Electronic Supplementary Information (ESI)

Magnetization reversal in circular vortex dots of small radius

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Here we describe the morphological characterization of the nanostructures used in the work. The samples were prepared by hole mask colloidal lithography (HCL) following the steps described in Ref. 18 of the manuscript. As discussed in the paper, the magnetic properties of the dots are quite sensitive to small changes of dimensions (radius and height), so a thorough morphological characterization is required. Additionally, we include the MFM images showing the displacement of the vortex core under the application of in-plane magnetic fields.

The lateral dimensions (R) of the dots are established by image analysis of zenithal scanning electronic microscopy (SEM) photographs. ImageJ software was use for that purpose (Ref. 23 of the manuscript).

The thickness of the dots (T) was accurately determined by atomic force microscopy (AFM). The lateral resolution of AFM is rather poor due to the convolution effect caused by the tip finite size. An AFM standard (20 nm high step) is used to quantify the magnitude of this effect, which results to be about 75 nm (Figure ESI.1). Within that uncertainty, the lateral dimensions measured by AFM agree with the ones measured by SEM.

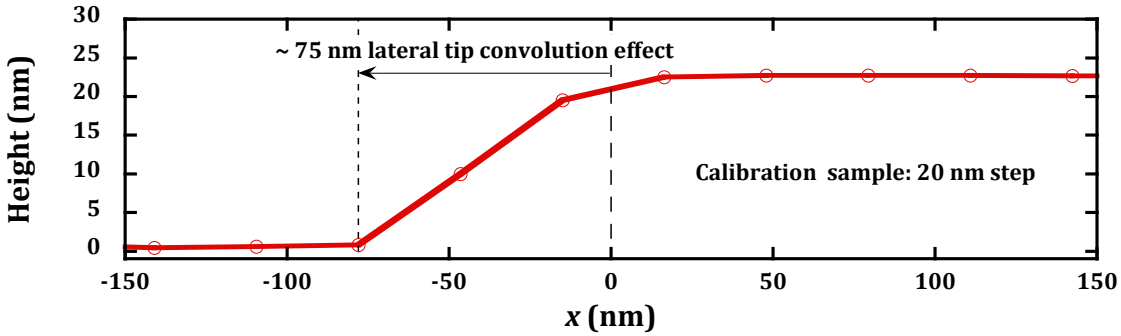

Fig. ESI.1. Quantification of the magnitude of the tip convolution effect in AFM measurements. The "rising" slanted profile caused by this effect in a 20 nm high calibration standard, measured in the same conditions that the samples, is about 75 nm long.

As an example the morphological characterization performed on each sample, the results obtained in two samples with different radii are presented next.

Sample S30. Nominal dimensions: R = 30 nm, T = 30 nm.

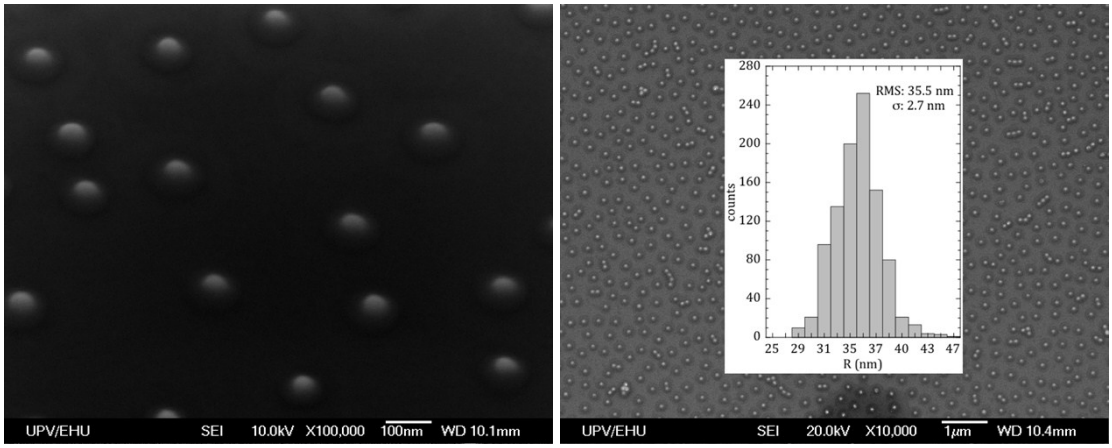

Fig. ESI.2. *Left*: tilted SEM image of the S30 dots. *Right*: zenithal image used for determining the size distribution, which is displayed in the inset.

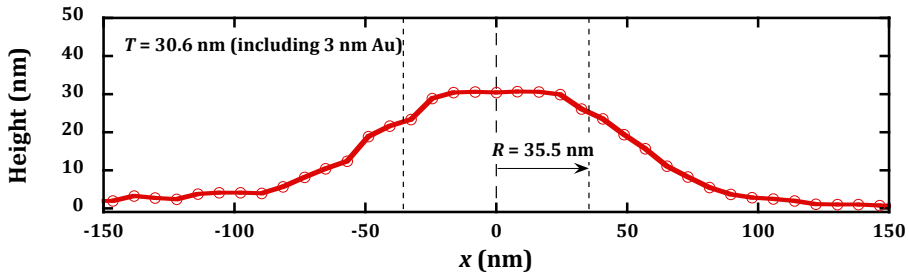

Fig. ESI.3. AFM profile of sample S30. Dotted vertical lines indicate the lateral dimensions of the dot established by SEM, which are compatibles with the lateral resolution of AFM determined in Fig. ESI.1.

Sample L30. Nominal dimensions: R = 70 nm, T = 30 nm.

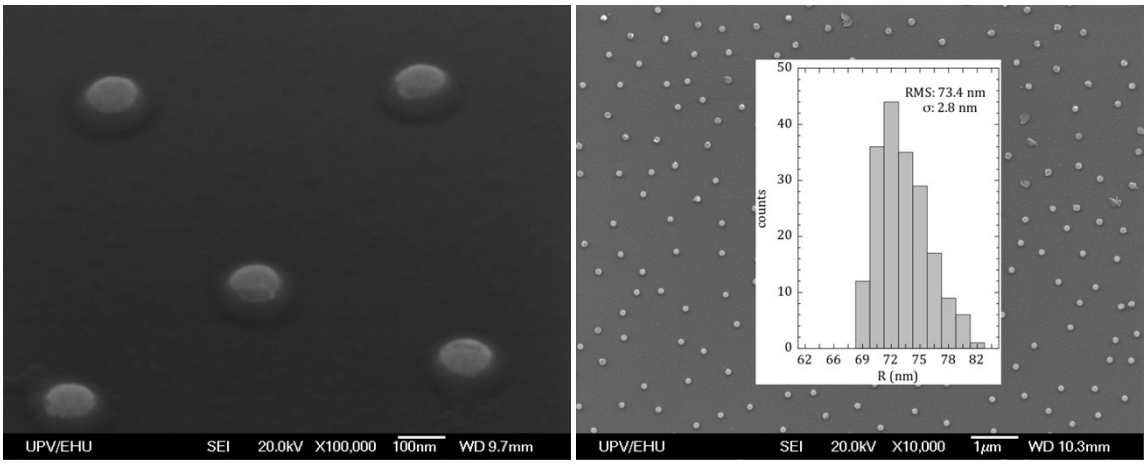

Fig. ESI.4. *Left*: tilted SEM image of the L30 dots. *Right*: zenithal image used for determining the size distribution, which is displayed in the inset.

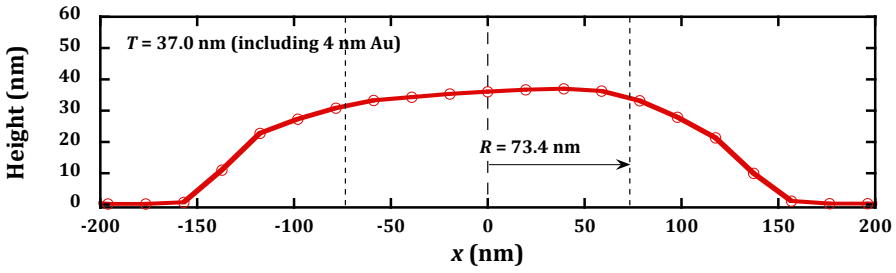

Fig. ESI.5. AFM profile of sample L30. Dotted vertical lines indicate the lateral dimensions of the dot established by SEM, which are compatibles with the lateral resolution of AFM determined in Fig. ESI.1.

Variable-Field MFM confirms the behaviour deduced from hysteresis loops and simulations. At zero applied field -Fig. ESI.6(c)- the vortex cores are centred, while the core moves towards the edge of the dot when a small field is applied. As it can be seen in the loops, the available fields are not enough to completely expel the vortex and go to a saturated in-plane configuration.

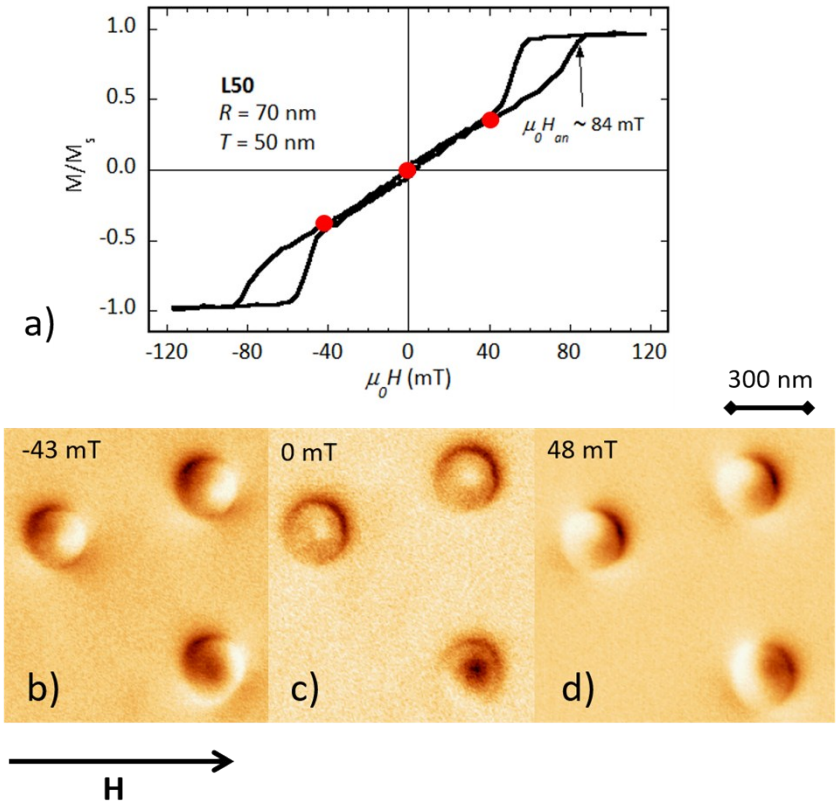

***Fig. ESI.6*. (a)** SQUID hysteresis loop corresponding to the sample L50 with the imaged points marked in red. **(b), (c)** and **(d)** show the corresponding MFM images of the same dots under different in-situ fields.