Experimental report

12/09/2019

Proposal: **5-54-286** **Council:** 10/2018

Title: Magnetic induction in Re doped Co35Fe65 alloy thin films

Research area: Physics

This proposal is a new proposal

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Samples: CoFe
CoFe with Re (12.6 at%) doping
CoFe with Re (6.6 at%) doping
CoFe with Re (3 at%) doping

Instrument	Requested days	Allocated days	From	To
SUPERADAM	4	3	02/09/2019	05/09/2019

Abstract:

The absolute value of magnetization plays an important role in spin dynamics properties of thin films. For example, low damping and the high magnetization of ferromagnetic (FM) materials are used to reduce the critical current density in spin-transfer-torque (STT) devices. Therefore, CoFe alloys, have ultra-low damping, is the most suitable material for STT devices. Apart from this, damping is increased by radiative and eddy-current contribution. These contributions have to be subtracted from total damping and depend on the static properties such as magnetization and resistivity of FM. Damping and magnetization can be tuned by adding rhenium as a dopant and it is very important to understand how the Re concentration influences the damping and magnetization in order to tailor the material's properties. Therefore, the absolute value of the magnetization is extremely important.

SuperADAM is a reflectometer with polarisation analysis offering extremely high sensitivity to magnetic structure. This instrument is ideally suited for our measurements. The difference in critical angle between spin up and spin down measurements is directly proportional to the absolute value of magnetization.

Report (Proposal: 5-54-286)

Title: Magnetic induction in $(Co_{35}Fe_{65})_{(1-x)}$ Re_x ($0 \leq x \leq 12.6$ at %) alloy thin films.

Sample details: The sample are DC magnetron sputtered films of Ru/$Co_{35}Fe_{65}$/Ru/oxide deposited on Si with a thick SiO_2 buffer layer with varying Re doping in $Co_{35}Fe_{65}$ layer in the range from 0 to 12.6 at%. The nominal thickness of individual layers are 3 nm and 20 nm for Ru and CoFe, respectively.

Results and Discussion:

As proposed we have performed polarized neutron reflectivity (PNR) for all four samples in magnetic field of 440mT (saturation) to extract the reduction in magnetic moment resulting from the Re doping. Fig. 1 shows the PNR measurements together with fits (solid lines) to the data performed by minimising the Chi squared by iteratively calculating the PNR using the super matrix formalism. The insets (upper right) show the resulting scattering length density profiles including the magnetic scattering. The fitted parameters are summarised in Table (1). We would like to note that the fits are of exceptional quality underlining the outstanding sample quality and excellent performance of the instrument. As expected, the magnetization decreases with increase of Re doping.

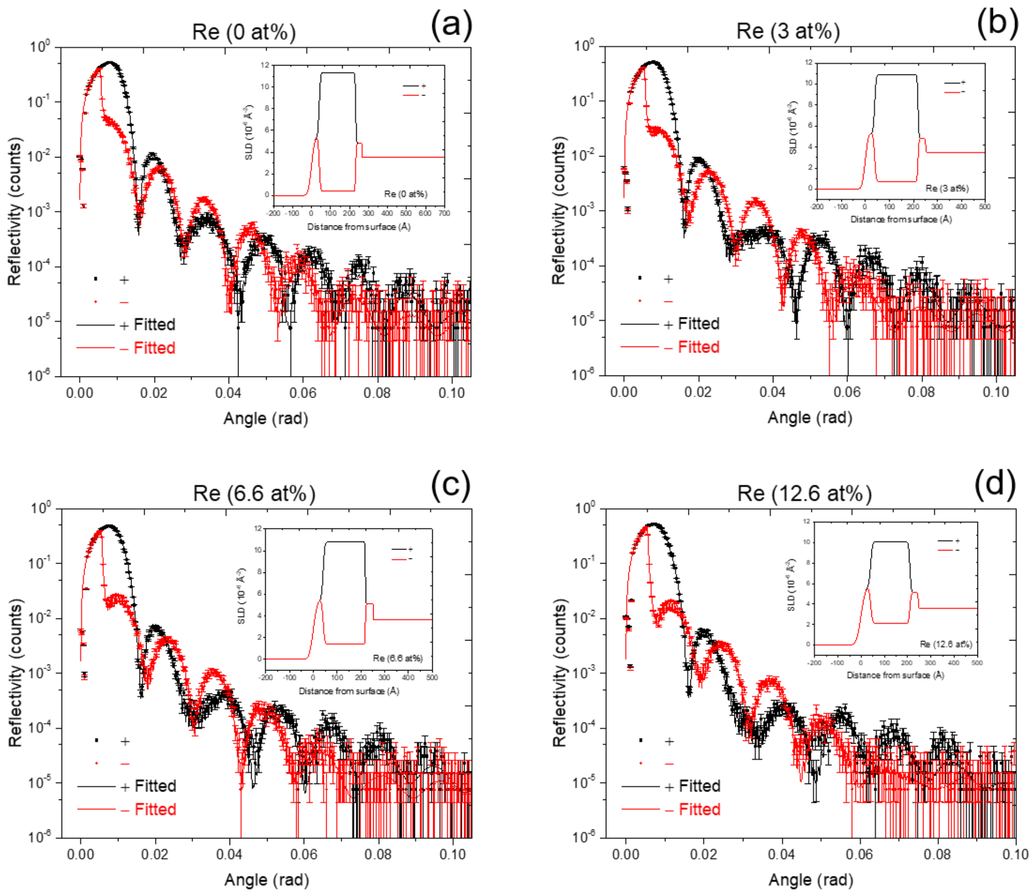

Fig. (1): Polarised neutron reflectivity (dots) plotted together with the corresponding fit to the data (lines). Red and black colours represent spin up and down, respectively. The insets (top right) show the scattering length density profiles for (a). Re (0 at %), (b). Re (3 at %), (c). Re (6.6 at %) and (d). Re (12.6 at %)-doped samples.

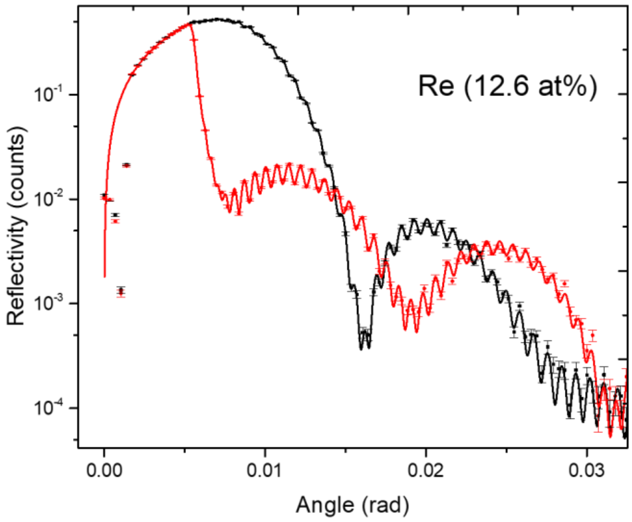

Fig. (2): Zoom into the low Q regime of the data for the sample with 12.6 at% doping demonstrating the high quality of the fit following the narrow oscillations corresponding to the SiO_2 seed layer.

Table (1): Fitted parameters. The χ^2 values are found to be 1.62, 1.42, 1.68 and 1.40 for Re (0 at%), Re (3 at%), Re (6.6 at%) and Re (12.6 at%) doped samples, respectively. The imaginary part of nuclear scattering density kept constant during fitting.

Re doping (at %)	layers	t (Å)	σ (Å)	n-SLD ×10^{-6} (Å^{-2})	m-SLD ×10^{-6}(Å^{-2})	$\mu_0 M$ (T)
0	Ru	40.72 ± 0.37	14.02±0.43	5.50±0.06	-	-
	CoFe	191.97 ±0.11	5.6±0.28	5.86±0.008	5.49±0.008	2.373±0.003
	Ru	31.93±0.69	3.24±0.41	4.78±0.03	-	-
	SiO_2	2970.69±0.97	0	3.54±0.002	-	-
	Substrate	-	8.23±1.4	2.17±0.03	-	-
3	Ru	39.55±0.27	10.12±0.36	5.33±0.04	-	-
	CoFe	180.28±0.11	5.10±0.31	5.82±0.01	5.08±0.01	2.195±0.004
	Ru	32.00±0.68	3.06±0.45	4.80±0.03	-	-
	SiO_2	3117.85±1.1	1.91±2.6	3.50±0.004	-	-
	Substrate	-	11.60±1.5	2.18±0.04	-	-
6.6	Ru	41.47±0.32	13.34±0.35	5.52±0.05	-	-
	CoFe	177.51±0.11	5.6	6.10±0.01	4.69±0.01	2.027±0.004
	Ru	32.92±0.53	1.83±0.64	5.09±0.03	-	-
	SiO_2	2950.35±0.87	0	3.64±0.003	-	-
	Substrate	-	11.09±1.1	2.01±0.02	-	-
12.6	Ru	41.31±0.36	15.81±0.39	5.82±0.06	-	-
	CoFe	168.99±0.13	6.25±0.34	6.08±0.008	3.96±0.007	1.711±0.003
	Ru	35.75±0.53	4.66±0.38	5.12±0.03	-	-
	SiO_2	2946.95±0.79	1.90±0.23	3.57±0.001	-	-
	Substrate	-	7.56±1.2	2.06±0.02	-	-