Magnetoresistance in positive and negative exchange bias Ni/FeF_2 bilayered antidots

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The comprehensive explanation of the exchange bias phenomenon (EB) in nanostructured materials still remains a challenge, despite the number of experimental and theoretical investigations [1]. We used focused ion beam lithography to fabricate a series of ordered arrays of antidots, as a function of the antidot-antidot distance in the *x*-*y* plane (Fig.1). The fabrication was performed on bilayered samples prepared by electron beam evaporation consisting of antiferromagnetic (AF) FeF_2 (70nm), ferromagnetic (FM) Ni (50nm) and Al (4nm) as a protective layer. FeF_2 was epitaxially grown on top of single crystalline MgF_2, while the FM layer was polycrystalline. The antidots were fabricated in a square/rectangular array, with antidot size of 200 nm and *x* and/or *y* antidot-antidot distances within the range 120-900 nm. The antidot density was set within 5% and 55%. Atomic force and scanning electron microscopy were used to characterize the quality of the nanostructures. Magnetoresistance (MR) measurements were carried out to determine the exchange bias field (loop shift) in both continuous thin films and nanostructures. MR was measured with the standard four probe technique in the temperature range 4.2 K – 300 K up to 50 kOe. The magnetic field was applied either parallel or transversal to the in plane easy magnetization axis of the AF, while the in plane current was set parallel to the latter. The resistivity was measured at various field cooling conditions (from 100 Oe to 50 kOe). The measuring field was applied parallel the cooling field.

Three types of behaviour were observed: for small cooling fields, MR curves display a shift towards negative field values (negative EB), while for large cooling fields the shift is positive (positive EB) (Fig.2). At intermediate cooling fields, two MR peaks are observed (one shifted to negative fields; the other one shifted to positive fields), whose relative height and area depend on the cooling field. However, in all cases the absolute value of the exchange bias field is almost independent of the cooling field, at a given antidot density. Consequently, the AF domain size is suggested to be comparable to or larger than the FM domain size, such that each FM domain couples only to one AF domain with a particular direction of the EB [2]. Therefore, for small/large cooling fields we have only one EB direction, while two directions appear for intermediate cooling fields. Finally, it is worth stressing that both the magnetization reversal mechanisms (domain nucleation and propagation and non-uniform rotation) and switching from positive to negative EB depend on the antidot density. We have developed a model based on the micromagnetic simulations that allow accounting for all the foregoing results.

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References:

[1] O. Iglesias, A. Labarta, X. Batlle, Journal of Nanoscience and Nanotechnology, **8** (2008) 2761; J. Nogués and I. K. Schuller, J. Magn. Magn. Mater., **192**, (1999) 203.

[2] O. Petracic, Z.P. Li, I. V. Roshchin, M. Viret, R. Morales, X. Batlle ,and I. K. Schuller, Appl. Phys. Lett., **87** (2005) 222509; I. V. Roshchin, O. Petracic, R. Morales, Z.P. Li, X. Batlle and I.K. Schuller, Euro. Phys. Lett., **71** (2005) 297; R. Morales, Z.P. Li, O. Petracic, X. Batlle, and I.K. Schuller, Appl. Phys. Lett. , **89** (2006) 072504.

Figures:

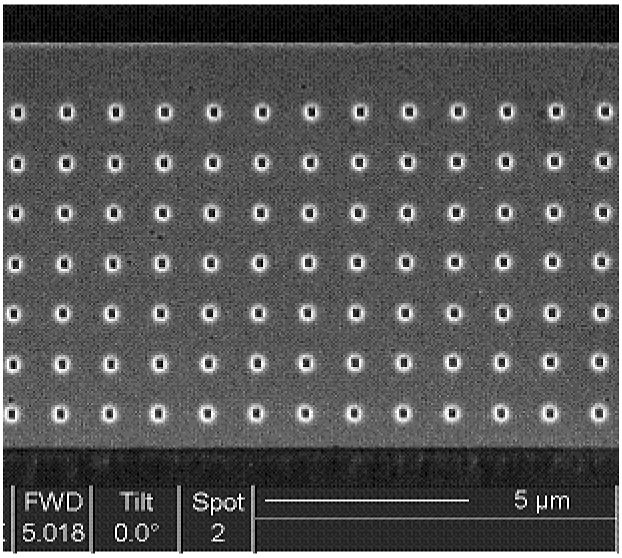

Fig.1. SEM image for square array antidots.

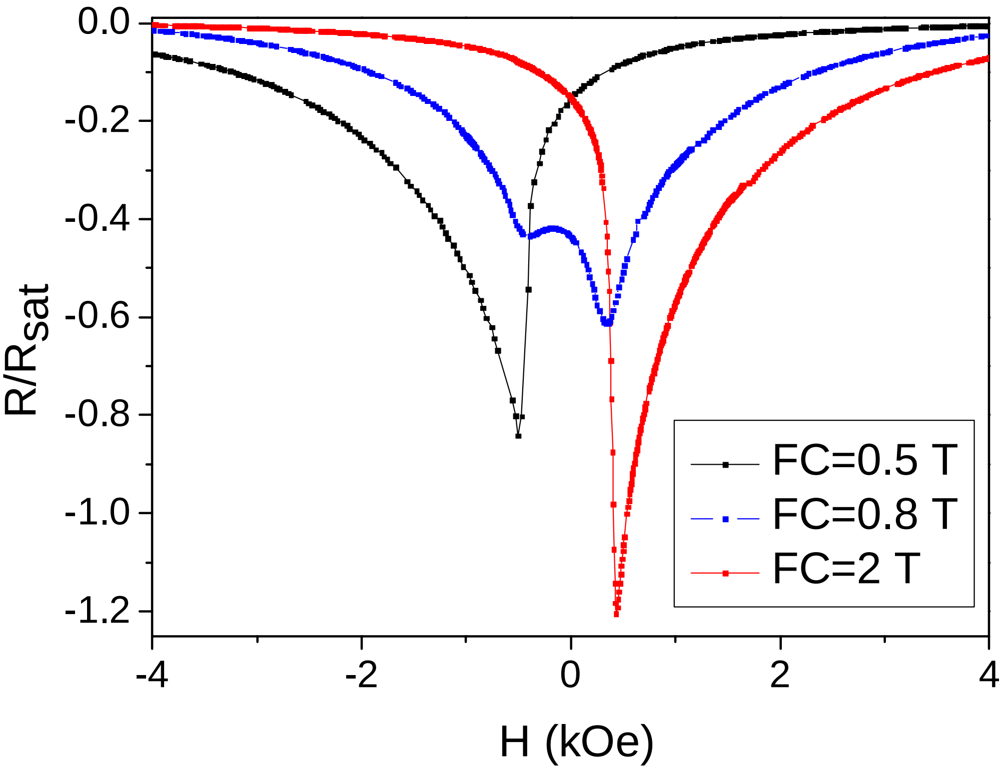

Fig.2. (Colour online) Example of the ratio of the resistance *R* to the minimum resistance $R_{saturation}$, $R/R_{saturation}$, as a function of magnetic field, *H*, measured at 4.2 K after a field cooling process at the following cooling fields FC = 0.05(black squares), 0.08 (blue triangles), 2 T (red circles) for antidot density = 0.06.