European School on Magnetism 2009

Inhomogeneities in magnetic systems

Inhomogeneous magnetic systems: control and applications

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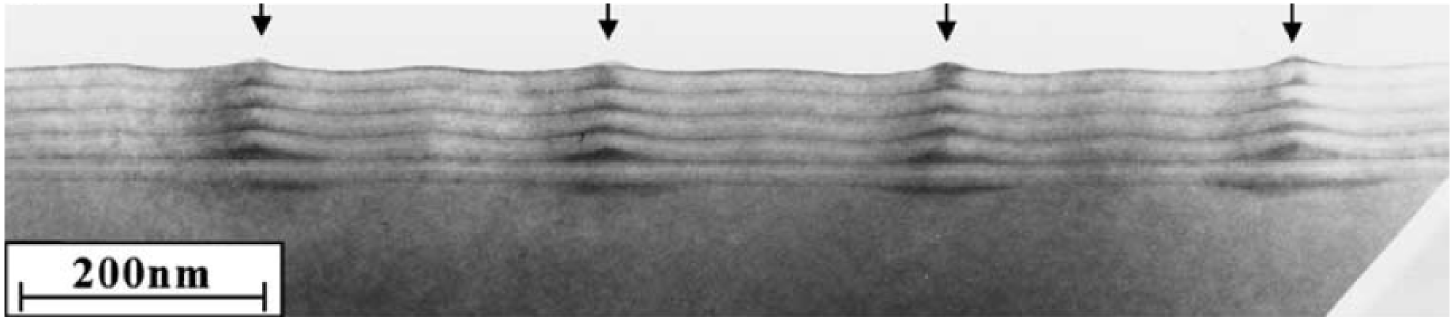
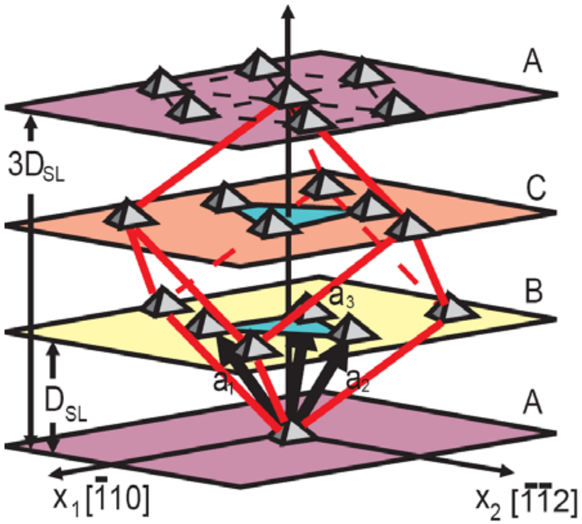
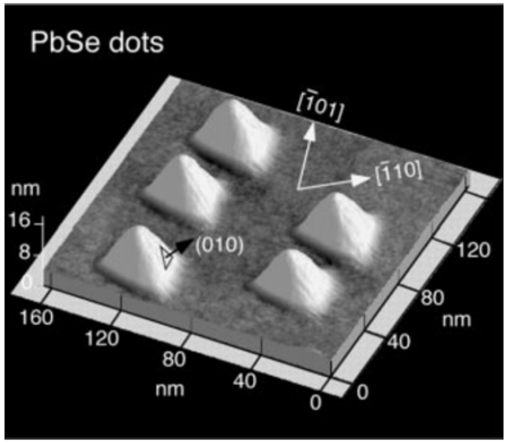
Control over magnetic ions aggregation

Strain



e.g. vertical alignement of InAs QDs in GaAs





PbSe/Pb$_{1-x}$Eu$_x$Te superlattices

G.Springholz *et al.* Science **282**, 734 [1998]

Review: J.Stangl, V.Holý, G.Bauer, Rev.Mod.Phys. **76**, 689 [2004]

Ways to control the aggregation of TM

1] growth rate

2] growth temperature

3] co-doping with donors or acceptors

T. Dietl, Nature Mat. **5**, 673 [2006]

L.H. Ye and A. Freeman, Phys.Rev. B **73**, 81304 [2006]

Why aggregation of magnatic ions?

Unique aspect of our material systems:

- *d*-levels in the gap
- contribute to the bonding
- foster attractive force between magnetic ions
- kinetic barrier to the formation of ferromagnetic nanocrystals

By changing the valency

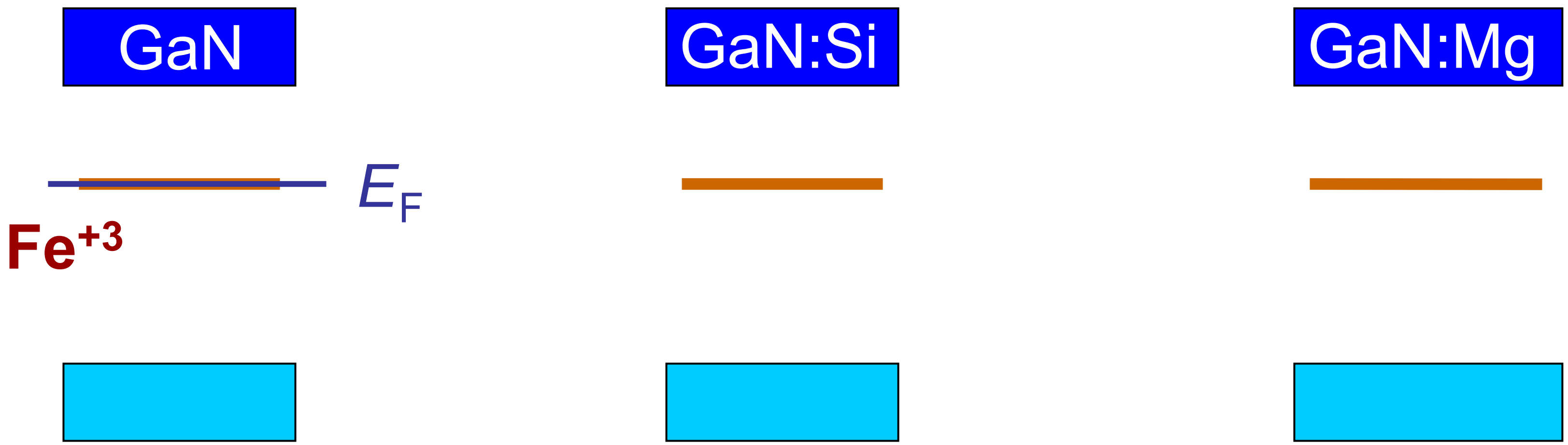
- modification of the attractive force
- influence on the magnetic ions aggregation

3]   co-doping with donors or acceptors

A. Bonanni *et al.* Phys.Rev.Lett. **101**, 135502 [2008]

Control by co-doping

- TM-related states reside in the host band gap
- charge state and intersite Coulomb repulsion can be changed by **co-doping** with shallow impurities
- the Coulomb repulsion between TM ions hinders spinodal decomposition



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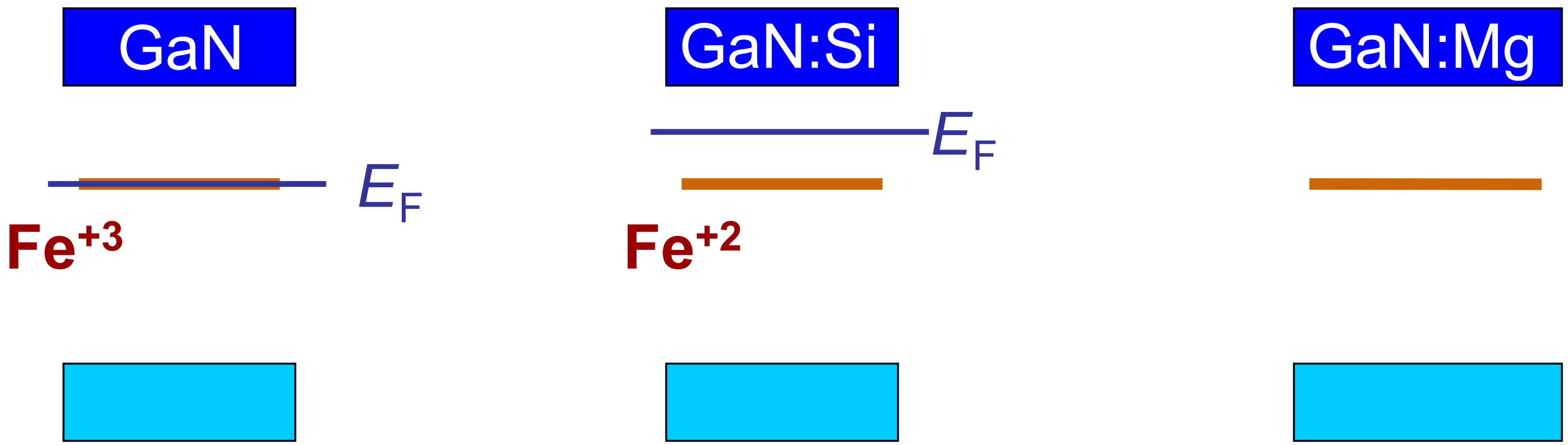

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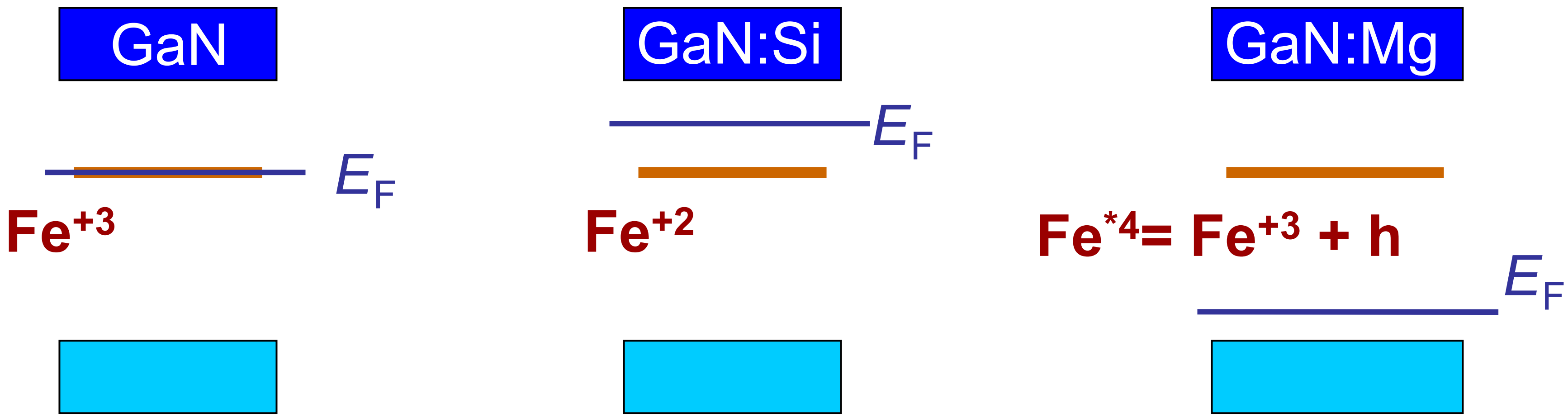
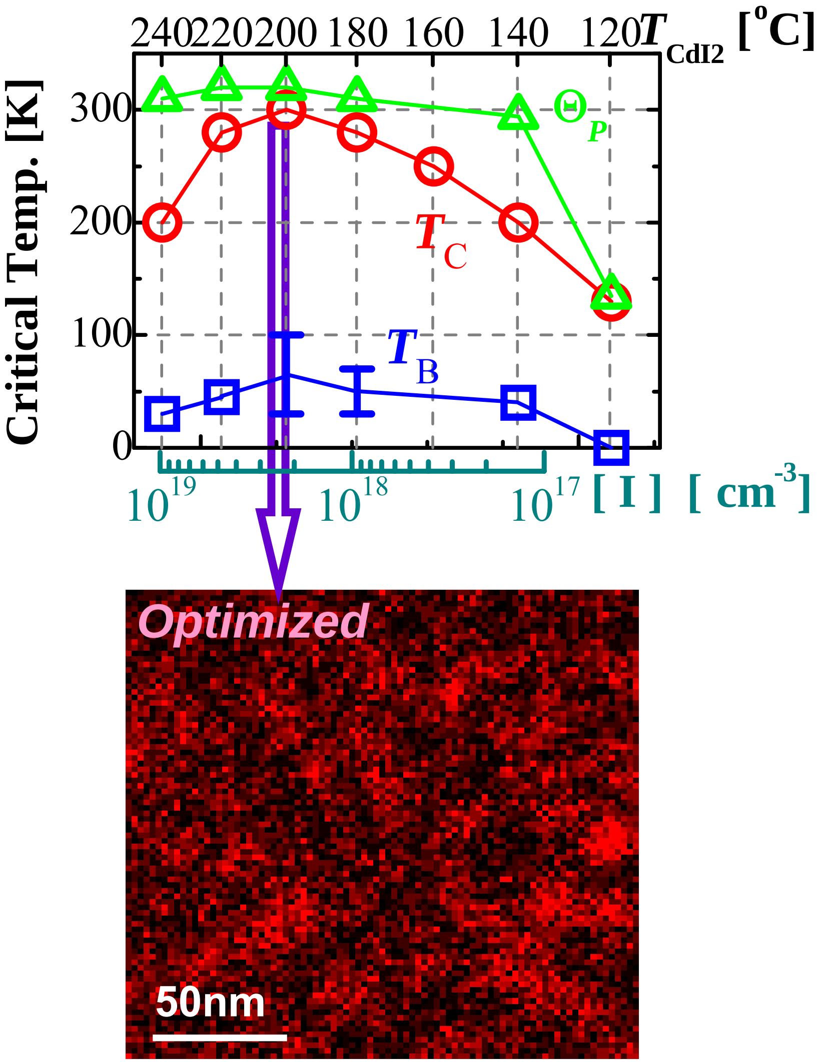
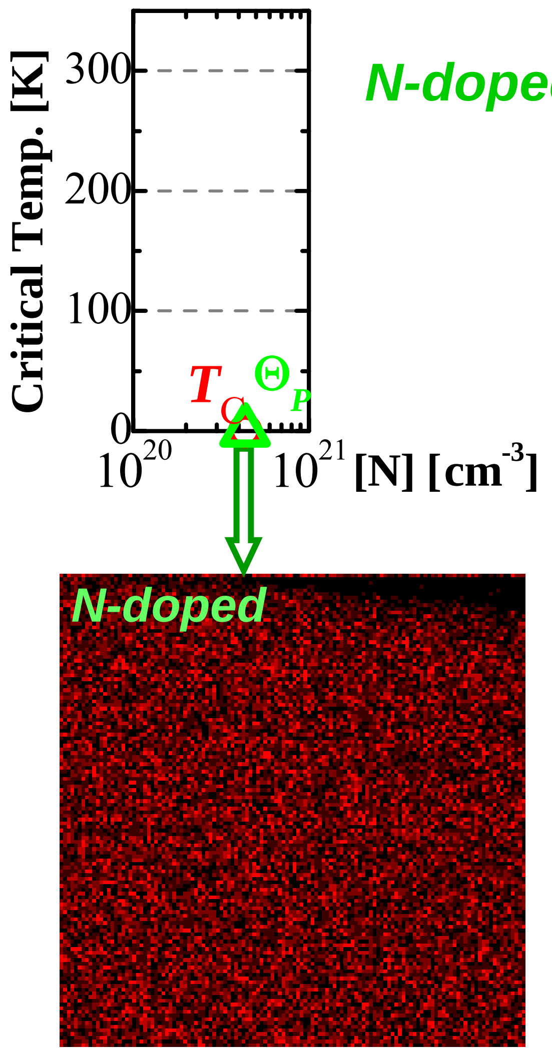


T. Dietl, Nature Mat. **5**, 673 [2006]

(Zn,Cr)Te – effect of codoping on Cr distribution



Inhomogeneous

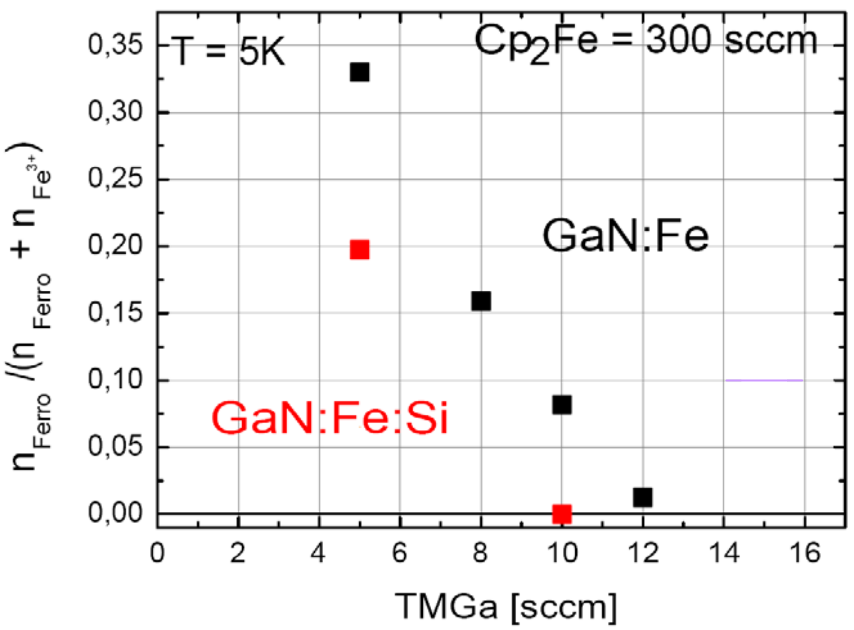


Homogeneous

S. Kuroda *et al*., Nature Mater. **6**, 440 [2007]

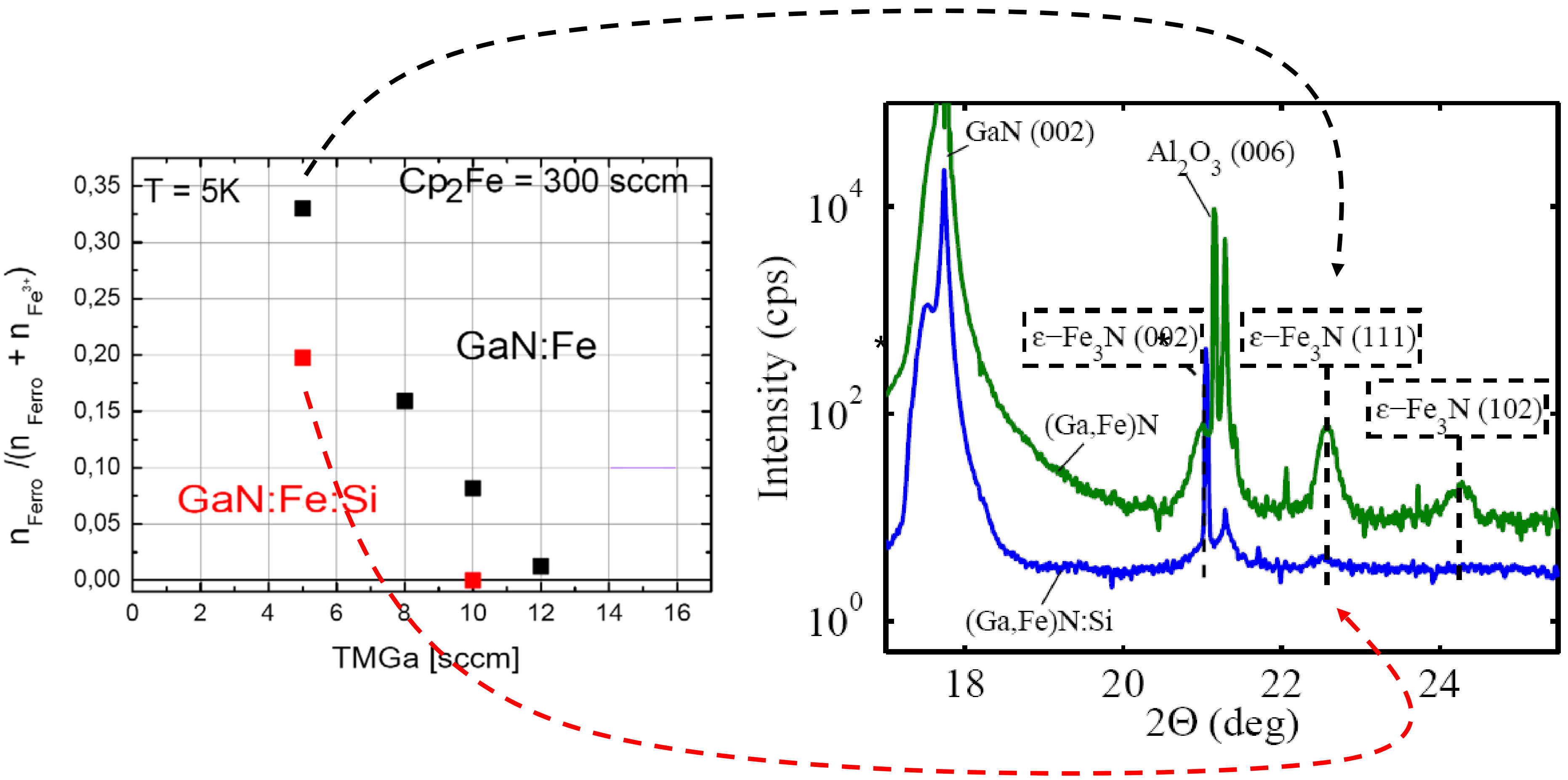
Effect of Si-doping

Quenching of ferromagnetic response



Effect of Si-doping [on secondary phases]

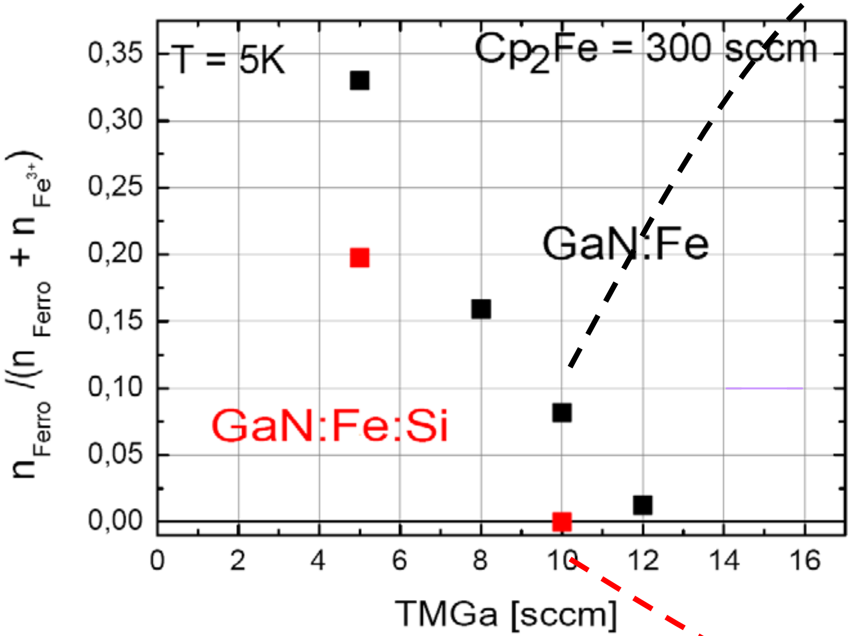
Quenching of ferromagnetic response

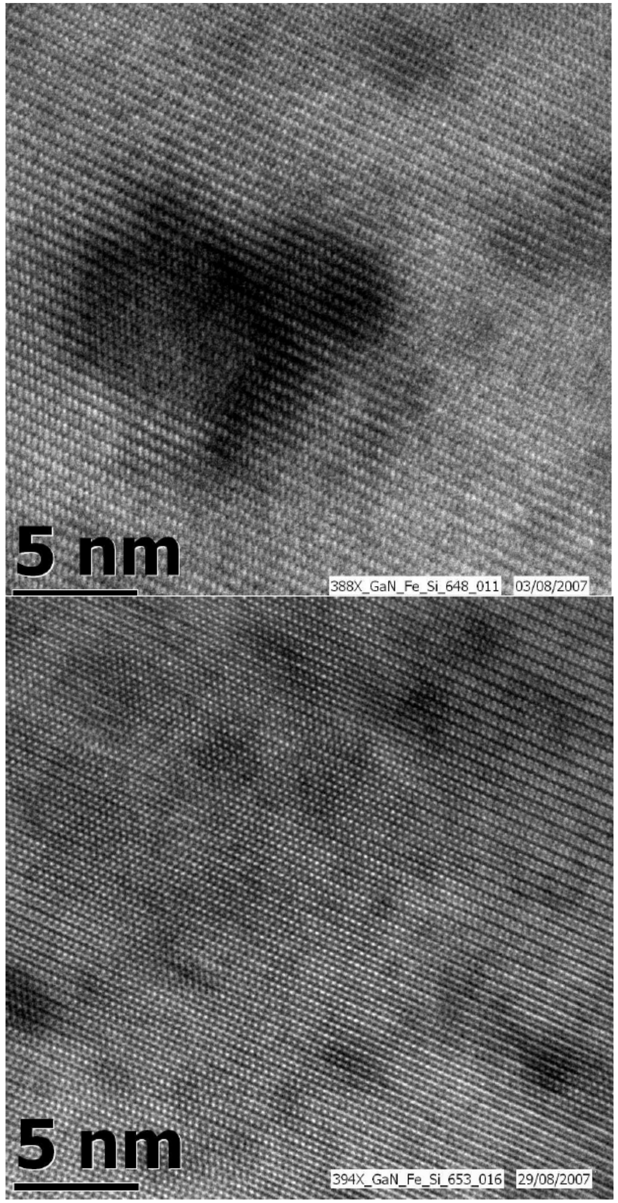


Reduction/dissolution of secondary phases

Effect of Si-doping [on chemical decomposition]

Quenching of ferromagnetic response

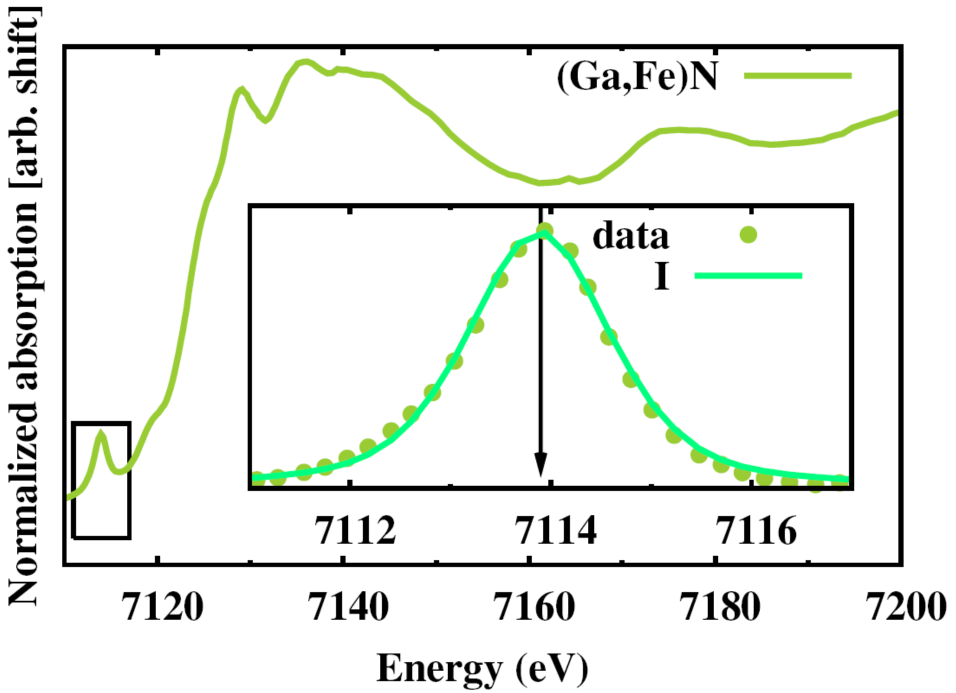




Reduction/dissolution of chemical decomposition

(Ga,Fe)N:Si – synchrotron XANES

Si doping – effect on Fe charge state



M. Rovezzi, ..AB, ...Phys.Rev. B **79**, 195209 [2009]

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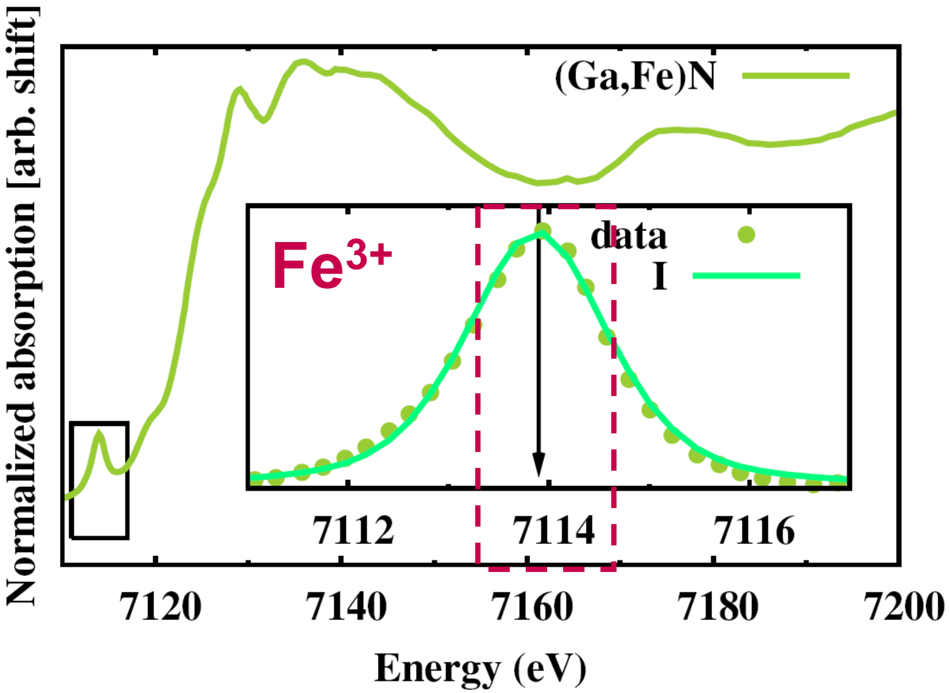

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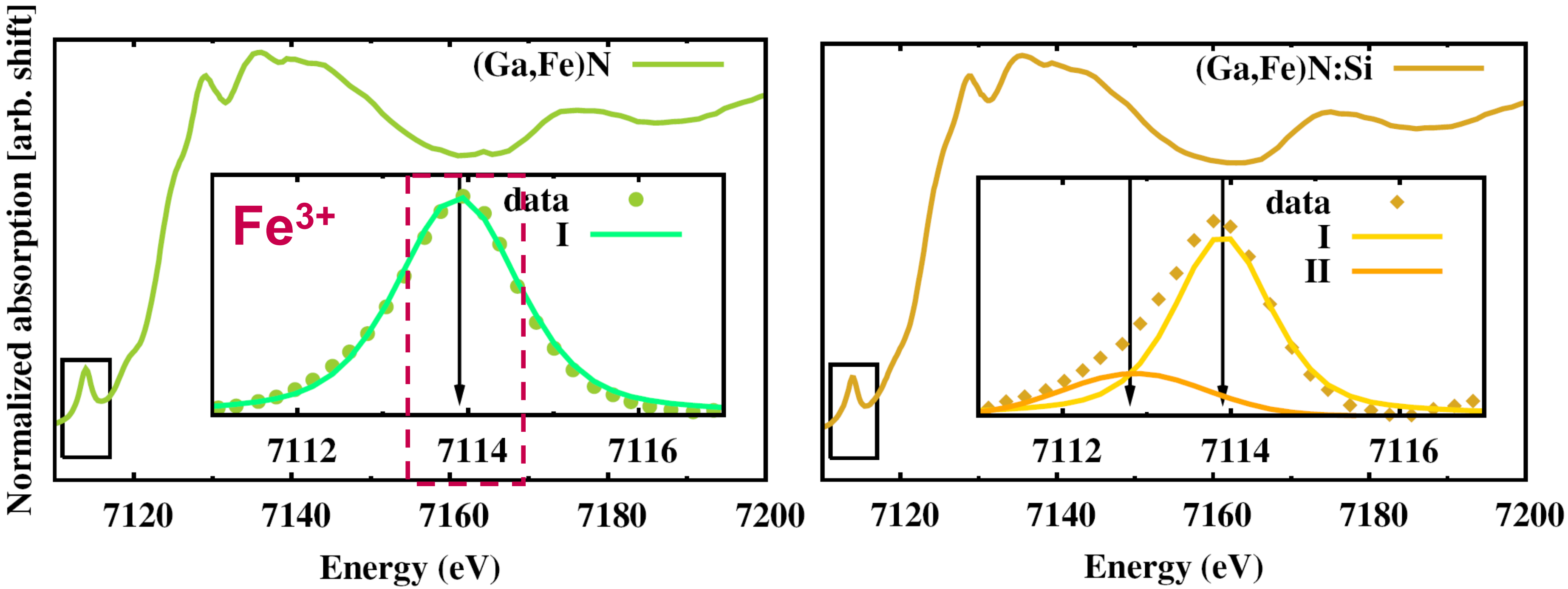

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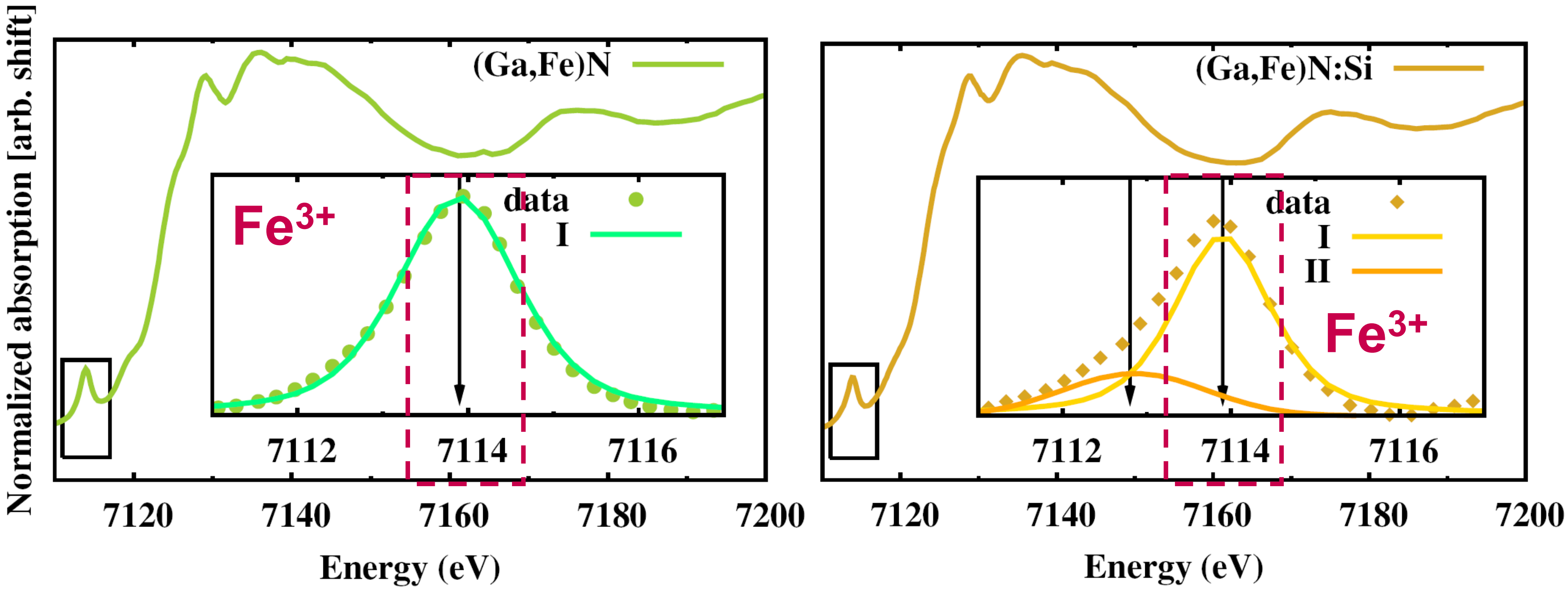

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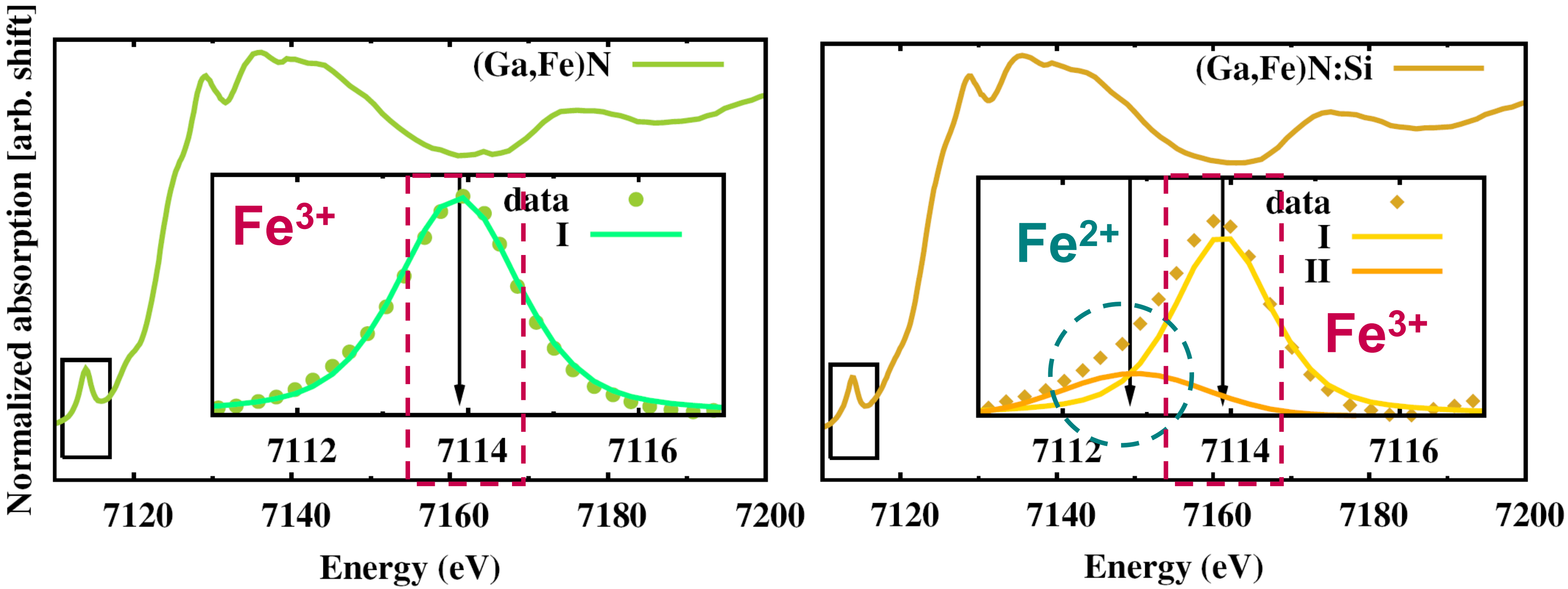
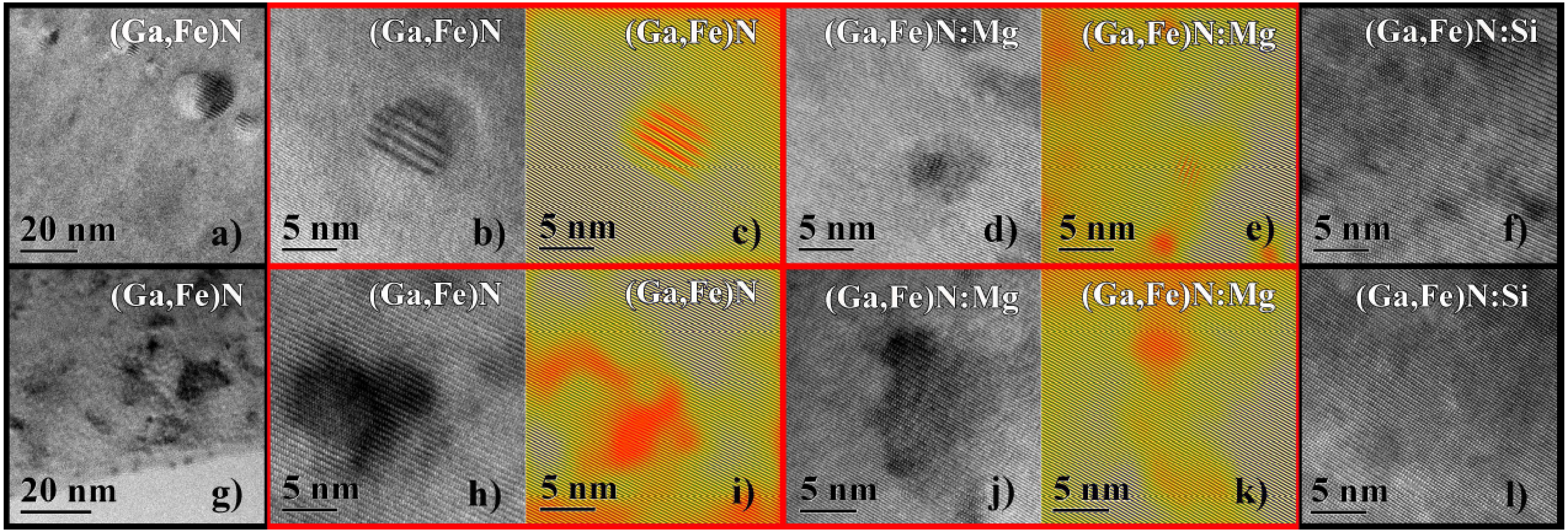


M. Rovezzi, ..AB, ...Phys.Rev. B **79**, 195209 [2009]

Co-doping and TM aggregation

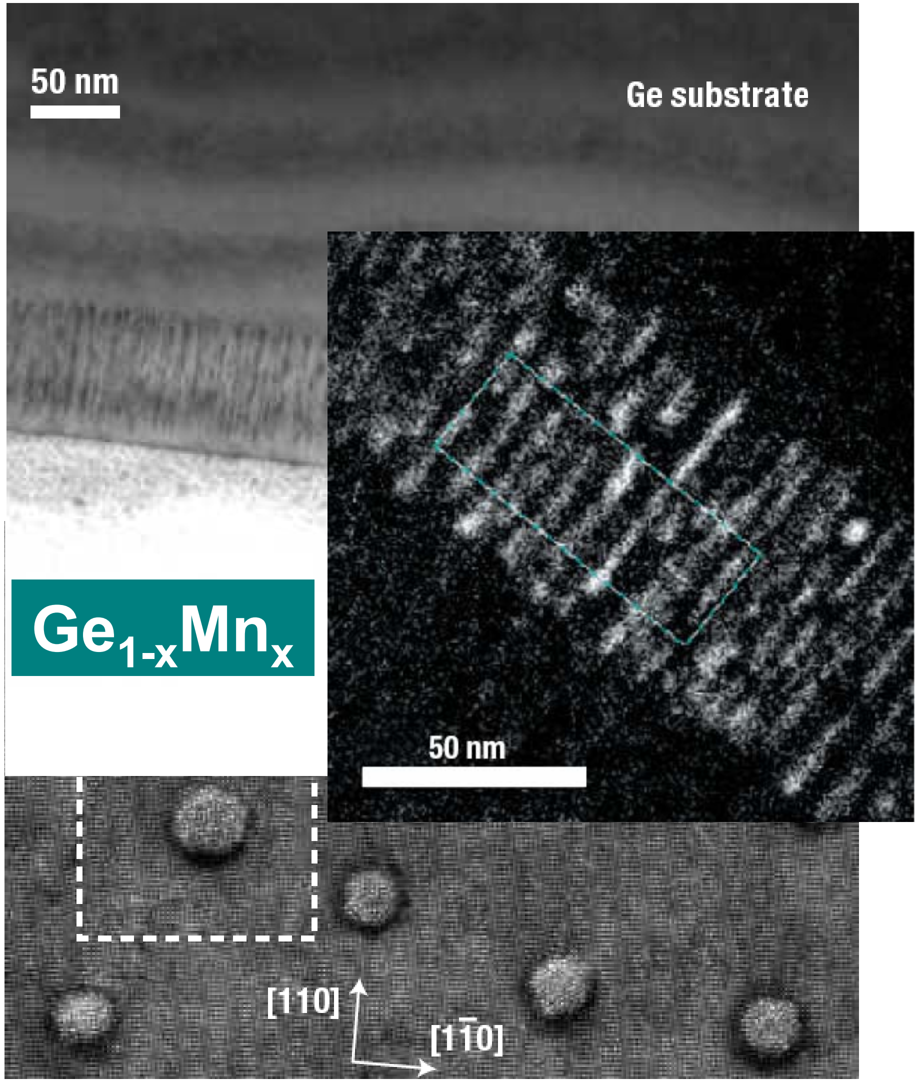
summary



A. Bonanni *et al.* Phys.Rev.Lett. **101**, 135502 [2008]

Outlook

Outlook: self-organized nanocolumns



M. Jamet *et al.*, Nature Mat. **5**, 653 [2006]

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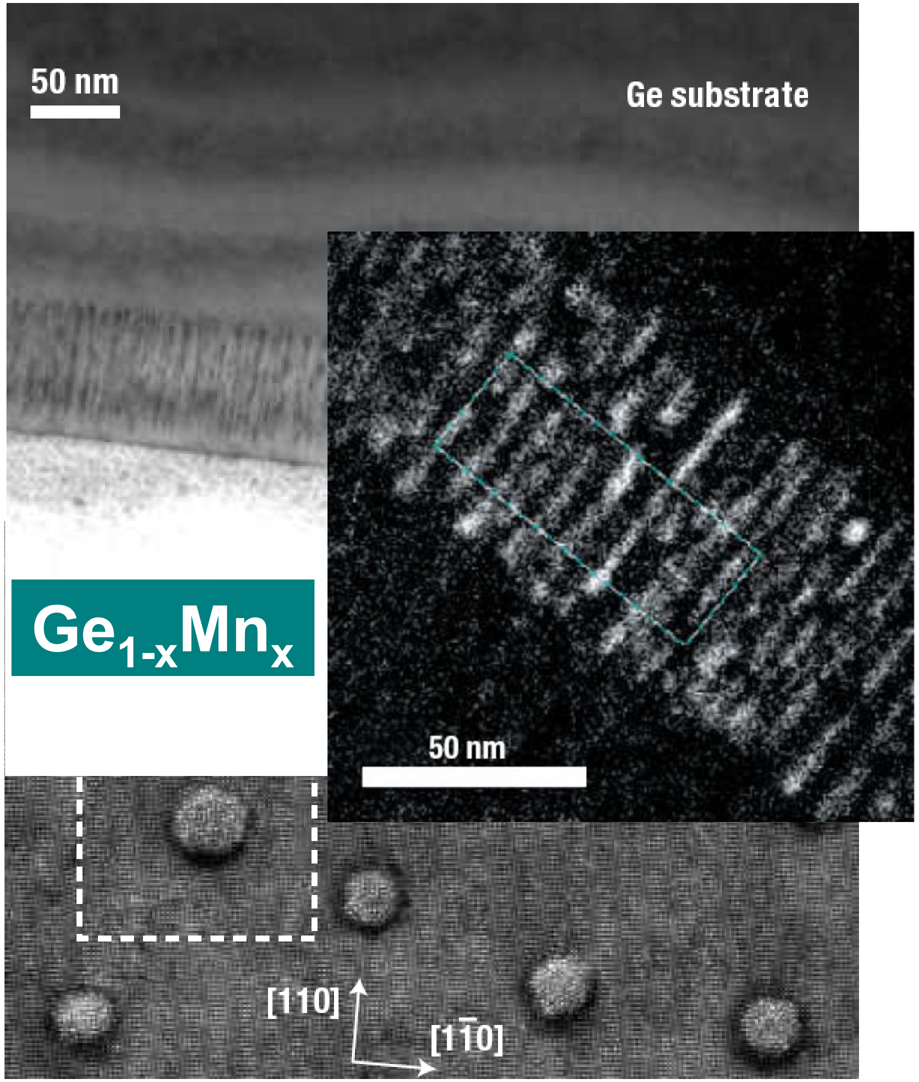
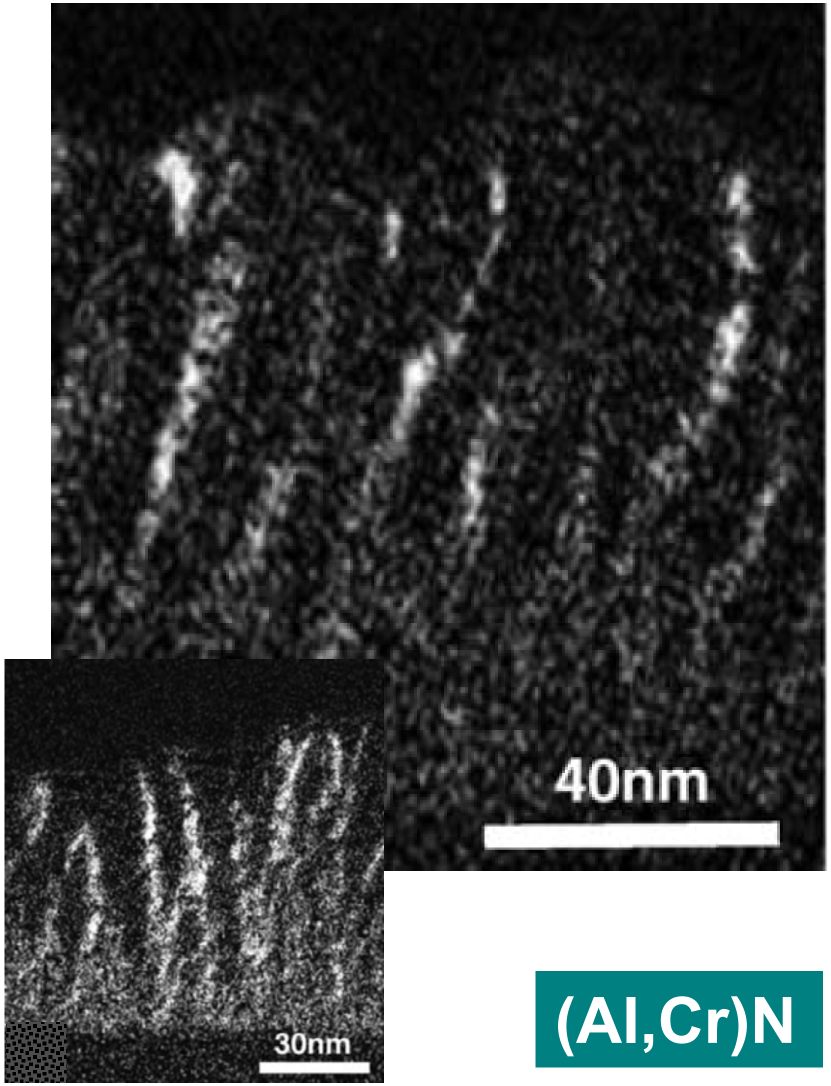
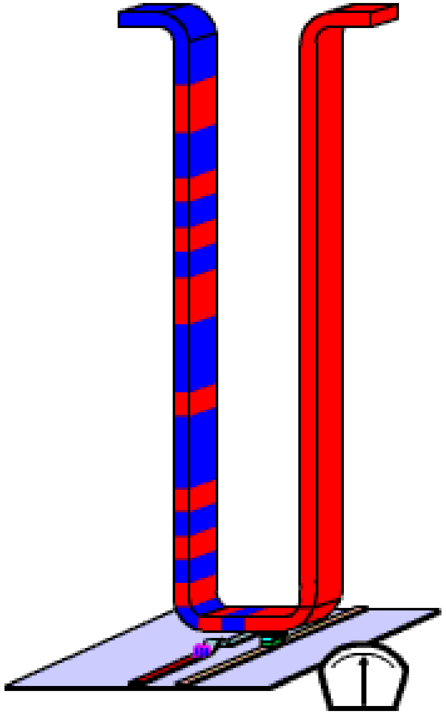


M. Jamet *et al.*, Nature Mat. **5**, 653 [2006]



L. Gu *et al.*, JMMM **290**, 1395 [2005]

Self-organized nanomagnets in semiconductors



Domain walls for 3D memories

electric current induces the shift of magnetic regions along a wire

⬇

HD does not need to spin

increased data storage and speed

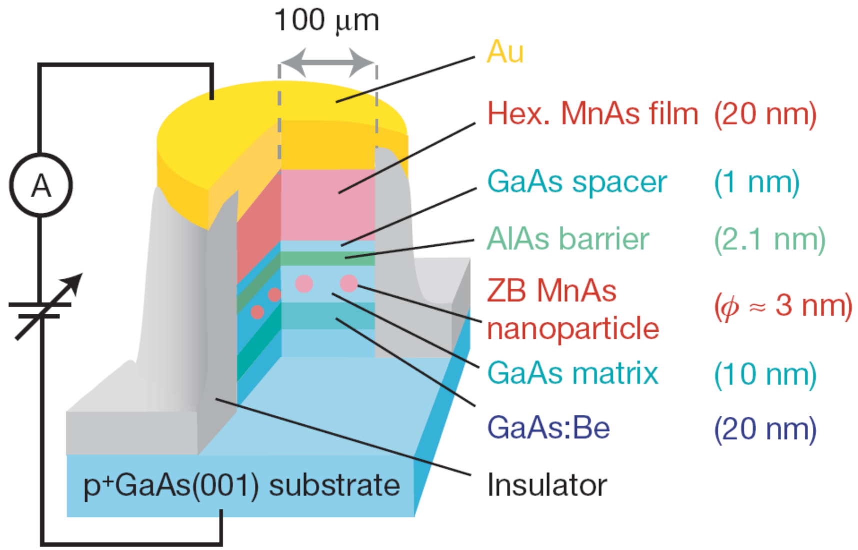
G. Meier *et al.*, Phys.Rev.Lett. **98**, 187202 [2007]

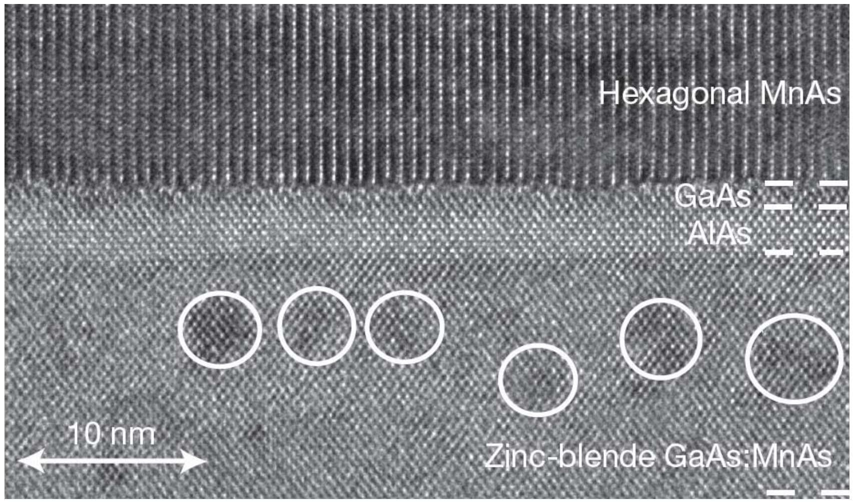
Unclear:

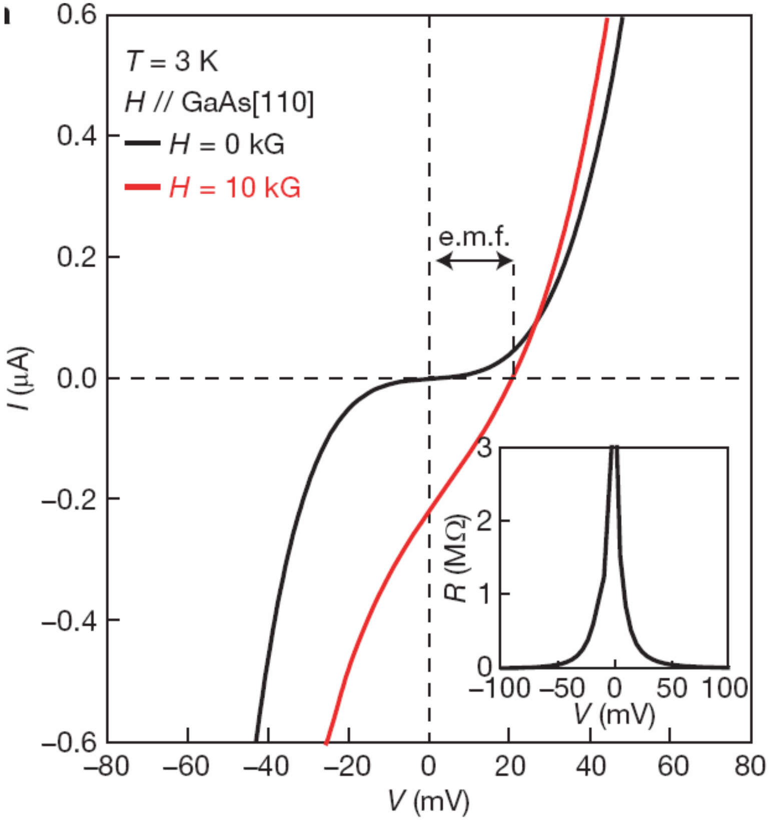
how to fabricate dense arrays of required nanocolumns

self-organized nanocolumns in DMS [?]

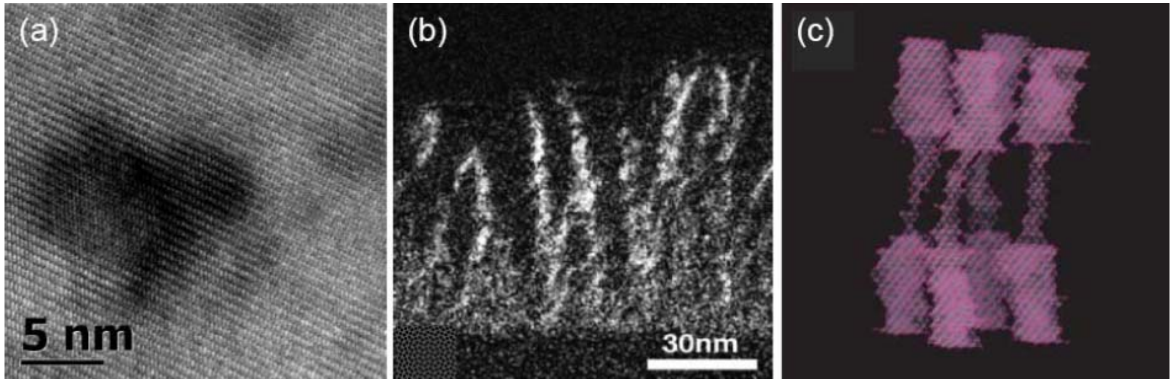
Spin-battery – GaAs:MnAs







P. Nam-Hai *et al.*, Nature **458**, 489 [2009]



Functionalities

- nanometallization:
  nanoelectronics, optoelectronics, plasmonics

- large magnetotransport effects
  field sensors

- large magnetooptical effects
  optical isolators, tunable photonic crystals

- spintronic structures
  high density MRAMs/race track memories/logic

- spin battery

P. Nam-Hai *et al.*, Nature **458**, 489 [2009]

- large spin entropy
  thermoelectricity

H. Katayama-Yoshida *et al.*,
Jpn.J.Appl.Phys **46**, L777 [2007]

In collaboration with

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