Self-Assembly And Self-Organization Of Magnetic Dots And Stripes: From Surfaces To Functional Magnetic Materials

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The epitaxial growth of nanostructures can be favored instead of a continuous thin film. This process may be called self-assembly (SA) for randomly distributed structures, and self-organization (SO) when a long-range positional order is induced by nucleation on an atomic template (surface dislocations, atomic steps, etc). SA and SO of semiconductors have been extensively studied, while fewer examples exist for magnetic materials. We shall present examples of SO and SA magnetic systems that display interesting properties as materials.
Concerning SO, SO nanostructures are generally obtained in the sub-Atomic-Layer (AL) range, and are thus atomically-thin. This implies that magnetic SO objects are superparamagnetic down to low temperature due to their small volume (their magnetization flips spontaneously with thermal fluctuations). This restricts the use of SO to surface physics and fundamental studies. With a view to lifting this limitation, we suggested how one can make use of effects like surface energy, immiscibility and elastic stress to fabricate thicker SO structures, thereby increasing their volume and overcoming superparamagnetism[1,2]. Such processes could bridge the gap between surface physics and functional materials. We will focus on our recent study of 'thick' Fe(110) stripes organized along atomic steps of slightly vicinal cc(110) (cc=Mo,W). Upon deposition at moderate temperature followed by annealing, stripes of height 1.5 to 8 nm depending on cc, are formed, that are SO along the arrays of atomic steps of the buffer layer. The magnetic properties of the stripes at 300K are similar to those of magnetic materials: square hysteresis loops displaying significant coercivity and high remanence, and stable magnetic domains after a demagnetization procedure is performed[3,FIG.1].
Concerning SA we report micron-sized Fe(110) dots deposited on cc(110). Such dots display a 3D ingot shape and atomically-flat facets following the Wulff-Kaishev's construction [4,FIG.2]. Such dots can be used as model systems for micromagnetism. As they display simple flux-closure magnetic states[5], they can bridge the gap between nanomagnetism (single-domain), well understood quantitatively, and macroscopic materials (with a large number of domains and domain walls), which must still be described phenomenologically due to their complexity. Magnetic microscopy of remanent states [MFM(FIG.2) and X-PEEM(FIG.3)] and magnetization processes investigated on single dots will be presented.
For both examples (dots and stripes) we evidence that both the in-plane lattice parameter (Mo,W solid solutions) and the chemical interface (ultrathin pseudomorphic W or Mo layer) influence the shape of the structures, and thus can be used to tailor their properties

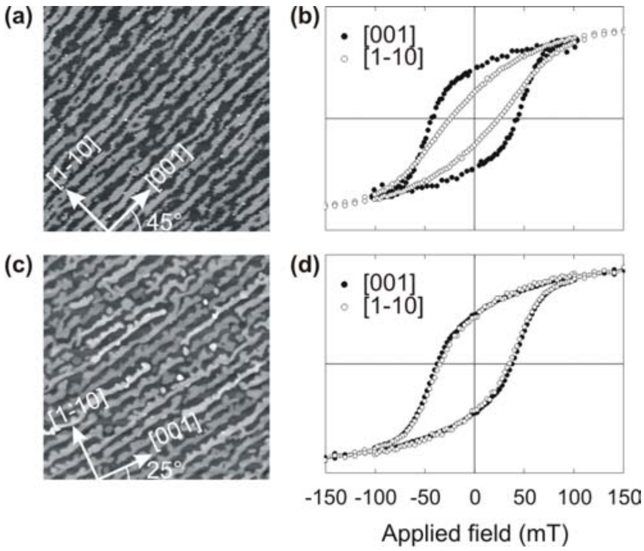

FIG. 1 : (a,c) 5x5 □m AFM pictures of self-organized Fe/W(110) and Fe/W(1nm)/Mo(110) stripes. The height of the stripes is 5.5nm and 4nm, respectively. The in-plane lattice directions are shown. (b,d) Room-temperature in-plane hysteresis loops of samples shown in (a,c).

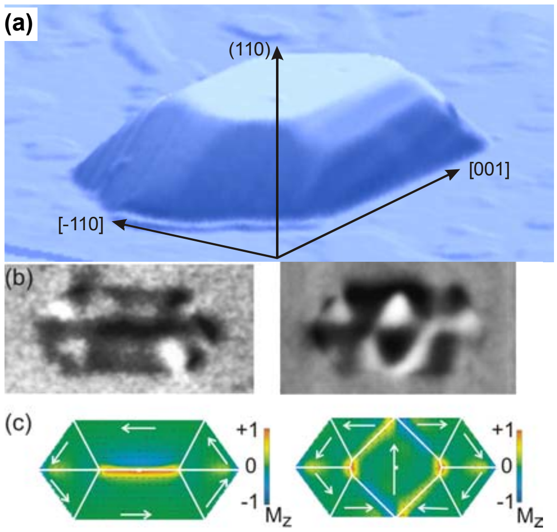

FIG. 2 : (a) 3D AFM view of a self-assembled Fe/Mo(110) dot of length ~1□m. Crystal directions are shown. (b,c) MFM images and simulated micromagnetic configurations of dots (length ~600nm, height ~60nm). In (c) the color codes the perpendicular component of magnetization. The in-plane component is shown by white arrows.

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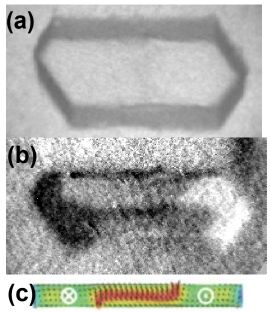

FIG. 3 : an Fe/Mo(110) dot of height 175nm and length 1.6□m (a) LEEM top view (b) X-PEEM top view, revealing the in-plane component of the surface magnetization (c) schematic cross-sectional view displaying the core of perpendicular magnetization (red) of the Bloch domain wall, explaining the asymmetric picture in (b).