Tuning exchange bias in Ni/FeF_2 heterostructures using antidot arrays

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The microscopic origin of exchange bias (EB) represents one of the challenges in solid state physics, despite the extensive experimental and theoretical investigations [1]. We used focused ion beam lithography to fabricate a series of ordered arrays of Ni/FeF_2 antidots to get a deeper insight of EB in nanostructures (Figure 1). Ni/FeF_2 heterostructures were deposited by electron beam evaporation onto (110) MgF_2 single-crystal substrates of 70 nm of antiferromagnetic (AF) FeF_2, 50 nm of ferromagnetic (FM) Ni and 4 nm of Al. The antidots were fabricated in a square array, with antidot size of 200 nm and periodicity ranging from 100 to 900 nm (antidot density, AD, from 5% to 24 %). Magnetoresistance measurements were used to determine the EB field in the temperature range 4.2–300 K, in both the parallel and transversal configurations, after field cooling (Figure 2). For small/large cooling fields, the magnetoresistance curves display a shift towards negative/positive fields. At intermediate cooling fields (CF), two MR peaks are observed (one shifted to negative and the other to positive fields), whose relative height and area depend on CF. However, the absolute value of the EB field is almost independent of CF. This suggests that the AF domain size is comparable to or larger than the FM domain size, so each FM domain couples mostly to one AF domain with a particular direction of the EB [2]. The transition from positive to negative EB can be systematically tuned with AD. The onset of positive EB appears at a CF one order of magnitude lower for AD=24 % than the unpatterned samples. These results are a consequence of the energy balance and suggest that the nanostructure plays a key role in the formation of pinned, uncompensated spin regions in the FeF_2 layer. The non-interfacial magnetic moments created at the antidot faces favor the onset of positive EB at lower CF [3].

The financial support of the Spanish MICINN (MAT2009-08667 and CSD2006-00012), Catalan DURSI (2009SGR856) and the U.S. Air Force are recognized.

References:

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Figures:

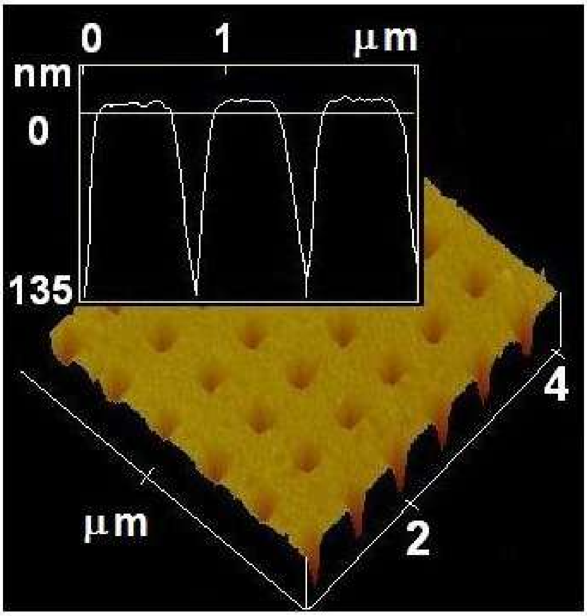

Figure 1. Atomic force microscopy image for AD = 0.12; The inset shows that the antidot is carved through the whole depth of the heterostructure.

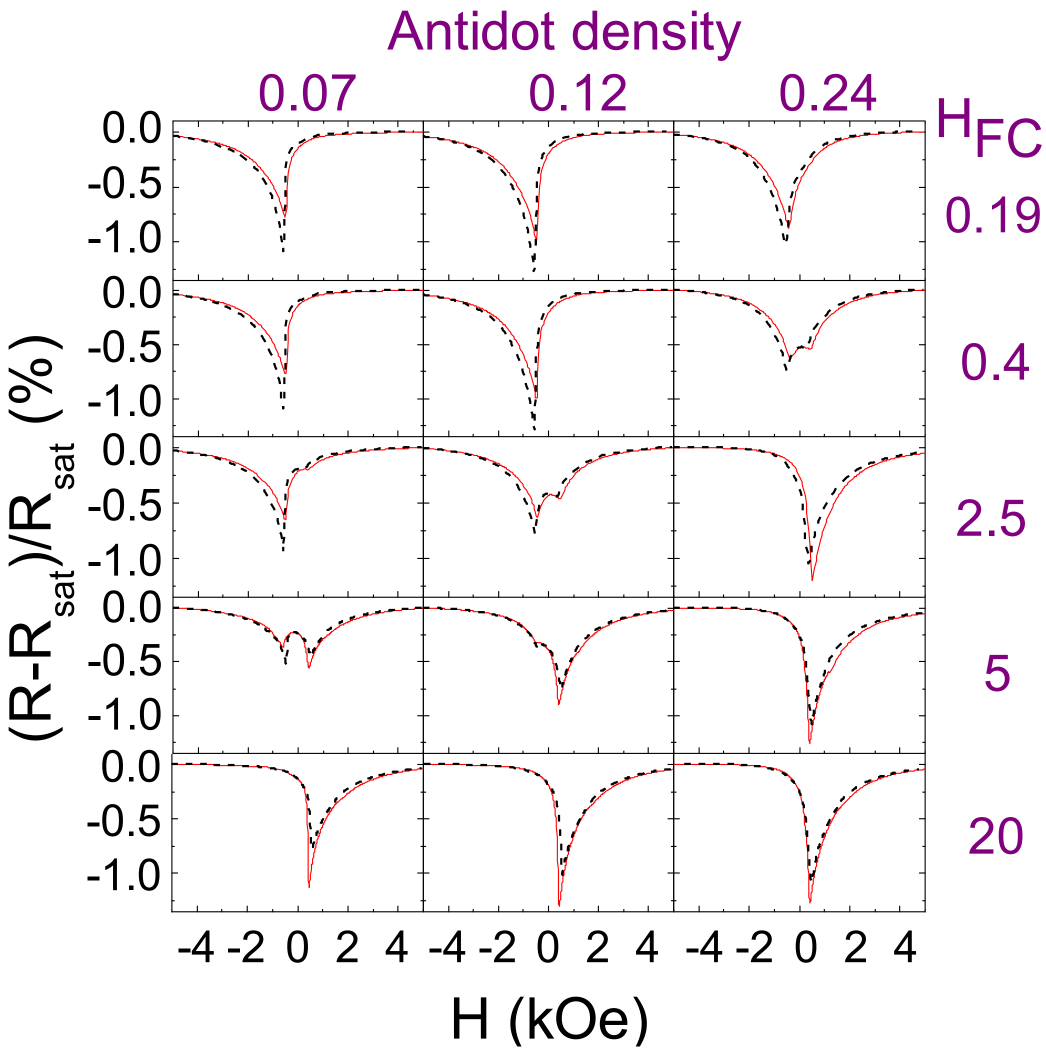

Figure 2. $(R(H) - R_{sat})/ R_{sat}$ measured at 4.2 K as a function of H applied parallel to the current, after cooling under H_{FC} = 0.19, 0.4, 2.5, 5 and 20 kOe, for AD = 0.07, 0.12 and 0.24. The solid (red)/dash (black) line corresponds to the decreasing/increasing field branches.