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Get perpendicular: the spin microstructure in Fe-FePt bilayers

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Abstract – Using nuclear resonant scattering of synchrotron radiation (basically the synchrotron analogon to Mössbauer spectroscopy) the microscopic spin structure in epitaxial Fe-FePt bilayers has been investigated. Close to the interface, the Fe spins are out-of-plane, while further away from the interface the Fe magnetization cants to the in-plane Fe[001] direction.

Due to its perpendicular magnetic anisotropy, FePt in the L_{10} phase is an attractive candidate for high-density magnetic recording media. Epitaxial FePt thin films, highly ordered in the L_{10} phase, can be obtained when grown directly onto MgO(100) substrates. Furthermore, by depositing a thin Fe film onto such an L_{10} FePt layer, a new phenomenon emerges: while the hard FePt layer forces its magnetization perpendicular to the film plane, the soft Fe layer prefers its magnetic moments to orient in plane. Hence, a perpendicular exchange spring magnet is formed due to the interfacial exchange coupling between the soft and hard ferromagnetic layers. It combines the high magnetization of the soft Fe phase with the high magnetic anisotropy of the hard FePt phase. In this work, we present a comparative study of the structural properties of an (Fe/)FePt (bi)layer and its spin microstructure.

By using enriched ^{57}Fe, one can study the orientation of the Fe-moments via conversion electron Mössbauer spectroscopy (CEMS). On the other hand, X-ray diffraction and ion channeling allow to probe the crystalline structure, the defects and the lattice relaxation, while vibrating sample magnetometry provides information on the macroscopic magnetic properties. With this approach, a direct correlation between the structure and magnetism is obtained for FePt layers grown at various temperatures.

In a second stage, the spin orientation in the soft Fe layer of Fe-FePt bilayers is investigated for epitaxially grown ^{56}Fe(x)/^{57}Fe(0.7 nm)/^{56}Fe(y)-^{56}FePt(30 nm). By inserting the ^{57}Fe probe layer at different depths inside the ^{56}Fe-layer, a spin depth profile is obtained. Rather than applying CEMS on a large number of samples, an alternative approach is possible via nuclear resonant scattering of synchrotron radiation (NRS). The highly brilliant and narrowly monochromatized beam of third generation synchrotron facilities and the possibility to reduce the beamsize to the micrometer scale allow to reduce the acquisition time to a few hours and to obtain the spin depth profile by growing one single thin film with a wedged ^{57}Fe probe layer. Synchrotron radiation incident on the sample will simultaneously excite the hyperfine-split nuclear energy levels of the ^{57}Fe atoms, giving characteristic beats in the temporal evolution of the subsequent nuclear decay signal. The analysis of this beat pattern, which is the time-based analog of classical Mössbauer spectra, allows a precise determination of the moment rotation through the wedged ^{57}Fe-layer. It will be shown that for Fe layers close to the interface, the magnetically hard FePt pins the magnetization in the soft Fe layer to the out-of-plane direction. For Fe layers further away from the interface, the influence of the FePt diminishes and the magnetization cants to the in-plane Fe[001]-direction. In addition, we performed magnetometry measurements to investigate the strength of the exchange coupling, with an external field applied along the in-plane Fe[110] direction. From the time spectra we could deduce that the field required to cant the moments towards the external field decreases as the distance from the interface increases.