CHARACTERIZATION OF COERCIVITY AND STRAY FIELD OF MFM TIP

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Magnetic Force Microscopy (MFM) [1,2] reveals as a useful technique to analyze the local magnetic behavior of the materials [3]. In some cases, the MFM data are complementary to the magnetic characterization performed by using standard macroscopic methods like SQUID or VSM magnetometers. So far, in the case of nanometric devices, only few techniques can supply valuable information about the behavior of individual nano-objects, and the MFM presents highest resolution and provides information about their general magnetization process [4] and particularly magnetization reversal [5].

Nevertheless, some handicaps of MFM technique are the difficulty to provide quantitative information of the magnetic moments direction, and the unpleasant tip-sample interaction that can cause reversible and irreversible changes in the sample's magnetic state. In this concern, previous MFM tip characterization can help to improve the quantitative MFM image interpretation as well as to prevent or reduce the stray field influence.

The objective of this work has been to obtain quantitative interpretation of MFM images. For this pourpose, we have calibrated MFM tips along two ways: by measuring the coercivity of the MFM tips and calculating the stray field of the tip applied to the sample. Firstly, we have characterized the coercivity of the tips by applying an external magnetic field to the tip during the microscope operation. The tip changes are evaluated by acquiring successive MFM images of longitudinal magnetic recording samples as shown in figure 1 (results are for a commercial hard disk which magnetic state is not altered by the MFM tip).

The stray field of the tip is calculated imaging a sample with well define magnetic moment distribution. For that, we have considered ordered arrays of Ni nanowires grown into nanoporous membrane with diameters about 30 nm and 1000 nm long. The array shows hexagonal symmetry with a lattice parameter of 105 nm. The nanowires present axial easy axis due the shape anisotropy [6] and as a first approximation, individual nanowires can be taken as nearly single-domain. In this situation the MFM images can be used to evaluate the remanent magnetization of the sample [7,5,8]. MFM images of the sample have been obtained varying the remanent state. Irreversible changes in the individual nanowires have been observed due to the tip field (see fig 3). A shift of the remanent values is observed due to the stray field of the tip as shown in figure 4.

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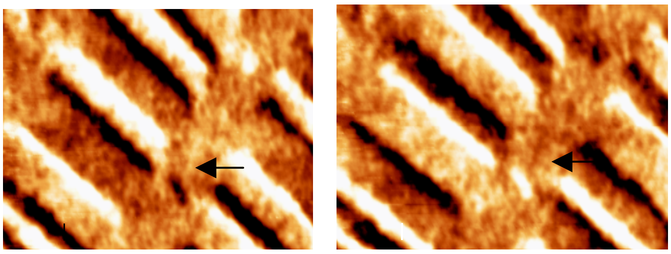
Figure 1:



MFM image of commercial hard disk obtained before (a) and after (b) the application of 150 Oe to the tip. Notice the change of the MFM contrast in the region shown by the arrow.
Images size 10 µm x 4 µm

Figure 2:

Evolution of the magnetic contrast obtained from commercial hard disk MFM images as a function of the magnetic field applied to the tip.

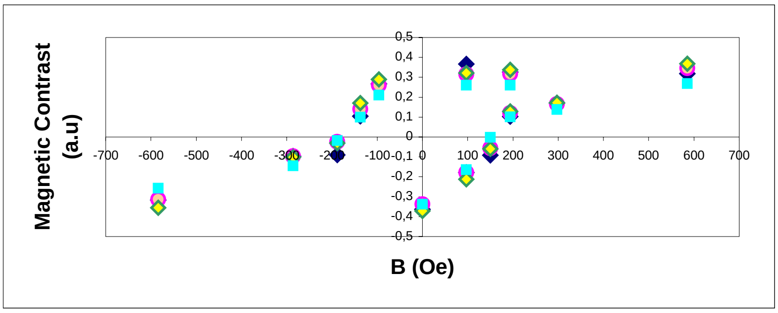
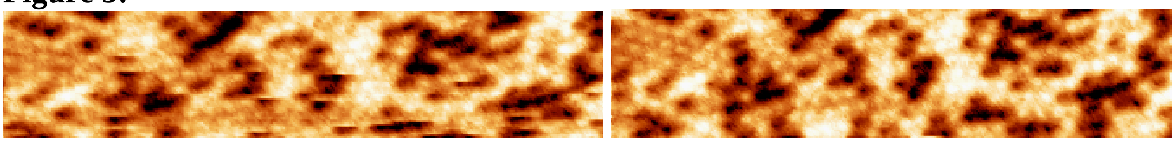


Figure 3:



Two consecutive MFM images of an array of Ni nanowires. Notice the irreversible changes in the individual nanowires due to the tip field.
Size: 4 µm x 1 µm

Figure 4: Magnetic remanence values deduced from the MFM images obtained for different magnetic states of the sample. In this figure we observed a shift of the remanence values due to the stray field of the tip.