2]. The simulated results outcome a dependence of ΔSm_{MAX} on Tc-2/3, for both second- and first-order systems. This dependency is further justified by establishing a direct relation between ΔSm_{MAX} and system parameters and is confirmed experimentally in several families of both second- and first-order magnetocaloric materials, such as: Gd_5(Si_xGe_{1-x})_4 for x < 0.4 , RCo_2, MnFe(P_{1-x} As_x) and RR´Al_2 [1], all candidates for room temperature refrigeration applications.

[1] K. A. Gschneidner Jr. , V. K. Pecharsky and A. O. Tsokol Rep. Prog. Phys. 68, 1479–1539, (2005)
[2] J. Amaral et al, Appl. Phys. Lett. 91, 172503 (2007).
[3]V. Franco et al, J. Phys.: Condensed Matter 20, 285207 (2008).

TH-33

Tuning the Curie Temperature of γ-FeNi Nanoparticles for Magnetocaloric Applications by Controlling the Oxidation Kinetics

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Soft magnetic γ−FeNi nanostructures have the potential to be good candidates for magnetocaloric applications. They have low hysteresis losses and tunable Curie temperatures, T_C with minor compositional changes. They also can be suspended in solutions thus providing versatility in applications. Mechanical alloying (MA) is a well-known technique to produce nanostructured γ−FeNi particles. In this paper, the aim is to demonstrate the tunability of the T_C of γ-FeNi nanoparticles by controlling the oxidation kinetics during synthesis. This is applicable to the Fe–Ni system since there is a strong compositional dependence of the Curie temperature, T_C, on composition in the γ-phase. In other words, any fluctuation in the composition due to oxidation leads to changes in the T_C. In addition, we propose γ-FeNi alloys as promising magnetocaloric refrigerants near room temperature. Along with good magnetocaloric properties, FeNi system is known to be the most economically advantageous alternative to many of the materials under study for magnetocaloric

applications. The effect of Mo addition to the FeNi system will also be investigated as it can provide further clues on the relationship between oxidation and the T_C.

TH-34

Complete Magnetocaloric Characterization Of Magnetic First order transformation: A Case Of Study

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The magnetocaloric effect (MCE) is a very fertile field in material science as it opens huge perspectives as far as the realization of innovative heat exchangers is concerned [1].
The characterization of MCE usually starts performing isothermal magnetization curves across the studied process in order to get its isothermal entropy change ($-\Delta S_T(H,T)$) which is one of the main observables of the system [1]. The second main property of MCE is the direct adiabatic temperature change (ΔT_{ad} (H,T)) which requires a properly made experimental set up in order to be measured.
In particular, while investigating first order magneto-structural transformations, the importance of measuring ΔT_{ad} (H,T) has been underlined since overestimations of this quantity while calculating it from indirect $-\Delta S_T$ (H,T) have been often reported (see for instance [2]). Most of the works [2-,3] which try to correlate ΔT_{ad} (H,T) and $-\Delta S_T$ (H,T) measured peak values across first order transformations report mismatches of the order of 40%, even if in some cases [3] concerning the differencies between the peak values of different samples good agreement between calculated and measured peak values has been obtained. In this contribution we will correlate direct and indirect measurements on the first order magneto-structural transformation occurring in Ni-Co-Mn-Ga alloys.
In order to complete the characterization of the MCE DSC calorimetric measurements have been performed at different applied magnetic fields in order to correlate ΔT_{ad} (H,T) and $-\Delta S_T$ (H,T) by directly measuring the entropy $S(H,T)$ curves.

[1] M. Tishin and Y.I. Spichkin, The Magnetocaloric Effect and its Applications, Institute of Physics, Bristol, (2003).
[2] X. Moya,et al. ,Phys. Rev. B 75, 184412 (2007).
[3] G. Porcari et al., J. Appl. Phys. 31, 27S (1960)

TH-35

Analysis of suitability of NiMnGa alloys for magnetic refrigeration

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Compositional dependence of magnetic entropy change in polycrystalline Ni-Mn-Ga Heusler alloys was investigated experimentally. Three series of Ni-rich Heusler alloys' samples were prepared using arc melting method – two $Ni_{100-(a+b)}$-Mn_a-Ga_b series with different a/b ratio (a/b=0.66;1.5) and one $Ni_{50}Mn_{25+c}Ga_{25-c}$ (c=0; 2.3; 4.2; 5.8; 7.15; 8.35). The goal of the study was to select the alloys best meeting the criteria of suitability in magnetic refrigeration at room temperature. The transition temperatures were obtained using vibrating sample magnetometer (VSM), and the magnetic entropy changes (ΔS) were calculated using the experimental M(T) curves and the integrated Maxwell relation. The largest entropy change ΔS = 1.5 J/kgK in the magnetic field ΔH = 1.5 T was revealed in the $Ni_{47.50}Mn_{31.50}Ga_{21.00}$ alloy.

TH-36

Magnetocaloric effect in Ni-Co-Mn-In flakes

M.U. Gutowska [1], J. Wieckowski [1], A. Szewczyk [1], W. Maziarz [2], N. Nedelko [1], S. Lewińska [1], A. Ślawska-Waniewska [1], M. Kowalczyk [3], A. Kolano-Burian [4]

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Magnetocaloric effect in a $Ni_{47}Co_3Mn_{35.5}In_{14.5}$ sample, which had a form of a set of flakes made of rapidly quenched ribbon, was studied by determining temperature dependences of two parameters: the isothermal entropy change and the adiabatic temperature change, occurring upon changes in the external magnetic field. It was accomplished by using two experimental methods, i.e., by measuring temperature dependences of a specific heat from 3 to 380 K, in zero magnetic field and in the field of 1 T, and by measuring temperature and field dependences of magnetization. In the former method, both parameters were determined by analyzing the system entropy, calculated by integrating the measured temperature dependences of specific heat. In the latter method, the Maxwell thermodynamic relation was applied to get the isothermal change in entropy.
Two extrema of opposite sign were found in the temperature dependences of the parameters characterizing the magnetocaloric effect. The first one appeared near the magneto-structural transition between the non-magnetic martensitic and the magnetic austenitic phase, and the other one - at the Curie temperature. The values of the parameters characterizing the magnetocaloric effect near room temperature in relatively low field (for the field of 1 T, the adiabatic temperature change was of the order of 0.9 K), make this material promising for application in magnetic refrigerators. The magnetocaloric effect was found to be anisotropic, being larger for magnetic field applied in the plane of flakes. This effect was shown to be related to the shape anisotropy. Such property can be useful for designs, in which the active medium rotates in the field or is located within a rotating field.
This work was supported by the European Regional Development Fund, Innovative Economy Grants POIG.01.03.01-00-058/08, POIG.01.01.02-00-108/09, and POIG.02.02.00-00-025/09.

TH-37

Magnetocaloric effect in Ni-Mn-X Heusler alloys

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Magnetic entropy changes, structural and magnetic transition temperatures for two Ni-rich Heusler alloys series: $Ni_{50}Mn_{25+a}X_{25-a}$ (a=0; 2.3; 4.2; 5.8; 7.15; 8.35), with X= Ga, Sn, were studied. The goal of the study was to determinate how the replacement of Ga for Sn would influence magnetocaloric properties of the alloys. The magnetization curves were obtained using vibrating sample magnetometer (VSM), at magnetic fields of ΔH=0.5, 1.0, 1.5 T, in the temperature

range of 120–400 K. The magnetic entropy changes (ΔS) were calculated using the experimental M(T) curves and integrated Maxwell relation. The largest entropy change ΔS = 2.1 J/kgK in the magnetic field ΔH = 1.5 T was revealed in the $Ni_{50.00}Mn_{29.20}Sn_{20.80}$ alloy.

TH-38

Direct measurement of magnetocaloric effect in Co-doped Mn-rich Ni_2MnGa alloys

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Ni_2MnGa compound belongs to family of ferromagnetic shape memory materials. Its huge shape memory effect is based on the very sharp first order structural transition from the high temperature cubic austenite to the low temperature tetragonal martensite that is accompanied by a pronounced change of magnetization which is also origin of the significant magnetocaloric effect (MCE) in the compound. The structural and magnetic properties of the Heusler Ni-Mn-Ga compounds are very sensitive to an off-stoichiometry and to a doping. Recently, we have studied magnetic and magneto-caloric properties of the polycrystalline Co-doped Mn-rich Ni-Co-Mn-Ga alloys with positive magnetization jump (ΔM) at the M-A transitions in the compounds with $x \geq 5$ [1]. The huge entropy change of ΔS_m and inverse MCE were determined from magnetization isotherms. The direct measurements of MCE are of particular importance for the characterization of MCE in alloys with the first order magneto-structural transitions [2]. Our direct measurements of ΔT_{ad} have provided a large collection of the experimental data on MCE of the polycrystalline $Ni_{50-x}Co_xMn_{25+y}Ga_{25-y}$ alloys (x = 5, 7 for y = 6 and x = 9 for y = 7). The direct measurements confirmed the inverse MCE around the M-A transition. With respect to values of ΔS_m around 12 J/kgK, the observed absolute values of ΔT_{ad} were rather small of about 1 K for a field spam of 4.7 T. These results are fully relevant to specific heat of these compounds that was presented just recently [3]. The observed values of ΔT_{ad} associated with the second order magnetic transition of the austenite reached almost 2 K for the same field span.

[1] S. Fabbrici et al.: Acta Mater. 59 (2011) 412
[2] J. Kamarad et al: Acta Physica Polonica A 118
[3] 3 V. Basso et al.: Phys. Rev. B 85 (2012) 014430

TH-39

Peculiarities of Magnetocaloric Effect in Manganites Connected with Magnetic Heterogeneous State

L. Koroleva [1], D. Zashchirinskii [2], A. Morozov [2], R. Szymczak[3]

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Magnetocaloric effect (MCE) was studied in $La_{1-x}Sr_xMnO_3$, $Sm_{0.55}Sr_{0.45}MnO_3$ and $PrBaMn_2O_6$ manganites belong to three classes of manganites: $La_{1-x}A_xMnO_3$ (A = Ca, Sr, Ba), $Sm_{0,5+x}Sr_{0,5-x}MnO_3$ and $RBaMn_2O_6$ (R is rare earth ion). It has been found that the maximum absolute value of MCE, measured by direct method, is far less than the one obtained by computation from the change of magnetic entropy in temperature of magnetic ordering. This phenomenon is explained by presence in abovementioned manganites of the magnetic heterogeneous state. So in $La_{1-x}Sr_xMnO_3$ negative contribution from the lesser antiferromagnetic portion of sample lowers the summary MCE and modifies MCE versus temperature T curve displacing it's maximum to the higher temperature than Curie point T_C on 20-30 K. It's known that the cooling in the oxygen of $Sm_{0.55}Sr_{0.45}MnO_3$ restores Mn-V-Mn broken connections (V is oxygen vacancy), so the summary volume of clusters with the CE-type of antiferromagnetic order increases. In result the maximum on MCE(T) curve is disposed at Neel temperature of clusters with the CE-type antiferromagnetic order (243 K) but not in T_C = 134 K of ferromagnetic clusters. Magnetic field, applied to the sample at MCE measurement, transfers these antiferromagnetic clusters in ferromagnetic state and in Neel temperature both states are destroyed. But maximum on MCE(T) curve of $Sm_{0.55}Sr_{0.45}MnO_3$ is disposed near T_C in the air cooling single-crystal and ceramic sample. Transition from antiferromagnetic to ferromagnetic state occurs in $PrBaMn_2O_6$ compound at 231 K. The MCE(T) curve of this sample have the sharp minimum at T = 234 K in which MCE is negative and the wide maximum including T_C = 295 K. MCE absolute value in both extremes is several times smaller than the one computed from the magnetic entropy change. It's explained by the antiferromagnetic clusters presence in the ferromagnetic phase and ferromagnetic clusters in antiferromagnetic phase.

TH-40

Magnetic and magnetocaloric properties of $Pr_{0.67}Pb_{0.33}MnO_3$

S. Kilic Cetin [1], M. Acet [2], A. Ekicibil [1], C. Sarikürkcü [3], K. Kiymac [1]

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We present an investigation on structure, magnetic and magnetocaloric properties of the perovskite compound $Pr_{0.67}Pb_{0.33}MnO_3$. The ferromagnetic-paramagnetic phase transition of the sample is determined as $T_C \approx 234K$ from thermomagnetic measurements in a 50Oe applied magnetic field. To determine the magnetic entropy changes we have measured the *M(H)* isotherms at various temperatures near T_C. The maximum magnetic entropy-change values are 2.4, 3.8, 4.7, 5.3 and 5.7 $Jkg^{-1}K^{-1}$ for 1.0, 2.0, 3.0, 4.0 and 4.8 T , respectively. These values are similar to those of Gd (ΔS=3.32 $Jkg^{-1}K^{-1}$ for ΔH=1.35kOe). We have also measured the cyclic adiabatic temperature-change of the sample in an adiabatic calorimeter directly and have found a maximum reversible temperature-change of about 2.5K around 236K in a field of 3T.

TH-41

Investigations on the magnetic and magnetocaloric properties of the $La_{0,67}Ba_{0,33}Mn_{0,9}Cr_{0,1}O_3$ manganite perovskite

M. Oumezzine [1], O. Peña [2], S. Kallel [1]

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Magnetic properties and magnetocaloric effect of the $La_{0,67}Ba_{0,33}Mn_{0,9}Cr_{0,1}O_3$ perovskite are investigated. The maximum values of the magnetic entropy change ($-\Delta S_M$) at 324 K are 4.20 $JKg^{-1}K^{-1}$ and 1.56 $JKg^{-1}K^{-1}$ for magnetic field variations of 5 and 1 T, respectively, which are closely related with a second-order magnetic phase transition from the ferromagnetic to the paramagnetic state. The reversible magnetocaloric effect, with a relatively broad operating temperature range, makes of $La_{0,67}Ba_{0,33}Mn_{0,9}Cr_{0,1}O_3$ an attractive candidate for room-temperature magnetic refrigeration [1]. The critical behaviour [2] around the transition temperature is investigated in detail using both the standard Kouvel-Fisher procedure as well as the study of the field dependence of the magnetocaloric effect. Results indicate that the critical exponents deduced from our experiments are reliable, and that the present sample exhibits a three-dimensional Heisenberg behaviour with short-range interactions [3].

[1] V. K. Pecharsky, K. A. Gschneidner, Jr., Phys. Rev. Lett. 78 (1997) 4494
[2] M. Fähnle, W.U.Kellner, H. Kronmüller, Phys.Rev.B 35 (1987) 3640
[3] S. N. Kaul, J. Magn. Magn. Mater. 53 (1985) 5

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

Chair: P. Luches

TH-42
Growth and Magnetic characterization of 1D Permalloy Nanowires using self-developed AAO templates
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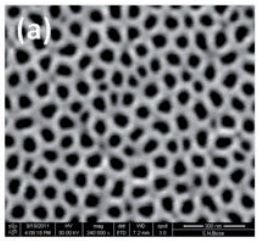
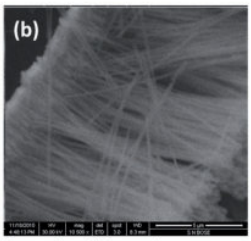
Permalloy refers to an alloy of Ni and Fe with 80% and 20% composition respectively. Permalloy nanowires are particularly attractive because of their high permeability, low coercivity, near zero magnetostriction and high anisotropic magnetoresistance. Because of low magnetostriction of Permalloy shape anisotropy plays a very important role. As a result, the nanowires show unidirectional anisotropy along their length. Because of this property, they can be used in many applications such as recording head sensors, magnetic storage devices etc. In the present work 1D Permalloy nanowires arrays were fabricated into the pores of self engineered Anodic Aluminium Oxide (AAO) templates by a simple electrodeposition technique (EDT). By varying the Anodization voltage and the parameters of the electrolytic solutions we developed various AAO templates with different average pore diameters. We developed the 1D Permalloy NW's of different diameters depending on the pore size arrangement of AAO templates by varying the deposition conditions. Structural characterization of AAO templates and 1D Permalloy NW's was performed by Transmission and Scanning Electron Microscopy (TEM & SEM). XRD studies of 1D Permalloy NW's shows their fcc crystalline structure and the AAO template was found to be amorphous in nature. Magnetic studies show the 1D Permalloy NW's arrays to have obvious anisotropy, and the easy axis was found to be parallel to the nanowires axis. We performed the angular dependence measurement of 1D Permalloy NW's. When the applied magnetic field was parallel to the nanowires, the coercivity (H_c) and the maximum remanent ratio (M_r/M_s) were considerably higher than those while the magnetic field perpendicular to the nanowires.

[1] B. Das et al., J. Appl. Phys. 103, 013908 - 013908-4 (2008)
[2] J. Wang et al., J. Phys. D: Appl. Phys. 34, 3442–3446 (2001)



(a) AAO Template



(b) 1D Permalloy Nanowires

TH-43

Local modification of magnetic properties via Ga^+ irradiation for the control of domain wall pinning in planar NiFe nanowires

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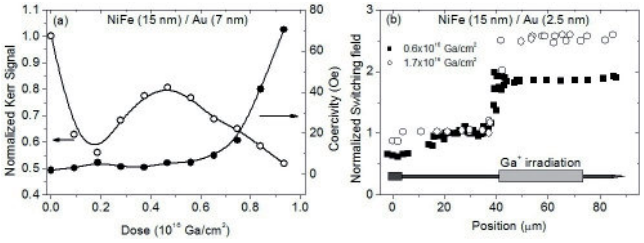
The control of domain walls in magnetic nanowires is a popular research theme as their use in spintronic devices for memory, sensing and logic processing applications grows. In such devices information is represented by the magnetisation direction of regions of the nanowire separated by domain walls. To achieve high density devices, controlling the pinning of these domain walls is essential.

Domain wall pinning has previously been achieved by modifying the structural geometry of the wire with notches or anti-notches [1]. Here we show that domain wall pinning behaviour can be achieved through local modifications to the underlying magnetic material of the nanowire through focussed Ga^+ ion irradiation. With this technique the positioning and the potential energy of the pinning sites can be controlled without the need for lithographic structuring.

A detailed investigation has been performed on the magnetic changes (Fig 1(a)) taking place within NiFe / Au bilayers as a result of low dose irradiation induced interfacial intermixing [2]. This has revealed that fine control over the saturation magnetisation can be achieved for low dose irradiation. Localised control of domain wall pinning using irradiation induced intermixing has been demonstrated in nanowires here (Fig 1(b)). Furthermore, this approach could also potentially lead to a reduction in the critical current density for current induced domain wall motion when Ga^+ irradiated pinning sites are used [3].

[1] L.K. Bogart et.al., Phys. Rev. B **79**, 054414 (2009).
[2] E. Arac et.al., J. Appl. Phys. **111**, 044324 (2012).
[3] K.J. Lee et. al., J. Magn. Magn. Mater. **304**, 102 (2006)



Magnetic properties of Ga^+ irradiated NiFe / Au bilayer (a) structures and (b) nanowires.

TH-44

Mechanism of localization of the magnetization reversal in 3 nm wide Co nanowires

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Ferromagnetic nanowires (NWs) have drawn considerable interest in the past few years for their applications in data storage devices such as computer hard disks or magnetic random access memories. From a more fundamental perspective, nanowires - with diameter falling below characteristic magnetic length scales such as the exchange length or the domain wall width - represent a testing ground in the field of nanomagnetism.

The most commonly used technique in order to grow ferromagnetic NWs consists in electro-depositing a ferromagnetic metal into a porous self-assembled alumina template. In this work, we report on the self-assembly of Co NWs embedded in an epitaxial $CeO_2/SrTiO_3(001)$ films grown by pulsed laser deposition. These wires have diameter in the 3-5 nm range, depending on the growth parameters, and are oriented in average along the growth direction of the CeO_2 epilayer.

The crystallographic structure of the Co wires could be determined through high-resolution transmission electron microscopy in a system containing NWs of 3 nm diameter. The NWs are composed of hexagonal cobalt (Co hcp) grains with a preferential orientation: the [001] direction of Co hcp is aligned with one the <111> directions of the CeO_2 matrix. The magnetic properties of such a system were then probed using static and dynamic magnetization measurements. Micromagnetic modelling based on the structural analysis allows us to correlate the structure and the magnetic behaviour of the wires, revealing competition between shape anisotropy, magnetocrystalline anisotropy and exchange in the localized reversal within Co hcp oriented grains.

Further studies on these objects are currently underway and we will also present preliminary results obtained on the self-assembly and epitaxy of Ni NWs in $CeO_2/SrTiO_3(001)$ which is an all-epitaxial system.

We acknowledge support from C'nano IdF and ANR (contract ANR-2011-BS04-007-01).

TH-45

Angular dependence of the coercivity of ordered arrays of Ni and Co nanowires

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(1) Universidad Diego Portales, (2) Universidad de Santiago de Chile

The angular dependence of the coercivity and remanence of Ni and Co nanowire arrays produced with electrodeposition in nanoporous aluminum membranes was investigated through magnetometry, analytical calculations, and micromagnetic simulations using the three-dimensional Object Oriented MicroMagnetic Framework (OOMMF) code [1, 2]. Depending on the angle between the wire and the applied magnetic field, our results show that while for Ni nanowires the magnetization reversal is driven by means of the nucleation and propagation of a transverse domain wall, in Co arrays the reversal mode changes from vortex to a transverse domain wall. By means of micromagnetic simulations we observed that the dipolar interactions causes a reduction in coercive fields, mainly in the direction of easy magnetization of the nanowires. Good agreement between numerical, analytical and experimental data is obtained [3]. Figure 1 shows the coercivity measured at different angles for Ni and Co nanowire arrays. Dots and solid lines (in Fig. 1 (a) and (b)) represent the coercivity obtained by means of experimental measurements and analytical model, respectively. Fig. 1 (c) and (d) shows the coercivity obtained by means of micromagnetic simulations. Figures 1(c) and 1(d)

show that the effect of dipolar interactions between nanowires reduces the coercivity for all the angles considered. However, the effect of interactions between Co nanowires strongly modified the value of the coercive field for $\theta = 60^{o}$.

[1] R. Lavín, J. Escrig, J. C. Denardin, D. Altbir, A. Cortés, H. Gómez, Journal of Applied Physics 106, 103903 (2009).
[2] R. Lavín, C. Gallardo, J. L. Palma, J. Escrig, J. C. Denardin, J. Mag. Mag. Mater., In Press (2012).
[3] J. Escrig, R. Lavín, J. L. Palma, J. C. Denardin, D. Altbir, A. Cortés, H. Gómez, Nanotechnology 19, 075713 (2008).

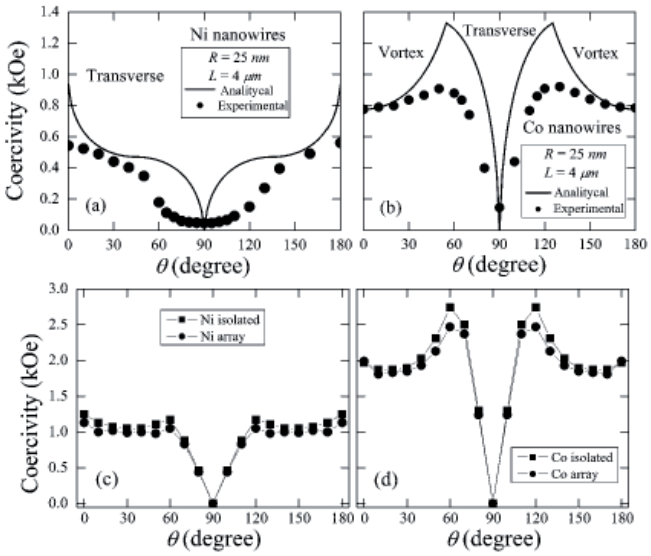

Fig. 1: Angular dependence of the coercivity of Ni and Co nanowire arrays.

TH-46

Magnetization reversal behavior of Fe and Co planar nanowire arrays grown of oxidized step-bunched Si(111) templates

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Fabrication of planar NW arrays using existing self-assembly based methods (step flow growth and step decoration) is a challenging task considering the effect of dimensionality and small thickness of the structures (leading to super-paramagnetism).[1] Here, we report on the structural and magnetic properties of planar arrays of Fe and Co-nanowires of varying width (15 - 100 nm) grown on oxidized step bunched Si (111) templates (45-140 nm periodicity) using the atomic terrace low angle shadowing (ATLAS) technique [2]. Structural and morphological investigations on these NW arrays reveals that the NWs possess polycrystalline character and are formed by coalescence of small sized islands (*3D* growth mode of Fe and Co on oxidized silicon) nucleated on the terraces. These planar NW arrays exhibit ferromagnetic behaviour at room temperature. Element specific x-ray magnetic circular dichroism measured for Fe (Co) $L_{3,2}$ edge in total electron yield (TEY) mode further confirmed the ferromagnetic nature of wires. The effective magnetic anisotropy of these NW arrays is dominated by the shape anisotropy, which keeps the magnetization in-plane with easy axis parallel to the wires. Temperature (T) dependent magnetization studies on these NW arrays show that the shape related uniaxial anisotropy is preserved even at low temperatures (10 K). Further analysis of magnetization data based on an analytical model that takes into account the effect of thermal activation and magnetostatic interactions among the wire suggest that the magnetization reversal is governed by the curling mode reversal for both Fe and Co NW arrays of (4.5 nm thickness and with 30 nm average wires width). Whereas the thinner wires exhibits a more complex behaviour which is related to thermal effects and size distribution of the crystal grains that constitute the NWs.

[1]. C. Teichert, Appl. Phys. A 76, 653 (2003)
[2]. S.K. Arora et al., J. Appl. Phys**.** 109, 07B106 (2011)

TH-47

Magnetic Properties of Magnetic Nanowire Arrays with Tuned Strength of Interactions

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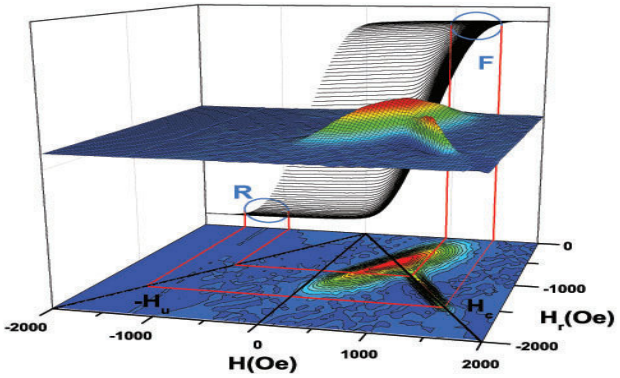
Magnetic nanowires are an important class of magnetic nanostructured materials. One of the most important effects in magnetic nanowire arrays is the interwire magnetostatic interactions. In order to be able to understand the obtained experimental results reliable methods for interactions evaluation are needed. To quantify the effect of interactions one needs on the one hand a suitable method to experimentally vary the strength of interactions in arrays of magnetic nanowires and on the other hand a method to measure the effect of the interactions. In this study, we present a comprehensive investigation of magnetic interactions in arrays of magnetic nanowires grown in highly-ordered anodic alumina membranes. The static magnetic properties were probed using vibrating sample magnetometry following several measurements protocols. Interactions and static magnetization reversal of Ni nanowires arrays have been investigated by the first order reversal curves (FORC) method [1]. Several series of samples with controlled spatial distribution were considered including simple wires of different lengths and diameters (70 nm and 110 nm) and complex wires with single modulated diameter along their length [2]. Subtle features of magnetic interactions are revealed through a quantitative analysis of the local interaction field profile distributions obtained from FORC. In addition the FORC analysis indicates that the nanowire systems with a mean diameter of 70 nm appear to be organized in symmetric clusters indicative of a reversal-field memory effect [3].
Work at AMRI was supported by the NSF grants ECCS-1028547 and EPS-1003897(LASiGMA)

[1] A. Rotaru et al., *Phys. Rev. B*, vol. 84, p. 134431, Oct 2011.
[2] J. H. Lim et al., *J. Mater. Chem*. vol. 20, 9246, 2010.
[3] H. G. Katzgraber et al., *Phys. Rev. Lett.* vol. 89, 257202, 2002.



A family of FORCs and the corresponding diagram for a 4.8 μm long nanowire array

TH-48

Conductance and magnetic properties of mixed Au-Co nanowires

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The research of magnetic properties and properties of electronic structure of mixed Au-Co nanowires is conducted. It is shown that evenly mixed wire possesses magnetic properties. Value of the local magnetic moments of Co atoms is 2.35μ_B, however in Co nanowire 2.2 μ_B. Our calculations has shown, that magnetic properties of Au-Co wires strongly depend on its atomic structure. Contraction of the Au- Co wire to interatomic distances smaller 2.4Å
leads to its transition from linear configuration to a "zig-zag" one [1], it laeds to the strongly suppression of nanowires magnetic properties.
The study of transport properties of evenly mixed Au-Co nanowires has shown , that current through nanowires is spin-polarized at room temperature (G_0=1.5).
Our results indirectly confirmed by the result of experimental work of St. Egle et al.[2] in which it is revealed «ballistic magnetoresistance» in quasione-dimensional mixed Au-Co nanocontacts.

[1] E. M. Smelova, K. M. Tsysar', D. I. Bazhanov, A. M. Saletsky, JETP Lett. 93, 3, 129-132 (2011)
[2] Stefan Egle, Cecile Bacca, Hans-Fridtjof Pernau, Magdalena Huefner, Denise Hinzke, Ulrich Nowak, Elke Scheer Phys. Rev. B 81, 134402(2010)

TH-49

Giant magnetic anisotropy in Au/Co nanowires

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For the first time quasi-one dimensional Au/Co nanocontacts was obtained in the experimental work of Egle *et al.*[1]. They found the "giant magnetoresistance" in mixed Au/Co nanocontacts. At present time there is a significant amount of data on the quantum properties of mixed nanostructures, while the investigation of magnetic properties of mixed nanowires is still the less studied. Present work is devoted to the study of anisotropic magnetic properties of mixed Au/Co nanowires. Our calculations have shown that evenly mixed Au/Co nanowires are more stable to strain deformations "stretching-contraction"in large area of interatomic distances (1.6 Å- 3.0 Å) in compare to gold nanowires [2]. We have found the emergence of giant magnetic anisotropy in Au/Co nanowires and its dependence on the atomic structure of the Au/Co wire. Our study has shown that only evenly mixed Au/Co wires exhibit "giant magnetic anisotropy" with magnetic anisotropy energy (MAE) ~130meV per Co atom in a wire. We have found, that easy magnetization axis in Au/Co wire is perpendicular to the wire axis. At the same time the MAE of the unevenly mixed Au/Co nanowires is about ~0.1meV per Co atom. Thus it was shown that dimerization of cobalt atoms completely suppressed the magnetic anisotropy. Our calculations have shown that the MAE also depends on the geometry of the wire. Strongly stretched nanowire up to 2.8Å loses the magnetic anisotropy property, the MAE decreases to 0.1-0.2meV per Co atom. The contraction of the Au/Co wire leads to its transfer from linear geometry to a "zig-zag" one, which accompanied by decreasing of MAE to 20meV.
This work was supported by grant of RFBR No10-02-01274-a, 11-02-12256-ofi-m, grant of "Dynasty Foundation".
[1] S. Egle, et al., Phys. Rev. B 81, 134402 (2010)
[2] E. M. Smelova, et al., JETP Lett. 93, 3, 129-132 (2011)

TH-50

Magneto-Optical microscopy studies of individual Pt/Co/Pt nano-scale wires fabricated by focused ion beam patterning

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Co/Pt multilayer systems have long attracted enormous interest due to their tunable perpendicular magnetic anisotropy, which makes them suitable candidates for different technological applications such as ultrahigh density magnetic storage, for instance [1]. But despite the vast amount of work on these material structures, nano-scale patterning of Co/Pt-multilayers and the understanding of magnetization reversal processes in such nano-structures are still within the widely open field of research.
In our studies, we have successfully patterned wires down to 100 nm width into Pt (5.0 nm)/Co (0.8 nm)/Pt (3.0 nm) multilayer films by means of focused Ga-ions. The magnetization reversal behavior of these wires has been measured by magneto-optical Kerr effect (MOKE) microscopy, which, allows to simultaneously measure hysteresis loops and image domains for individual wires [2]. Figure 1 (a) shows averaged hysteresis loop measured for 100 nm wide wire in polar MOKE

configuration while figures 1 (b)-(d) show the corresponding images of domains during an individual reversal process. As can be observed in figs. 1 (b)-(d), the magnetization reversal in this wire proceeds via domain creation. While figure 1 (b) shows the initial uniform magnetic state, we observe nucleation of a magnetic domain in the central area of the wire in figure 1 (c). Figure 1 (d) shows again a uniform magnetic state image after completion of reversal process. Interestingly, the nucleation of the reversal occurs in the central part of the wire, away from the end points, in clear contrast to wires with in plane magnetization, where reversal nucleates at the wire ends.

[1] C. Chappert et al. Science 280, 1919 (1998).
[2] E. Nikulina et al. accepted for publication in Appl. Phys. Lett.

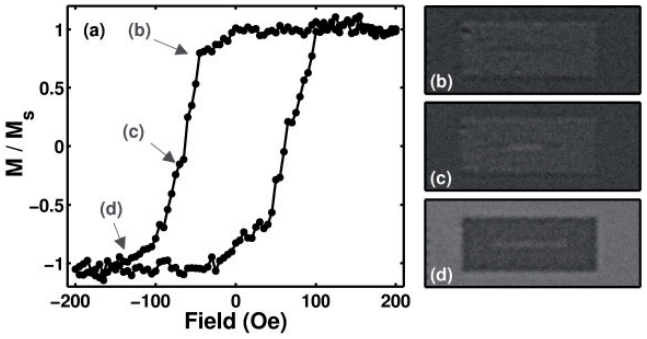

Figure 1: (a) multi-cycle averaged hysteresis loop measurement of a single 100 nm wide Pt/Co/Pt wire. (b)-(d) domain images of an individual magnetization reversal process.

TH-51

Galvanostatic deposition of Transition Metal-Pd magnetic nanowires in anodic alumina templates

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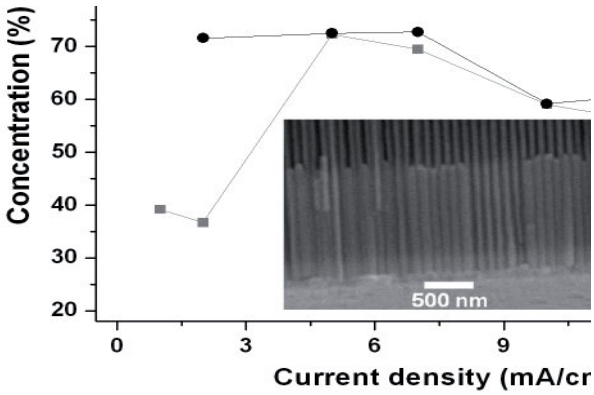
Ferromagnetic Transition Metals (TM) alloyed with Pd have recently attracted much attention due to their wide range of magnetic effects and functional properties. Bimetallic Fe-Pd compound is extensively studied for applications based on shape memory effect [1]. In addition to the high magnetic anisotropy present in Co-Pd and some Fe-Pd alloys, Ni-Pd alloys are also good candidates for magnetic refrigerators, since they can exhibit magnetocaloric effect.
In this work, (Co, Fe, Ni)-Pd alloys nanowires with carefully controlled compositions have been fabricated by means of electrochemical process employing templates of nanoporous alumina membranes. The electrochemical deposition of these Nanowires Arrays (NW) has been performed starting from a chloride-based electrolyte containing ammonia, 0.2 M ammonium citrate, 2 mM $PdCl_2$ and 18 mM of $FeCl_2$, $CoCl_2$ or $NiCl_2$ [2], carried out under galvanostatic conditions at current densities ranging from 2 up to 15 $mA{\cdot}cm^{-2}$, in order to keep an accurate control on the relative composition of nanowires through the ionic current density crossing throughout the pores. Morphology and relative chemical composition of NW as a function of the electrodeposition current density for each metallic ion present in the electrochemical bath have been determined. Furthermore, the influence of the electrodeposition parameters and composition on their magnetic properties have been discussed from isothermal magnetization and thermomagnetic curves measured in the temperature range of 50K to 400K and under applied magnetic fields up to 3T. Magnetic properties of NW, such as their anisotropy and magnetocaloric behavior, are demonstrated to be strongly dependent on their chemical compositions.

[1] B. Jeon et al., Electrochim. Acta 56, 401–405 (2010)
[2] S.C. Hernández et al., Electrochim. Acta 53, 5621-5627 (2008)



MT-Pd NW composition dependence on deposition current. Inset: SEM of Fe-Pd NW.

TH-52

Coercivity enhancement and magnetization reversal modes in narrow FePt nanowires

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We present the dependence of coercivity and magnetization reversal modes in FePt nanowires when reducing the wire width, down to 30 nm. It is found that an enhancement of the coercitive field appears at low sizes. An invasion percolation model [1], as well as simulations, is proposed to describe the coercivity enhancement. We suggest that the coercivity increase is not due to a lower probability for extrinsic nucleation to occur in smaller structures, but rather to the suppression of available propagation paths for the domain wall in thin wires [2].
Further study of the magnetization reversal process using MFM measurement shows that three different reversal modes can appear. Forwidths above 500 nm, the structure of the reversed domains appears to be similar to those of the continuous FePt film: the reversed magnetic domain grows and expands within

a dendritic structure [1]. For widths below the characteristic dendrite width (~300 nm), the reversal takes place by propagation of a single DW that reverse the whole wire. Finally, another behavior appears at very low widths: Reducing the widths below 50 nm leads to the propagation field becomes larger than the nucleation field. Nucleation thus occurs randomly the reversal consisting in a mix of nucleation and propagation. The origin of this effect is discussed as such behavior could prevent the use of ultra-narrow wires for DW-based devices.

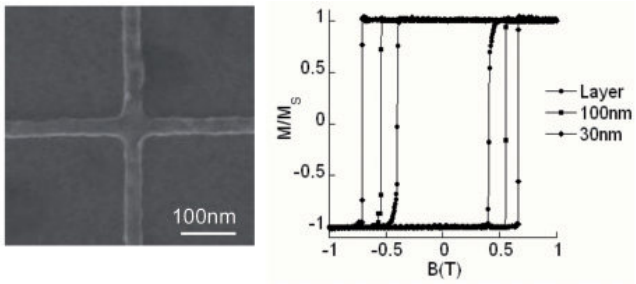

Fig. 1: (a) SEM image of a Hall cross, (b) hysteresis loops of a FePt layer and of 100, 30nm wide

[1] J.P. Attané *et al.,* Phys. Rev. B, **82**, 024408 (2010)
[2] J.P. Attané *et al.,* Phys. Rev. B, **84**, 144418 (2011)

TH-53

Magnetic Nanowire Arrays in Cylindrical Porous Anodic Alumina Membranes: Synthesis and FORC Analysis

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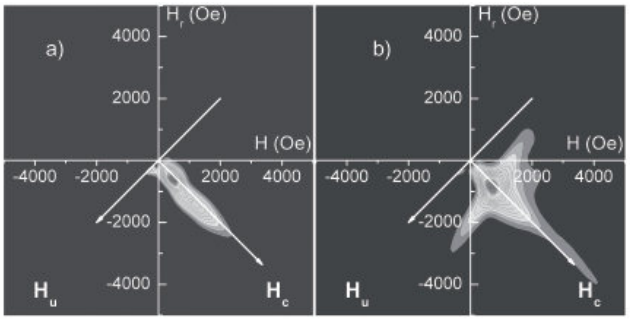
Two-step anodization process is among the most common techniques to produce self-assembled hexagonal symmetry nanostructures since Masuda and Fukuda presented their original work in 1995 [1]. This process is typically used to produce planar porous alumina membranes by anodization of aluminium foils [2]. In this work we present a new family of anodic porous alumina with cylindrical symmetry (CPAA) as first introduced first by Sanz et al. [3]. Using this technique we were able to anodize several cylindrical Al wires and to electroplate into theirs pores ferromagnetic nanowires with different compositions (Fe, Co, Ni, $Ni_{80}Fe_{20}$ and $Co_{75}Ni_{25}$). Structural and magnetic properties are discussed for each individual sample. Magnetic measurements show that the variation of composition determine the final balance between anisotropies in each nanomaterial, therefore we are able to produce samples with radial anisotropy, due to nanowires shape anisotropy, as well as axial anisotropy, due to their magnetocrystalline anisotropy. We also compare the magnetic properties of these samples with thin films electrodeposited onto the same diameter Al wires and, eventually, with nanowires produced in Al foils. First-order reversal curves (FORC) have been used to determine the interaction field between nanowires and also the switching field distribution in these samples. Such cylindrical porous anodic alumina (CPAA) materials open new opportunities for research and technological applications over a wide spectrum of topics from microfluidics in biomedical test/ trials, to magnetotransport and electromagnetic detection.

[1] H. Masuda and K. Fukuda, Science 268, 1466 (1995)
[2] M. Vázquez et al., Eur. Phys. J. B 40, 489 (2004)
[3] R. Sanz et al., Small 3, 434 (2007)



FORC diagrams along axial (a) and perpendicular (b) axes for Co nanowires in CPAA.

TH-54

Synthesis and Magnetic Properties of Zinc Ferrite/Carbon Nanotubes Nanocomposites

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Wet chemistry has been used to synthesize zinc ferrite inside the hollow carbon nanotubes cavities (CNTs). The presence of zinc ferrites in the sample was confirmed by X-ray diffraction analysis. Transmission electron microscopy and field emission scanning electron microscopy showed the hollow structure of CNTs of (5-10) nm inner diameter filled with zinc ferrite. Small hysteresis was observed in the magnetization measurement of the nanoferrite/CNT composite using vibrating sample magnetometer. The measurements revealed that the saturation magnetization, remanent magnetization and coercivity are 3.3 emu/g, 0.36 emu/g and 25.7 Oe respectively. However, Mossbauer spectroscopy shows very well resolved paramagnetic doublet at room temperature. We have also synthesized zinc ferrite nanoparticles with an average diameter of 60 nm ±5nm using the polyol-based co-precipitation method and were found to be paramagnetic.

TH-55

Controlling the magnetic properties in Fe_2O_3 nanorods using of fullerene-like structure

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In this work we have studied the role of the addition of sucrose on the structural and magnetic properties of α-Fe2O3 nanoparticles obtained by coprecipitation method. The precursors have been prepared for adding different concentrations of the sucrose as chelating agent. To obtain the nanoparticles these precursors were heated in the temperature range between 200 and 400°C. Samples have been characterized via X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and magnetization measurements. XRD data confirm that crystalline phase is already formed at temperatures around 200°C showing a preferential growth to (110) crystallographic plane to the sample at 0.01 mol/l of sucrose. Figure 1 shows a TEM image of the precursor with 0.01mol / l sucrose indicating presence of fullerene-like structures in region around the edges of particles. Due to the elongated shape of the fullerene-like, we suggested as a possible reason for the preferential growth of the plane (110) of the nanorods produced after heat treatment. Besides, a more careful analysis performed in the Zero Field Cooling and Field Cooling (ZFC-FC) magnetization data show clearly the dependence of the size, shape and size distribution of the samples as function of the chelating agent concentration.

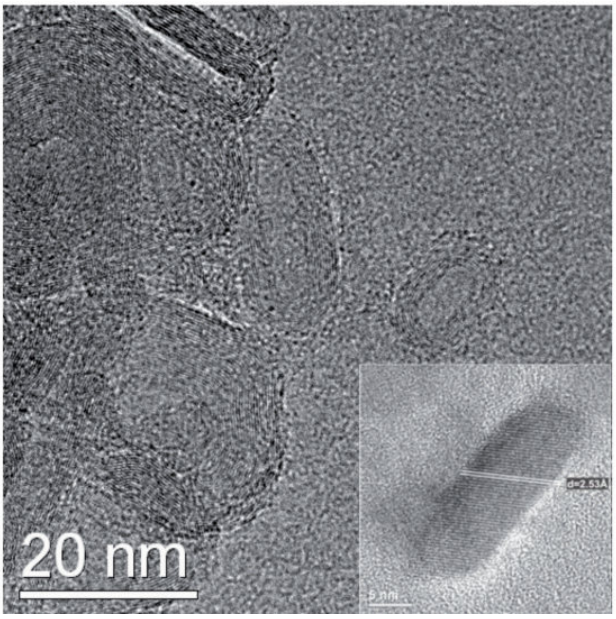

Figure 1: TEM image of precursor with 0.01 mol/l sucrose, showing the structure of fullerene-like. In particular, HR-TEM image of a nanorod showing the interplanar distance of 2.53A, the correspondent (110).

TH-56

Effects of Oersted field on current induced domain wall motion and domain wall chirality in multilayer nanostripes

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We have recently shown that current-induced domain wall (DW) motion is more efficient in Co\Cu\Permalloy(Py) trilayer nanostripes [1] than in commonly used single Py nanostripes. One possible origin of this high efficiency is the current-induced transverse magnetic Oersted field acting on the Py layer [2]. It has been shown previously, for field-induced domain wall motion in Py nanostripes [3], that a transverse magnetic field can stabilize transverse domain walls with their magnetization parallel to the field. This pushes the Walker breakdown to higher fields leading to an increased DW mobility.

To investigate the effect of Oersted field on DW stability, chirality and mobility we have investigated DW motion in Ir\Py bilayer stripes, using Magnetic Force Microscopy (MFM). The absence of Co layer allows separating the effect of the Oersted field from flux-closure magnetostatic interactions with the Co underlayer, and also avoiding effects of spin accumulation in the spacer layer on the domain wall motion. We confirm that the Oersted field can stabilize transverse domain walls with a transverse component parallel to the Oersted field (fig.c), even for widths and thicknesses of the Py layer for which vortex walls are more stable. Our measurements also show that once the chirality of the transverse wall is compatible with the Oersted field, the domain wall can be moved with current pulses without changing the chirality, suggesting that the Walker breakdown is indeed suppressed.

[1] V. Uhlir et al., Phys. Rev. B 81,224418 (2010)
[2] V. Uhlir et al., Phys. Rev. B 83, 020406(R) (2011)
[3] S. Glathe et al., Appl. Phys. Lett. 93, 162505 (2008).

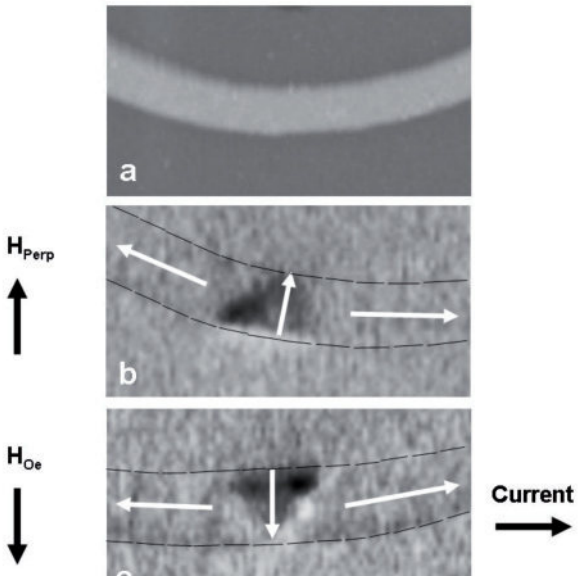

Fig.(a) Topography 400nm wide Ir(10nm)\Py(10nm) nanostripe (b) Initial configuration of tail to tail transverse DW in 400nm wide nanostripe (c) DW Configuration after 20mA current pulse, switching the DW chirality

TH-57

Magnetism in compact clusters of Cr deposited on Co(0001) hcp: density functional calculations

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Quantum Espresso code, which is based on density functional

theory, has been used within the generalized gradient approximation to study the magnetic properties of compact clusters of Cr_N (N=1-4) deposited on Co (0001) hcp substrate. We have calculated the stability of Cr adatom when deposited on one of the following adsorption sites: hcp, fcc, bridge, and atop sites. We have found that Cr adatom prefers to be localized at the hcp site with a magnetic moment antiferromagnetically coupled to the Co substrate magnetic moment. For Cr dimer, the lowest energy magnetic configuration shows one magnetic moment parallel to the Co substrate magnetic moment and the other one antiparallel. This suggests to us that the Cr-Cr interaction is stronger than the Cr-Co interaction. For Cr trimer (tetramer), the lowest energy magnetic configuration shows two Cr atoms with magnetic moments antiparallel to the Co substrate magnetic moment and the other one (two) with magnetic moment(s) parallel. In general, we have found high Cr magnetic moment values; for example, Cr adatom magnetic moment is equal to -4.60 μ_B.

TH-58

Dynamic vs static vortex core switching in GMR nanopillar with two vortices

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Excited by the spin transfer torque oscillation of magnetization in magnetic nanostructures can be used for creation of promising integrated microwave applications with the frequencies tunable using applied currents and fields. Particularly of a high interest are the Spin Transfer Vortex Oscillators (STVO), which can combine significant output power, small linewidth and relatively large frequency agility even at no bias magnetic fields.
First we present a numerical investigation of magnetization dynamics in STVO made of a Py 4/Cu 10/Py 15nm nanopillar, in which the magnetization of both Py layers can be controlled to be in a vortex state, similar to the system studied experimentally in [1]. When electrical current is passed through the pillar, a mode corresponding to a coupled vortices dynamics can be excited. We study this dynamics at different values of current and bias field perpendicular to the plane by micromagnetic simulations. In particular, we focus on the critical fields corresponding to core reversal in each magnetic layer as a function of the current. Then we compare these results with the experimental ones and find a good qualitative agreement between the critical fields for the cores' switching for different currents. Interestingly we conclude from the simulations that both dynamic [2] and static [3] scenarios of the core switching are observed at different fields/currents.
This work has been supported by RFBR grants 10-02-01162, CNRS-PICS n°5743, ANR through VOICE PNANO-09-P231-36 and EU MASTER No. NMP-FP7-212257.

[1] N. Locatelli et al, Appl. Phys. Lett. 98, 062501 (2011)
[2] A. V. Khvalkovskiy, A. N. Slavin, J. Grollier, et al., Appl. Phys.Lett., 96, 022504 (2010).
[3] A. Thiaville, J. M. García, R. Dittrich, et al., Phys. Rev. B 67, 094410 (2003).

TH-59

Controlling the magnetic vortex size by the magneto-crystaline anisotropy

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The magnetic configuration of a magnetic nanostructure depends on several parameters like magneto-crystaline anisotropy, shape, size, magnetic stiffness and the roughness of the layer. Except for the magnetic stiffness, it is possible to control all these parameters by means of different fabrication methods. In our case, we can tune the effective anisotropy of the Co/Pt multilayer by controlling the Co thickness to have either perpendicular or parallel effective anisotropy[1]. Certain kind of nanostructures of a few micron size can develop a flux closure structure containing a magnetic spin vortex. Since the magnetic vortex core size depends on the effective magnetic anisotropy, we can actually control the size of this vortex core by handling the anisotropy of the magnetic multilayer. The vortex size also has implications in its dynamics, which plays a fundamental role for further vortex based devices. Garcia et al. [2] proposed recently a simple model, which links the vortex diameter to the sample's out-of-plane anisotropy. They confirmed the model's prediction using micromagentic simulations. We here present our approach to verify their model's validity using high resolution imaging by scattering of coherent x-ray beams[3].

[1] M. T. Johnson, P. J. H. Bloemen, F. J. A. den Broeder, and J. J. de Vries, Rep. Prog. Phys. 59, 1409 (1996).
[2] F. Garcia, H Westfahl, J. Schoenmaner, E, J. Carvalho, A.D. Santos, M.Pojar, A.C. Seabra, R. Belkhou, A. Bendounan, E. R. P. Novais and A. P. Guimaraes, Appl. Phys. Lett. 97, 022501, (2010)
[3] S. Eisebit *et al*. Nature 2004

TH-60

Magnetism and self-organization of 3d metals nanostructures embedded into Cu(100)

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Recent years have brought significant advances in experimental and theoretical studies
of small magnetic clusters. The small magnetic clusters are current focus of intensive research due to both their importance in fundamental low-dimensional physics and the potential applications in nanoscale materials and devices.
The main goal of our work is to investigate the evolution of 3d metals nanostructures embedded into a Cu(100) surface at the atomic scale. The present calculations using the kinetic Monte Carlo method with energy barriers of all relevant events calculated by means of the molecular-dynamics method with ab initio based interatomic potentials are
performed. The atomic processes responsible for the linear and

angular chain formations are identified. We demonstrate the key role of substrate vacancies in the motion of embedded atoms and investigate the self-organization of atoms in different conditions. The interplay between structure and magnetic properties of small clusters (linear and angular chains) embedded in a Cu(001) surface is studied performing ab initio calculations in a fully relaxed geometry. We reveal that, despite the small macroscopic mismatch between 3d impurity and Cu, the strain relaxations at the interface have a profound effect on the structure of the clusters and the substrate. We show that the atomic relaxations strongly reduce the magnetic anisotropy energy (MAE) and the orbital magnetic moments of embedded clusters. The largest MAE is found for a single atom in the Cu(001) surface.

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TH-61

Exchange-Bias in Co/CoO Nanostructures

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Exchange Bias (EB) refers to the exchange coupling occurring at the interface between a ferromagnet (F) and an antiferromagnet (AF). Despite of large theoretical and experimental activity on EB, there are still many controversial issues especially concerning size effects that can be observed when going from the macrocopic scale down to the nanometer scale [1].

We report on an investigation of EB properties in assemblies of Co/CoO nanostructures of dimensions ℓ x 3 ℓ, with three different Co thicknesses (6, 10, 23 nm). At small Co thickness, a strong increase in the bias field and in the coercive field is found as the nanostructure size is reduced from ℓ = 120 nm to ℓ = 30 nm. This indicates that the AF characteristic length, D_{AF} which governs EB effects, is the nanostructure size. By contrast, at larger Co thickness the EB field does not depend on size implying that D_{AF} is smaller than the nanostructure size. The results are explained in the framework of a model proposed by A.P. Malozemoff [2], but considering that the coupling between AF grains is reduced. In very thin samples, TEM studies suggest that the ferromagnetic layer is not continuous. Then, the F-AF coupling is weakened and D_{AF} is maximized to the nanostructure size. In contrast, in thick Co layer samples , the F layer is continuous and the EB is governed by the F/AF interfacial coupling. D_{AF} is smaller than ℓ, and it does not depend on the size of the nanostructures [3].

[1] J. Nogues et al., Phys. Rep. **422**, 62 (2005)
[2] A. P. Malozemoff, Phys. Rev. B **35**, 3679 (1987)
[3] S. Laureti et al., Phys. Rev. Lett. **108**, 077205 (2012)

TH-62

Large-Scale Synthesis of Single-Crystalline Iron Oxide Magnetic Nanorings and Nanotubes

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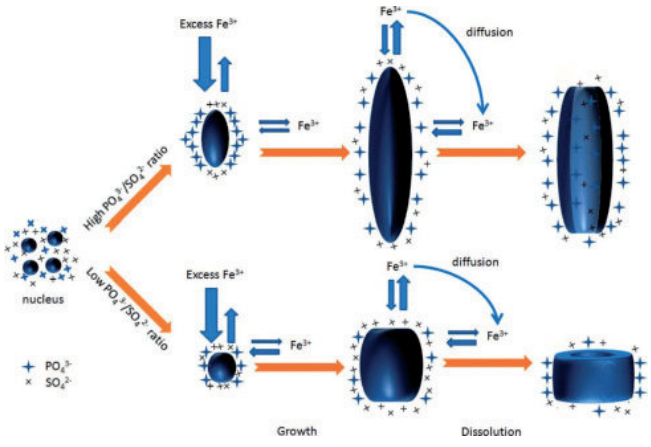
In recent years, magnetic nanostructures have attracted significant attention, not only because of their fascinating physical properties but also because of their potential use in a range of applications, including magnetic random access memory, magnetic sensors, and logic devices [1-3]. Ferromagnetic rings have particularly been the focus of interest because they have well-defined, reproducible magnetic states that result from their unique geometry. Such states are particularly interesting for industrial applications, since they can be easily detected and manipulated either in a magnetic field or with a spin-polarized current.

We present the controllable synthesis of single-crystal α-Fe_2O_3 nanorings and nanotubes, which makes use of the cooperative action of phosphate and sulfate ions. The α-Fe_2O_3 hollow nanostructures are then converted to magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3) by a subsequent reduction or reduction-oxidation process while preserving the nanoring and nanotube morphology. The high-quality single-crystal nature of the Fe_3O_4 and γ-Fe_2O_3 is confirmed with various analytical techniques, and employing off-axis electron holography, we observe that the magnetic states in the magnetite rings are dependent on the ring thickness. The magnetic vortex state is present in the thinner rings, and there is a more complex three-dimensional magnetic configuration in the thicker rings, indicating the transition from the vortex to the "tube" state. With the fabrication of iron oxide nanorings and nanotubes by double anion mediation, we provide a new strategy for large-scale fabrication of tailor-made magnetic nanostructures.

Figure 1: a Phosphate ions, with their strong affinity for (110) planes, act as a shape controller to induce anisotropic growth, while the sulfate ions, with their weak adsorption affinity, induce only the growth of polyhedra.



[1] S. A. Wolf, et al., Science **294**, 1488 (2001).
[2] P. Cowburn, et al., Science **287**, 1466 (2000).
[3] J. G. Zhu, et al., J. Appl. Phys. **87**, 6668 (2000).

TH-63

Magnetic Properties of Hexagonally Ordered Arrays of Dome Like Nanostructure

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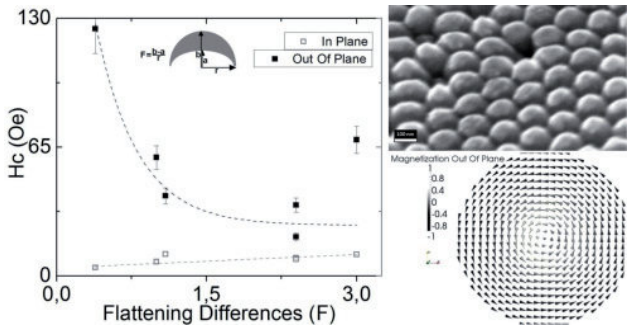
The dependence between the geometry and the magnetic properties of arrays of domes like nanostructures was studied by means of magnetometry techniques (AGM Aleternating Gradient Magnetometer) and micromagnetic simulations, using Oommf package [1]. The structures were synthesized by a replica technique from a home made porous alumina membranes and aluminum with hexagonally ordered nano valleys, obtained after removing the oxide layer of alumina. Structures composed by Permalloy and Cobalt were investigated systematically for different diameters and separation between elements. It was observed that the geometry of an individual element influence strongly their magnetic properties and reversal mode mechanism, depending on the direction of the applied field and the geometry. Two kinds of magnetic reversion where observed in the micromagnetic simulation of one isolated element. Coherent reversion and vortex reversion of the magnetization was present depending of the diameter of the nano domes.
[1] math.nist.gov/oommf/



Coercive field as a function of geometry, SEM image and micromagnetic simulation.

TH-64

Microscopic study of spin-wave excitations in 2D magnetic nanodots and nanorings

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Studies of the magnetic nanodots and nanorings are of major importance regarding to the potential applications from data processing and high-density magnetic random access memory (MRAM) elements to microwave-frequency oscillators and single magnetic nanoparticle sensors. The vortex spin configuration seems to hold great promise because of the possibility of switching the chirality of the in-plane magnetization component by means of external magnetic field or electric current. An important role in magnetization switching is played by spin-wave excitations.
We use microscopic model to study spin-wave excitations and their influence on the stability of the vortex state in 2D magnetic nanodots and nanorings. Our theoretical approach is based on the damping-free Landau-Lifshitz equation with the nearest-neighbour exchange and dipolar interactions fully taken into account [1]. Two different vortex types are examined: flux-closure state and Landau state in circular and square shaped systems, respectively.
Two types of magnetic reordering were found: via in-plane oscillations for predominating dipolar interactions and via out-of-plane oscillations for predominating exchange interactions. Up to few thousand of spins we found the first type of the transition very sensitive to the size of the system as well as to the edge conditions. In contrary, the transition forced by predominating exchange interactions is size-independent in a wide range of the size except circular rings in which growing of the ring results in stabilisation of the flux-closure state. This behaviour has a great impact on the possibility of stabilisation of the vortex state, e.g. for Co rings on Cu(001) the Landau state is not stable independently on the size of the square ring while the flux-closure state is stable for large enough circular rings. We show the character of the spin-wave profile to be a key factor for such behaviour.

[1] S. Mamica *et al.*, J. Nanopart. Res. 13, 6075 (2011)

TH-65

Domain walls in epitaxial Ni rings

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Domain walls (DWs) control dynamic properties in nanostructured magnetic materials due to the geometrical confinement of the magnetization, as observed in rings [1].
Here, we present a magnetic force microscopy (MFM) study on epitaxial (Cu/Ni(15nm)/Cu) rings obtained via focused ion beam. The ring diameter is 1 μm and the ring width *w* ranges from 100 to 400 nm. The perpendicular magnetoelastic anisotropy constant K_u of the Ni film is smaller, but comparable [2] to the value of the shape anisotropy constant, $2\pi M^2$.
MFM images taken at remanence resemble onion states with a DW structure that depends on *w*: below 250 nm, the images show monopole features, while above that value a dipolar structure appears (see Fig. a and b). Micromagnetic calculations show that the in-plane component of the DWs has a 180º standard feature. But, by including the contribution of the perpendicular magnetoelastic anisotropy ($K_u \approx 0.9\ (2\pi M^2)$), also out-of-the plane magnetic features arise in the DW. For small *w* this contribution has a monopole character that, as *w* increases, turns into a dipolar contribution with M rotating 180 degrees along the ring (see Fig c),. The calculated MFM images show monopole character and oscillation in the contrast (Fig. d), that reproduces qualitatively the experimental images.

[1] M. Klaui J. Phys.: Condens. Matter 20 313001(2008).
[2] K. Ha et al, J. Appl. Phy, 85,2688 (1999).

Caption: MFM images in rings with D = 1μ and *w* = 200 (a) and 400 (b) nm. (c) Micromagnetic simulation done on a ring with $K_u = 1.35$ Merg/cm^3 , arrows stand for the in-plane component of M and the gray scale for the perpendicular component of M. (d) Second derivative of the stray field, evaluated at a height of 80 nm from the ring surface.

TH-67

Effects of heat current in magnetic nanostructures

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This work is aimed at investigating the interplay between spin dynamics and heat current in magnetic systems. We looked e.g. at Co/Cu granular films and conducted local ferromagnetic resonance (FMR) measurements at 4.4 GHz. The samples were in the famous Spin Seebeck geometry [1] and subjected to a temperature gradient of the order of 20K/cm. We studied also electrically detected FMR of electrodeposited Co/Cu/Co asymmetric spin valves positioned at the middle of Cu nanowires, when subjected to a strong heat current in order to extend the quasi-static study of switching field versus heat current [2]. This work is supported by the Polish-Swiss Research Program NANOSPIN under the grant number PSRP-05/2010.

[1] Uchida, K. et al. Nature 455, 778–781 (2008).
[2] Yu, K. et al., Phys. Rev. Lett. 104, 146601 (2010)

TH-68

Collective phenomena in magnetic nanoarchitectures

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Due to progress in a high-resolution methods the research of a nanostructured materials such as the magnetic force microscopy, the scanning tunneling microscope and high-performance supercomputing techniques, the nanoscale structures are currently the object of intensive fundamental and applied research. Nanoarchitectures are interesting from the application point of view because they could be used for production elements of random access memory, and magneto-electronic devices. From a fundamental point of view the interest to nanoarchitectures is determined by the complexity of the theory of strong-correlated state. The number of interacting particles in such nanoarchitectures is usually greater than the number of particles, for which ones are possible to obtain exact solutions. Open questions on today in this array: the trajectory in the phase space, choice of microstates at magnetization reversal of an array of nanoparticles and the magnetization reversal mechanisms, the transition from individual behavior of isolated magnetic nanoparticles to the collective behavior of nanosystems and role which one played the magnetostatic interaction in this transition.
The aim of this work to identify patterns of magnetization of the square array of 10x10 nanoparticles with desired geometric characteristics of nano-elements [1]. It is interesting to study the hysteresis properties in connection with trajectory in phase space, takes into account the distribution of magnetization in each of the nanoparticle array, taking into account the influence of dipole-dipole (magnetostatic) interaction between the particles and the field of anisotropy required for magnetization reversal in nanoparticles in the internal field interaction and the external magnetic field.

[1] Yu. P. Ivanov, A. I. Il'in, E. V. Pustovalov, K. V. Nefedov, and L. A. Chebotkevich, J. The Physics of Metals and Metallography V. 113, Number 3, pp. 222-227

TH-69

Spin inelastic electron transport through magnetic nanostructures

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Recent experimental advances in scanning tunneling microscopy make the measurement of the conductance spectra of isolated and magnetically coupled atoms on nonmagnetic substrates possible. Notably, these spectra are characterized by a competition between the Kondo effect [1] and spin-flip inelastic electron [2] tunneling. In particular they include Kondo resonances and a logarithmic enhancement of the conductance at voltages corresponding to magnetic excitations, two features that cannot be captured by second order perturbation theory in the electron-spin coupling. We have now derived a third order analytic expression for the electron-spin self-energy, which can be readily used in combination with the non-equilibrium Green's function scheme for electron transport at finite bias. We demonstrate that our method is capable of a semi-quantitative description of the competition between Kondo resonances and spin-flip inelastic electron tunneling at a computational cost significantly lower than that of other approaches. The examples of Co and Fe on CuN will be discussed in detail. Our current work is focused on explaining the theoretical origin of the conductance asymmetry that is present in all of the experimentally determined spectra for Mn, Fe and Co [3]. We propose that the real part of the calculated self-energy is an odd function of bias, which results in a conductance asymmetry highly dependent on the magnitude of the onsite energy. This effect is explained for both spin and non spin polarized STM probes and to cases when the spin-system is driven out of equilibrium.

[1] A. Hurley, N.Baadji and S. Sanvito, Phys. Rev. B 84, 115435 (2011).
[2] A. Hurley, N.Baadji and S. Sanvito, Phys. Rev. B 84, 035427 (2011).
[3] A. Hurley, N.Baadji and S. Sanvito, arXiv:1203.6238 (2012).

TH-70

Influence of pore diameter on competing anisotropies in FePd antidot arrays

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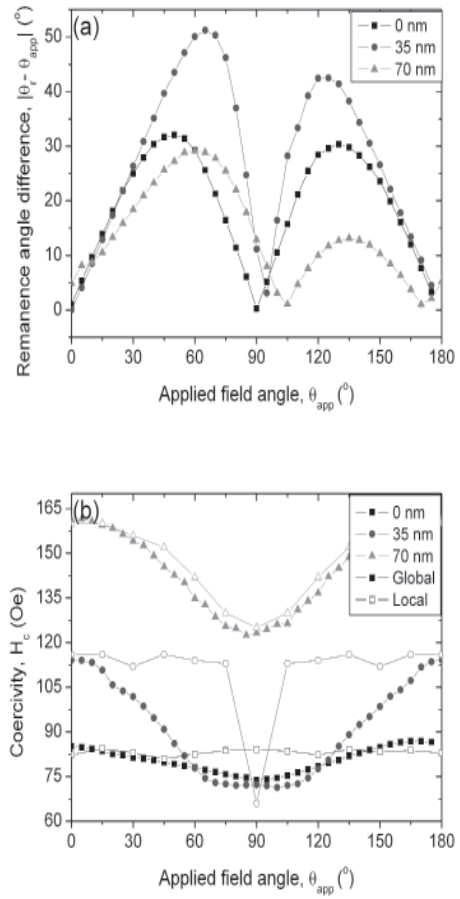
Large-scale area nanometric antidots are easily fabricated by metallic thin film deposition on nanoporous alumina templates top-surface. For a magnetic film, the pores modify its local magnetic behaviour, in comparison with a plain thin film, due to their shape anisotropy. In contrast with perfectly regular antidots fabricated by lithography, the alumina templates are isotropic on a large scale. In this work, we characterised (through major hysteresis curves, first-order reversal curves (FORC) and remanence measurements) the pores diameter influence (0, 35 and 70 nm) of polycrystalline 50 nm thick FePd thin film antidots. Unlike one could expect due to their structure, they present an in-plane anisotropic behaviour [1]. The anisotropy arises from large and parallel undulations (50 μm wide, 500 nm

high) done in the aluminium substrate prior to the anodisation procedure. Without pores, these undulations yield to a biaxial behaviour in terms of remanence direction, while global coercivity and ferromagnetic resonance measurements exhibit uniaxial anisotropy and local coercivity remains constant. We successfully modelled the plain film behaviour by two phases, one isotropic and one with uniaxial anisotropy, ranging in linear proportion with the applied field angle. Introducing hexagonally ordered pores in this patterned substrate yields to an anisotropy competition between the uniaxial (long range, from the undulations) and the shape one (short range, from the nanopores). This situation differs from the one created by a uniaxial magnetocrystalline anisotropy of the magnetic thin film. Our results show that the antidots mainly maintain the global behaviour of the thin film counterpart: remanence biaxial and global coercivity characters. However, their local magnetostatic properties cease to be isotropic. Therefore, this new kind of structure could be interesting for tailoring the magnons propagation in magnonic crystals.

[1] F. Béron, et al., New J. Phys. 13, 013035 (2011)



In-plane remanence direction (a) and coercivity (b)

TH-71

Band structure of a two-dimensional ferromagnetic antidot array

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The spin wave band structure of a two-dimensional square array of NiFe circular antidots having diameter of 120 nm and periodicity of 800 nm has been investigated by using Brillouin light scattering technique and micromagnetic calculations based on the dynamical matrix method [1]. The external magnetic field was applied in the plane and perpendicularly to the transferred wave vector. Extended and localized spin modes having a propagative nature were found. Opening of bandgaps is interpreted in terms of Bragg diffraction of spin waves from the antidot lattice and this effect is explained by studying the behaviour of the internal field as shown in Fig.1. The mean internal field is larger along the vertical rows of antidots and smaller between the antidots (see panel (a) for extended modes and (c) for localized modes). By developing an analytical model according to which the mean internal field is represented by means of a rectangular step function characterized by a region 1 corresponding to vertical rows of antidots and a region 2 between the antidots (see panels (b) and (d)), the relevant scattering potential for Bragg reflection is not provided by the holes themselves, but by the concomitant internal field inhomogeneity between holes [2]. This is in contrast to antidots in photonics and electronics where the back-reflection is directly caused by the presence of holes. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n228673 (MAGNONICS).

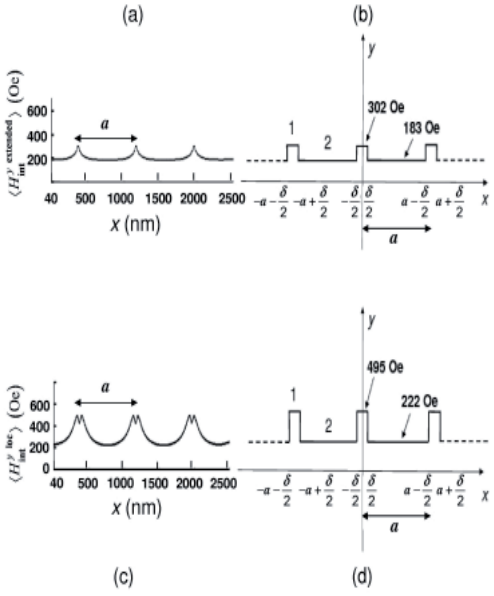

Fig.1. Internal field. (a) and (c): micromagnetic profile. (b) and (d): step functions.

[1] L. Giovannini, F. Montoncello, and F. Nizzoli, Phys. Rev. B 75, 024416 (2007).
[2] R. Zivieri, S. Tacchi, F. Montoncello, L. Giovannini, F. Nizzoli, M. Madami, G. Gubbiotti, G. Carlotti, S. Neusser, G. Duerr, and D. Grundler, Phys. Rev. B 85, 012403 (2012).

TH-72

Magnetization and coercivity of Co antidots with different pore diameters

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Antidot films are attracting attention of the magnetism community due to their enhanced coercivity as compared to continuous films. Co antidots have not been extensively studied so far, and in this work we investigate the magnetization reversion mechanism in Co films deposited on porous membranes with different pore diameters. We have used real SEM images of the antidots as inputs for the simulation program. Ordered AAO membranes with pore diameters of 20, 40 and 60 nm have been fabricated by the two anodization process. Co films with thickness of 28 nm were deposited on top of the nanoporous membranes and on a glass substrate by means of sputtering. Magnetization curves of the films have been measured by a gradient field magnetometer and simulations were carried out using real SEM images of the antidots as inputs for the oommf program [1]. In Figure 1(a) it is shown the magnetization curves of the Co films deposited on the porous membranes, the SEM images in the inset are the original images that have been used for simulations with oommf. From this figure it is clearly seen that coercivity increases as the pore diameter of the antidots increase. In Figure 1(b) the results of the hysteresis curves of the simulated antidots are displayed. The inset figures correspond to the magnetic configurations taken near the coercive field (M=0). It is observed from the figure that in the film with pores of 20 nm the domain configuration is similar to the one in the continuous film, while in the films with pores of 40 nm and 60 nm the holes are responsible for a more effective pinning of the domain walls, that is responsible for the increase of the coercivity.

[1] M.J. Donahue, D.G. Porter, URL: http://math.nist.gov/oommf/

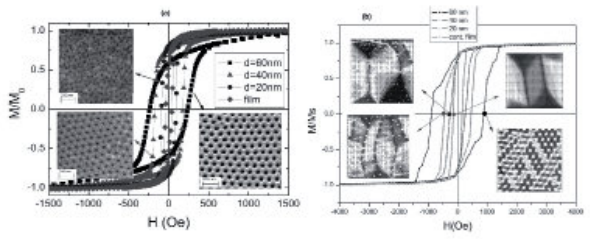

Fig. 1 (a) Hysteresis curves measured and (b) simulated.

TH-73

Magnetic properties of Co/Pd multilayers films deposited on GaSb nanocones

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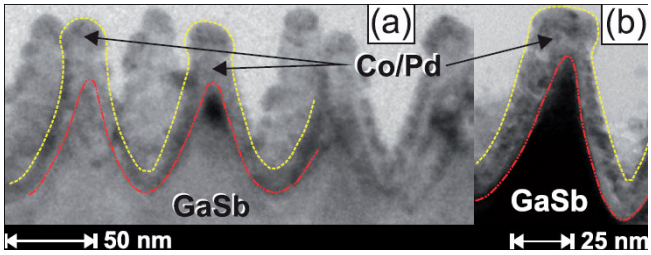
Investigation of the magnetic behavior of arrays of magnetic nanostructures is relevant for both fundamental studies as well as for application as magnetic data storage. To push the recording density of a hard disk drive beyond 1 Tbit/inch^2 the so-called *recording trilemma* must be overcame and novel recording concepts are required [1]. Bit-patterned media concept realized either by lithographic or self-assembly methods [2] is among the most promising approaches.

In the present work we report on the investigation of the magnetic behavior of Co/Pd multilayer films with perpendicular magnetic anisotropy sputtered onto pre-patterned nanocone templates (see Figure), which are fabricated by Ar^+ ion irradiation of GaSb single crystals. By tailoring the irradiation conditions, the self-organized assemblies of nanocones can be modified in size and periodicity [3]. Due to the self-organization, large patterned areas can be fabricated which is challenging using e-beam lithography.

Macroscopic magnetic measurements performed using vector-VSM magnetometry indicate that all samples possess the magnetic easy axis perpendicular to the cone surface. The remanence as well as the coercivity decreases with increasing cone size, as the letter leads to a larger angular spread of easy axis following the morphology of the pattern. Additionally, MFM characterization shows that in the case of small cone structures the underlying cone pattern results in a pinning of magnetic domain walls on cone locations as there is a clear correlation between the morphology and positions of magnetic domain walls. For larger cone sizes, exchange decoupled magnetic caps are achieved with single domain areas confined to the cones apexes.

[1] S. N. Piramanayagam and T. C. Chong, Developments in data storage, John Wiley & Sons (2011)
[2] P. Krone et al., Nanotechnology 21, 385703 (2010)
[3] S. Facsko et al., Phys. Rev. B 69, 153412 (2004)



TEM cross-sections of a Co/Pd multilayer deposited onto a nanocone template

TH-74

First principles study of domain walls through a Co nanocontact

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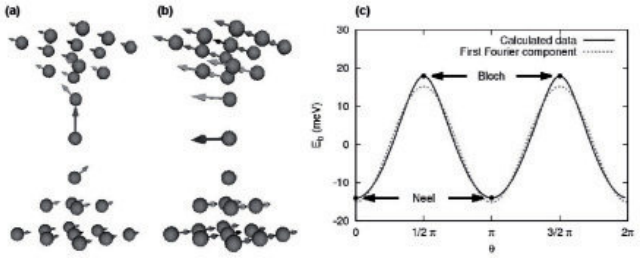
Magnetic nanojunctions are subjects of intensive research due to fundamental challenges in solid state physics and their potential application in spintronics devices [1,2]. We present self-consistent first principles calculations suitable to find the magnetic ground

state of nanoparticles without any assumption of a spin-model and point-group symmetry. For this purpose, we evaluate the band energy and its derivatives provided by a fully relativistic Green's function technique based on the Embedded Cluster Multiple Scattering method within the local spin-density approximation of the density functional theory. The ground state configutation is then searched by means of Newton-Raphson iterations. The method is tested on a cobalt nanocontact that turns out to show a Néel-type of domain wall between antiparallelly magnetized Co leads. In terms of magnetic force theorem, we indeed found that the Néel-type wall, see Fig. (a), is by about 30 meV lower in energy than the Bloch-type wall, depicted in Fig. (b). In Fig. (c) we show the variation of the energy of the system during an artificial global spin rotation from one configuration into the other.
A detailed investigation elucidated that the uniaxial anisotropy on the central atom contributes up to 60 % to this energy difference. This high uniaxial anisotropy energy is accompanied by a huge enhancement of the orbital magnetic moment of the central atom, μ_{orb} = 1.08–2.06 μ_B. Furthermore, we calculated the anisotropy energy function on the central atom up to an order of $\ell = 4$ in terms of the spherical harmonics and identified the Weiss-field term, the terms related to the crystal field, and even those due to higher order spin-spin interactions.

[1] M. R. Calvo *et. al*, Nature **458**, 1150 (2009).
[2] A. Thiess *et. al*, Phys. Rev. B **81**, 054433 (2010).



Domain wall configurations and variation of the energy by global spin-rotation.

TH-75

Mechanisms of reversing stripe domain structure in Co(111) nanowires

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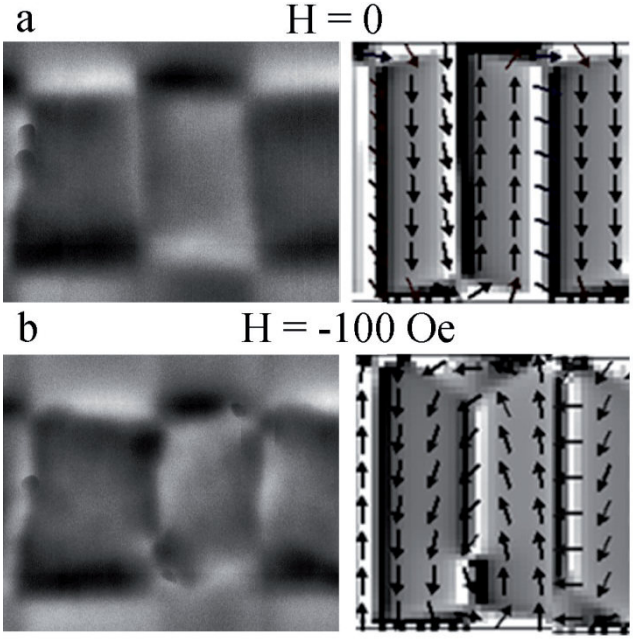
In this work we investigate reversing of the stripe domain structure (SDS) in the epitaxial Co(111) nanowires by means of magnetic force microscopy (MFM) and computer simulation.

The nanowires reveal step-induced (K_{step}) and shape (K_{shape}) magnetic anisotropies, the easy axis of which are perpendicular to each other and lie in the plane of the nanowires. Magnetization reversal of the nanowires depends on relation of energies of magnetic anisotropies. Magnetic field was directed parallel to the long axis of the wires. The thickness of Co wires was 10 nm, the width was varied from 500 to 1800 nm.
SDS with 180° Neel-type domain walls (DW) is observed in the nanowires of width 1800 nm ($K_{step} > K_{shape}$) in the remanent state of the magnetization. Positively directed closure domains (PDCD) present on the opposite ends of adjacent DW (fig.a). After applying magnetic field H = -100 Oe (coercive force) negatively directed closure domains (NDCD) appear on the other ends of the DW. Negatively polarized area of the DW nucleates from NDCD and moves to PDCD changing the polarization of the DW (fig.b). PDCD disappear after applying higher negative fields.
As in the upper case PDCD are formed in the SDS at the remanent state of the nanowires of 900 nm width ($K_{step} \cong K_{shape}$). However magnetization reversal of the nanowires occurs through stable intermediate domain structure formation.
Dispersion of the single domain state is observed in the remanent state of the nanowires of width 500 nm ($K_{step} < K_{shape}$). When negative magnetic field has been applied, SDS begins developing in the nanowires. Oppositely magnetized domains are nucleated on the nanowires ends, when H reaches the switching field, and momentary propagation of vortex-like DW switches the magnetization in the nanowires.



MFM images and computer modeling of magnetization reversal in the Co wires.

TH-76

Effect of aluminum capping on the magnetic behaviour of core-shell iron nanoclusters.

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This work reports on the magnetic behaviour of thin films containing oxidized iron nanoclusters (less than 10 nm diameter) prepared by the gas-phase aggregation technique. Depending on the cluster density and capping conditions, a wide range of magnetic behaviours have been obtained. Knowing the distance between particles as well as the relative size and nature of core and shell is needed to explain the conditions determining the appearance or not of exchange bias in the hysteresis loops (i.e. when the magnetic exchange between core and shell becomes relevant). Therefore, in order to properly explain the differences in the magnetic behaviour a comprehensive structural and electronic characterization (including AFM, TEM and SEM microscopies and Rutherford backscattering, Mössbauer and X-ray absorption spectroscopies) has been carried out to explore the nature of the obtained nanoclusters. The combined structural, electronic and

magnetic study shows that slightly different conditions in the preparation method strongly determine the magnetic properties and especially the stability of the ferromagnetic state. Slight changes in the amount of Al among the Fe clusters have a mayor effect in the relative role of two competing effects: magnetization pinning due to the shell and interparticle interaction. The magnetic measurements show that Al capping gives rise to a clear reduction of the value of both the coercive and exchange-bias fields. This is explained in terms of both electronic and density effects due to the Al matrix, which determines not only the interparticle distance but also the relative proportion of iron phases (metal vs. oxide) and presence/absence of interaction between clusters.

TH-77

Enhancement of the coercivity of a porous silicon/Ni composite by magnetic field assisted template etching

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In the frame of this work the magnetic behaviour of a nanocomposite consisting of magnetic field assisted etched mesoporous silicon utilized as matrix for electrodeposition of ferromagnetic metals has been investigated. First, within the pores of conventional etched porous silicon matrices – anodized without magnetic field - Ni nanostructures have been deposited, whereas their shape and arrangement determine the coercivity and remanence of the samples. Second, porous silicon anodized in the presence of a magnetic field has been employed as matrix for metal deposition. In both cases comparable metal wires longer than one micrometer are reached. In applying a magnetic field perpendicular to the sample surface during the anodization the pore formation is influenced. With increasing magnetic field strength up to 8 T an enhancement of the pore aspect ratio is achieved due to a directional regulation on supply of holes into the pore-tips along the normal to the substrate [1]. Furthermore the growth of side-pores is decreased and thus the effective mean distance between the pores is enhanced. After deposition of Ni within the pores the achieved nanocomposite offers a significantly increased coercivity and remanence compared to standard porous silicon Ni-filled samples which is due to the smoothed walls of the Ni deposits leading to weaker magnetic coupling between Ni-structures of adjacent pores. The deposition of Ni structures within these pores results in a more than doubled coercivity (increase from 270 Oe to 650 Oe) and a doubled remanence (from 0.42 emu to 0.85 emu) compared to samples etched without magnetic field containing comparable Ni-deposits.

[1] D. Hippo, Y. Nakamine, K. Urakawa, Y. Tsuchiya, H. Mizuta, N. Koshida, S. Oda, *Jpn. J. Appl. Phys*. **47**, 7398 (2008).

TH-78

2D Diffraction of unpolarized beams of electrons by linear chain of charged nanomagnets

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It is shown that the scattering of the unpolarized beams of electrons by nanomagnets in the vicinity of some scattering angles reveals completely spin polarized electrons. This result is obtained with the help of the Born approximation. The dipole-dipole interaction between the magnetic moment of the nanomagnet and the magnetic moment of electron is treated as a perturbation. This interaction is not spherically symmetric and depends on the electrons spin variables. It in turn results in spinor character of the scattering amplitudes. Due to the smallness of the magnetic interactions, the scattering length of this process is very small to be checked experimentally. To enhance the relevant scattering lengths, we considered the diffraction of unpolarized beams of electrons by linear chains of charged nanomagnets. The presence of charged nanomagnets enhances the scattering lengths by one order than the case of scattering of electrons from neutral nanomagnets. By tuning the distance between the nanomagnets it is possible to obtain the diffraction maximum of the scattered electrons at scattering angles which corresponds to complete spin polarization of electrons. It is shown that the total differential scattering length is proportional to N^2 (N is a number of scatterers). Even for not very large number of nanomagnets in the chain, it is possible to obtain the experimentally visible enhancement of the polarization of the scattered electrons. Our numerical calculations and graphical analysis show that the 2DEG silicon is good candidate than other 2DEGs.

V. N. Mal'nev and T. Senbeta, JMMM. **323**, 1581-158 7(2011). J. Wang, P. Beeli, Y. Ren Guo-meng Zhao, Phys. Rev. B **82**, 193410 (2010).

TH-79

Exchange Biasing in Co/CoO nanocaps and nanoislands

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Recently self-assembly of colloidal microspheres or nanospheres has been proven an effective strategy for bottom-up fabrication of ordered nanostructures. It is therefore suitable for the fabrication of model exchange biasing systems where precise control of microstructure is desirable [1-3]. In this work we present a study of exchange biasing phenomena in sputtered cobalt oxide/cobalt bilayers that have been nanostructured by using polystyrene spheres (970nm and 170nm) both as a template for the deposition of nanocaps and as a mask for the formation of triangular-like islands (330nm and 60nm respectively). Cobalt layers 30nm thick have been magnetron sputtered deposited and subsequently oxidized by prolonged heat treatment at 800^0C in oxygen atmosphere to form a 15nm thick CoO layer. Upon field cooling under 30kOe, the nanocaps show coercivity Hc=1kOe and exchange biasing Hex=0.4 to 0.6 kOe that does not depend sensitively on the size, compared to Hc=0.1 kOe and H_{ex}=0.27 kOe of a continuous film prepared under the same conditions. The nano-islands show Hc =1 kOe and Hex=0.37 kOe only for the smaller size. The Hc and Hex values correlate well with blocking temperatures estimated by magnetization vs temperature measurements.

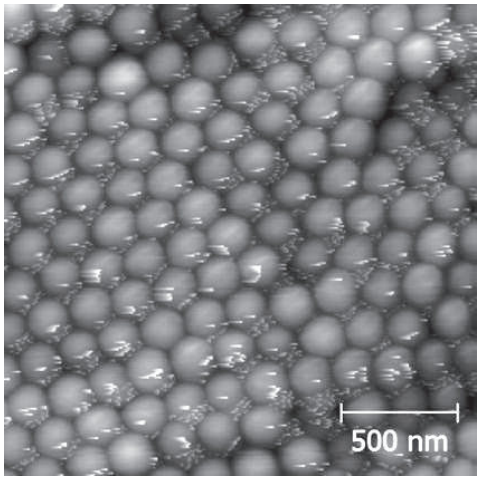

Figure: Atomic Force Microscopy Image of a nanosphere array.

[1] I.L. Guhr, S. van Dijken, G. Malinowski, P. Fischer, F. Springer, O. Hellwig and M. Albrecht, J. Phys. D: Appl. Phys. 40, 3005 (2007)
[2] Y. J. Zhang, Y. X. Wang, X. D. Meng, Y. Liu, X. Ding and J. H. Yang, J. Appl. Phys. 105, 083910 (2009)
[3] Y.X. Wang, N.N. Yang, M.B. Wei, Y.J. Zhang, H.B. LiuY. Liu, J.H. Yang, Journal of Alloys and Compounds 509, 6626 (2011)

TH-80

Effect of irradiation on the magnetic properties of FeSiB patterned dots

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Magnetic thin films are widely employed as building elements of nanodevices. Exposure to ion beams is used for nanopatterning and for tailoring their properties at a very small scale, as microstructure, magnetic anisotropy and domain configuration are affected [1]. In this paper we present the effect of ion beam irradiation on patterned dots of amorphous $Fe_{78}Si_9B_{13}$. This alloy displays a spin reorientation transition (SRT) at room temperature in the as-prepared condition, i.e. a reorientation of the magnetic anisotropy from in-plane to out-of-plane above a critical sample thickness (≅ 120 nm), in which case a dense stripe domain configuration develops [2]. A 250 nm thick film is patterned by optical lithography into an array of square dots (size ≅ 6 μm, centre-to-centre distance 15 μm). The domain configuration of the dots, observed by magnetic force microscopy (MFM), is characterized by a meander-like structure, with dark and bright regions whose magnetization is tilted upward and downward. A Focused Ion Beam (FIB) exploiting Ga^+ ions accelerated at 30 kV is used to irradiate individual dots uniformly. Through proper exposure calibration, a controlled thickness reduction is obtained on individual dots. Their magnetic properties are investigated with MFM, in static conditions and as a function of an applied magnetic field (local hysteresis loops). The SRT is studied as a function of dot thickness. The magnetic domain configuration is also correlated to the surface roughness, affected by the ion beam exposure. The role of ions irradiation on the magnetic domain configuration and on anisotropy of FeSiB patterned thin films is discussed.

[1] M. Jaafar, R. Sanz, J. McCord, J. Jensen, R. Schäfer, M. Vázquez, A. Asenjo, Phys. Rev. B 83 (2011) 094422
[2] M. Coïsson, F. Celegato, E. Olivetti, P. Tiberto, F. Vinai, M. Baricco, J. Appl. Phys. 104 (2008) 033902

TH-81

Magnetization process of dot arrays in $Ni_{80}Fe_{20}$ films fabricated by Focused Ion Beam lithography

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The fabrication of ferromagnetic nanodot arrays has been played a key role for applications in magnonics [1]. In this work, dots with different diameters have been fabricated in a magnetically soft thin film. The patterned system fabrication process starts with the RF sputter deposition of a $Ni_{80}Fe_{20}$ film having thickness t=20 nm on a thermally oxidized Si substrate. Focused ion beam (FIB) lithography in a FEI Quanta 3D Dual-beam using a standard Ga ions source has been exploited to obtain the nanodot arrays. The dose profile has been optimized to reduce redeposition and amorphization effects paying attention to minimize the implantation of Ga ions. An example of the dot arrays is shown in the Fig. 1(a) (dot diameters 800 and 600 nm at a distance ~50 nm). Magnetic domain patterns have been imaged by magnetic force microscopy (MFM). The measurements have been performed in lift-mode (CoCr tip, coercive field 40 mT). The image of Fig. 1(b) has been acquired at the magnetic remanence from a field of 1.5 T applied perpendicularly to the sample plane.
We also performed numerical simulations of the experimental geometry by using GPU micromagnetic code GPmagnet [2]. To characterize the device, static simulation of the hysteresis loop applying a field along the x-direction (from left to right in Fig. 1(a)) is shown in Fig. 1(c). Finally, to compare experimental MFM measurements to micromagnetic simulations, we saturated the sample along out of plane direction and after we leave the sample to the remanence (see Fig. 1(d)). As expected, the magnetization configuration is a vortex state in agreement with experimental data.

[1] V.V. Kruglyak, P. S. Keatley, A. Neudert et al., Phys. Rev. Lett., 104, 027201 (2010)
[2] www.goparallel.net

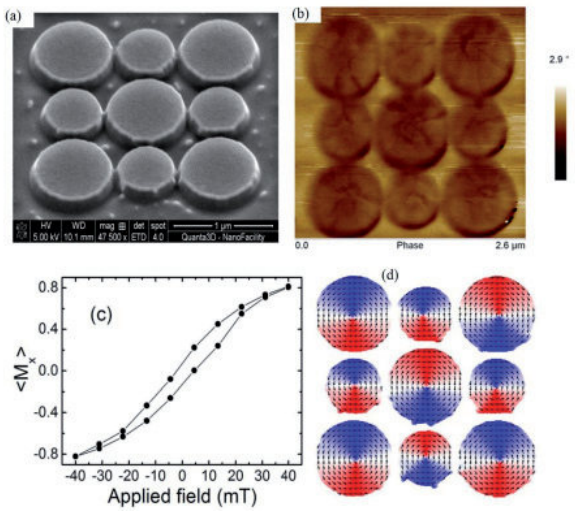

Fig. 1 (a) SEM topological image, (b) MFM image at remanence, (c) micromagnetic hysteresis loop, (d) micromagnetic simulation at remanence.

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

MAGNETISM AND SUPERCONDUCTIVITY

Chair: G. Allodi

TH-82

Probing the FLL motions in iron-pnictide superconductors by high magnetic field NMR

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Since the discovery of high temperature superconductivity in the Fe-based pnictides, the structural and dynamical properties of the flux lines lattice (FLL) have been the subject of intense research activity, and the investigation of the mixed phase in these materials is important both for the fundamental and the applicative aspects.
We present a ^{75}As NMR study of a single crystal iron-based superconductor, belonging to the 122 family: $Ba(Fe_{0.93}Rh_{0.07})_2As_2$. The sample shows some similarities with the Co-doped compounds but, unlike the majority of those samples [1], this Rh-doped sample shows a clear peak in the spin-lattice relaxation rate $1/T_1$, below the irreversibility temperature. Since this feature is characteristic of the superconducting phase, and it is field-orientation dependent, we argued that this effect is typical of the FLL dynamics taking place in the liquid-FLL phase, where the vortices are rather uncorrelated 2D objects. Furthermore the peak cannot be ascribed to the opening the superconducting gap (Hebel-Slichter peak). As far as the FLL phase diagram is concerned, the thermally activated response of the 2D pancakes can be very different depending on the field and temperature conditions. In particular, increasing the field intensity one expects a more "movable" FLL (Fig. 1). Another marker of the vortices dynamics is the spin-echo decay time T_2. A strong peak in $1/T_2$ was seen for **H** || c, and also in the Co-doped compounds by Oh et *al*. [2]. The peak is strongly suppressed in the transverse geometry, evidencing the presence of an anisotropic dynamics.

[1] F. Ning et *al.*, Jour. Phys. Soc. of Jpn. **77**, 103705 (2008)
[2] S. Oh et *al.*, Phys. Rev. B **83**, 214501 (2011)

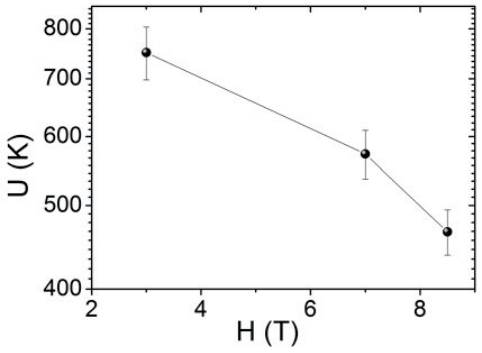

Fig. 1: Pinning activation energy obtained by fitting the peak in $1/T_1$

TH-84

Muon spin spectroscopy in RECoAsO and RECoPO under hydrostatic pressure

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Oxy-pnictide materials REFeAsO belonging to the so-called 1111 family offer a rich magnetic phenomenology associated to the interplay of both itinerant (*d*-like) and localized (*f*-like) magnetic degrees of freedom, different extents of hybridization among these being achieved by the effect of chemical (as well as external) pressure. An investigation of magnetism at a local level as a function of the two different kinds of pressure, then, is of great interest also in view of the possible implications for the possibly magnetically-mediated superconducting pairing mechanism.
REFeAsO materials are known to experience antiferromagnetic correlations on the FeAs bands resulting in a spin-density wave phase at low temperatures in the undoped parental limit. Surprisingly, in Co-based RECoAsO compounds ferromagnetic correlations are at work [1] and, at variance with the former materials, superconductivity is not displayed in their phase diagram. In RECoAsO compounds, interesting magnetic properties due to the simultaneous presence of both Co and RE magnetic sublattices have been reported [2]. A somewhat similar phenomenology has been reported in the isostructural compounds RECoPO [3] even if, in this case, detailed systematic local investigations are still lacking.
Here we present the results of a local μSR investigation on RECoAsO and RECoPO samples under applied external pressure. At this stage of the work, LaCoPO appears to be the most interesting compound due to its high sensitivity to pressure, even if DFT calculations do not evidence any sizeable effect on the structure of the electronic bands.

[1] H. Ohta, K. Yoshimura, Phys. Rev. B 79, 184407 (2009)
[2] J. Sugiyama et al., Phys. Rev. B 84, 184421 (2011)
[3] A. Pal et al., Journ. Appl. Phys. 110, 103913 (2011)

TH-85

Local features of Ce magnetism in $CeFeAsO_{1-x}F_x$ by means of ^{19}F-NMR spectroscopy

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In spite of the sizeable improvements in understanding the most relevant macroscopic properties of $REFeAsO_{1-x}F_x$ superconductors, several questions about these materials are still open on the microscopic point of view. On the one hand, superconductivity is typically reported to emerge close to the

disruption of an antiferromagnetic phase. Similarly to the scenario possibly holding for cuprate materials, then, a magnetically-mediated superconducting pairing can be envisaged. Different rare-earth ions, on the other hand, dramatically affect the overall features of the superconducting phase in these compounds. For instance, a full Sm/La substitution is known to double the T_c value even if it is not understood yet whether such effects are due to the magnetic moment localized onto the rare earth ions or not. It is then clear how the local investigation of the microscopic magnetic features of the rare-earth sublattice across the whole phase diagram for different rare-earth ions is of extreme importance and interest for a better microscopic understanding of superconductivity itself.
The results of an experimental investigation performed on an optimally-doped sample of $SmFeAsO_{1-x}F_x$ by means of ^{19}F-NMR spectroscopy show a sizeable *f-d* hybridization of Sm with electronic bands from Fe orbitals which are not involved with superconductivity [1]. In a multi-band scenario, an indirect RKKY-like interaction among Sm magnetic moments results to be favoured through non-superconducting bands.
Here we discuss the results of ^{19}F-NMR measurements performed on Ce-based compounds, where the degree of *f-d* hybridization is expected to be much higher due to the peculiar features of such ion. The multi-band scenario envisaged for Sm-based materials is clearly confirmed, making it possible to guess that the magnetic and superconducting ground states in the phase diagram of 1111 materials are strictly confined onto different and non-interacting electronic bands.

[1] G. Prando et al., Phys. Rev. B 81, 100508(R) (2010)

TH-86

Manganese poisoning effect in La-based iron pnictides superconductors

M. Mazzani [1], G. Allodi [1], P. Bonfà [1], R. De Renzi [1], S. Sanna [2], P. Carretta [2], G. Prando [3], M. Sato [4], Y. Kobayashi [4]
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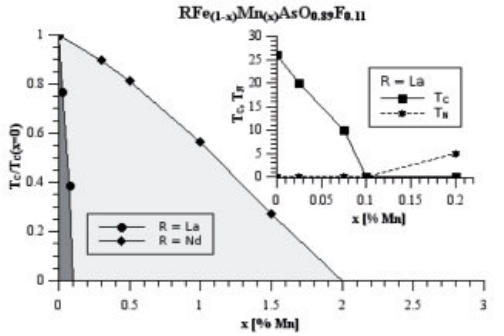
Magnetic pairing is the candidate for the mechanism of high temperature superconductivity, and the effects of magnetic impurities may probe this hypothesis. It is well known that in iron-based pnictides superconductors additional hole or electron doping, both outside and inside the Fe layers, controls superconductivity [1]: this is at play in Mn-doped $NdFeAsO_{0.89}F_{0.11}$ and Co-doped $RFeAsO_{0.89}F_{0.11}$ (R=Nd,La), where Fe substitutions of a few percent is needed to inhibit superconductivity [2,3].
Here we investigate the specific, extraordinary **poisoning** effect of Mn on the superconducting ground state of $LaFeAsO_{0.89}F_{0.11}$ [3]. As shown in the figure, 0.1% of Mn suffices to destroy optimal superconductivity, an impressive observation when compared to the behaviour of the other compounds.
We have performed μSR experiments to check the magnetic phase diagram of this system as a function of Mn doping. The SC ground state is confirmed to disappear for [Mn] > 0.001, while a magnetic phase arises at higher Mn concentrations (see figure inset). These results have prompted a more detailed study of the microscopic electronic properties, initially in the [Mn]=0.002 sample, by ^{55}Mn NMR. The complex NMR spectrum features the presence of a dominant meta-magnetic staggered phase, probably due to the diluted Mn, and the unambiguous signature of a small fraction of double-exchange ferromagnetic (DEF) manganite $LaMnO_{3+x}$. Notably, the La-La distance in the manganite matches that of $LaFeAsO_{1-x}F_x$. Furthermore only R=La yields a DEF phase among all $RMnO_{3+x}$ compositions.
Our results rise the question whether DEF $LaMnO_{3+x}$ is an inter-growth in $LaFeAsO_{0.89}F_{0.11}$:Mn and might play a role in the spin polarization of the Fe layers, tipping the balance away from superconductivity. The combination of NMR with SQUID magnetometry has allowed the quantitative estimation of the Mn phases observed by NMR, showing that all ^{55}Mn nuclei give rise to amplified NMR signals, characteristic of magnetically ordered phases.

[1] A.S. Sefat et al., *Phys. Rev. Lett. 101, 117004 (2008).*
[2] E. Satomi et al., *Journal of the Physical Society of Japan*, vol.79, 094702 (2010).
[3] M.Sato et al., *Journal of the Physical Society of Japan*, vol.79, 014710 (2010).



Depression of T_c against Mn doping, for compounds based on different rare earths. Inset: Phase diagram of $LaFe_{1-x}Mn_xO_{0.89}F_{0.11}$

TH-87

Tuning the interplay between magnetism and superconductivity in optimally F doped $REFe_{1-x}Ru_xAsO$ with RE=Sm, Nd, La

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In the REFeAsO family it is found that SC and static magnetism strongly compete and hardly coexist simultaneously, apart for RE=Sm and Ce within a small doping range where both order parameters are depressed [1-5]. In case of coexistence both cuprates and pnictides display a short range magnetic order, related to magnetic clusters nanoscopically mixed with SC regions. A combination of recent experiments of muon spin relaxation and nuclear quadrupolar resonance on $REFe_{1-x}Ru_xAsO_{0.85}F_{0.15}$ with RE=Sm show that superconductivity and

magnetism are tightly related to two distinct well defined local electronic environments of the FeAs layers, which can be finely tuned by isoelectronic and diamagnetic Ru substitution [6]. It is also shown that, by going from RE=Sm to Nd to La, the re-entrant static magnetism is progressively weakened, while the superconductvity is less perturbed. In addition the residual resistivity is increased when magnetism is strongly pinned, displaying that electrons and magnetic excitations are intimately coupled. Indirect evidence is given that superconductivity is assisted by Fe magnetic fluctuations, which are at least partially frozen when static order appears and are absent above the Fe/Ru spin dilution threshold [6-7].

[1] S. Sanna, et al., *Phys. Rev. B* 80 052503 (2009).
[2] G. Prando et al., *Phys. Rev. B* 81 100508(R) (2010).
[3] S. Sanna et al., *Phys. Rev. B* 82, 060508(R) (2010).
[4] R. Khasanov et al., *Phys. Rev. B* 84, 100501(R) (2011).
[5] T. Shiroka et al., *Phys. Rev. B* 84, 195123 (2011).
[6] S. Sanna et al., *Phys. Rev. Letters* 107, 227003 (2011).
[7] P. Bonfà et al., *Phys. Rev. B* 85, 054518 (2012).

TH-90

Crystal structure and magnetism in $CeIr(Si_xGe_{1-x})_3$ compounds

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The $CeMX_3$ intermetallics adopting the noncentrosymmetric tetragonal BaNiSn3-type crystal structure recently attracted much attention mainly owing to unconventional superconductivity observed in some of them [1]. $CeIrSi_3$ and $CeIrGe_3$ were reported to exhibit antiferromagnetic ordering with T_N = 5.0 K and 8.5 K, respectively. $CeIrGe_3$ also undergoes an order-order transition at T_1 = 4.7 K. When applying hydrostatic pressure T_N gradually decreases and a superconducting dome appears in the vicinity of QCP for the pressure Pc = 2.2 and 23 GPa, respectively [1, 2]. Our work has been motivated by the desire to know how the magnetism and superconductivity evolve with the composition of the SiGe sublattice. For this purpose we have prepared polycrystalline samples of selected compositions of the SiGe sublattice by arc melting, annealed and characterized them and measured magnetization, resistivity and specific heat in a wide temperature range and various magnetic fields. The solutions keep the crystal symmetry of the parent compounds and the lattice parameters follow Vegard's law. The T_N vs. x dependence is not entirely monotonous (T_N does not scale with volume); a minimum T_N is observed for x between 0.75 and 1. The results of powder neutron diffraction will be presented as well.

[1] Ch. Pfleiderer, Rev. Mod. Phys. 81, 1551 (2009) and ref. therein
[2] F. Honda et al., PRB 81, 140507 (2010)

TH-91

μSR studies of superconductivity in eutectically-grown mixed ruthenates

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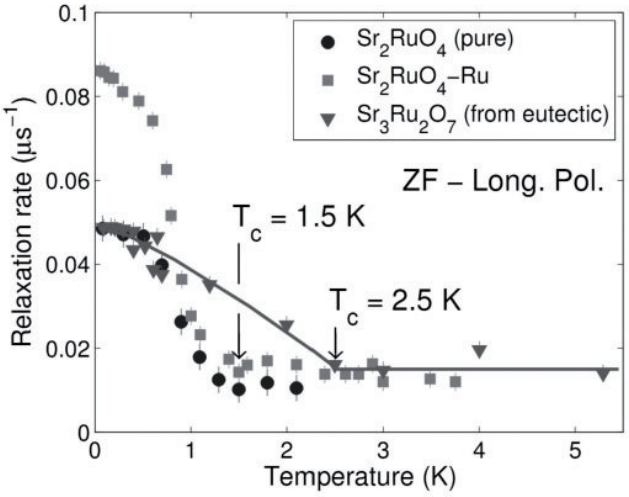
Although less prominent than Sr_2RuO_4, the odd-parity spin-triplet pairing superconductor [1], the itinerant metamagnet $Sr_3Ru_2O_7$ reserves also surprises. Recently, we tried to investigate the low-temperature magnetic behaviour of $Sr_3Ru_2O_7$ crystals as grown from an eutectic Sr_2RuO_4-$Sr_3Ru_2O_7$ system by means of zero- and transverse-field muon-spin rotation. The gradual increase of the muon relaxation rate observed below 2.5 K, even in the absence of applied magnetic fields, indicates the occurrence of a spontaneous breaking of time reversal symmetry. The onset of the latter at a temperature above 1.5 K, the T_c of the single phase Sr_2RuO_4, provides evidence about an *unconventional superconducting state* in the eutectic phase, which most likely takes place at the interface between the Sr_2RuO_4 and $Sr_3Ru_2O_7$ domains, or even inside the $Sr_3Ru_2O_7$ phase. We show that the superconducting state manifests a two-component behaviour in the transverse-field response with change-over at about T = 2.5 K and T = 1.5 K. The comparison with zero-field MuSR data in the Ru-Sr_2RuO_4 eutectic system rules out the possibility of spurious effects due to embedded Ru islands.

[1] A.P. Mackenzie and Y. Maeno, Rev. Mod. Phys. 75, 657 (2003)



Zero-field μSR relaxation vs. T in eutectic $Sr_3Ru_2O_7$ vs. pure Sr_2RuO_4 and Sr_2RuO_4-Ru metal system

TH-92

Stabilization of ferromagnetic order and existence of ferromagnetic quantum critical point in $UCo_{1-x}Ru_xGe$ system

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UCoGe is one of few examples of coexistence of weak ferromagnetism ($T_C \sim 3$ K) and ambient pressure superconductivity ($T_{sc} \sim 0.6$ K). We have prepared a series of polycrystalline samples of $UCo_{1-x}Ru_xGe$ compounds for $x \leq 0.35$ in order to study development of magnetism and superconductivity of this compound with Ru doping. All samples have been thermally treated and the stoichiometry has been verified by X-ray powder diffraction (XRPD) and Energy dispersive X-ray spectroscopy (EDX). The whole series adopts the orthorhombic TiNiSi-type structure of the parent UCoGe compound. Evolution of the lattice parameters follows well the Vegard's law. All samples have been subjected to magnetization, ac susceptibility, heat capacity and electrical resistivity measurements in wide temperature and magnetic field intervals. The Ru doping leads to the sharp increase of the Curie temperature up to the $T_C = 8.5$ K for $x = 0.12$. Further increase of Ru content destabilized ferromagnetic state, which dissolved through a ferromagnetic quantum critical point (FM QCP) for $x \approx 0.3$. No sign of superconductivity has been detected in the Ru doped samples. The next stage our research has been focused on growth and characterization the single crystals $UCo_{0.88}Ru_{0.12}Ge$ (maximum T_C) and $UCo_{0.70}Ru_{0.30}Ge$ (FM QCP) for further detailed study. The magnetic state of the $UCo_{0.88}Ru_{0.12}Ge$ single crystal has been studied with polarized neutron diffraction (D3 in ILL) under the magnetic field to describe magnetic state in microscopic scale. We have focused on individual contributions of the spin and orbital U, Co (and Ru) moments to total magnetic moment, their cancellation and magnetic field evolution. The stability of ferromagnetism of the magnetically stable $UCo_{0.88}Ru_{0.12}Ge$ and magnetically unstable $UCo_{0.70}Ru_{0.30}Ge$ (FM QCP) has been studied also under external pressure.

TH-94

Solubility limit of molybdenum in Mo-Sr-R-Cu system and magnetism and superconductivity in $Mo_{0.3}Cu_{0.7}Sr_2RCu_2O_y$ (R = Y, Er)

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A systematic study is reported on the range of stability of molybdenum substituted Sr-based 123 compounds with Mo-Sr-R-Cu (R = Y and Er) system, synthesized under ambient pressure. All materials crystallize in the space group: P4/mmm and the observed solubility limit of Mo is rather low in this structure because secondary phases start to form as soon as $x > 0.3$ in nominal composition is reached. A detailed study of the structure-composition-properties correlation is also reported for the as prepared and oxygen annealed pure $Mo_{0.3}Cu_{0.7}Sr_2RCu_2O_y$ (R = Y and Er) materials. Their crystal structure is characterized by the combination of X-ray/neutron powder diffraction and electron diffraction techniques. The influence of oxygen annealing in the electronic states for the $Mo_{0.3}Cu_{0.7}Sr_2RCu_2O_y$ (R = Y and Er) systems associated with an oxidation reaction from a non-superconducting material to a superconducting material has also been investigated by means of X-ray photoelectron spectroscopy. We unambiguously show the predominance of the Mo^V state over the Mo^{VI} one on both as-synthesized and annealed phases; annealing under an oxygen atmosphere enhances both the Mo^{VI} and Cu^{II} amounts. The as prepared $Mo_{0.3}Cu_{0.7}Sr_2ErCu_2O_y$ material shows the existence of ferromagnetic cluster originated from the short-range ordering of the Mo^V cations. On the other hand oxygen annealed samples are superconducting ($T_{onset} = 36$ K and 33 K for Y and Er respectively). A partial oxygen ordering in the $(Mo/Cu)O_{1+\delta}$ chain could explain the superconductivity in the oxygen annealed material. We also suggest that the enhancement of Mo^{VI} under oxygen annealing is in close relation with the decrease in the O 2p→Cu 3d charge-transfer energy resulting in superconducting properties.

TH-95

Growth of Heteroepitaxial $La_{2-x}Sr_xCuO_4/La_{0.67}(Ca,Sr)_{0.33}MnO_3$ Superlattices using Pulsed Laser Deposition

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The complex interplay between the competing SC and FM order parameter across the interface of high Tc superconductor and ferromagnetic manganite layers in $YBa_2Cu_3O_7/La_{0.67}Ca_{0.33}MnO_3$ superlattices has lead to the observation of a number of intriguing phenomena e.g. a giant magnetoresistance[1] and a magnetic proximity effect[2-3]. Here we present the growth of superlattices which contain instead of $YBa_2Cu_3O_7$ the cuprate high Tc superconductor $La_{2-x}Sr_xCuO_4$(LSCO). The latter has a simpler crystallographic structure and offers access to a wide doping range by controlling the Sr doping concentration.

In our poster we shall present the Pulsed Laser Deposition growth of $La_{2-x}Sr_xCuO_4$ (x=0.15,0.2) thin films on $SrLaAlO_4$ (001) substrates.We have applied a new approach of using pure N_2O as the background gas to obtain stoichiometric samples. The film growth has been monitored and characterized by *in-situ* RHEED as to ensure a layer-by-layer growth. The samples exhibit excellent metallic properties with a superconducting transition temperature of T_c(R=0ohm)=36K for the optimally doped sample. Moreover we have managed to grow ultrathin (~10nm) samples without reducing the superconducting transition temperature. X-ray diffraction analysis reveals that the samples are highly c-axis oriented and have excellent crystallinity. Subsequently, we developed heteroepitaxial $La_{2-x}Sr_xCuO_4/La_{0.67}(Ca,Sr)_{0.33}MnO_3$ superlattices. A brief overview of their transport, magnetic as well as structural properties will also be presented in this poster.

[1] V. Peña et al., Phys. Rev. Lett. 94, 057002 (2005).
[2] J. Stahn et al., Phys. Rev. B 71, 140509 (2005).
[3] J. Chakhalian et al., Nat. Phys. 2, 244 (2006).

TH-96

The range of antiferromagnetism in copper oxide superconducting ceramics

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We put forward the single band extended Hubbard model to represent the YBCO compound. We solve this model in the Hartree-Fock (H-F) and in the coherent potential (CP) approximation for the presence of antiferromagnetism [1].
Our Hamiltonian includes the on-site Coulomb repulsion *U* and the hopping interaction Δt (see [2,3]), which causes the rapid growth of the bandwidth when the carrier concentration *n* departs from unity. In addition we have the single-site Hund's type interaction, F_{in}. This interaction can be interpreted as the interaction between different orbitals on the same lattice site in the multiorbital single band model. We compare the occurrence of AF state in the H-F and CP approximations with the experimental data. We show that the fast disappearance of antiferromagnetism observed experimentally can be supported by relatively large bandwidth and additionally by the hopping interaction.
The CP approximation used for the on-site Coulomb repulsion *U* is justified by the large ratio of Coulomb repulsion to the effective bandwidth, *D*, being reduced by the hopping interaction,

$$D = D_0\left(1-\frac{\Delta t}{t}n\right),$$

where D_0 is the initial half bandwidth and *t* is the hopping integral. Fig. 1 shows the critical curves for the antiferromagnetic interaction (F_{in})$_{cr}$
The Coulomb repulsion *U* is treated in the CP approximation. The F_{in} values fitted to the Néel's temperature at n=1 are shown in this figure by the horizontal lines. At the intersection with critical curves they determine the range of AF state. The parameters used are: Δt = 0 , U = 0.3eV

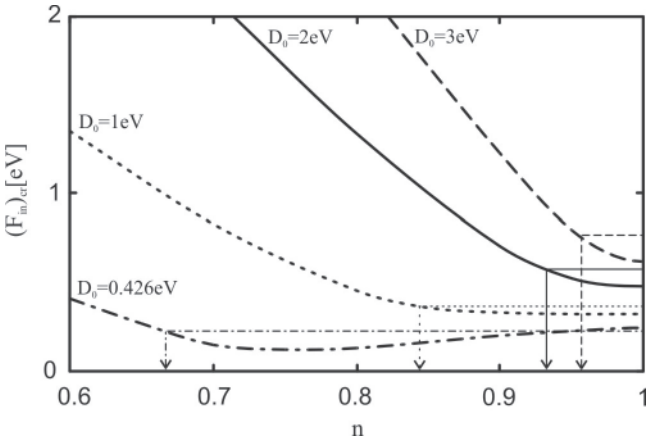

Fig. 1 The critical curves for the antiferromagnetic interaction (F_{in})$_{cr}$.

[1] J. Mizia and G. Górski, *Models of itinerant ordering in crystals: An introduction*, Elsevier Ltd., Amsterdam (2007).
[2] J.E. Hirsch and F. Marsiglio, Phys. Rev. B 39, 11515 (1989).
[3] L. Arrachea and A.A. Aligia, Phys. Rev. Lett. 73, 2240 (1994).

TH-97

Critical Regime and FIC Studies of ($Bi_{0.25}Cu_{0.25}Li_{0.25}Tl_{0.25}$) $Ba_2(Ca_{1.5}Be_{0.5})Cu_3O_{10-\delta}$

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We investigated the effect of oxygen annealing in the transition region and beyond of $(Bi_{0.25}Cu_{0.25}Li_{0.25}Tl_{0.25})Ba_2Ca_2Cu_3O_{10-\delta}$ samples and studied their excess conductivity analyses (FIC) of conductivity data. In these studies effect of oxygen annealing on the superconductivity parameters at the microscopic level are investigated. We have observed a major increase in the width of 3D-2D LD regime and 0D MT regime from the analysis of FIC. We haven't observe any change in the critical temperature but coherence length ζc(0) has enhanced which in turn increases the interplaner coupling in oxygen annealed samples. Using Ginzburg-Landau (G-L) number [N_G] and GL equations, the thermodynamic critical magnetic field $B_c(0)$, the lower critical field $B_{c1}(0)$, the upper critical field $B_{c2}(0)$, the critical current density $J_c(0)$ and penetration depth $\lambda_{p.d}$ are also calculated from these analyses. The values of critical fields [$B_c(0)B_{c1}(0)$], $J_c(0)$, phase relaxation time τ_φ are increased whereas the penetration depth$\lambda_{p.d}$and κvalues are suppressed with Be-doping. It is most likely that due to the enhancement in the density of the carriers in $(Bi_{0.25}Cu_{0.25}Li_{0.25}Tl_{0.25})Ba_2(Ca_{1.5}Be_{0.5})Cu_3O_{10-\delta}$ sample, this charge density gap is suppressed which in turn suppresses the pseudo-gap resulting into enhancement of $B_c(0)$, $B_{c1}(0)$and $J_c(0)$.

TH-98

Para-Conductivity of $Cu_{0.5}Tl_{0.5}Ba_2Ca_{2-x}Mn_xCu_3O_{10-\delta}$ Superconductors

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The Fluctuation induced Conductivity (FIC) of oxygen-post annealed $Cu_{0.5}Tl_{0.5}Ba_2Ca_{2-x}Mn_xCu_3O_{10-\delta}$ (x = 0.15,0.25,0.35,0.5,0.75) superconductors has been carried out. Since oxygen atmosphere changes the carrier density in CuO_2 planes. It has been observed that over all zero resistivity critical temperature Tc(0) decreases with increasing manganese content. To analyze the intrinsic effect of Mn-doping on the conductivity of the samples we have carried out FIC analyses on the basis of the Aslamazov-Larkin (AL) theory in the neighborhood of transition region, Lorentz-Danish (LD) model beyond the transition region and Ginzburg-Landau (GL) equations in the critical regime. The results of these samples clarified the existence of four regimes in the conductivity fluctuations, namely the critical (cr), three-dimensional (3D), two-dimensional (2D) and zero dimensional (0D). The thermodynamic critical magnetic field, the lower critical magnetic field, the upper critical magnetic field, the critical current density, penetration depth, Fermi velocity, phase relaxation time, κvalues and energy required to break apart the cooper pairs are also calculated from the FIC analyses. In Mn-doped samples, the coherence length along the c-axis $\xi_c(0)$ with inter-plane coupling increases up to Mn doping of x=0.35. Beyond this doping level (i.e x>0.35) most of the superconductivity parameters are suppressed that indicated that x=0.35 is the optimum level of doping in $Cu_{0.5}Tl_{0.5}Ba_2Ca_{2-x}Mn_xCu_3O_{10-\delta}$ superconductors.

TH-99

Direct and crossed Andreev tunneling through two quantum dots coupled to ferromagnetic and superconducting leads

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Due to the presence of a superconducting gap in the superconductor density of states, the normal tunneling processes from a non-superconductor to the superconductor are blocked for bias voltages

smaller than the energy gap. However, the electrons can tunnel from a normal (ferromagnetic) lead into the superconductor *via* Andreev-like processes [1]. We have considered electron transport through the system consisting of two quantum dots coupled to a common superconducting electrode. Each of the dots is additionally attached to its own ferromagnetic lead. In general, Coulomb interactions on the dots are also taken into account. Transport characteristics, including linear and nonlinear conductance, have been calculated by means of nonequilibrium Green function approach.
The considered system allows us to investigate not only the direct Andreev reflection (AR) processes, but also the crossed Andreev reflection (CAR) ones. In contrast to the direct AR, where the hole is reflected back to the electrode from which the incoming electron originates, the holes in CAR processes are reflected into the second, spatially separated electrode. In particular, we investigate variation of the conductance with the leads magnetic polarization as well as with relative alignment of the magnetic moments of ferromagnetic leads. Moreover, proximity effects can induce the superconducting correlations in the quantum dots, which also have been considered.
Recently, efficient Cooper pair splitting (which can be understood as an inverse CAR effect) has been achieved in a system consisting of two quantum dots coupled to a common superconductor and two nonmagnetic leads [2,3].

[1] A. F. Andreev, Sov. Phys. JETP **19**, 1228 (1964).
[2] L. Hofstetter, S. Csonka, J. Nygard, C. Schonenberger, Nature 462, 960 (2009).
[3] L. G. Herrmann, F. Portier, P. Roche, A. Levy Yeyati, T. Kontos, C. Strunk, Phys. Rev. Lett. 104, 026801 (2010).

TH-100
Andreev reflection through a ferromagnet-quantum dot-superconductor system with intradot Coulomb correlations
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The spin-dependent Andreev reflection tunnelling through a quantum dot coupled to one ferromagnetic and one superconducting electrode is studied within the nonequilibrium Green function technique. We have calculated electric current and differential conductance for energies within the superconducting gap where transport is dominated by Andreev scattering process. Effects due to spin splitting of the dot discrete level with intradot Coulomb correlations taken into account are analyzed in both linear and nonlinear bias voltage regimes. It is shown that the coherent intradot spin rotation strongly affects the current-voltage characteristics leading to such effects as double-peak Andreev reflection conductance. New phenomena in Andreev reflection current, induced by Zeeman splitting of the dot discrete level are also discussed.

[1] Z. Y. Zeng, Baowen Li, F. Claro, Phys. Rev. B 68, 115319 (2003)
[2] Liu, Y.-S., Yang, X.-F., Fan, X.-H., Xia, Y.-J., Phys. Lett. A 372, 1930 (2008)

TH-101
Critical current density in HIP-ed SiC-doped MgB_2 wires measured with magnetic measurements – by Bean model
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The critical current density (J_c), pinning force density (F_p) measurements and analysis of pinning force density scaling have been made for multicore monel-sheathed type MgB_2 wires. The wires were manufactured by Hyper Tech Research Inc., with their standard technology of Cu-based monocore wire with nano-SiC addition to the precursor Mg+B powder. The in-situ method with Nb barrier was used. The Hot Isostatic Pressing (HIP) process has been performed at IHPP PAS Unipress with high Ar gas pressure for short wire samples of about 130 mm length. Pressure used in HIP reached 1 GPa, and temperatures ranging from 680 ^oC to 725 ^oC have been used with various times of exposition. Magnetic measurements were performed by use of vibrating magnetometer (VSM) at 4.2 K, 15 K and 20 K in ILHMFLT PAS. Critical current density J_{cm} was determined from the hysteresis loop - Bean model. The perpendicular field configuration to the 20 mm length samples have been used. Microstructure investigations were performed with SEM and EDX methods.

TH-102
Effect of nanoparticle doping on properties of Cu-Tl based bulk superconductors
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Higher value of critical current density (J_c) is one of the most important parameters for the selection of high T_c superconducting materials for applications. The weak links is one of the limitations to obtain higher critical current density (J_c). We have addressed this issue by doping of different types and concentration of nanoparticles in CuTl-based bulk superconducting material in order to improve inter-granular coupling. Nanoparticles have been synthesized separately by using sol-gel method and bulk CuTl-based superconducting matrix has been synthesized using solid-state reaction method. Nanoparticles have been incorporated during the synthesis of superconducting material. Structural characterization includes X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and FTIR-spectroscopy. Inter-granular coupling has been improved in these composites, which results in higher values of current density (J_c). The dielectric properties of these samples shows an anomalous behavior e.g., existence of *negative dielectric constant*. We have also done some theoretical studies on these composites which are consistent with the experimental results.

TH-103
Specific heat study of R_2RhIn_8 (R = Y, La, Lu) compounds
P. Čermák [1], M. Kratochvílová [2], K. Pajskr [2], P. Javorský [2]
(1) Institut Laue-Langevin, 38042 Grenoble, France, (2) Department of Condensed Matter Physics, Charles University in Prague, 121 16 Prague, Czech republic

Intermetallic compounds RE_2RhIn_8 (*RE* = rare earth) are structurally related to a class of Ce-based heavy-fermion superconductors. Superconductivity in these compounds is presumably magnetically

mediated and strongly dependent on dimensionality of rare-earth atoms. Ce_2RhIn_8 is an antiferromagnet with a pressure induced superconductivity (Tc = 2 K) [1]. Thus studies of magnetic properties and anisotropic crystal field effects are important to understand principles of the observed superconductivity.
To analyze correctly measured magnetic properties, one often needs the non-magnetic analogues. We have grown single crystals of the non-magnetic R_2RhIn_8 (R = Y, La, Lu) compounds. In this work, we present mainly the analysis of the specific heat. We focus on the lattice contribution and analyze the dependence of all the characteristic parameters in the Debye and Einstein models on the atomic masses and interatomic distances. Obtained parameters will be used to describe the phonon and electronic contributions to the specific heat in magnetic compounds from the series [2, 3].

[1] M. Nicklas et al., Phys. Rev. B, 67 020506(R) (2003)
[2] P. G. Pagliuso et al., Phys. Rev. B 63 054426 (2001)
[3] P. Čermák et al., J. Phys.: Cond. Matter, *accepted for publication*

TH-104
Cubic gamma-phase uranium molybdenum alloys stabilised by splat-cooling technique
N.T.H. Kim-Ngan [1], I. Tkach [2], S. Maskova [2], L. Havela [2], A. Warren [3], C. Stitt [3], T. Scott [3]
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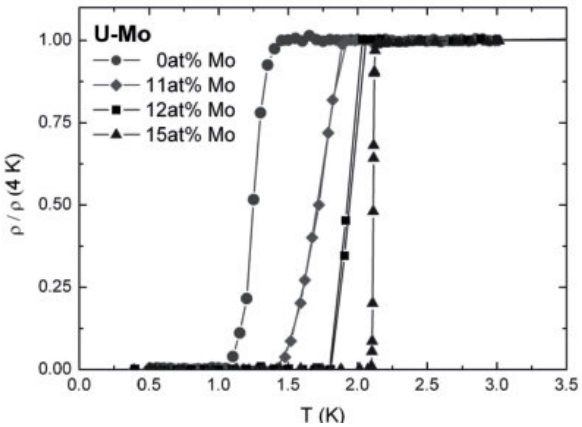
U-Mo alloys with Mo concentration in the range 0 - 5 at.% Mo (x = 0 - 0.15) were synthesized using a splat-cooling technique with a cooling rate of the order of 10^6 K/s. Phase analysis using X-ray diffraction (XRD) indicated the presence of a small amount of (cubic) γ-U phase retained at room temperature alongside the majority (orthorhombic) α-U phase in the splat-cooled pure-U specimen (x = 0). The double-phase (α+γ) structure with predominance of the α-phase was obtained in the alloys with x ≤ 0.10. Increasing further Mo doping leads to the transformation to the (body centered tetragonal) γ° phase for x = 0.11 - 0.12 and pure (cubic) γ phase for x = 0.15. Scanning electron microscopy (SEM) and electron back-scatter diffraction (EBSD) analysis performed on the samples with x = 0, 0.15 corroborated the XRD results.
The U-Mo splats become superconducting with T_c ranging from 1.24 K (for pure U-specimen) to 2.11 K (for 15 at.% Mo). The $H_{c2}(T)$ dependence for the U-Mo alloys revealed neither a quadratic dependence as the temperature approaches 0 K expected for type-I superconductors, nor a linear dependence typically exhibited by strongly interacting Fermi liquid superconductors e.g. U_6Fe.
Our study opens a new possibility of stabilising the γ-phase at room temperature in uranium by ultrafast cooling. Moreover, it has demonstrated stabilization of the γ°-phase and the pure cubic γ-phase in uranium alloys contained 11-12 at.% Mo and 15 at.% Mo respectively in the as-obtained state and without any reversion to an α-phase.



Superconducting transition in the splat-cooled U-Mo alloys

TH-105
Modeling the mutual interaction between ferromagnetic and superconducting materials in hybrids systems
N. Del-Valle [1], *S. Agramunt-Puig* [1], C. Navau [1], A. Sanchez [1]
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The study of ferromagnetic/superconducting hybrid systems has been intensified in the recent years. This interest is motivated for improving the vortex pinning landscape and the critical-current transport in the superconductors, and for the development of tunable elements of superconducting electronics, for example. Athough there is a broad understanding of the response of both the superconductor and the ferromagnet separately to an applied magnetic field, it has only been analyzed theoretically the joint behavior in very simplified cases. We present a theoretical model based on the energy minimization method that it allows to study the mutual interaction between the domains of a ferromagnetic material and the critical currents of a superconductor. This model assumes that the superconductor is in the critical state and treats the ferromagnet within the micromagnetism formalism.

TH-107
Topological ice-rule phase in a Cairo pentagonal quantum magnet
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(1) Néel Institute, Condensed Matter and Statistical Physics Group, CNRS and Grenoble University, 38000, Grenoble, France

Based on a recent experimental realization of a classical magnet with a two-dimensional Cairo pentagonal geometry, the low-temperature spin-1/2 quantum phase diagram is studied. I show how such corner sharing frustrating unit lattice, with complex connectivity, enhances the frustration and leads, under a magnetic field, to unconventional phases such as a 1/3-ferrimagnetic plateau stabilized by quantum fluctuations and ferrimagnetic superfluids. More particularly, a 5/12-topological phase induced by a specific local "ice-rule" constraint is presented, for which only quantum winding moves are available at zero temperature.

[1] E. Ressouche, V. Simonet, B. Canals, M. Gospodinov, and V. Skumryev, Phys. Rev. Lett. 103, 267204 (2009)
[2] A. Ralko, Phys. Rev. B 84, 184434 (2011)

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

MICROMAGNETICS, MAGNETIZATION PROCESSES AND MAGNETIZATION DYNAMICS

Chair: S. Pizzini

TH-108

Optimal switching of a nanomagnet assisted by a microwave field

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Magnetic recording is a key technology in the field of high density information storage. In order to increase thermal stability, small nanoparticles with high anisotropy may be used. However, high fields are then needed to reverse the magnetization. In 2003 it has been shown experimentally [1] that the addition of a small microwave (MW) field pulse can decrease dramatically the switching field. Further studies proved that chirped MW fields are more efficient than monochromatic fields.
The aim of our work is to find theoretically the optimal MW field triggering the switching of a nanomagnet from a given initial state to a specified target state. We consider an isolated single-domain nanoparticle, modelled by a macroscopic magnetic moment (macrospin). The shape of the MW field is then sought by minimizing the energy injected in the system, following the trajectory of the macrospin, rendered by the damped Landau-Lifshitz equation.
In the case of a particle with a uniaxial anisotropy in a longitudinal static field, the optimal MW field can be expressed analytically. However, for more general energy potentials, the problem is solved numerically by defining a cost functional, that is minimized using the conjugate gradient algorithm [2].
The optimized MW field is found to be modulated both in amplitude and in frequency. For an efficient pumping, the initial frequency of the MW field must match the FMR frequency of the macrospin. The injected energy is proportional to the energy barrier between the initial and target states and to the damping parameter. This result could be used to probe experimentally the damping in real nanoparticles. The effects of size and surface anisotropy are also investigated.

[1] C. Thirion, W. Wernsdorfer, D. Mailly, Nat. Mater. 2, 524 (2003)
[2] N. Barros, M. Rassam, H. Jirari, H. Kachkachi, Phys. Rev. B 83, 144418 (2011)

TH-109

Tailoring Six-fold Anisotropy in Triangular Magnetic Nano-elements – A Micromagnetic Study

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The magnetic nano triangular elements are proven to be the possible structures for achieving the six-fold anisotropy artificially[1]. By tailoring the dipolar field the magnetization reversal in these elements can be tuned. In the present study, we demonstrate the tuning of the six fold anisotropy in Permalloy triangular nano dot and triangular nano ring using micromagnetic simulation. We establish that the coercivity of the triangular ring structure is tailorable in a controlled way than that of triangular nano dot. This ring structure finds its importance as a building block for a 2-dimentional network in magnonics.
An equilateral triangular dot and a ring element of Permalloy with an edge length of 100 nm and thickness of 5 nm were considered for this study. The ring element was of arm width of 10nm. We compare the magnetisation reversal of triangular element with that of triangular ring. Micromagnetic simulations for these elements were done using finite element method based open source package –Nmag[2]. The angular variation of remanence and coercivity showed that there is six-fold anisotropy in both the elements. Though the remanence was found to be of the same order in both the structures, the coercivity was increased by two orders of magnitude in triangular ring, as depicted in fig.1. A phase shift of 30 degrees in the six-fold anisotropy was observed in this. The phase shift is due to the variation in stray field configuration in the elements which is also the reason for increase in coercivity. A detailed study on effect of geometric parameters of triangular ring on magnetisation reversal is presented in this work.

[1] L. Thevenard et al., J. Appl. Phys.106, 063902 (2009)
[2] Thomas Fischbacher et al., IEEE Trans. Magn. 43, 2896 (2007).

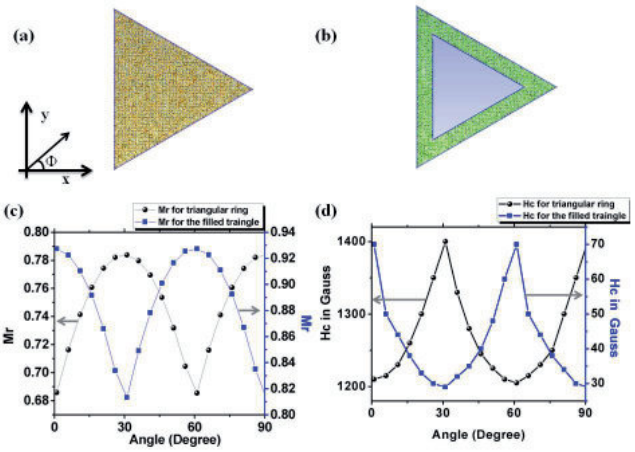

Fig.1 Angular variation of remanence (c) and coercivity (d) of triangular dot(a) and ring(b)

TH-110

Micromagnetism of dense Permalloy antidots arrays

P. Gawronski [1], K. Merazzo [2], O. Chubykalo-Fesenko [2], A. Asenjo [2], R.P. Del Real [2], M. Vázquez [2]
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We present numerical and experimental study of the hexagonally ordered Permalloy antidots array, prepared by sputtering from alumina membranes templates. From the point of view of magnetic

properties, these antidots, as opposite to lithographically one, form a highly dense hexagonal lattice which diameter *d*, can be tailored from 10 to 160 nm and its center-to-center distance *D* from 65 to 200 nm Experimental measurements show that coercivity monotonically increases with the antidot diameter. To understand the hysteresis process of dense Permalloy array we have performed micromagnetic modeling of a thin film consisted of Permalloy antidots with hexagonal symmetry, having parameter *D* equal to 100 and 200 nm and antidot diameters *d* ranging from 16 to 85 nm. The total system size was 1000 x 1038 nm with the discretization equal to 2 nm, and periodic boundary conditions were used. The hexagonal ordering for such arrays extends few square microns only and the ordered regions are separated by dislocations-like border region. In our simulations we rotated the lattice in half of the simulated sample by 30 degrees, and filled the empty spaces by antidots. The simulated coercivity values increase as a function of the antidot diameter in a good qualitative agreement with the experiment.

TH-111

Two-dimensional magnetic domain pattern with P6 symmetry as tunable magneto-photonic crystal

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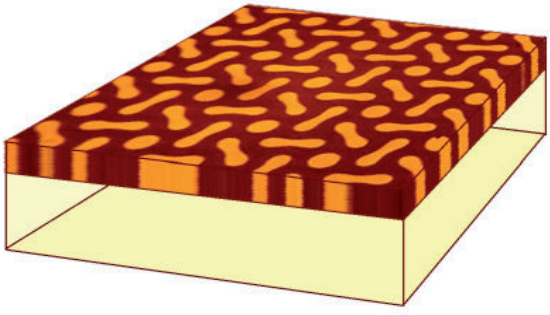
Two-dimensional magnetic domain patterns with various symmetry can be produced in soft magnetic films [1-3]. Some of such domain patterns can be realized in uniaxial ferromagnetic garnet films.

This paper presents the results of experimental study of two-dimensional magnetic domain patterns with *P*6 symmetry (fig.) in garnet films. The patterns consist from topologically modified bubble domains. It is necessary to put 10^4-10^5 impulses of magnetic field H_p for formation of P6 pattern from initial labyrinth structure at presence of constant bias field H_b. Temperature dependences of the intervals of H_p and H_b field parameters as well as period of patterns and stability regions were found. Spatial orientation of *P*6 patterns can be changed by means of a series of impulses of magnetic field.

The patterns were formed in Bi-contained garnet films with high magneto-optic quality factor. Film thickness (~10 μm) was comparable with diameter of optical fiber. Periodically ordered domain pattern with *P*6 symmetry can be applied as tunable magneto-photonic crystal by light propagation through the end face of the film (fig.).



This work is supported by Ministry of Science and Education of Russia under grant 11.519.11.3023.

[1] E. Asciutto, C. Roland, and C. Sagui, Phys. Rev. E 72, 021504 (2005)
[2] K. Kudo, K. Nakamura, Phys. Rev. B 76, 036201; 054111 (2007)
[3] N. Abu-Libdeh, D. Venus, Phys. Rev. B 84, 094428 (2011)

TH-112

Dipolar effects on the magnetic relaxation of nanoclusters: A Monte Carlo investigation

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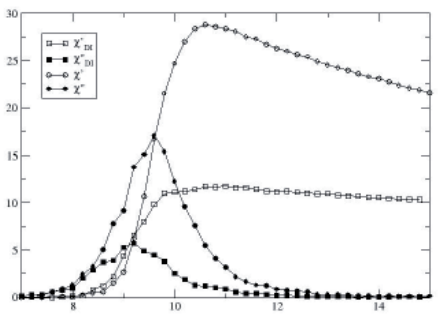
(1) Groupe de Physique des Matériaux, UMR 6634 CNRS-Université de Rouen, 76801 Saint-Etienne-du-Rouvray, France, (2) Unité de Recherche MPE, Université M'Hamed Bougara de Boumerdes, Algérie

Ferromagnetic nanoclusters with a diameter of few nanometers are potential candidates for ultra high density perpendicular recording media (≈ 1 Tbit/inch^2). For such nanocluster assemblies, most of the experimental investigations indicate an increase of the blocking temperature due to DI [1]. On the other hand, semi-analytical [2] or numerical [3] studies evidence that dipolar effects depend on the damping, the strength of the DI, the orientation of the anisotropy axes… Here, we propose to use the Monte Carlo method to investigate the DI effects on the ac susceptibility $\chi_{ac} = \chi' - i\,\chi''$

In our model, the nanoclusters are at the vertices of a simple cubic lattice (self-organized assemblies) or randomly placed in a parallelepipedic box. Each nanocluster which is modelled by a macrospin is assigned an easy axis either along the *z*-axis or randomly oriented.

For self-organized assemblies of cobalt nanoclusters with all easy axes along the *z*-axis, i.e. parallel to the oscillating field, our results show that the DI increase χ' and χ'' and shift the location of χ'_{max} and χ''_{max} towards higher temperatures in the case of elongated samples in the *z*-direction. The increase of χ' and χ'' is due to shape effects since the DI favour the magnetization process in such samples. Opposite effects on χ' and χ'', and on the location of the maxima (figure) are observed for thin films *Oxy*. So, our simulations evidence significant shape effects which could appear in real samples. Numerical simulations on samples with random anisotropy are in progress.

[1] S.H.Masunaga et al., Phys. Rev. B 80, 184428 (2009)
[2] P.E. Jonsson and J.L. Garcia-Palacios, Europhys. Lett. 55, 418 (2001)
[3] D.V. Berkov and N.L. Gorn, J. Phys. Condens. Matter. 13, 9369 (2001)



Thermal variation of the ac susceptibility with and without DI for thin films *Oxy*

TH-114

Control of magnetic reversal in sub-µm Py dots by shape engineering

B. Negulescu [1], J. Wolfman [1], N. Jaber [1], A. Ruyter [1], V. Grimal-Perrigouas [1]

(1) GREMAN, François Rabelais University, Tours, France

By playing with the geometry of a Py nanodot we could control the switching mechanism of the structure. When the symmetry of an elliptical shape is disrupted by flatting it on one side, a C type remnant magnetization state is favoured [1]. The switching of the particle is then realized passing through a vortex state. By adding a notch on this flat part of the dot we could pin the vortex outside the magnetic structure and stabilize a 360° domain wall in a certain field range. This magnetic configuration is confirmed by micromagnetic simulations.

The influence of the magnetic interactions between dots on the switching characteristics will be detailed in our presentation. Magnetoresistive measurements on isolated dots are now in progress and will be presented at the conference.

The studied structures are created by the means of classical photo and e-beam lithography processes. The hysteresis cycles of single dots are obtained using a MOKE magnetometer that was also adapted for magneto-resistance measurements.

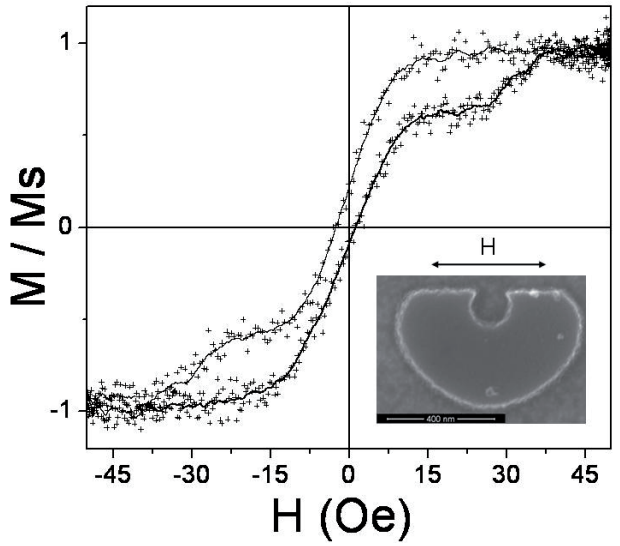


Fig.1 Hysteresis cycle of a single dot. Inset showing the SEM image of the structure.

[1] A.S. Arrott, Proceedings of the 46th Annual Conference on Magnetism and Magnetic Materials, Seattle, 12–16 November, (2001)

TH-115

Finite-size effects in scaling: from critical exponents to state functions

J. Amaral [1], J. Heringa [2], E. Brück [2], V. Amaral [1]

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We present a novel approach for critical phenomena studies. By quantifying scaling plot data overlap, we introduce a 'goodness of scaling' parameter, allowing an iterative search for the 'best' critical exponent values for a given set of magnetization data. The main advantage of this method is going beyond the usual power-law fits of the critical isotherm or low field susceptibility curve, by considering the complete equation of state and all data within the critical region. We consider Monte-Carlo simulated data of the 3D Ising model, and evaluate finite-size effects using our scaling method. Our results are in good agreement with the bibliography, including the dependence of pseudo-critical exponents on system size [1]. Interestingly, we have found that even with a strong dependence of these pseudo-critical exponents on system size, the equation of state is not affected by finite-size effects. The resulting scaling function is in good agreement with recent theoretical predictions for both exponent values and equation of state [2,3]. Our results suggest that while some effects may change the values of observed critical exponents of a given magnetic system, the state equation may retain its identity. In a sense, the state equation can be more universal than exponent values.

[1] Häggkvist R., Rosengren A., Lundow P. H., Markström K., Andrén D., Kundrotas P., Adv. Phys. 56, 653-755 (2007).
[2] Campostrini M., Pelissetto A., Rossi P., E. Vicari, Phys. Rev. E 65, 066127 (2002).
[3] D. O'Connor, J. A. Santiago, and C. R. Stephens, J. Phys. A 42, 045003 (2009).

TH-116

Monte Carlo modeling of the magnetic properties and magnetocaloric effect in lanthanum manganite.

O. Pavlukhina [1], V.D. Buchelnikov [1], V.V. Sokolovskiy [1]

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Among the various alternative technologies that could be used in refrigeration devices, the increasing attention of researchers in the world attracts the technology of magnetic refrigeration. The magnetocaloric effect (MCE) is a magneto-thermodynamic phenomenon in which a reversible change in temperature of a suitable material is caused by exposing the material to a changing magnetic field [1]. The magnetic materials with large values of magnetocaloric effect can be applied as work substances in magnetic cooling devices such as industrial and household refrigerators, air conditioners, heat pumps etc. Manganites have a special place among various materials which have a magnetocaloric effect. This materials, first, allow varying temperature of phase transitions in wide region of temperatures, and secondly, they are cheap and ecological. Experimental studies have shown that the manganites are also attractive for the application in magnetic refrigeration [1].

In our work the temperature dependence of magnetization, entropy changes, and the Curie temperature of $La_{1-x}Ca_xMnO_3$ using Monte Carlo method and Heisenberg model were investigated. In the simulation, magnetic Mn^{3+} and Mn^{4+} ions are described by classical Heisenberg spins, while oxygen, lanthanum and calcium ions are considered as non-magnetic. For the modeling lattice samples of size L^3 with L=15 were used. The number of Monte Carlo steps is 5×10^5. Curie temperature obtained during the theoretical simulations for $LaMnO_3$ (T_C ~120 K), $CaMnO_3$ (T_C~125 K) and $La_{0.1}Ca_{0.9}MnO_3$ (T_C~150 K) agrees well with theoretical result for this compound [2]. The Curie temperature and magnetocaloric effect obtained during the theoretical simulations agree well with experimental data.

Support by RFBR grants 10-02-96020-r-ural, 11-02-00601 and Federal Target Program № 14.740.11.1442 (03.11.2011) is acknowledged.

[1] M. Phan et al., J., Magn. Magn. Mater. 308, 325 (2007)
[2] P. Restrepo et al., J. Magn. Magn. Mater. 323, 1477 (2011)

TH-117

Modeling and Experimental Analysis of Magnetostriction in High Strength Steels

H. Elbidweihy [1], C.D. Burgy [2], E. Della Torre [1], M. Wun-Fogle [2]
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Many of the commonly used high strength steels have small amounts of magnetostriction. However, there are numerous situations in which the magnetostrictive properties of these steels are important; e.g. in torque carrying shafts requiring high strength to weight ratios [1]. Previous studies on the magnetostriction in high strength steels have ignored the internal anisotropies due to previous material handling. Cold-rolling an iron alloy will stretch and distort the magnetic domains in the direction of rolling [2]. These altered domain shapes impact the magnetic characteristics of the alloy; adding an additional preferred direction of magnetization to the easy or hard axes within the crystalline structure.

This paper presents data taken on rods of a high strength steel that have been machined parallel to the rolling direction; as well as simulated results using a Preisach-type magnetostriction model. The model, whose formulation is based on the DOK magnetization-based model [3], aims to specifically simulate the Villari reversal phenomenon observed in the magnetostriction measuerements of high strength steels and some Terfenol-D alloys. As the longitudinal magnetic field is increased under a compressive load, the axial magnetostriction in the direction of the applied field first increases to a maximum value and then drops gradually and eventually saturates.

The magnetoelasticity is incorporated in the model by a stress-dependent Preisach factor and a crystallographic anisotropy parameter. In this round of fittings, the material-specific parameters were manually determined for the best fit. By only changing the crystallographic parameter with the compressive stress magnitude, very good results were obtained (Fig. 1).

[1] M. Wun-Fogle, et al., IEEE Trans. Magn. 45, 4112 (2009)
[2] Bozorth, R. M. *Ferromagnetism*. IEEE, 1993.
[3] E. Della Torre, et al., IEEE Trans. Magn. 26, 3052 (1990)

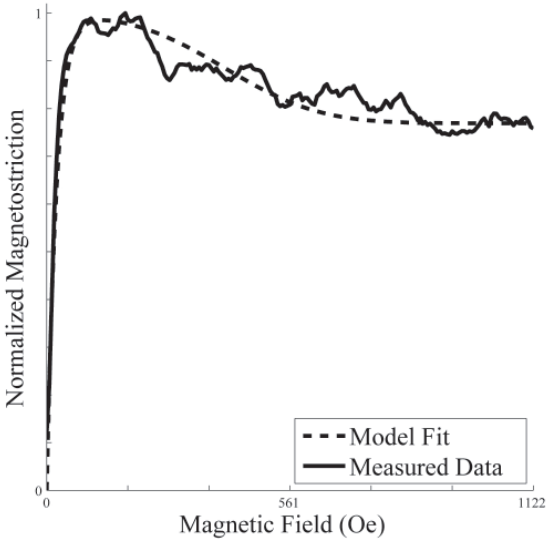

Fig. 1: Magnetostriction measurement and model fit for a steel sample under 50 MPa

TH-118

The hysteretic behavior of $Ni_{50}Mn_{35}In_{15}$ Heusler alloy near its first-order transition temperature

V. Provenzano [1], *E. Della Torre* [2], L.H. Bennett [2]
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The interest on the off-stoichiometric Ni50Mn35In15 Heusler alloy is driven by its potential as a refrigerant for near-room temperature magnetic refrigeration applications. It exhibits inverse and conventional magnetocaloric effect (MCE) peaks near room temperature. The inverse is a first-order transition from ferrimagnetic-to-ferromagnetic martensite, while the conventional peak another first-order transition to the paramagnetic austenite [1]. Within a temperature range, thermally driven first-order transitions can be field-induced in reverse order by applying a large enough field, resulting in hysteresis. The M-H first quadrant loops shown in the figure were sequentially measured at 280 K (in the temperature range of the reverse MCE peak) after the Ni50Mn35In15 alloy had been thermally demagnetized. The ascending segment of the M vs. H loop measured first is the virgin curve at this temperature. After the virgin curve was measured, the loop was completed by reducing the field to zero; recycling the field between zero and saturation, the major loop in the first quadrant was measured. The key characteristics of the two loops are: (1) the virgin curve lies outside the major loop; (2) descending segments of both loops are identical; and, (3) all subsequent major loops are identical. We explain the above characteristics as follows. First, field-induced reverse transitions are hysteretic, the details of which depend on the first-order transformation rates and magneto-thermal history. The time constants for these rates in the Ni50Mn35In15 alloy are long. Consequently, when the field is reduced to zero in the first loop, the magnetic state does not return to its initial virgin state. By contrast, in the first major and subsequent loops, the initial and final states are identical. We account for the hysteretic difference between the virgin and the major loops by slow transformation rates and magneto-thermal history.

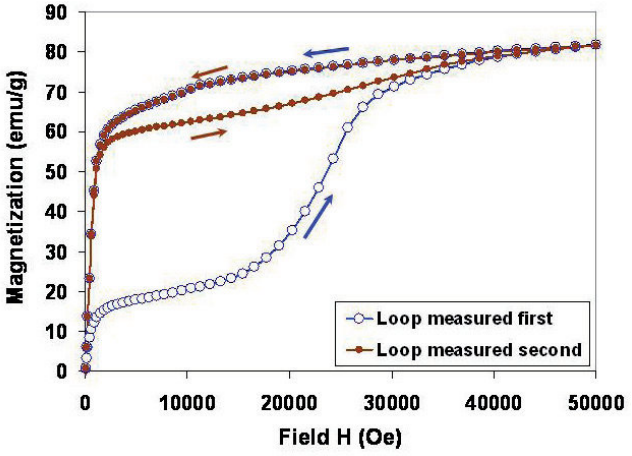

Figure 1 The virgin curve and the major loop.

TH-119

Critical temperature study in nanocylinders using Fast Monte Carlo method

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Based on the framework of the Fast Monte Carlo approach[1], which combines the Scaling Approach [2] and Monte Carlo simulations, we present a study on the diameter dependence of the critical temperature in magnetic nanostructures of cylindrical shape. Several Fe cylindrical-shaped samples of different sizes (20 nm high, 30-100 nm in diameter) have been considered; and magnetic properties like magnetization, specific heat and magnetic susceptibility have been computed as functions of the scaled temperature. Results on the size dependence of the critical temperature indicate that there are three different order-disorder magnetic transition modes (see Fig. 1). For nanostructures below around 60 nm in diameter, the transition process takes place directly from the low-temperature ferromagnetic phase to the paramagnetic one. For those samples with diameters above 70 nm approx., the transitions start at a low-temperature vortex state and end at the high-temperature paramagnetic state. For those cylinders with intermediate diameter, due to the small value of the energy barriers between ferromagnetic and vortex states, the process involves the existence of two metastable states, ferromagnetic and vortex, which the system occupies alternately as temperature increases. We have also found that the critical temperature follows a linear scaling relationship as a function of the scaling factor x, for all the studied sizes. This finding rules out a scaling relation proportional to the volume ($T'_C = x^{3n} T_C$) that has been proposed in literature, and suggests that temperature should scale linearly with the scaling factor x, in accordance with mean field theory.

[1] P. Vargas, et al., Phys. Rev. B 73, 092417 (2006).
[2] J. d'Albuquerque e Castro et al., Phys. Rev. Lett. 88 237202 (2002)
[3] M. Bahiana, et al., Phys. Rev. B 74, 174412 (2006).

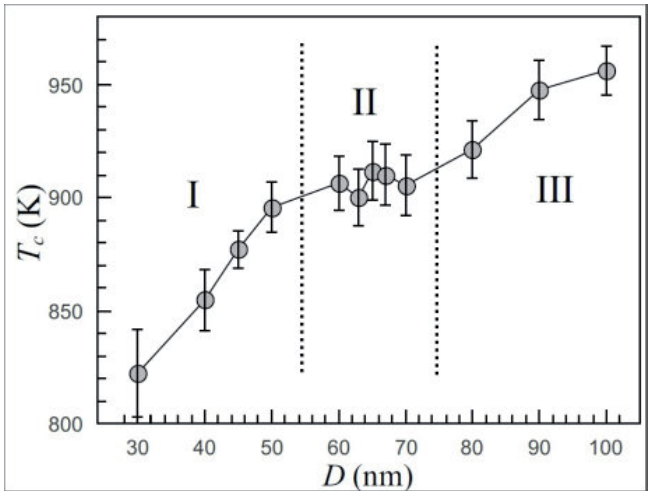

Fig 1. Critical temperature as a function of the diameter for the studied cylinders.

TH-120

Microscopic reversal mechanism in exchange-biased FeMn/FeCo bilayer systems

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Exchange Bias (EB) is a phenomenon exploited in many spintronics devices which consists in a translated hysteresis loop along the magnetic field axis in ferromagnetic/antiferromagnetic (FM/AFM) arrangements. This work is devoted in deepening the understanding of the mechanisms which lead to EB, in order to improve the response of real structures. We have studied MnFe/CoFe bilayers deposited ,with a Cu underlayer, on silicon by rf magnetron sputtering, exploring how the details of the growth conditions influence the coercive and EB fields (H_C and H_B).
The choice of the FM/AFM system is appropriate for room temperature applications. Moreover, the FM CoFe alloy is also interesting for its magneto-elastic properties.
In order to investigate the magnetization reversal mechanisms at the FM/AFM interface governing the EB phenomenon, we have characterized many samples differentiated by thickness and growth rate of each individual layer. The variations of H_B and H_C demonstrate that these parameters can be optimized by adjusting the growth conditions. Furthermore, by repeating successively the hysteresis loops, training effects and relaxation phenomena were revealed. These observations, in conjunction with first order reversal curves (FORC) and remanence curves are used to interpret and single out the asymmetric different processes controlling the reversal of magnetization during the ascending and descending branches of hysteresis, establishing the role played by incomplete domain walls present at the interface.

TH-121

Monte Carlo investigation of the microstructure effect in exchange-biased bilayers

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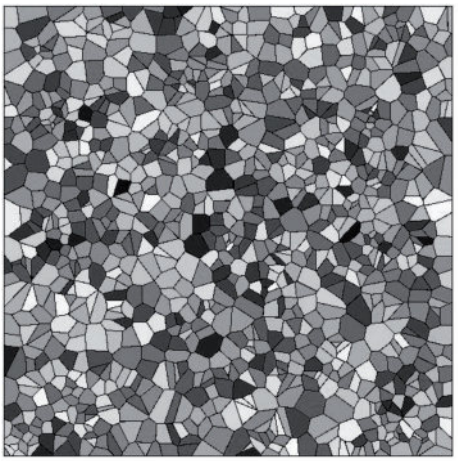
Coupled F/AF bilayers exhibit exchange bias (EB). EB, which was discovered in 1956 by Meiklejohn and Bean [1], is evidenced by a shift in magnetic field (H_E) of the hysteresis loop. In this study, a model of polycrystalline F/AF bilayers based on the Voronoi construction (figure 1) is considered to investigate the microstructure effect on EB properties. Assuming that the grain magnetization reverses by uniform rotation, each grain is modelled by a macro-spin.
The temperature dependence of the exchange field (H_E) and of the coercive field (H_C), and the blocking temperature distribution are investigated by means of Monte Carlo simulations. Our results are in good agreement with experimental results on NiFe/NiMN bilayers [2]. In particular, it is shown that the vanishing of H_E occurs in the vicinity of the (average) blocking temperature $\langle T_B \rangle$ of the AF grains, which is attributed to the superparamagnetic behavior of the AF grains, resulting in a zero time-averaged-coupling at the F/AF interface. The increase of H_C also close to $\langle T_B \rangle$ which is well reproduced in our simulations occurs because the F grains drag the AF grains during the reversal.
Concerning the T_B distribution, we have evidenced that taking into account a decrease of the magnetization at low-temperature

at the F/AF interface in some of the AF grains leads to the observation of the unusual low-*T* peak [3].
In a near future, we will focus on the grain volume distribution effect (average volume and width) on the EB properties.

[1] W. H. Meiklejohn and C. P. Bean, Phys. Rev. 102, 1413 (1956)
[2] C. Hou *et al*., Phys. Rev. B 63, 024411 (2000)
[3] V. Baltz *et al* , Phys. Rev. B 81, 052404 (2010)



Cross-sectional view of the granular structure of the AF layer

TH-123
Studies in NiFe/IrMn/Ta exchange biased multilayers by broadband ferromagnetic resonance measurements
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Rotatable anisotropy in exchange-coupled systems was studied by broadband ferromagnetic resonance (FMR) measurements employing a vector network analyzer FMR (VNA-FMR). Multilayered films based on Permalloy and IrMn with a Ta spacer layer, with nominal structure [NiFe(t_{FM})/IrMn(t_{AFM})/Ta(3 nm)]$\times$10, where t_{FM} = 4, 15 and 20 nm, were produced by magnetron sputtering upon magnetic field in order to induce EB during deposition. The resonance frequencies of the samples were extracted from the resonance spectra in the range of 0.1 to 7 GHz and magnetic fields of up to 300 Oe. Static magnetization curves were also obtained in the same field range. The experimental data are compared to numerical calculations obtained from a granular exchange-bias model for FM/AFM. Studies on rotatable anisotropy and high-frequency exchange bias can be found in literature [1]. Within the range of the frequencies used, resonance takes place in non-saturated magnetization states in contrast to conventional FMR measurements. As a consequence, the actual magnetization angle should be taken into account in the dispersion relation calculations. We obtained a good agreement between experiment and model for magnetic field applied at 0, 45 and 90 degrees away from the exchange bias direction. The estimated rotatable anisotropy fields are significantly increased when the AFM films thickness is decreased. Our results confirm the influence of the rotatable anisotropy on the coercivity enhancement and on the isotropic shift of the angular variation of the resonance field.

[1] Geshev et al, Phys. Rev. B 75, 214402 (2007)

TH-124
Energy barrier calculations for classical exchange-spring chains of spins
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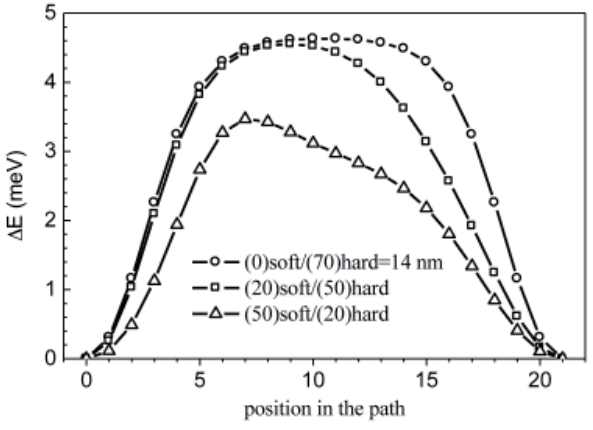
Exchange-coupled soft-hard nanocomposites have long been known for specific properties that make them attractive in application areas such as permanent magnets and magnetic recording. In recent years it has been argued that exchange-spring bilayers can be optimized in order to achieve a sufficient small coercivity that they can be written with conventional write heads, while preserving at the same time the high thermal stability due to the hard phase [1]. Thermal stability of different magnetic systems can be compared from a theoretical point of view by calculating the energy barriers that separate stable and metastable states. In the present work, a known efficient and simple algorithm, the string method [2], has been utilized in the framework of the micromagnetic theory. This method has allowed us to calculate minimum energy paths and related energy barriers in single phase and exchange-spring classical Heisenberg spin chains, as a function of magnetic and geometric parameters, with and without an external applied field. The total micromagnetic energy is the sum of the exchange, uniaxial anisotropy, magnetostatic and Zeeman terms. This study is not only significant in itself as it could also be applied to experimental systems since the existence of ferromagnetic order and anisotropy barriers for one-dimensional single-phase monatomic chains has been widely demonstrated [3] and the extension to real exchange-coupled chains cannot be excluded.

[1] D. Suess et al., Appl. Phys. Lett. 87, 012504 (2005).
[3] G. D. Chaves-O'Flynn et al., IEEE Trans. Magn. 46, 2272 (2010).
[3] P. Gambardella et al., Nature 416, 301 (2002).



Minimum energy path of spin chains.

TH-125

Defect influence on magnetic nanodot magnetization reversal

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We report on defect influence on magnetization reversal of magnetic nanodots with perpendicular anisotropy. The dots are induced in an ultrathin Co films by a patterned buffer grown as self-assembled Au islands on a Mo surface [1,2]. Micromagnetic simulations of the dot magnetization reversal are conducted with help of an object oriented micromagnetic framework OOMMF [3] using the Landau-Lifshitz-Gilbert equation. Simulation results are related to the experimental observations obtained from magnetic force microscopy (MFM) and polar magnetooptical Kerr magnetometry (PMOKE).
Structural defects play a crucial role in magnetic state of the dots and in their magnetization reversal mechanism. In this work we simulate an influence of defects which are responsible for domain wall pinning and in consequence – for undesired multidomain structure of the dots. Magnetic defects originate from fluctuations of the Co layer thickness, strains induced by the lattice mismatch at the Au/Co interface or local direction deviation of the anisotropy easy axis. Performed micromagnetic simulations reveal the dependence of the magnetization reversal stages of the individual dots, their switching field and the shape of hysteresis loop on parameters describing the defects such as: local magnetic anisotropy fluctuations at the site of defects, the size of defects and their surface density. Comparison of the simulations with the experimental results allows estimating the parameters describing realistic defect, which is not available from merely experimental way.

[1] E.Sieczkowska, A.Petroutchik, L.T.Baczewski, P.Aleszkiewicz, Z.Kurant, A.Maziewski, A.Wawro IEEE Trans. Magn, V47, No.10, 2011.
[2] A. Wawro, E. Sieczkowska, A. Petroutchik, L.T. Baczewski, Z. Kurant, and A. Maziewski, *Phys. Rev. B* **83** (2011) 092405.
[3] J. Donahue, D. G. Porter, *OOMMF*, http://math.nist.gov/oommf.

TH-126

Exchange-spring magnets in cylindrical geometries

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Nano-structuring of magnetic materials can improve their performance. Exchange-spring magnets are widely used to overcome the superparamagnetic limit in recording media, where the required low nucleation field and high energy barrier can be optimized independently [1].
Thin-film hard-soft bilayers make excellent permanent magnets, since the hard phase provides high anisotropy and coercive field while the soft phase provides high saturation magnetization [2]. This enhances the overall energy product $(BH)_{max}$.
We extend these ideas by investigating cylindrical geometries, specifically a core-shell nanowire consisting of a soft magnetic core and a hard magnetic reinforcement.
By numerically solving the LLG equation, we perform simulations on a number of core-shell structures in order to assess improvements in performance over non-reinforced soft wires. A two-stage hysteresis process is observed (Fig. 1).
The nudged-elastic-band (NEB) method [3] is used to compute the energy barrier as a function of applied field, and the finite temperature nucleation fields can be estimated. These are around 75% of the LLG values.

[1] Suess et al., App. Phys. Lett. 87 1 (2005).
[2] Fullerton et al., Phys. Rev. B 58 18 (1998).
[3] Dittrich et al., JMMM 250 12 (2002).

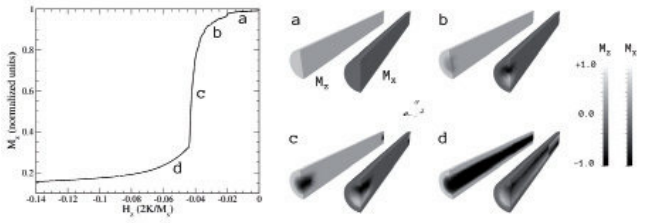

Fig. 1 Switching of the soft core in a core-shell nanowire begins with nucleation of a domain wall, which propagates through the core before being pinned at the soft-hard interface. The hard shell switches at much higher fields. In the simulation, anisotropy of the soft core is zero,. The ratio of the hard and soft Ms values is 0.75. The outer diameter of the hard shell is 21.5 L_{ex}, and the diameter of the soft core is 18.4 L_{ex} where L_{ex} is the exchange length of the soft material. The wire length is 10 times the outer diameter. The applied field is given in units of 2K/Ms of the hard material.

TH-127

Coplanar probe microwave current injection ferromagnetic resonance of magnetic nanostructures

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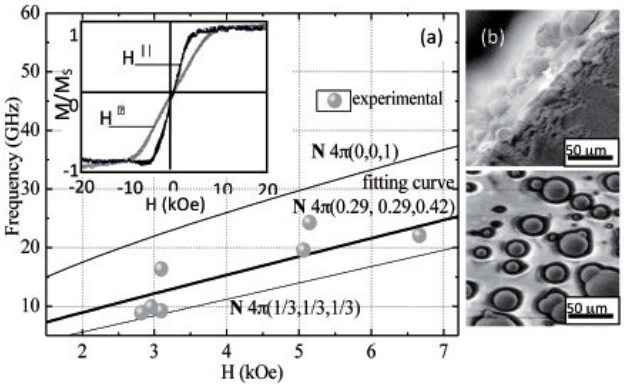
Magnetic nano-stripes (MNS) show promising technological applications as microwave filters, delay lines, and magnetic memory storage. One way to characterise the dynamic magnetic properties of magnetic materials is using ferromagnetic resonance (FMR). The standing spin wave modes (SSWMs) in thin magnetic films and nanostructures provide important information about the exchange interaction and magnetic conditions at surfaces and buried interfaces. Often, SSWMs with odd symmetry are lacking in FMR spectra for symmetry reasons [1].
The objects studied are periodic arrays of Permalloy ($Ni_{80}Fe_{20}$) stripes patterned using deep-ultraviolet lithography [2]. Each stripe is 100 nm thick, 264 nm wide and 4 mm long with stripe edge-to-edge spacing of 150 nm. We performed FMR measurements on this MNS using a new method; by direct injection of microwave currents into the MNS using a sub-milimetre rf coplanar probe [3]. The probe has a ground-signal-ground tip width of 400 microns and contacts the MNS such that microwave current flows from the signal tip to the ground tips

through the MNS. External magnetic field is applied parallel to the stripes.
We show that in contrast with the traditional microstrip method, our coplanar probe method is able to efficiently excite SSWMs with odd symmetry in the MNS. We propose this is due to confinement of real microwave currents along the nano-stripes which induce a non-uniform microwave magnetic field, and which in turn, couples efficiently with SSWMs with odd symmetry. The proposed method is quick and also allows easy spatial mapping of magnetic properties with resolution down to 100 microns, which is the tip size of the smallest commercially available probe.

[1] C. Kittel, Phys Rev, 110 (1958) 1295.
[2] A.O. Adeyeye & N. Singh, J Phys D Appl Phys, 41 (2008) 153001.
[3] C.S.Chang et al., Europhys Lett, 96 (2011) 57007.



Fitting of *f*-H dependence (a) and magnetic loops (inset) of Co microgranules (SEM) (b)

TH-128

Magnetic anisotropy in array of cobalt microgranules

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Ferromagnetic Co particles with micron sizes deposited onto anodized porous alumina surface were prepared by electrodeposition. This method allows controlling of some factors to organize the metal into granular assembly with various particle shape. Such composite materials exhibit interesting magnetic properties required for microwave application for both frequency selective and wide band.
Magnetic hysteresis loops were measured by vibrating sample magnetometer (Figure (a), inset). The morphology of the surface and cross-section of the samples were analyzed by scanning electron microscopy (SEM) (Figure (b)). The microwave magnetic resonance absorption was investigated by FMR-technique using Agilent PNA-L N5230A Vector Network Analyzer in the frequency ranges of 8-10 GHz and 15-25 GHz. The X-Ray diffraction diagram contains peaks indicating that cobalt presents only as fcc-phase. Therefore, it is impossible to explain the difference between saturation fields of in-plane hysteresis loop and normal to plane one by magnetocrystalline anisotropy.
The experimental resonance frequency–field dependence for one of a series of investigated samples is plotted in Fig. (a) (circles). To fit the resonance data we have applied the Kittel formula [1] assuming that the particles were flattened spheroids (Figure (a)). We have determined the most probable values of demagnetization factors of ellipsoidal particles. These values corresponded to ratio of spherioid axes $c/a = 0.75$ where a is the in plane axis. This result agrees well with SEM data and magnetization curves. A good agreement of dynamic and static magnetic measurements as well as structure investigation were found for all samples obtained by dc electrodeposition of cobalt onto alumite films. Thus, the nature of magnetic anisotropy of the samples under investigation is conditioned by the shape of individual particles.

[1] Ch. Kittel, Introduction in Solid State Physics, fourth ed., Wiley, 1973.

TH-129

Ferromagnetic resonance studies of Fe_3O_4 (110) films grown on MgO (110)substrates

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Study of epitaxial thin films and hetero-structures based on magnetite (Fe_3O_4) have attracted considerable attention during the last decade due to its half metallic nature and high Curie temperature (858K) [1]. Most of the investigations have relied on (100) oriented films grown on either MgO or other substrates [2]. However our recent reports on (110) oriented Fe_3O_4 films grown on MgO (110) substrates show a remarkable difference compared to (100) oriented films. This includes observation of positive magnetoresistance at low fields due to the influence of antiphase boundary domain walls (APBDW) and anomalous magnetisation reversal process due to proximity effects of antiphase boundaries (APB) [2,3]. The results on Fe_3O_4 (100) films show out of plane uniaxial shape anisotropy. In contrast, in Fe_3O_4 (110) films a large in-plane magneto crystalline anisotropy is observed with easy and hard axes lying along [-110] and [100] respectively. The (110) films showed high coercivity (~ 0.1Tesla in 20 nm film) [3]. In this report we present the results on ferromagnetic resonance measurements on Fe_3O_4 (110) films grown on MgO (110) which shows a distinct behaviour compared to Fe_3O_4 (100) films. The effective magnetization is significantly larger (~0.3 Tesla higher compared to Fe_3O_4 (100) films) and line width doesn't increase linearly with frequency as expected, in contradiction to what is observed in Fe_3O_4(100) films. The thickness dependence and influence of APB will be discussed.

[1] S. Serrano-Guisan, Han-Chun Wu, C Boothman, M. Abid, B. S. Chun, I. V. Shvets, and H. W. Schumacher, J. Appl. Phys. 109, 013907 (2011)
[2] R. G. S. Sofin, S. K. Arora and I. V. Shvets, Phys. Rev. B 83, 134436 (2011)
[3] R. G. S. Sofin, Han-Chun Wu and I. V. Shvets, Phys. Rev. B 84, 212403 (2011)

TH-130

Interaction between pairs of magnetic nanodisks

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Interacting magnetic nanoobjects constitute one key component for many proposed spintronic devices, from microwave nanooscillators to magnetic memory elements. For this reason, the mechanism of this interaction and its dependence with distance d between nanoobjects has been the subject of several recent studies [1]. In the present work, through micromagnetic simulation, we have investigated interacting pairs of nanodisks presenting magnetic vortex structure, in the form of an area array of fifty 20 nm-thick disk pairs. The disk diameters follow a Gaussian distribution centered at 250 nm and standard deviation that can be varied. In order to verify the magnetic coupling strength as a function of the distance between the disks of each pair, we have used a recently developed tool, the magnetic vortex echoes. This is an effect analogous to the NMR spin echoes, and arises from the gyrotropic motion of the vortex cores in arrays of inhomogeneous disks [2]. Analyzing the vortex echo, in quite similar way as done for NMR, it is possible to obtain two relaxation times, T2 and T2*, which depend on the interactions between the nanodisks, diameter distribution and Gilbert damping constant. T2* is directly related to the interaction strength [2] We determined the dependence of this strength with d, for the 50 disk pairs array, as also found in studies employing other techniques [1, 3].

[1] H. Jung, et al. Sci. Rep. 59, 1-6 (2011/08/10/online).
[2] ArXiv:1201.3553.
[3] O.V. Sukhostavets, J.M. Gonzalez and K.Y. Guslienko, Appl. Phys. Express 4, 065003 (2011).

TH-131

Fractal basin boundaries in magnetization relaxations of nanomagnets subject to weak AC excitations

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In this work, we analyze the influence of weak time-harmonic (AC) external excitations on magnetization relaxation dynamics in a uniformly magnetized nanomagnet. We show that the transient relaxation of magnetization toward states of lower energy may become chaotic. In the case of constant external fields, the magnetization energy landscape of the magnet has two wells corresponding to two stable magnetization equilibria. In this situation, magnetization relaxation originating from any magnetization state will tend, after a transient, toward one of the two stable equilibria. This leads to a natural partitioning of the unit sphere, representing magnetization orientations, into two regions (basins of attraction) by associating each initial state to the corresponding final stable equilibrium. The boundaries separating the two basins are smooth curves. This picture is considerably modified when a weak time-periodic external excitation (field or injected current) is applied to the system. Magnetization relaxations tend toward two stable periodic solutions located in the vicinity of two energy minima. For extremely small AC excitations, the unit sphere is still partitioned in two basins of attractions associated to these two periodic stable solutions and separated by smooth boundaries. However, if the amplitude of the AC excitations is above a certain threshold the smooth boundaries of the two basins are destroyed and the basins of attraction become separated by fractal boundaries [1]. The final periodic solution approached in long-time limit depends sensitively and discontinuously on the initial conditions and the long-time predictability of magnetization dynamics is practically lost. In the work we illustrate this complex phenomena through numerical simulations and we provide analytical formulas, based on a perturbation technique, to compute the threshold which corresponds to the destruction of the smooth basin boundaries.

[1] Y. Ueda et al., Phil. Trans. Royal Soc.: Physical Sciences and Engineering Vol. 332, No. 1624, 1990

TH-132

Surface effects and non-Gilbert relaxation in magnetoferritin studied by electron spin resonance

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Magnetic nanoparticles (MNPs) are at the forefront research in Nanoscience as they hold the promise of increasing the data storage capabilities of hard disk devices (HDD). The key properties of MNPs are: **magnetic anisotropy** (MA) and **magnetisation dynamics** (MD). MA arises an energy barrier between two opposite states of the magnetisation against thermal fluctuations while MD governs the motion of the magnetisation across the energy barrier. The understanding and controlling of MA and MD are still far from being achieved specially because of the size distribution and interparticle interactions, but are of fundamental importance for the performance of MNPs for any applications.

Magnetoferritin[1] provides a useful route to encapsulate MNPs into a diamagnetic cage (apoferritin) leading to weakly interacting MNPs with narrow size distribution and spherical shape. Thus, magnetoferritin may help the full understanding of MA and MD in MNPs.

I will present a study of MA and MD of magnetoferritin containing maghemite/magnetite MNPs with average diameter of 5.7 ± 1.6 nm by means of temperature-, frequency- and angle-dependent **Electron Spin Resonance** technique.[2]

The static and dynamic magnetic properties of magnetoferritin strongly differs from those of the bulk. The observed reduced magnetic moment per particle, increased magnetic anisotropy and particle uniaxial symmetry give evidence of surface effects

(**spin canting** and **reduced chemical coordination**). The MD studied by the resonance field – linewidth correlation extracted from the temperature dependence of the EMR spectra deviates from the classical **Landau-Lifshitz-Gilbert (LLG) model**. Further evidence for deviations of the magnetisation dynamics from the Gilbert-like relaxation is observed from the saturation of the frequency-dependent linewidth. An exponential decay function satisfactorily describes the magnetisation dynamics providing an overall relaxation time T_2 of the order of sub-nanoseconds.

[1] M. J. Martinez-Perez, et al. Nanotechnology **21**, 14 (2010).
[2] F. Moro, et al. Submitted to Phys. Rev. B.

TH-133

Micromagnetic energy minimization for low-rank tensor magnetization

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A tensor grid algorithm for the minimization of the micromagnetic energy is presented.
Based on the *method of multipliers* [1] this approach allows the treatment of the micromagnetic side constraint in a *tensor-structured framework* [2], but also offers a competitive alternative to well-established approaches in numerical micromagnetics for non-tensor-structured considerations.
Since energy components and their gradients can be computed efficiently for low-rank tensor magnetizaton (e.g. Tucker tensors) [3], the algorithm shows sub-linear complexity with respect to the grid size in terms of costs per iteration. Apart from that, the ill-conditioning of the unconstrained subproblems usually arising in penalty-like methods is overcome, which is shown by estimates on the convergence rate.
We compare with results of the Standard Problem No.3 posed by the µMag micromagnetic modeling activity group at the National Institute of Standards and Technology (NIST). Furthermore, we validate our method by computing critical switching fields for small ferromagnetic particles and compare with the Stoner-Wohlfarth model and related results in the literature [4].

[1] D.P. Bertsekas, Automatica 12, 133 (1976)
[2] B.N. Khoromskij, Chemometr. Intell. Lab. 110, 1 (2012)
[3] L. Exl et al., J. Comp. Phys., 231,2840 (2012)
[4] M.E. Schabes, H.N. Bertram, J. Appl. Phys. 64: 1347 (1988)

TH-134

Magnetic dispersion in a soft amorphous layer with a helical anisotropy profile

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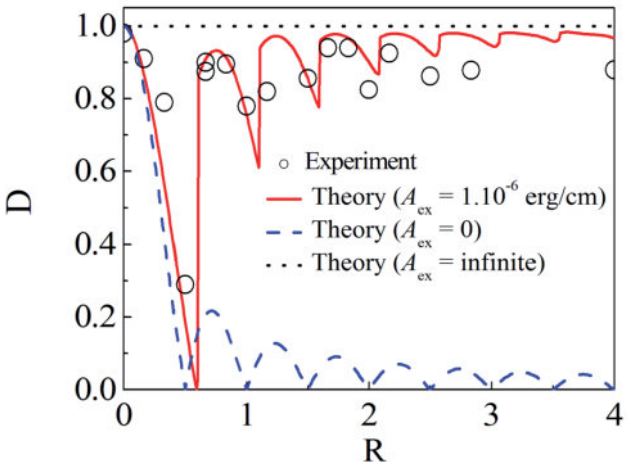
The static and dynamic magnetic properties of a soft amorphous CoNbZr layer with a helical anisotropy are studied experimentally and theoretically [1]. The aim is to investigate the possibility of achieving an evanescent anisotropy by randomizing the effective anisotropy. High levels of microwave permeability and reduced resonance frequencies f_{res} are then expected. The helical anisotropy profile in the layer thickness is obtained by imposing a continuous rotation R of the sample during sputtering deposition.
A new method is proposed to investigate the magnetization dispersion which is generated here by the anisotropy profile. Based on the angular measurement of the integral criterion [2], it requires no particular law of magnetization distribution. The main assumption is that the matter fraction with an infinitesimal magnetization orientation is a periodic function which can be described by a Fourier series. A D dispersion parameter quantifying the magnetization dispersion (isotropic and uniaxial behaviors for D = 0 and 1, respectively) and an easiest axis orientation are deduced.
As shown in Figure, a maximal dispersion is found for R = ½ turn in an 800 nm layer. For higher rotations, the magnetization does no longer follow the anisotropy profile due to exchange. A 1D static and dynamic model taking into account both exchange and the anisotropy profile reproduces correctly the observed behaviour. VSM magnetometry shows a significant decrease of the effective anisotropy of about 50% although no evanescent anisotropy is achieved experimentally. The decrease is not fully reflected on f_{res} measured on the permeability spectra, a feature well explained by a ripple-like phenomenon.

[1] M. Gloanec et al., Phys. Rev. B in Press
[2] O. Acher and S. Dubourg, Phys. Rev. B 77, 104440 (2008)



D as a function of the turn number during deposition.
(A_{ex} designs the exchange constant.)

TH-135

Study of magnetic structure and magnetization process of the glass-coated amorphous microwire

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Magnetic structure of amorphous $Fe_{73,9}B_{13,2}Si_{10,9}C_2$ microwires was studied. The samples were amorphous glass-coated microwires fabricated by the Ulitovsky-Taylor method. The total diameter of the microwire was 25 µm, the glass coating thickness was 3 µm. The microwire had a positive saturation magnetostriction $\lambda_s \approx 2\text{-}2.5\times10^{-5}$. The magnetic characteristics of the microwire were measured using a vibrating-coil magnetometer. The magnetic structure was studied by the method of magneto-optical indicator films (MOIF) and

magnetic-force microscopy. The magnetic force images were obtained by the two-pass technique. NSG10 ferromagnetic Co film-coated cantilevers were used. The magnetic cantilever had both a normal and tangential magnetic moment components with respect to the sample surface which enabled us to obtain information on the gradients of the scattering fields from the sample as normal and tangent surface plane components.
The magnetic structure of the as-prepared microwire was found to consist of a magnetic core and a ring-shaped surface magnetic layer made up by radially magnetized small ring domains. The geometric characteristics of microwire magnetic structure were first experimentally determined. The width of the surface ring domains is about 5 μm, and the thickness of the surface magnetic layer is 2 μm. The magnetic core of the as-prepared microwire has been shown to consist of extensive domains, no less than 500 μm in size, and their spontaneous magnetization vector deviating from the microwire axis. The effect of magnetostriction on magnetic structure and its changes induced by magnetization has been established.
The magnetic structure model for microwires with positive magnetostriction constant is proposed.
The authors are grateful to the RFBR (project 12--02-00537 and 10-02-00195) for the financial support

TH-136
Optical study of the domain structure in glass-coated microwires
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Amorphous glass-coated microwires are well-known by high domain wall velocities that reach up to 15 km/s [1]. In the previous works was shown, such fast domain wall could be effectively tuned by magnetic anisotropies introduced to wires [2]. However, along with geometry of anisotropies, the domain wall dynamics is strongly influenced by surface domain structure too [3].
Here we perform the study of spontaneous magnetization at the surface of the microwire and its influence on fast domain wall dynamics.
Imaging by Bitter technique revealed the periodic domain structure with inclination of app. 40° with respect to the wire axis (Fig. 1). Annealing of the samples leads to slight relaxation of mechanical stresses resulting in decrease of the domain size. However, the angle of surface structure seemed to be unchanched by thermal treatment. Detailed analysis of periodic surface structure was done by combination of longitudinal and transverse MOKE. It was shown that the surface helical domain structure is responsible for this pattern. This approves that surface of the wire is characteristic by multi-axis stress field, that could be important factor for fast domain wall propagation.

Support by the project NanoCEXmat Nr. ITMS 26220120019, Slovak grant APVV-0266-10, VEGA grant No.1/0076/09 and VVGS 2/12 -13 is acknowledged.

[1] R. Varga et al., Phys. Rev. B 76, 132406 (2007)
[2] K. Richter et al., Appl. Phys. Lett. 96, 182507 (2010)
[3] E. R. Lewis et al, Nature Mater. 9, 981 (2010)

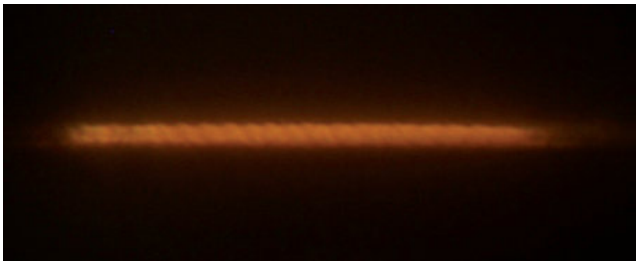

Fig.1 Surface domain structure of the FeSiB microwire with fast domain wall

TH-137
Domain structure evolution in ferromagnetic films with artificially created boundary conditions
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Nanostructuring of artificially constructed exchange coupled ferromagnet/antiferromagnet (FM/AFM) bilayers is significantly affecting formation domain structure and evolution in the ferromagnet layers during their magnetization reversal. Visualizing the kinetics of remagnetization process in patterned FM/AFM nanocomposites enables us to reveal a new phenomenon of the FM exchange bias in the lateral direction [1]. We report the detailed experimental studies its origin in ferromagnetic NiFe or NiFeMoCu films exchange-coupled to a thin film antiferromagnet IrMn and FeMn square meshes. Using magnetooptical indicator film technique and vibrating sample magnetometer we observed the domain wall (DW) nucleation and motion in FM layers, which are surrounded by artificial FM/AFM boundaries. It was found that topologically stable domain walls located near AMF edges crucially influence the free FM layer magnetization reversal. We observed three different modes of the domain structure transformation depending on an angle between external magnetic field and unidirectional anisotropy axis in the exchange-biased FM layers. In each type the pattern-controlled nucleation of domain walls and an overall asymmetry in the reversal behavior of the free FM layers were registered. In most cases, the vortex and antivortex types of the spin structures into topologically stable parallel and perpendicular to the unidirectional anisotropy DWs, respectively, were formed during magnetization reversal of the free FM layers. Artificial topologically stable domain walls and magnetostatic fields at the borders between exchange-biased and free parts of the FM layer are considered to be responsible for these effects.

[1] Yu. P. Kabanov, et al., Phys. Rev. B, 79, 144435 (2009)

TH-140
Magnetization processes in nanoparticle assemblies
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Despite numerous previous studies [1-3], it remains a largely

unsolved challenge to get a quantitative description of the magnetic properties of an assembly of magnetic nanoparticles. The first difficulty in such analysis is the fact that the particle size and particle size distribution are poorly known. These however can now be reasonably approached thanks to observations with modern TEMs. The second and more stringent difficulty is the description of the dipolar interactions. These are long ranged but depend as well on the local arrangement of the nanoparticles and thus may differ from one particle to another. Previous models to take these interactions into account have been proposed which often gave reasonable account of experimental data, but the range of their applicability was not clarified in general.
An analysis of the magnetic properties of assemblies of magnetite nanoparticles will be presented. The susceptibility of each particle is assumed to be given by a Langevin function with the magnetization fluctuating either within the entire solid angle (superparamagnetic particles) or within an hemisphere only (blocked particles). The magnetic field acting on a given particle is the sum of the applied field and of a mean field representing dipolar interactions. For specific sample shape, a quantitative description of the experimental temperature dependence of the coercivity and isothermal field dependence of the magnetization are obtained. The validity of the hypothesis made will be discussed.

[1] J. L. Dormann, D. Fiorani, and E. Tronc, Adv. Chem. Phys. **98**, 283, (1997)
[2] T. Jonsson, P. Svedlindh, and M. F. Hansen, Phys. Rev. Lett. **81**, 3976 (1998)
[3] P. Allia, M. Coisson, P. Tiberto, F. Vinai, M. Knobel, M. A. Novak, and W. C. Nunes, Phys. Rev. B 64, 144420 (2001).

TH-141
Dynamics of successive minor hysteresis loops
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Cumulative growth of successive minor hysteresis loops in thin Co/Pd multilayers with perpendicular magnetic anisotropy was studied in the context of time dependent magnetization reversal dynamics. We show that in disordered ferromagnets, where magnetization reversal involves nucleation, domains' expansion and annihilation of remnant non-reversed enclaves, differences between the time dependencies of these processes are responsible for accumulation of nuclei for rapid domain expansion, for the asymmetry of forward and backward magnetization reversals and for the respective cumulative growth of hysteresis loops. Loops stop changing and become macroscopically reproducible when populations of upward and downward nucleation domains balance each other and the respective upward and downward reversal times stabilize. Phenomenology of the effect is applicable for variety of nonequilibrium phase and state transitions.

TH-142
Critical behavior of pure ferromagnetic and random diluted nanoparticles: variational and Monte Carlo approaches
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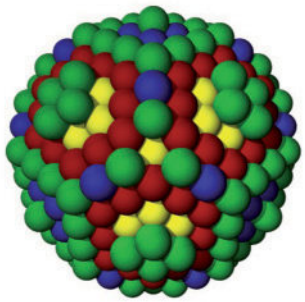
By using both the free energy variational principle based on the Bogoliubov inequality and Monte Carlo simulation [1], the magnetic properties and critical behavior of metallic nanoparticles having concurrently atomic disorder, dilution and competing interactions, are studied within the framework of an Ising model. As a case of study we have considered the Fe0.5Mn0.1Al0.4 alloy characterized for exhibiting, under bulk conditions, low temperature reentrant spin glass (RSG) behavior and for which experimental and simulation results are available. Our results [2] allow concluding that the variational model is successful in reproducing features of the dependence of the critical temperature with particle size and low temperature magnetization reduction consistent with a RSG behavior. Our results are in accordance with the Almeida-Thouless line at low fields and a linear dependence of the freezing temperature with the reciprocal of the particle diameter was also obtained. Computation of the correlation length critical exponent yielded the values ν=0.926 via Bogoliubov and ν=0.71 via Monte Carlo. This fact indicates that even though thermodynamical models can be indeed used in the study of nanostructures and they can reproduce experimental features, special attention must be paid regarding critical behavior. From both approaches, differences in the exponent with respect to the pure Ising model agree with Harris and Fisher arguments.

[1] J. Restrepo and G. A. Pérez Alcázar, Phys. Rev. B 61, 5880 (2000); J. Restrepo and J. M. Greneche, Phys. Rev. B 71, 064406 (2005).
[2] E. A. Velásquez, J. Mazo-Zuluaga, J. Restrepo, and Ò. Iglesias, Phys. Rev. B 83, 184432 (2011).



Particle with diameter D=10 having 1067 atoms, bcc structure, and an average coordination number <z>=6.96.

TH-143
Fast switching main poles in perpendicular write heads
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High data rates are essential for future magnetic data storage. Whereas media grains can be switching within 100 picoseconds and below, the maximum frequency of the write field is limited today by domain processes in the write head. With current designs the maximum write frequencies reaches 2 GHz to 3 GHz. In this work we show that the use of precessional

switching may increase the write frequency by a factor of 10. During writing a bit the writer is energized. The magnetization obtains a high energy state which is supported by the coil field. Switching the coil current polarity changes the coil field. The domain configuration in the main pole of the writer is modified and the write field reverses its direction.
Here we propose a main pole shape that supports a quasi-uniform magnetization when the write head is switched on. This magnetization configuration can be reversed by applying a field pulse perpendicular to the plane of the main pole. This field provides a torque only and does not increase the total energy of the system. The magnetization remains quasi-uniform during switching. After switching an in plane field that stabilized switched magnetization is applied. We apply micromagnetics combined with numerical optimization techniques, in order to optimize the switching of the main pole. Pulse duration and the main pole shape are free parameters in the optimization process. They are varied by the optimization software so that the switching time is minimal. The simulations show that an ellipsoidal shaped disk with a long axis of 650 nm, a short axis of 430 nm and a thickness of 100 nm can be switched within 40 picoseconds. When we include an exchange break layer along the long axis of the writer, the simulations show that the writer switches off in zero field within 100 picoseconds.

TH-144
Magnetic micro-helix coil structures
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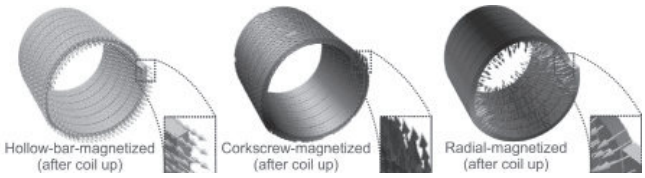
(1) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany and Globalfoundries Inc., 01109 Dresden, Germany, (2) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany, (3) Institute for Theoretical Physics, IFW Dresden, 01069 Dresden, Germany, (4) Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany and Material Systems for Nanoelectronics, Chemnitz University of Technology, 09107 Chemnitz, Germany

The impact of topology on magneto-electric properties, of physical objects with complex magnetic configurations, allows for new effects to be observed such as the topological Hall Effect in helimagnetic materials. Helimagnetic materials [1] are characterized by a gradual spatial tilt of adjacent discrete spin moments. An alternative approach for creating complex magnetic patterns relies on a continuous distribution of a macroscopic magnetic moment. Such geometries can be prepared using nanofabrication techniques. Here we create and investigate helimagnetic-like configurations, namely hollow-bar-, corkscrew-, and radial-magnetized 3D micro-helix coils (Figure) [2]. The fabrication starts with a planar strip geometry, possessing a well-defined easy axis of magnetization, either in-plane (20-nm-thick Co layer) or out-of-plane ($[Co(0.4\ nm)/Pt(0.6\ nm)]_5$ multilayers). If the magnetic moment is oriented in-plane, orthogonal to the strip axis, the coiling process results in a hollow-bar-magnetized structure. If, instead, the magnetic moment is oriented in-plane, parallel to the strip axis, corkscrew-magnetized coils are expected. Alternatively, if the easy axis of magnetization of the strip is pointing out-of-plane, a radial-magnetized helix coil geometry is realized. These distinct magnetic configurations are probed through dynamical magnetometry using parametric magnetic excitation [2,3].
The continuously distributed macroscopic magnetic moment of the micro-helix coils resembles that of the discrete spin patterns intrinsic to helimagnetic materials. Our approach opens the possibility to investigate the complex magnetic transitions, characteristic of helimagnetic materials, for the first time at the micrometer scale. Furthermore, the coil structures are of interest as a microscale geometrical realization of the so-called magnetic toroidal moment, thus allowing for experimental investigations on this novel type of multiferroic material.

[1] X.Z. Yu et al., Nature 465, 901 (2010)
[2] E.J. Smith et al., Phys. Rev. Lett. 107, 097204 (2011)
[3] V.M. Fomin et al., Phys. Rev. B 84, 174303 (2011)



3D micro-helix coils with distinct magnetic configurations

TH-145
Cumulative growth of minor hysteresis loops - Kolmogorov model
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Orthodoxly, hysteresis dependencies $M(H)$ are repeated under cyclic varying the field. But in practice, the periodicity of $M(H)$ dependencies is to the full observed for major hysteresis loops only, while minor loops are sometimes non-repetitious. Par example, for ultrathin Co/Au films the minor loop area gradually doubles under periodic field varying [1]. Even greater effect (up to 400%) being called “cumulative growth of minor loops” is observed in Co/Pt, Co/Pd films [2]. Authors connect the effect with non-uniformity of films including hypothetic asymmetric centers, near which domains of opposite signs arise with different probabilities and grow with different velocities.
Asymmetry results in some special memory – the system “keeps in mind” how it has been magnetized at the start and returns to that state much faster than to the inverse magnetization state. Similar results are obtained for Co/Pd films [3], where the magnetization relaxation has been basically studied. Hysteresis and relaxation are related phenomena. However, from the experimental point of view, studying hysteresis is easier, while the relaxation is easier to describe analytically. Interestingly, the latter is similar to the crystallization which could be described by the simple and powerful Kolmogorov approach [4].
We believe that under certain assumptions Kolmogorov model could be applied to describe non-repetitious suc-cessive magnetic relaxation cycles in thin Co films where the mentioned cumulative effect has been observed. In Figure, magnetic relaxation cycles calculated within Kol-mogorov model are shown. They are in quantitative agreement with experiments.
The work is supported by Russian Foundation of Basic Researches’ Grant N° 12-02-00550-a.

[1] J. Ferre, e.a., Phys. Rev. B, **55**, 15092 (1997).
[2] A. Berger, e.a., Phys. Rev. B, **82**, 104423, (2010).
[3] Y.W. Windsor, A. Gerber, and M. Karpovski, arXiv:1201.5791 (2012).
[4] A. E. Kolmogorov, Izv. Akad. Nauk USSR, Ser. Phys. Math. Nauk, **1**, 355 (1937).

TH-146

Magnetic feature of the structure "disk on disk"

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Manipulation of micromagnetic configuration in nanoscale object is an important trend of the fundamental and applied physics. In this work we have proposed a new type of magnetic nanostructures with 3D architecture. It allows to control vortex chirality in a magnetic disk without use of its deformation of shape. Manipulation of remanence in big disk with a diameter 600 nm is performed by means of fabrication on its top a smaller disk with a diameter 200 nm, inset in Fig. 1a.

Structure was fabricated using a two-stage process. It involves electron-beam lithography techniques and following magnetron sputtering of Py. The fabricated system was as follows Py(35nm)/Cu(3nm)/Py(35nm). The interlayer of Cu favors to prevent a direct ferromagnetic exchange between disks.

In this work has studied behavior of the system depending on the distance between centers of disks ***s*** and orientation of the external field ***φ,*** Fig. 1b. Research has shown that presence of the small disk affected significantly on magnetization reversal in the big disk. The MH curves of single disks and "*disk on disk*" structures in the case when an external magnetic field was aligned at angle $\varphi \approx 0$ are represented in Fig.1a.

Our investigation has shown that during magnetization reversal the small disk is in single-domain state. An inverse remanent magnetization state can be found in dependence on external magnetic field alignment relatively the studied object, inset in Fig. 1b. Moreover, the vortex chirality can be controlled by the direction of external magnetic field. We have found that magnetization of small disk has two stable single domain states. It gives opportunity to realize four stable magnetic states in the structure and use it in a practical application.

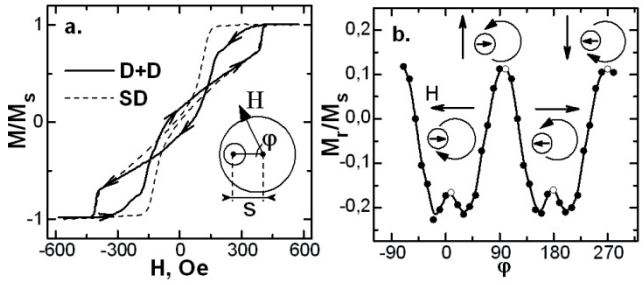

Fig.1. a) *Hysteresis curves for the disk and "D on D" system;* b) *the angular dependences of the remanence.*

TH-147

Nanofabrication and simulation of MgO-MTJ nanopillar devices for application as nano-oscillators

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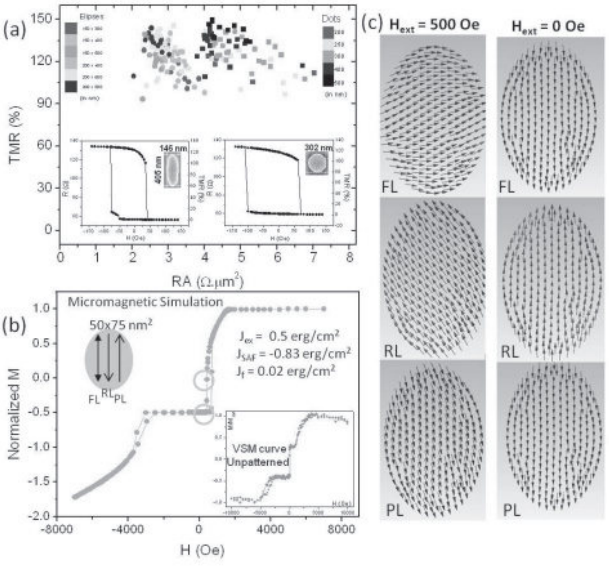
Intense research regarding the development of magnetic tunnel junctions (MTJ) has been mainly driven by the magnetic data storage industry [1]. Particullarly, MgO-based MTJs showing large tunnel magnetoresistance (TMR>200%) are expected to originate new spintronic devices such as spin-transfer magnetic random access memories or spin-transfer driven microwave oscillators [2]. Nevertheless, the capability to fabricate MTJs with low resistance-area (RxA) and TMR>100% must be combined with the aptitude to define structures below 100nm, together with an effective integration of the pillar into a device architecture.

The MTJ stack was deposited on a Timaris sputtering tool, consisting of Si/SiO_2/Ta(5)/CuN(50)/Ta(30)/CuN(50)/Ta(3)/PtMn(15)/CoFe30(2.3)/Ru(0.85)/CoFe40B20(2.5)/MgO<1/CoFe40B20(2.5)/Ta(10)/CuN(30)/Ru(7) (thickness in nm), showing TMR~200% and RxA~5Ωμm^2. The MTJ films were patterned into circular (diameters=100nm to 500nm) and elliptical pillars (150x300nm^2 to 200x650nm^2), combining electron beam lithography, ion-milling and lift-off to define the nano-pillar[3].

The measured devices show an average RxA~6.6Ω.μm2 with TMR up to 145% [Fig.1(a)], demonstrating the quality, robustness and yield of the nanofabrication process. Overall, squared TMR curves with large coercivity values are observed in these samples [Fig.1(a)-inset]. Also, Barkhausen jumps are visible indicating the presence of multiple domain-walls (DW) within the MTJ free-layer, instead of reversal through a single DW as expected considering the dimensions used. To further understand the magnetic behavior, micromagnetic simulations were performed with SpinFlow3D software [Fig.1(b)-(c)]. The simulated M(H) curve for a 50x75 nm^2 pillar correlates with the experimental data, although with higher saturation fields due to smaller size. The micromagnetic configurations of the pinned, reference and free layers present a single domain behavior as expected for a sub-100nm pillar.

[1] P. P. Freitas et al. J. Phys.-Cond. Mat. 19 (2007) 165221
[2] Shen, W. et al. (2005) Appl. Phys. Lett. 86, 253901
[3] R. Macedo et al. J. Nanosc. Nanotech. 10 (2010) 5951

Fig.1:(a) TMR versus RA; (b) M(H) curves; (c) Micromagnetic configurations.



TH-148

Mechanical Oscillations of Magnetic Strips under the Influence of External Field

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In-plane Weiss domains occur in soft ferromagnetic ribbons as a consequence of magneto-static energy minimisation. These domains can be reoriented on application of an applied field. Using finite elements we compute the mechanical resonance frequency of magneto-elastic platelets in an applied magnetic field.

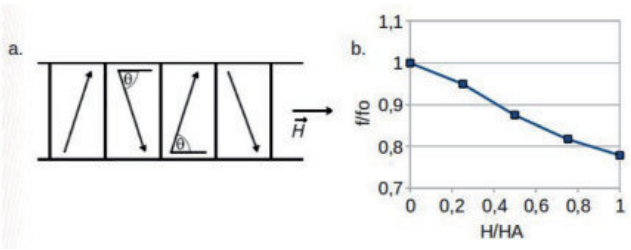

Fig.1: Orientation of magnetisation of Weiss domains on a metallic strip (Fig.1a),
computed mechanical frequency change with the applied magnetic field (Fig.1b).

First we solve the one dimensional wave equation for the longitudinal mechanical oscillation of a metallic strip.

The right hand side of this equation contains the magneto-mechanical coupling that links the magnetization angle ϑ with the mechanical displacement. This coupling is nonlinear as the magnetisation angle depends on the external field *H* and the local stress *σ(X)*.
After discretization with linear finite elements, equations (1) to (3) build a differential - algebraic system. This is solved using the Adams-Bashforth method for the differential equation and a fixed-point iteration for the non-linear algebraic equation. Fig 1b shows how the computed resonance frequency changes with the applied field.

[1] L. Banas: On dynamical Micromagnetism with Magnetostriction. PhD Thesis June 2005 University of Gent
[2] J.D.Livingston: Magnetomechanical Properties of Amorphous Metals. Phys. Stat. Sol. (a) 70, 591 (1982)

TH-150

Magnetization Switching of CoFeB/MgO/CoFeB Pseudo Spin-Valves with Perpendicular Anisotropy

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In an attempt to design of Magnetic Tunnel Junction (MTJ) with a low critical switching current and voltage, sample with crossed double CoFeB wedge $t_{bot}Co_{40}Fe_{40}B_{20}$/0.8 MgO/$t_{top}Co_{40}Fe_{40}B_{20}$ was deposited on the oxidized silicon wafer with buffer multilayers of 5Ta/[10CuN/3 Ta]x2 ($0.66 \leq t_{bot} \leq 1.08$, $0.99 \leq t_{top} \leq 1.62$, thickness in nm) using Singulus sputtering cluster tool system. Sample was patterned into circular shape nanopillars with 150 up to 370 nm diameter. In order to check the Perpendicular Magnetic Anisotropy and Gilbert damping parametr (α) of each CoFeB layer, additional samples with a single CoFeB under and on the top of the MgO barrier, were deposited. Annealed at 330 ºC, MTJs revealed the TMR ratio of up to 28%, although a shift of of minor hysteresis loop depending on bias voltage V_b was observed. Extrapolation for zero bias gives a 19 kA/m shift field due to ferromagnetic coupling $J=7x10^{-6}$ J/m^2. Field-voltage phase diagram reveals that antiparallel magnetization state can be established in zero-field with $V_b = -75$ mV, which corresponds to a current density of $J_c = -4.2$ MA/cm^2. Although quasi-static hysteresis loop suggests only one easy axis perpendicular to the plane, FMR measurements of the trilayer system show two resonance modes: one, indicating the in-plane anisotropy and the other one, typical for PMA. This is in agreement with micromagnetic simulations and with VSM/MOKE measurements for the samples with a single CoFeB. They reveal the presence of PMA for the *bottom* CoFeB layer (deposited under the MgO) and the in-plane anisotropy for the *top* one. The Gilbert damping parameter alpha is near two times lower for the *bottom* than for the *top* CoFeB wedge. Dependence of α on CoFeB thickness, annealing treatment and ferromagnetic interlayer coupling will be discussed.
The study was co-financed through the Swiss Contribution, project NANOSPIN-PSPB-045/2010 and National Science Centre, grant NN515544538.

TH-151

Spin-dependent Transport in Epitaxial Spinel-based Magnetic Tunnel Junctions Probed by Shot Noise Measurement

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Magnetic tunneling junctions (MTJs) have been one of the central topics in the spintronics field. MTJs not only have potential in various applications, but also enable us to directly address spin-dependent transport. Recently, a large tunnel magnetoresistance was obtained in the MTJs with a crystalline spinel ($MgAl_2O_4$) barrier [1]. Although conventional *I-V* characteristic measurements have been applied to investigate the transport properties in this system, additional experimental probes such as shot noise would be preferable to clarify more the nature of electron tunneling.
Here we report the precise measurement of the shot noise in the Fe/$MgAl_2O_4$/Fe based MTJs. Figure 1 (a) shows a typical magnetoresistance (MR) curve at 4 K. Figure 1 (b) shows a typical current noise power spectral density in the parallel configuration as a function of bias voltage. Although the Fano factor, which characterizes the shot noise, is 1.002 ± 0.010 in the antiparallel case, it is reduced to be 0.979 ± 0.009 for the parallel configuration. We interpret this result as a signature of coherent transport of the Δ_1 state as is the case in the MgO-based MTJs [2],[3].

[1]H. Sukegawa *et al*., Appl. Phys. Lett. **96,** 212505 (2010)

[2]T. Arakawa *et al*., Appl. Phys. Lett. **98** 202103 (2011)
[3]K. Liu *et al*., arXiv:1111.2681vl

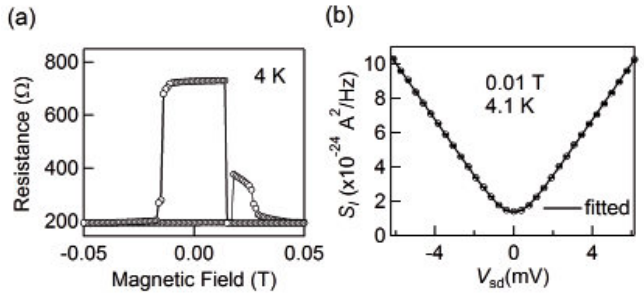

Figure 1 (a) Typical MR curve at 4 K. (b) current noise power spectral density for the parallel configuration. Solid curve is the result of the fitting to the conventional shot noise theory with $F = 0.979 \pm 0.009$.

TH-153

Self-sustained oscillations in a nanopilar with a synthetic–antiferromagnetic free layer and perpendicular polarizer

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Using a perpendicular polariser associated with an in-plane magnetised free layer is extremely attractive from an application point of view for both spin-torque oscillators [1] and spin-transfer torque MRAM [2]. At zero applied field, an out-of-plane precession (OPP) can be generated above a current threshold. Thus, the amplitude of the dc current controls the frequency which is in the range of few GHz, and no external magnetic field is needed. For the case of a single ferromagnetic free layer, experimental results [1] show that the frequency increases with current until it reaches a plateau. For high currents, the self-sustained oscillations disappear since the free layer is highly non-uniform. It is possible to extend the range of current controlling the frequency by replacing the single free layer with a synthetic antiferromagnetic (SAF) layer [3]. Micromagnetic simulations were performed to compare both cases. In the SAF structure, one of the ferromagnetic layers is excited by the spin-torque due to the perpendicular polariser, while the other layer oscillates because of the RKKY coupling. Our results confirm the existence of the OPP steady state in the SAF free layer for a current window much larger than that of the equivalent single free layer. Thus, the frequency varies more slowly with the current than for the single free layer.

[1] D. Houssameddine et al. Nat. Mater. 6, 447 (2007)
[2] A Vaysset et al. Appl. Phys. Lett, 98, 242511 (2011)
[3] M. Marins de Castro et al. J. Appl. Phys. 111, 07C912 (2012)

TH-154

Perpendicular Magnetic Tunnel Junction for nano-oscillator applications

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A new class of magnetic tunnel junctions (MTJ) with perpendicular anisotropy has been recently used for fast switching applications [1]. Here, the same materials are studied to be applied as microwave nano-oscillators. These devices are based on the use of interfacial perpendicular anisotropy employing CoFeB-MgO, that with respect to the commonly known perpendicular-anisotropy materials, use noble metals with high spin-orbit interaction and low magnetic damping. These materials have the characteristics that anisotropy field increases as thickness reduces and changes its sign reflecting the change of magnetic-easy-axis around 1.5 nm [1]. We numerically studied a CoFeB(1.0nm)/MgO(0.9nm)/ CoFeB(1.3nm) multilayer by means of our micromagnetic code [2]. The different thickness of two ferromagnetic layers is a key point to fix the thin layer (high anisotropy constant, K_u=1 10^6 J/m^3) along the out of plane direction and to get free the thick in-plane layer (K_u=2 10^5 J/m^3). In this way, very small circular devices as low as d=40 nm diameter have both high thermal stability (>40) and TMR ratio. Precessional modes at very low bias (order of 10^5 A/cm^2), in a large range of current, and at zero field for two different cross-sectional area (d=40 and 150 nm) are found. Fig. 1(a) and (b) show frequency and power behaviour as function of current. For both structures the frequency increases with current and in the smaller one no frequency jumps are visible. At high bias the precession frequency of the large device is higher but its oscillation amplitude is smaller and the power falls (see fill pattern in Fig. 1).

[1] S. Ikeda, K. Miura, H. Yamamoto et al., Nature Materials 9, 721 (2010)
[2] M. Carpentieri, E. Martinez, G. Finocchio, J. Appl. Phys. 110, 093911 (2011)

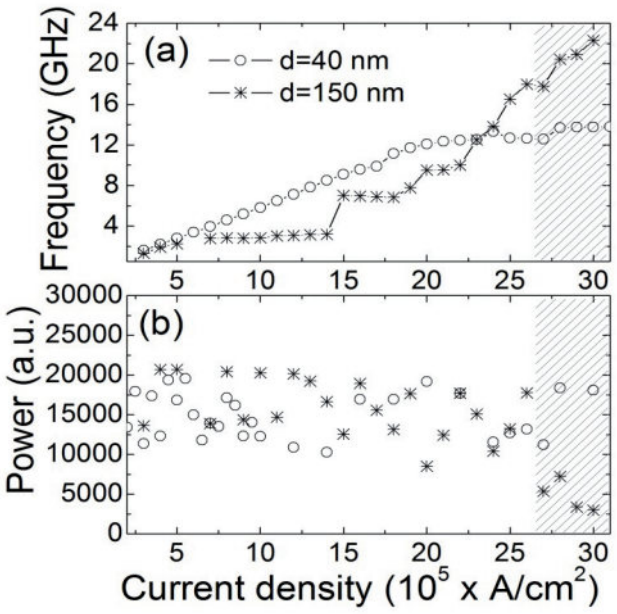

Fig. 1 (a) Frequency and (b) power as function of current density for different diameters at zero field.

TH-155

Electric field induced magnetization switching in ferromagnet-magnetoelectric two-layer system

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It is common knowledge that in thin layer of multiferroic $BiFeO_3$ a spiral magnetic ordering is suppressed and a commensurate antiferromagnetic ordering with weak ferromagnetism occurs in parallel with the ferroelectric ordering. The electric field applied to $BiFeO_3$ changes the sign of a weak ferromagnetic moment caused by a tilting of sublattices. At the expense of the exchange interaction between the spins of multiferroic and the spins of the neighboring ferromagnetic layer such a change of the sign may give rise to the ferromagnetic magnetization switching.

In some papers it was proposed to cut out the $BiFeO_3$ layer with the normal oriented in parallel with the polarization vector directed along the main diagonal of the pseudocubic lattice. But the (111) atomic planes are uncompensated, i.e. contain the atoms of only one of antiferromagnetic sublattices. Depending on the sign of the exchange interaction between the layers the spins of ferromagnetic layer tend to be oriented parallel or antiparallel to the spins of the upper atomic plane of $BiFeO_3$.

The sign change of the weak ferromagnetic moment shall cause the spin rotation in the upper atomic plane by a small angle equal to double angle of the tilt of the sublattices and to the same rotation of the spins in the ferromagnetic layer.

To realize the 180º tern of the ferromagnetic layer magnetization the upper atomic plane of $BiFeO_3$ must be compensated, i.e. to contain equal number of the atoms of each of antiferromagnetic sublattices. These are the (100) and (110) planes of the pseudocubic lattice.

Assuming such cuts, the ferromagnet magnetization interacts profitably with the resulting magnetic moment of the upper atomic plane of $BiFeO_3$, and this makes it possible to reverse its direction by the electric field applied to the single-domain multiferroic layer.

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

MOLECULAR MAGNETISM

Chair: V. Corradini

TH-156

Low temperature spin dynamics in Cr_7Ni-Cu-Cr_7Ni coupled molecular rings

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The molecular ring Cr_8 contains eight Cr^{3+} ions (spin s=3/2) which are antiferromagnetically coupled to yield a total S=0 singlet ground state. By replacing one Cr^{3+} atom with Ni^{2+} (s=1), the ground state of the formed Cr_7Ni becomes magnetic, with total S=1/2. The coupling of two Cr_7Ni heterometallic offers the possibility of investigating quantum entanglement. The capability of engineering a weak magnetic coupling between two Cr_7Ni rings has been demonstrated by the insertion of a moiety containing a single Cu^{2+} ion between two rings [1]. This results in a system which can be described at low temperature as three weakly coupled S=1/2 magnetic centers, with a S=3/2 triplet ground state due to the weak (J = 1K) ferromagnetic interaction between the Cu^{2+} ion and the adjacent rings [1]. We have investigated the spin dynamics of the coupled rings system by NMR proton spin-lattice relaxation rate, T_1^{-1}, vs. T and H. When the results are compared with previous results in isolated Cr_7Ni AFM rings [2], one finds that while for T > 1 K the behavior of T_1^{-1} is practically identical in the isolated and coupled rings, at very low T the proton T_1^{-1} in the coupled ring is faster and it displays a broad field dependent maximum just below 200mK. The maximum can be fitted with a Lorentzian spectral density function for the magnetic spin fluctuations, with an activated correlation frequency with a barrier of about 1K and a prefactor of about 10^{11} rad/sec. This correlation frequency is linked to spin fluctuations persisting at very low T. The nature of the spin fluctuations is yet to be established by taking into account the energy level structure [1].

[1] G.A.Timco et al. Nature Nanotech. **4** , 173 (2009)

[2] H. Amiri et al. Phys.Rev B **82**, 144421 (2010)

TH-157

Redistribution of local spin density in Cr_7Ni antiferromagnetic molecular ring from ^{53}Cr NMR

C. Casadei [1], E. Garlatti [2], L. Bordonali [1], Y. Furukawa [3], F. Borsa [1], A. Lascialfari [4], S. Carretta [5], G. Timco [6], R.E.P. Winpenny [6]

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Antiferromagnetic molecular rings are an ideal playground for investigating magnetism at nanoscale. The homometallic Cr_8 ring is formed by eight Cr^{3+} moments (s=3/2) which form at low temperature a total S=0 ground state (GS) with zero expectation value of the local spins. When one Cr^{3+} ion is replaced by a diamagnetic ion (e.g. Cd) or a different magnetic ion (e.g. Ni^{2+} with s=1) the ground state becomes magnetic and there is a redistribution of the local spin density which can be calculated theoretically. In a previous work we measured the ^{53}Cr-NMR in Cr_7Cd and determined unambiguously the local spin density in the ring with excellent agreement with the theory (Phys. Rev. Letters 97, 267204 , 2006). In this work we tried to do the same for Cr_7Ni. Unfortunately, due to poor S/N ratio, only one ^{53}Cr was detected down to 100mK and the ^{61}Ni signal is too weak. Nevertheless, by using the core polarization field H_{cp} = -12.3 Tesla found in Cr_7Cd we could prove that the measured ^{53}Cr NMR signal corresponds to sites 2,4,6 with the local spin density calculated theoretically, as can be evinced from the table below. The table gives the calculated spin densities in the Cr_7Ni ring in the GS at T=0, with the applied field perpendicular to the ring plane. The sum of $\langle s \rangle$ is close to S=1/2 as expected for the GS. The ^{53}Cr NMR signal measured at 1.6 K is in good agreement with: resonance frequency = Larmor frequency + γ_{Cr} H_{cp} $\langle s \rangle$, with γ_{Cr} = gyromagnetic ratio of ^{53}Cr nucleus, $\langle s \rangle$ values for sites 2,4,6 (see table) and H_{cp} = -12.3 Tesla.

ion site	g<s>	<s>
Cr1	1.25315	0.633
Cr2	-1.07189	-0.541
Cr3	1.18954	0.601
Cr4	-1.07047	-0.541
Cr5	1.18954	0.601
Cr6	-1.0719	-0.541
Cr7	1.25315	0.633
Ni	-0.79632	0.362

TH-158

Magnetic properties and hyperfine interactions in Cr_8, Cr_7Cd and Cr_7Ni molecular rings from ^{19}F-NMR

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We present a detailed investigation of the static magnetic properties of molecular homometallic Cr_8 antiferromagnetic (AFM) ring and heterometallic Cr_7Cd and Cr_7Ni rings in the low temperature ground state, by ^{19}F-NMR. The original idea was to utilize the ^{19}F nucleus as a local probe for the electronic spin densities of the nearby Cr^{2+} and Ni^{2+} spins. However, the fact that the F atom is located midway between two magnetic ions gives rise to ^{19}F-NMR spectra which have a complicated field dependent structure, due to both isotropic transferred hyperfine contact interactions and anisotropic dipolar and pseudo-dipolar interactions. Therefore the NMR spectra have to be analyzed in connection with the theoretical results concerning the local spin distribution in order to establish the values of the hyperfine interaction constants, not known at present. In Cr_8 the ground state is a singlet with total spin S=0. The ^{19}F-NMR spectra at 1.6K and at fields lower than 2 Tesla show a single narrow line, proving that the local spin density in the ground state is zero as expected for a molecular singlet state. When the magnetic field is not negligible with respect to the level crossing field $H_c \approx 7$ Tesla, a structure appears in the ^{19}F-NMR spectrum which is orientation dependent (in a single crystal), indicating a dominant anisotropic contribution to the hyperfine fields. In Cr_7Cd we could detect in the ^{19}F-NMR spectrum a shifted line attributed to the F nuclei next to a Cr ion close to the Cd, thus allowing the unambiguous determination of the transferred hyperfine constant F-Cr. A similar analysis was possible on the ^{19}F-NMR spectra in Cr_7Ni. The values of the isotropic hyperfine constants (A ≈ 1 Tesla) are comparable to the ones known for F-Mn in AFM $KMnF_3$ and MnF_2.

TH-159

Ab-initio construction of spin Hamiltonians by means of Boys orbitals: application to the molecular nanomagnets Fe_4 and Cr_8

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Molecular nanomagnets (MNMs) have attracted a large interest both as model systems to investigate fundamental issues and for technological applications. The parameters of the low-energy spin Hamiltonians are usually obtained by fitting experimental data.

In this work we calculate the spin Hamiltonian of MNMs from first principles. The established scheme is based on DFT and relays on the assumption that exchange-correlation functionals such as the hybrid functional B3LYP properly account for correlation effects in the d shells. It consists in performing total energy calculations for different broken symmetry spin configurations.

Here we propose an alternative scheme, in which many-body effects are explicitly treated and no assumption is made on the form of the spin model Hamiltonian. The idea is to construct system-specific low-energy many-body Hamiltonians from DFT-based calculations. To build the low-energy model, we first perform DFT calculations using a quantum-chemistry code. Next, we construct localized Boys orbitals which span the low-energy d-like molecular states. In this basis we build a generalized multi-band Hubbard model for the molecule, including spin-orbit and direct exchange. The local screened Coulomb parameter is obtained using the constrained LDA (cLDA) scheme. Then the Hubbard Hamiltonian is mapped into a Heisenberg model by second order perturbation theory, while

direct exchange is obtained with the cLDA approach.
This method is applied to the study of two very different prototype MNMs, the high-spin Fe_4 trigonal molecule and the antiferromagnetic ring Cr_8. The calculated exchange constant for the Cr_8 ring is 1.7meV, very close to the experimental value of 1.5 meV. For Fe_4 we have found two different couplings: an antiferromagnetic coupling between the central Fe ion and the three on the vertices (J=2.8meV) and a small ferromagnetic interaction between the latters (J'=-0.09meV). Also these results are in good agreement with experimental values (J = 2.05 meV and J'=-0.08meV).

TH-160

Relaxation dynamics in a Fe7 nanomagnet probed by NMR

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We investigate magnetic properties and phonon-induced relaxation dynamics in the Fe7 molecule. Fe7 is made of two Fe(III) triangles bridged together by a central Fe(III) ion [1]. The spin Hamiltonian has been determined by magnetic measurements. The competition between different antiferromagnetic exchange interactions leads to a low-spin ground state multiplet with a complex pattern of low-lying excited levels. We theoretically investigate the decay of time correlations of molecular observables, such as fluctuations of the cluster magnetization, due to the spin-phonon interaction. Relaxation dynamics can be probed by the nuclear spin-lattice relaxation rate $1/T_1$ [2]. The interpretation of ^1H nuclear magnetic resonance measurements allows to determine the magneto-elastic coupling strength and to calculate magnetization relaxation times. We find that more than one time contributes to the decay of the molecular magnetization.

[1] K. Mason, J. Chang, E. Garlatti, A. Prescimone, S. Yoshii, H. Nojiri, J. Schnack, P.A. Tasker, S. Carretta and E. K. Brechin, Chem. Commun. 47, 6018–6020 (2011)
[2] P. Santini, S. Carretta, E. Liviotti, G. Amoretti, P. Carretta, M. Filibian, A. Lascialfari and E. Micotti, Phys. Rev. Lett. 94, 077203 (2005)

TH-161

Investigating the Electronic Structure of Cr_7M 'purple' wheels

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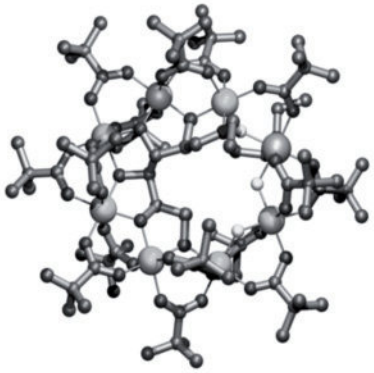
We have been investigating the chemistry and physics of transition metal clusters comprising anti-ferromagnetically coupled heterometallic rings ("Cr_7M") with a low but non-zero spin ground state. Studied by multi-frequency Electron Paramagnetic Resonance (EPR), Inelastic Neutron Scattering (INS), magnetic susceptibility and specific heat will be reported which allow us to deduce the electronic structure of $Cr^{III}_7M^{II}$ clusters (M = Zn, Mn, Ni).
The use of a pentadeprotonated aminopolyol as a scaffold has led to a new variant[2], containing five alkoxides in place of five fluorides. This purple variant is less geometrically symmetric and so exhibits greater magnetic anisotropy than the green counterpart.



$[Cr_7M^{II}F_3(Etglu)(O_2C^tBu)_{15}L]$

Etglu = N-ethyl-d-glucamine
phpy = 4-phenylpyridine
L = terminal ligand at M

[1] F. Troiani, A. Ghirri, M. Affronte, S. Carretta, P. Santini, G. Amoretti, S. Piligkos, G. Timco, R. E. P. Winpenny, *Phys. Rev. Lett.* **2005**, *94*, 207208-1
[2] G. A. Timco, E. J. L. McInnes, R G. Pritchard, F. Tuna, R. E. P. Winpenny, *Angew. Chem. Int. Ed.*, **2008**, *47*, 9681

TH-162

Deposition of Fe_{14} and Mn_2 molecular coolers on surfaces

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Examples of molecular magnets have been recently proposed as efficient coolants to exploiting the magnetocaloric effect. For the realization of on-chip refrigerators, these molecules must be deposited on a surface in a controlled way. While the preservation of their thermodynamic properties is preliminary required, the capability to drive their grafting and packing on the surface is important for the optimization of the cooling power.
We have studied the deposition of different types of molecular coolers: 1,2,3-triazolate-bridged tetradecametallic Fe_{14} clusters have shown a highly degenerate ground state and large magnetocaloric effect [1], whilst lighter Mn_2 dimers, made with either manganese(II)-diketonate [2] or manganese(II)-azido [3] complexes, represent a viable alternative. We have carried

out a bulk characterization by magnetization and specific heat measurements that show a comparably large magnetocaloric effect with entropy change of about 28 J Kg^{-1} K^{-1}.
A preliminary deposition study has been performed by using liquid-phase methods. Deposition on the Au(111) surface was carried out by dipping the sample in a 10^{-3} M solution and by subsequently rinsing with solvent. STM images shows a distribution of Fe_{14} molecules deposited on the Au(111) surface (Figure 1). We will discuss the applicability of other deposition methods, such as electrospray ion beam deposition and ultra-high vacuum sublimation, which may allow fabricating denser monolayers and multilayers.

[1] R. Shaw et al., Inorg. Chem. 46, 4968 (2007).
[2] M. Ryazanov et al., Polyhedron 23, 879 (2004).
[3] C.-M. Liu et al., Inorg. Chim. Acta 358, 834 (2005).

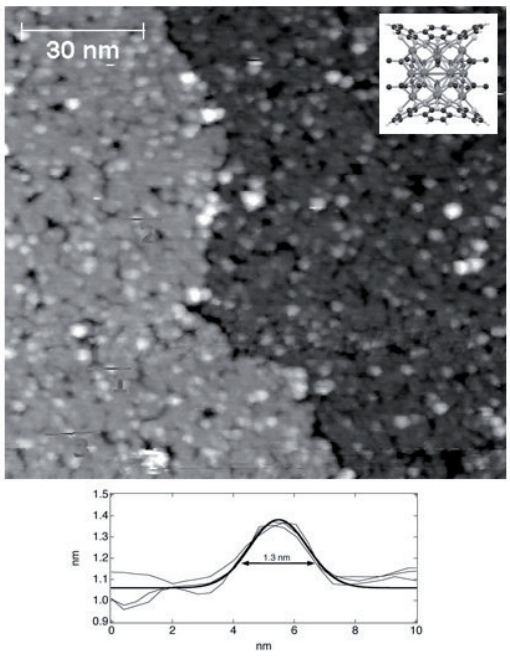

Figure 1. STM image showing a sub-monolayer distribution of Fe_{14}-bta molecules deposited on Au(111) from dichloromethane solution.

TH-163
Comprehensive study of magnetic properties on unique molecular magnet $\{[Fe^{II}(pyrazole)_4]_2[Nb^{IV}(CN)_8]\cdot 4H_2O\}_n$
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The self-assembly of $[Nb^{IV}(CN)_8]^{4-}$ with iron center in aqueous solution and an excess of pyrazole resulted in the formation of 3D network $\{[Fe^{II}(pyrazole)_4]_2[Nb^{IV}(CN)8]\cdot 4H_2O\}_n$. It crystallizes in the $I4_1/a$ space group and shows cyanido-bridged structure decorated with pyrazole molecules coordinated to Fe^{II} centers [1]. It is a unique structure with one type of Fe^{II} – NC-Nb^{IV} linkage with negligible interaction between Fe ions. In this arrangement Nb is bridged by four CN to Fe and Fe is bridged to two Nb ions. In order to characterize the magnetic properties of the above compound we performed the AC/DC magnetometry in the range 0-5 T, zero field muon spectroscopy and calorimetry studies in the range 0-9 T. The special attention was paid to the phase transition at 7.9 K. The study in magnetic field supports magnetic ordering below 7.9 K. The value of the coupling constant $J_{Fe\text{-}Nb}$ was estimated availing of mean field model.

[1] Dawid Pinkowicz et al., Inorg. Chem. 49, 7565 (2010)

TH-165
Structural and magnetic properties of dimeric Ni(II) complex $Ni_2(bhich)_2py_6$
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We report the preparation, structural characterization and magnetic study of a new Ni(II) dimeric complex. $Ni_2(bhich)_2py_6$ (*bhich* = 2,6-bis(hydroxyimino)cyclohexanone, py = pyridine) was obtained in the direct reaction of nickel perchlorate, *bhich* and pyridine in ethanol. The molecular structure of the discussed cluster is based on two Ni^{2+} octahedral centers, which are bridged together through two *bhich* ligands. Their coordination spheres are saturated by pyridine molecules. Crystal structure of $Ni_2(bhich)_2py_6$ reveals a 3D arrangement. 1D chains are formed due to the strong intermolecular hydrogen bonds between the terminal N-OH groups. As pyridine ligands of neighboring chains non-covalently interact by pi stacking, the 3D network is formed. The magnetic susceptibility has been studied over the temperature range 2 – 298 K in the applied field ±9 T. At high temperatures (23 – 300 K) a behaviour typical of binuclear magnetic complexes with dominant antiferromagnetic coupling was observed. At lower temperatures ($T < 23$ K) the compound undergoes long range magnetic ordering with noncollinear spin structure as indicated by a small hysteresis with a coercive field of 630 Oe at 2 K. Additionally, in ZFC $\chi(T)$ curve two peaks are observed at low temperatures revealing different types of magnetic interactions in the system studied.
This work was partially performed in the laboratory founded by POIG.02.02.00-00-025/09

TH-166
AC susceptibility of the low-dimensional dipolar magnet $CsGd(MoO_4)_2$
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The experimental study of magnetic relaxation in the magnetic system of $CsGd(MoO_4)_2$ was performed. This material crystallizes in the orthorhombic system with the cell parameters a = 9.52 Å, b = 5.07 Å and c = 8.05 Å. Previous specific heat studies in B = 0 revealed a phase transition to the magnetically ordered state

at T_c = 0.45 K and confirmed a spatial anisotropy of magnetic correlations expected from the crystal structure [1]. The strength of intrachain and interchain dipolar coupling was estimated, $J_1/k_B \approx 0.6$ K and $J_2/J_1 \approx 0.01$, respectively. Magnetization, ac susceptibility and dc susceptibility of $CsGd(MoO_4)_2$ single crystal have been investigated in the temperature range from 2 to 30 K, magnetic fields from 0 to 5 T and frequencies from 0.5 Hz up to nominally 1 kHz in the commercial Quantum Design SQUID magnetometer. Magnetic field was applied along the magnetic chains running parallel to the c-axis. Analysis of dc susceptibility measured in B = 100 mT using Curie Weiss law yielded g =2, S = 7/2 and θ = -0.73 K. Investigation of isothermal magnetization indicates $S_z = \pm 1/2$ ground state doublet as a result of crystal field splitting of $^8S_{7/2}$ multiplet. Experimental study of ac susceptibility in zero magnetic field did not indicate any magnetic relaxation. Slow relaxation appears in $B \neq 0$. Temperature dependence of the relaxation time deduced from the χ'' maximum can be described by Raman process. Frequency dependence χ'' and corresponding Cole-Cole diagrams point at the existence of two or more separate relaxation processes with temperature dependent distribution of relaxation times. Other studies are necessary for understanding the origin of the relaxation.
This work has been supported by VEGA grant 1/0078/09 and ITMS26220120047.

[1] A. Feher, P. Stefanyi, A. Orendáčová, et al., Fiz. Nizk. Temp. **14**, 1304 (1988).

TH-167

Multispin interactions in Ni_4Mo_{12} and Ni[22] single molecule magnets

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It is a well-known fact that pairwise electrostatic interaction between electrons can give rise to effective multispin interactions between magnetic ions. Single molecule magnets Ni_4Mo_{12} [1] and Ni[2×2] [2] are convenient objects to study these effects. The present work is devoted to the theoretical analysis of both these materials.
At the present time two models can more or less describe the magnetic properties of Ni_4Mo_{12}. The first one [3] is based on assumption of essential role of non-Heisenberg exchange interactions in Ni_4Mo_{12} (biquadratic and three-spin). The second one [4] comprises two assumptions, strong violation of symmetry of exchange interactions, and strong single-ion anisotropy. In the present work it is shown that mechanism responsible for non-Heisenberg exchange interactions is the same as mechanism resulting in interaction of spin chirality with external magnetic field. As an example, additional level splitting in magnetic field must be observed in the case of model [3]. In the case of model [4] quite different phenomena are expected. The violation of symmetry of exchange interactions inevitably leads to nonzero toroidal moment of some spin states. This effect can be observed via set of magnetoelectric phenomena.
The Ni[2×2] differs from Ni_4Mo_{12} by topology of exchange interactions (square versus tetrahedron). Calculations made in the present work show that changes in topology of exchange interactions drastically (qualitatively) change the magnetic properties of single molecule magnet.

[1] J. Schnack, M. Bruger, M. Luban, et al., Phys. Rev. B 73, 094401 (2006)
[2] O. Waldmann, J. Hassmann, P. Muller, et al., Phys. Rev. B 58, 3277 (1998)
[3] V.V. Kostyuchenko, Phys. Rev. B 76, 212404 (2007)
[4] A. Furrer, K. Kramer, T. Strassle, et al., Phys. Rev. B, 81 214437 (2010)

TH-168

Angular resolved magnetic measurements on Er single ion magnet: beyond the triclinc system

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Single-molecule magnets (SMMs) are among the most attracting systems for information storage and processing through single-spin manipulation. These molecules exhibit a magnetic bistability due to the presence of an anisotropy barrier that, at low temperature, opposes the reversal of the molecular giant spin leading to a memory effect [1]. Among SMMs complexes comprising single lanthanide ion (Single Ion Magnets) are of particular interest. These systems are characterized by a strong magnetic anisotropy accompanied by the presence of axially symmetric coordination environments. Angular resolved magnetic measurements on single-crystal of SIM DyDOTA, favoured by his triclinic lattice system, showed in a recent work [2] a strong correlation between the coordination geometry and magnetic anisotropy.
One of the latest SIM studied is represented by the evaporable organometallic complex (Cp*)Er(COT) [3]. We performed studies about angular dependence of magnetic anisotropy on single-crystal of (Cp*)Er(COT) obtaining information about the correlation between the coordination geometry and magnetic anisotropy although the lattice system of these crystals is orthorhombic. As the molecules have two almost perpendicular orientations in the crystal cell the magnetic anisotropy is averaged. However, by working in the hysteretic region, it has been possible to observe additional features that enhance the contribution of each subset of SIMs.
*) The research has been supported by the European Research Council through the AdG MolNanoMaS, and the NSFC and the National Basic Research Program of China.

[1] D. Gatteschi, R. Sessoli, J. Villain, Molecular Nanomagnets, Oxford Univ. Press, Oxford (2006)
[2] G. Cucinotta, et al., Angew. Chem. Int. Ed. 51, 1606 (2012)
[3] S. D. Jiang, et al., J. Am. Chem. Soc. 133, 4730 (2011); S. D. Jiang, et al., Inorg. Chem. 51, 3079(2012).

TH-169

Vibronic Approach to Cooperative Spin Transitions in Crystals Based on Cyano-Bridged Pentanuclear M_2Fe_3 (M=Fe, Co, Os) Clusters

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We present a theoretical microscopic approach to the problem of cooperative spin transitions in crystals based on cyano-bridged pentanuclear metal clusters $\{[M(CN)_6]_2[Fe(tmphen)_2]_3\}$ (M =Fe, Co, Os) with a trigonal bipyramidal structure. The low-spin to high-spin transition is considered as a cooperative phenomenon that is driven by the interaction of the electronic shells of the Fe ions with the full symmetric deformation of the local surronding that is extended over the crystal lattice via the acoustic phonon field. Due to the proximity of Fe ions within the metal cluster the short-range intracluster interactions between these ions via the optic phonon field is included as well. The interrelation between short- and long-range phonon induced interactions between metal ions was shown to determine the type and the temperature of a spin transition in cluster systems. The proposed model is applied to cluster compounds with temperature induced spin crossover as well as to the complexes with spin transitions caused by the charge transfer between different ions inside the complex. A wide set of the experimental data on the temperature dependence of the magnetic susceptibility and Mössbauer spectra is interpreted qualitatively and quantitatively. The suggested approach represents a theoretical tool for the study of spin transitions in crystals containing metal clusters as structural units.

TH-170

Dodecanuclear $[Cu^{II}_6Gd^{III}_6]$ Nanoclusters as Magnetic Refrigerants

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Molecular materials have recently gained progressive interest for the exploitation of the magnetocaloric effect (MCE) in cooling applications at low temperature. The requirements for these materials include high spin degeneracy and low anisotropy, conditions that can be accomplished at synthetic level by an accurate choice of magnetic centers and bridging ligands.

Among rare-earth complexes, gadolinium systems are particularly attractive because of the high spin (s=7/2) of the isotropic Gd^{III} ions. Here we report the synthesis and characterization of a novel Gd_6Cu_6 dodecanuclear complex, namely $[\{(HL)(L)(dmf)Cu^{II}Gd^{III}(dmf)(H_2O)\}_6]\cdot 6dmf$, which has been synthesized from the ligand resulted from the condensation of 3-formyl-salicylic acid with hydroxylamine (H_3L) (Figure 1). The characterization of the thermodynamic properties was carried out by low temperature susceptibility, magnetization and specific heat experiments. The fit of the whole set of data evidence a weak ferromagnetic interaction (J = +1.01 cm^{-1}) between the phenoxo-bridged Cu^{II} and Gd^{III} ions, while the exchange interactions between Gd^{III} ions show negligible effects for T>1 K. The energy separation between the ground (S=4) and the first excited (S=3) multiplets is 4.04 cm^{-1}, while the anisotropy is weak.

Entropy vs. temperature curves are calculated for different magnetic fields and compared with the results directly obtained from the experimental data. The curve calculated for the entropy change ΔS_m[0-7 T] shows a maximum at T= 2.3 K with a significant value of $\Delta S_m[0-7\ T] = 13.8\ R = 23.5\ JKg^{-1}K^{-1}$.

[1] A. S. Dinca, A. Ghirri, A. M. Madalan, M. Affronte and M. Andruh, Inorg. Chem., DOI**:** 10.1021/ic3001762 (2012).

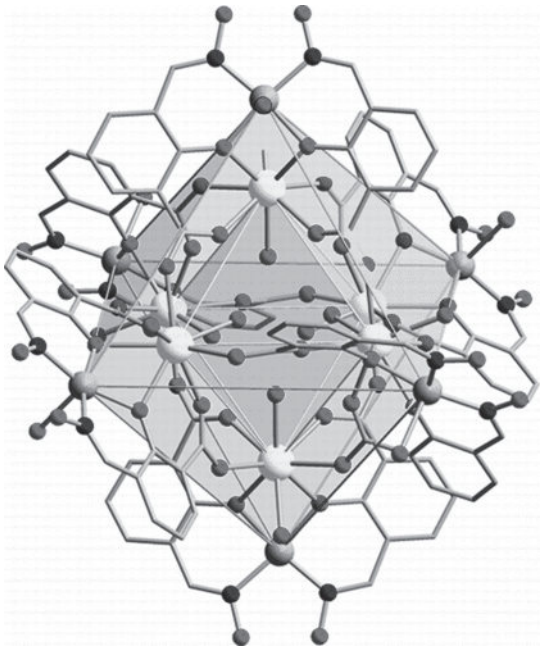

Figure 1. Crystallographic structure of Gd_6Cu_6.

TH-171

The effect of pressure on magnetic properties of $KMnCr(CN)_6$

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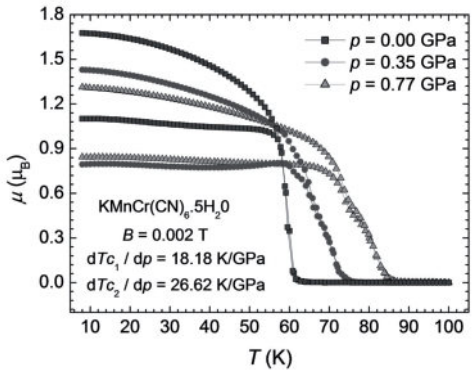
Prussian blue analogues of general formula $M_nA_p[B(CN)_6]q_{\cdot x}H_2O$, A and B are transition metal ions and M is monovalent countercation, are well known for the fact that their magnetic properties are very sensitive to the effect of external parameters such as humidity, light and pressure [1,2]. In the contribution we present the effect of pressure on magnetic properties of $KMnCr(CN)_6$. The prepared sample crystallizes in cubic face centred system with lattice parameter a = 10.786793 Å. Magnetization saturates in a very low magnetic fields at low temperatures and above $\mu_0 H$= 200 mT is almost independent on applied magnetic field. The saturation is reached at higher magnetic fields under pressure, but the effect of the pressure on the values of saturated magnetization μ_s, remnant magnetization μ_r and coercive field H_C are almost negligible. Zero field cooled and field cooled thermomagnetic curves for three pressures are displayed on figure. Observed pronounced increase of Curie temperature T_C with increasing pressure can be attributed

to strengthening of antiferromagnetic superexchange interaction. Additionally we observed the presence of the second magnetic phase existing only under pressure. All pressure changes were fully reversible. Measured data were in paramagnetic region fitted by Curie-Weiss law. Obtained negative value of paramagnetic Curie temperature θ = - 44.7 K points out to dominant antiferromagnetic superexchange interaction.

[1] M. Verdaguer and G. Girolami, Magnetism: Molecules to MaterialsV., WILEY-VCH Verlag, (2004), ISBN: 3-527-30665-XB., p.283-341
[2] M. Zentková et al, : J. Phys.: Condens. Matter 19 266217, (2007)



Magnetization M(T) measured under different pressures in ZFC and FC regimes.

TH-172

Effect of pressure on exchange bias in bulk layered hydroxylammonium fluorocobaltate

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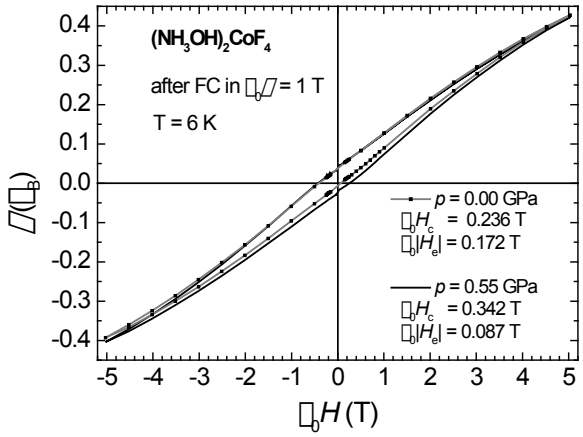
Recently a study of magnetic properties and exchange bias in bulk layered hydroxylammonium fluorocobaltate $(NH_3OH)_2CoF_4$ was presented in [1, 2]. The compound crystallizes with a monoclinic $P2_1/c$ unit cell. The fundamental building units are NH_3OH^+ cations and CoF_6 octahedra. Cobalt ions lie on the inversion centre and, together with fluoride ligands, form a layered structure. Each of the CoF_6 octahedra shares four of its vertices such that each vertex is shared between two octahedra. The cobalt layers are separated by two layers of NH_3OH^+[3]. Two magnetic phase transitions of the compound $(NH_3OH)_2CoF_4$ correspond to transition from paramagnetic to canted antiferromagnetic state at T_C = 46.5 K and to antiferromagnetic state at T_N = 2.9 K. Both transition temperatures are pressure dependent with pressure coefficients dT_C/dp =-2.2 K GPa^{-1} and dT_N/dp = 0.26 K GPa^{-1}[2]. The compound undergoes a magnetic field induced phase transition between 30 and 40 kOe at a temperature of 2K. The exchange bias observed below 20 K was ascribed to the exchange anisotropy due to quasi-2D structure of investigated compound [1].
In our paper we study the effect of pressure on exchange bias in pressure range up to 0.9 GPa and at different temperature below T_C. Hydrostatic pressure was generated by a CuBe pressure cell filled with a mixture of mineral oils serving as the pressure transmitting media. Applied pressure broadens hysteresis loops (the critical field H_C increases) and suppresses the exchange bias effect, (exchange bias field H_e decreases).

[1] Z. Jagličić et al , J. Phys.: Condens. Matter 24, 056002 (2012)
[2] Z. Jagličić et al, acta physica polonica A, Vol.118, 1074 (2010)
[3] M. Kristl et al., Journal of Fluorine Chemistry 131, 907 (2010)



Magnetization curves after FC treatment in 1 T at 6 K.

TH-173

Finite size effects in a quantum chain of antiferromagnetic coupled spins 3/2

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Molecular wheels are a subclass of molecular magnets constituted by a finite number of magnetic atoms at the vertices of regular polygons and interacting antiferromagnetically. The molecular wheel $[Cr_8Cd]$ provides a model of a finite antiferromagnetic chain of spins 3/2 carried by the eight Cr^{3+} ions in the ring which is interrupted by a diamagnetic Cd^{2+} ion. Antiferromagnetic coupling between first nearest neighbors Cr^{3+} ions, via the bridging organic ligands, leads to a singlet spin ground state S_{tot} = 0 and to excited states with integer spin values S_{tot} = 1,2,... Application of a high magnetic field at low temperature induces a lifting of degeneracy of the excited states and the existence of $S_{tot} \neq 0$ spin states with lower energy than the S_{tot} = 0 zero-field ground state. The experimental induced spin density in two different states (S_{tot} = 1) and (S_{tot} = 2), reached by applying a field of 4.6 and 9 Tesla respectively, was determined from polarized neutron diffraction measurements on a single crystal using D3 (ILL) and 5C1 (LLB) polarized neutron diffractometers. A non-uniform distribution of the induced magnetic moments on the Cr^{3+} finite chain is observed, with accumulation of positive spin density at the extremities of the chain.

TH-174

Hyperfine-induced decoherence in triangular chirality qubits

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Molecular nanomagnets are currently being investigated as candidate systems for the qubit encoding and manipulation [1]. While most of the investigation is so far based on the use of total spin projection S_{z} as the relevant degree of freedom, alternative encodings – such as spin chirality C_{z} – have recently been suggested, in order to enable the qubit rotation by means of electric fields [2]. The choice of the degree of freedom not only determines the manipulation means, but also affects the coupling to the nuclear environment, and the resulting decoherence.
Here, we theoretically investigate the hyperfine-induced decoherence of a chirality qubit, physically consisting of an antiferromagnetic spin triangle. The decoherence of C_{z} is contrasted with that of S_{z} and of the partial spin sum S_{12} (a good quantum number in isosceles spin triangles, that can also be manipulated by pulsed electric fields). We find that spin chirality is highly protected with respect to the nuclear environment, with decoherence times T_{d} that reach the ms range for suitable orientations of the (static) magnetic field. In S_{12}, the different spin texture that characterizes the |0> and |1> states results in values of T_{d} comparable to those obtained for S_{z}, i.e. in the microsecond range.

[1] F. Troiani, A. Ghirri, M. Affronte, S. Carretta, P. Santini, G. Amoretti, S. Piligkos, G. Timco, and R. E. P. Winpenny, Phys. Rev. Lett. 94, 207208 (2005).
[2] M. Trif, F. Troiani, D. Stepanenko, and D. Loss, Phys. Rev. Lett. 101, 217201 (2008).
[3] A. Ardavan, O. Rival, J. J. L. Morton, S. J. Blundell, A. M. Tyryshkin, G. A. Timco, and R. E. P. Winpenny, Phys. Rev. Lett. **98**, 057201 (2007).

TH-175

Molecular nanomagnets as quantum simulators

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Quantum simulators (QSs) are controllable quantum systems that can be used to simulate other quantum systems. QSs can tackle problems intractable on classical computers. Here we focus on the dynamics of qubits encoded in chains of molecular nanomagnets. For istance, we have shown that Cr7Ni rings are good candidates qubits and can be linked to each other either directly or through magnetic complexes [1,2]. We theoretically show that the dynamics of such chains can be controlled by means of uniform magnetic pulsed fields and used to mimic the coherent time evolution of other quantum systems (e.g., spin-one chains) [3]. We propose two significant proof-of-principle experiments [3].

[1] G.A. Timco et al., Nature Nanotechnology 4, 173 (2009)
[2] A. Candini et al., Phys. Rev. Lett. 104, 037203 (2010)
[3] P. Santini, S. Carretta, F. Troiani, G. Amoretti, Phys. Rev. Lett. 107, 230502 (2011)

TH-176

Dimensionality selection in a molecule-based magnet

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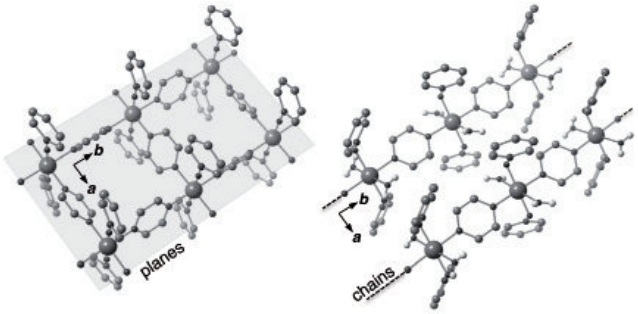
Gaining control of the building blocks of magnetic materials and thereby achieving particular characteristics will make possible the design and growth of bespoke magnetic devices. While progress in the synthesis of molecular materials, and especially coordination polymers, represents a significant step towards this goal, the ability to tune the magnetic interactions within a particular framework remains in its infancy. Here we demonstrate a chemical method which achieves dimensionality selection via preferential inhibition of the magnetic exchange in an S = 1/2 antiferromagnet along one crystal direction, switching the system from being quasi-two- to quasi-one-dimensional while effectively maintaining the nearest-neighbour coupling strength [1].

We will discuss how, after first designing a material based on coordinated planes of Cu(II), we adapt the recipe such that the ligand bridges are broken along a specific crystal direction, resulting in a chain-like compound. We show the results of x-ray diffraction, pulsed-magnetic-field magnetization, muon-spin relaxation and electron-spin resonance measurements that confirm the change in structural and magnetic dimensionality. Because the ligand mediating the magnetic interactions in both cases is unchanged, the nearest-neighbour exchange energies of the two materials are found to be equal to each other to within 5%. The difference in numbers of nearest-neighbours, however, means that the strength of the combined magnetic exchange interactions acting on each magnetic ion in the quasi-two-dimensional material is twice that of its quasi-one-dimensional cousin.

[1] P. A. Goddard et al. Phys. Rev. Lett. 108, 077208 (2012).



Planar (left) and chain-like (right) compounds. Largest sphere denotes magnetic Cu ion.

TH-178

Enhancing Magnetic Properties of Cyanide Based Molecular Magnetic Materials: The role of Single Ion Anisotropy

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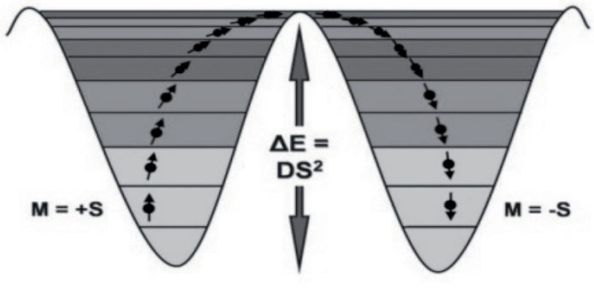
Single Molecule Magnets (SMMs) are a remarkable class of molecules that display magnetic bistability of a molecular origin which arises from the combination of a high ground state electron spin (*S*) and a large negative zero-field splitting |*D*|. This magnetic bistability provides an excellent potential for molecular spintronics.[1]

A major focus in this field is to increase the barrier to the reversal of the magnetization by tuning the anisotropy parameters and ground state spin value in order to increase the blocking temperature T_b to a range suitable for applications. Much attention has been recently directed at complexes containing heavier transition metal ions for their high spin orbit coupling terms as well as diffuse d orbitals which provide better overlap with cyanide orbitals, leading to large exchange constants |J|. In this vein, our group has previously reported a highly anisotropic building block $[Re^{II}(triphos)(CN)_3]^-$ (triphos = 1,1,1-tris(diphenylphosphino-methyl)ethane)) that was incorporated in a family of molecular cubes $[Re^{II}(triphos)(CN)_3]_4[M^{II}Cl]_4$ (M = Mn, Fe, Co, Ni and Cu).[2] The $[Re^{II}_4Mn^{II}_4]$ molecular cube **1** was found to behave as a SMM. Current efforts focus on enhancing the magnetic properties of these clusters by introducing more single ion anisotropy using anisotropic manganese salen-type complexes. The reaction with $[(Mn(5\text{-}Br\text{-}Salen))_3]ClO_4$ resulted in $[Re^{II}(triphos)(CN)_3(Mn(5Br\text{-}Salen))_3]^+$(**3**) cluster which exhibits very weak antiferromagnetic interactions. The $[Re^{II}(triphos)(CN)_3]^-$ building block was also incorporated in a family of trigonal bipyramidal clusters (TBP) to test the hypothesis that lanthanide assemblies with axial crystal field could give rise to SMM behavior. The $[Re^{II}(triphos)(CN)_3(Sm(NO_3)_3)_3]^{2-}$ (**2**) TBP shows very large temperature independent paramagnetism.

[1] Seo, D. M.; Meenakshi, V.; Teizer, W.; Zhao, H.; Dunbar, K. R. J. Magn. Magn. Mater. 2006, 301, 31.

[2] Schelter, E. J.; Prosvirin, A. V.; Dunbar, K. R. *J. Amer. Chem. Soc.*, **2004**, *126*, 15004.



Molecule Magnet

TH-179

Effect of pressure on magnetic properties of a novel 3D cyano-bridged hybrid ferrimagnet

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(1) Institute of Experimental Physics SAS, Watsonova 47, 040 01 Košice, Slovakia, (2) Faculty of Chemistry, Jagiellonian University, Ingardena 3, 30-060 Kraków, PolThe design and synthesis of molecule-based magnets follow the fundamental rules of molecular building blocks approach to provide original 0D, 1D, 2D and 3D coordination networks. More detailed understanding of structure–properties relationship requires systematic studies on the series of networks. Recently, the magneto-structural correlation in the series of $[Nb(CN)_8]^{4-}$ based architectures were studied on a new hybrid organic–inorganic ferrimagnet $\{Mn_2^{II}(imH)_2(H_2O)_4[Nb^{IV}(CN)_8]\}\cdot 4H_2O$ with T_C = 25 K, where imH = imidazole [1]. The compound crystallizes in monoclinic crystal system, space group $P2_1/c$. Its 3D inorganic –Nb–CN–Mn– framework is built of two groups of mutually parallel 1D-ladders cross-linked at niobium centres. Imidazole molecules reveal terminal coordination mode only. It is proposed that magnetic structure consists of ferromagnetically coupled Mn^{II} centres with a magnetic moment of Nb^{IV} aligned antiparallel to them. All observations point out that the compound is a classical soft 3D ferrimagnet [1].

In our contribution we present the study of pressure effect on magnetization and AC susceptibility of this molecule based magnet. Hydrostatic pressure usually enables reversible modification of electron structure which results in change of magnetic properties of material. Effect of pressure is remarkable in the case of the magnetic phase transition T_C which rises from the value of 25.2 K at ambient pressure to 30.2 K at pressure p = 0.85 GPa with the rate dT_C/dp = 5.7 K/GPa (see figure). The magnetic hysteresis loop is modified only slightly by pressure; saturated magnetization increases with pressure.

[1] D. Pinkowicz et al., Inorganica Chimica Acta **361, 3957** (2008)

TH-180

Crossover from SMM behavior to ferromagnetic order: a slow motion phase transition

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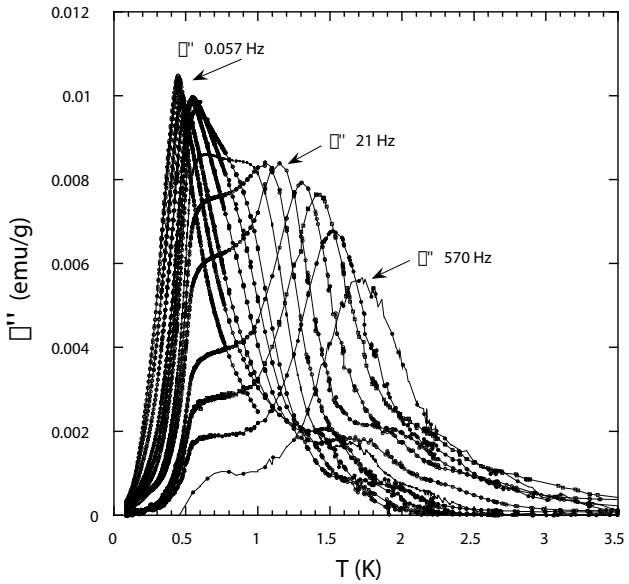
As temperature tends toward zero, ordering is the ultimate fate of most respectable magnetic systems. However, for super paramagnetic clusters and single molecular magnets this can be quite a slow process due to the exponentially increasing relaxation times. Recently it has been reported[1] that a tetranucleur Cu-Tb complex $[Cu^{II}LLn^{III}(hfac)_2]_2$ presents SMM behavior with a crossover to ferromagnetic order at very low temperature. We report extensive new low temperature measurements on both single crystals and powder samples of this complex. A large anisotropy is evidenced by magnetization measurements along different sample directions. SMM behavior is shown by the frequency dependent peaks in the imaginary part of the ac susceptibility near 2K. If the sample is cooled at a sufficiently slow rate, a crossover to an ordered state occurs below 0.45K. Just above this temperature, we can analyze the frequency dependence in terms of critical slowing down near a phase transition: $\tau=\tau_0(T/T_c\text{-}1)^{-z\nu}$

[1] Hamamatsu et al., Inorg. Chem. 46, 4458-4468 (2007)



Plot of the imaginary part of the ac susceptibility vs temperature showing SMM behavior near 2K with a crossover to critical slowing down behavior on approaching the phase transition below 0.5K

TH-181

Numerical analysis of magnetic state mixing in antiferromagnetic Heisneberg model with the dihedral symmetry

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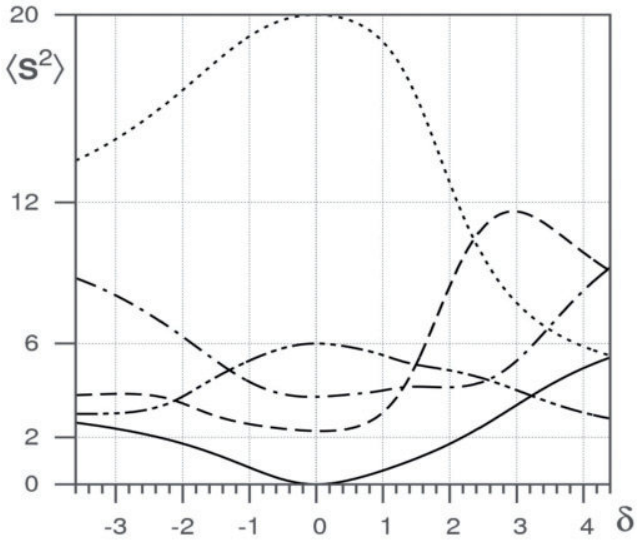
The total spin number *S* is not 'a good quantum number' for the Heisenberg model with single-ion anisotropy, so the Hamiltonian eigenstates with different *S* may mix, providing that at least one of new states has smaller energy. Eigenvalues of other operators commuting with the Hamiltonian, as well as the symmetry properties, have to be preserved. Sometimes it is assumed that S can be used as 'an approximate quantum number' [1], though some results show that mixing of *S*-states is important in investigations of magnetic molecules with antiferromagnetic interactions [2].

We analyze some small spin systems with the dihedral symmetry (models of ring-shaped magnetic molecules) to investigate different schemes of mixing and its dependence on *D*/J. The time reversal symmetry is also taken into account for non-magnetic states (*M*=0). The very first results [3] have shown various behaviour of the magnetic state mixing.

The plot presented below shows that the mean (over a state) value of total spin is quite stable for the ground state (*S*=0 for *D*=0), but in other cases this dependence is nonlinear and, sometimes, non-monotonic for large anisotropy. It may happen that mixing is also present in the limit *D*=0. Different behaviour for positive and negative values of *D*/*J* is as well characteristic feature of similar plots for different values of *s*, *M* and symmetry properties. Results for different systems are compared and some general conclusions are presented.

[1] G. Kamieniarz et al., Inorg. Chim. Acta 361, 3690 (2008)
[2] M. Affronte et al., Phys. Rev. B 68, 104403 (2005)
[3] W. Florek et al., Cen. Eur. J. Chem. 7, 211 (2009)



$\langle S^2 \rangle$ vs $\delta = D/J$ for four spins $s=1$ ($M=0$, fully symmetric states)

TH-182

Magneto-structural correlations in TCNQ anion-radical salts with metal-included cations.

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Organic materials – anion radical salts (ARS), based on TCNQ anion-radical (7,7,8,8-tetracyanoquinodimethane) belong to the charge transfer complexes and were the first organic objects to exhibit metallic properties. After the discovery of their ability of melting without decomposition, the wide application possibilities were revealed, such as insulating, semiconducting, metallic or superconducting behaviors, accompanied by a large variability of magnetic ordering phenomena.

The electron-density localization on the structural TCNQ dimer is the source of magnetism in genuine organic ARS. Materials based on TCNQ are therefore useful systems for the study of low-dimensional magnetic models due to their uniqueness - small modification of their crystal structure has a substantial impact on their physical properties. In previous research, we have studied the correlations between the crystal and magnetic structure of several TCNQ - ARS, where major influence of an organic-cation-structure on the magnetic properties of the sample was observed.

Situation is more complicated in case of our new ARS materials with metallic atom in cation molecule, where both, the electrons from metallic atom and from dimers of TCNQ, contribute to the magnetism of the material.

We report the experimental results of $[Fe(bipy)_3](TCNQ)_4 \cdot (CH_3)_2CO$ (**I**) and $[Mn(phen)_3](TCNQ)_4 \cdot 2H_2O$ (**II**), where *bipy* is bipyridine, and *phen* is phenantroline .

The temperature and field dependence of magnetic susceptibility

was studied in the temperature range from 2 K to 300 K in applied magnetic fields. This studies revealed presence of antiferromagnetic interactions in both samples.
The temperature dependence of the heat capacity (**II**) performed in the temperature range 0.4 K – 50 K, reveals a broad maximum at temperature ~ 0.5 K which shows significant dependence on magnetic field.
The correlations between crystal structure and magnetic properties of (**I**) and (**II**) are discussed.
This work was supported by the Slovac Agency VEGA No.1/0159/09 and the ERDF EU fund No.ITMS26220120047.

TH-183

Prussian Blue Analogue thin films as promising materials of future molecule-based spintronic devices

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The family of Prussian blue analogues (PBA) of general formula $C_cA_a[B(CN)_6]_b \cdot n\ H_2O$ (C = alkali cation, A, B = transition metal ions) are molecule-based magnetic materials with interesting properties that rely on: i) the presence of strong magnetic interactions between the spin carriers mediated by the cyanide bridge; and ii) the high dimensionality (3D) and connectivity of the magnetic lattice. As a result, PBA showing spontaneous magnetization even above room temperature have been obtained.[1,2]
Due to their transparency in the visible region and their charge-transfer properties, these materials offer many advantages with respect to classical magnets in magneto-optics (i.e., in the study of the crossing-effect between magnetic and optical properties). Thin films of PBA can also be interesting materials for the fabrication of future molecule-based spintronic devices[16] combining magnetooptical properties and spin transport. In this context, it has to be noted that a hot topic in molecular spintronics is that of fabricating spin valves [17] in which either the spin collector layer[18,19], or the ferromagnetic electrodes [20] are based on molecule-based materials. PBA magnets may exhibit several advantages with respect to the classical magnets used in spintronics (inorganic metals and metal oxides), such as the processability using solution techniques, the transparency and new added functionalities (like photomagnetism,[21–23] piezomagnetism,[24] etc.). Furthermore, their molecular nature could facilitate the spin injection towards the organic spin collector layer. In view of these applications, it is necessary to scale down the growth of the magnetic films to the nanometer level. A powerful technique like MOKE, with high sensitivity down to monolayer detection and a high spatial resolution limited by the laser spot,[25] seems promising in the study of the magnetic properties of such ultra-thin films and multilayered systems.

TH-184

Carbon nanotube NEMS as magnetic torque detector for single molecule magnets

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Carbon nanotubes have become an essential building block for nanoelectromechanical systems (NEMS). Their extraordinary mechanical and electronic properties provide for instance a strong electromechanical coupling and ultrahigh quality factors $Q=10^5$ compared to semiconductor based NEMS, which is key to various applications, for example high sensitivity mass or force sensing.[1]
It was recently proposed in theoretical calculation that one can use such high-Q CNT NEMS as magnetic torque or force detectors for single molecule magnets grafted to the CNT NEMS, with a sensitivity approaching one μ_B.[2]
We will demonstrate the successful grafting of bis-(phthalocyaninato) Terbium(III) single molecule magnets ($TbPc_2$ SMM)[3] via solution drop casting (and subsequent critical point drying) on suspended carbon nanotube resonators. We will report on a characteristic spin valve behavior of $TbPc_2$ SMM grafted to CNT's [3] and the interplay with the CNT's mechanical resonance. Finally, we will show first evidence for a magnetic torque detection of $TbPc_2$ SMM using carbon nanotube based NEMS: Induced by the reversal in magnetic fields of such a SMM, a torque will act on the CNT and cause a shift of its resonance frequency.

[1] M. Poot and H.S.J. van der Zant, Physics Reports 511, 273 (2012)
[2] A. A. Kovalev, L. X. Hayden, G. E. W. Bauer, and Y. Tserkovnyak, Phys. Rev. Lett. 106, 147203 (2011)
[3] M. Urdampilleta, S. Klyatskaya, J.-P. Cleuziou, M. Ruben, and W. Wernsdorfer, Nature Mater. 10, 502 (2011)

Thursday, 13 September 2012
Poster Area, 17.00 – 19.00

ORGANIC & CARBON BASED SPINTRONICS

Chair: P. Seneor

TH-186
Fabrication and Magnetotransport properties of Graphene-Based Lateral Spin-Valves

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(1) INAC/SP2M, CEA-Grenoble and Université Joseph Fourier, 38054, Grenoble, France, (2) Unité Mixte de Physique CNRS-Thalès, Palaiseau, France, (3) SPINTEC, UMR CEA/ CNRS/ UJF-Grenoble 1/ Grenoble-INP, INAC, Grenoble, F-38054, France

Graphene is a very promising material for spintronic applications, due to its small spin-orbit interaction and very small hyperfine interaction. High spin signal and very large spin relaxation length in exfoliated or epitaxial graphene at room temperature were already demonstrated [1,2,3] and electric field effects could allow spin manipulation in graphene-based devices.
In this contribution, we demonstrate non-local measurements in graphene-based Lateral Spin-Valves (LSV). We will present the fabrication method using electron beam lithography and evaporation or sputtering techniques. Typical LSV structures consist of two or four laterally separated ferromagnetic Co contacts (with and without tunnel barriers), connected by a graphene ribbon. In these structures, the charge and spin currents can be separated in order to eliminate the magneto-resistance effects of the electrodes and to avoid the presence of a background resistance coming from the contacts. A gate voltage can also be applied to the graphene sheet, in order to control the carrier density. Electrical properties have been thus studied with non magnetic contacts as a function of the gate voltage to access the resistivity and mobility of the graphene ribbon. We compare the spin signal amplitude obtained from different ferromagnetic contacts, either direct or through tunnel barriers targeting high output values. We measured devices having Co in direct contact with the graphene, and also with MgO and Al_2O_3. Although a sizeable spin signal can be obtained with direct contacts, the signal can be much increased by inserting the tunnel barrier.

[1] N. Tombros et al., Nature 448, 571 (2007).
[2] Wei Han et al. Phys. Rev. Lett., 105, 167202 (2010).
[3] B. Dlubak, Nat. Phys., In press.

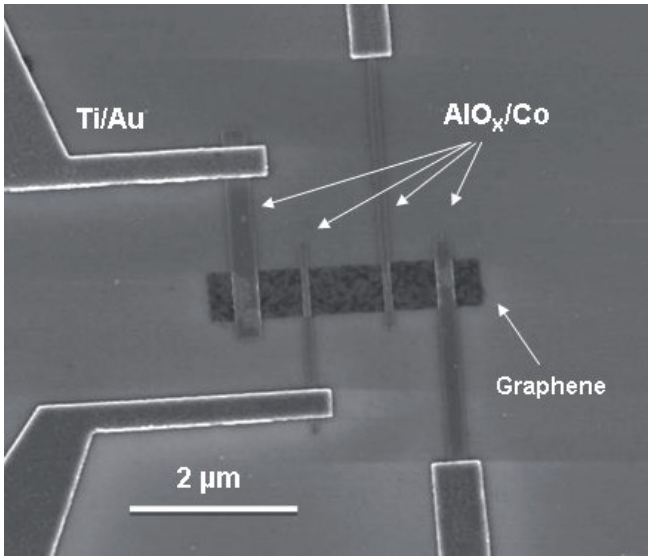

Figure: SEM micrograph of a graphene-based lateral spin-valve.

TH-187
Effect of Zeeman splitting on the indirect RKKY-like coupling between impurity spins in graphene nanoflakes

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The magnetic properties of graphene nanostructures attract considerable attention due to their potential applicability in spintronics [1]. One of the topics within this field is the form of indirect, charge-carrier mediated interaction between spins of magnetic impurities in graphene monolayer [2] and graphene nanostructures [3]. This coupling, resembling Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction, presents unique behaviour in graphene due to its peculiar electronic spectrum.
A crucial factor shaping the behaviour of graphene systems is the presence of substrate. This appears especially important in the case of graphene nanoflakes. One of the effects of the ferromagnetic substrate is the appearance of Zeeman splitting caused by the exchange field.
The aim of the paper is to analyse the effect of Zeeman splitting on the indirect (RKKY-like) coupling between magnetic impurity spins located in ultrasmall graphene nanoflakes. Structures possessing various forms of edges, both zigzag- and armchair-like, are discussed. Among the other, the properties of triangular nanostructures indicating the presence of zero energy-states in the electronic spectrum are investigated. The emergence of spin-space anisotropies in indirect coupling under the influence of Zeeman splitting is particularly interesting.
The study is based on a tight-binding model supplemented with a Hubbard term to include electron-electron interactions [2,3]. The exact diagonalization in one-electron approximation allows the determination of indirect coupling energies.
This work has been supported by Polish Ministry of Science and Higher Education by a special purpose grant to fund the research and development activities and tasks associated with them, serving the development of young scientists and doctoral students.
The computational support on HUGO cluster at Department of Theoretical Physics and Astrophysics, P. J. Šafárik University in Košice is gratefully acknowledged.

[1] O.V. Yazyev, *Rep. Prog. Phys.* 73, 056501 (2010)
[2] A.M. Black-Schaffer, PRB 81, 205416 (2010); PRB 82, 073409 (2010)
[3] K. Szałowski, PRB 84, 205409 (2011)

TH-188

Spin polarized transport of transition metal atoms on graphene nanoribbons with spin-orbit effects: an ab initio study

W.Y. Rojas [1], A. Fazzio [2], A.J.R. Da Silva [3], S. Sanvito [4], A.R. Rocha [1]
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Recently, the amazing properties found in graphene, a two dimensional carbon-based crystal, shows a linear dispersion relation (electrons behave as massless particles very similar to photons) allowing high electric conductivity. Furthermore, due to the small spin-orbit coupling [1] in carbon one might envision the using of electronic spin degrees of freedom - instead of their charge – for information processing applications. In this, so called, field of spintronics there are three main challenges one needs to address before obtaining solid-state devices, namely: the most effective way to polarize a spin system at the source, long spin coherence times (small spin relaxation) during electronic transport, and the ability to detect spin at the drain. In this work, we address, using a combination of density functional theory and non-equilibrium Green's functions [2], the electronic transport properties of graphene nanoribbons containing different types of impurities considering the effects of spin-orbit coupling [3]. In our calculation we focus on armchair graphene nanoribbons with adsorbed metal transition atoms (Ni and Co) as impurities. Using a recursive method we also consider a large number of impurities randomly distributed along the nanoribbon in order to infer, for different concentrations of defects, the spin-coherence length.

[1] Tsukagoshi, K., Alphenaar, B. W. & Ago, H., Nature 401, 572–574 (1999); Hueso, L.E., Pruneda, J.M., Ferrari, V. *et al.*, Nature 445, 410-413 (2007).
[2] Soler, J. M. *et al.*, J. Phys. Condens. Matter 14, 2745–2779 (2002).
[3] L Fernández-Seivane *et al., J. Phys.: Condens. Matter,*18-7999,*(*2006).

TH-189

Li-doping induced magnetism in graphene

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The presence of low-temperature half-spin paramagnetism in graphene is well known to be due by vacancies and point defects (*e.g.* chemisorbed hydrogen). In a recent work it has been demonstrated that no long range magnetic order is formed on different highly defective graphene samples [1]. On the other hand, there are some theoretical studies that suggest the presence of a superconducting phase transition [2] and the possibility of increase the hydrogen capture cross-section in Li-graphene systems [3]. In this work we show that Li doped graphene (with Li at the nominally stoichiometry of LiC_3) induces an increase of the ferromagnetic signal at room temperature.
Graphene was prepared by exfoliation of graphite oxide at 1150°C in dynamical vacuum. Pure Lithium (Aldrich 99.9%) and graphene were let react in a close vial under Ar atmosphere (less than 1ppm of O_2 and H_20) and then treated in liquid ammonia at -50°C for 12 hours. All samples were handled in air free conditions and avoiding any contamination with magnetic tools.
SQUiD measurements were carried out on as prepared graphene, Li-doped graphene and Li reagent. Pure Li does not show any significant saturation in the magnetization. The saturation magnetization at 300K increase from 7.37(8) *memu/g* for the as synthesized graphene to 38.129(9) *memu/g* after the treatment with Li (Figure 1). Saturation of as prepared graphene is due to the magnetic impurities inevitably present in graphite oxide and corresponds to ~32 ppm of Fe. The increase of this value after the treatment with Li is not well understood and is still under investigation.

[1] M. Riccò, et al., Nano. Lett. 11, 4919 (2011)
[2] G. Profeta, et al., Nature Phys. 8, 131 (2012)
[3] W. Zhou, et al., J. Phys. Chem. Solids, 73, 245 (2012)

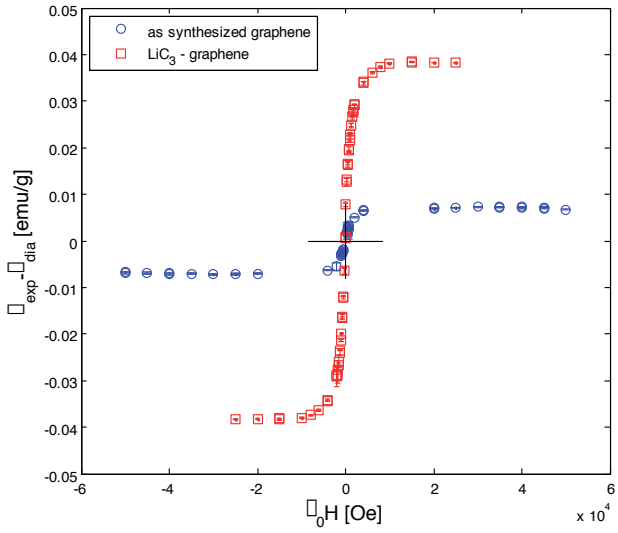

Figure 1 : Magnetization at room temperature (diamagnetic contribute subtracted).

TH-190

Self-organized antiferromagnetic fluorine chains on graphene planes

T. Makarova [1], A. Shames [2], G. Chekhova [3], D. Pinakov [3], N. Yudanov [3], A. Okotrub [3], L. Bulusheva [3]
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It was recently shown [1] that nonmagnetic fluorine adatoms induce a magnetic response in graphene carrying magnetic moments with spin ½. No magnetic ordering was detected down to liquid helium temperatures. Here we show the method for obtaining magnetic ordering in fluorinated graphite.
Using the method of room-temperature wet fluorination, we obtained planar fluorinated graphene sheets where the contribution

of magnetism from isolated defects and from the edge spins is minimized giving the possibility to study the basal plane inherited carbon magnetism. The mechanism of fluorination assumes the random attachment of primary fluorine atom to graphite network and further random direction of chain formation. When the process of wet synthesis is finished, the fluorine atoms continue reorganizing on the basal plane: isolated fluorine atoms diffuse rapidly along a path above C-C bonds till the structure reaches the energetically preferable state. A joint experimental and theoretical investigation suggests a description of this compound as coupled alternating antiferromagnetic Heisenberg chains. Magnetization measurements evidence a spin gap of about 110 K. Having performed the measurements on the same samples during 5 years, we observed the gradual formation of antiferromagnetic carbon in a self-assembly process.
Semifluorinated graphite inclusion compounds represent a system of loosely bound bilayer graphenes and serve as an excellent model for studying low-dimensional magnetism. We show experimentally that controlled decoration of the graphene basal plane provides a novel way to tune the magnetic carbon properties with unprecedented potentials for applications. According to Sir A.Geim, "The most likely use of the found phenomenon [1] is in spintronics."[2].
"**Spin-half paramagnetism in graphene induced by point defects**", by R. Nair, M. Sepioni, I-Ling Tsai, O. Lehtinen, J. Keinonen, A. Krasheninnikov, T. Thomson, A. Geim and I. Grigorieva, *Nature Physics* (2012).
[2] http://www.physorg.com/news/2012-01-graphene-reveals-magnetic-personality.html

TH-191
Permalloy contacts for carbon based spintronics devices
J. Samm [1], J. Rebling [1], M. Weiss [1], H. Aurich [1], A. Baumgartner [1], M. Elkin [2], B.J. Hickey [2], C. Schönenberger [1]
(1) Department of Physics, University of Basel, CH-4056 Basel, Switzerland, (2) Condensed Matter Physics Group, University of Leeds, LS2 9JT Leeds, United Kingdom

Thermally evaporated Permalloy (Py) contacts have been shown to couple to carbon nanotubes, leading to the formation of quantum dots at low temperatures [1]. Since the coercive fields of Py strips can be controlled to a high degree, Py is an ideal material for nanometer-scaled spintronic experiments. Thermal evaporation is, however, restricted to a narrow range of materials and the growth of multicomponent materials is often not stochiometric. In this respect sputtering provides a much higher degree of versatility, allowing the stochiometric deposition of multicomponent materials, including oxides and nitrides.
In the present contribution we report on results of the fabrication of magnetically well defined magnetic contacts made from Py using lift-off technology and a dedicated UHV magnetron sputtering system. We have patterned the Py into 10 micrometer long strips of different widths and studied there magnetic and electrical properties. The characterizations show the same degree of control over the magnetic properties as for the evaporated Py. The advantage of sputtered materials is to be able to develop electrical contacts to carbon nanotubes with, for example, out of plane magnetizations using CoPt multilayers or exchange biased systems. In addition to the characterization of sputtered Py contacts strips we will discuss preliminary results of sputtered Py-based multilayers and nanostructures on carbon nanotubes.
[1] H. Aurich et al., Appl. Phys. Lett 97, 153116 (2010)

TH-192
Theoretical Aspects and Simulation of STM and STS measurements of single molecular magnets on different substrates
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(1) Institute for Theoretical Physics, TU Freiberg, D-09596 Germany, (2) Institute for Theoretical Physics, TU Dresden, D-01076 Germany

STM (scanning tunneling microscopy) and STS (scanning tunneling spectroscopy) experiments are the methods of choice to study the transport characteristics of single molecules in an well defined environment [1]. Metal Phthalocyanines are known to be promising candidates for applications in molecular spintronics. The interpretation of measured STM/STS data is crucial for the understanding of material properties. We compare theoretical results obtained from DFT - NEGF (density functional theory - non equilibrium green functions formalism) [2] and QME (quantum master equation) [3] investigations and discuss their impact on the interpretation of experimental data.

[1] C. Iacovita et. al., Phys. Rev. Lett. 101, 116602 (2008)
[2] C. Toher, I. Rungger, S. Sanvito, Phys. Rev. B 79, 205427 (2009)
[3] Timm, Phys. Rev. B 77, 195416 (2008)

TH-193
Molecular magnetic tunnel junctions based on Langmuir-Blodgett films
P. Truitt [1], J.T. Tee [2], N. Abdullah [2], M. Chisholm [3], E. Johnston-Halperin [4]
(1) Department of Mathematical Sciences, Montclair State University, Montclair, NJ 07043 USA, (2) Department of Chemistry, University of Malaya, Kuala Lumpur, Malaysia, (3) Deparment of Chemistry, The Ohio State University, Columbus, OH 43210 USA, (4) Deparment of Physics, The Ohio State University, Columbus, OH 43210 USA

We present an approach to large area molecular magnetic tunnel junctions based on a Langmuir-Blodgett (LB) monolayer sandwiched between ferromagnetic electrodes. The first aspect of this work is the synthesis of paramagnetic Schiff base coordination complexes that self-assemble at the air/water interface and can be transferred onto the bottom contact of a tunnel junction structure. Through substitution of the central transition metal ion ($M=Zn^{2+}$, Cu^{2+}, Co^{2+}, Ni^{2+}) the magnetic behavior of the film can be varied, which is expected to provide unambiguous evidence of the molecules' influence on the spin transport through the junction. We have used SQUID magnetometry to measure the susceptibility of these complexes from 5 to 300K and from 0 to 5T. Examination of the susceptibility temperature product suggests weak intermolecular antiferromagnetic coupling as well as the effect of zero field splitting below 10K. These complexes were then spread on a Langmuir trough and the resulting film's stability was determined through measurements of surface pressure over time as well as Brewster angle microscopy, with initially poor results used to inform modifications to the coordinating ligands, resulting in improved behavior.
The second aspect of this presentation will be an examination of fabrication methods used to deposit the top contact of the junction without damaging the molecular layer or forming shorts through already present pinhole defects. After ruling out

several techniques that are used with self-assembled monolayers and charge based devices but do not translate well to LB films and magnetic electrodes, we have borrowed from a recently developed high yield technique [1] that meets our requirements and will present data from preliminary devices.
[1] G. Wang et al., Adv. Mater. 23, 683 (2011)

TH-194
Ab-Initio Study of the Magnetic Properties of Boron Nitride Nanoribbon
J. Rufinus [1]
(1) Widener University, Chester, PA 19013, USA

The emerging field of spin electronics (spintronics) has been continuously attracting researchers. Substantial theoretical and experimental efforts have been made in the quest to find the candidates for future spintronics devices. Recently, the search for new spintronics materials has also included graphene-based materials due to the theoretical prediction that this type of material may show the half-metallic property. Here, we present the results of an ab-initio density functional theory within a generalized gradient approximation study of Boron Nitride nanoribbon. The objective of this study is to determine whether this type of material will be ferromagnetic or antiferromagnetic. Our results show that Boron Notride nanoribbon prefers ferromagnetic or antiferromagnetic states depending on the shape of its edges. These results are of the scientific interest in exploring the magnetic properties of Boron-Nitride-based nanoribbon for future spintronics.

TH-195
Spin transport in thiophene derivatives based organic spin valves
M. Palosse [1], I. Séguy [1], C. Villeneuve [2], C. Mallet [3], P. Frère [3], C. Gatel [4], J.F. Bobo [5]
(1) CNRS, LAAS, 7 avenue du Colonel Roche, F-31400 Toulouse, France/ Univ de Toulouse, LAAS, F-31400 Toulouse, France, (2) LAPLACE, Université Paul Sabatier, 118, route de Narbonne 31062 Toulouse cedex 9/Univ de Toulouse, UPS, F-31400 Toulouse, France, (3) MOLTECH-Anjou, UMR CNRS 6200, Univ d'Angers, Faculté des Sciences, 2 Bd Lavoisier 49045 ANGERS Cedex, France, (4) CNRS, CEMES, 29 Rue Jeanne Marvig, 31055 Toulouse Cedex 4/ Univ de Toulouse, CEMES, F-31400 Toulouse, France, (5) CNRS, CEMES-ONERA, NMH, 2 avenue Edouard Belin, FR-31055 Toulouse Cedex 4/ Univ de Toulouse, CEMES, F-31400 Toulouse, France

Organic semiconductors (OSCs) are widely used in devices such as OLEDs or OFETs and solar cells. Since the discovery of magnetotransport in T6 and Alq_3 based structures respectively in 2002 and 2004 [1, 2], the spintronics route in organic materials has been opened. OSCs have appealing characteristics for efficient spin transport media, such as long spin relaxation times and the advantage of simple device fabrication techniques.

Organic Spin valves (OSV) are multilayer devices composed of two ferromagnetic (FM) electrodes separated by an OSC layer. Most studies of spin injection in OSC focus on hybrid junctions with $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) electrode because of its nearly 100% spin polarization at low temperature. However LSMO electrodes do not allow efficient room temperature spin injection since this material presents a low Curie temperature ($T_C \sim 300$ K). To overcome this drawback, organic spin valves were prepared with high T_C magnetic electrodes (NiFe, Co, and Fe_3O_4).
We will present spin valve devices based on BF-T2 (benzofurane bithiophene) sandwiched between two ferromagnets. The electrodes were dc-sputtered and the OSC was vacuum sublimated with in-situ mask change [3]. Magnetic hysteresis loops of the FM1/BF-T2/FM2 stacks evidence spin-valve behavior with magnetically uncoupled electrodes down to 50 nm BF-T2 (Fig. 1). For thinner organic layers, loss of SV behavior is due to coupling through pinholes or intermixing and degradation of the organic spacer. These results were correlated with a morphological study by AFM of each layer, tunnelling AFM for probing current distribution. Finally, magnetotransport characteristics of the devices will be presented.

[1] V. Dediu et al, Solid State Com., 122, 181 (2002)
[2] Z.H. Xiong et al, Nature, 427, 821 (2004)
[3] J.F. Bobo et al, IEEE T-Mag., 46, 2090 (2010)

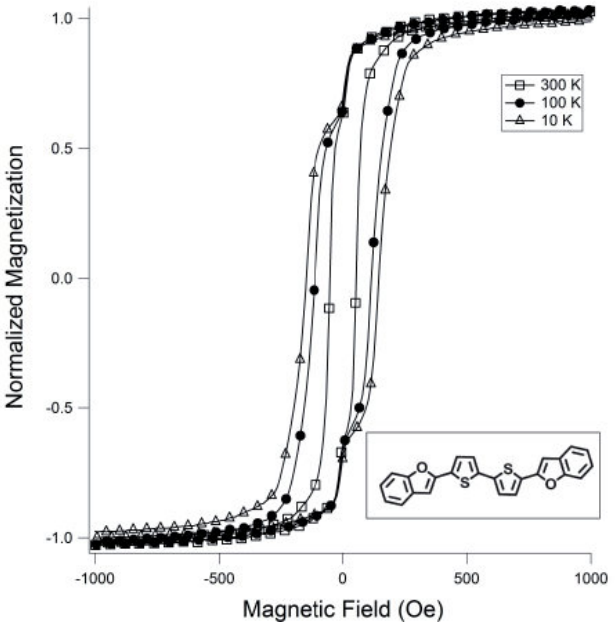


Fig. 1: MH loops of a Fe_3O_4/BF-T2(50nm)/Co sample at various temperatures
Inset: representation of the BF-T2 molecule

Friday, 14 September 2012

Oral Communications

Friday, 14 September 2012
Aida Room

PLENARY
Chair: S. Blundell

08.30 – 09.15
New trends in Single Molecule Magnetism: From crystals to surfaces
R. Sessoli [1]
(1) Dipartimento di Chimica & INSTM, Università degli Studi di Firenze, 50019, Sesto Fiorentino, Italy

After almost twenty years since the discovery of magnetic hysteresis of molecular origin in Mn_{12}ac crystals the field of Single Molecule Magnets (SMMs) continues to be active in different directions. Thanks to rational synthetic efforts the blocking temperature could recently be raised to above 10 K,[1] while the crystalline phase of more traditional SMMs, e.g. Fe_8, allowed to investigate sources of decoherence in spin systems of potential interest for quantum computation.[2] The last years have been experiencing a shifting of the interest towards the ultimate goal of manipulating the magnetic moment of individual SMMs and the fruition of their outstanding properties in applications such as molecular spintronics.[3] Although it has been demonstrated that the magnetic bistability of bunches of atoms can be addressed by measuring its transport properties with an STM tip,[4] an exhaustive analysis can be obtained by magneto-optical techniques based on synchrotron radiation, which are capable to reach sub-monolayer sensitivity. Deposition of SMM on surface has been achieved by thermal evaporation or self assembly from solution. The observation of the magnetic bistability and quantum phenomena typical of SMMs when these are deposited on surfaces behavior is still seldom observed.[5] On the other side, deposition of SMMs on magnetic substrates allows to combine hysteretic behaviors of classical and quantum nature delineating a new type of hybrid magnetism.
(*) The research has been supported by the European Research Council through the AdG MolNanoMaS.

1. J. D. Rinehart *et al., Nature Chem.*, 2011, **3**, 538-542.
2. S. Takahashi, *et al.*, *Nature*, 2011, **476**, 76-79.
3. M. Urdampilleta *et al., Nature Mater.*, 2011, **10**, 502-506.
4. S. Loth *et al.*, *Science*, 2012, **335**, 196-199.
5. M. Mannini *et al.*, *Nature*, 2010, **468**, 417-421.

Friday, 14 September 2012
Aida Room

SEMIPLENARY
Chair: V. Dediu

09.15 – 10.00
Spin transistors: Electric field control over molecular magnetism
H. Van Der Zant [1]
(1) Kavli Institute of Nanoscience, Delft

By merging the fields of molecular magnetism, molecular electronics and nanotechnology, we fabricate planar three-terminal nanodevices containing individual magnetic molecules or nanoparticles. Source and drain electrodes are made of noble metals such as Pt, Au or of (multi-layered) graphene. A third gate electrode allows the modification of charge transport independently from the source/drain electrodes. In this way, a spin transistor is built in which the electric current through the individual magnetic molecule or nanoparticle is sensitive to its spin properties. The molecular complexes of interest are single-molecule magnets (SMMs) and spin-crossover compounds. Coulomb blockade is generally observed but finer details such as Kondo correlations and excited states are observed at cryogenic temperatures [1]. In a Fe-4 SMM based transistor, we observe features that confirm the high-spin state and find Kondo behavior, spin blockade and a zero-field splitting that depends on the redox state; in the charged state the molecule turns out to be a better magnet. Using an in-situ sample rotator, direct observation of magnetic anisotropy is demonstrated. Recent progress includes transport through a single spin-crossover molecule [3] and the fabrication of a molecular memory device based on a spin-crossover nanoparticle that operates near room temperature [4]. Interestingly for molecular spintronics, the spin crossover in these devices can be induced by applying a voltage, showing that its magnetic state is controllable electrically.
Work supported by FOM and through the EU FP7 program (ELFOS).

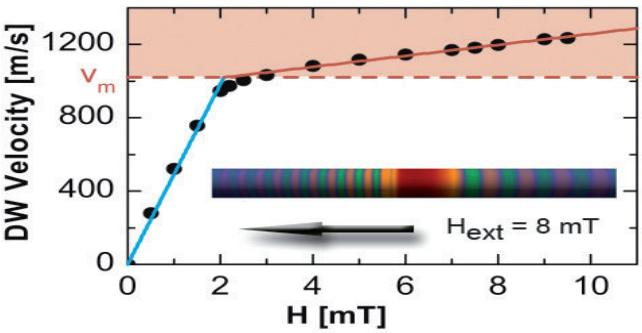
[1] H.B. Heersche *et al*., Rev. Lett. **96** (2006) 206801; E.A. Osorio *et al.*, Nano Letters **10** (2010) 105; J.M. Thijssen and H.S.J. van der Zant,Phys. stat. sol. (b) **245** (2008) 1455-1470.
[2] A. Zyazin *et al*. Nano Letters **10** (2010) 3307.
[3] V. Meded *et al.*, Phys. Rev. B **83** (2011) 245115.
[4] F. Prins *et al*. Adv. Mat. **23** (2011) 1545.

Friday, 14 September 2012
Nabucco Room

SEMIPLENARY
Chair: G. Carlotti

09.15 – 10.00
Ultrafast vortex dynamics in magnetic nanotubes - Cherenkov-type spin wave radiation and chiral symmetry breaking
R. Hertel [1], C. Andreas [2], F. Garcia-Sanchez [2], M. Yan [2], A. Kakay [2]
(1) IPCMS, CNRS and UdS, UMR 7504, 67034 Strasbourg, France, (2) 2. Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, Jülich, Germany

Magnetic vortices in nanostructures display highly non-trivial dynamic properties [1]. The scientific aesthetics of these dynamic properties and their potential for applications in nanotechnology have given rise to increasing interest in this field of research. The time scale of vortex dynamics spans an enormous range, as it goes from lowest-frequency mode known in ferromagnetism, *i.e.*, the gyrotropic rotation of a vortex [1], to the ultrafast vortex core switching [2], which represents the fastest magnetization reversal process known to date.
So far, most studies on magnetic vortices and their dynamics have been conducted on thin-film nanostructures. By means of finite-element simulations we found that changes in the geometry may reveal further surprising aspects. Our simulations show that field-driven vortex-type domain walls in ferromagnetic nanotubes display very unusual properties: a chiral breaking of symmetry and the occurrence of super-stable domain walls [3].



Owing to their extraordinary stability, vortex domain walls in nanotubes can propagate smoothly at ultrafast velocities. When driven by moderate fields of a few mT, they move at speeds above 1000 m/s without encountering the usual instabilities and oscillations which occur at much lower velocities for any other type of domain wall known so far. The velocity of these superstable walls may even exceed the speed of spin waves, thereby causing an effect reminiscent to the Cherenkov radiation, *i.e.*, the spontaneous emission of spin waves above a critical velocity [3]. By means of detailed and systematic simulations, this effect has been studied in detail, making it possible to explain its physical origin and to provide clear predictions for observations of this phenomenon which is yet unconfirmed by experiments.

[1] S.-B. Choe et al.,Science **304**, 420 (2004).
[2] R. Hertel et al., Phys. Rev. Lett. **98**, 117201 (2007).
[3] M. Yan et al., Appl. Phys. Lett. **99**, 122505 (2011).

Friday, 14 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES
SURFACES/INTERFACES 3
Chair: S. Rezende

10.30 – 10.45
Nanoscale investigation of the very early stages of the NiO/Fe interface formation
A. Brambilla [1], A. Picone [1], G. Bussetti [1], M. Riva [1], A. Calloni [1], L. Duò [1], F. Ciccacci [1], M. Finazzi [1]
(1) CNISM and Dipartimento di Fisica, Politecnico di Milano, piazza Leonardo da Vinci, 32 - 20133 Milano (Italy)

Low-dimensional antiferromagnetic (AF) systems display magnetic properties that can be considerably different from the ones observed in the bulk [1]. Moreover, AF-FM interfaces represent very interesting physical systems thanks to the rich phenomenology related to interface exchange coupling [1,2].
In particular, AF transition metal monoxides can be grown as high quality thin films on appropriate substrates and are therefore widely investigated to understand the correlations between magnetic, chemical, structural and morphologic features.
We have now collected a rich record of investigations on AF-Fe layered structures [2]. Several issues, such as chemical interactions at the interfaces, magnetic couplings in AF/Fe and Fe/AF/Fe systems, spin reorientation transitions as a function of the AF thickness, have been investigated [2]. Moreover, very peculiar micromagnetic structures, characterized by nanometer sized domains and very sharp domain walls, have been observed in Fe/NiO/Fe systems [2].
A further challenge consists in understanding the role of the interface properties at the nanometer scale. Recently, we reported on a Scanning Tunneling Microscopy/Spectroscopy (STM/STS) investigation of the early stages of formation of the CoO/Fe interface [3]. In the present work we employ STM/STS to study the formation of the NiO/Fe interface by growing Ni, in the submonolayer limit, on the oxidized Fe(001)-*p*(1x1)O surface. Such an approach allow us to have, on the surface, the correct stoichiometry for NiO and to control the observed strong redox interactions that are known to occur, pointing towards a sharp NiO/Fe interface. We observe that Ni does not form a NiO wetting layer but prefers to organize in islands that are higher than one atomic layer from the very early stages of the interface formation. We will finally discuss the role and implications of our experimentals results on the known magnetic behavior of these systems.

10.45 – 11.15
Magnetic properties of Fe epitaxial layers on NiO by nuclear resonant scattering of synchrotron radiation *(invited)*
P. Luches [1], L. Pasquini [2], S. Benedetti [1], S. Valeri [3], R. Rueffer [4], F. Boscherini [5]
(1) S3, Istituto Nanoscienze, CNR, I-41125 Modena, Italy, (2) Dipartimento di Fisica e CNISM, Università di Bologna, I-40127 Bologna, Italy, (3) Dipartimento di Fisica, Università di Modena e Reggio Emilia, I-41125 Modena, Italy, (4) European Synchrotron Radiation Facility, F-38043, Grenoble Cedex, France, (5) Dipartimento di Fisica e CNISM, Università di Bologna, 40127 Bologna, Italy

Friday, 14 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 3

Chair: S. Rezende

The complex nature of the interfaces between ferromagnetic (FM) and antiferromagnetic (AF) materials is expected to play a major role in the exchange interaction between the two magnetic phases, which determines the overall magnetic properties of the system. In order to gain insight in this question we performed a depth- resolved study of the magnetic properties of Fe films on NiO(001) - a model epitaxial FM/AF system - using nuclear resonant scattering (NRS) of synchrotron radiation. The depth resolution is obtained by measuring samples containing a ^{57}Fe probe layer at different distances from the interface. Previous studies pointed out that the Fe/NiO interface presents an interfacial buckled FeO-like layer [1]. NRS measurements, compared to density functional calculations, allowed to determine that the spins in the interfacial FeO-like phase are antiferromagnetically coupled and that the Fe atoms have a significantly increased magnetic moment compared to the case of a sharp interface [2]. The interface-mediated coupling between Fe and NiO induces a relevant increase of the coercive fields of Fe films compared to the case of non-interacting substrates. The reversal of the magnetization involves a non-negligible component of the magnetization in the Fe film plane perpendicular to the applied field, except for the Fe layers in close proximity to the interface with NiO. There is no chemical or magnetic modification in the ferromagnetic layer after field cooling, except for the appearance of a significant unidirectional anisotropy, giving rise to an exchange bias field, which is independent of the distance from the underlying antiferromagnetic phase and decreases with increasing Fe film thickness.

[1] P. Luches et al., Phys. Rev. Lett. 96, 106106 (2006)
[2] P. Luches et al., Phys. Rev. B 83, 094413 (2011)

11.15 – 11.30
In-Plane Magnetic Anisotropy in Ultrathin Fe Films Grown on a Stepped Ag(116)

E. Jal [1], M. Dąbrowski [2], J. Tonnerre [1], M. Przybylsky [2], M. Elzo [1], S. Grenier [1], N. Jaouen [3], J. Kirschner [2]
(1) Institut Néel, CNRS & Université J. Fourier, F-38043 Grenoble, France, (2) Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany, (3) Synchrotron SOLEIL, L'Orme des Merisiers, 91192 Gif/Yvette, France

Magnetic anisotropy is one of the key properties for the applications in magnetoelectronics. The anisotropy of Fe films grown on a stepped substrate Ag(116) depends on the film thickness, the step density, the covering material and the temperature [1,2]. Magneto-Optic Kerr Effect (MOKE) experiments on Au/Fe/Ag(116) have shown that, at room temperature, decreasing the Fe thickness, the easy magnetization axis (EMA) rotates from parallel to perpendicular to the steps. At low temperature (LT), an oscillation of the anisotropy strength is observed [1] and leads to an oscillation of the EMA. However, MOKE measurements probe only the average characteristics of the magnetization throughout the magnetic films. In order to get more insights in the understanding of the anisotropy modification, especially in the case of different interfaces, the depth-resolved magnetization profile has been addressed using soft x-ray resonant magnetic reflectivity [3].
At LT, the magnetic asymmetries measured on a 13.7ML thick Fe layer, where the EMA is along the steps, show that, under a saturating magnetic field applied parallel or perpendicular to EMA, the magnetic profile exhibits a reduced magnetization in the center of the layer. In remanence, after having applied a magnetic field perpendicular to the EMA, the analysis reveals that the magnetic moments near the Fe/Ag interface do not complete the rotation towards the EMA. The measurements on a 12.3ML thick Fe layer, where the EMA is perpendicular to the steps, show that the magnetization distribution is not homogeneously distributed throughout the Fe layer and prefers to be oriented perpendicular to the steps at the Fe/Ag interface.

[1] J. Li *et al.*, Phys. Rev. Lett. **102**, 207206 (2009)
[2] U. Bauer *et al.*, Phys. Rev. B **81**, 134428 (2010)
[3] J.-M. Tonnerre *et al.*, Phys. Rev. B **84**, 100407(R) (2011)

11.30 – 11.45
Electronic structure and magnetization at the Cr/MgO interface

M.A. Leroy [1], A. Bataille [1], F. Ott [1], F. Bertran [2], T. Hauet [3], A. Neggache [3], S. Andrieu [3]
(1) Laboratoire Léon Brillouin, CEA Saclay, 91191 Gif-sur-Yvette, France, (2) Synchrotron Soleil, 91192 Gif-sur-Yvette, France, (3) Institut Jean Lamour, Université Henri Poincaré, 54506 Vandoeuvre, France

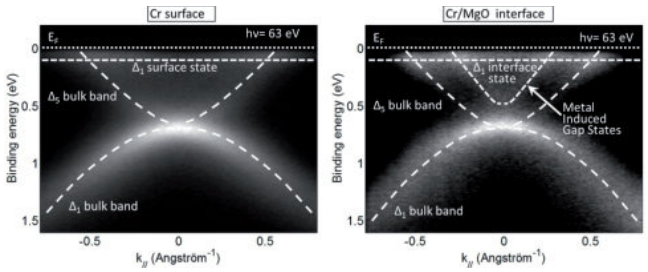
Antiferromagnetic thin films have recently attracted a renewed interest triggered by the perspective to use them as active layers in spintronic devices [1]. For spin transfer torque as for the tunnel coupling we observe in Cr/MgO/Cr epitaxial heterostructures [2], interfaces have a crucial contribution. For Cr, our model antiferromagnet, main studies focus yet only on the surface properties. We have hence developed a new understanding of the Cr/MgO interface electronic and magnetic properties.
To evidence the modification of Cr electronic properties by MgO, we carried out symmetry- and angle-resolved photoemission spectroscopy on two samples (bare Cr surface and Cr surface covered with 1.5 monolayers MgO) for photon energies from 20 to 110eV. Contrary to some previous photoemission studies, we find that only the low binding energy Δ_1 state is a surface state and could be responsible for the surface magnetism. Its position suggests a surface moment much smaller than predicted in both samples. For the Cr/MgO interface, along with a similar Δ_1 interface state, we evidence metal induced gap states stemming from the MgO. The magnetism at the interface should be triggered by the position of the Δ_1 surface state, highly sensitive to hybridization [3], changing in return the surface moment magnitude.
High sensitivity polarized neutron reflectivity measurements on a high quality epitaxial Cr/MgO superlattice show that the enhanced magnetization at the interface, if existent, is small (inferior to $0.59\mu_B$, bulk moment being $0.5\mu_B$). This result, along with the known behavior of 3d bcc metal/MgO interfaces strongly questions the theoretically predicted magnetization for the Cr(001) surface ($2.3\text{-}3\mu_B$).

Friday, 14 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 3

Chair: S. Rezende



Photoemission signal intensity versus $k_{//}$ at 150K in linear horizontal polarization

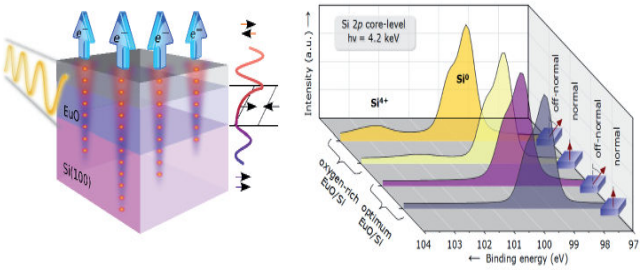
[1] F. Jonietz *et al., Science* **330** 1648 (2010)
[2] M.-A. Leroy et al., *in revision in Nature Nanotechnology*
[3] W.H. Butler et al., *Phys. Rev. B* **63** 054416 (2001)

11.45 – 12.00

Functionalization of the EuO/Si(001) interface for spintronics

C. Caspers [1], M. Müller [1], W. Drube [2], A. Gloskovskii [3], M. Gorgoi [4], C.S. Fadley [5], C.M. Schneider [1]
(1) Peter Grünberg Institut, Research Center Jülich, 52425 Jülich, Germany, (2) DESY Photon Science, Deutsches Elektronen-Synchrotron (DESY), 22603 Hamburg, Germany, (3) Institut für Analytische und Anorganische Chemie, Johannes Gutenberg-Universität, 55128 Mainz, Germany, (4) BESSY II, Helmholtz-Zentrum für Materialien und Energie, 12489 Berlin, Germany, (5) Department of Physics, University of California Davis, CA, USA

Integrating Europium Oxide (EuO) into spintronics devices is an appealing route for realizing highly efficient spin filtering. Moreover, the conductance of EuO is largely tunable and the material is the only magnetic oxide predicted to be stable on silicon [1].
We succeeded in integrating high-quality EuO thin films directly on Si(001) [2,3]. The main experimental challenge involves the suppression of SiO_2 and/or $EuSi_x$ formation at the interface, which counteracts with the need for elevated temperatures for stoichiometric EuO synthesis.
We performed a HAXPES study, which is a powerful method (Fig.1, left panel) to selectively probe the bulk EuO electronic structure and the EuO/Si interface. Tuning of the photoelectron information depth by using either the deep core-levels (Eu3d, Eu4d, and Eu4s) or the valence level (Eu4f) allows to compile a consistent chemical depth profiling of the EuO/Si heterostructure. First, a quantitative analysis of the Eu photoemission peaks reveals a nearly ideal stoichoimetry of ultra-thin EuO/Si(001) films (d=4 nm), consisting of 97% ferromagnetic Eu^{2+} cations, which show a homogeneous distribution in the entire EuO layer. An increase of few 10^{-9} mbar oxygen during EuO synthesis, however, leads to a formation of 66% antiferromagnetic Eu^{3+}.
A careful inspection of the Si2p core level provides insights into the chemical state of the EuO/Si interface. We observed negligible oxidation of Si for stoichiometric EuO/Si (Fig.1, right panel), whereas interfacial silicides amount less than 0.3 nm.
Our study demonstrates the successful stabilization of high-quality EuO thin films directly on silicon, paving the way for future spin injection applications.



Electronic structure study of magnetic oxide EuO/Si(001) heterostructures.

[1] K. J. Hubbard and D. Schlom, J. Mater. Res. 11(11), 2757 (1996)
[2] C. Caspers, M. Müller et al., Phys. Status Solidi RRL 5(12), 441 (2011)
[3] C. Caspers, M. Müller et al., Phys. Rev. B 84, 205217 (2011)

12.00 – 12.15

Room temperature magnetism in MB_6 (M = Ca, Sr, Ba) films grown by pulsed laser deposition

K. Ackland [1], M. Venkatesan [1], J.M.D. Coey [1]
(1) School of Physics and CRANN, Trinity College, Dublin 2, Ireland

Magnetism has been reported in alkaline earth hexaborides MB_6 (M = Ca, Sr, Ba) which nominally contain no 3d, 4d or 4f electrons [1, 2]. Here amorphous BaB_6 thin films were deposited by pulsed laser deposition on Al_2O_3 (0001) substrates at different temperatures using a BaB_6 target synthesized from high purity barium and boron powders by solid state reaction. Neither the boron nor the resultant BaB_6 powder exhibited any trace of ferromagnetism at room temperature. Multiple precautions were taken to ensure that extrinsic ferromagnetic contamination was minimised during the experiments.
Magnetization data (Fig. 1) shows ferromagnetic-like signals for substrate temperatures in the range 450 - 550 °C only; furthermore, the largest magnetization, 150 kA m^{-1}, is found for films 15 nm thick. The magnetization is virtually anhysteretic, isotropic and independent of temperature down to 4 K. The ferromagnetic volume fraction *f* of the samples, the volume that is magnetically ordered, is about 4 % for the 120 nm thick magnetic films, and rises to 80 % for t = 15 nm, suggesting that the magnetism may be spatially localised within a thin layer at the substrate-film interface. Additionally, low energy muon spin rotation spectroscopy is used to elucidate the location and nature of the magnetism.
The results are discussed in terms of a spin-slit, defect-band model, first applied to CaB_6 [3].

[1] L.S. Dorneles et al., APL, 85, 6377 (2004)
[2] K. Ackland et al., J. Appl. Phys. **111**, 07A322 (2012)
[3] D. M. Edwards et al., J. Phys. C: Cond. Matt. 18, 7209 (2006)

Friday, 14 September 2012
Aida Room

MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 3

Chair: S. Rezende

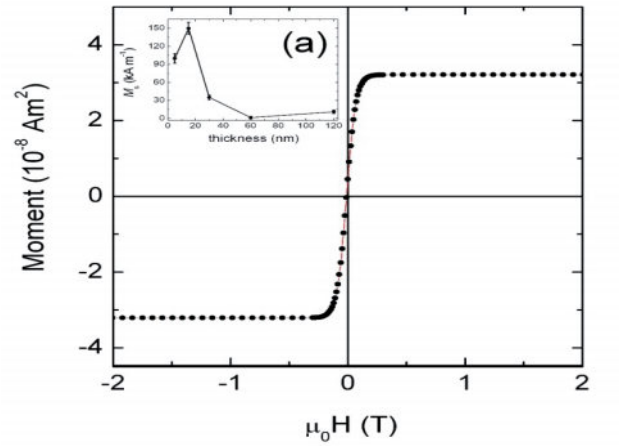


Fig. 1. Room temperature magnetization data (fitted to a tanh function) for a 120 nm BaB_6 film grown on Al_2O_3 (0001) at 500 °C. Inset (a) shows the variation of M_s with film thickness

12.15 – 12.30

Role of the interface in the magnetic coupling of Fe nanoparticles in pulsed laser deposited Fe-Ag thin films

M.L. Fdez-Gubieda [1], J. Alonso Masa [1], A. García Prieto [2], L. Fernández Barquín [3]

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Granular thin films composed of magnetic nanoparticles in a metallic matrix present outstanding magnetic properties. The magnetic behaviour depends on the size, concentration, and the interface between the nanoparticle and the matrix [1,2]. The role of this interface in mediating interparticle magnetic interactions has been analyzed in FexAg100-*x* ($x \approx 50$) thin films deposited by Pulsed Laser Deposition technique (PLD), which allows us to modify the interface. These samples are composed of crystalline bcc Fe (2-4 nm) nanoparticles and fcc Ag (10-12 nm) nanoparticles, separated by an amorphous Fe50Ag50 interface occupying ~20% of the volume.
Interfacial magnetic coupling between Fe nanoparticles has been studied by DC and AC magnetization. In figure 1 we present some schematic pictures describing the magnetic state of the Fe nanoparticles for different ranges of temperatures. As can be seen, $T < 65$ K, the amorphous Fe50Ag50 interface, which separates the magnetic nanoparticles, is frozen in a spin glass-like state, as revealed by the presence of exchange bias in the hysteresis loops (H_{ex} = -4.3 Oe) and the unsaturated magnetic behaviour. Direct exchange interactions between the Fe nanoparticles are blocked, and the system enters into a superspin-glass state (frequency shift of the AC maximum, $\delta \sim 0.05$-0.06). At intermediate temperatures, $70 < T < 205$ K, the amorphous interface is ferromagnetically ordered, enabling the direct exchange between the nanoparticles. At high temperatures ($T > 210$ K), the amorphous interface becomes paramagnetic and, therefore, the direct exchange between the nanoparticles is again disabled. The magnetization of the system decreases in a similar way to re-entrant magnetic alloys (dynamical critical exponent, $z\nu = 5.5$).

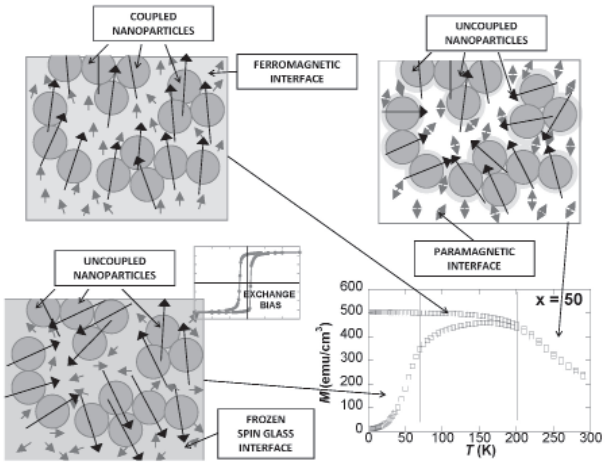

Fig1. Thermal evolution of the magnetic structure for a PLD FexAg100-x thin film.

[1] J. Alonso et al., Physical Review B 82 054406 (2010)
[2] J. Alonso et al. IOP Nanotechnology 23 025705 (2012)

12.30 – 12.45

Anomalous Extraordinary Hall Effects as a function of temperature and magnetic field in Pt/Co/AlO_x

F. Fettar [1], H. Mohamed Garad [1], F. Gay [1], S. Auffret [2], B. Rodmacq [2], B. Dieny [2]

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The **E**xtraordinary **H**all **E**ffects (**EHE**) in ferromagnetic materials has high potential for memories. For the applied temperature **T**, EHE effects display a standard behavior as the form $\boldsymbol{\rho(EHE) \approx a.\rho + b.\rho^2}$ **[1]** (**a** and **b** are two coefficients). Here, both resistivity's, **ρ(EHE)** and **ρ**, namely the **EHE** resistivity and the **longitudinal** resistivity, increase when the temperature **T** for metallic structures. These physical results give valuable information about the electronic band structure and spin polarization at Fermi level of these ferromagnetic materials.
In as-grown Pt(3 nm) / Co(0.6 nm) / AlO_x(2 nm) with different oxidation times of the Al layer ($\mathbf{T_{ox}}$), the situation is more complex. The resistivity's versus **T** for both **ρ(EHE)** and **ρ** data with $\mathbf{T_{ox}}$ (15, 25, 40 and 55 seconds) are represented in **Fig. 1(a)** and **Fig. 1(b)** respectively.
These trilayers exhibit several very interesting and very spectacular features:
(1) Presence of minima's at very low temperatures. See the $\boldsymbol{\rho_{min}}$ values in **Fig.1(a)** and **1(b)**. The reason is probably the existence of defects present in the multilayer, as discussed in **[2]**, where the oxidation process causes a deformation of the structure.
(2) Overshoots of EHE at intermediate temperatures between roughly 170 K and room temperature. It also appears similar ef-

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MAGNETIC NANOSTRUCTURES, SURFACES AND INTERFACES

SURFACES/INTERFACES 3

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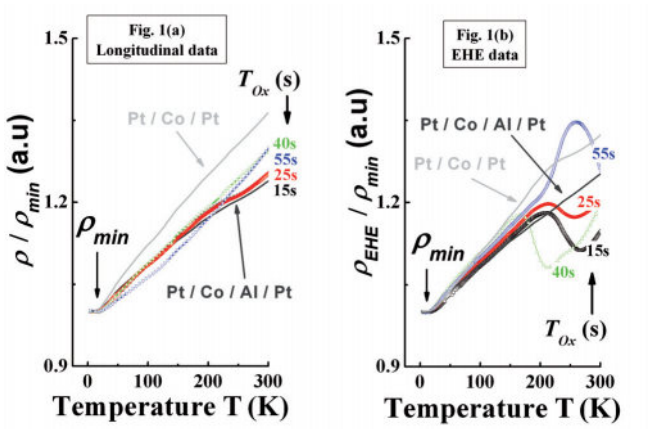
fects due to the applied magnetic field on the shape of overshoots. A discussion about the deviation from the standard behavior of **ρ(EHE)** will be given starting from magnetic interactions.
(3) For longitudinal me asurements performed on our trilayers, and for reference samples (Pt/Co/Pt and Pt/Co/Al/Pt miltilayers without oxygen), these minima's and overshoots are weakly apparent. These surprising characteristics will be detailed in the light of spin hall effects **[1]**.

[1] N. Nagaosa et al., Reviews of modern physics **82**, 1539 (2010)
[2] Y. H. Cheng et al., Phys. Rev. B **80**, 174412 (2009)

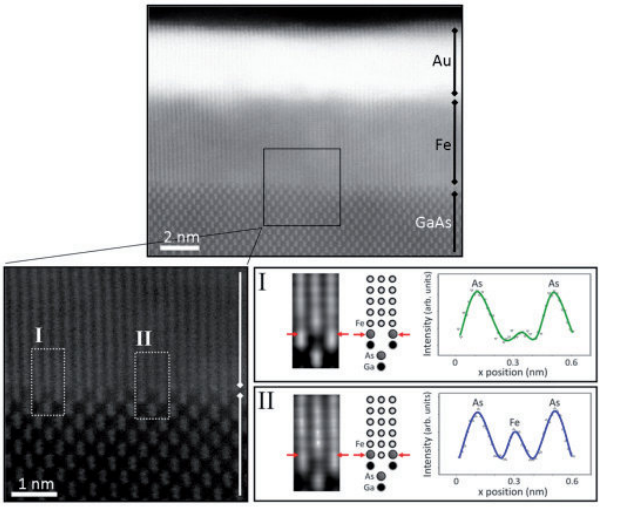


12.45 – 13.00
Transport and Structural Properties of the Fe/GaAs(001) Interface

L. Fleet [1], K. Yoshida [2], H. Kobayashi [3], Y. Kaneko [3], S. Matsuzaka [3], Y. Ohno [3], H. Ohno [3], S. Honda [4], J. Inoue [5], *A. Hirohata* [6]
(1) Department of Physics/The University of York/ York, YO10 5DD, UK, (2) Department of Crystalline Materials Science and Ecotopia Science Institute/ Nagoya University/ Nagoya, 464-8603, Japan, (3) Research Institute of Electronic Communication/ Tohoku University/ Sendai, 980-8577 Japan, (4) Institue of Applied Physics/ University of Tsukuba/ Tsukuba, 305-8573, Japan, (5) Department of Applied Physics/ Nagoya University/ Nagoya, 464-8603, Japan, (6) Department of Electronics/The University of York/ York, YO10 5DD, UK

In this work we describe a series of TEM studies of the interface structure in the Fe/GaAs(001) system. The studies have been carried out to atomic resolution and using HAADF-STEM we are able to identify individual atomic species. We have observed perfectly abrupt interfaces where the Fe is bonded to the As as expected but we have also been able to identify regions in the interface where the bonding is between Ga and Fe with the Fe lying in interstitial sites in the lattice. Because of the resolution of our double Cs corrected TEM we have been able to measure the lattice spacings at the interface and thereby allow for calculations of the interface states at different positions across the sample for the first time. An example of the resolution of our imaging is shown in the figure.
Our observation of these mixed interfaces accounts for the lower than expected Schottky Barrier heights measured in this system [1]. It is also clear that within any Fe/GaAs(001) system there will exist a distribution of Schottky Barrier heights at the interface. This implies that when a current flows regions having a lower Schottky Barrier height will experience a greater flow of current which will inevitably lead to Joule heating. This heating can lead to thermionic emission into the semiconductor which will further lower the effective barrier to conduction across the interface. The process of conduction in these systems has been studied using Hanle curves [2] and a full analysis of the consequences of these differing interface structures will be discussed in the paper.

[1] L.R. Fleet et al., IEEE Trans. Magn. 47, 10 (2011)
[2] L.R. Fleet et al., J. Appl. Phys. 109, 07C504 (2011)



HAADF-STEM image showing the (I) abrupt and (II) partially mixed interfaces.

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MAGNETIC MEMORIES AND MAGNETIC RECORDING

Chair: O. Heinonen

10.30 – 11.00
Magnetism for Nonvolatile Memories and Beyond *(invited)*
H. Ohno [1]
(1) Center for Spintronics Integrated Syst.; WPI-Advanced Inst. for Mat. Science; Lab. for Nanoelec. and Spintronics, Res. Inst. Biol. Communic., Tohoku University, Sendai, Japan

Nonvolatile memory based on magnetism is currently the only nonvolatile memory technology that is capable of fast-read/write with high endurance, compatible with back-end-of-line of existing CMOS integrated circuits, and has high potential for scalability. This set of properties allows magnetoresistive random access memory to challenge the existing semiconductor memories. I first review current technology of magnetic tunnel junction (MTJ) and its variants, the devices that made this challenge possible, particularly those based on perpendicular CoFeB-MgO system. I then discuss what remains to be done to replace existing semiconductor memories. In addition to replacing existing memories, high performance magnetism-based elements like MTJs in combination with CMOS integrated circuits offer a new route to high-performance low-power logic circuits; a nonvolatile logic VLSI. I present current status of logic integrated circuits that combine the power of magnetism and semiconductor VLSI. This work was supported by the FIRST program of JSPS.

11.00 – 11.30
Bit patterned media and percolated media for magnetic storage applications *(invited)*
F. Ganss [1], C. Schulze [1], C. Brombacher [1], A. Cattoni [2], A. Haghiri-Gosnet [2], M. Faustini [3], D. Grosso [3], *M. Albrecht* [1]
(1) Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany, (2) Laboratory for Photonics and Nanostructures, CNRS, F-91460 Marcoussis, France, (3) Laboratoire Chimie de la Matière Condensée de Paris, UMR UPMC-CNRS, Université Pierre et Marie Curie, F-75231 Paris, France

Among several approaches to achieve magnetic storage densities beyond 1 Tbit/in^2, bit patterned media (BPM) has received a lot of interest. Several ways to create regular nanostructure arrays do exist and combining patterned structures with the deposition of magnetic film systems with high anisotropy seems to be a promising way to achieve such media.
In this presentation, first I will focus on Co/Pd multilayer stacks with perpendicular magnetic anisotropy which were sputter deposited onto arrays of SiO_x pillars prepared by electron beam lithography and high temperature post-baking of HSQ resist [1]. Pillar arrays with pitches as small as 26 nm were fabricated corresponding to a potential storage density of 1.1 Tbit/in^2. The deposition was carried out under different deposition angles up to 60 deg to investigate the benefit of the shadowing effect in order to decrease material deposition into the trenches.
Alternatively, the concept of percolated perpendicular media in which densely distributed pinning sites lead to smooth transition boundaries might be realized by the deposition of a magnetic film with perpendicular easy axis of magnetization onto self-assembled nanoperforated membranes [2, 3]. In this case, each nanopore acts as a defect structure providing a site for nucleation and domain wall pinning.

[1] A. Cattoni et al., Microelectron. Eng. 87, 1015 (2010).
[2] C. Schulze et al., Nanotechnology 21, 495701 (2010)
[3] M. Grobis et al., Appl. Phys. Lett. 98, 192504 (2011)

11.30-11.45
Electrochemical deposition, $L1_0$ ordering and magnetic properties of Fe-Pt equiatomic films and multilayers
D. Liang [1], *G. Zangari* [1]
(1) Department of Materials Science and Engineering and CESE, University of Virginia, 22903, Charlottesville, VA, USA

The high magnetic anisotropy (~ 6.6 MJ/m3) of the L10 superstructure of equiatomic Fe-Pt enhances the thermal stability of magnetization and makes this material an outstanding candidate for perpendicular and patterned recording media, as well as for permanent magnets in microsystems. The availability of an electrodeposition process for Fe-Pt is advantageous as it would enable the purely additive synthesis of micro- or nano-structures, simplifying the fabrication of hard magnetic components. Previous efforts to electrochemically grow Fe-Pt however have led to films with high oxygen content and porous morphology, which required high temperature annealing in strongly reducing atmospheres to develop hard magnetic properties.
A novel electrolyte formulation [1] and deposition under potential control have been shown to form Fe-Pt films with closely controlled composition and low oxygen content (< 5 at%). Equiatomic alloys in particular exhibit a face-centered cubic structure in the as-deposited state, which is transformed to the L10 structure by annealing in forming gas at temperatures as low as 400C. Annealing for 1h at 450C is sufficient to fully harden 100 nm thick films, which exhibit a coercivity of 1.3 T.
The phase transformation kinetics however is found to slow down in thinner films, due to nucleation and growth constraints imposed by the presence of surfaces [2]. In order to circumvent this limitation, we exploite 1 d the dependence of ordering kinetics on alloy composition [3]. Specifically, [Fe50Pt50 (15nm)/Fe65Pt35 (10 nm)] were grown by periodically varying the deposition potential; the phase transformation was found to start in the Fe-rich layer and to propagate to the equiatomic layer, decreasing the transformation temperature and enabling significant hardening at lower temperatures.

[1] D. F. Liang, J.J. Mallett, G. Zangari, *J. Electrochem*. Soc. 158 (3) D149 (2011)
[2] D.C. Berry, K. Barmak, *J. Appl. Phys*. 101, 014905 (2007)
[3] K. Barmak, J. Kim, D.C. Berry, et al., *J. Appl. Phys*. 95, 7486 (2004)

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MAGNETIC MEMORIES AND MAGNETIC RECORDING

Chair: O. Heinonen

11.45 – 12.00

3D spintronics: perpendicularly magnetized soliton rachet

R. Lavrijsen [1], J. Lee [1], A. Fernández-Pacheco [1], D. Petit [1], R. Mansell [1], R. Cowburn [1]

(1) Cavendish Laboratory/Thin Film Magnetism Group/University of Cambridge, CB3 0HE Cambridge, United Kingdom

This work aims to harness the enormous space above our traditional 2-dimensional spintronic devices making them truly 3-dimensional.

In this contribution we show, for the first time, an active control of a sharp magnetic kink soliton propagating vertically through a carefully engineered anti-ferromagnetically (AF) coupled superlattice (SL). This soliton is a frustration separating two anti-phase domains, analogous to a magnetic domain wall (DW). This provides an excellent alternative to the proposed non-volatile 3-dimensional data storage method based on magnetic DWs [1] as it provides well-defined magnetic SL configurations and acts as a shift-register.

The SL consists of sputter-deposited perpendicularly magnetized ultrathin Pt/CoFeB/Pt layers coupled AF through a Ru spacer by the RKKY mechanism [2]. By tuning the AF-coupling strength between the ferromagnetic (FM) layers and thickness of individual FM layers a ratchet-lattice for soliton propagation is created. We show by means of the polar magneto optical Kerr effect (P-MOKE), vibrating sample magnetometry (VSM) and anomalous Hall effect how such a soliton is injected and controllably propagated layer-by-layer via an externally applied field sequence. In Fig. 1 a major hysteresis-loop of a SL with 11 FM layers is shown with to the right the corresponding switching order. The soliton is indicated by a star at (5) and (6). The results will be substantiated by an Ising macrospin model which allows us to fully understand and model the soliton injection and propagation through the SL.

These results pave the way for true 3-dimensional spintronics and understanding of topological kink-solitons in synthetic AF superlattices.

[1] S.S.P. Parkin, M. Hayashi, L.Thomas, Science, 320, 5873, (2008)

[2] R. Lavrijsen, A. Fernandez-Pacheco, D. Petit, R. Mansell, J.H. Lee, R.P. Cowburn, Appl. Phys. Lett, 100, 052411, (2012)

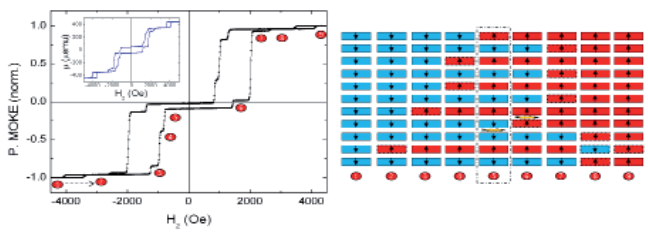

Fig.1, P. MOKE and VSM (inset) hysteresis loop of a perpendicularly magnetized soliton ratchet with layer-switching identification

12.00 – 12.15

Multi-bit magnetic memory based on the Extraordinary Hall effect

A. Gerber [1], A. Segal [1]

(1) School of Physics and Astronomy, Tel Aviv University, 69978 Tel Aviv, Israel

We demonstrate a novel concept of multi-bit random access memory system in which each memory cell is split among several multilevel dots exhibiting perpendicular magnetic anisotropy with different coercive fields. The extraordinary Hall effect (EHE) is used to read the stored information. The reversed magnetic field reciprocity protocol is applied to extract the odd in field Hall signal from high background inter-cell resistance. Feasibility of the approach was supported by realization of four-, eight- and sixteen- memory state cells. In addition to multiplicity of states, probably the most important advantage of the split cell architecture is freedom in positioning dots of the same cell at separate locations and different levels, thus building an effective three-dimensional memory.

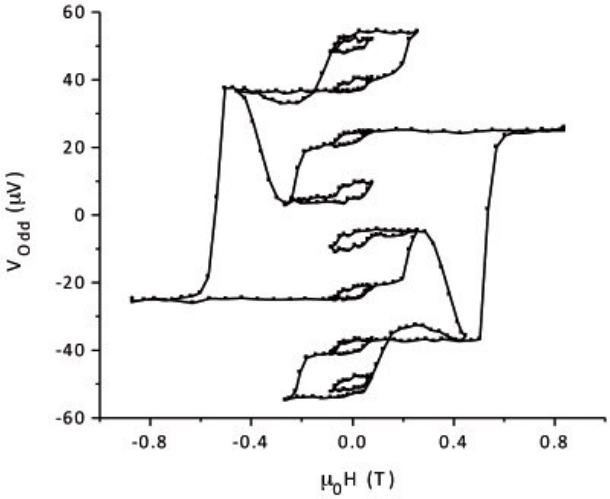

Fig.1. Demonstration of a four-bit states memory: sixteen zero field Hall voltage states achieved in respective sequences of field pulses.

12.15 – 12.30

Magnetisation reversal in FePt/Fe_3Pt nanocomposites for ultrahigh-density magnetic recording

F. Casoli [1], P. Lupo [1], L. Nasi [1], S. Fabbrici [1], R. Cabassi [1], F. Bolzoni [1], P. Ranzieri [1], F. Albertini [1]

(1) IMEM, CNR, 43124 Parma, Italy

Exchange-coupled composite (ECC) media, where each grain is composed of a hard and a soft phase, have been proposed to go beyond the magnetic recording "trilemma" by exploiting the hard/soft coupling to reduce the switching field. Further advantages have been predicted compared with single-phase media: increased thermal stability when the soft phase has a positive anisotropy constant; faster switching; reduced sensitivity to the writing field angular distribution [1].

Model systems with controlled extrinsic properties, like grain shape and hard/soft interface, could be fruitfully exploited to understand the limits of real ECC systems and improve

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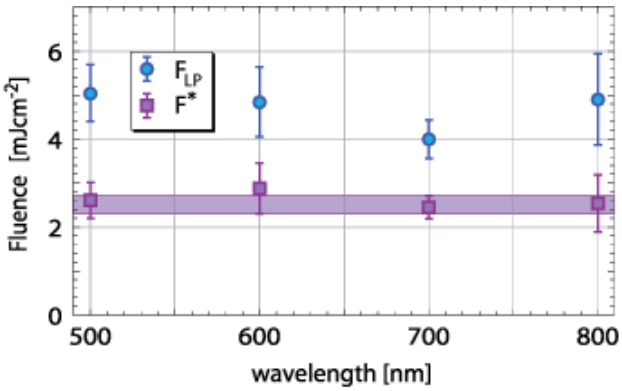
the functional properties. We have grown FePt/Fe_3Pt nanostructures by sputtering on both MgO and $SrTiO_3$, exploiting the different FePt/substrate matching to modify island morphology, size, and inter-island separation. We have obtained capped-type Ledge nanocomposites [2,3] with Fe_3Pt growing pseudomorphic and ordered on $L1_0$-FePt. Morphology evolves with thickness as in $L1_0$-FePt and is influenced by the substrate: on $SrTiO_3$ larger and well-separated nanostructures with atomically flat surface form. Coercive field strongly decreases with increasing Fe_3Pt thickness; the reduction is larger on $SrTiO_3$ and with higher Fe content in the soft phase (H_C/H_C^{hard} down to 0.21).
We have fully investigated the magnetisation reversal process in the different magnetic regimes. At the lowest Fe_3Pt thickness the samples exhibit Rigid Magnet behaviour, with single-step reversal processes. For higher Fe_3Pt thickness, the hysteresis loops are two-step processes, typical of the Exchange-Spring regime, with positive nucleation fields and a reversible portion of the demagnetising process. The magnetic regime at fixed soft phase thickness can be tuned by changing substrate and nominal composition of the soft phase.

[1] D. Suess et al., J. Magn. Magn. Mater. 321, 545 (2009)
[2] V. Lomakin et al., Appl. Phys. Lett. 92, 022502 (2008)
[3] D. Goll et al., Appl. Phys. Lett. 93, 152512 (2008)

12.30 – 12.45
Role of Magnetic Circular Dichroism in All-Optical Magnetic Recording
S. Khorsand [1], M. Savoini [1], A. Kirilyuk [1], A.V. Kimel [1], A. Tsukamoto [2], A. Itoh [2], T. Rasing [1]
(1) Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, Nijmegen, The Netherlands, (2) College of Science and Technology, Nihon University, 7-24-1 Funabashi, Chiba, Japan

With a single 40fs circularly polarized laser pulse, the magnetization of ferrimagnetic GdFeCo can be reversed in the absence of an external magnetic field [1]. In a certain intensity window, this phenomenon is helicity dependent and is therefore called "all-optical helicity dependent switching" (AO-HDS) [2]. Until now, the origin of the helicity dependence of all-optical switching was poorly understood, and was assigned to the "inverse Faraday effect". Using magneto-optical microscopy in combination with ellipsometry measurements, we show that all-optical magnetization reversal is subjected to a threshold fluence absorbed in the magnetic layer. This threshold fluence is independent of either the excitation wavelength or the polarization of the laser pulse (see figure). Furthermore, we present a quantitative explanation of the intensity window in which all-optical switching is helicity dependent [3], based on magnetic circular dichroism. This explanation is consistent with all the experimental findings on this phenomenon so far, varying from single- to multiple-shot experiments.

[1] C. D. Stanciu *et al.*, Phys. Rev. Lett. **99**, 047601 (2007).
[2] K. Vahaplar *et al.*, Phys. Rev. Lett. **103**, 117201 (2009).
[3] A.R. Khorsand et al., Phys Rev. Lett. **108**, 127205 (2012).



Threshold fluence at which all-optical switching occurs with a 40 fs excitation pulse is plotted as a function of the excitation wavelength. The blue dots (F_{LP}) show the threshold fluence of the incoming linearly polarized pulse, and the purple squares (F^*) show the actually absorbed intensity of the laser pulse at which switching occurs.

12.45 – 13.00
Magnetization reversal in GdFeCo nanostructures induced by single femtosecond laser pulse
L. Le Guyader [1], S. El Moussaoui [1], M. Buzzi [1], R.V. Chopdekar [2], L.J. Heyderman [2], A. Tsukamoto [3], A. Itoh [3], A. Kirilyuk [4], T. Rasing [4], A.V. Kimel [4], F. Nolting [1]
(1) Swiss Light Source, Paul Scherrer Institut, Villigen PSI Switzerland, (2) Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, Villigen PSI Switzerland, (3) College of Science and Technology, Nihon University,s Funabashi-shi, Chiba, Japan, (4) Radboud University Nijmegen, Institute for Molecules and Materials, Nijmegen, The Netherlands

Recently it has been shown both theoretically and experimentally[1] that in GdFeCo 3d-4f metallic ferrimagnetic alloys, an ultrafast heating via absorption of a linearly polarized femtosecond laser pulse can reverse the magnetization without any applied magnetic field. The femtosecond laser pulse heats up the free electrons and thus excites the magnet on the time scale of the exchange interaction, bringing it into a transient strongly non-equilibrium state due to the different demagnetizing time scales of the Gd and Fe sublattices[2], from which the system relaxes deterministically into the reversed state[3]. Up to now, this laser induced magnetization switching was only demonstrated in micrometer sized structures. For data storage applications, it is of primary importance to investigate this switching in more technologically relevant nanostructures.
Here we report the demonstration of laser induced magnetization reversal in GdFeCo nanostructures with domain sizes down to 200nm. These structures were produced with electron beam lithography and lift-off techniques. The magnetic domain configuration was imaged using X-ray mag-

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netic circular dichroism (XMCD) at the Fe L3 edge with a photoemission electron microscope (PEEM). An azimuthal dependent study, allowing the determination of the magnetization vector components, revealed that the nanostructures display in-plane magnetized rims and out-of-plane central domains. Spectromicroscopy and atomic force microscopy investigations suggest that these in-plane magnetized rims arise from a thinning of the magnetic layer at the nanostructure edge. However, no drastic influence of these rims on the switching efficiency of the central out-of-plane domains was observed. These results constitute an important step towards the application of laser induced magnetization switching in storage devices.

[1] T. A. Ostler et al. Nature Commun. 3, 666 (2012)
[2] I. Radu et al. Nature 472, 205 (2011)
[3] J. H. Mentink et al. Phys. Rev. Lett. 108 057202 (2012)

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Otello Room

MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS…)

Chair: S. Fabbrici

10.30 – 11.00
γ-FeNi Magnetic Nanostructures for Magnetocaloric Applications *(invited)*
M.E. Mchenry [1], H. Ucar [1], J.J. Ipus [2], V. Franco [3]
(1) Department of Materials Science and Engineering, Carnegie Mellon University, 15207 Pittsburgh, PA, USA, (2) Dept. of Mat. Science and Engin., Carnegie Mellon Univ., 15207 Pittsburgh, PA, USA and Dept. of Physics, University of Sevilla, Spain, (3) Department of Physics, University of Sevilla, Spain

Magnetocaloric materials are of current interest for magnetic refrigeration near room temperature, because this technology is energetically more efficient than that based on conventional gas compression refrigeration, by about 20 %. Studies of magnetocaloric effects have focused on materials systems with sharp first order structural phase transformations along with magnetic transitions. However, using second order (higher order) magnetic transitions, the refrigerant capacity can be optimized by tuning the breadth of the transition to optimize the efficiency of a particular thermodynamic cycle. This talk will summarize work based on our studies of metastable nanostructures and distributed exchange interactions for their role in tuning second order magnetic phase transitions. The choice of the Fe-Ni alloy system offers cheap and environmentally friendly alternatives to many of the materials currently under study for magnetocaloric applications. The alloys exploit the metastable γ–FCC phases The tunable Curie temperature, ability to produce interesting nanostructures and low cost. The focus is to find the most economically advantageous magnetic refrigerant with highest performance.

11.00 – 11.30
Advanced Magnetocaloric Materials. An overview *(invited)*
V.K. Pecharsky [1], K.A. Gschneidner Jr. [1], Y. Mudryk [2], D. Paudyal [2]
(1) Ames Laboratory, US Department of Energy, and Department of Materials Science and Engineering, Iowa State University, Ames IA, 50011-3020, USA, (2) Ames Laboratory, US Department of Energy, Iowa State University, Ames IA, 50011-3020, USA

The discovery of the giant magnetocaloric effect in $Gd_5Si_2Ge_2$ and other R_5T_4 compounds (R = rare earth metal and T is a Group 14 element) generated a broad interest in the magnetocaloric effect and magnetic refrigeration near room temperature in particular, and in magnetostructural transitions in general. Reports on the giant magnetocaloric effect in other systems soon followed. These include $MnFeP_xAs_{1-x}$ and related compounds, $La(Fe_{1-x}Si_x)_{13}$ and their hydrides, $Mn(As_xSb_{1-x})$, $CoMnSi_xGe_{1-x}$ and related compounds, Ni_2MnGa and some

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MAGNETIC MATERIALS FOR ENERGY APPLICATIONS (PERMANENT MAGNETS, MAGNETOCALORICS…)

Chair: S. Fabbrici

closely related Heusler phases, and a few non-metallic systems. A common feature observed in all giant magnetocaloric effect materials is the enhancement of the magnetic entropy effect by the overlapping contribution from the lattice. In addition to the interplay between magnetic and lattice entropies, both of which are intrinsic materials' parameters that in principle can be modeled theoretically from first principles, extrinsic parameters such as microstructure and nanostructure, have been found recently to play a role in controlling magnetostructural transition(s) and magnetocaloric effect. Both the intrinsic and extrinsic parameters are, therefore, important in order to have the optimum magnetocaloric effect. The role of different control parameters and the potential pathways towards materials exhibiting advanced magnetocaloric effect will be discussed.
This work is supported by the U.S. Department of Energy – Basic Energy Sciences under contract No. DE-AC02-07CH11358.

11.30 – 11.45
Ultrafine Sm-Fe-N Particles Prepared by Planetary Ball Milling
G. Hadjipanayis [1], D. Neil [1], A. Gabay [1]
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Magnetically hard nanoparticles are needed for the fabrication of anisotropic exchanged-coupled permanent magnets using the bottom-up approach. In this study we have chosen $Sm_2Fe_{17}N_x$ because of its high anisotropy field and large saturation magnetization. A multi-stage planetary ball milling process was used to obtain the nanoparticles. The milling parameters were controlled carefully and nanoparticles with the desired properties were obtained. The key is to find the right balance of energy used to mill the precursor particles; it must be high enough to break the particles and reduce their size but, not so high as to destroy the crystal structure of the nanoparticles that would lead to deterioration of the magnetic properties. First the coarse powders were subjected to a wet milling with 2 mm diameter media. This stage was used to reduce the size and variation of the precursor powder. Smaller media was introduced in stage two of the wet milling process. It was found that the smaller media was unable to break the largest particles but, necessary to produce the nanoparticles obtained. In general, the smaller the particle size desired, the smaller the media that must be used. Size distribution of the particles obtained by ball milling can be quite wide. Using such a process we produced particles in the size range from 100-800nm with a coercivity as high as 10kOe at room temperature.
Work supported by DOE ARPA-E

11.45 – 12.00
Giant magnetocaloric materials: disorder effects
J. Amaral [1], V. Amaral [1]
(1) Departamento de Física and CICECO, Universidade de Aveiro 3810-193 Aveiro, Portugal

In striving for mass production of magnetocaloric materials for refrigeration applications, one has to face the fact that these will not be laboratory-grade materials, and will necessarily present composition gradients due to lower quality reagents. Some consequences are expected: the maximum value of magnetic entropy change (dSM) should decrease compared to a "pure" material, and broadening of the dSM(T) curves, as observed in elementary ferromagnets [1]. Some theoretical work has focused on this topic, for second-order phase transition systems [2-5]. Still, these theoretical considerations do not directly apply to giant magnetocaloric materials.
We present a study on the effect of disorder on the magnetic and magnetocaloric properties of first-order phase transition systems, via the use of the Bean-Rodbell [6] model. Disorder is shown to "smooth" the discontinuities on magnetization and dSM, and also affect magnetic hysteresis. For sufficiently large disorder, the dSM(T) curves resemble the distribution function. We discuss how the magnetic field dependence of dSM is affected by disorder, in light of a "second-order like" dependence of dSM on applied magnetic field, for disordered LaFeSi samples [5]. Aging effects on hydrogenated LaFeSi samples, that degrade even in storage [7], are discussed taking into account our theoretical simulations.

[1] Gschneidner Jr. K. A., Pecharsky V. K., Tsokol A. O., 2005, Rep. Prog. Phys. 58 1479.
[2] Romanov A. Y., V. P. Silin V. P., 1997, Phys. Met. Metallogr. 83, 111.
[3] Amaral J. S. et al., 2008, J. Non-Cryst. Solids 354, 5301.
[4] Bahl C. R. H., et al., 2011, J. Magn. Magn. Mat. 324 564.
[5] Lyubina J. et al., 2011 Phys. Rev. B. 83 012403.
[6] Bean C. P., Rodbell D. S., 1962, Phys. Rev. 126 104.
[7] Barcza, A. et al., 2011, IEEE Trans. Magn. 47 3391.

12.00 – 12.15
Magnetic force microscopy study of magnetization reversal in NdFeB-based hard magnetic films
G. Ciuta [1], F. Dumas-Bouchiat [1], N.M. Dempsey [1], O. Fruchart [1], D. Givord [1]
(1) Néel,CNRS,Grenoble,France

Magnetic force microscopy is an appropriate tool to study the formation and evolution of magnetic domains during magnetization reversal due to its nanometer scale resolution. When films are studied, there is no need for special sample preparation steps such as polishing, which could introduce defects that may affect the reversal process.
The increased market demand for NdFeB-based magnets operational at elevated temperatures has revived the scientific interest in this type of material. Much effort is now going into enhancing the coercivity of NdFeB-based magnets containing little or no heavy rare earth additions. We have used high rate triode sputtering to prepare thick NdFeB-based films (5um) with varied microstructures [1]. The virgin magnetic domain structures of as-deposited (amorphous, soft) and annealed (crystallized, hard) films were studied using magnetic force microscopy [2].

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In this paper we will report on the evolution of the magnetic domain structure in NdFeB-based films by MFM imaging in different remanent states. A comparison of domain evolution in films with different values of coercivity (0.2T - 2.6T) will be made. This study will contribute to understanding the link between microstructure and coercivity in these technologically important materials.

[1] N.M. Dempsey, A. Walther, F. May and D. Givord, K. Khlopkov and O. Gutfleisch, Appl. Phys. Lett. 90 092509 (2007)
[2] T.G. Woodcock, K. Khlopkov, A. Walther, N. M. Dempsey, D. Givord, L. Schultz and O.Gutfleisch, Scripta Materialia 60 (2009) 826–829

12.15 – 12.30
The magnetocaloric effect in hematite nanoparticles
L. Caron [1], D. Peddis [2], L. Suber [3], D. Fiorani [3], P. Nordblad [4]
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Recently, hematite α-Fe_2O_3 nanoparticles have been attracting increasing attention due to a variety of possible applications such as gas sensors, catalysts and water splitting treatments, to name only a few.
Hematite crystallizes in the corundum structure and is antiferromagnetic below $T_N \sim 960$ K. At around 263 K a spin reorientation from the a-axis to the c-axis (with decreasing temperature) takes place. While keeping the antiferromagnetic arrangement a small canting of the spins also occurs resulting in a weakly ferromagnetic response in a phenomenon called Morin transition [1]. The Morin temperature (T_M) is extremely sensitive to variations of stoichiometry and lattice parameters as well as to induced strains and stresses. In hematite, particle size acts as negative pressure, increasing the lattice parameters and thus pushing T_M towards lower temperatures [2]. Although the magnetic properties of hematite have been extensively studied, the entropy change related to its first-order spin reorientation transition has never been measured. Several characteristics are favorable for magnetocaloric applications: T_M can be easily tuned using particle sizes, the nanoparticles high surface-area-to-volume ratio maximizes heat exchange and T_M itself is highly sensitive to the applied magnetic field.
In this work we report on the magnetocaloric properties of rhombohedral-shaped hematite nanoparticles ($\langle D \rangle \cong 62$ nm). The transition, that at zero field occurs at 186 K (on heating), shifts at a rate higher than -10 K/T, compared to 4 K/T presented by the most promising magnetocaloric materials [3]. The entropy change, 18 mJ/kgK at a 2 T field change, while small may be of interest for dedicated applications.

[1] F.J. Morin, *Phys. Rev.* **78**, 819 (1950).
[2] D. Schroeer and R.C. Nininger, *Phys. Rev. Let.* **19**, 632 (1967).
[3] E. Brück, Handbook of Magnetic Materials, Vol. 17, chapt. 4 (2007).

12.30 – 12.45
Multiscale Characterisation and Modelling in Nd-Fe-B Sintered Magnets
T. Woodcock [1], Q. Ramasse [2], G. Hrkac [3], T. Schrefl [4], *O. Gutfleisch* [5]
(1) IFW Dresden, PO Box 270116, 01171 Dresden, Germany, (2) SuperSTEM Laboratory, STFC Daresbury Campus, Keckwick Lane, Daresbury WA4 4AD, UK, (3) Department of Engineering Materials, University of Sheffield, Mappin Street, Sir Robert Hadfield Building, Sheffield, S1 3JD, UK, (4) St. Pölten University of Applied Sciences, Matthias Corvinus Str. 15, St. Pölten, A-3100, Austria, (5) TU Darmstadt, Institute for Materials Science, Petersenstr. 23, 64287 Darmstadt, Germany

Nd-Fe-B sintered magnets play an important role in energy applications such as hybrid electric vehicles and wind turbines. Dy is often partially substituted for Nd in $Nd_2Fe_{14}B$ in order to obtain sufficient coercivity (H_c) at the elevated temperatures required by these applications. The disadvantages of Dy substitution are the decrease in remanence which results from the antiparallel coupling of Dy and Fe, and the current high costs of heavy rare earth elements. Production of Dy-free Nd-Fe-B magnets with high H_c, suitable for high temperature applications, requires greater understanding of the H_c mechanism. The microstructure of Nd-Fe-B sintered magnets contains features of interest which range in size from ~ 1 nm thick, Nd-rich grain boundary phases to ~ 5 µm $Nd_2Fe_{14}B$ grains. Characterisation combined with modelling on multiple length scales is therefore required.
Aberration-corrected scanning transmission electron microscopy (STEM) has been used to obtain highest spatial resolution "z-contrast" images of interfaces between the $Nd_2Fe_{14}B$ and Nd-rich grains in Nd-Fe-B sintered magnets. Composition profiles, resolving the chemical information from individual lattice planes have been measured using electron energy loss spectroscopy (EELS). Atomistic simulations based on these results predict the presence of distorted regions of $Nd_2Fe_{14}B$, leading to local changes in the magnetic anisotropy, which may have a detrimental effect on coercivity. On a larger length scale, electron backscatter diffraction (EBSD) and finite element modelling (FEM) have been used to study magnetic reversal in ensembles of grains around a large Nd_2O_3 grain. The results showed that a higher H_c is predicted for the cubic (Ia3) structural variant of Nd_2O_3 than the rhombohedral variant (hP5). This observation indicates that some Nd-rich phases at grain junctions may be more detrimental to H_c than others.

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12.45 – 13.00

Magnetic properties and the inverse magnetocaloric effect in $Mn_3Ga_{1-x}Pt_xC$ at the magnetostructural transition

Ö. Cakir [1], M. Acet [2]
(1) Physics department, Yildiz Technical University, 34210 Istanbul,Turkey, (2) Physics Dept., Duisburg Essen University, 47048 Duisburg, Germany

The ferromagnetic to antiferromagnetic transition on decreasing temperature in the antiperovskite $Mn_3Ga_{1-x}Pt_xC$ is accompanied by a structural distortion which leads to thermal hysteresis. This magnetostructural transition occurs in the temperature range $150 \leq T \leq 170$ K and has a thermal hysteresis-width of about 4-10 K as observed from magnetization measurements. The transition shifts to lower temperature under higher applied fields. This shift is accompanied by a field-induced reverse transformation from the antiferromagnetic to the ferromagnetic state, giving rise to the inverse magnetocaloric effect. We study the inverse magnetocaloric effect, both by determining the entropy change from magnetization isotherms and by direct adiabatic temperature-change measurement around the transition. We further study the properties of the effect of the thermal hysteresis on the inverse magnetocaloric effect.

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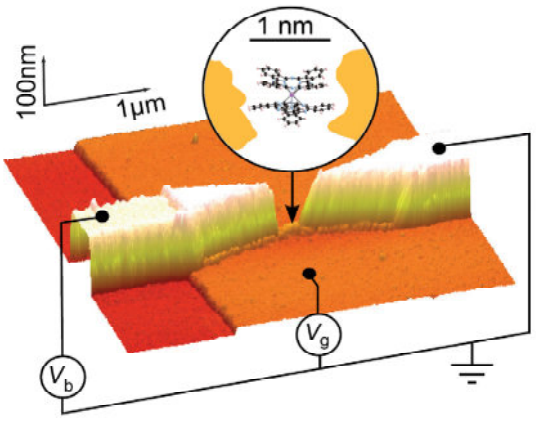
10.30 – 11.00

Molecular Quantum Spintronics using Single-Molecule Magnets *(invited)*

W. Wernsdorfer [1]
(1) Institut Néel, CNRS, BP 166, 38042 Grenoble Cedex 9, France

A revolution in electronics is in view, with the contemporary evolution of three novel disciplines, spintronics, molecular electronics, and quantum computing. A fundamental link between these fields can be established using molecular magnetic materials and, in particular, single-molecule magnets [1], which combine the classic macroscale properties of a magnet with the quantum properties of a nanoscale entity. The resulting field, molecular quantum spintronics aims at manipulating spins and charges in electronic devices containing one or more molecules. The objective is to fabricate, characterize and study molecular devices in order to read and manipulate the spin states of one or several molecules and to perform basic quantum operations. The visionary concept of molecular quantum spintronics is underpinned by worldwide research on molecular magnetism and supramolecular chemistry, and in particular within the European Institute of Molecular Magnetism (http://www.eimm.eu/).
During the last years, we already demonstrated the first important results in this new research area. For example, we have built a novel spin-valve device [2] in which a non-magnetic molecular quantum dot, consisting of a Single-Wall Carbon Nanotube contacted with non-magnetic electrodes, is laterally coupled *via* supramolecular interactions to a $TbPc_2$ molecular magnet. We observed a magnetic field-dependent modulation of the conductance with magnetoresistance ratios of up to 300 %. Using a molecular spin-transistor [3], we also achieved the electronic read-out of the nuclear spin of an individual metal atom embedded in a single-molecule magnet (SMM). We could show very long spin lifetimes (> 10 s). Our results open up prospects for new spintronic devices with quantum properties.

[1] L. Bogani, W. Wernsdorfer, *Nature Mat.* **7,** 179 (2008)
[2] M. Urdampilleta, S. Klyatskaya, M.-P. Cleuziou, M. Ruben, W. Wernsdorfer, *Nature Mater.* ***10*****,** 502 (2011)
[3] R. Vincent, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro**,** submitted



Molecular spin-transistor

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Chair: R. Winpenny

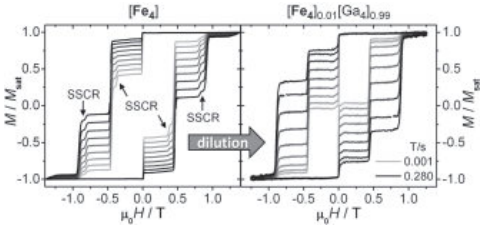
11.00 – 11.15

The realization of magnetic dilution in crystals of polynuclear single-molecule magnets

A. Cornia [1], L. Vergnani [1], A.L. Barra [2], P. Neugebauer [2], M.J. Rodriguez-Douton [1], R. Sessoli [3], L. Sorace [3], W. Wernsdorfer [4]
(1) Dipartimento di Chimica & UdR INSTM, Università di Modena e Reggio Emilia, 41100 Modena, Italy, (2) LNCMI, CNRS & Université Joseph Fourier, 38042 Grenoble Cedex 9, France, (3) Dipartimento di Chimica "Ugo Schiff" & UdR INSTM, Università di Firenze, 50019 Sesto Fiorentino, Italy, (4) Institut Néel, CNRS & Université Joseph Fourier, 38042 Grenoble Cedex 9, France

Intermolecular magnetic interactions (IMIs) bias molecular responses and act as important sources of decoherence in crystals of single-molecule magnets (SMMs) [1]. While superexchange couplings are seldom operative in the lattice, dipolar interactions are ubiquitous and require considerable magnetic dilution to be suppressed. Among amorphous diamagnetic matrices, organic polymers and frozen solvents can host spatially well-separated molecules but they afford poorly resolved hysteresis loops due to orientational disorder. Better suited are crystalline solid solutions prepared from SMMs and isomorphous diamagnetic analogues. So far, this strategy was not applied to polynuclear SMMs due either to failure to prepare the corresponding diamagnetic complexes or to the formation of heterometallic species via metal scrambling.
We have now successfully incorporated a tetrairon(III) SMM (S=5) in the lattice of its tetragallium(III) analogue at doping levels down to 1% molFe_4 without detectable metal scrambling. The guest species retain the same spin and anisotropy as pure Fe_4, but dilution leads to a profound reshaping of hysteresis loops in the quantum tunneling (QT) regime. Upon dilution, the main resonant transitions become sharper and QT probabilities change significantly. In addition, satellite resonances observed in pure Fe_4 disappear completely, in agreement with a spin-spin cross relaxation (SSCR) mechanism mediated by IMIs [2]. These changes have been explained by calculation of internal dipolar fields and provide a clear experimental picture of the impact of IMIs on SMM behaviour [3]. At the same time, samples containing magnetically-diluted and iso-oriented SMMs represent welcome systems for the coherent manipulation of giant spins, a hot topic in quantum information processing.

[1] S. Takahashi, et al., Nature 476, 76 (2011)
[2] W. Wernsdorfer, et al., Phys. Rev. Lett. 89, 197201 (2002)
[3] L. Vergnani, et al., Chem. Eur. J. 18, 3390 (2012)



Hysteresis loops recorded on Fe_4 in pure (left) and diluted (right) form at 40 mK

11.15 – 11.30

Exchange and Anisotropy in a Room-Temperature Molecular Magnet. An ab initio approach

F. Cimpoesu [1], B. Frecus [2], C.I. Oprea [3], *M.A. Girtu* [3]
(1) Department of Theoretical Chemistry, Institute of Physical Chemistry, Bucharest 060021, Romania, (2) Department of Theoretical Chemistry, Royal Institute of Technology, Stockholm S-106 91, Sweden, (3) Department of Physics, Ovidius University of Constanța, Constanța 900527, Romania

We present a consistent set of models and calculations providing the exchange coupling constant and the magnetic anisotropy of a room-temperature molecular magnet $V[TCNE]_2$ (TCNE = tetracyanoethylene). Density Functional Theory (DFT) calculations with periodic boundary conditions indicate antiparallel spin alignment between the spin on the V(II) ion and the spins on the two corresponding $[TCNE]^-$ radicals, resulting in ferrimagnetic ordering. As broken symmetry DFT methods heavily overestimate the value of the exchange coupling we performed *ab initio* multiconfiguration calculations on smaller molecular models cut from the optimized crystal lattice and obtained better estimates of the exchange coupling parameters, J, in the expected range of -175 to -150 K. We explain intuitively, on a simple chemical basis, the mechanism for antiferromagnetic coupling in this room-temperature molecular magnet, in terms of the orbital pathways approach. The modeling of the effects due to the immediate environment of the V(II) ions yield a $10Dq$ ~18400 cm^{-1} Ligand Field parameter, which compares well with the experimental estimation, of about 20000 cm^{-1}. Adding the Spin Orbit effects, we calculate the magnetic anisotropy of the system explaining the small uniform zero-field-splitting (D = -0.03 K) of the bulk. A key issue of our modeling is the explanation offered for the propensity of the proposed crystal structure to undergo disorder and defects, which correlates well with the random anisotropy behavior, observed experimentally. The sites at which a ligand vacancy occurs show sensibly enhanced anisotropy (D = 0.45 K). Band DFT calculations provided the density of states and showed that the upper valence states exhibit a significant hybridization between V(3d) and TCNE π* orbitals, in agreement with spectroscopy studies.

11.30 – 11.45

The ground states of molecule-based magnets revealed with muon spectroscopy

T. Lancaster [1], J.S. Moeller [2], S.J. Blundell [2], F. Pratt [3], J. Manson [4]
(1) Department of Physics, University of Durham, DH1 3LE Durham, UK, (2) Department of Physics, University of Oxford, OX1 3PU Oxford, UK, (3) ISIS Facility, STFC Rutherford Appleton Laboratory, OX11 0QX Didcot, UK, (4) Department of Chemistry and Biochemistry, Eastern Washington University, 99004 Washington, USA

Muons are subatomic particles that may be implanted in materials and used as sensitive magnetometers. In many cases, muons have been shown to be sensitive to magnetic transitions that are invisible to more conventional magnetometry. This is especially useful in low-dimensional and frustrated magnetism where strong thermal and quantum fluctuations make transitions to states of long-range magnetic order difficult to observe.
Here we show how muon-spin relaxation has been used to identify magnetic transitions in several examples of molecular magnetic material (Fig. 1). This includes the observation of long-range order in magnetic coordination polymers based on Cu^{2+}

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centres linked with pyrazine ligands. In such systems, exemplified by the series $[Cu(HF_2)(pyz)_2]X$, magnetic interactions are constrained to act in reduced dimensions leading to low-dimensional magnetic behaviour. Moreover, small changes in structure can promote quite different magnetic dimensionality, allowing us to tune the ground state of the system. In addition, we show how measurements made in applied magnetic fields allow us to reveal an unusual non-monotonic phase boundary that are thought to have a topological origin[1].
We also discuss how muons may be used to probe the properties of more exotic magnetic ground states found in molecule-based magnets, including the fluctuations of molecular nanomagnets[2], disorder and spin diffusion in one-dimensional spin-chains and the phase diagram of the quantum spin liquid κ-$(BEDT\text{-}TTF)_2Cu(CN)_3$[3].

[1] A.J. Steele *et al*., *Phys Rev B* 84 064412 (2011)
[2] T. Lancaster *et al*. *Phys Rev B* 81 140409(R) (2010)
[3] F.L. Pratt *et al*., *Nature* 471 612 (2011)

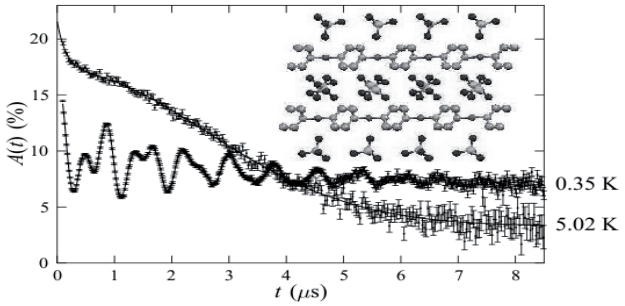
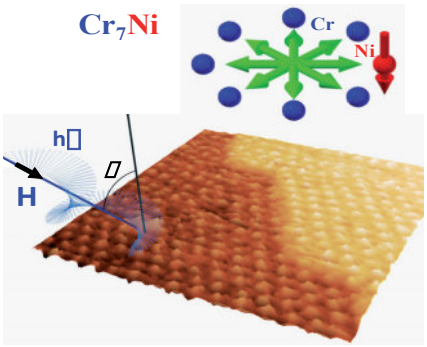


Fig 1: Muon-spin relaxation reveals magnetic order in $Cu(pyz)_2(ClO_4)_2$ below T_N=4.2 K.

11.45 – 12.00
Magnetic anisotropy of Cr_7Ni spin clusters on surfaces
V. Corradini [1], A. Ghirri [1], E. Garlatti [2], R. Biagi [3], V. De Renzi [3], U. Del Pennino [3], V. Bellini [1], S. Carretta [4], P. Santini [4], G. Timco [5], R.E.P. Winpenny [5], M. Affronte [3]
(1) S3 Centre, Institute Nanoscience - CNR, via G. Campi 213/A, 41125 Modena (I), (2) Dipartimento di Scienze Molecolari Applicate ai Biosistemi, Università di Milano, via Trentacoste 2, 20134 Milano (I), (3) Dipartimento di Fisica, Università di Modena e Reggio Emilia, via G. Campi 213/A , 41125 Modena (I), (4) Dipartimento di Fisica, Università di Parma, v.le delle Scienze, 43100 Parma (I), (5) School of Chemistry and Photon Science Institute, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

We address here the problem of the experimental and theoretical determination of magnetic anisotropy in isolated molecular spin clusters. To this end, we consider the case of molecular Cr_7Ni rings sublimated in UHV conditions and assembled in ordered fashion on Au(111) surface [1] and we investigate it by X-ray magnetic dichroism (XMCD) and theoretical calculations. Fixing the experimental conditions at T=8K and magnetic field 5T, the angular-dependence of the dichroic signal reveals an easy-axis anisotropy for the Ni magnetization along the direction perpendicular to the ring whilst the magnetization of the whole Cr_7Ni molecule results preferentially aligned within the ring plane. These features are well reproduced by spin Hamiltonian simulations wich essentially reflect the character of the S=3/2 first excited multiplet, which dominates at T=8K and 5T. DFT calculations show that local spin orbit interactions determine an easy axis anisotropy at the Ni site while the Cr magnetic moment turns out to be more isotropic. This is, to our knowledge, the first direct observation of the interplay between the single ion and the overall magnetic anisotropy in complex (polynuclear) molecular systems.

[1] A. Ghirri, V. Corradini, V. Bellini, R. Biagi, U. del Pennino, V. De Renzi, J. C. Cezar, C. A. Muryn, G. A. Timco, R. E. P. Winpenny, and M. Affronte, ACS Nano. 2011, 5, 7090.



STM image of a complete self-assembled monolayer of Cr_7Ni-bu on Au(111) surface.

12.00 – 12.15
LT-MFM Characterization of Prussian Blue Analogues
S. Kumar [1], E. Pinilla-Cienfuegos [1], J.P. Prieto-Ruiz [1], A. Forment-Aliaga [1], H.P. Garcia [1], E. Coronado [1]
(1) Instituto Ciencia Molecular (ICMol). University of Valencia

Prussian Blue Analogues (PBA) are a family of molecule-based magnetic compounds of general formula $A_xM_y[M'(CN_6)]_z$, (where A is an alkali-metal cation and M and M' are transition metal ions) whose magnetic properties can be tuned by an external stimulus. This tunability makes PBA good candidates for their integration into new electronic or spintronic devices. Even though the study of PBA has traditionally been limited to bulk compounds, lately they have also been processed onto surfaces as films[1] and more recently into nanoscale particles[2] opening the possibility of using them for the development of new electronic or spintronic devices. A Low-temperature Magnetic Force Microscope (LT-MFM) was used to characterize the PBA compounds having different morphologies on surfaces. LT-MFM was used due to its ability to characterize magnetic behavior of materials depending on their size distribution [3]. The PBA films which were electrochemically deposited on Si/SiO_2 (native oxide) showed long range ferrimagnetic behavior below their critical temperature (Tc=240K). Whereas, a more confined superparamagnetic behavior was observed in the case of nanoscale particles below their blocking temperature (T_B=9K)

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which were self-assembled on functionalized Si surface. No prominent magnetic features were observed in either cases above the critical temperature (for films) or blocking temperature (for nanoscale particles).

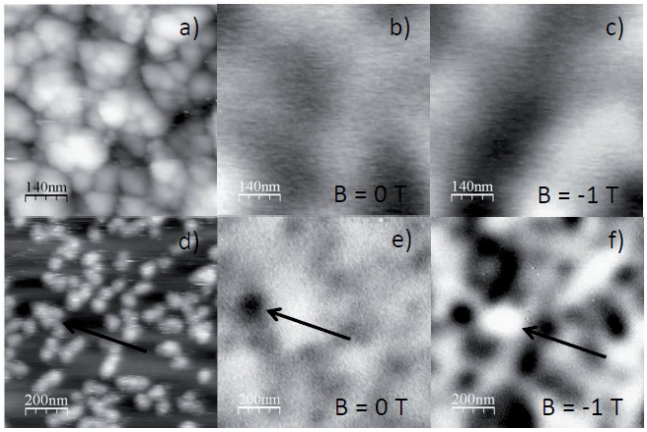

Figure 1: LT-MFM of PBA thin film (a, b and c) and on nanoscale particles (d, e and f).

[1] a) J. T. Culp et al., Coord. Chem. Rev. **249**, 2642-2648 (2005); b) E. Coronado et al., Adv. Mater. **23**, 4323–4326 (2011)
[2] a) S. Vaucher et al., Angew. Chem. Int. Ed. **39**, 1793-1796 (2000); b) S. Vaucher et al., Nano. Lett. **2**, 225-229 (2002)
[3] a) P M. Liebmann et al., Phys. Rev. B **71** 104431 (2005); b) I. Schmid, et al., Phys. Rev. Lett. **19**, 197201 (2010).

12.15 – 12.30

$Gd(hfac)_3NITEt$ fully frustrated XY Helimagnet: a NMR investigation

M. Mariani [1], A. Lascialfari [2], A. Caneschi [3], D. Gatteschi [3], M.G. Pini [4], A. Rettori [5]
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The family of quasi-1D molecular magnetic chains $Gd(hfac)_3NITR$ (hfac is hexafluoro-acetylacetonate and NITR is 2-R-4,4,5,5-tetramethyl-4,5-dihydro-1H-imidazolyl-l-oxyl 3-oxyde) has been intensively studied in the last 10 years. These systems consist in a regular alternated pattern of $Gd(hfac)_3$ moieties (S_{Gd}=7/2) and nitronyl-nitroxide organic radicals *NITR* (R = iPr, Et, Ph, Me) (s_{rad}=1/2) [1][2] where the shortest interchain distance is ~10.5Å and, thus, the ratio between interchain and intrachain exchange interactions is $J_{inter}/J_{intra}<10^{-5}$ [1]. In the compound with the R=Ethyl group (in short Gd-Et) the frustration between *nn* and *nnn* intrachain exchange interactions is strong [3]. To implement the study of spin dynamics begun with the μSR experiments and to confirm the occurrence of a 3D phase transition, we present here a low temperature NMR investigation of Gd-Et performed through ^1H nuclear spin-lattice relaxation rate (NSLR) $1/T_1$ and ^1H absorption spectra measurements at low applied magnetic field H=0.1T, in order to be far from the critical field (H_c≅2.06T), where a distortion of the spin arrangement takes place. The transition to the 3D long-range magnetic phase is confirmed to occur at ~1.9K. NSLR shows a sharp peak at the transition temperature T~1.9K, giving evidence of an anomaly in the two-spin correlation function; the NMR ^1H spectra present a full width at half maximum (FWHM) that remains small (~100 kHz) for T>1.9K while just below the transition temperature becomes suddenly much larger (>1 MHz), due to the insurgence of a local field H_{loc} at protons sites, generated by the ordered arrangement of the electronic spins.

[1] A. Caneschi et al. Inorg. Chem. 27 (1988) 1756
[2] C. Benelli et al. Inorg. Chem. 29 (1990) 4223
[3] M. Affronte et al. Phys. Rev. B 59 (1999) 6282

12.30 – 12.45

Magnetic Anisotropy in a Series of DOTA-based Single Ion Magnets of Lanthanides

M.E. Boulon [1], G. Cucinotta [1], C. Degl'Innocenti [1], M. Perfetti [1], J. Luzon [2], R. Sessoli [1]
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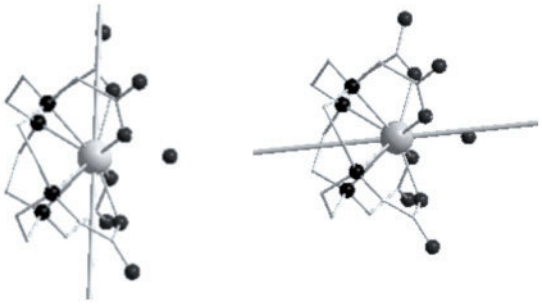
The DOTA ligand (1,4,7,10-tetraazacyclododecane-N,N',N'',N'''-tetraacetate) provides a coordination environment with the idealized tetragonal symmetry [1] and the complexes formed with lanthanides are particularly stable, which is a key point in the use of the Gd(DOTA) as a contrast agent for magnetic resonance imaging. In another field, lanthanides based Single Ion Magnets (SIM) are very investigated due to their large magnetic moment and their strong magnetic anisotropy.
The series of isostructural DOTA lanthanide complexes allows investigating the correlation between the shape of the 4f electron density and the magnetic behavior of the compound [2].
In order to measure the magnetic properties and the uniaxial anisotropy in relation to the nature of the lanthanide we have synthesized a series of DOTA complexes. Along the series, surprisingly no slow magnetization dynamics has been observed for Ho and Tb, neither in the diluted samples, whereas Dy, Er and Yb exhibit field induced SIM behavior.
Moreover, the investigation of the angular dependency of the magnetization [3] reveals significant changes in the orientation of the anisotropy tensor (Figure 1) correlated to equatorial distribution of the negative charges on the DOTA ligand.
*) The research has been supported by the European Research Council through the AdGMolNanoMaS.

[1] F. Benetollo, G. Bombieri, S. Aime, M. Botta, Acta Crystallogr. Sect. C 55, 353 (1999)
[2] J. D. Rinehart, J. R. Long, Chem. Sci. 2, 2078, (2011)
[3] G. Cuccinotta, M. Perfetti, J. Luzon, M. Etienne, P.-E. Car, A. Caneschi, G. Calvez, K. Bernot R. Sessoli, Angew. Chem., Int. Ed 51, 1606, (2012)

Friday, 14 September 2012
Macbeth Room

MOLECULAR MAGNETISM

Chair: R. Winpenny



Representation of the easy axe on DyDOTA (left) and on ErDOTA (right) complexes

12.45 – 13.00
Single Molecule Magnet Behaviour in Lanthanides Complexes based on Electroactive Tetrathiafulvalene Ligands

F. Pointillart [1], B. Le Guennic [1], S. Golhen [1], O. Cador [1], O. Maury [2], L. Ouahab [1]
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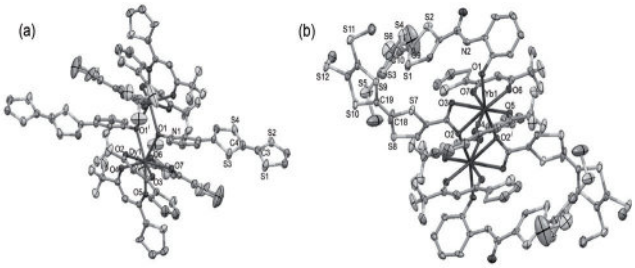
Since the discovery of TTF in early 1973, many interesting materials have been obtained as organic metals, semi-conductors, superconductors, magnets, and so on. In the last decade, TTF derivatives have been associated to *d* metal ions to elaborate multifunctional materials which possess magnetic and electrical properties.
Lanthanide ions are also well-known to exhibit strong magnetic anisotropy and therefore they are considered as good candidates for the elaboration of Single Molecule Magnets (SMM). We have associated the tetrathiafulvalene-3-pyridine-*N*-oxide ligand to the Ising Dy(III) ions producing a centrosymmetric dinuclear complex (see figure (a)) in which the magnetic moments are antiferromagnetically coupled. Surprisingly, the complex behaves as an electro-active SMM with both strong frequency dependent out-of-phase signal of the ac magnetic susceptibility and complex butterfly magnetization loop [1].
Dinuclear complexes of lanthanides associating both 4,5-Bis(thiomethyl)-4'-carboxylictetrathiafulvalene and 4,5-Bis(thiomethyl)-4'-*ortho*-pyridyl-*N*-oxide-carbamoytetrathiafulvalene ligands have been elaborated (see figure (b). *Dc* magnetic susceptibility measurements highlight ferromagnetic interactions between the metallic centres. The two oblate Dy(III) and prolate Yb(III)-based analogues display SMM behaviour. Experimental and theoretical magnetic and photo-physical investigations have been realized to confirm that a multi-electroactive luminescent SMM is obtained in the case of the Yb(III) analogue [2].

[1] F. Pointillart, Y. Le Gal, S. Golhen, O. Cador, L. Ouahab, Chem. Eur. J. 17, 10397 (2011)
[2] F. Pointillart, B. Le Guennic, S. Golhen, O. Cador, O. Maury, L. Ouahab, submitted



X-ray structures of the two dinuclear systems which display SMM behaviour

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10.30 – 11.00
Molecular Spintronics: properties beyond inorganics *(invited)*
P. Seneor [1], R. Mattana [1], C. Barraud [1], B. Dlubak [1], S. Tatay [1], M. Galbiati [1], M.B. Martin [1], A. Anane [1], K. Bouzehouane [1], S. Fusil [1], C. Deranlot [1], F. Petroff [1], A. Fert [1]
(1) Unite Mixte de Physique CNRS/Thales, 91767 Palaiseau, France

Organic/molecular spintronics is a rising research field at the frontier between spintronics and chemistry. Beyond, plasticity and low cost, organic materials were first seen as very promising for spintronics devices due to their expected long spin lifetime. While originally overlooked it was later unveiled that opportunities arising from chemistry could also lead to develop new spintronics functionalities. Among them, we have shown the opportunity to tailor spintronics thanks to hybridization of discrete levels available in molecular compounds [1]. While initially developed for Alq3 this could be applied to any molecule. While focusing on tailoring, we will present experiments on carbon based compounds (from small molecules to graphene) addressing those multiple issues: plasticity [2], tailoring [1] and long spin lifetime [3]... This shows evidence that several properties unavailable with inorganic materials can now be achieved by organics.

[1] C. Barraud et al. , Nat. Phys 6 615 2010
[2] C. Barraud et al., Appl. Phys. Lett. 96 072502 2010
[3] B. Dlubak et al., to appear

11.00 – 11.15
Spin-filtering at hybrid organic-inorganic interfaces
S. Steil [1], N. Grossmann [1], N. Haag [1], M. Cinchetti [1], M. Aeschlimann [1]
(1) Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany

Organic semiconductors have demonstrated their potential as a new class of materials for spintronics applications [1]. One of their most intriguing properties is that they form hybrid interfaces with ferromagnetic metals, expected to constitute a new building block for advanced spintronics devices [2]. As an example, we have recently shown that the spin-injection efficiency at the cobalt-copper phthalocyanine interface can be tailored by electron doping [3]. Here, we will show our recent experiments on the interface between the 3d-ferromagnetic metal cobalt and the organic semiconductor tris(8-hydroxyquinoline) aluminium(III) (Alq3). Interface formation was studied by means of spin-resolved ultraviolet photoemission spectroscopy, while the spin- and time-resolved two-photon photoemission spectroscopy was used to measure the spin-dependent lifetime of hot charge carriers excited in an unoccupied hybrid interface state. The absolute value of the lifetime gives information about the degree of hybridization of the considered state. More importantly, we found that the lifetime in such state is spin-dependent, providing direct evidence that hybrid organic-inorganic interfaces can be employed as a novel kind of spin-filter.

[1] V. A. Dediu, et al., Nat Mater. 8, 707 (2009)
[2] S. Sanvito, Nat Phys. 6, 562 (2010)
[3] M. Cinchetti et al., Phys. Rev. Lett. 104, 217602 (2010)

11.15 – 11.30
Interfacial effects on hybrid spintronic devices
I. Bergenti [1], A. Riminucci [1], M. Prezioso [1], P. Graziosi [1], A. Gambardella [1], F. Borgatti [1], A. Dediu [1]
(1) ISMN-CNR, via Gobetti 101, 40129 Bologna, Italy

Combining the advantages of organic semiconductors with the concepts of magnetoelectronics and thereby introducing spin functionalities into organic devices is a very promising step for the development of a generation devices with intrinsic mutifunctionalities[1]. Organic spintronic devices are complex and heterogeneous systems including typically an organic semiconductor sandwiched between two ferromagnetic contacts. The understanding of spin properties of such hybrid organic/ferromagnetic interfaces is one of the key factor for understanding and improving device performances. We present a full characterization of ferromagnetic thin films, both Cobalt (Co) and the complex magnetoresistive oxide $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), and their interfaces with one of most used organic semiconductor, Alq3. The results are then correlated with the magnetoresistive response of the LSMO/Alq3/Co spin valve highlighting the effects of electronic and magnetic correlations. This research received the financial support of FP7 EU project HINTS.

[1[Dediu, V. A.; Hueso, L. E.; Bergenti, I.; Taliani, C. *Nature materials* **2009**, *8*, 707-16.

11.30 – 11.45
Single spin-transition molecules triggered with a STM
M. Gruber [1], T. Miyamachi [2], V. Davesne [1], E. Beaurepaire [3], W. Wulfhekel [2]
(1) Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS-UdS, 67034 Strasbourg, France and Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany, (2) Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany and DFG-Center for Functional Nanostructures, Karlsruhe Institut of Technology, 76128 Karlsruhe, Germany, (3) Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS-UdS, 67034 Strasbourg, France
A nano-scale molecular switch can be used to store information in a single molecule. The conductance of the molecule changes when switched and can be electrically detected. Adding spin functionality to molecular switches is a key concept for realizing molecular spintronic devices. Spin crossover (SCO) molecules consisting of organic ligands around a transition metal ion are known to be switchable between a high- and a low-spin state by external stimuli [1]. It is the ultimate aim to achieve combined spin and conduction switching functionality on the level of individual molecules.
$Fe(1,10\text{-phenanthroline})_2(NCS)_2$ molecules, SCO complexes, were deposited on Cu(100) and CuN/Cu(100) surfaces and

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studied with a scanning tunneling microscope (STM) in ultra-high vacuum at 4K.
Both spin species coexist at low temperatures as deduced from spectroscopic STM data. While on bare Cu(100), the molecules cannot be switched between the two spin states, molecules on CuN can individually and reproducibly be switched between a high-spin, high-conduction state and a low-spin, low-conduction state. This difference is explained by the role of the CuN layer to decouple the molecules from the metallic surface [2].

[1] P. Gütlich et al., Chem. Soc. Rev. 29, 419–427 (2000)
[2] T. Miyamachi et al., submitted.

11.45 – 12.15
Graphene: The best material for spintronics? *(invited)*
B. Van Wees [1]
(1) Zernike Institute of Advanced Materials, University of Groningen, 9747 AG Groningen, The Netherlands

Graphene has been predicted to be an ideal material for spintronics, due to the low abundance of C_{13} (which has a nuclear spin), and the spin-orbit interaction which is predicted to be weak, thus allowing for long spin relaxation times. Combined with the high intrinsic carrier mobility this should lead to long spin relaxation lengths, perhaps even exceeding 100 micrometer.
The standard device to study spin transport in graphene is based on exfoliated graphene on an Si/SiO_2 substrate, where the doped substrate is used as a back gate. In these devices the spin relaxation times were found to be of the order of 100 ps, and the corresponding spin relaxation lenghts of the order of 1 micrometer [1].
To understand the discrepancy with theoretical predictions, we have investigated spin transport and spin relaxation in graphene devices prepared on different substrates. I will give an elementary introduction into spin transport and spin relaxation in graphene. It will be discussed which mechanisms could limit the spin relaxation in graphene (Elliot-Yafet of Dyakonov-Perel). I will discuss recent results on graphene on silicon carbide SiC [2]. These results will be compared with graphene devices with boron-nitride (BN) substrates [3]. Finally we have studied spin transport in fully suspended graphene, which should approach the situation for intrinsic graphene [4].
The maximum spin relaxation lengths obtained sofar (at room temperature) are of the order of 5 micrometer. Although the mechanisms for spin relaxation in graphene are not fully understood yet, the results sofar seem to confirm that graphene can be considered as the best material for spin transport.

[1] N. Tombros et al., Nature 448, 571 (2007)
[2] T. Maassen et al., Nano Letters 12 (3), 1498 (2012)
[3] P. Zomer et al., in preparation
[4] M. Guimaraes et al., submitted to Nanoletters

12.15 – 12.30
Efficient spin transport in epitaxial graphene
M.B. Martin [1], B. Dlubak [1], C. Deranlot [1], B. Servet [2], S. Xavier [2], R. Mattana [1], M. Sprinkle [3], C. Berger [4], W.A. De Heer [3], F. Petroff [1], A. Anane [1], P. Seneor [1], A. Fert [1]
(1) Unité Mixte de Physique CNRS/Thales, 91767 Palaiseau, France and Université de Paris-Sud 11, 91405 Orsay, France, (2) Thales Research and Technology, 91767 Palaiseau, France, (3) School of Physics, Georgia Institute of Technology, Atlanta, GA 30332, USA, (4) School of Physics, Georgia Institute of Technology, Atlanta, GA 30332, USA and CNRS-Institut Néel, 38042 Grenoble, France

Spintronics is a paradigm focusing on spin as the information vector. Ranging from quantum information to zero-power non-volatile magnetism, the spin information can also be translated from electronics to optics. Several spintronics devices (logic gates, spin FET, etc) are based on spin transport in a lateral channel between spin polarized contacts. However while spin is acclaimed for information storage, a paradox is that efficient spin transport has remained elusive.
We will present magneto-transport experiments on epitaxial graphene multilayers on SiC connected to cobalt electrodes through alumina tunnel barriers. The spin signals are in the MΩ range in terms of $\Delta R = \Delta V/I$ [1]. This is well above the spin resistance of the graphene channel. The analysis of the results in the framework of drift/diffusion equations leads to spin diffusion length in graphene in the 100-300 μm range (as high as 285μm) for a series of samples having different lengths and different tunnel resistances. Magnetoresistances up to 10% are observed. In the best case, the spin transport efficiency of epitaxial graphene is found to be of 75% of the ideal channel [1].
Our results show that graphene could be envisioned as a material of choice for transport/processing of spin information and unlock large scale logic circuits. Understanding the mechanism of the spin relaxation, improving the spin diffusion length and also testing various concepts of spin gate are the next challenges.

[1] B. Dlubak, M.-B. Martin, C. Deranlot, B. Servet, S. Xavier, R. Mattana, M. Sprinkle, C. Berger, W. A. De Heer, F. Petroff, A. Anane, P. Seneor and A. Fert, *Nature Physics (accepted)*

12.30 – 12.45
Dynamics and dissipation induced by single-electron tunneling in carbon nanotube nanoelectromechanical systems
M. Ganzhorn [1], W. Wernsdorfer [1]
(1) Institut Neel, Nanoscience Department, CNRS & Universite Joseph Fourier, 38042 Grenoble, France

Carbon nanotubes have become an essential building block for nanoelectromechanical systems (NEMS). Their extraordinary mechanical and electronic properties provide for instance a strong electromechanical coupling compared to semiconductor based NEMS, which is key to various applications, for example high sensitivity mass or force sensing.[1,2]
Here we demonstrate the effect of single-electron tunneling (SET) through a carbon nanotube quantum dot on its nanomechanical motion at cryogenic temperatures. We find that the frequency response and the dissipation of the nanoelectromechanical system (NEMS) to single electron tunnelling strongly depends on the electronic environment

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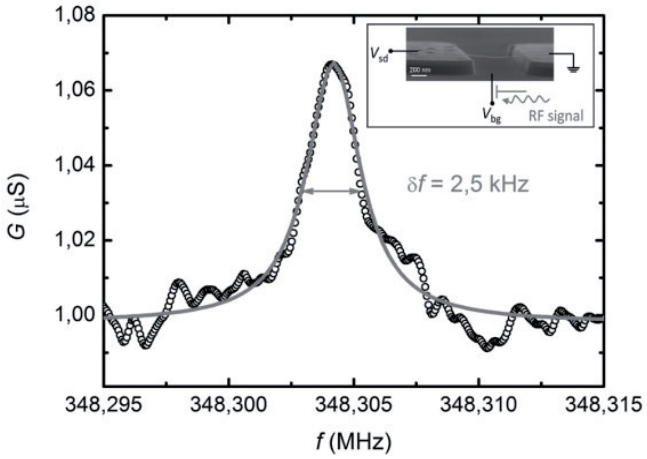
of the quantum dot, in particular on the total dot capacitance and the tunnel coupling to the metal contacts.[3] Our findings suggest that one could achieve quality factors as high as 10^6 by choosing the appropriate gate dielectric and improve the tunnel coupling to the metal contacts. So far, we have achieved quality factors of 140000 at very low temperature, which is the highest value reported for carbon based NEMS at cryogenic temperatures.[2]

[1] B. Lassagne et al., Science 325, 1107 (2009)
[2] M. Poot and H.S.J. van der Zant, Physics Reports 511, 273 (2012)
[3] M. Ganzhorn and W. Wernsdorfer, Phys. Rev. Letts (2012)



A carbon nanotube NEMS (inset) and its mechanical resonance yielding Q = 140000

12.45 – 13.00

C_{60}-based hot-electron magnetic tunnel transistor

M. Gobbi [1], A. Bedoya-Pinto [1], F. Golmar [1], R. Llopis [1], F. Casanova [2], L.E. Hueso [2]
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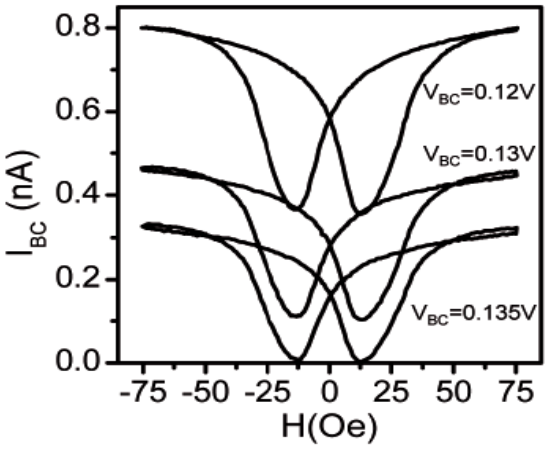
Organic semiconductors (OS) have emerged as a promising material class for spintronic applications [1], mainly due to their weak spin relaxation mechanisms which result in long spin lifetimes. While recent efforts have focused on the spin injection and transport in organic semiconductors, the fact that OSs behave as ordinary semiconductors has not been fully exploited in organic spintronics yet.
In this work, we report the achievement of a magnetic tunnel transistor (MTT) which employs C_{60} as a semiconducting collector. The MTT represents one of the most successful spintronic devices based on the combination between ferromagnetic materials and semiconductors [2]. MTTs are 3-terminal devices with the same scheme of a metal base transistor: a hot electron current is injected into the device by an emitter, and a spin-valve base modulates the amount of current reaching the collector. In this configuration, the current can be modulated not only by the applied gate voltage, but also by the magnetic field (magnetocurrent).
We show that the C_{60}-based MTT, composed of an Al/Al203/Co/Cu/Py/C_{60}/Al multilayer, performs as state-of-the-art inorganic MTT with a magnetocurrent (MC) reaching 89% at room temperature. Moreover, we show that this MC value can be enhanced by the application of a proper voltage VBC at the collector, reaching 8500% (see figure).
These results demonstrate that, for this application, C_{60} behaves as a conventional n-type inorganic semiconductor. In particular, the energy barrier at the C_{60}/metal interface resembles a conventional Schottky barrier, and its height is directly determined.

[1] V. A. Dediu, L. E. Hueso, I. Bergenti, and C. Taliani, Nature Materials, 8 707 (2009)
[2] R. Jansen, *Journal of Physics D: Applied. Physics* 36 R289 (2003)



Magnetocurrent measured in a C60-based magnetic tunnel transistor as a function of the base-collector voltage.

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