Magnetic, electrical and magneto-transport thin nanohole arrays grown on flat anodic aluminum oxide templates

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Abstract

The introduction of voids into a thin film significantly alters the characteristics of the medium, leading to exotic and interesting physical properties. In fact, such voids can lead to quantum effects in the conductivity, enhanced optical transmission, artificial vortex pinning sites in superconductors and magnonic crystals, facilitating research and technological applications. In particular, the inclusion of micrometer or nanometer sized artificial defects in magnetic materials is an effective way to engineer the corresponding physical properties.

At present the main stress is put on the study of nanohole arrays of nanometer dimensions (inter-hole distances and hole diameter sub micrometer range), which magnetic properties (domain morphology and reversal processes) are very distinct from micrometer-period structures.

However the main challenge still lies in the fabrication of nanometer scale nanohole structures. On the one hand one can take advantage of well established nanofabrication processes like electron-beam litpgraphy and litf-off, focused-ion-beam processing and deep ultraviolet methods. On the other hand, the bottom-up approach offers self-assembling procedures. One reliable method arises from the use of anodic aluminum oxide (AAO), which provides a simple and low cost route to fabricate tailored nanometric dimensions.

In the present contribution we show the results of an extensive study of the magnetic, transport and magnetotransport properties, including Hall effect measurements of NiFe nanohole arrays with thickness ranging from 2 to 100 nm, ion beam sputtered on top of AAO templates. Atomic Force Microscopy images show the replicated AAO hexagonal pattern when a 25 nm thick NiFe film is deposited on top (see figure 1a and 1b respectively).

By correlating magnetic (see figure 2) and magnetotransport (see figure 3) properties of nanohole arrays we detect a strong dependence on the film thickness (*t*) and therefore the morphology. For small *t* a granular-like film is formed. With increasing *t* morphological percolation occurs and the Tunneling Magnetoresistance contribution decreases together with apparition of the bulk-like behavior and Anisotropic Magnetoresistance contribution. The latter one becomes dominant for even bigger film thickness.

Using a simple and straightforward low-incidence-angle ion-milling process it was also possible to significantly reduce the particular topography of AAO, showing a major impact on the physical properties of nanohole arrays grown on top and to achieve high-quality thin-NhA films with well controlled morphology. One may thus provide nanostructured magnetic materials with engineered physical properties and give the potential for further technological advances in magnetic sensing and storage.

References

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Figures

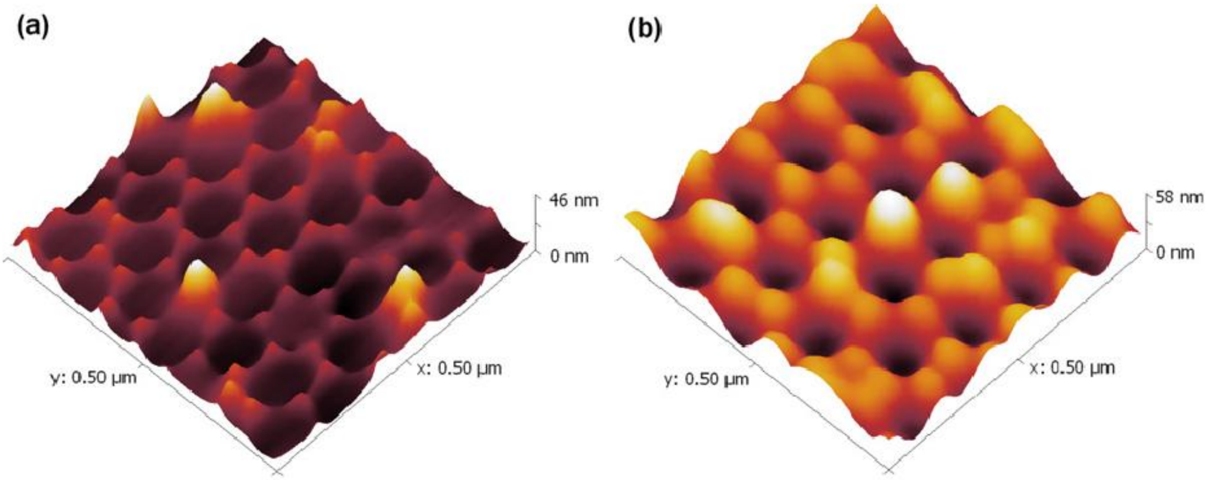

Figure 1. AFM images of the (a) as-grown AAO substrate and (b) 25 nm thick NiFe nanohole array.

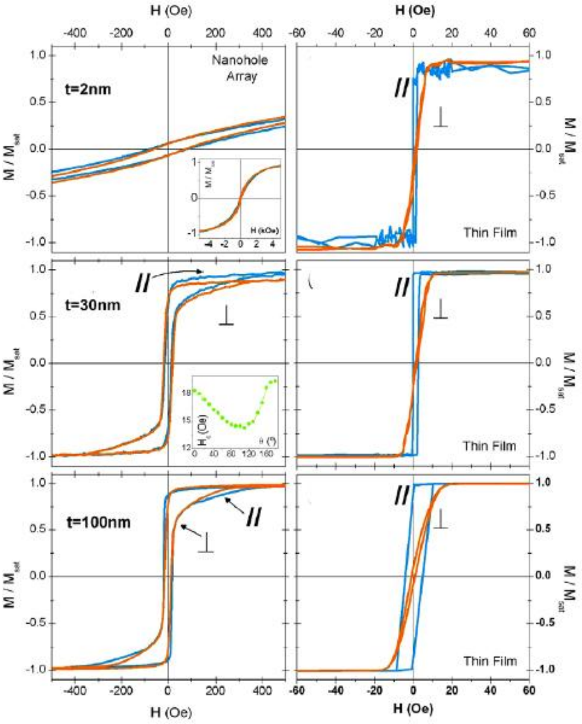

Figure 2. Room temperature M(H) curves for nanohole arrays and corresponding continuous thin films with t = 2 nm (thin), t = 30 nm (intermediate) and t = 100 nm (thick). Note the distinct magnetic field magnitudes of the nanohole and thin film samples.The ⊥ and ǁ symbols correspond to the direction of H relative to the growth-induced axis.

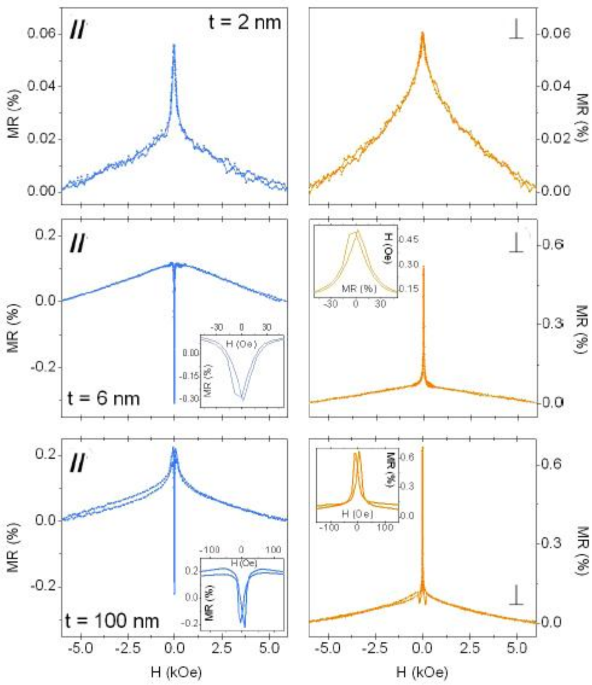

Figure 3. MR curves at 100 K for selected nanohole arrays with t = 2, 6 and 100 nm, measured in the longitudinal (ǁ) and transverse (⊥) geometries. The insets show details near H_{sw} (switching field).