Experimental report

17/02/2020

Proposal: 5-54-285 **Council:** 10/2018

Title: Effects of interdiffusion and antiferromagnetic grain alignment on the pinning strength in IrMn /(Co, CoFe) bilayers and multilayers

Research area: Physics

This proposal is a new proposal

Main proposer: **Alexey DOBRYNIN**

Experimental team: Alexei VOROBIEV
Alexey DOBRYNIN

Local contacts: Alexei VOROBIEV

Samples: Ta 15A Ru 20A / IrMn3 40A / Co 30A / Ru 20A not annealed
{Ta 15A Ru 20A / IrMn3 40A / Co 30A}10 / Ru 20A annealed at 250C
{Ta 15A Ru 20A / IrMn3 40A / Co 30A}10 / Ru 20A annealed at 300C
{Ta 15A Ru 20A / IrMn3 40A / Co70Fe30 30A}10 / Ru 20A annealed at 250C
{Ta 15A Ru 20A / IrMn3 40A / Co70Fe30 30A}10 / Ru 20A annealed at 300C
Ta 15A Ru 20A / IrMn3 40A / Co 30A / Ru 20A annealed at 300C
Ta 15A Ru 20A / IrMn3 40A / Co70Fe30 30A / Ru20A annealed at 300C
Ta 15A Ru 20A / IrMn3 40A / Co70Fe30 30A / Ru 20A not annealed

Instrument	Requested days	Allocated days	From	To
SUPERADAM	10	2	27/06/2019	29/06/2019

Abstract:

Ferromagnetic (FM) / antiferromagnetic (AFM) bilayers are widely used in magnetic recording read heads and in magnetic random access memory (MRAM) for pinning of reference layers or synthetic antiferromagnets in magnetic tunnel junctions (MTJs). Processing such devices involves numerous annealing steps at different temperatures, which may lead to interdiffusion at the FM/AFM interface and thus to degradation of interfacial exchange coupling strength. Pinning strength in polycrystalline FM/AFM systems depends on the FM/AFM exchange coupling, as well as on setting of AFM grains, achieved either by annealing or deposition in applied magnetic field. Polarised neutron reflectometry provides a way to get structural and magnetic depth profiles at the FM/AFM interface, as well as to determine net orientation of the AFM lattice. We propose to investigate {Ta/Ru seed / AFM IrMn / FM (Co, CoFe)} superlattices. The pinning strength of the samples with pure Co decreases much faster with annealing than that with CoFe samples. By comparing the two types of multilayers annealed at different temperatures, we shall be able to determine the main mechanisms behind the pinning strength degradation.

Experiment number **5-54-285**

Title: **Effects of interdiffusion and antiferromagnetic grain alignment on the pinning strength in IrMn /(Co, CoFe) bilayers and multilayers**

Team: A. Dobrynin (Seagate)
Local contact: A. Vorobiev
Date: 27-28 July 2019

Polarised neutron relectometry ws performed on samples 7 and 8, described in the proposal. Measurements on samples 1-6 haven't been completed due to the limited allocated time.

Fig. 1 shows an example of PNR data and best fit for sample 8 (Ta 15A Ru 20A / $IrMn_3$ 40A / $Co_{70}Fe_{30}$ 30A / Ru 20A annealed at 300C), with red line corresponding to "Up" neutron polarization, and blue line – "Down" polarisation:

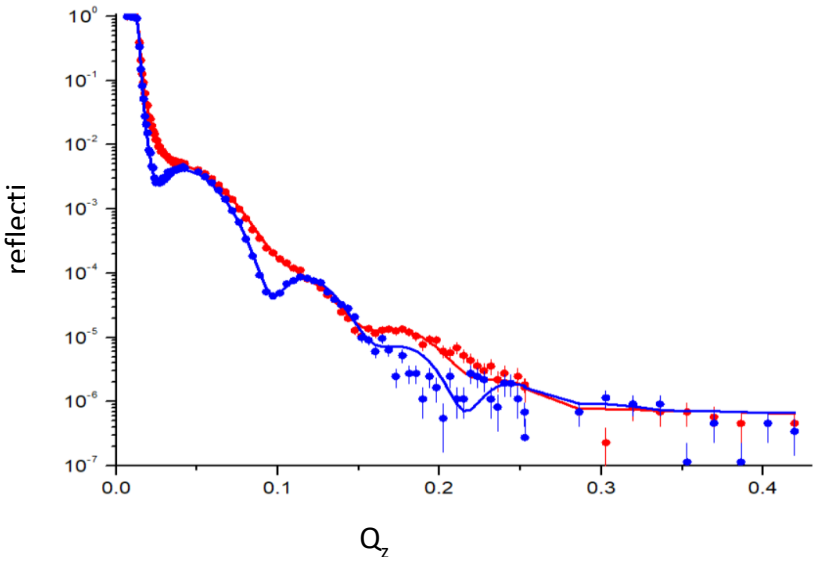


Table values for all related elements and substances, used for fit:

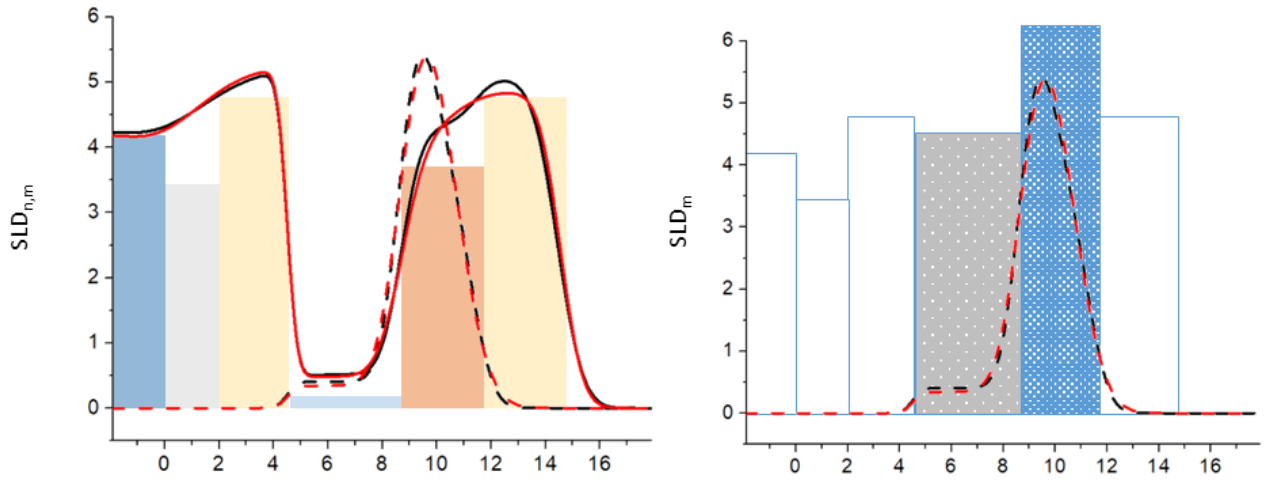
	SLD_n	SLD_m	density
Ta	3.82		16.6
Ru	5.24		12.2
Ir	7.44		22.4
Mn	-2.95	8.85	7.2
Cr	5.24		12.2
Co	2.3	4.24	8.9
Fe	8.09	5.12	7.86
$Co_{70}Fe_{30}$	4.08*	4.5*	8.59
$Ir_{0.25}Mn_{0.713}Cr_{0.038}$ $Ir(Mn_{0.95}Cr_{0.05})_3$	0.09*	6.3*	11.2
SiO_2	4.19		2.65

Description of sample 7 (SLD_n – nuclear, SLD_m – magnetic scattering length density):

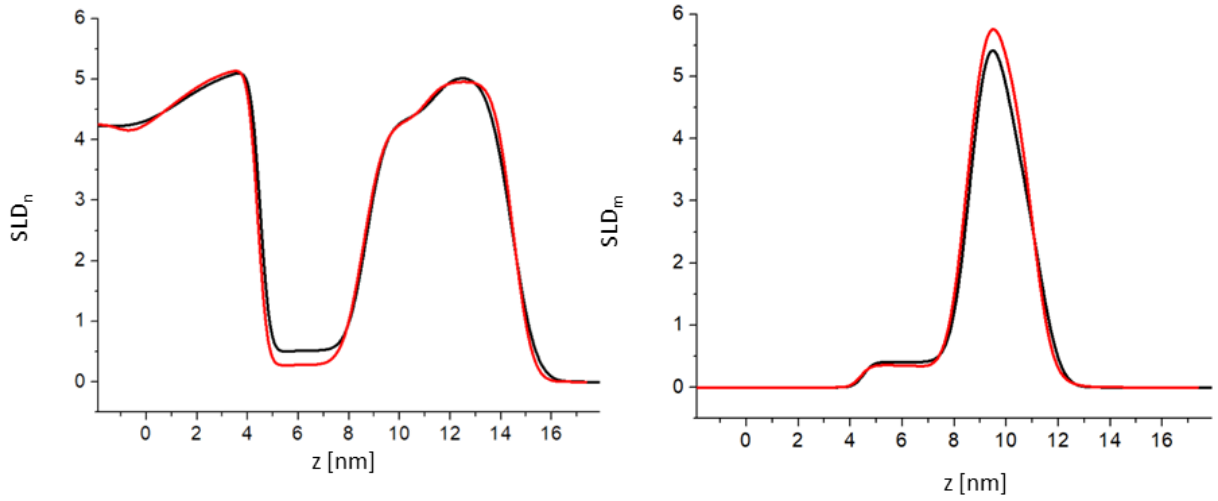
	SLD_n	SLD_m	density	thickness
Ta	3.82	0	16.6	20
Ru	5.24	0	12.2	25
$Ir(Mn_{0.95}Cr_{0.05})_3$	0.09	6.3	7.36	40
$Co_{70}Fe_{30}$	4.08	4.5	8.59	30
Ru	5.24	0	12.2	30
total				**145**
SiO_2	4.19			bulk

Model SLD_n (solid lines), SLD_m (dashed lines).

Black: fit with assumed intermediate layer between IrMn abd CoFe. Red: no additional layers assumed.



Annealed sample 8 (red) vs as-deposited sample 7 (black):



The obtained results demonstrate that a fraction of Mn from the IrMn layer is reduced by about 10% in the annealed sample 8, indicating intermixing at the IrMn/CoFe interface, resulting in increased magnetic roughness at this interface. However, the measured Q_z values limit the z resolution to about 5A, and more time is needed to improve experimental statistics at high Q_z, and possibly extend the Q_z range.
Furthermore, measuring the multilayer samples 3-4 should help to achieve better spatial resolution.
Also it is important to complete measurements on bilayer samples 5 and 6, and the corresponding multilayers 1-2, as the purpose of the experiment was to compare structural and magnetic interdiffusion for samples containing CoFe30 (7,8 , 3,4) and Co (5,6, 1,2), as they demonstrate different magnetic behaviour, as described in the proposal.