CLOSURE STRUCTURES AROUND NON MAGNETIC INCLUSIONS IN UNIAXIAL MAGNETIC THIN FILM: MFM CHARACTERIZATION AND THEORETICAL ANALYSIS

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The study of magnetic nanostructures either in the shape of thin film magnetic nanoelements or of continuous patterned magnetic films has deserved increased attention in recent years, due to their possible applications in the field of high density magnetic recording [1]. One common feature in many of these magnetic nanostructures, such as magnetic nanorings or thin films patterned with arrays of antidots [2], is the existence of non magnetic holes within the magnetic material. Most of the attention has been devoted to the analysis of the different magnetic configurations corresponding to each different kind of structure, such as the transitions between in-plane, axial and vortex states in nanorings, the different kinds of periodic closure domain structures in magnetic films with antidots, or the domain wall pinning characteristics of the patterned holes [2,3]. However, up to now, the simplest problem of a continuous magnetic film with a single non magnetic hole has received little attention, even though it is qualitatively very different from the typical blade domains that appear around non-magnetic inclusions in bulk magnetic material.

In this work we have performed a detailed study by Magnetic Force Microscopy (MFM) of the magnetic configuration around non magnetic holes patterned in Co-based magnetic amorphous thin films by electron beam lithography and etching [4]. The results have been compared with micromagnetic simulations using the OOMMF code [5] as a function of material parameters (saturation magnetization M_S, uniaxial anisotropy K and exchange constant A). Also an analytical model based in the competition of magnetostatic and anisotropy energies has been developed in order to understand the characteristic confinement distance of the magnetic perturbations induced by the hole.

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References:

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[5] Object Oriented Micromagnetic Framework is available at http://math.nist.gov/oommf.

Figures:

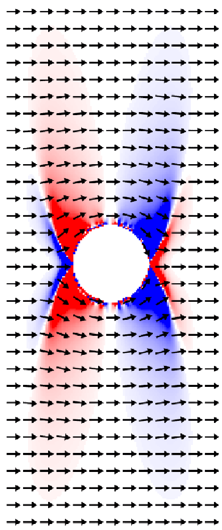

Fig.1 Micromagnetic simulation of the closure structure around a hole in an uniaxial magnetic film composed of two pairs of charged Neel walls emanating from two -1/2 half vortices situated at opposite sides of the hole.

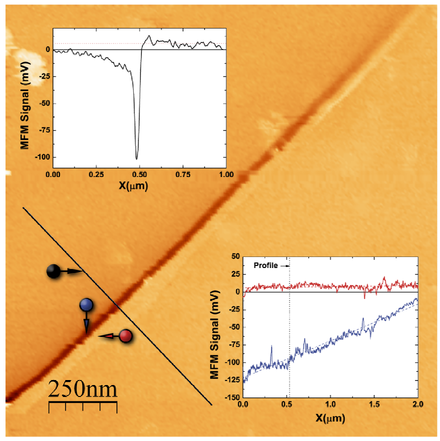

Fig.2 MFM image of a domain wall emanating from a hole in a Co-Zr magnetic film. Top inset is a profile of the MFM contrast across the wall, typical of a charged Neel wall. Bottom inset shows the contrast evolution as a function of distance to the hole, that fades away in agreement with micromagnetic simulations.

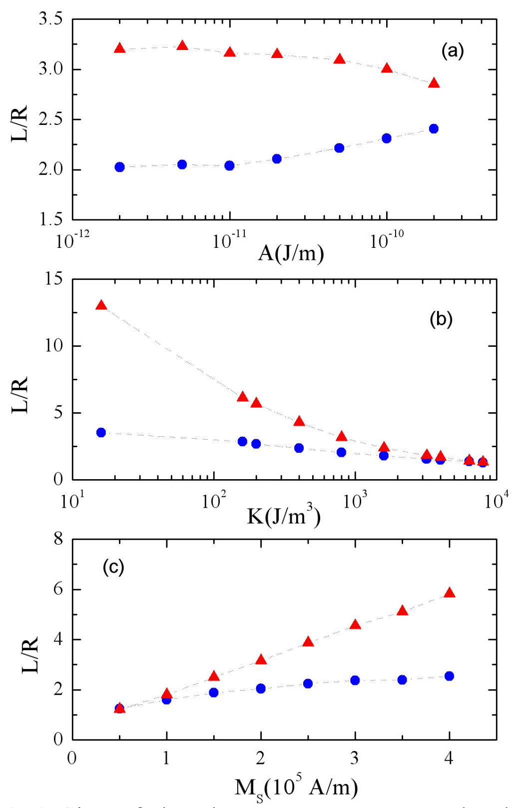

Fig.3 Size of the closure structure around a hole of radius R as a function of (a) exchange, (b) anisotropy, (c) saturation magnetization obtained from micromagnetic simulations. Triangles; along hard axis, circles: along easy axis,

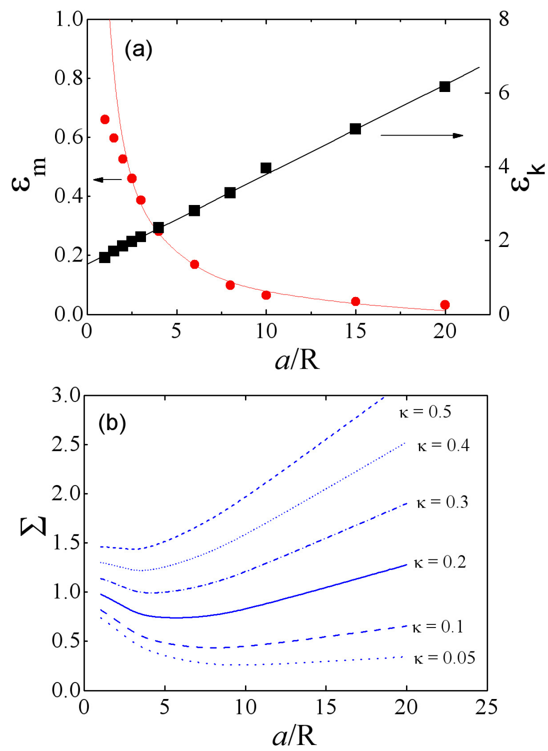

Fig.4 (a) Anisotropy ε_k and magnetostatic ε_m energy of the closure structure around a hole of radius R calculated with an analytical model as a function of wall position (determined by parameter *a*/R). (b) Total system energy $\varepsilon_k + \varepsilon_m$ showing the change in optimum wall position (minima in the curve) as a function of $\kappa = 2K/\mu_0 M_S^2$.