AN ION-BEAM SPUTTER SYSTEM FOR FABRICATION OF NON-CONFORMAL FILMS, MULTILAYERS AND SUB-200nm NANOMAGNETS

C. Redondo[a], S. Moralejo[a], F. Castaño[a*], W. Lee[b], K. Nielsch[b], C. A. Ross[c] and F. J. Castaño[c]

[a]*Dpto. Química Física. Facultad de Ciencia y Tecnología. UPV. Apart. 644, 48080 Bilbao*
[b]*Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle, Germany*
[c]*Depart. of Materials Science and Engineering. Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA.*
** qfpcaalf@lg.ehu.es*

The physical properties of magnetic thin films have been an important area of research during decades and our recent ability to fabricate thin film elements with deep-submicron lateral dimensions (nanomagnets) has prompted an upsurge of research focused on new spintronic devices for information storage [1] and magneto-logic applications [2].

An Ion beam sputter (IBS) system, designed to grow non-conformal magnetic thin films and multilayers, has been built. The system consists of two connected chambers with a base pressure below 5×10^{-8} Torr (see fig. 1(a)). The lower chamber contains a 3cm-diameter DC Kaufman-type ion source focussed on a rotating carousel with four 6.4×15.2 cm^2 rectangular targets of isolating or metallic materials. The upper chamber houses a rotating substrate stage which can be loaded with up to four 7.6 cm-diameter wafers. Film growth using IBS can be undertaken at inner-gas-pressures (typically Ar) in the 10^{-4} Torr range, while conventional sputtering requires gas pressures in the 10^{-3} Torr regime. This feature and a large (35 cm) target-to-substrate distance allow for high-quality smooth thin films with thickness profiles below 10% over 5cm-diameter wafers (fig 1(b)). The deposition rate and microstructure for $Ni_{80}Fe_{20}$ and Co_{86} Fe_{14} alloy films has been optimized for different ion-beam-currents and Ar-pressures. The surface roughness of the films was investigated using atomic force microscopy and their magneto-transport properties using magnetoresistance and magneto-optical-kerr effect (MOKE) magnetometry. The effects of surface roughness on the magneto-transport properties of NiFe and CoFe single-magnetic-layer-films, as well as pseudo-spin-valve (NiFe/Cu/CoFe) multilayers (Fig1(c)) will be presented.

We have used this IBS system to fabricate arrays of thin film nanomagnets with lateral aspect ratio of ~1 and dimensions ranging from 80 nm to 150 nm (Fig(2(a)), using shadow masks made from metal membranes replicated from long-range ordered porous alumina templates [3]. These membranes consist of arrays of metal tubes for periodicity of 500 nm (see Fig 2(b)-(c)) and were positioned onto thermally-oxidized Si(100) substrates. NiFe and CoFe films were then deposited using IBS, followed by liftoff of the metal membrane. The magnetization reversal of these nanomagnet arrays has been investigated using spatially resolved MOKE with a resolution of 2.8µm. The hysteresis loops of an unpatterned 13-nm-thick NiFe film and the corresponding nanodot array are shown in Fig.2a. The loop of the nanomagnet array shows a broad distribution of switching fields due to shape variability between the nanomagnets in the array. Thinner circular elements show sharp switching at low applied fields [4] due to the onset of single-domain behaviour. The magnetization reversal for NiFe and CoFe nanomagnets with different thicknesses and sub-200 nm dimensions will be discussed.

References:

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Figures:

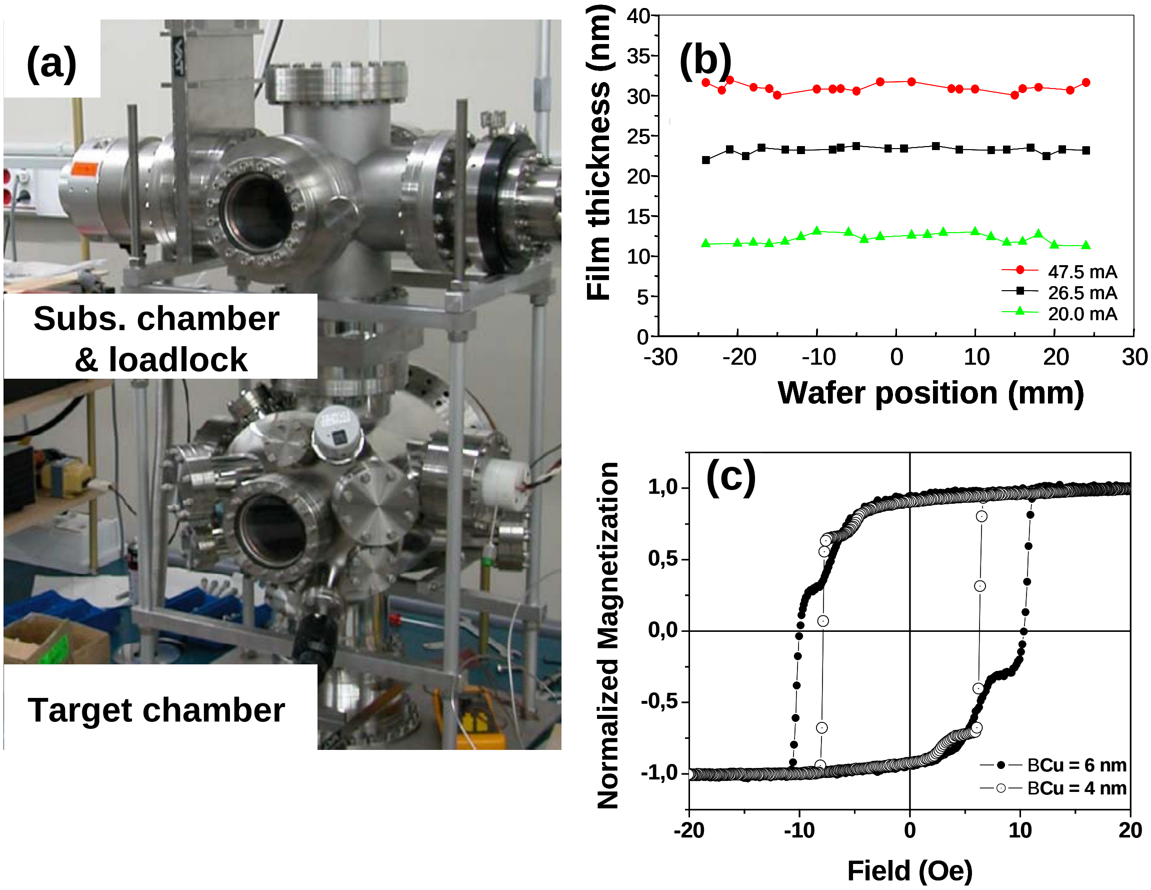

Fig. 1. (a) Image of the Ion-beam sputter system with labels for the upper and lower chambers. (b) Thickness variations over a 5cm-diameter silicon wafer for NiFe films grown at beam-currents of 47.5 mA (full circles), 26.5 mA (full squares) and 20 mA (full triangles), respectively. (c) Room temperature MOKE hysteresis loops showing distinct layer switching for NiFe (6 nm)/ Cu (6 or 4 nm)/ CoFe (6 nm) pseudo-spin-valves.

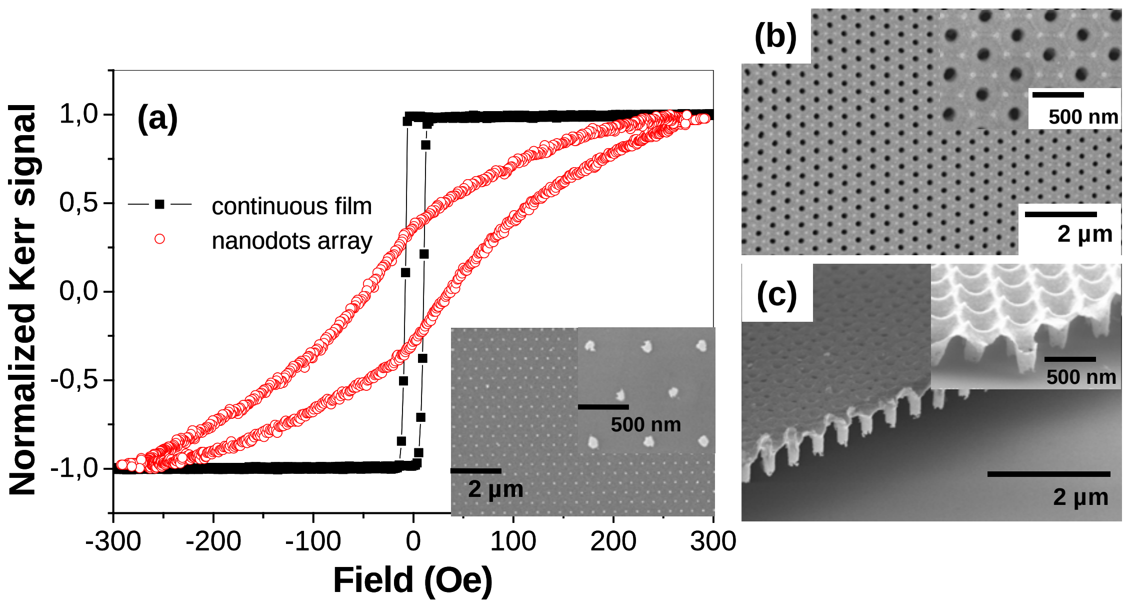

Fig. 2. (a) Moke hysteresis loop probing a 2.8 µm-diameter area of a NiFe array of nanomagnets with lateral dimension of 120 nm and thickness of 13 nm. The inset show scanning electron micrographs (SEMs) of the array with different magnifications. (b) Plan-view and (c) side-view SEMs corresponding to membranes used as shadow-masks.