

Effects of Ga irradiation on the nucleation and propagation of magnetic domain walls in cobalt nanostructures grown by focused-electron-beam-induced deposition

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Abstract

Focused-electron-beam-induced deposition (FEBID) techniques are useful to grow cobalt nanostructures with resolution down to 30 nm [1], with potential applications in magnetic logic, sensing and storage. Magnetic Force Microscopy studies revealed the existence of single-domain magnetic states with appropriate dimensions of the cobalt nanostructures [2]. Magneto-optical Kerr effect (MOKE) measurements identified domain-wall conduit behavior (lower propagation than nucleation fields) in L-shaped nanowires [3]. Lorentz microscopy experiments showed the different types of domain walls appearing in L-shaped nanowires as a function of the cobalt thickness [4]. In the present contribution, we will report recent experiments on the use of Ga irradiation produced by means of a Focused Ion Beam in order to modify the nucleation and propagation of domain walls in cobalt nanostructures grown by FEBID techniques [5]. MOKE and Scanning Transmission X-ray Microscopy (STXM) studies have given evidence for remarkable changes in the nucleation and propagation of domain walls as a function of the Ga irradiation dose. In linear structures with an injection pad [see figure 1(a)], STXM measurements show that Ga doses of the order of 10^{16} ions/cm² are required to produce local pinning in the propagation of domain walls. MOKE experiments in L-shaped nanowires indicate that, below 6.4×10^{15} ions/cm² irradiation, the separation between the nucleation and propagation field increases significantly [see figure 1(b)]. Thus, Ga irradiation results into the enhancement of the operating margin of domain-wall-based devices. Transmission Electron Microscopy experiments show that this range of doses modifies significantly the microstructure of the outer 20 nm of the nanowires where the gallium is implanted, especially the grain size, leaving the core of the wire intact. As a consequence, the nucleation field increases rapidly due to an increase in the magnetocrystalline anisotropy at the outer shell at the end of the wires, where the domain walls are formed, while the propagation field, more dependent on the magnetostatic and exchange energy, remains almost constant. In conclusion, Ga irradiation is a powerful method to manipulate domain walls in cobalt nanostructures.

References

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Figures

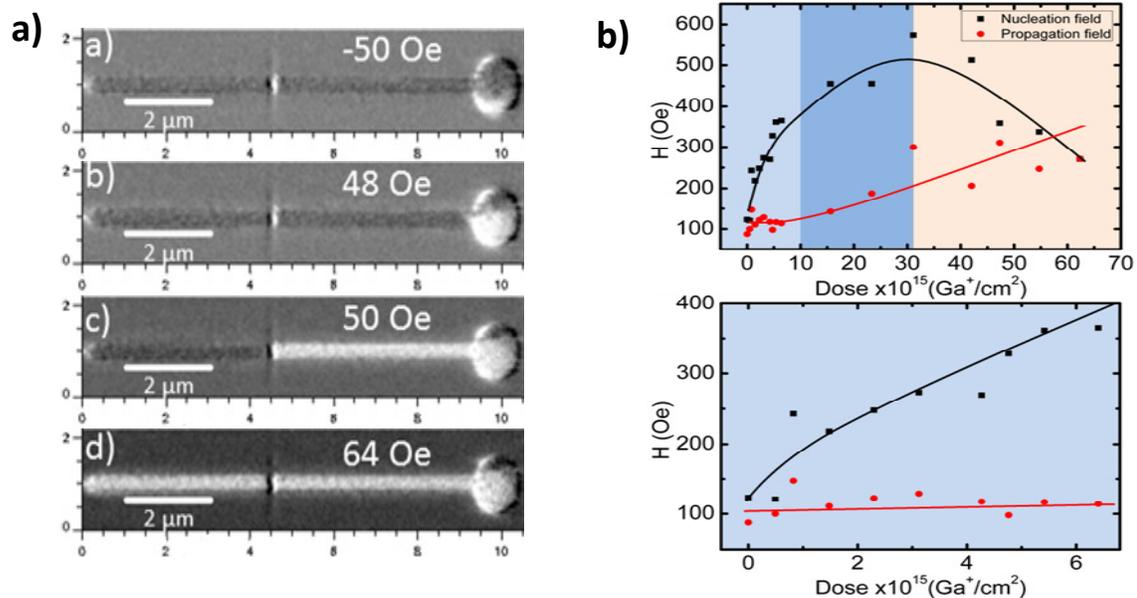


Figure 1(a): Sequence of Scanning Transmission X-ray Microscopy images of the magnetization reversal in one of the cobalt nanowires with local Ga focused-ion-beam irradiation (irradiation dose of 4.48×10^{16} ions/ cm^2) in the central part of the wire. *(b)* Top image: Variation of the nucleation (black) and propagation field (red) of L-shaped cobalt nanowires as a function of the Ga irradiation dose. The lines are guides to the eye. The three different regimes of irradiation are illustrated by changing the color of the chart: light blue for low irradiation doses, dark blue for medium irradiation doses and pale pink for high irradiation doses; Bottom image: Zoom-in of the first regime of low irradiation doses in the top image.