ESRF	**Experiment title:** Imaging the exchange coupling in FePt-Fe bilayers with perpendicular magnetization	**Experiment number**: HE-2408
Beamline: ID18	**Date of experiment**: from: 10.07.2007 to: 16.07.2007	**Date of report**: 06.06.2008
Shifts: 15	**Local contact(s)**: Dr. Cornelius STROHM	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

B. Laenens*, N. Planckaert*, J. Demeter*, K. Temst*, A. Vantomme and J. Meersschaut

Instituut voor Kern- en Stralingsfysica and INPAC, Katholieke Universiteit Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium

Report:

The exchange-spring magnet, which is based on interfacial exchange coupled soft and hard ferromagnetic materials combines the high magnetisation of the soft phase with the high magnetic anisotropy of the hard phase. This kind of material is of interest for low-cost permanent magnets and other novel functional magnetic nanostructures. Fe-FePt bilayers are the prototypes of exchange spring magnets [1-3]. FePt in the $L1_0$-phase is a hard material with a high magnetocrystalline anisotropy [4-5] while Fe is a soft ferromagnetic material with a low anisotropy and high spontaneous magnetization. So far, experimental work has been performed on thin exchange spring bilayers with both the hard and the soft magnetic moments oriented in the film plane [3].
Nowadays, great interest goes to magnetic structures having their easy magnetization axis orthogonal to the film plane. Epitaxial FePt thin films stabilised in the $L1_0$-crystal structure show this property when grown on MgO(100) [4-5]. Moreover, by depositing a thin Fe-film onto a $L1_0$ 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 be in plane [1-2].

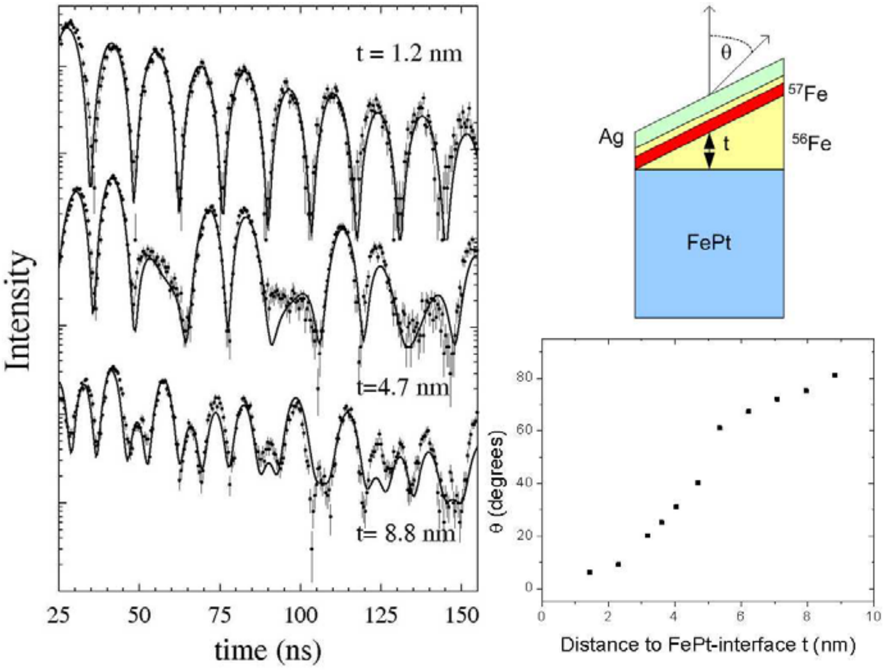

Figure 1: (left) Time spectra of the ^{57}Fe(0.7 nm)/^{56}Fe(t) /^{56}FePt-structure taken at zero field as a function of increasing distance t to the FePt-interface. The solid lines through the data are the fits obtained by the fitting program CONUSS [6]. (right) Illustration of the sample composition and depth dependence of the spin rotation in the ^{57}Fe layer.

In this work we studied an Fe-FePt(30 nm) bilayer grown with molecular beam epitaxy of which the sample composition is illustrated in Fig.1. The soft Fe-layer consists of a wedged ^{56}Fe layer with a thickness ranging from 0 to 8.7 nm. Subsequently, an isotopically enriched ^{57}Fe layer with a thickness of 0.7 nm was grown onto the wedge. The sample was capped with 0.6 nm of ^{56}Fe and 3 nm of Ag. The isotopic enrichment has no influence on the electronic or magnetic properties of the bilayer, but allows us to selectively probe the magnetic structure of the ^{57}Fe layer as a function of the distance to the FePt-interface, using nuclear resonant scattering of synchrotron radiation (NRS). 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 ^{57}Fe-layer. The dependence on the distance t to the FePt-interface can be probed by moving the sample transversally with respect to the synchrotron beam.

Time spectra are recorded at 11 positions on the sample at the NRS beamline ID18 of the ESRF. Fig.1 shows a selection of the time spectra. The spectra are analysed using the fitting routine CONUSS [6]. From the analysis the angle θ, which is defined as the angle between the sample normal and the magnetic spins of the ^{57}Fe-layer, could be deduced. The right panel in Fig. 1 shows the rotation of the spins in the ^{57}Fe-layer as a function of the distance t. For a few monolayers of Fe, the magnetically hard FePt pins the magnetisation in the soft Fe layer to the out-of-plane direction. By increasing the Fe-layer thickness to 9 nm, the influence of the FePt diminishes and the magnetization cants to the in-plane Fe[001]-direction.

In addition, we performed magnetometry measurements at different positions on the wedge to investigate the strength of the exchange coupling. The external field was applied along an in-plane Fe[110] direction. From the time spectra we could deduce how the moments start to cant towards the external field as the field increases. A field of 4.5 Tesla was required to saturate the ^{57}Fe-spins in the middle of the wedge.

We thus were able to directly probe the magnetic properties of exchange-spring Fe-FePt bilayers by exploiting the isotope selectivity of NRS. Our results will be modeled in the framework of one-dimensional micro-magnetical calculations. A manuscript is in preparation to publish to results.

[1] G. Asti et al., Phys. Rev. B, 73, 94406 (2006).

[2] F. Casoli et al., IEEE Trans. Magn. 41, 3877 (2005).

[3] R. Röhlsberger et al., Phys. Rev. B, 899, 237201-1 (2002).

[4] A. Cebollada et al., Phys. Rev. B 50, 3419 (1994).
[5] R. F. C. Farrow et al., J. Appl. Phys. 79, 5967 (1996).
[6] W. Sturhahn et al., Hyp. Interact 125, 149-172 (2000).