

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

Takashi IMAZONO,\* Noboru MIYATA, Osamu KITAKAMI, and Mihiro YANAGIHARA  
Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577

### Introduction

The giant magnetoresistance originates from the antiferromagnetic coupling between the magnetic layers spaced by a nonmagnetic layer. The Fe/Si multilayers has been widely studied for the strong interlayer coupling. 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<sub>1-x</sub>Si<sub>x</sub> ( $0.4 \leq x \leq 1.0$ ) multilayers deposited at a high rate. The temperature dependence of the interlayer coupling was explained qualitatively by the quantum-well model rather than the RKKY model. Besides, they found a drastic enhancement in the interlayer coupling with increasing Si content up to  $x = 1.0$ , that is, Fe/Si multilayers. However, the origin of the enhancement has not been yet understood. In this study we investigate using soft X-ray emission (SXE) spectroscopy the interface of the Fe/Si multilayers whose magnetic and electric properties were confirmed by Endo *et al.*

### 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 strongest interlayer coupling was observed for the Fe/Si(1.3nm) multilayer. The SXE experiments were carried out at BL-12A using a soft-X-ray spectrometer of a flat-field type. The resolution of the spectrometer was about 1.0 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  $t = 0.5, 1.0, 1.5, 2.0,$  and  $4.0$  nm and amorphous Si ( $a$ -Si) excited at 128 eV. The spectrum of the Fe/Si(4.0nm) multilayer is very similar to that for  $a$ -Si, which suggests that the Si layer almost consists of  $a$ -Si. On the other hand, the spectrum of Fe/Si(0.5nm), quite different from  $a$ -Si, seems to be similar to that of the Fe/Si(1.0nm) multilayer, suggesting that the Si layer in Fe/Si(0.5nm) has completely changed into Fe<sub>3</sub>Si [2]. The dominant alloy generated at the interface of the Fe/Si multilayers is Fe<sub>3</sub>Si. However, because Fe<sub>3</sub>Si is metallic and ferromagnetic, the result of Endo *et al.* concerning the temperature dependence of the resistivity cannot be interpreted. It should be noticed in Fig. 1 that there is a slight difference in the spectral profile of the plateau region between the Fe/Si(1.0nm) and Fe/Si(1.5nm) multilayers, which are immediately close to the Fe/Si(1.3nm) multilayer. Figure 2 compares the measured spectrum of the Fe/Si(1.5nm) multilayer with

that reproduced from the Fe/Si(1.0nm) multilayer and  $a$ -Si. The result suggests that there should remain a thin layer of high resistive Fe-Si alloy or  $a$ -Si sandwiched between the Fe<sub>3</sub>Si layers. However, the kind of the alloy has not been still assigned in this study.

### References

- [1] Y. Endo *et al.*, Phys. Rev. B **59**, 4279 (1999).
- [2] J.J. Jia *et al.*, Phys. Rev. B **46**, 9446 (1992).

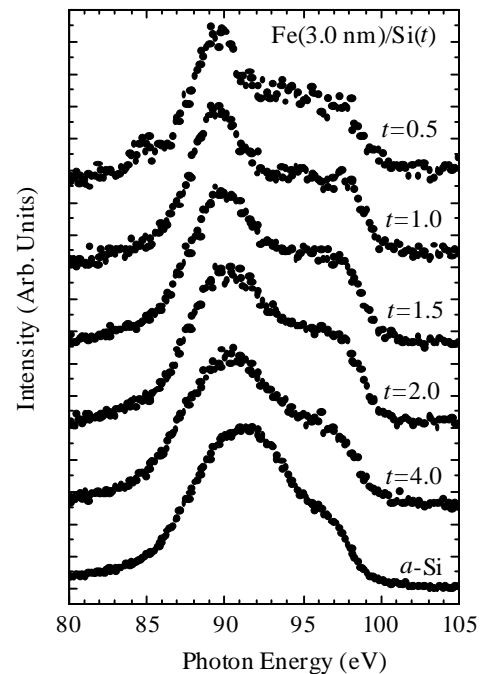


Fig. 1. Si  $L_{2,3}$  SXE spectra of the Fe/Si( $t$ ) multilayers of  $t = 0.5, 1.0, 1.5, 2.0,$  and  $4.0$  nm and  $a$ -Si.

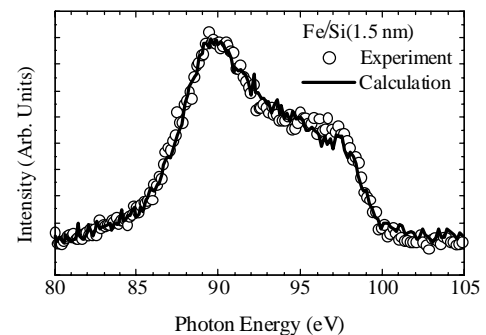


Fig. 2. Comparison of the spectra of the Fe/Si(1.5nm) multilayer; dots: measured, solid curve: calculated using the spectra of the Fe/Si(1.0nm) multilayer and  $a$ -Si.

\* imazono@rism.tohoku.ac.jp