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X-ray MCD studies for Fe/Si interfaces using standing waves

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Introduction

Fe/Si multilayers are attractive for the strong anti-ferromagnetic interlayer coupling. However, mechanism of the strong interlayer coupling has not yet been resolved. A possible reason for the controversy is the serious interdiffusion between Fe and Si layers. Using soft X-ray fluorescence (SXF) spectroscopy we have so far found for an antiferromagnetically-coupled Fe/Si multilayer that Si layer was not left and an $FeSi_2$ layer was sandwiched with Fe_3Si layers [1]. The $FeSi_2$ layer was interpreted to be active in the magnetic coupling in terms of a quantum interference model. As a next step magnetic property of the interdiffused layer should be made clear. For such studies X-ray magnetic circular dichroism (MCD) spectroscopy combined with soft X-ray standing waves is promising [2].

Experimental

Fe/Si/Fe trilayer samples were deposited using a magnetron sputter system on W/B_4C multilayers, which act as standing wave generators. All the samples were covered with a C layer of 2.0 nm thick to prevent the topmost Fe layer from oxidation. Fe $L_{2,3}$ MCD spectra were measured for each sample for grazing angles of incidence around 15° at 0.2° intervals. Scattering vector of the standing wave is essential to obtain information of a layer at a constant depth, because the loop of a standing wave stays for the same scattering vector. From the surface of the aligned MCD spectra, we obtained MCD spectra as a function of scattering vector. Figure 1 shows an example of the MCD spectra *vs.* scattering vector q, which was obtained for a ferromagnetically-coupled Fe/Si(0.51nm)/Fe sample. Using the magnetic sum rules for the q-dependent MCD spectra we obtained depth resolved magnetic moments. Physicochemical state of the interdiffused layer of the samples was also analyzed using SXF spectroscopy.

Results

Depth-resolved orbital moments obtained for a ferromagnetically-coupled Fe/Si(1.35nm)/Fe sample are plotted in the upper column of Fig. 2, where the Si layer is temporarily presented to range from z = 3.00 nm through to 4.35 nm in depth. The orbital moment is almost constant over the Si layer, while it changes drastically near the Fe/Si interfaces. In the lower column of Fig. 2 is shown the Fe/Si interdiffused layer resolved using SXF spectroscopy. It is found that the enhancement in the orbital moment occurs inside the Fe_3Si layers. Because Fe_3Si film is ferromagnetic, while FeSi and $FeSi_2$ films are nonmagnetic, it is quite reasonable that the enhancement originated from magnetic anisotropy at interfaces occurs in the Fe_3Si layer. Similarly, it was also found for an antiferromagnetically-coupled sample that the orbital moment enhances inside the Fe_3Si layers. Our result suggests strongly that the phase of the interlayer coupling between the ferromagnetic layers including Fe_3Si depends on the thickness of the nonmagnetic layers, and that the quantum interference model is valid for the system. It is also suggested that the SXF technique can predict partly magnetic properties of the interdiffused layers from physicochemical viewpoint.

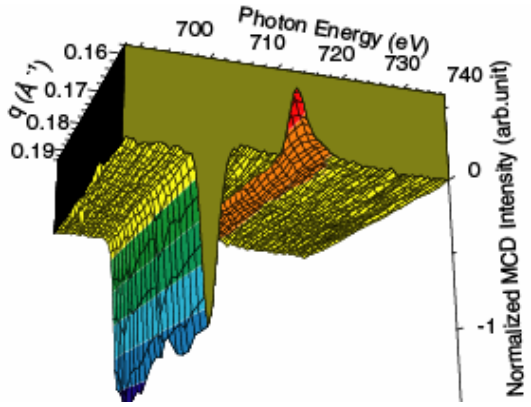

Fig. 1. Fe $L_{2,3}$ MCD spectra *vs.* scattering vector obtained for an Fe/Si(0.51nm)/Fe sample.

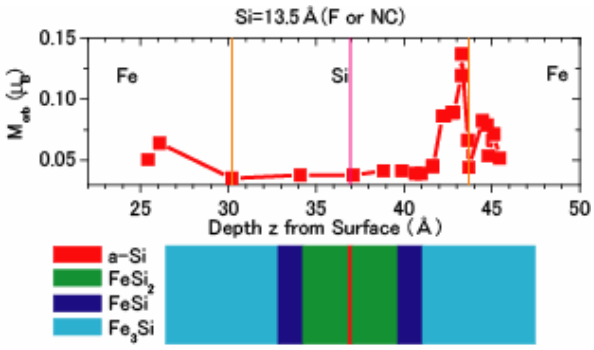

Fig. 2. Orbital moments *vs.* depth z obtained for an Fe/Si(1.35nm)/Fe sample (top), and its interdiffused layer resolved using the SXF technique (bottom).

References

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