XMaS the UK-CRG	**Experiment title:** **Structural and Magnetic Interface Morphology of Co/Cu/Dy Multilayers**	**Experiment number**: 28-01-056
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Report:

While Giant Magnetoresistance (GMR) has been observed for a decade in multilayers containing 3d transition metals such as Cu/Co and Fe/Cr, it is only recently that the effect has been reported in materials containing rare earths. Extremely weak GMR has been observed in rare-earth (RE) transition metal (TM) systems such as $[Dy/Cu]_N$ and $[Gd/Cu]_N$. Replacing every alternate RE layer with a transition metal such as Co results in MR which is similar in magnitude but inverted in sign. This does not occur for the lighter rare-earths such as Nd. These results have been explained assuming that the MR is proportional to the polarisation of the spins at the Fermi Energy. Although this is weak (~2%) in the heavy rare-earth systems, it is opposite in sign to that of Co, resulting in an inverse MR. The magnitude of the inverse MR of such a $[Dy/Cu/Co/Cu]_N$ system can be enhanced by introducing thin layers of Co adjacent to, and in direct contact with, the RE layer (figure 1).

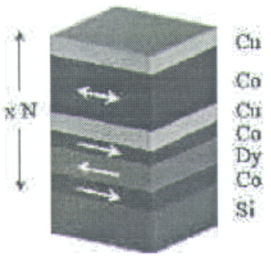

Fig 1: A Schematic of the sample structure

When a magnetic transition metal is placed in contact with a rare earth, the coupling between them is related to the hybridisation of the spin-polarised 3d and 5d/6s bands. The coupling can be calculated from spin-density functional theory, but if the polarisation of the RE and TM bands are anti-parallel, then the moments will also align antiparallel (fig. 1). The GMR enhancement in a Co/Dy/Co/Cu/Co/Cu system arises from the Co/Cu/Co trilayer, where the top Co layer which is free to rotate in an applied field with respect to the 'pinned' Co contained within the Co/Dy/Co block.

The aims of the experiment were to concentrate on the Co/Dy/Co block and investigate the role that both the structural and magnetic interface play on the magneto-transport properties in these systems. Grazing incidence x-ray reflectivity was conducted at the Dy L_{III} edge (E=7.79keV) on a sample with a nominal structure $[Co(6Å)/Dy(20Å)/Co(6Å)/Cu(9Å)/Co(30Å)/Cu(9Å)]_{12}$, similar to that shown in figure 1, and on a more simple $[Dy(40Å)/Co(8Å)]_{20}$ sample.

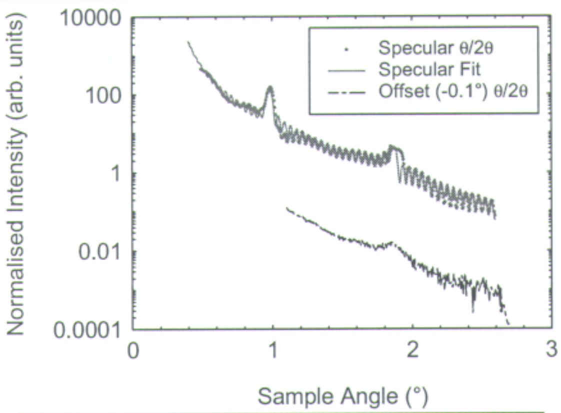

Fig 2: Specular and longitudinal diffuse scans from the Dy/Co recorded away from the Dy L_{III} edge at 20K.

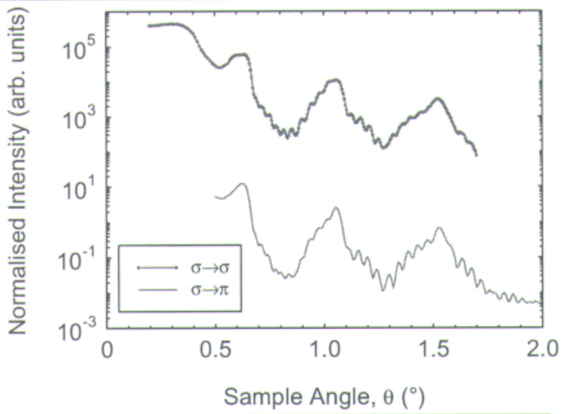

Fig 3: Specular scatter recorded in the $\sigma \rightarrow \sigma$ and $\sigma \rightarrow \pi$ channels for the Co/Dy/Cu multilayers at 20K

Specular and diffuse scatter were recorded from both samples as a function of temperature and applied field. Clear specular Bragg peaks were observed in both samples. Fits to the specular data in the Dy/Co multilayer (fig. 2) show the Co/Dy interface to be wider (12Å) than the Dy/Co interface (6Å). Analysis of the diffuse scatter taken through the second order Bragg peak shows that the correlated roughness was of the order of 1Å r.m.s., with the dominant contribution to the interface width arising from an intermixing between the Dy and Co. The roughness was defined by a low in-plane correlation length, typical of these sputtered systems.

Energy scans at the fixed momentum transfer of the second Bragg peak showed a peak at the Dy L_{III} edge for both samples. Polarisation analysis of the incident and scattered beam was conducted at this energy using an analyser crystal with a d-spacing allowing diffraction at close to 90°. At room temperature, the polarisation of both the incident and reflected beams was measured to be over 99% σ polarised as a result of the analyser crystal not being ideally matched. Cooling the sample to 20K did not result in any reproducible change in either the degree of polarisation or intensity of the scattered radiation. The specular scatter in the $\sigma \rightarrow \sigma$ and $\sigma \rightarrow \pi$ channels was similar for all scattering angles measured (fig. 3). A magnetic ($\sigma \rightarrow \pi$) signal was only expected at the Bragg peaks and the intensity away from these positions can only originate from 'leak through' from the $\sigma \rightarrow \sigma$ channel caused by diffraction slightly away from the ideal 90°. Intensity changes in either scattering channel could not be observed for any field direction applied either during cooling or under experiment conditions.

We were successful in measuring the interface morphology in Dy/Co based multilayers, although it has not proved possible to perform magnetic x-ray scattering studies of the magnetisation distribution within the Dy layers. The origin of this discrepancy is unclear.