Interfacial structure and magnetism in Fe/Gd multilayers

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Introduction

Interface structure affects many of the phenomena exhibited by magnetic films and multilayers. Yet even though the importance of interface structure is widely acknowledged, studies to date have generally ignored the magnetic component of the interface structure due to the surface sensitivity of most magnetic probes (e.g., magnetic force microscopy and magneto-optical Kerr effect). This shortcoming can be remedied through the use of a tunable, high-brilliance x-ray beam, and this report describes an investigation of an Fe/Gd multilayer using x-ray resonant magnetic scattering (XRMS) on Advanced Photon Source beamline 1-ID.

Methods and Materials

The experimental set up used for the XRMS measurements is shown below in Figure 1. The diamond phase retarder produces a circularly polarized beam and data are collected in an A-B-B-A sequence, where A and B represent opposite helicities of the beam polarization. Pure charge and charge-magnetic interference data are extracted from the data by taking the sum and difference, respectively, between the sum of the A measurements and the sum of the B measurements.

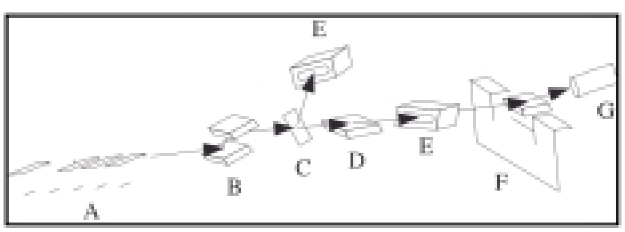

Figure 1: Experimental setup on beamline 1-ID. Components include the undulator (A); double-crystal Si(111) monochromator (B); diamond phase retarder (C); harmonic-rejection mirror (D); ionization chambers (E); permanent magnet and sample (F), which can be rotated about the surface normal of the sample; and Si(Li) solid-state detector (G).

Results

Both specular reflectivity and diffuse scattering data were collected in order to obtain magnetic information about the multilayer. Examples of the charge-magnetic interference reflectivity measured near the Gd L2 and L3 edges are shown in Figure 2(a), while pure charge and charge-magnetic interference diffuse scattering are presented in Figures 2(b) and 2(c), respectively. In all figures, Born approximation fits [1, 2] to the data are also displayed.

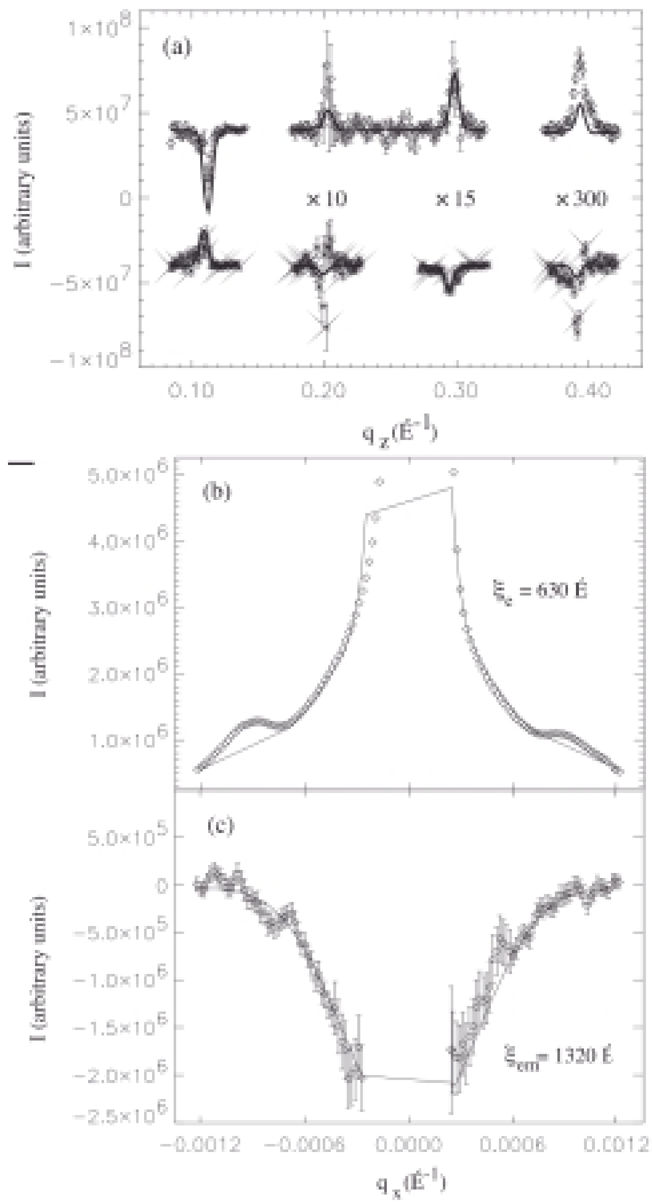

Figure 2: Born approximation fits (—) to (a) charge-magnetic interference reflectivity measured near the Gd L2 (Δ) and L3 (*) edges, (b) pure charge diffuse scattering, and (c) charge-magnetic interference diffuse scattering. The data and fit in (a) have been shifted by $\pm 4 \times 10^7$ and enlarged, as labeled, for clarity.

Discussion

The fits to specular reflectivity data of the type shown in Figure 2(a) [2, 3] indicate a direct proportionality between the structural roughness and the range of the Fe-Gd exchange coupling. Fits to the diffuse scattering also provide information about the relationship between the structural and magnetic properties of the multilayer. For example, the fits shown in Figures 2(b) and 2(c) and fits to additional diffuse data measured from other Fe/Gd multilayers [4] result in longer correlation lengths for both in-plane and out-of-plane charge-magnetic roughness than for pure charge (or structural) roughness. Additional studies focusing on the temperature and energy dependences of the XRMS data in the Fe-Gd system are already underway.

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References

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