Reflectivity Measurements of a Multilayer Mirror at 110 keV

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Introduction

For high energy x-rays (>100 keV), it is quite difficult to use conventional total reflection mirrors. This is because the critical angle for the total reflection mirrors becomes smaller as the energy of x-rays becomes higher.

As one of the substitutes for total reflection mirrors at high energy, single d-spacing multilayers have been investigated.[1] They can, in principle, give high reflec-tivity at a glancing angle giving the first interference maximum, which can be 3 times as far as the critical angle of the total reflection.

In this report we show the design and performance test of a single d-spacing multilayer for high energy x-rays.

Sample

A multilayer sample was designed so as to make the first interference maximum to be at a glancing angle of 2.2 mrad for 110 keV. The detailed design parameters are listed in Table 1.

Table 1: Parameters of the sample

Materials	W/B_4C
d-spacing	26(13+13)Å
Number of bi-layers	65+0.5
Substrate	Si(Single crystal)
Dimensions	$50\times25\times7$ mm^3
Roughness of substrate	2Å
Flatness of substrate	$\lambda/10$

For the future development of large scale multilay-ers, we took two-step fabrication (flipping method): first coat one-half of the substrate, flip the substrate end-over-end and coat the second half of the substrate. The tolerance of the d-spacing change was evaluated to be 0.2 Å (0.78%). The sample multilayer was deposited with RF-sputtering (OSMIC Co.).

Experimental

The reflectivity were measured at 110 keV at beam-line NE-5A of the TRISTAN Accumulation Ring (AR) in KEK. Figure 1 shows schematically the experimental set up. The X-ray beam was monochromatized by Si 333. Incident flux to the multilayer sample was 10^4 cps at a ring current of 30 mA. Reflectance was measured by scanning the sample and the detector in θ-2θ mode.

The origin of the glancing angle to the sample was determined from two dips appearing in the transmitted beam (Fig. 2). Neglecting the small shift by refraction, the origin should be the center of the two dips.

Result and discussion

Figure 3 shows the measured reflectivities as a function of the glancing angle. The solid curve shows the reflectivity at an irradiated area containing both flipped regions. Since the main peak has many satellite peaks, this multilayer has a good periodic structure. The
measured peak reflectivity was as high as 78 %.

The dashed and dotted curves are the reflectivities of the respective areas of two flipping process. The dif-ference of the d-spacing between the two areas calculated from the peak shift was 0.15 Å. This value represents the enough repeatability of the flipping method.

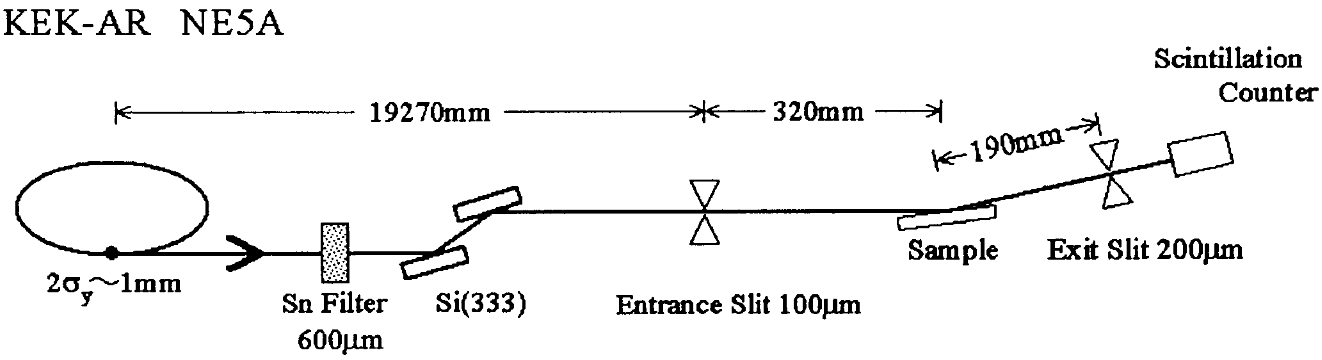

Figure 1: Schematic view of the reflectivity measurement system.

By estimating the d-spacing from peak angle, the layer numbers from the spacing of the satellite peaks, and the roughness of the Debye-Waller type from the peak reflectivity, we made a fit of the experimental curve (Fig. 4). This fit does not involve the angular and energy spread of the incident beam. We observed some discrep-ancy between fitted parameters shown in Fig. 4 and design parameters (Table 1).

To summarize, we observed as high as 78 % reflec-tivity at 110 keV for a single d-spacing multilayer. This is enough for the practical application as a beamline component, although the uniformity may become a prob-lem.

Reference

[1] P. Hoghoj, K. Joensen, F. E. Christensen, J. Susini, E. Ziegler, A. K. Freund, E. Luken, and C. Riekel., SPIE vol. 2011, 354 (1993)

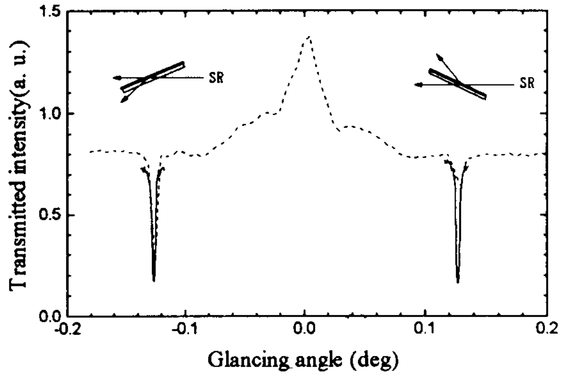

Figure 2: Transmitted intensity from the sample plotted as a function of the glancing angle. From the two dips, we accurately determined the origin of the sample rotation angle (θ =0).

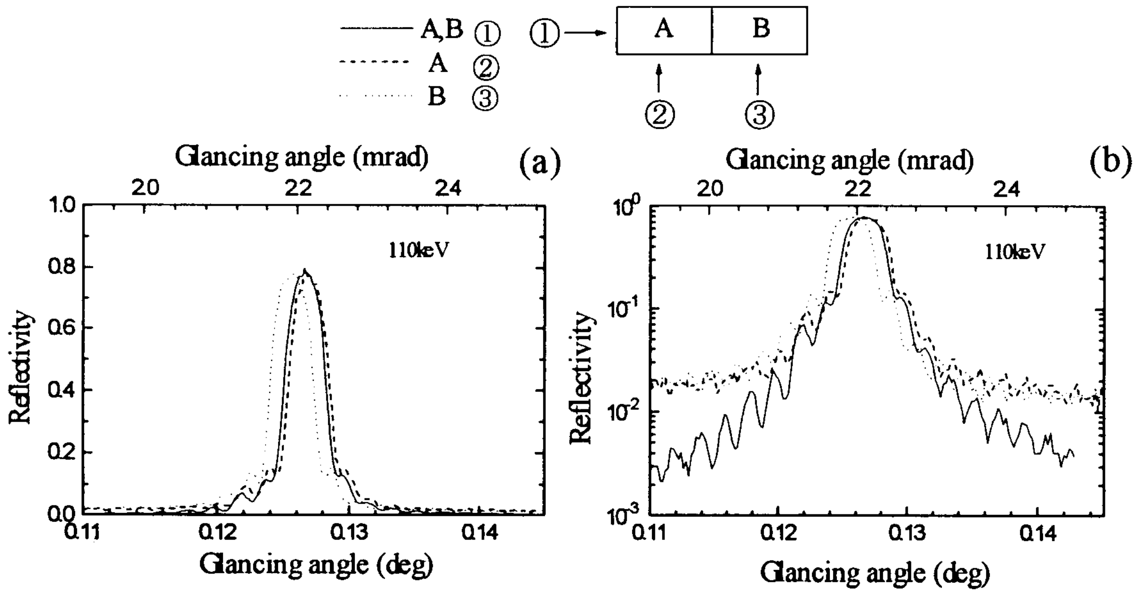

Figure 3a, 3b: Reflectivities of the sample as a function of the glancing angle in the linear scale (Fig. 3a) and in the logarithmic scale (Fig. 3b).

Figure 4: The result of the fitting. The solid line shows the measured data, and the dashed line shows the fitted calculation.