Coercivity, morphology and anionic defects in Fe/NiO layers on nanoporous Al_2O_3 membranes

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We report on the morphological and magnetic properties of two Au(capping)/ Fe/ NiO series of samples, grown on top of Si substrates (series 1) and Al_2O_3 nanoporous membranes (series 2), respectively. The NiO layers in both series were prepared by magnetron sputtering of a NiO target in an argon-oxygen atmosphere with different O_2/Ar ratios. The presence of oxygen in the deposition plasma produces a density of interstitial anionic defects whose magnitude is known to increase with the increase of the oxygen pressure. The aim of our work is to examine the influence of i) the antidot-type morphology and ii) the properties of the antiferromagnetic layer, on the hysteretic behavior of the metallic-ferromagnetic/oxide-antiferromagnetic, exchange coupled layers.

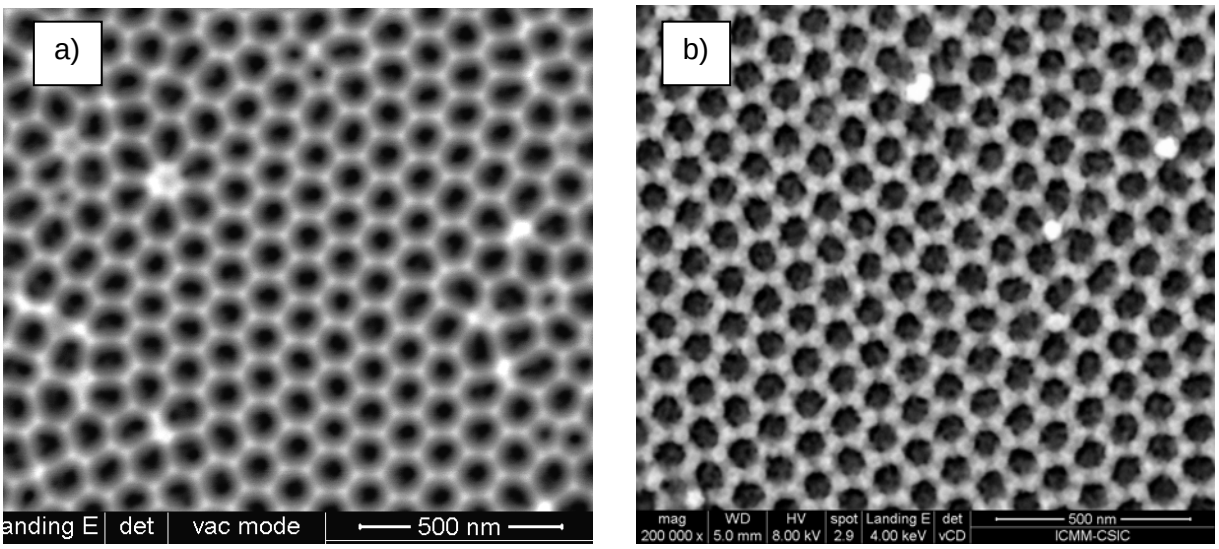

Figure 1. *Field emission scanning electron micrographs (FE-SEM) taken in: a) Al_2O_3 membrane substrate; b) Au(5 nm)/ Fe(5 nm)/ NiO(160 nm)/ Al_2O_3 sample (series 2).*

Samples were prepared by magnetron sputtering (NiO layers, 160-200 nm), pulsed laser ablation (Fe layers, 5 and 20 nm) and molecular beam epitaxy (Au capping layers, 5 nm). Analysis of the sample surface morphology by means of atomic force microcopy and field emission scanning electron microscopy (FE-SEM) evidenced that: i) a continuous film was formed in series 1 (Si substrate), and ii) the nanoporous morphology of the Al_2O_3 membranes was preserved in series 2 (see Figure 1). Nevertheless, FE-SEM reveals significant differences from sample to sample in series 2, depending on the Fe layer thickness and the growth parameters of the NiO layer. Originally, the Al_2O_3 membranes exhibited a hexagonal lattice with average pore diameter of 45 nm and inter-pore distance of ca.100 nm.

The magnetic characterization of the samples included the measurement of the temperature dependence of the low field magnetization measured after zero field cooling and field cooling the samples, and that of the temperature dependence of saturated hysteresis loops recorded after field cooling the samples.

In Figure 2 we have plotted the hysteresis loops measured at 290 K for series 2 samples with 10 nm-Fe layers and different plasma oxygen concentrations during NiO growth. From the figure it is evident that the coercivity in these samples increases with the increase of the oxygen partial pressure (up to a value of 160 Oe measured in the sample deposited with a 70% oxygen partial pressure). A similar trend is observed for samples with thicker (20 nm) Fe layers, whereas for thinner (5 nm) Fe layers the highest coercivity (240 Oe) corresponds to samples grown without oxygen in the plasma. A distinctly different behavior is found in series 1 (Si substrate) samples, where the presence of oxygen significantly deteriorates sample coercivity, independently of the Fe layer thickness.

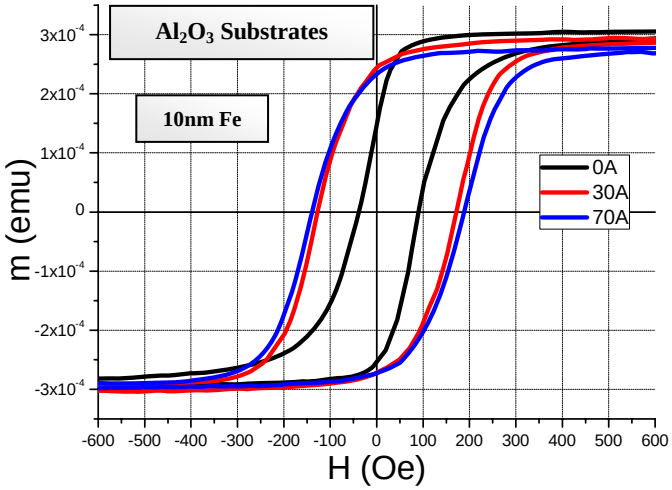

Figure 2. *Hysteresis loops measured at 290 K in series 2 samples for 10 nm-Fe layers; sample labeled OA was grown without oxygen in the Ar plasma (NiO growth); samples 30A and 70A were grown under 30% and 70% oxygen partial pressure, respectively.*

Figure 3 presents the temperature dependence of the loop displacement measured in the samples with 20 nm Fe layers after cooling them down to the measuring temperature under a field of 1000 Oe (all the displacements are opposite to the saturating field). As it is clear from the figure, the loop displacements are larger in series 1 than in series 2, and the same occurs for 10 nm Fe layers. Note, however, that the displacement in series 1 decreases with the oxygen pressure increase, whereas in series 2 and thick (10-20 nm) Fe layers, samples grown with oxygen exhibit larger displacements than those without it.

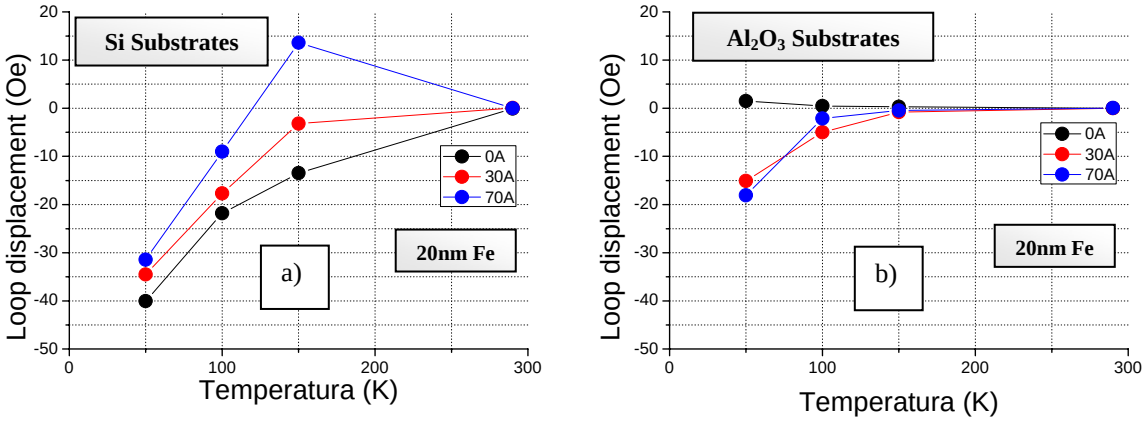

Figure 3. *Temperature dependencies of the loops displacements measured after field cooling the sample in the case of 20 nm-Fe layers; a) series 1; b) series 2.*

These results are discussed in terms of i) the amount of anionic defects present in the NiO layer and ii) the lateral limit to the size of the locally coupled regions associated to the nanoporous morphology. We conclude that it is possible to maximize the coercivity of Fe films grown onto NiO layers by preparing them under large oxygen partial pressures and using nanoporous Al_2O_3 membranes as substrates.

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