ESRF	**Experiment title:** XMCD experiments on a magnetically coupled interface: Co on NiO(111)	**Experiment number**: HE-544
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Shifts: 9	**Local contact(s)**: Philippe OHRESSER (e-mail: ohresser@esrf.fr)	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Antoine BARBIER*, Cristian MOCUTA*, Michel BELAKHOVSKY*, Bernard DIENY*

CEA Grenoble, DRFMC/SP2M
17, rue des Martyrs
38054 Grenoble Cedex, France

Report:

The aim of this experiment was to measure for the first time the magnetic moments of the Co and Ni atoms at the Co/NiO(111) interface, single crystalline or not. We investigated two types of interfaces obtained by different preparation methods, thus of different qualities:

a) 20Å Au/70Å Co/NiO(111) single crystals; the Co layer was MBE deposited and it was monocrystalline in cube/cube epitaxy onto the substrate (see **32-3-39**, **SI-470**);

b) 30Å Cu/60Å Co/300Å NiO(111), entirely prepared by sputtering on SiO_2/Si substrates. The measurements were performed in a standard way. In this case, no ferromagnetic signal coming from the Ni was found (figure 1(b)), and the Co has the literature expected m_L/m_S~0.1 measured value.

For the single crystalline case, the measurements were quite difficult to perform. We used the flipper setup[1] of the ID12B beamline. In order to get a correct XMCD signal, it was necessary to perform the measurements in a particular way: taking only one "flip" spectrum (which for usual experimental conditions, conducting samples, already contains the clean XMCD signal) reveals strange effects (figure 2). In fact, in order to obtain clean XMCD spectra (mainly for the small Ni signal), several measurements were performed. For each polarization of the X-rays (left/right), two kind of flip scans were recorded, by changing the order of

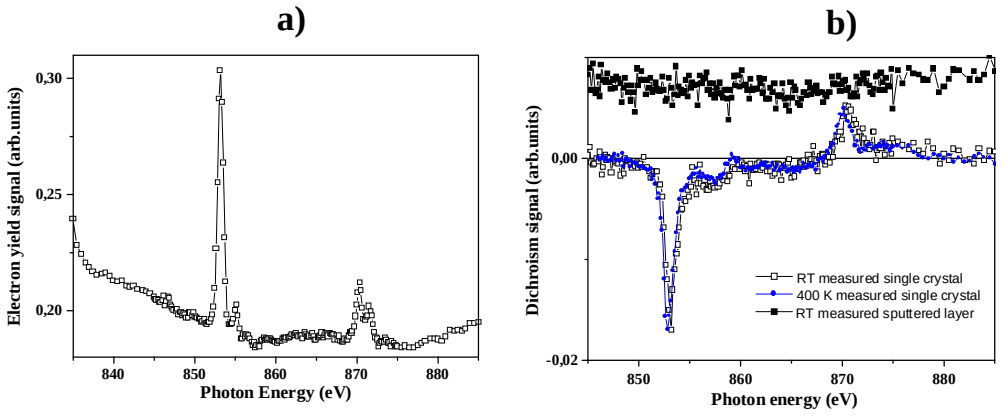

Figure 1: a) NiO XAS, measured in electron yield. The strange shape of the background is mainly due to charging effects. b) dichroism signal at $L_{3,2}$ Ni edges for a single crystalline interface, RT (□) and 400 K (●) measured. The dichroism signal for the sputtered Co/NiO layers is also reported (■).

[1] At each energy value, two measurements are performed, with opposite external magnetic field; then the energy is moved

flipping the field[2] (+ to – and – to + respectively). By combining (adding and subtracting) in the right way each 4-spectra, either the "pure" dichroism signal or the setup contribution can be extracted (figure 2).

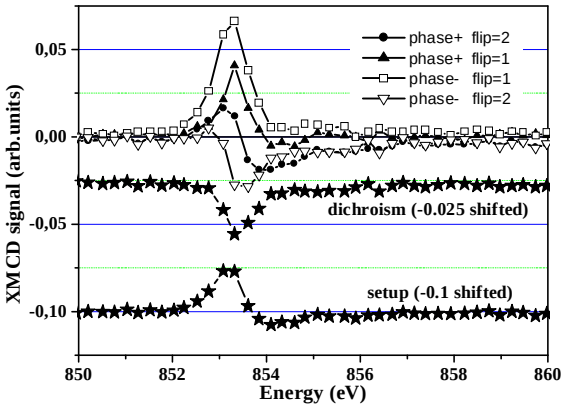

Figure 2 : Deduced dichroism signals in several measured configurations. The spectra taken with + phase (• and ▲) are the ones the most affected. The corrected signal and the contribution coming from the experimental setup are also shown.

This approach was performed at Ni edges only, where the dichroic signal (if any) is expected to be very small. Figure 3 shows a spectrum obtained by averaging 12 dichroism spectra. The shape of the signal is very similar to the one measured for metallic Ni [1]. The great number of acquired spectra allowed making the small signal visible, although the absorption through the Co layer was important.

Comparing the branching ratios and the amplitudes of our XMCD signal at the Ni L_3 edge with Ni references [1] yield to estimate thickness of the Ni layer between 1 and 2 ML. For the Ni XMCD signal, it is possible to calculate the orbital/spin momentum ratio (m_L/m_S) from the spectra; although the XAS spectra have strange shapes (figure 3(a)), the dichroism signal remains quite clean and not very noisy (figure 3(b)). The obtained values were in the 0.375 to 0.72 range, which are found to correspond to a thickness range of θ_{Ni}=1.8 to 0.2 ML respectively, by comparison with a reference Ni thickness dependence [1]. Using the approach described in [4] based on the comparison of XMCD spectra with a reference one, it was possible to estimate, for the case of the Co/NiO(111) single crystal, that the signal is coming from 1.5 to 4 ML of Ni.

From these different approaches and values, we can estimate that the magnetic Ni contribution is likely to come from **1.5±1.3 ML of Ni**, that behaves like metallic Ni, and is parallel coupled to the Co layer. This suggests the existence of a surface layer that might come from the initial existence of the reconstruction [5] (which represents 0.75 ML of Ni), showing that the non-stoichiometry at the interface (2ML) remains.

The Co exhibits the expected XMCD signal. Deducing quantitative values for the orbital and spin momentum using the sum rules remains however hazardous. Indeed, the XAS spectra are also affected by the insulating NiO (curved shape of the background); this effect can be relatively nicely corrected for the dichroism signal (it is removed by performing the difference of the two spectra), but not for their sum. Thus, one can be confident only in the m_L/m_S ratio for the Co signal. The obtained values of the m_L/m_S ratios for Co spread from 0.07 to 0.2 (there were even two extreme values, of 0.024 and 0.245). The average value obtained for all the data is 0.101 (0.095 if the two extreme values are not taken into account), which is finally in good agreement with the expected bulk value of Co, *i.e.* 0.09-0.1.

Trying to perform these measurements at low temperatures (15 K) was difficult; the sample become more and more insulating and flickering of the signal in the spectra was very frequent.

The differences in the dichroism signals can be explained simply by the difference in the structure of the two substrates: both are NiO(111), but while the single crystal has an excellent crystalline quality and exhibits the reduced p(2×2) reconstruction, the sputtered NiO films are (111) textured only. It is not surprising that they do not exhibit the surface p(2×2) reconstruction, view their poor crystalline quality and the deposition of Ni-O molecules. This remark supports the existence of a different magnetic behavior of Ni layers of the single crystal surface. The present experiment does not confirm the presence of F parts in the AF substrate (apart the initial non-stoichiometries) or they could be not affected by the external field we used.

We do not fully understand the presence of (relatively) strong non-XMCD signal, but it is likely that the charges on the sample (which cannot be fully evacuated) were responsible for this difficulty. The most surprising feature is however the possibility of extracting clean XMCD signal by combining the different measurements. Even with these precautions, the signals are still quite noisy and small and extracting quantitative data from them remains difficult, mainly for the Ni case, but also in the Co case: effects like curved-shape background may render quantitative analysis difficult. This is mainly the consequence of the insulating character of the NiO substrate, rendering difficult electron yield measurements.

[1] S.S.Dhesi, H.A.Dürr, G.van der Laan, E.Dudzik, N.Brookes, Phys.Rev.B **60** (1999) 12852.

[2] the dichroism signal is expected to be reversed