Temperature driven interlayer exchange coupling in Fe/Cr/Gd multilayers

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Ferromagnetic 4f rare-earth/ 3d transition metal (RE/TM) multilayers are popular model systems showing a rich variety of magnetic phases in applied field. In particular, complex magnetic order in Fe/Gd multilayers is governed by several competing mechanisms: enhancement and temperature-independence of Gd magnetic moment in the interfacial region near Fe, strong RE-TM antiferromagnetic coupling at interfaces, and Zeeman interaction with external fields.
It was recently shown that RE/Cr/TM multilayers, where RE-TM exchange is mediated by antiferromagnetic Cr, display a number of novel magnetic phases, including switching an otherwise AFM Gd-Fe coupling to ferromagnetic coupling, together with a dominant biquadratic RE-TM exchange coupling over bilinear coupling at certain Cr thicknesses near where the oscillatory interlayer coupling (with Cr thickness) changes sign. The latter should lead to non-collinear ordering. Cr layer thickness in the samples was chosen in order to cover 3 different types of magnetic ordering in the system: ferromagnetic, antiferromagnetic and non-collinear.
The [Fe(35 Å)/Cr(t Å)/Gd(50 Å)] (t = 0-60 Å) multilayer was grown via magnetron UHV sputtering onto a Si substrate with Cr buffer (50 Å) and cap (30 Å) layers. The structural properties of the multilayer were characterized with resonant x-ray magnetic reflectometry (RXMR). Magnetometry measurements were performed with a superconducting quantum interference device (SQUID).
The sample [Fe(35 Å)/Cr(7.2 Å)/Gd(50 Å))/Cr(Å)]$_{12}$ was successfully measured with resonant x-ray magnetic reflectometry (RXMR) and x-ray magnetic circular dichroism (XMCD) (ID-12 ESRF) instruments. These x-ray measurements were performedat the Gd L_2 absorption edge E=7941,5 eV, at the Gd L_3 E=7247, 09 eV and at the Fe K E= 1743 eV. The scans were performed at temperatures T =45, 100, 200 and 300 K with circularly polarized light and averaged over the two opposite helicities.

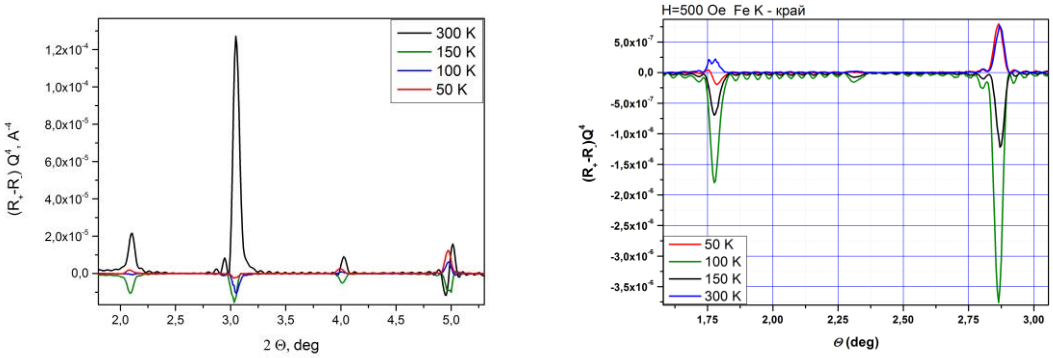

Fig. 1 Experimental RXMR spectra of sample [Fe(35 Å)/Cr(7.2 Å)/Gd(50 Å)/Cr(7.2 Å]$_{12}$ for H=500 Oe a) at the Gd L_2 E=7941,5 eV, b) at the Fe K E= 1743 eV.

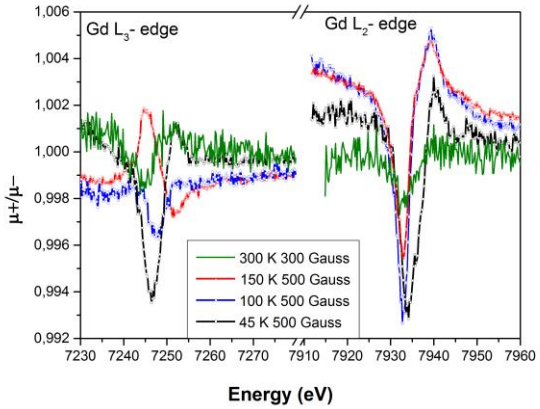

Fig. 2. Gd L_3 –edge and Gd L_2 –edge XMCD

The goal of the experiment was to prove temperature driven variations in magnetic ordering in Fe/Cr/Gd multilayers.

We expect to determine depth- and element-dependent magnetic structure in three Fe/Cr/Gd multilayers and provide direct experimental evidence for temperature dependent Fe-Gd magnetic ordering in these structures. Successful determination of magnetic structure in these systems helps gain a deeper understanding of RE-TM magnetism and opens ways to create RE-TM systems with temperature driven magnetic ordering.

References:

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