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

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Exchange spring magnets with perpendicular magnetic anisotropy represent new magnetic properties with respect to their constituent components. These systems typically consist of a hard magnetic layer and a soft magnetic layer which are strongly coupled. The modification of their bulk magnetic properties arises from this strong ferromagnetic exchange coupling, interfacial effects and competing magnetic anisotropies of the two magnetic layers.

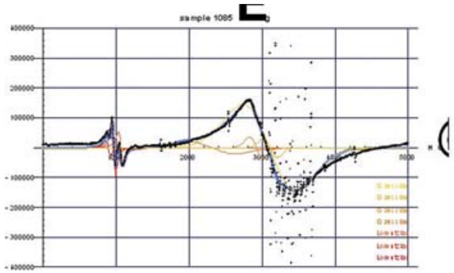
We have studied the magnetic bilayer system which consists of an Fe (soft) film exchange coupled to an FePt (hard) layer which has an easy axis aligned along the direction perpendicular to the film plane. The entire structure has the form: MgO/FePt (10 nm)/Fe (2nm or 3.5nm)/ Ag (2nm), where the Ag overlayer acts as protection against oxidation. The epitaxial FePt layers were deposited on MgO (100) substrates using the RF sputtering technique at a substrate temperature of about 390 C. The epitaxy of this layer was studied using x-ray and electron diffraction techniques. Layer morphologies were further studied using atomic force microscopy (AFM), these studies reveal a granular morphology with grain sizes of the order of 40 – 50 nm.

We have made detailed angular measurements using the ferromagnetic resonance (FMR) at room temperature. This angular FMR study, which includes the orientations of in-plane and out-of-plane, was performed in order to study the magnetic anisotropies as well as the exchange coupling between the magnetic layers and interfacial effects. In particular, we have chosen to study two samples with 2 nm and 3.5 nm of Fe, which effectively constitute the rigid magnet (RM) and exchange spring (ES) regimes, respectively. The RM and ES regimes depend implicitly on the magnetic anositropies and properties of the two coupled layers [1].

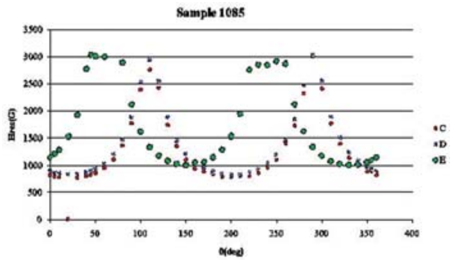
In figure 1 (a) we show an example of an FMR spectrum for the RM (2 nm Fe) sample. Of the various resonances observed, only the three low field lines are due to the Fe layer. It will be noted that the FePt does not have any FMR signature in the field range studied due to it very high magnetocrystalline anisotropy. The other resonance features evident in the spectrum arise from the MgO substrate and show no significant angular variations. As such the only FMR signals observed in our samples will arise from the Fe layer. In figure 1 (b) we show the angular variation of the resonance field of the three Fe resonance lines. Of these, two resonances display a uniaxial anisotropy with the easy axes aligned along the direction perpendicular to the film plane and will be directly related to the exchange coupling with the hard (FePt) layer. The third resonance, while also manifesting a uniaxial anisotropy, displays an easy axis direction which is canted by about 50 degrees from the film normal. While the origin of this resonance is not entirely clear, we suspect it may arise from the interfacial region between the FePt and Fe layers. In figure 2 we show the corresponding FMR results for the ES (3.5 nm Fe) sample. It will be noted that in addition to the resonances observed in the RM sample, there are a further two resonance, whose angular dependences are illustrated in figure 2 (b). These also display a uniaxial like behaviour with easy axes close to the film normal. In all spectra lines were fit using a home made programme which allows multiple peak fitting of Lorentzian and Gaussian lines.

We develop a model of FMR based on the magnetic free energy of the coupled layers which is required to interpret the angular dependences of the resonance fields [1]. Existing models fall short of a full explanation of all the resonance lines and we are working to bridge this gap by considering the effects of boundary conditions and spin wave modes.

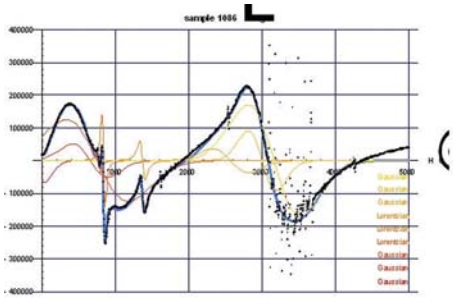
[1] G. Asti et al., Phys. Rev. B, 73, 094406 (2006)



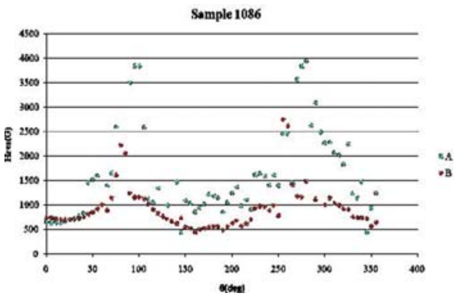
FMR spectrum of the RM sample, C, D and E indicate the three FMR resonances.



Angular dependences of the three FMR lines



FMR spectrum of the ES sample



Angular dependences of the additional resonances (A and B)