MAGNETIZATION REVERSAL PROCESS IN SPIN SPRING MAGNETS. ELECTRONIC STRUCTURE CALCULATIONS

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One of the nanostructures in which a non-collinear magnetic structure can be continuously and reversibly tuned by an external magnetic field is the spin spring permanent magnet which consists of exchange-coupled hard and soft magnetic bilayers or multilayers. Exchange spring media are of technological interest as permanent magnets but are also promising nanostructures for magnetic recording[1,2]. Various experimental methods have been used for the investigation of magnetic ordering in spring magnets[3,4], which in turn became a model system for benchmarking different methods to study non-collinear magnetism. Due to their complexity, the interpretation of experimental data has been made so far with the help of phenomenological models[3,4].

For the description of the magnetization reversal process in exchange spring magnets with Fe (and Fe capped by Cr or V) as the soft phase, we developed an atomic-scale quantum-mechanical theory for itinerant magnetism based on a realistic non-collinear Tight-Binding formulation of the Hamiltonian with universal parameters for each chemical element. Therefore, the behaviour of the soft magnetic films as a function of the intensity and orientation of an external magnetic field is described in the framework of fully self-consistent electronic structure calculations. Our results reproduce qualitatively all the main trends experimentally observed.

In Fig.1 we show the calculated spin-configuration for the 100ML thick Fe slab in an external magnetic field applied in the film plane. Fig. 2 illustrates the angle between the magnetic moment of the Fe layers and the easy axis of the hard magnet for different external fields applied opposite to this easy axis. In Fig. 3 we plot the reversible part of the hysteresis loop. The critical intensity of the external field required for the onset of the non-collinear spiral formation depends on both the thickness of the soft magnetic phase and on the orientation of the field, and the spin spiral structure undergoes a change of chirality in rotating fields. Our theoretical approach opens new prospects for investigating the response of other nanostructures to external magnetic fields, beyond the usual phenomenological models.

References:

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Figures:

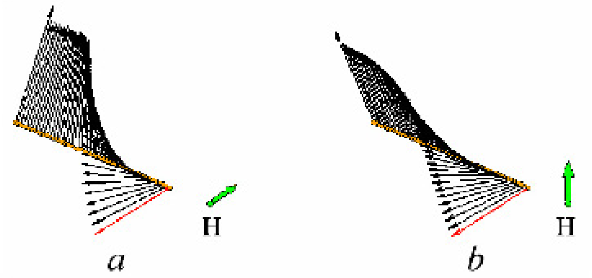

FIG. 1: Calculated spin configuration of the 100 ML thick Fe slab in an external magnetic field ($h = 3.0 \times 10^{-5}$), applied in the film plane opposite (a) and perpendicular (b) to the easy axis of the substrate (hard magnet). The direction of the lower (red) Fe moment is fixed along this easy axis. The arrows are proportional to the local magnetic moments. Only each second layer is shown. See also [21].

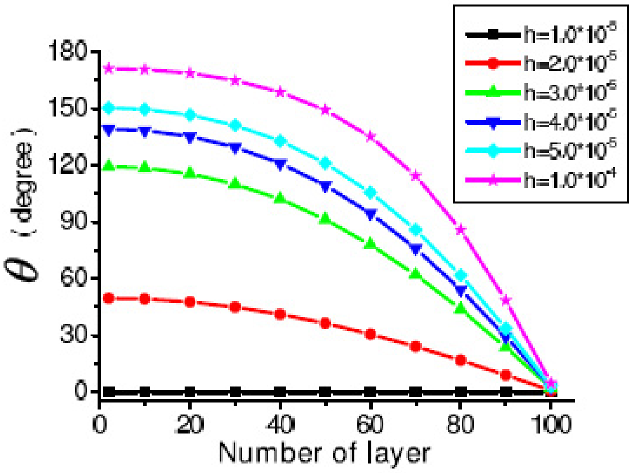

FIG. 2: Layer dependence of the angle θ_i between the magnetic moment and the easy axis of the hard magnet for different values of the external magnetic field applied opposite to the easy axis. The surface layer has number 1.

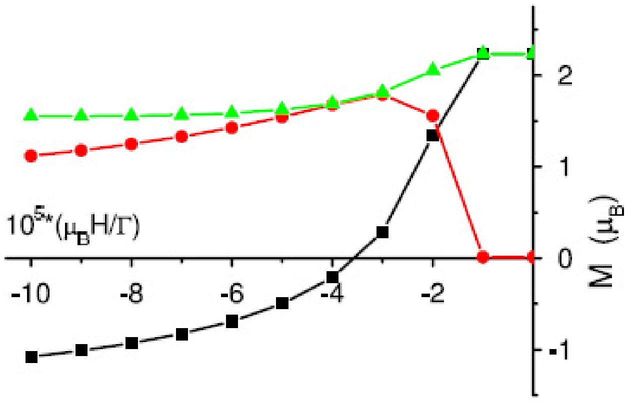

FIG. 3: Average modulus (triangles), longitudinal (squares) and transverse (circles) components of the magnetic moment (see text) as a function of the external magnetic field applied opposite to the easy axis of the hard magnet. See also [21].