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Experiment title: Layer resolved magnetism of fcc-Fe films	**Experiment number:** HE-473

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Report:

A fundamental issue in solid state magnetism is how the magnetic properties of a material are altered by modifying its atomic geometry. Epitaxial fcc-Fe films, stabilized on Cu(100) and Co(100), are an exemplary case, where the magnetic properties (e.g. ferromagnetic and antiferromagnetic ordering, moments and anisotropies) critically depend on the film thickness and lattice volume. Despite intensive experimental and theoretical efforts a comprehensive picture of these systems has not yet been achieved, also because the magnetic behaviour of the individual atomic layers in the films can hardly be experimentally resolved. We have used nuclear resonance scattering with synchrotron radiation (14.4 keV photon energy) from the ID18 beamline to examine the magnetic structure of epitaxial fcc-Fe films sandwiched between Co(100) layers. The experiment has been designed to exploit site-selective measurements of the hyperfine field in order to separately probe the magnetism of interface and inner atomic layers. Grazing incidence radiation has been scanned across (1-10 atomic layer (ML)) Fe films grown in a wedge geometry and opportunely structured by inserting ^{57}Fe monolayers in a ^{56}Fe matrix as schematically shown in Fig. 1 a, 2 a. This new experimental approach is able to provide layer-resolved information on the orientation of the moments within the ultrathin films. The radiation selectively excites groups of nuclear transitions, depending on the orientation of the light polarization and the hyperfine-field vector. The quantum-beat pattern in the time resolved spectra of the scattered radiation reflects thus the orientation of the hyperfine field in the films.

The time spectra of nuclear forward scattered radiation from films entirely consisting of ^{57}Fe are shown in Fig. 1 a, b for two selected film thickness. Whereas the 2 ML spectrum closely correspond to the one expected for hyperfine-field vector in the film plane, the 7 ML spectrum does not fit any simple pattern, suggesting a non-uniform distribution of the hyperfine-field in the film. The analysis of the 7 ML film magnetic structure is made possible by the measurement of layer-resolved spectra (Fig. 2 b, c), from a sample where an atomic layer of ^{57}Fe is located at different distances from the interface (Fig. 2 a). The spectrum of inner atomic layers (Fig. 2 c) displays a beat-pattern with a more uniform frequency than the one of the interface (Fig. 2 b). The different pattern results from a rotation of the hyperfine-field vector. Spectral evaluation (in collaboration with the KFKI Budapest) shows that the hyperfine field vector at the interface lies close to the film plane, whereas it points at an angle of more than 60 degrees out of the film plane in inner atomic layers. While either a ferromagnetic or an antiferromagnetic configuration is commonly assumed to represent the magnetic ground state of fcc-Fe films, depending on their thickness and atomic volume, a non-collinear spin structure was not previously observed nor theoretically predicted for these systems. The occurrence of such a non-collinear-spin state appears to be unique among ultrathin (<10 atomic layers) films of itinerant-electron systems.

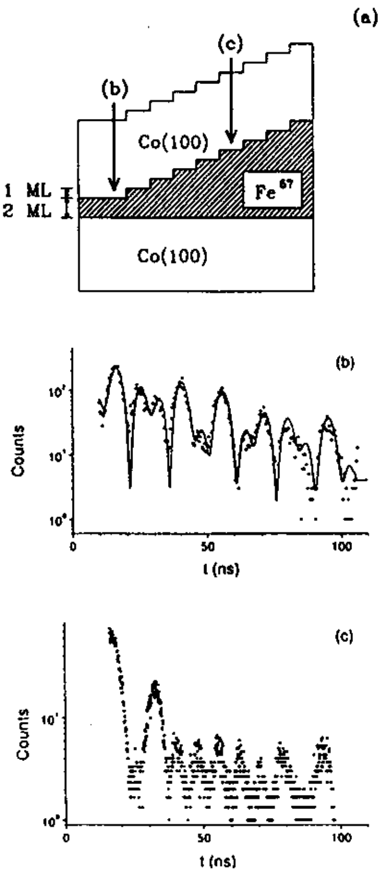

Fig. 1

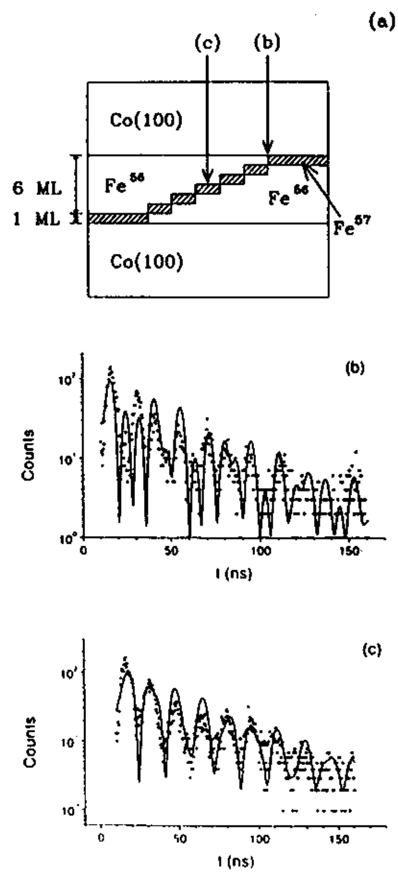

Fig. 2

Fig. 1 a) *Scheme of a 2-10 ML fcc-Fe wedge consisting entirely of ^{57}Fe, sandwiched between two Co(100)-films. Time spectra of nuclear forward scattered radiation have been measured scanning the synchrotron beam along the wedge.*

b) *Time dependence of nuclear forward scattered radiation from a 2 ML fcc-Fe film.*

c) *Time dependence of nuclear forward scattered radiation from a 7 ML fcc-Fe film.*

Fig. 2 a) *Scheme of a sample with a uniform fcc-Fe film with a thickness of 7 ML. A single ^{57}Fe monolayer is inserted at various positions within a ^{56}Fe film. Layer-resolved spectra have been mesaured by scanning the radiation on the sample.*

b) *Time dependence of nuclear forward scattered radiation from the ^{57}Fe layer at the interface.*

c) *Time dependence of nuclear forward scattered radiation from the ^{57}Fe layer in the center of the Fe film.*