ESRF	**Experiment title:** Depth-resolved Fe spin structure at the Fe/NiO(001) interface	**Experiment number**: SI 1514
Beamline: ID18	**Date of experiment**: from: 09/05/2007 to: 13/05/2007	**Date of report**: 30/08/2007
Shifts: 12	**Local contact(s)**: Rudolf Rueffer	*Received at ESRF:*

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Report:

The aim of this experiment was to obtain a quantitative description of the Fe spin configuration at the interface with NiO(001). In spite of its importance, a general understanding of the origin of the coupling at ferromagnetic/antiferromagnetic interfaces is still lacking. This is due to the large number of possible magnetic configurations in such systems, including frustrated and non-collinear spin structures. The situation is even more complicated by the fact that real interfaces often present a complex chemistry and defectivity which may give rise, for example, to uncompensated spins in the antiferromagnetic layer or to alloyed phases with unknown magnetic properties. A detailed description of the chemistry, structure and magnetic configuration of these interfaces at the atomic scale is therefore crucial to elucidate the microscopic mechanisms at the origin of the macroscopic magnetic couplings.

Fe grows epitaxially on NiO(001) with the [100]//[110] orientation. The presence of the Fe layer causes the reduction of approximately 1 ML of NiO [1,2,3]. We have demonstrated that the uncompensated moments formed by NiO reduction are not confined at the interface, but rather incorporated into the Fe layer forming a bct Fe-Ni alloy [3]. Furthermore, in a recent study [4] we pointed out the presence of an interfacial buckled FeO-like layer, which is predicted to have an increase in the spin magnetic moment compared to the ideally abrupt interface of $0.6\mu_B$ (from $2.6\ \mu_B$ to $3.2\ \mu_B$). The couplings of such layer with the underlying NiO and with the overlying metallic Fe-Ni layers and the possible presence of uncompensated moments within the FeO-like phase are expected to have a deep influence on the magnetic couplings in this system.

The samples for this study were prepared by the proposers in ultra-high vacuum at the S3 laboratories in Modena, Italy. The substrates used were Ag(001) single crystals of disc shape with 10 mm diameter, prepared by repeated cycles of sputtering and annealing. 10 ML NiO films were grown on top of them by reactive deposition of Ni in an O_2 partial pressure. The Fe thickness for all samples was 8 ML, a thickness just above the one which guarantees room temperature ferromagnetism. One of the samples was divided into 2.5 mm wide stripes, containing a 2 ML Fe^{57} probe layer embedded at different depths, from the interface to the surface of the Fe film. The second sample was a uniform sample with a 2 ML Fe^{57} probe layer in contact with the NiO interface, necessay for azimuth dependent measurements. The third sample was a 8 ML Fe^{57} film for reference. All samples were capped by a 5 nm Ag film, which proved to be effective in preventing the Fe film contamination, and carried to the ESRF in non reactive atmosphere.

We measured time resolved nuclear resonant scattering (NRS) spectra at the ID 18 beamline with the storage ring operating at 16-bunch mode, with subsequent bunches separated by 176 ns. The radiation was monochromatized to a bandwidth of 6-7 meV around the nuclear resonance of Fe^{57} (14.413 keV). Grazing incidence at the critical angle for total reflection was used in order to maximize the nuclear reflectivity signal. The three samples were measured at room temperature both before the application of an external magnetic field and at remament magnetization after the application of the magnetic field (1 T) in the plane of the samples along the Fe [001] azimuth. The uniform samples were measured with the k vector of the photon beam both parallel and perpendicular to the direction of the magnetic field. The NRS count rate was of the order of a few counts per second on our samples.

The time spectra measured before the application of the magnetic field showed a zero net magnetization. The most significant spectra measured at remanence are shown in fig.1. The figure includes the spectrum of the 8 ML Fe^{57} sample (top), of the sample with a 2 ML a Fe^{57} probe layer at the interface (middle) and of the sample with a 2 ML a Fe^{57} probe layer within the film (bottom), measured (only in the case of the uniform samples) with the photon k vector parallel (left) and perpendicular (right) to the direction of the applied magnetic field B. A qualitative analysis of the spectra in the two scattering geometries indicates, as expected, that the samples are magnetized in the direction of the applied field. However there are non negligible differences between the spectra of the different samples. In particular, the spectra measured with k parallel to B show different relative heights of the peaks and a different shape of the background. Such differences are even more evident in the spectra measured with k perpendicular to B (see for example the intensity of the peaks indicated by the arrows in fig.1). This indicates that the spin structure changes at the different distances from the interface.

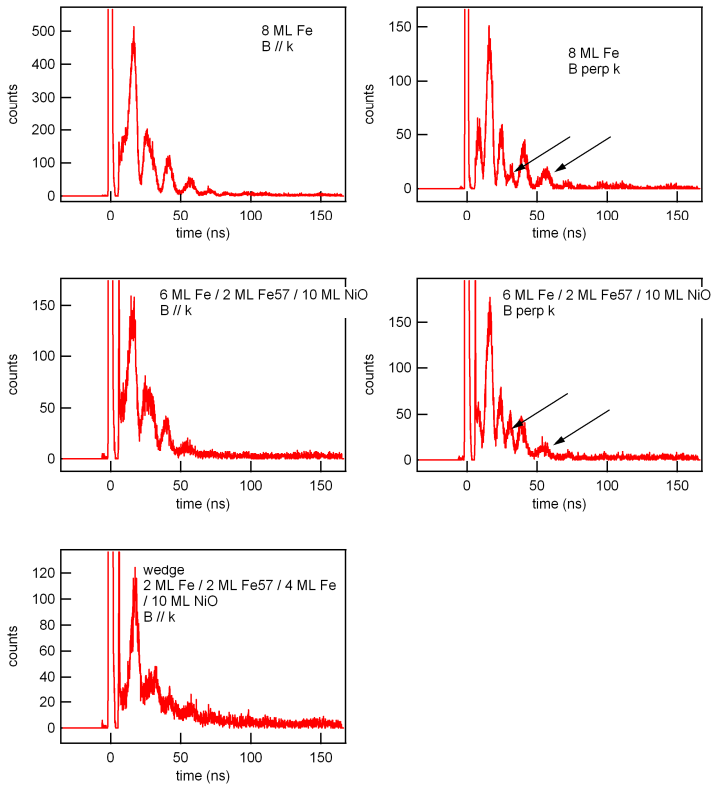

Fig.1: NRS spectra for the 8 ML Fe^{57} sample (top), for the sample with a 2 ML a Fe^{57} probe layer at the interface (middle) and for the sample with a 2 ML a Fe^{57} probe layer within the film (bottom), measured with the photon k vector parallel (left) and perpendicular (right) to the direction of the applied magnetic field. All spectra are measured at remanence. The arrows indicate the peak with the most evident intensity change.

By means of a quantitative data analysis, including the simulation of the spectra by the MOTIF program [5], currently in progress, we expect to be able to evaluate the hyperfine splitting and the isomer shift of the different samples. From these we will determine the magnitude and orientation of the Fe magnetic moment as a function of the distance from the interface and the Fe chemical environment. In this way we expected to have a realistic picture of the microscopic magnetic coupling mechanism for this system.

References

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