Structure Evaluation of Mo/Si Multilayer by XAS and X-Ray Reflectivity Measurements

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Soft X-rays are actively used for the research of materials with electronic structure, because an interaction between X-ray and the material is large. Since the refractive index of the soft X-ray is almost unity for any materials, it cannot be applied to the focusing of X-ray beam. Therefore, a multilayer mirror having a high reflectivity for a vertical incidence beam is used for this purpose. A characterization of the reflectivity of the multilayer mirror is also available to use the soft X-rays, because it allows to measure without damage for sample surface. On the other hand, it is difficult to analyze X-ray reflective spectra, if the unknown material is deposited on the surface or in the interface.

In this study, we suggest an analytic method to get the model of the multilayer structure from X-ray absorption spectrum (XAS), and applied it to the interpretation of X-ray reflective spectra in order to characterize the reflectivity of the multilayer mirror. The XAS measurements were taken at the BL-10 and the X-ray reflective spectra were taken at the BL-3 of SR Center at Ritsumeikan University. The samples used in this study consist of mutually laminated Mo and Si layers deposited by the ion sputter method on a Si substrate. The layer structure is shown in Fig.1. The thickness of one layer is 7nm (Si: 4nm, Mo: 3nm), and the number of layers is 60.

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XAS spectra for the Si K-edge of the Mo/Si multilayer film, $MoSi_2$, Si and SiO_2 are shown in Fig.2. It is seen that the spectrum of the multilayer film has a different shape from that of the Si reference sample. The result indicates the Si state at the surface and interface of the multilayer film. From the comparison with the spectrum shape of the multilayer film and those of other Si compounds, it is seen that Si atoms in the multilayer film are in the same electric state as that of the Si, SiO_2, $MoSi_2$. Figure 3 shows XAS spectra for the Mo L-edge of the multilayer film, Mo and $MoSi_2$. In this figure, it is confirmed that the spectrum shape of multilayer film is different from those of Mo and $MoSi_2$. From the observations, we conclude that the surface of the multilayer film is covered with SiO_2 and the interface between the Mo layer and the Si layer is constructed from Mo and Si mixed phase. The model derived from this assumption is shown in Fig.4.

Fig.5 shows an X-ray reflective spectrum of the multilayer film (solid line: measurement, dotted line: calculated). When this model is used, the experimental spectrum is in good agreement with that of the calculation one. The calculated value is shown in Table.1. It is seen that Mo and Si mixed layer is formed in the Si layer by comparing designed value with calculated value. And the density of the Mo and Si mixed layer formed on Si is near the density of $MoSi_2$, is lower than that of the Mo and Si mixed layer formed on Mo. And the film thickness of the Mo and Si mixed layer formed on Si is thinner than that of the Mo-Si layer formed on Mo.

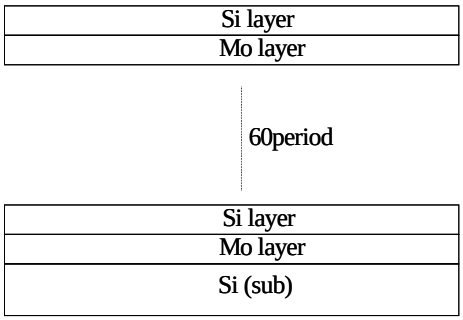

Fig.1 Mo/Si multilayer film

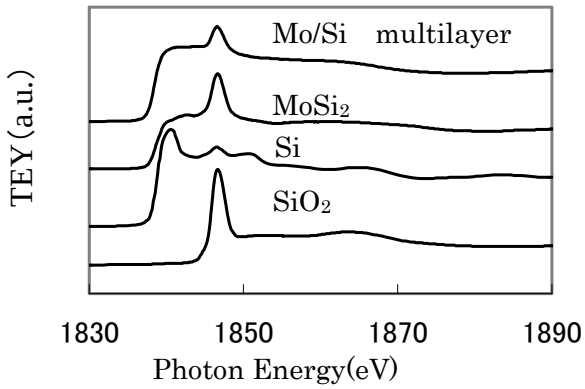

Fig.2 Si K-edge XAS spectrum

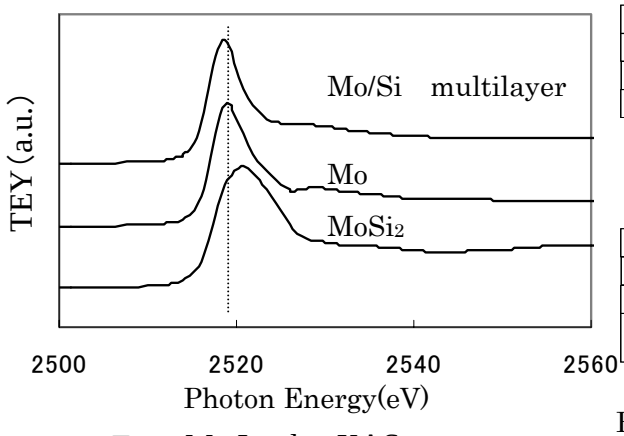

Fig.3 Mo L-edge XAS spectrum

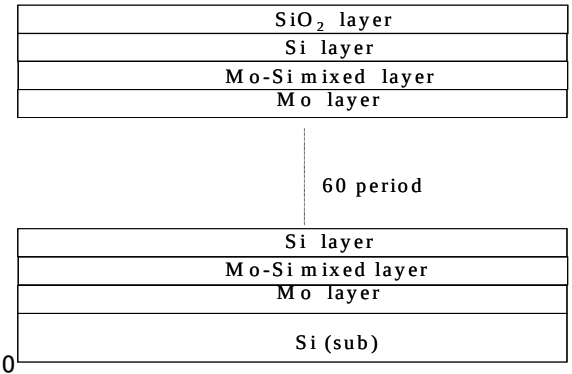

Fig.4 Model of Mo/Si multilayer film by XAS

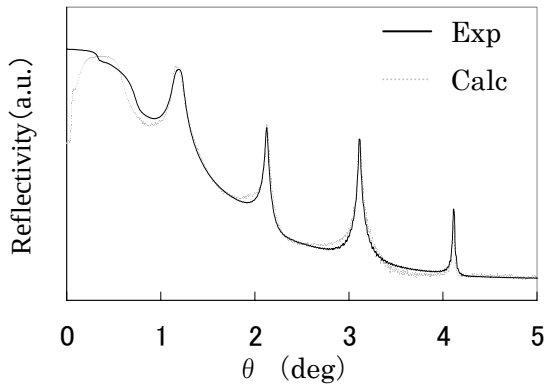

Fig.3 X-Ray reflectivity spectrum

Table.1 Results of Analysis

	density (g/cm3)	thickness(nm)	
SiO2	2.15	0.46	
Si	2.47	1.7	
MoSi2	4.37	1.59	60period
Mo	11.9	2.95	
MoSi2	6.42	0.76	
Si (sub)	2.33	∞	