SELF-ORGANISED HEXAGONAL PATTERNS OF INDEPENDENT MAGNETIC NANODOTS

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An alternative approach to the fabrication of high-density patterned magnetic media by nanolithography is the formation of nanostructures by self-organization, where spontaneously ordered, large-area patterns of nanometric objects appear. This fabrication method potentially represents a new parallel patterning technology, much advantageous regarding speed and efficiency with respect to serial procedures.

Two different nanofabrication methods are demonstrated. The first one takes advantage of the formation of self-organized patterns on a semiconductor surface by ion erosion [1] to produce large-scale arrays of uniformly-sized, hexagonally-arranged magnetic nanodots. A special sample design has been used in which a magnetic layer was epitaxially grown by magnetron sputtering on a GaSb substrate; this film was subsequently covered with another GaSb layer, 1000 nm thick. The erosion of this sacrificial layer with Ar^+ ions leads to the formation of a periodic dot pattern which eventually intersects the buried thin magnetic film. By interrupting this process at the appropriate moment, isolated magnetic nanodiscs can be generated. By using an intercalated Co layer and 400 eV Ar^+ ions, arrays of dots 25-30 nm in diameter, 5 nm thickness and 40 nm nearest-neighbor separation have been obtained. Figure 1 shows the final surface morphology as determined by Atomic Force Microscopy after completing the erosion process.

The system's magnetic behavior was characterized by means of vectorial Kerr magnetometry. The saturation intensity for the dotted sample is approximately 3 times smaller than for the continuous film, confirming the partial removal of material during the patterning process. Furthermore, the coercive field increases by almost one order of magnitude upon patterning, up to ~15 mT. This effect can be explained by a change in the mechanism of magnetization reversal, which in the 2-dimensional film must be achieved by domain wall propagation. The dots, in contrast, have sizes of the order of the domain wall width and can therefore be expected to be single-domain. Their magnetization reversal must hence take place by coherent rotation. These observations are confirmed by numerical simulations based on the Stoner-Wohlfarth model, which successfully reproduce the the shape of the experimental hysteresis loops [2].

These results thus confirm that arrays of magnetically independent nanodots can be produced by this efficient patterning method; if used as a magnetic storage material, a density as high as 0.4 Tbit per square inch could be attained. Furthermore, the patterning process depends only on the semiconductor capping, and different intercalated magnetic materials can be used with the only limitation that their thickness remains below ca. 10 nm, so that the ordered pattern is preserved. This opens up the possibility to tailor the dots' magnetic properties, such as coercivity or anisotropy, to suit different applications.

The second approach uses grazing-incidence deposition of the magnetic material in Ultra-High Vacuum onto self-organized SiGe substrates [3] consisting of an arrangement of truncated pyramids with approximately square base and lateral faces forming an angle of ~25 deg. with respect to the base plane. When the magnetic material is obliquely deposited onto this template, facets oriented towards the incoming beam receive the highest flux, while those in the back of the pyramids remain shadowed and unexposed. (Pt/Co/Pt) trilayers have been chosen as the evaporation material in order to enhance the magnetic anisotropy of the nanodots.

Fig. 2 displays an XMCD-PEEM image obtained from a (4 ML Pt/4.5 ML Co/4 ML Pt) sample prepared in-situ by this method; the field-of-view is 5 microns. The dichroic contrast obtained by utilizing circularly polarized X-rays reveals nanoparticles with in-plane magnetization, separated by perpendicularly magnetized areas depicted in gray. The nanoparticles show remanent magnetization at room temperature, and their magnetization directions are uncorrelated with those of their neighbors.

In summary, both nanofabrication methods described are quite general, and can be used with different substrates and deposited materials.

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References:

[1] S. Facsko *et al.*, Science **285**, 1551 (1999).
[2] T. Bobek *et al.*, Adv. Mater. **19**, 4375 (2007).
[3] C. Teichert *et al.*, Appl. Phys. A **74**, 588 (1999).
[4] A. M. Mulders *et al.*, Phys. Rev. B **71**, 214422 (2005).
[5] Z. G. Li, P. F. Garcia and Y. Cheng, J. Appl. Phys. **73**, 2433 (1993).

Figures:

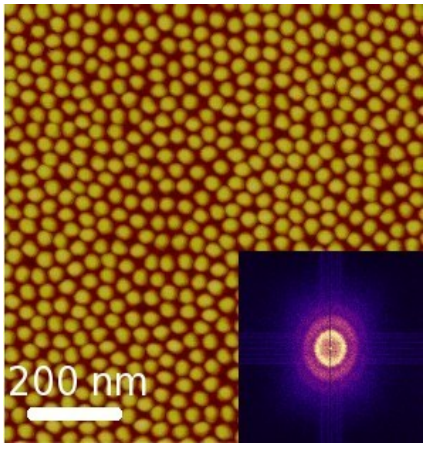

Figure 1

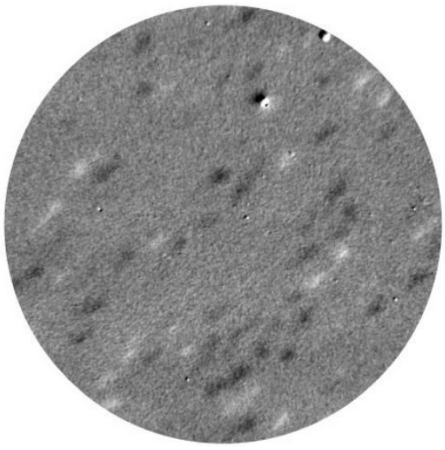

Figure 2.