Buried interfaces of annealed Mo/Si multilayers studied by soft-X-ray emission spectroscopy

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Introduction

Soft-X-ray emission (SXE) spectroscopy is a useful tool to study chemical bonding of buried interfaces. Using this method, we have shown that Mo_3Si is formed at the interfaces of as-deposited Mo/Si multilayer (ML) coatings [1]. A Mo/Si ML coating is very useful for its high reflectance at normal incidence for soft X-rays. Novel optical systems with ML coatings, such as a soft-X-ray microscope, have been developed. But for the uses as a first mirror in SR beamlines or a cavity of soft-X-ray laser, the thermal stability is a serious problem, because the ML structure is broken by the heat load of the intense light. It is important to study this mechanism for the development of thermally stable ML coatings. In this study we measured Si $\boldsymbol{L}_{2,3}$ SXE spectra of annealed Mo/Si ML coatings.

Experiments

Mo/Si ML samples were made by a magnetron sputtering system. The sample A was not annealed, as a reference sample. The others were annealed for 5 hours at 400 °C for the sample B and 10 hours at 400 °C for the sample C. SXE experiments were performed at the beamline BL-12A. The FWHM of the excitation soft X-ray was about 2.5 eV. The SXE emission spectrometer we used was of plane-focusing type equipped with a 1200 grooves/mm grating. The energy resolution was about 1 eV. We measured the Si $\boldsymbol{L}_{2,3}$ spectra of not only ML samples but also some bulk compounds such as amorphous Si (***a***-Si) and $MoSi_2$ for reference data.

Results and discussion

The Si $\boldsymbol{L}_{2,3}$ SXE spectra of ML samples are shown in Fig. 1. The spectrum of the sample A resembles that of ***a***-Si because most part of the Si layers is left as amorphous. The spectrum of the sample B is different from that of the sample A, not annealed one. The spectrum of the sample B is more different. Comparison with that of $MoSi_2$ suggests that this change is caused by the formation of $MoSi_2$ at the interfaces.

From the spectral analysis, we estimate the thickness of $MoSi_2$ interlayer for the annealed samples. It is 19 (±3) Å for the sample B and 30 (±5) Å for the sample C. Using them we also estimate a diffusion coefficient between Mo and Si as 1.1 $(\pm 0.2)\times 10^{-18}$ cm^2/s. Our value is roughly consistent with previously reported ones [2]. From the results, we show that SXE spectroscopy is useful to study the thermal change of the buried interface non-destructively.

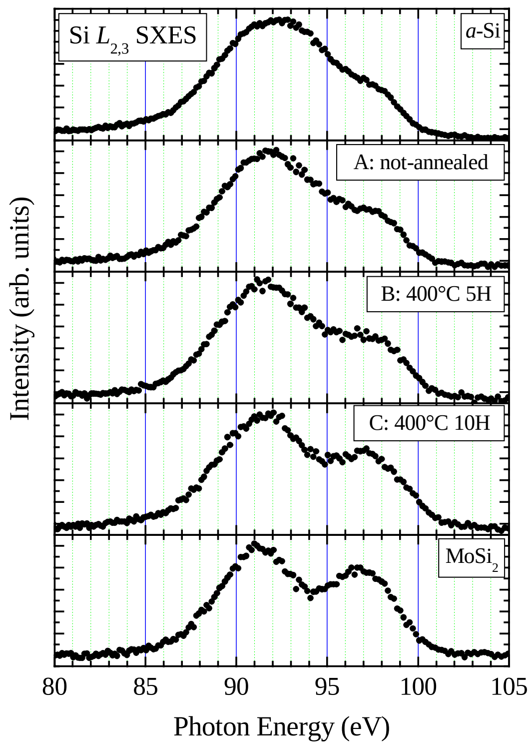

Figure 1. Si $\boldsymbol{L}_{2,3}$ SXE spectra of ***a***-Si, not-annealed ML coating (A), 5 hours at 400 °C annealed (B), 10 hours at 400°C annealed (C) and $MoSi_2$.

References

[1] N. Miyata, et al., Jpn. J. Appl. Phys. **38** (1999) 6476.
[2] Previously reported data are 8.9 $\times 10^{-17}$ cm^2/s by K. Holloway, et al. (J. Appl. Phys. **65** (1989) 474), and 3 or 4 $\times 10^{-18}$ cm^2/s by D. G. Stearns, et al. (J. Appl. Phys. **67** (1990) 2415).

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