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Depth profiling of interdiffused layers in Fe/Si multilayers using standing-wave soft-X-ray fluorescence spectroscopy

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Introduction

Fe/Si multilayers are widely studied from the aspect of the interlayer magnetic coupling. We have assigned the mediating layer for the interlayer coupling to be an amorphous $FeSi_2$ layer of 0.7 nm thick resulted from interdiffusion using soft-X-ray fluorescence (SXF) spectroscopy [1]. However, if the interdiffused layers have an asymmetric structure with respect to the Fe or Si layer, the SXF technique provides an average of the equivalent silicide layers on both sides. For further analysis of the interdiffusion layer the standing-wave technique is promising as in the X-ray region. Antinodes of the standing wave generated in the multilayer under the Bragg condition enhance the fluorescence locally, which can differentiate a silicide layer from the equivalent one on the opposite side.

Experimental

An Fe(3.0nm)/Si(1.9nm)/Fe(3.0nm) trilayer deposited on a Mo(2.3nm)/B_4C(2.7nm) multilayer of 20 bilayers was prepared using a magnetron sputter system. Standing wave is generated dominantly by the Mo/B_4C multilayer, while it is slightly modulated by the trilayer. Standing wave was first confirmed to be present in the sample by measuring total photoelectron yield vs. incident photon energy. The SXF experiment was carried out at BL-16B using an SXF spectrometer of a flat-field focusing type under a resolution of about 0.4 eV at 100 eV.

Results

Figure 1 shows the Si $L_{2,3}$ fluorescence spectra from the Fe/Si/Fe trilayer at 136.1 eV for 22° and 28° angles of incidence from the normal, where the latter angle was not under the Bragg condition. A slight difference is found between the two spectra in the shoulder region. Differences between 22° and 28° in the fluorescence intensity estimated by a curve fitting analysis for the silicide layers are summarized in Table I. The signs of $FeSi_2$ and Si are different, whereas those of Fe_3Si and Si are the same. It is not reasonable because the $FeSi_2$ layer is closer to the Si layer than the Fe_3Si layer. It must result from the symmetric layer model. Figure 2 shows the depth structure obtained from an analysis for the Si $L_{2,3}$ fluorescence spectra measured for 20° at five photon energies between 134 eV and 142 eV. The $FeSi_2$ layer above the Si layer is thinner than that below it, and vice versa for the Fe_3Si layer. Therefore, it is ascertained that the interdiffused layer has an asymmetric structure. The origin of the asymmetric structure is though still under question, our result means that the standing wave SXF technique is promising for interface analysis and thus depth profiling.

Table I. Relative changes in the SXF intensity for the silicide layers between 22° and 28°.

Silicides	Fe_3Si	$FeSi_2$	a-Si	SiO_2
Change (%)	+13.5	-17.6	+9.4	-4.6

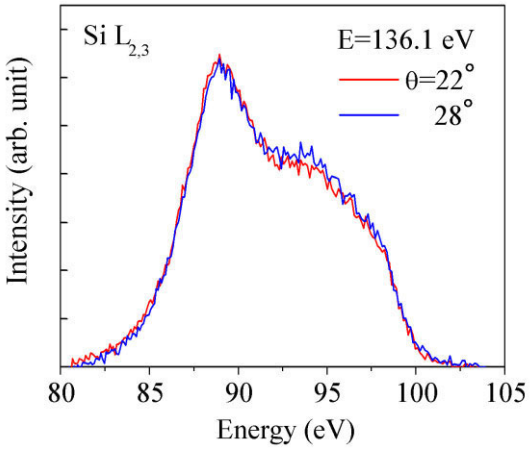

Fig. 1. Si $L_{2,3}$ SXF spectra from an Fe/Si/Fe trilayer for 22° and 28° angles of incidence at 136.1 eV.

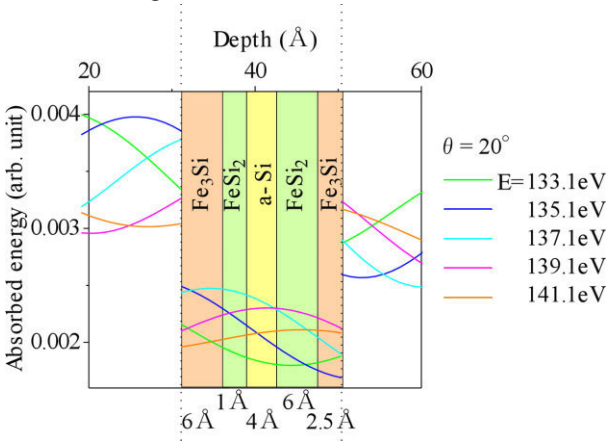

Fig. 2. Depth structure of the Fe/Si/Fe trilayer. Standing waves are also shown as absorbed energy for several E's.

References

[1] T. Imazono *et al.*, Jpn. J. Appl. Phys. **43**, 4327 (2004).

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