Ferromagnetic resonance study of Fe/FePt coupled films with perpendicular anisotropy

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The magnetic interaction between hard and soft magnetic materials is of current technological interest due to their potential for applications in magnetic storage devices. Such systems are referred to as "exchange springs" [1]. We have studied exchange coupled FePt/Fe magnetic layers using the technique of ferromagnetic resonance (FMR). The FePt layers show strong uniaxial perpendicular anisotropy, growing in the $L1_0$ epitaxial phase on MgO (100). We have considered the case for two thicknesses of Fe; 2 nm and 3.5 nm, which exhibit rigid magnet and exchange-spring behaviour. All FePt thicknesses are limited to 10 nm. The FMR results display multi-peaked spectra, where we have identified three Fe resonance lines in the rigid magnet sample and an extra two in the exchange spring sample [Fig.1(a)]. Angular FMR studies show a strong uniaxial anisotropy induced in the Fe layer via the strong exchange coupling with the FePt film. An additional uniaxial component is also observed with an easy axis inclined by about 50º from the film normal. Supplementary magnetic measurements have been used to aid with the magnetic characterisation. In this paper we discuss the elements of the theory of FMR in these exchanged coupled systems. We have developed a model of FMR for these exchange coupled systems, which is be based on the magnetic free energy of the coupled layers and is required to interpret the angular dependence of the resonance fields. For this we start by applying the model by Asti *et al*. [3]. In our theoretical modelling we have carried out both analytical and numerical simulations in order to aid with the interpretation of our experimental results. Since our FMR data only measure the Fe (soft) magnetic layer, we only need consider this in our analysis, where the effect of the FePt (hard) layer is to exchange couple with the Fe film effectively pinning the interface spins. To do this we have firstly evaluated the analytical and numerical equilibrium conditions of the Fe spins as a function of distance within the layer. In the numerical minimization model, the software minimizes the free energy of the system using Monte Carlo method. It creates an array of spins in which the first one (at the Fe/FePt interface) is fixed in the perpendicular direction[Fig.1(b)]. All other spins have a random direction and the system has an initial magnetic free energy. We then minimize the free energy on a spin by spin basis in order to evaluate the equilibrium orientation as a function of position. The coupled spins have a perpendicular (uniaxial) anisotropy in the FePt film, shape anisotropy with easy axes on the plane in the Fe film. The simulations reveal a 90 degree domain wall which moves up and down with the application of an external magnetic field.

References:

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