Manifold domain structure of double films with perpendicular magnetic anisotropy

Edna C. Corredor, David Coffey, José Luis Diez-Ferrer, José I. Arnaudas, Miguel Ciria,

Instituto de Ciencia de Materiales de Aragón, CSIC.
Instituto de Nanociencia de Aragón, Universidad de Zaragoza.
ednac@unizar.es

Structures made of blocks with competing magnetic anisotropies separated by interleaving layers suitable for large antiferromagnetic coupling are systems where a tiny difference in the energy, tuned by structural parameters, can be favored by a small magnetic field, resulting in a remarkable change of the magnetic configuration [1], suitable for the use as sensor or multiple storage states media [2].

Here we present magnetic force microscopy images in structures with a copper block separating two twin nickel layers with out-of-plane magnetization due to a magnetoelastic (ME) effect. We observe that the number of levels of the MFM signal changes with the thickness of the copper block, and images with two, tree and up to four stable states can be observed (see Figure 1a). Whereas the images with two and three levels are explained as result of dipolar and lineal exchange interaction that keep the magnetization in each Ni block perpendicular to the film plane but parallel or anti-parallel to each other [3], the fourfold contrast suggests the presence of domain structures with in-plane components of **M** in the Ni blocks. For the latter structures, the M-H loops show a plateau during the inversion of the magnetization (see Figure 1c),

To explain the presence and stability of magnetic domains with intermediate contrast we consider the formation of magnetoelastic domains that elude the clamping done by the buffer layer and balance the perpendicular anisotropy and a biquadratic exchange coupling that stabilize a non collinear orientation of **M** in each Ni block. The proposed domain structure is made of domains with in plane components separated by 90 degrees domains wall (see Figure 2). The calculation of the elastic energy shows that the domain configuration releases elastic energy in the Ni film blocks and can balance the effective perpendicular anisotropy, about 90 kJ/m^3 [4], if the average deformation in each domain is ~ -42 10^{-6} a value compatible with the bulk value (-60 10^{-6} [5]). Thus, if the perpendicular anisotropy is balanced out. the biquadratic exchange interaction that favors a orientation of 90 degrees, even being small in absolute value, could play the capital role of stabilizing non-collinear structures and be responsible for the plateaux observed in the MH loops since additional Zeman energy, supplied by increasing the magnetic field, is needed to unlock the non-collinear state. Considering that the energy associated to the area in the M-H loops due to the presence of plateaux [see figure 1(c)] can be assigned to the biquadratic term, a value of ≈ -0.005 mJ/m^2 is obtained for the biquadratic exchange constant.

References

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Figures

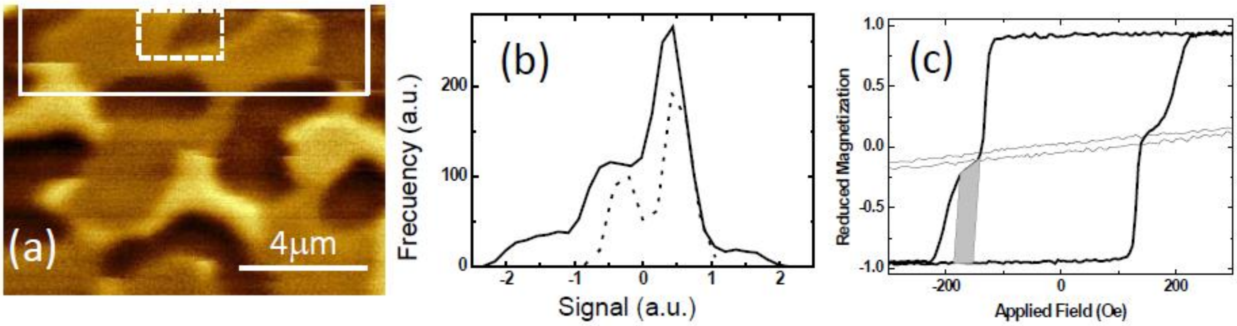

Figure 1(a) Magnetic force microscopy images taken on a Ni(3)/Cu(4.5)/Ni(3) structure. (b) Histograms taken on the areas marked with continuous and dashed lines on the MFM image (c) Detail of the M-H loops with H perpendicular (thick line) and parallel (thin line) to the plane. The grey area in panel is used to estimate the strength of the biquadratic exchange contribution.

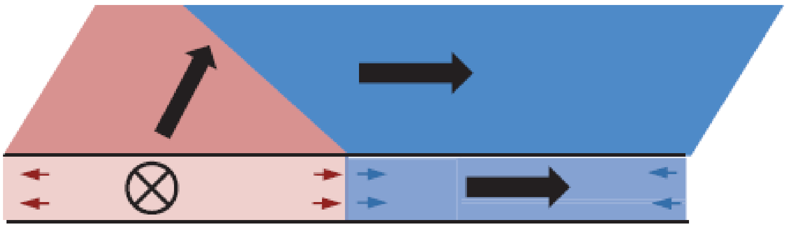

Figure 2 Stress distribution for a film with a 90^o domain wall, the thick arrows stand for the magnetization vector. The small arrows indicate the in-plane stress component at a section of the film within each domain for a material with negative magnetostriction.