Quantitative Evaluation of Transmission of X-ray Micrograph

K. Takemoto, K. Okuno, T. Okamoto**, M. Kubo*, and H. Kihara**

X-ray transmission depends on a composition element and its thickness of the specimen. When a highly collimated beam of monoenergetic photons passes through a medium of the thickness t, it suffers a decrease in intensity according to the relation

$$I = I_0 \exp(-\mu_M \rho \ t),$$

where μ_M is the mass absorption coefficient, and ρ is the density, I_0 is the incident beam intensity. In case of compound, $A_xB_yC_z$, the mass absorption coefficient is written as

$$\mu_M = \frac{\mu_A ax + \mu_B by + \mu_C cx}{ax + by + cz},$$

where each *a*, *b*, *c* is the atomic weight of its own. However, using a CCD camera system as a detector, it is impossible to perform quantitative evaluation of the X-ray transmission between several X-ray micrographs directly. Qualitative evaluation is only way to discuss between X-ray micrographs. However, the quantitative evaluation is quite attractive method for all specimens. In this report, we performed examination of a measuring method and an analyzing method in order to evaluate the transmission of X-ray micrographs quantitatively.

The experiment was conducted with the X-ray microscope beamline at BL-12. A sample is aluminum (Al) thin film (Nilaco). Using this Al thin film, three kinds of samples, a single Al film, a double Al film, and a two-stage thickness Al film that consisted of a single and double Al film, were prepared. Wavelength was 2.4nm and exposure time was 12 s.

Figure 1 shows an X-ray micrograph of a type (c) specimen. The micrograph consists of two contrast parts. We can see a clear interface between them.

Department of Physics, Kansai Medical University, 18-89 Uyamahigashi, Hirakata, Osaka, 573-1136, Japan

(*)SR Center, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga, 525-8577, Japan

(**)Department of Bioscience and Biotechnology, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga, 525-8577, Japan

The transmission calculation was carried out using such X-ray micrographs. At first, an X-ray transmission profile was evaluated at the distance to the left of 100 pixels. Similarly, an incident beam and background profiles were evaluated. Using these numerical data, each Al film transmission, T, is given by

$$T = (I - Bg)/(I_0 - Bg),$$

where Bg is the background. In addition, I and I_0 were corrected by the beam current. Calculation results presented in Fig. 2. As shown in Fig. 2, the transmission values of the single and double films show practically uniform values. If we assign the value of transmission of single Al film, then a corresponding value of the two-stage thickness Al film can be estimated. The experimental value coincides well with the estimated value. The theoretical transmission values were calculated by an interactive calculation tool at a web site of the Center for X-Ray Optics at Lawrence Berkeley National Laboratory [2]. Table 1 shows the theoretical transmission of the films at 2.4nm. A thickness was measured by HR-SEM. The thickness was slightly irregular and it was estimated to be 0.5 – 0.7 μm. In case of 0.5 μm thick Al film, the theoretical value is slightly larger than the experimental value. Inspection of Fig. 2 and Tab. 1 clearly demonstrate that it is possible to perform the quantitative evaluation of X-ray transmission based on an X-ray micrograph. The results of the analysis present a utility of this Al film as a standard sample. Especially, in case of a low transmission sample, it is possible to utilize for an incident beam correction as an attenuator.

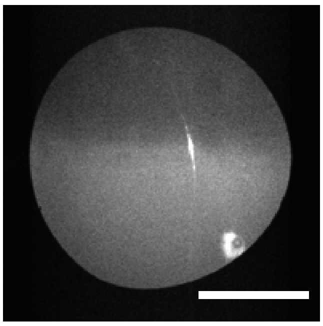

Fig. 1. X-ray micrograph of a two-stage thickness Al film. The scale bar is 5μm.

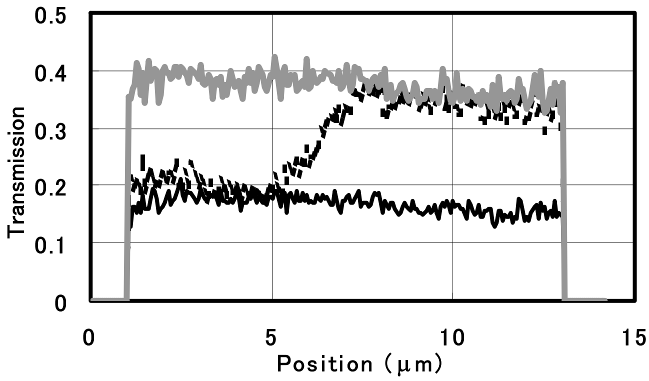

Fig. 2. Transmission of Al films. Solid gray line: single Al film, solid black line: double Al film, broken black line: two-stage thickness, a single and a double, Al film.

Table 1 Theoretical X-ray transmission.

	0.5μm	0.6 μm	0.7 μm
Single Al	0.39	0.32	0.27
Double Al	0.15	0.10	0.07

References

[1] http://www.cxro.lbl.gov/optical_constants/