Poster

REACTIVE SPUTTERING SYNTHESIS OF EXCHANGE-BIASED CO-COO/AG NANOSTRUCTURES

J. M. Riveiro, J. P. Andrés, P. S. Normile, , J. A. González, T. Muñoz, P. Muñiz, A. J. Barbero, and J. A. De Toro

Depto. de Física Aplicada, Universidad de Castilla-La Mancha, 13071 Ciudad Real, Spain
juanpedro.andres@uclm.es

The study of FM-AFM (ferromagnetic-antiferromagnetic) exchange coupling in fine particle systems has recently found interesting applications to improve permanent magnetic materials[1] (by means of the EB-induced coercivity enhancement) and the thermal stability of magnetic nanoparticles (*delaying* the superparamagnetic limit).[2] We present magnetic and structural characterization of two series of samples grown by reactive sputtering of Co and Ag: (i) thin films obtained by co-sputtering of these metals at different oxygen pressures, and (ii) $[\mathrm{Ag}(t_{\mathrm{Ag}})/\mathrm{Co}(1.2\ \mathrm{nm})]_{60}$ multilayers deposited with fixed Co layer thickness (1.2 nm) and oxygen pressure (2×10^{-5} mbar), and varying Ag layer thickness t_{Ag}. For both type of samples, the partial oxidation of the Co regions results in the appearance of exchange-bias. Furthermore, for certain preparation conditions the samples obtained with both synthesis methods consist of a dispersion of core-shell Co-CoO nanoparticles embedded in an Ag matrix.

Regarding series (i), it is remarkable that the interesting core-shell/matrix structure (Co-CoO/Ag) could be achieved using the simple one-step technique of reactive co-sputtering. Such structure is suggested by the data displayed in Fig.1, which shows: (a) the appearance of a large exchange-bias (H_E) field for $P_O > 2\times10^{-3}\ P_{Ar}$ (the argon pressure was 3×10^{-3} mbar), concomitant with a strong magnetic stabilization effect (increase of T_{max}, the blocking temperature of the FM Co cores, from 55 to 200 K)[3], and (b) a monotonically decreasing giant magnetoresistance (GMR) effect with increasing oxygen pressure, possibly signaling the progressive suppression of ferromagnetic-nonmagnetic (Co-Ag) interfaces. In the light of previous results on the annealing dependence of the GMR effect in Co/Ag granular films,[4] the initial decrease of the blocking temperatures has been interpreted in terms of the inhibition of RKKY-like interparticle interactions upon the formation of an electrically insulating CoO shell.[3]

In series (ii), the exchange-bias (H_E) and coercivity (H_C) fields strongly depend on the spacer layer thickness for $t_{Ag} < t^*_{Ag} = 4$ nm, and then become roughly thickness-independent (see upper panel in Fig. 2). A discontinuous-continuous transition in the silver layers with increasing t_{Ag}, similar to that observed in a previous study,[5] is hypothesized as the origin of the behavior of both fields. Below t^*_{Ag}, the island-like structure of the Ag layers induces a discontinuous multilayer structure as schematized in Fig. 2(a) [lower panel]. For $t > t^*_{Ag}$, continuous multilayers with a Ag-Co-CoO structure are formed, as it has been recently confirmed by depth-profile compositional analysis.[6] The change in morphology across t^*_{Ag} is consistent with X-ray reflectivity (XRR) and electrical resistivity data [see Ref. 6]. Furthermore, the saturation magnetization increases roughly linearly with t_{Ag} up to t^*_{Ag}, and then become constant. Thus, the Co oxidation is stronger for the granular structure –as expected from the higher surface to volume ratio-, whereas a smaller (but still large, 75%) fraction of Co is oxidized in the continuous multilayers. The t_{Ag} dependence of both H_E and H_C below t^*_{Ag} can be understood as follows: the thicker the AFM CoO regions surrounding the remaining FM Co nanoregions, the higher the AFM magnetic anisotropy and, thus, the larger H_E. On the other hand, the coercivity will decrease due to the difficulty in dragging interface AFM spins upon magnetization reversal with increasing AFM anisotropy.[1,6]

References:

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Figures:

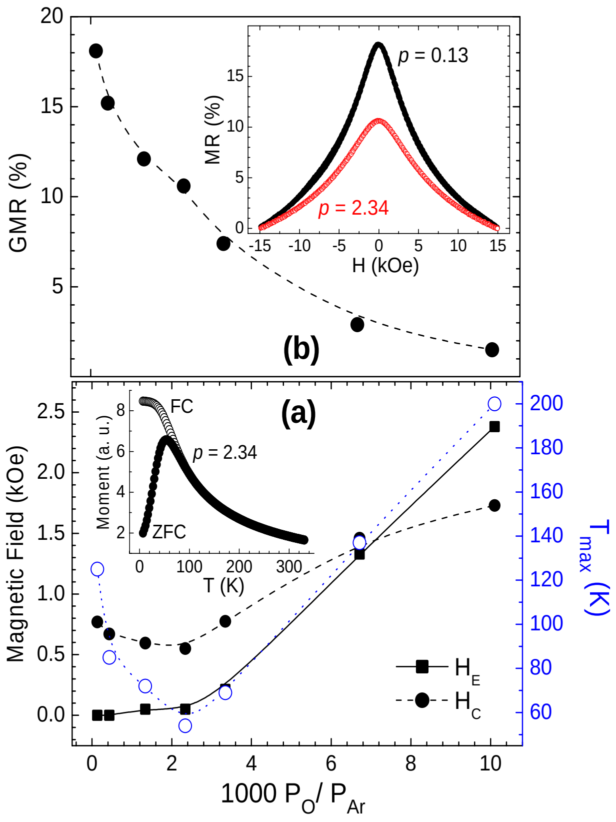

Fig. 1. (color) Oxygen pressure dependence of: (a) exchange-bias and coercivity fields measured at 10 K after cooling in a 40 kOe field, the blocking temperature (maximum of zero-field cooled magnetization *vs* temperature curves, see inset), and (b) the giant magnetoresistance effect measured at room temperature with a maximum field of 15 kOe [the inset shows two examples of *MR*(*H*)], in co-sputtered $Co_{22}Ag_{78}$ samples.

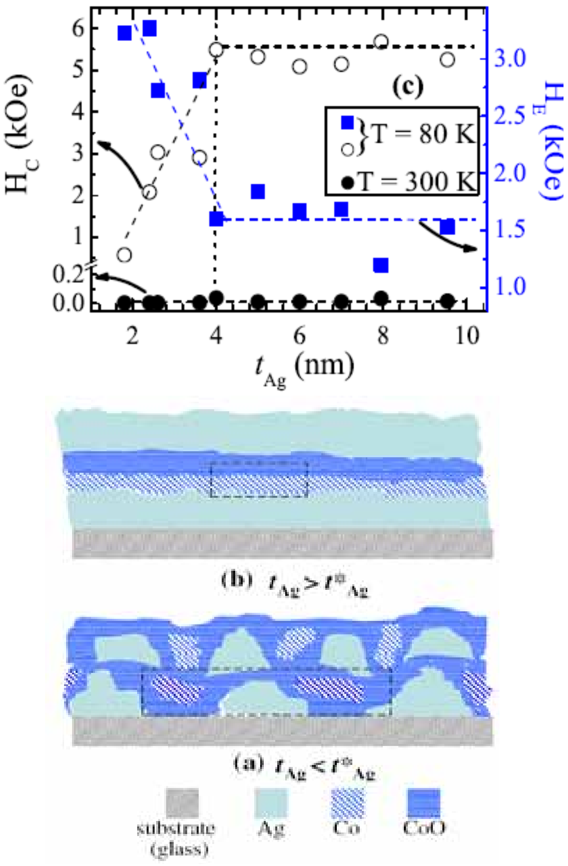

Fig. 2. Upper panel: dependence of the exchange-bias (H_E) and the coercive fields on the nominal thickness of the Ag spacer layer in reactively sputtered $[Ag(t_{Ag})/Co(1.2\ nm)]_{60}$ multilayers. The dashed line marks the continuity thickness t^*_{Ag}. Lower panel: schematics of the morphological change with t_{Ag} proposed to explain the data in the upper panel .