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Interfaces near the surface in Fe/Si multilayers studied by grazing-incidence soft-X-ray emission spectroscopy

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Introduction

Penetration depth of X-ray is limited when it is incident at the critical angle of total reflection. Utilizing this property, X-ray fluorescence analysis is used to study the depth profile of a sample in the hard X-ray region. It provides information on the ratio of constituent elements. Grazing-incidence soft-X-ray emission (SXE) spectroscopy thus might be a useful tool to study the chemical bonding state near the surface of multilayers.

Fe/Si multilayers have been widely studied for the strong antiferromagnetic coupling between Fe layers. In the previous study, we made clear that the interdiffused $FeSi_2$ layer mediates the antiferromagnetic coupling rather than the remained *a*-Si layer [1]. It was also confirmed that SiO_2 was slightly found. However, the site has not been specified. In this study, we applied grazing-incidence SXE spectroscopy to clarify this point.

Experimental

Three Fe (3.0 nm)/Si (*t*) multilayers were prepared, where the thickness *t* of the Si layer was 1.0, 1.3, and 1.5 nm for the respective samples. SXE experiment was carried out at BL-3B using a flat-field type spectrometer. The excitation energy was fixed at 155 eV. The critical angle of total reflection of Fe for E = 155 eV is 76.3°. In this case, penetration depth is estimated to be about 4 nm. The angles of incidence of the excitation light θ we chosen were 60° and 76°.

Results

Figure 1 shows the Si $L_{2,3}$ SXE spectra measured for the Fe/Si multilayers for θ = 60° and 76°, which are indicated with the solid and dotted lines, respectively. It is remarkable that the spectra for θ = 76° have a structure at 94 eV as compared with those for θ = 60°. It originates from SiO_2. Effective thickness of each layer was estimated by curve fitting analysis using the SXE spectra for Fe_3Si, FeSi, $FeSi_2$, *a*-Si, and SiO_2. The *t* dependence of the layer thickness concerning the spectra for θ = 60° and 76° is summarized in Figs. 2(a) and 2(b), respectively. The former is concerned with the whole multilayer. The remarkable difference between the two is that the SiO_2 layer is thicker for θ = 76° than for θ = 60° at t = 1.0 and 1.3 nm, while for the Fe_3Si layer the tendency is quite opposite. This is an evidence for the SiO_2 layer to be generated by oxidation of the Fe_3Si layer under the topmost Fe layer. As a result, the topmost Fe_3Si layer reduces in thickness. This result means that the grazing-incidence SXE spectroscopy is quite promising to estimate the bonding state near the surface.

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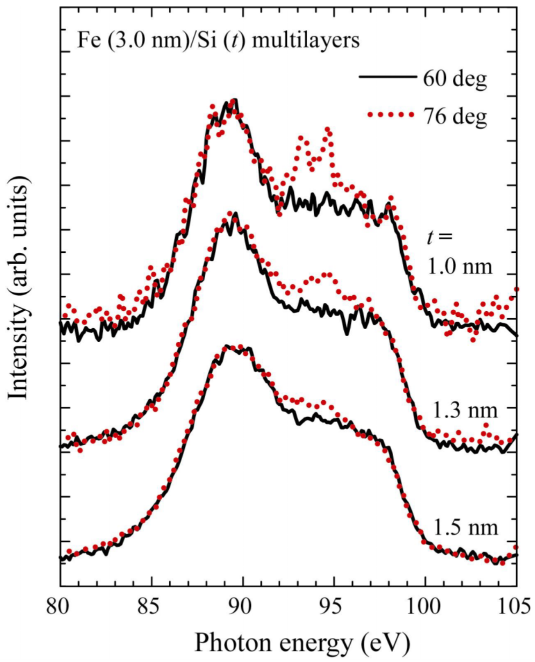

Fig. 1 Si $L_{2,3}$ SXE spectra measured for the Fe/Si(*t*) multilayers for θ = 60° (solid) and 76° (dotted).

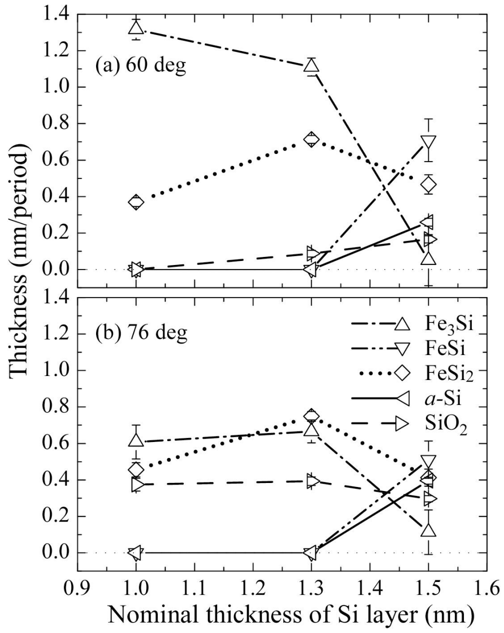

Fig. 2 Plot of the thickness of each layer vs. *t* concerning the spectra for θ = 60° (a) and 76° (b).

Reference

[1] T. Imazono et al., PF Act. Rep. 2001 Part B 56 (2002).

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