Si $L_{2,3}$ emission spectra from the interfaces in antiferromagnetically coupled Fe/Si multilayers II

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Introduction

The Fe/Si multilayer has been widely studied for the strong antiferromagnetic coupling between the Fe layers. However, the models so far proposed for the origin are controversial because of the severe interdiffusion at the interfaces. Endo *et al.* [1] studied the interlayer coupling for a series of Fe/$Fe_{1-x}Si_x$ ($0.4 \leq x \leq 1.0$) multilayers deposited at a high rate and explained the results qualitatively by the quantum-well model rather than the RKKY model. Besides, they observed the strongest interlayer coupling for the Fe/Si(1.3nm) multilayer among the Fe/Si(*t*) multilayer series. However, the origin of the enhancement was not yet understood because the material of the mediating layer was not assigned. In the previous study [2] we investigated using soft X-ray emission (SXE) spectroscopy the interface of the Fe/Si(*t*) multilayers whose magnetic and electric properties were confirmed by Endo *et al.* The result suggested that there should remain a thin layer of high resistive Fe-Si alloy or *a*-Si sandwiched between the Fe_3Si layers. However, the mediating material was not assigned in that study. In this study we remeasured the SXE spectra for the Fe/Si(*t*) multilayers at high-flux beamlines.

Experimental

The Fe/Si(*t*) multilayers were grown to 22 bilayers on Si substrates with the thickness of the Fe layer fixed at 3.0 nm and the thickness *t* of the Si layer using a dc magnetron sputter system. The SXE experiments were carried out at BL-3B and 16B using an SXE spectrometer of a flat-field type. The resolution of the spectrometer was about 0.5 eV at 100 eV.

Results and discussion

Figure 1 shows the Si $L_{2,3}$ emission spectra measured for the Fe/Si(*t*) multilayers of *t* = 0.5, 1.0, 1.3, 1.5, 1.7, 2.0, and 3.0 nm and amorphous Si (*a*-Si) excited at 120 eV. The spectrum of the Fe/Si(3.0 nm) multilayer is very similar to that for *a*-Si, which suggests that the Si layer almost consists of *a*-Si. The spectrum changes with decreasing *t*, which suggests that the interface region of the Fe/Si(*t*) multilayers almost consists of Fe-Si alloys rather than *a*-Si. The effective thickness of the alloys was estimated by reproducing the Si $L_{2,3}$ spectra of the multilayers using those of Fe_3Si, FeSi, $FeSi_2$, and *a*-Si. Figure 2 shows their thickness as a function of *t*. For the Fe/Si(1.3nm) multilayer Fe_3Si, $FeSi_2$, and FeSi are dominantly observed but not *a*-Si. This result means that the contribution of *a*-Si to the magnetic interlayer coupling is negligible. Fe_3Si is also excluded from the materials to mediate the interlayer coupling because it is ferromagnetic. Thus $FeSi_2$ plays an important role in the antiferromagnetic coupling in the Fe/Si multilayer. The effective thickness for $FeSi_2$ is about 0.7 nm.

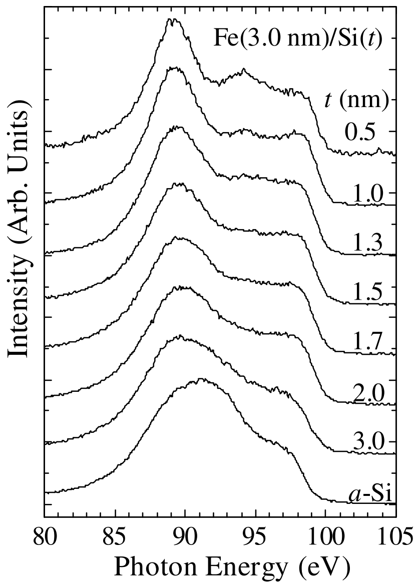

Fig. 1. Si $L_{2,3}$ SXE spectra of the Fe/Si(*t*) multilayers of *t* = 0.5, 1.0, 1.3, 1.5, 1.7, 2.0, and 3.0 nm and *a*-Si.

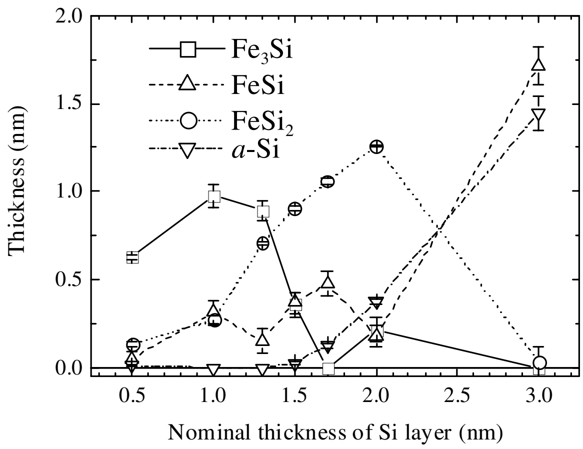

Fig. 2. Thickness of Fe_3Si, FeSi, $FeSi_2$, and *a*-Si estimated for the interlayer.

References

[1] Y. Endo *et al.*, Phys. Rev. B**59**, 4279 (1999).
[2] T. Imazono *et al.*, PF Activity Report 2000 Part B p.42.

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