Fabrication and magnetism of nano-objects

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1 Introduction

The lecture has been divided in roughly two parts. In the first part fabrication methods of nano-objects are reviewed. In the second part I have selected a series of magnetic topics, which from my point of view have benefited from the use of self-assembled or self-organized systems. Many references are directly included on the slides, that are not repeated here. I list at the end of this short abstract references of reviews related to the subject, some of those already found on the slides, some not. See `http://lab-neel.grenoble.cnrs.fr/themes/couches/ext/slides/` for other slides and references. For both fabrication and properties of self-organized systems at surfaces, see also the Special Issue of the C. R. Physique 6 (2005) (9 contributions).

2 Fabrication methods

An emphasis is put on epitaxial self-assembly and self-organization, although some other methods are illustrated (clusters by physical means, by chemical means, bulk preparation methods). I review growth modes, the shape of dots grown in the Stranski-Krastonov growth mode (Wulff and Wulff-Kaishev constructions and their extensions), the nucleation theory, and kinetic limitations like the Schwoebel effect. I then give examples of self-organization of dots and wires in the sub-atomic-layer range: step decoration, deposition on intrinsic or adsorbate-induced reconstructions, and spontaneous organization like in the spinodal decomposition of Fe-Ag/Mo(110), so-called Friedel crystals (isolated atoms organized through RKKY waves of surface electronics states). Current trends and prospects of self-organization processes are then reviewed: 3D self-organization, organization of vertical objects (columns), and the combination of growth methods with some kind of artificial structuring: lithography, wafer bonding with interfacial dislocations, Focused Ion Beam.

3 Selected magnetic properties

Up to now self-organization has mostly been used for fundamental studies, especially in the field of magnetism, owing to the status of model objects: UHV-quality of the interfaces, resolution down to the atomic size, single-crystallinity. I have identified the following areas in the case of magnetism:

- **Magnetic ordering**, *i.e.* experimental studies of the reduction of the Curie temperature, and the measurement of critical exponents. I recall results obtained on thin films, and then give examples of the further decrease of dimensionality in the case of Fe/W(110) stripes of variable-width fabricated by step-decoration on vicinal surfaces.
- **Magnetic anisotropy** I recall the origin and the phenomenology of two sources of magnetic anisotropy that arise in systems of reduced dimension: surface/interface anisotropy, and magneto-elastic anisotropy. I then focus on the system Co/Pt, that allows to follow the rise of orbital moment and thus of anisotropy, from bulk to single atoms sitting on a flat surface, through the use of various self-organized and self-assembled systems.

- **Magnetization reversal and superparamagnetism**, the basics of which are then reviewed theoretically, in the simplified framework of the Stoner-Wohlfarth and Brown model for thermal activation. Exemples are given for superparamagnetism, how one can get rid of it by increasing anisotropy, or growing self-organized structures with significant thickness, and discuss the semantic dispute between non-ferromagnetic and superparamagnetic for nano-objects. Exchange bias at the nanometer level is also illustrated.

- **Collective dipolar properties** are included in the slides, but could not be presented owing to a lack of time. The effects of dipolar coupling are presented, along with various techniques of analyzing hysteresis loops to estimate these.

- **Micromagnetism**. Although dealing with objects often larger than 100 nm, the use of self-assembled systems is interesting for two purposes: either because a specific technique requires UHV-quality objects for the investigation (*e.g.*, the spin-polarized STM), or because the effects investigated critically depend on the quality of the interfaces, like for magnetization reversal. The study of magnetic vortex and domain walls are presented, in the systems Fe/W(110) and Fe/Mo(110).

References

Growth modes (thin films, some things about dots :) 1-17.
Nanostructures and self-organization on surfaces : 18-26.
Some other techniques for the fabrication of nanostructures (not exhaustive...) :27-31.
Some magnetic characterization methods : 32-38.
Fundamental properties of magnetic thin films : 39-46.
Quantum well effects and interlayer exchange interactions : 47-50.
Exchange bias : 51-54.
Nanomagnetism and magnetic properties of nanostructures : 55-59.
(See also [30])

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