Quantification of Critical Magnetic Fields and Local Hysteresis Loops in Individual Nanostructures

O. Iglesias Freire[1], M. Jaafar[1,2], A. Awad[2], F. G. Aliev[2], L. Serrano[3], J. M. de Teresa[3], A. Fernández-Pacheco[3,4], R. Córdoba[5], M. Ibarra[3,5] and A. Asenjo[1]

[1] Instituto de Ciencia de Materiales de Madrid, Cantoblanco, 28049, Madrid, Spain
[2] Dpto. Física de la Materia Condensada, Universidad Autónoma de Madrid, 28049, Madrid, Spain
[3] Instituto de Ciencia de Materiales de Aragón, 50009, Zaragoza, Spain
[4] Imperial College London, South Kensington Campus, London, United Kingdom
[5] Instituto de Nanociencia de Aragón, 50009, Zaragoza, Spain

oiglesias@icmm.csic.es

Nanomagnetism is a research area of growing interest focused on phenomena related to the low dimensionality of magnetic elements. Besides its interest from a fundamental point of view, these magnetic nanostructures are of great technological importance in a wide variety of applications such as magnetic recording, sensors, biomagnetism, etc. For the development of such fields it becomes necessary not only the use of fabrication techniques which allow us to obtain patterned nanostructures but also access to characterization methods with suitable spatial resolution and sensitivity in order to study domain configurations and magnetization reversal processes on the nanoscale. In the last years, new alternatives based on magnetic nanostructures have emerged to the current electronic devices and information storage systems. Remarkable are new research lines based on the domain wall control in magnetic nanostripes (as racetrack memories [1] and domain wall logic [2]) or on the control of both the chirality and polarity of magnetic vortices [3], [4].

In this work we are able to quantify the critical fields in individual magnetic nanostructures. By means of a Variable Field Magnetic Force Microscope (VF-MFM) [5] and utilizing the so-called 3D Modes [6], the switching fields of individual cobalt nanostripes and the nucleation-annihilation fields of magnetic vortices in permalloy dots were obtained. Furthermore, a local hysteresis loop at every specific point of the nanostructure can be measured, providing an advantage over other magnetometer systems.

VF-MFM allows high quality imaging of magnetic nanostructures with high mechanical stability under a variable external magnetic field that can be applied both along in-plane and out-of-plane directions. In the 3D Modes, the MFM tip continuously scans over the same region as the external magnetic field is varied with the aim of performing a hysteresis loop.

References

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Figures

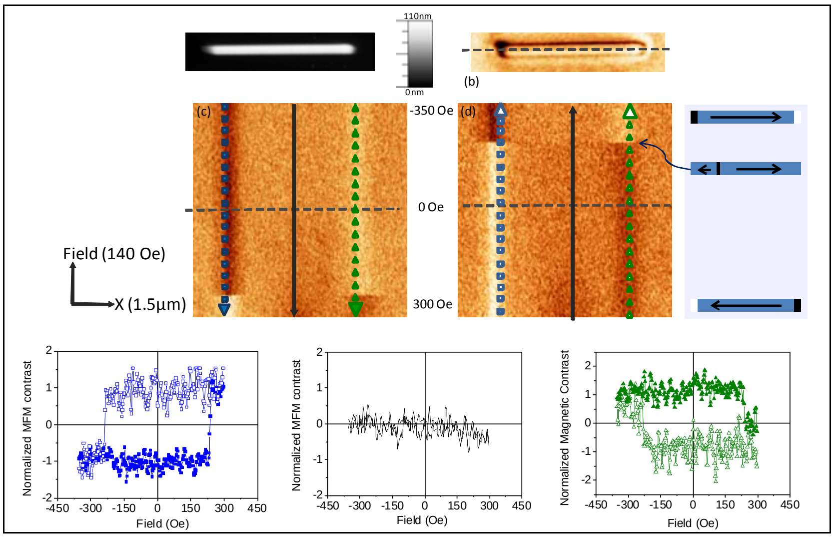

Figure 1. (a) Topography and **(b)** MFM images of a cobalt nanostripe of dimensions 250 nm x 5 µm. **(c)** and **(d)** MFM images using the *3D-Modes* (X vs Magnetic field), where and abrupt change in the nanostripe's magnetization can be clearly observed. **(e)** By plotting vertical profiles on images (c) and (d), local hysteresis loops are obtained (blue/black/green curves).

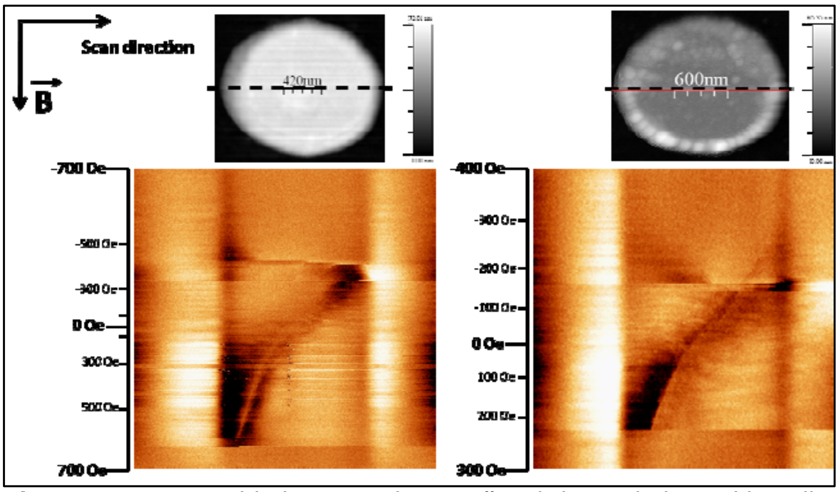

Figure 2. Topographic images of permalloy ($Ni_{80}Fe_{20}$) dots with a diameter of 1 µm and **(a)** 50 nm and **(b)** 20 nm thick. **(c)** and **(d)** MFM images obtained utilizing the 3D Modes (X vs. Magnetic field), both critical fields related to vortex nucleation-annihilation can be quantitative determined. Furthermore, it is indeed possible to observe a double-vortex metastable state on (d), as predicted in **[7]**.