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MAGNETOSTATIC DIPOLAR DOMAIN WALL PINNING IN CHAINS OF PERMALLOY TRIANGULAR RINGS MICROMAGNETS

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Manipulation of magnetic domain walls (DWs) in nanostructures has recently become the focus of intense research due to its great potential for application to spintronics and also because of the basic physics involved in the phenomenon. Crucial for application is the possibility to induce a controlled and reproducible DW displacement by either using magnetic fields or injecting polarized currents. Magnetic nanorings are particularly apt geometry to such investigations [1]. If the effects of magnetocrystalline anisotropy are negligible, only the geometry of the ring determines the microscopic spin structure of the magnetic states and the effects of geometrical constrictions, such as notches and corners, on DWs in nanorings have been intensively investigated [2].

In an earlier work we have studied the magnetization reversal in Permalloy (Py) triangular rings and we observed that head-to-head DWs can be positioned at selected corners and moved between corners by applying a field along a particular direction [3]. In this contribution we present the results of a combined experimental and numerical study with which we determined the details of the pinning of domain walls in isolated and interacting Py triangular rings (side 2 um, width 250 nm and thickness 25 nm) [4]. In the former case the rings form a square lattice with a period of ~4.2 um so that inter-element interactions are negligible; in the second sample the rings are arranged in chains with a corner tip of each triangle in proximity of the edge centre of the triangle above with inter-element spacing of 50 nm. Using the longitudinal and diffraction magneto-optics Kerr effect (L- and D-MOKE, respectively [5,6]), magnetic force microscopy (MFM), and micromagnetic simulations [7] we determined the field dependence of the spin structure in the rings. The results show that magnetization reverses from an onion state to the reversed state via the formation of a vortex. Each onion state is characterized by DWs (one head-to-head and the other tail-to-tail) geometrically pinned at two corners of the ring [see MFM image in Fig. 1 panel (a)]. We prepared each sample in a well defined onion state (monitored with D-MOKE) and determined the DW motion and pinning potentials recording the L-MOKE loops obtained by sweeping the wall with a field H1 applied along a branch of the ring. We studied this process as a function of a second field H2 applied perpendicularly to the branch of the ring along with the DW is swept and kept fixed during the sweeping, to prevent oblique segments from switching, as sketched in panel (b) of Fig. 1 for the chains of rings. In the case of isolated rings a DW moves freely between the geometric pinning potential wells determined by adjacent corners as the external field H1 reaches a critical value Hd and a single transition is observed in the loops at any value of H2 [solid line in Fig. 1 panel (c)]. For interacting rings, when the wall is swept in the branch closer to the corner tip of the nearest neighbor ring, the loops show an intermediate step for H2 above a certain value caused by the pinning of the wall by the magnetostatic dipolar field emanating from the corner of the nearest ring neighbor [see open symbols in Fig. 1 panel (c)]. Quite interestingly, the depinning of the DW from the starting corner is always (viz. at any value of H2) anticipated in the chains with respect to isolated rings [compare open dots (Hd) and open triangles (Hd1) in Fig. 1 panel (d)], due to the presence of the potential well created by the magnetostatic interaction. We observed that H2 affects appreciably only the depinning field Hd1 from the corner but not the depinning field Hd2 from the potential well due to the magnetostatic interaction [compare open and solid triangles in Fig.1 panel (d)]. Qualitatively, the process can be modeled as a domain wall in a triple potential well landscape with the depth of the two wells at the adjacent corners delimiting the branch, function of the vertical applied field H2. Micromagnetic simulations reproduce the behavior observed and provide additional details on the DW spin structure during its motion.

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Figures:

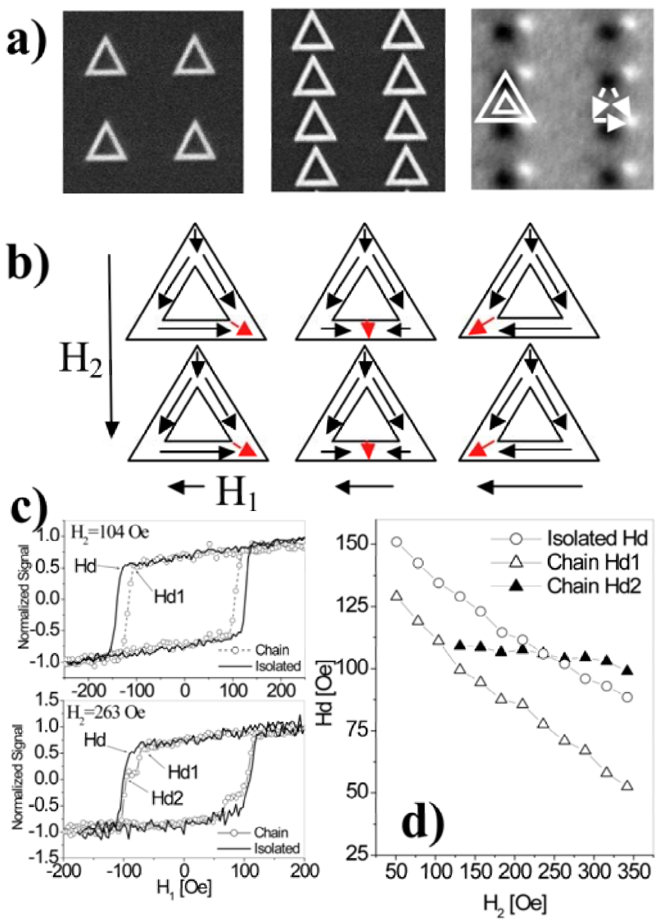

Fig. 1 Panel (a): SEM images of the two arrays and MFM image of the remanent state of the sample with chains of rings. Panel (b): schematic of the experiment described in the text. Panel (c) : loops of the two samples recorded at two different values of H2. Panel (d) : plot of the domain wall depinning fields for the two samples.