Ratchet effects on domain wall motion in Co-Si amorphous films with arrays of asymmetric holes: experiments and theoretical simulations

Alejandro Alija,[1] A. Pérez-Junquera,[1] G. Rodríguez-Rodríguez,[1] M. Vélez,[1] L.M. Álvarez-Prado,[1] J.M. Alameda,[1] J.I. Martín[1], J.V. Anguita,[2] Y. Souche,[3] V.I. Marconi,[4] A.B. Kolton,[4] and J.M.R.Parrondo.[4]

1. Depto. Física, Universidad de Oviedo - CINN, Oviedo, Asturias, Spain.
2. Depto. Dispositivos, Sensores y Biosensores, Instituto de Microlectrónica de Madrid (CNM-CSIC), Madrid, Comunidad de Madrid, Spain.
3. NANO, Institut Néel, CNRS and Universite Joseph Fourier, Grenoble, France.
4. Depto. Física Atómica, Molecular y Nuclear, and GISC, Universidad Complutense de Madrid, Madrid, Comunidad de Madrid, Spain.

alija@condmat.uniovi.es

The study of domain wall (DW) movement in magnetic films has long attracted a great interest since it provides both the basis for a wide number of magnetic devices [1] and a good experimental system to analyze the basic physics of an elastic interface in the presence of either ordered or random pinning defects [2,3]. When the pinning potential is asymmetric it can behave as a ratchet, so that DW propagation is favored in one direction. One of the first ratchet potentials used in the field magnetism were “angelfish” patterns that control the sense of propagation of bubble domains in shift registers [4]. Also, asymmetric motion of domain walls (DWs) in nanowires with triangular [5] or notched [6] shapes has been reported recently. However, up to now, in order to ensure a good control of the DW nucleation/propagation process, in all these cases DW motion has been confined to an essentially 1D path, so that its transverse wandering can be neglected. On the other hand, in a thin extended film with a 2D array of asymmetric pinning centers, novel ratchet phenomena can appear since a DW behaves as an elastic line that can distort all along its length in response to the 2D pinning potential.

In this work, the propagation of DWs in extended uniaxial Co-Si amorphous films patterned with a periodic array of asymmetric holes (see Fig.1) has been studied. For the first time, we have experimentally observed and theoretically simulated the existence of two crossed ratchet effects of opposite sign that change the preferred sense for DW motion depending on whether a flat or a kinked wall is moving.

When a magnetic field is applied to push a flat DW across the asymmetric holes, the DW moves more easily (i.e. with lower coercivity) in the direction in which the length of the pinned wall between two antidots increases smoothly. This asymmetric pinning has been experimentally observed [7] and confirmed by both numerical [7] and micromagnetic simulations with the OOMMF code [8]. In addition, micromagnetic simulations have been carried out on films with square arrays of triangular holes in order to optimize the flat domain wall ratchet effect as a function of the triangle base size (see Fig 2).

The novel ratchet behavior appears as the pinned wall inside the array develops kinks. This provides an extra mechanism for DW motion only possible in a 2D geometry through upward/downward kink propagation. This novel ratchet mechanism has an opposite sign in comparison to the flat DW ratchet and dominates the low field behavior. The interplay between both ratchets implies that the system keeps memory of the sign of the magnetization before a DW enters the array of asymmetric holes.

Work supported by Spanish CICYT (grants NAN2004-09087, MOSAICO and FIS2005-07392) and FICYT PhD grant ref BP06-109.

References:

[1] C.D. Mee and E.D. Daniel, Magnetic Storage Hand-book(1996) (New York: McGraw-Hill); G. Prinz, J.Magn. Magn. Mater. 200, 57 (1999).
[2] S. Lemerle et al., Phys. Rev. Lett. 80 849 (1998).
[3] E. Martínez et al., Phys. Rev. Lett. 98, 267202 (2007).
[4] N. Hayashi et al., IEEE Trans. on Magn. 8 370 (1972).
[5] D.A. Allwood et al., Appl. Phys. Lett. 85, 2849 (2004).
[6] A. Himeno et al., J. Appl. Phys. 97, 066101 (2005); M.Hayashi et al., Phys. Rev. Lett. 97, 207205, (2006); S.Savel'ev et al., New J. Phys. 7, 82(2005).
[7] A. Pérez-Junquera et al Phys. Rev. Lett. 100, 037203 (2008)
[8] OOMMF available at http://math.nist.gov/oommf

Figures:

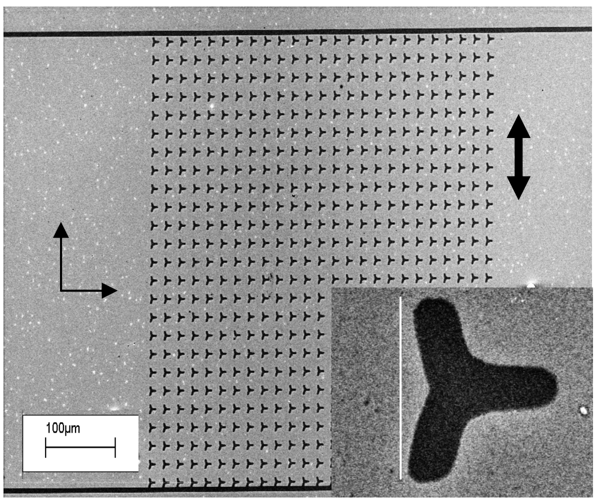

Fig.1 *Scanning electron microscopy image of an array of asymmetric holes on an uniaxial Co-Si film. Easy axis direction is indicated.*

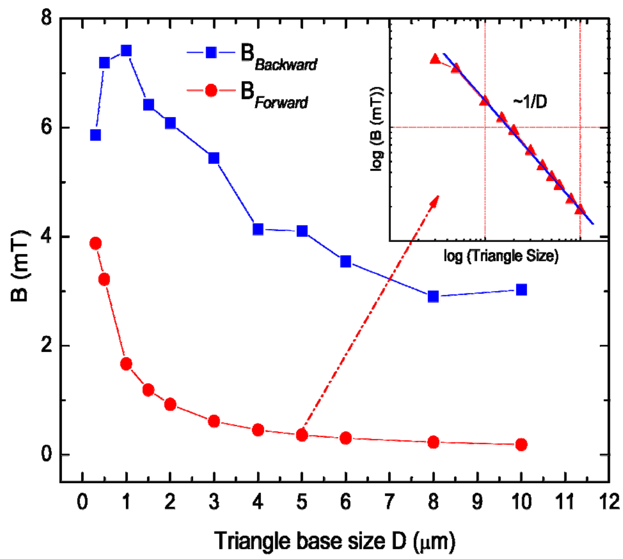

Fig.2 *Forward and Backward magnetic field related to the pinning and the de-pinning field. Inset shows 1/D law dependence of the depinning field versus triangle base size.*