



Experiment title:
Probing the antiferromagnet in exchange biased FePt-FePt₃ bilayer thin films

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HE 3054

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ID22N

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Report:

The aim of the experiment was to determine the internal spin structure of a FePt₃ epitaxial antiferromagnetic thin film grown on a FePt layer oriented along the (110) direction. This FePt₃/FePt bilayer forms a fully epitaxial exchange bias system, where the exchange interaction at the ferromagnet/antiferromagnet (FM/AFM) interface leads to a pinning of the magnetization of the ferromagnet. The pinning direction is determined by a magnetic field applied during cooling the sample through the Néel temperature T_N of the AFM. The configuration and spatial arrangement of the spins in the antiferromagnet plays an important role in the appearance of the exchange bias effect because it determines the preferential axis of magnetization and the strength of the interfacial coupling.

The ferromagnet used here, FePt, has the particularity of showing an easy axis of magnetization aligned 45° out of plane and along the (110) in-plane direction on the sample. Since this is a rather unconventional spin alignment in thin films, our goal was to determine to what extent it will affect the magnetic state of the antiferromagnet which is in contact to it. Further, we aimed at the determination of the Néel temperature of the FePt₃ film, to corroborate with the appearance of exchange bias at low temperature.

The sample studied here was grown by molecular beam epitaxy in our institute and has the structure MgO(110)/⁵⁶FePt(10nm)/⁵⁷FePt₃(60nm). The isotopic enrichment in ⁵⁷Fe allows to isolate and probe the magnetic state of the FePt₃ part of the system using nuclear resonant scattering of synchrotron radiation in grazing incidence geometry.

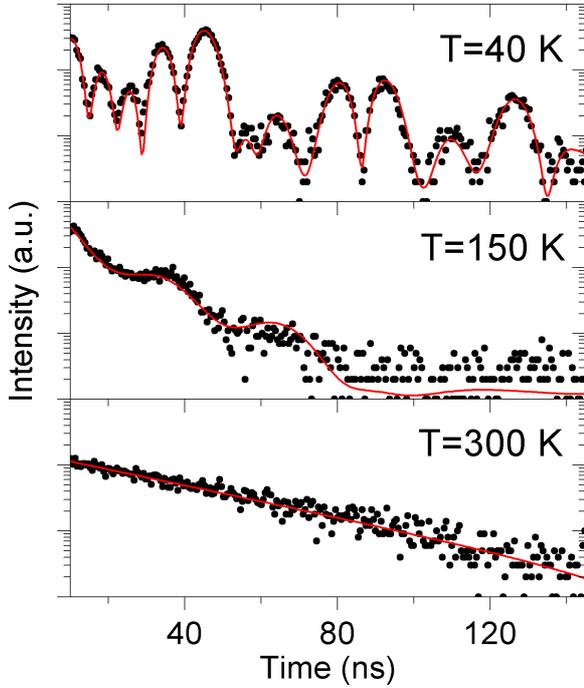


Fig. 1: Temperature dependent NRS timespectra on a MgO(110)/⁵⁶FePt/⁵⁷FePt₃ bilayer. Beatings are observed below 150 K, indicating the transition to antiferromagnetic ordering. Solid lines are fits.

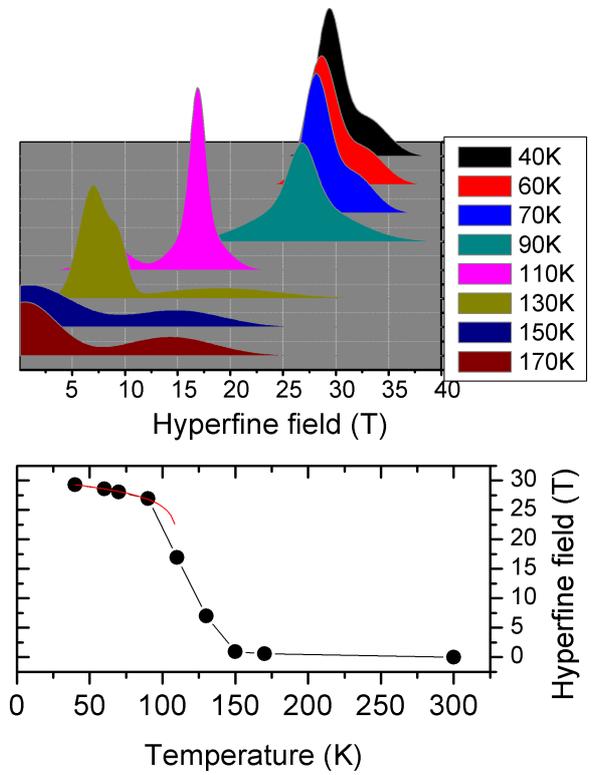


Fig. 2: Evolution of the hyperfine field distribution extracted from the fits. We see that the Néel temperature is around 120 K.

The experiment was performed at the ID22N nuclear resonance beamline. In the first part of the experiment, we aimed at the determination of the exact Néel temperature of the thin FePt₃ layer. For that purpose, the sample was placed in a closed cycle cryostat and cooled down to 15 K. Due to the strong absorption of the radiation by platinum, the time-integrated nuclear count rate was around 2 Hz at 15 K. Timespectra were recorded as a function of the sample temperature up to 300 K.

The magnetic state, which leads to the presence of a hyperfine field B_{hf} at the position of the nucleus, is reflected in the timespectra as a beating frequency in the time domain, as shown in Fig.1. The magnitude of the hyperfine field and its temperature dependence is shown in Fig.2. We estimate the ordering temperature to be around 120 K. This value is very similar to the exchange bias transition temperature for this system, meaning that the blocking and Néel temperature basically coincide.

In the second part of the experiment, we took advantage of the polarization dependence of NRS to directly probe the orientation of the spins in the antiferromagnet. For that purpose, the sample (still mounted in the cryostat) was aligned vertically so that the subsequent experiment is carried out in horizontal scattering geometry. This particular geometry is used to reduce the number of excited nuclear transitions, therefore allowing to obtain the preferential moment orientation. We recorded several timespectra along different sample orientations at 15 K after the sample was cooled in a field of 200 mT. Remarkably, the analysis shows that the the AFM spins are canted by 30° out of plane. We are also able to see that the spin axis is not parallel to the easy axis of the underlying FePt but is also canted by 45° in-plane.

This unexpected spin configuration indicates that interfacial coupling is very strong in this exchange bias system, but that spin frustration is sufficiently high to form a particular kind of "spin-flop" coupling at the interface. We are currently carrying out low temperature magnetometry measurements to completely characterize the magnetic state discovered in this experiment. We expect to obtain a consistent model of the interfacial magnetic interactions, which is predominant in this system.