COMPETING RATCHETS AND MEMORY EFFECTS FOR DOMAIN WALL MOTION IN MAGNETIC FILMS WITH ASYMMETRIC ARRAYS OF ANTIDOTS

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Patterned magnetic nanostructures have received much interest in recent years as they provide the ability to control and design the magnetic behavior for specific applications, as well as to study fundamental magnetic properties [1]. In particular, the study of domain wall (DW) propagation in these low dimensional magnetic systems has attracted a great interest since it provides both the basis for a wide number of magnetic devices [2], and a good experimental system to analyze the basic physics of an elastic interface in the presence of either ordered or random pinning defects [3,4].

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 that have been used are angelfish patterns that control the sense of propagation of bubble domains in shift registers [5]. Also, asymmetric motion of DWs in nanowires with triangular [6] or notched [7] shapes has been reported recently. However, up to now, in order to ensure a good control of the DW nucleation/propagation process, in all the cases DW motion has been confined to an essentially 1D path (either by narrow guide rails or by the nanowire geometry), 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, we have studied both experimentally and theoretically the propagation of DWs in extended uniaxial magnetic films that have been patterned with a periodic array of asymmetric holes by electron beam lithography and plasma etching (see Fig. 1). For the first time, we have found the existence of two crossed ratchet effects of opposite sign that change the preferred sense for domain wall propagation, depending on whether a flat or a kinked wall is moving [8]. This implies a change in the rectification effect on DW motion as a function of the magnetic field that has an interesting consequence from the applied point of view: the system keeps memory of the sign of the last saturating state even in a zero magnetization configuration. Thus, it is possible to record several magnetic states introducing the DWs in the array and to read them with a low amplitude AC field (see Fig. 2). By solving numerically a simple ϕ^4 model we show (see Fig. 3) that the essential physical ingredients for this effect are quite generic [8] and could be realized in other experimental systems involving elastic interfaces moving in multidimensional ratchet potentials. Also, this asymmetric pinning has been confirmed by micromagnetic simulations with the OOMMF code.

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References:

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Figures:

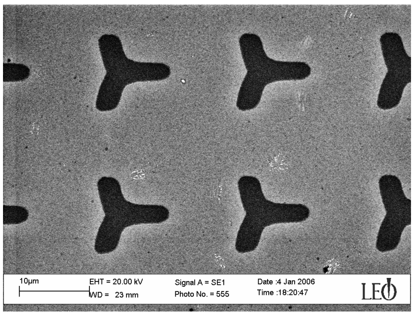

Fig. 1: SEM image of the array of asymmetric holes

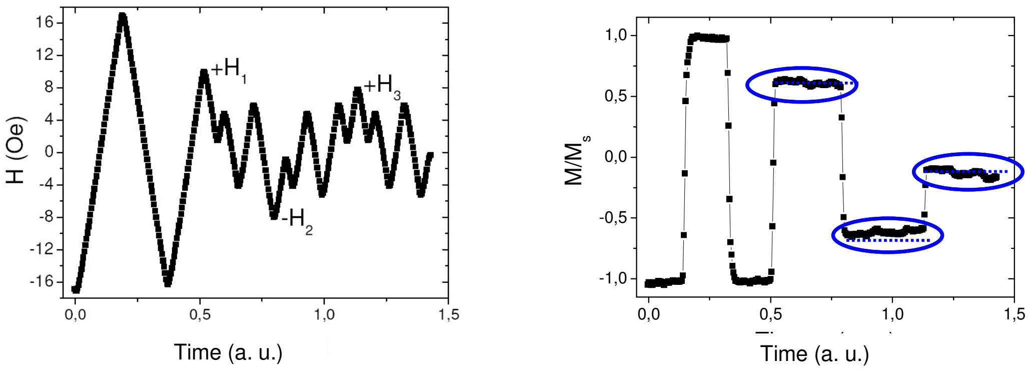

Fig.2: (Left) Field time evolution in order to record three magnetic states in the array. (Right) Corresponding magnetization vs. time evolution, where it can be seen how the reduction of the absolute magnetization due to the DW kinks movement keeps memory of the magnetic state.

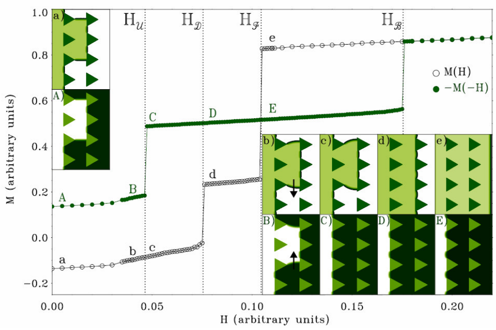

Fig. 3: Numerical simulations of the switching fields for DW motion in an array of asymmetric holes for the cases of a flat DW and a kinked DW, that present opposite ratchet effects.