Experimental report

18/11/2015

Proposal: **5-54-165** **Council:** 4/2014

Title: PNR study of interfacial magnetismin halfmetal spin valve heterostructures

Research area: Physics

This proposal is a new proposal

Main proposer: **Thomas HASE**

Experimental team: Balati KUERBANJIANG
Stephanie GLOVER
Andrew GOLDSBOROUGH
Thomas HASE

Local contacts: Thomas SAERBECK

Samples: Ag
Co2FeSi
CoMnSi
MnSb/GaAs
Fe3O4/SrTiO3

Instrument	Requested days	Allocated days	From	To
SUPERADAM	5	0		
D17	5	5	16/12/2014	21/12/2014

Abstract:

We propose an experiment to probe the interface magnetic profile in spin-valve structures with a half-metallic ferromagnet in direct contact with a Ag electrode. We will use our recently optimised L21 phases of the full Co-Heusleur alloys Co2MnSi and Co2FeSu as well as the mixed MnxFe(1-x) compound which have atomically flat interfaces with Ag. Our initial DFT models of the system, which are derived from high resolution TEM studies, has found intriguing evidence for an inversion of the spin-polarised density of states occurring at the interface. We propose a PNR study as a function of applied field (up-to 1 T) to probe the spatial extent of this layer and any exchange spring coupling that arises. Our results will provide new insights into how the interface structure (both magnetic and chemical) effect the efficiency and hence exploitability of these Co based materials as possible new spintronic electrodes.

PNR study of interfacial magnetismin halfmetal spin valve heterostructures - 5-54-165

Motivation:

Co-based Heusler alloys have attracted a lot of attention due to their predicted 100% spin polarization at the Fermi level, making them ideal for many spintronic applications [1]. Amongst the half-metallic ferromagnetic (HMF) full Heusler alloys of the form X_2YM (X,Y: transition metals, M: main group elements), $Co_2FeAl_{0.5}Si_{0.5}$ (CFAS) is of particular interest due to its high Curie temperature and, when used as an electrode in magnetic tunnel junctions, its huge tunnel magnetoresistance ratio at room temperature [2]. CFAS also has the weakest temperature dependence of spin polarization among known HMF materials, which is attributed to a mid-gap Fermi level [3]. During the experimental run 5-54-165 we successfully measured some CFAS thin films using polarised neutron reflectivity (PNR). By fitting the neutron data simultaneously with x-ray in-house laboratory x-ray reflectivity (XRR) ($\lambda_{CuK\alpha}$ = 1.54 Å), we have determined the magnetic profile and correlated it to the structure and disorder in the film.

Experimental details:

Samples were measured with polarised neutrons at room temperature and with an external magnetic field of up to a saturating field of 1 T. We measured from Q = 0.006 $Å^{-1}$ to Q = 0.1 $Å^{-1}$ using a wavelength of λ = 5.58 Å. We also exploited the spin-flip mode to search for angular changes in the magnetic moment within the film at lower magnetic field values.

Results:

Our fitted PNR data (figure 1) confirms a film of 20 nm with $Co_2FeAl_{0.5}Si_{0.5}$ stoichiometry with an interface layer at the substrate and a simple oxide. From the simultaneous fits (fig. 1) the film was found to have a magnetic moment of 5.7 μ_B/f.u which is in agreement, within error, of the theoretical value of 5.5 μ_B/f.u. We found direct evidence of a magnetic dead layer at the substrate interface (figure 2) which we have determined is due to silicon diffusion into the film leading to non-stoichiometry in this narrow region.

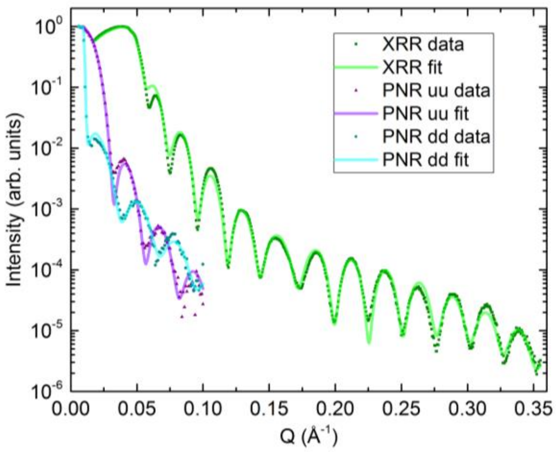
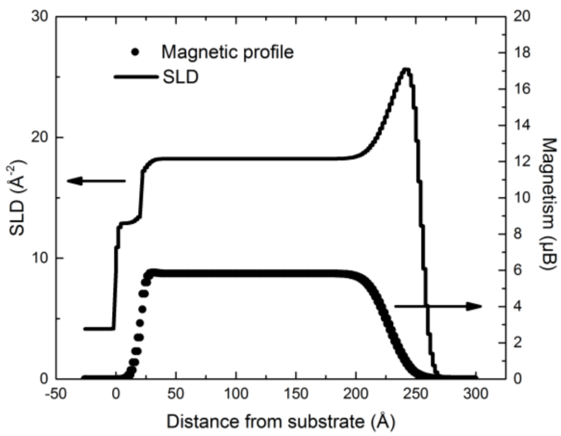


Figure 1: PNR and x-ray reflectivity of the 20 nm CFAS layer (points). Data fitted simulataneously to all data sets using the same model (line)



Fiure 2: Scattering length density (SLD) and moment profile of the sample as determined from the fits in figure 1.

During the experiment we also observed some spin-flip scattering at low fields. This scattering can only arise from non-aligned spins. Vibrating sample magnetometry (VSM) was later used to find the easy axis direction of the sample, which was found to be rotated by 60° from the previously assumed direction.

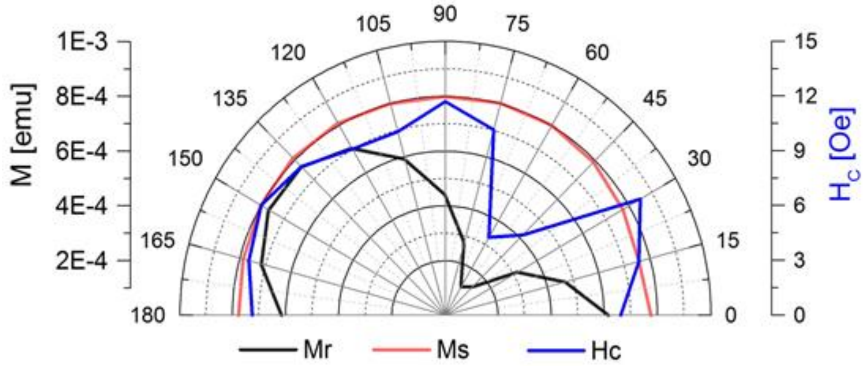


Figure 3: Anisotropy of the sample determined from VSM measurements. Neutron measurements were aligned along ϕ=0°, 60° rotated from the clear easy axis.

We have since fitted our spin-flip data using the same model as shown in figure 1 and find there to be an angular rotation of 25 degrees of the spins at our lowest field value of 28 G. From the SF we concluded that the sample does not split up into small magnetic domains.

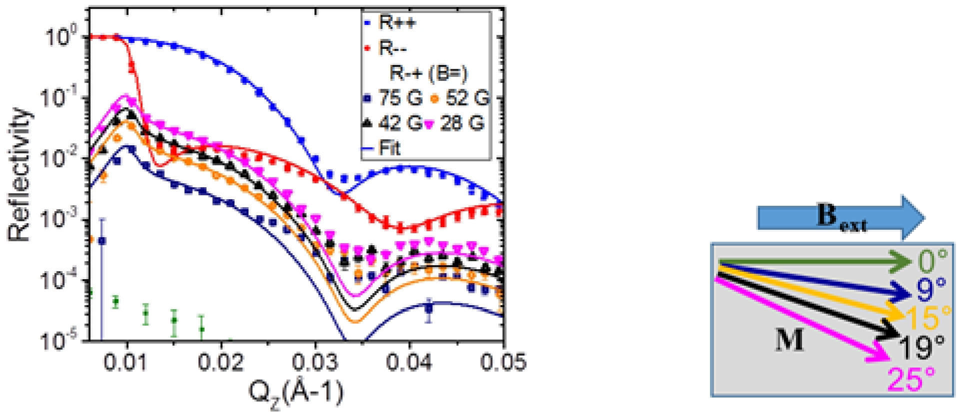


Figure 4: Polarised neutron reflectivity data (points) and fits (line) (Left). The spin flip data at low fields can be modelled assuming the layer rotates towards the easy axis as shown in the schematic (right)

Future work:

We are currently writing up our findings on our CFAS sample in a paper and expect to complete this very shortly. In addition, our experimental paper has guided some detailed DFT studies which is also under preparation to go alongside the PNR paper.

A proposal to investigate the magnetic properties of CFAS grown on Ge(111) has since been submitted to ISIS, RAL. We expect this to maintain the expected 5.5 μ_B/f.u of the CFAS film, but as there is no silicon diffusion from the substrate we expect the magnetism to be maintained to the interface with no magnetic dead layer.