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ESRF	**Experiment title:** Magnetism of Uranium in U/Gd multilayers investigated by XMCD	**Experiment number**: **HE-2130**
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Report:

Previous measurements (HE-1781) have demonstrated that a Gd-U hybridisation, resulting in a polarisation of the uranium layers, is measurable using the XMCD technique. Although greatly reduced in magnitude (~2%) from the induced moment observable in the U/Fe system (upto 20%), it was still possible to observe the magnetically polarised U 5f states. Initial measurements on two samples of $[U_{26}/Gd_{76}]_{20}$ and $[U_{39}/Gd_{20}]_{20}$ composition indicated that the spectral shapes of the XMCD signal at the U M_4 and U M_5 edges were different to those measured for U/Fe samples of similar layer thickness. It was also apparent that the sign of the signal reversed depending on the thickness of the respective U and Gd layers, suggestive of a non-uniform distribution of the induced magnetisation within the U layers and an inversion of the coupling direction. It was not certain from these measurements however, if the observed XMCD signal was a consequence of the Gd (4f-5d) – U (5f) hybridisation or an effect induced by the applied magnetic field.

A series of $[U_n/Gd_m]_x$ (n and m are the thicknesses of the respective layers in Å and x is the number of bilayer repeats) multilayer samples were fabricated using the DC magnetron sputtering technique (Table 1) and characterised by a combination of X-ray reflectivity (Figure 1), high angle X-ray diffraction and SQUID magnetometry. This series investigates the hybridisation effects between the localised magnetic 4f states and the extended 5f states of uranium as a function of the uranium layer thickness.

Sample	Composition
SN134	$[U_{10}/Gd_{19.8}]_{30}$
SN135	$[U_{15.8}/Gd_{18.2}]_{30}$
SN136	$[U_{19.2}/Gd_{19.4}]_{30}$
SN137	$[U_{28.2}/Gd_{19.5}]_{30}$
SN138	$[U_{4.8}/Gd_{20}]_{30}$
SN139	UGd alloy ~5% U

Table 1 – Summary of the sample compositions investigated in this experiment.

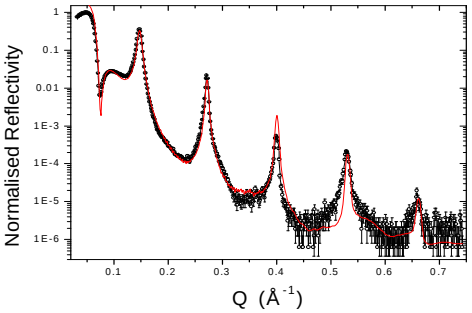

Figure 1 - The X-ray reflectivity from sample SN137 is shown above and indicates a multilayer structure with well-defined interfaces.

The XANES (X-ray absorption near edge spectrum) at both the U M_4 and M_5 edges and the Gd L_2 and L_3 edges were recorded in a backscattering geometry with a grazing incidence angle of about 15 degrees. The X-ray source for the U M edges is a hybrid electromagnet/permanent magnet helical undulator (EMPHU), which allows XMCD spectra to be obtained by flipping the helicity of the circularly polarized X-ray beam at each energy. To ensure that the measured XMCD spectra are free of any experimental artifact, the data were collected for both directions of the external applied magnetic field (parallel and antiparallel to the incoming X-ray beam). The applied magnetic field, up to 1 T, was produced by a superconducting cryomagnet. The measurements were performed at 10 K and at room temperature for all samples. At the energy of the U M_5 (3.55keV) and M_4-edges (3.73keV), the Bragg angle of the double Si(111) crystal monochromator is above the Brewster angle; therefore the degree of circular polarization of the monochromatic beam is reduced to 35% and 45%, respectively. The X-ray source for the Gd L_2 (7.93keV) and L_3 (7.243keV) edges was an Apple-II-type helical undulator. At this energy, the degree of circular polarization of the monochromatic beam is about 90%.

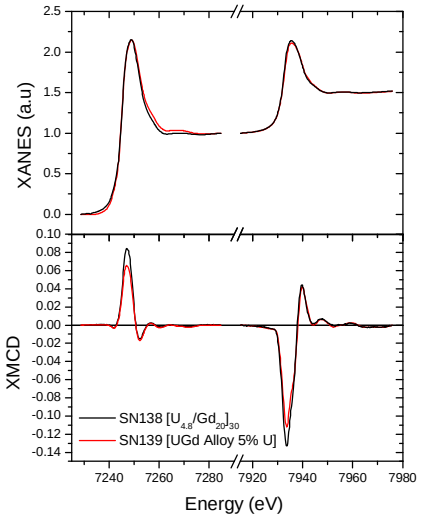

Figure 2 – XANES spectra and XMCD signals at the Gd L_2 and L_3 edges for multilayer sample SN138 and U-Gd alloy recorded at 5K in a field of 1T.

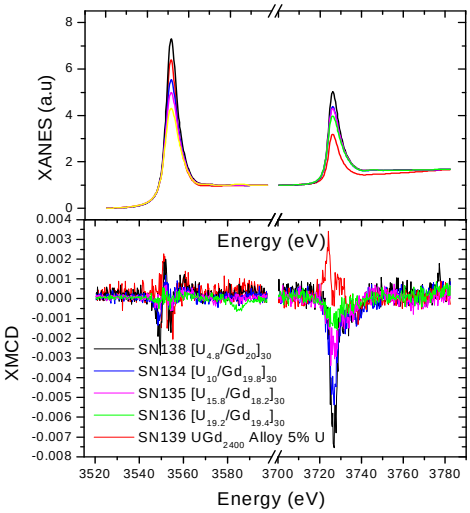

Figure 3 – U $M_{4,5}$ edges XANES and XMCD spectra collected at 15º grazing incidence, 5K in an applied magnetic field of 1T.

The XMCD spectra were obtained as the difference between consecutive XANES scans recorded with opposite helicities of the incoming circularly polarized X-ray beam. Figure 2 shows the spectra obtained at the Gd L edges for a selected U/Gd multilayer sample and for a U-Gd alloy, providing an environment similar to uranium in a matrix of gadolinium atoms. Figure 3 summarises the XANES and XMCD spectra obtained for the series of samples listed in table 1. A strong dependence of the XMCD signal on the U layer thickness is clearly visible, demonstrating a non-uniform magnetisation profile within the layer, suggesting that the U atoms closest to the interfacial region carry the largest induced polarisation. A full analysis, using XMCD sum-rules to extract the magnitudes of the spin and orbital induced moments is to be performed, enabling the determination of a magnetisation profile through the uranium layers.