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Experimental report - 28-01-779

X-ray resonant magnetic reflectivity (XRMR) from U/Ni multilayers

These measurements form part of an extensive research program investigating the structure and magnetism of uranium multilayers. The investigation of U/Ni multilayers is complementary to studies already carried out on U/Fe and U/Co systems. A detailed characterisation of the bulk structural and magnetic properties has been reported on a series of U/Fe multilayers [1, 2]. An initial XRMR study [3], carried out on the XMaS beamline investigated the magnetism of uranium, by tuning the incident energy through the U M_{IV} absorption edge. An induced polarisation was observed and its Q-dependence suggested a non-uniform distribution of the magnetisation within the U layers. A study of the spin and orbital components of the induced U *5f* moment has been completed [4], using the X-ray magnetic circular dichroism technique (XMCD) on the ID12 beamline at the ESRF. Further XRMR experiments on a number of U/Fe samples have lead to the development of key experimental improvements and software, capable of extracting a profile of the U polarisation. Figures 1 and 2 display profiles of the U density at the interfaces of a U/Fe sample and of the U magnetisation.

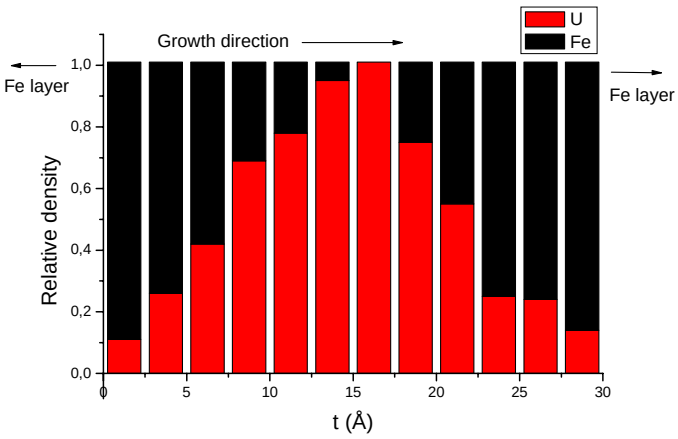

Figure 1 – Profile of the U and Fe relative densities at the interface regions in a U/Fe sample ($[U_9/Fe_{34}]_{30}$) as determined from XRMR measurements.

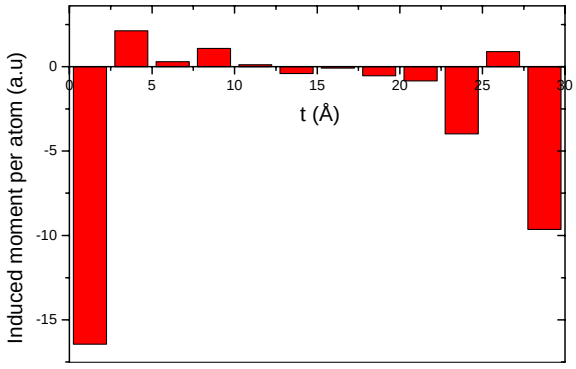

Figure 2 – Profile of the U 5f magnetisation through the U layer.

No such polarisation was observed in U/Co multilayers; a result confirmed by XRMR and XMCD measurements.

During this experiment a selection of $[U_n/Ni_m]_x$ samples were investigated (n and m are the thicknesses of the respective layers in Å and x is the number of bilayer repeats) and a $[U_n/Gd_m]_x$ sample was studied, to investigate the distribution of magnetisation within the Gd layers. In the case of the U/Ni multilayers, the reflectivity was measured over a number of Bragg peaks at several energies across the U M_{IV} edge (3.728keV). A diamond phase plate provided a high rate of circular polarisation to the incident X-ray beam and a magnetic field, large enough to saturate the samples in the plane of the films, was applied along the beam direction. The field direction was then flipped at each data point (+ - - +) and the intensity recorded. The beampath from optics to detector was kept under vacuum and the measurements made at room temperature.

As was the case for U/Co samples studied previously, there was no detectable difference in the reflected intensities for each field direction. This indicates that there is no detectable

polarisation of the uranium in the U/Ni system, in contrast to that observed for U/Fe multilayers. These results are consistent with ideas developed, concerning the hybridisation of the U *5f* states with the *3d* states of iron, cobalt and nickel in the UX_2 binary compounds [5].

In order to make further use of the beamtime, a $[U_{15}/Gd_{20}]_{30}$ sample was investigated. XMCD measurements have shown that there is an induced polarisation in the U layers, but the size of this effect is very weak in comparison to that observed in U/Fe multilayers and would not be easily detectable, using the XRMR technique with the current experimental set-up. A study of the bulk properties of U/Gd multilayers [6, 7] revealed a significantly reduced magnetic moment in the gadolinium layers compared with that found in the bulk metal (~$4\mu_B$ compared with $7.63\mu_B$). The XRMR technique was used to profile the magnetisation in the Gd layers in order to realise the distribution of magnetic moment within the layers and to better understand the mechanism for this reduction.

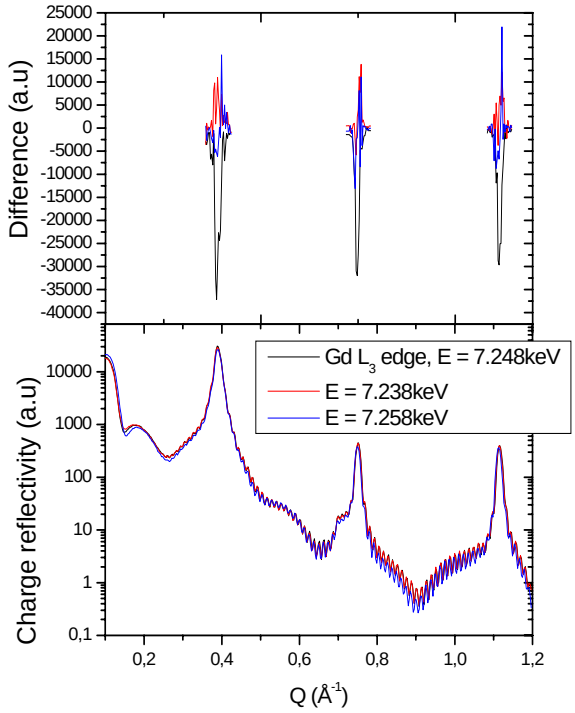

Figure 3 – Charge reflectivity (lower panel) and asymmetry (upper panel) at the Gd_{III} edge (black), at 10eV below the edge (red) and 10eV above (blue). Measurements were made on a $[U_{15}/Gd_{20}]_{30}$ sample at 10K.

The magnetic reflectivity was measured across the Gd L_{III} edge (7.248keV) using the same experimental conditions employed at the U M_{IV} edge, but at a temperature of 10K. Figure 3, lower panel, shows the charge reflected intensity at the Gd L_{III} edge and at energies 10eV below and 10eV above the edge. The upper panel of Figure 3 shows the difference in the reflectivities with the field applied in the scattering plane, perpendicular to the scattering vector.

This data will now be simulated using code developed by Mirone and Brown at the ESRF, in order to extract a profile of the magnetisation within the Gd layers. This measurement provides the interest for further studies of the magnetic reflectivity in U/Gd multilayers.

References

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