Investigation of In-plane Structures of Single d-Spacing Multilayers

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Introduction

Recent development in the technique of synthesizing multilayers made them available for optical elements in hard X-ray region [1]. Ideal multilayer reflectors have structural modulations only along the direction of the normal to the interfaces and exhibit only specular reflectance near the Bragg peaks. The structural inhomogeneities in the plane of the interfaces, however, yield a diffuse, non-specular scatterings [2,3,4,5,6].

We measured the non-specular diffuse scatterings through a two- dimentional scan changing the incident angle and the exit angle with a combination of ω and 2θ angles. In this way, we mapped out the intensity distribution around a Bragg peak. Using the Snell's law, we can transform the intensity distribution into a reciprocal space for evaluating the structural inhomogeneities normal to and in-plane of the interfaces (Kortright [5]).

Experimetal Setup

We here investigate a single d-spacing multilayer of W/B_4C (sample from OSMIC Co.[7]). Kimura, et al. [7] shows that this sample has the actual period of d = 26Å.

We measured the X-ray intensities on the BL 14B at Photon Factory in KEK. Monochromatic X-rays of 22 keV were obtained by the reflection from Si (1,1,1) plane. The distance between the source and sample was as large as 26 m. The horizontal divergence of the beam incident on the sample was 1.4×10^{-4}rad formed by the 20 mm slit in front. A 60 mm slit was set before the detector to limit the detectable angular divergence to 0.9×10^{-4} rad.

Result

The measured distribution of the scattered intensity in (ω-2θ) space is shown in Fig.1(a), and Fig.1(b) shows the transformed distribution in a reciprocal space by the Snell's law (Kortright [5]). Fig.1(b) apparently shows an elongated tail structure in the direction of k_x from the Bragg peak.

To simplify the analysis on the in-plane structure, investigate the property of the Bragg peak, we projected the elongated tail (including the main Bragg peak) along the k_z axis onto the k_x axis [see Fig.1(b)]. The resultant profile corresponds to the a rocking curve taken with a receiving slit opened.

In Fig.2, we plotted the profile with solid line. Dotted line shows a profile calculated for an ideal multilayer in the same optical system by the model described in [7]. In this figure, a sharp maximum and a nearly flat tail structure, weaker than the main Bragg peak by a factor of 10^3-2×10^3 , are observed.

Discussion

We investigated the distribution of the scattered intensity from a multi-layer reciprocal space, especially in-plane of the Bragg plane. The intensity appears as a superposition of two components, a sharp maximum and a diffuse scattering with their intersection at about $k_x=1\mu m^{-1}$.

The peak width of the sharp maximum is comparable to that of the ideal sample peak (corresponding to the detectable angular divergence of 0.9×10^{-4} rad). This indicates that angular scale of the in-plane inhomogeneities over μm scale (e.g. slope-error) is reletively small in this sample.

We also observed the diffuse tail intensity weaker than the main Bragg peak intensity by a factor of 10^3-2×10^3. We here suggest that this component is caused by either the in-plane inhomogeneities over sub-mm scale. These results do not contradict with the previous investigations by other authors ([5][6]).

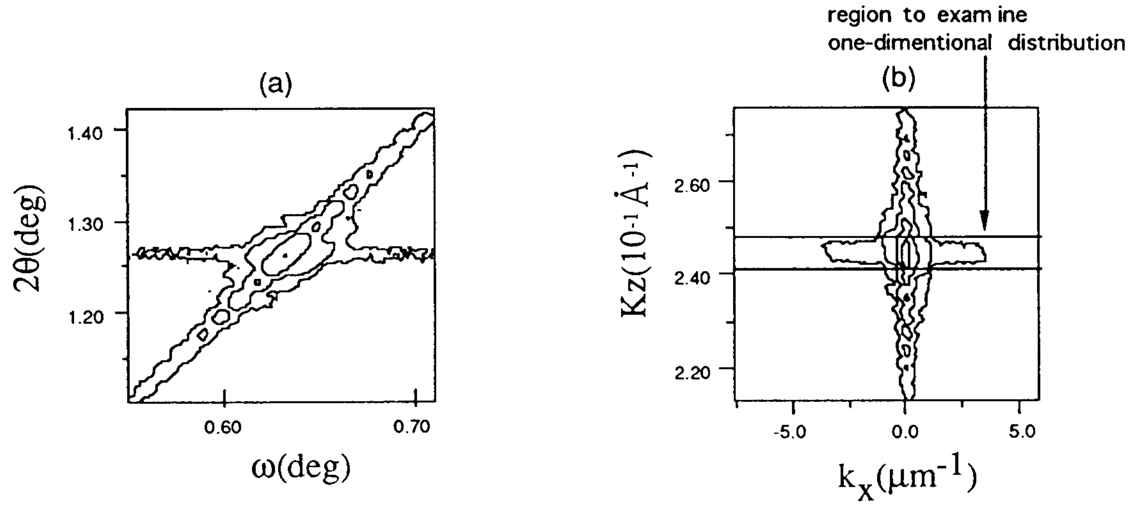

Fig.1 (a) Intensity distribution in (ω-2θ) space with the peak counts of 20000±140. The contours are plotted in a logarithmic scale. (b) the same intensity distribution represented in multi-layer reciprocal space.

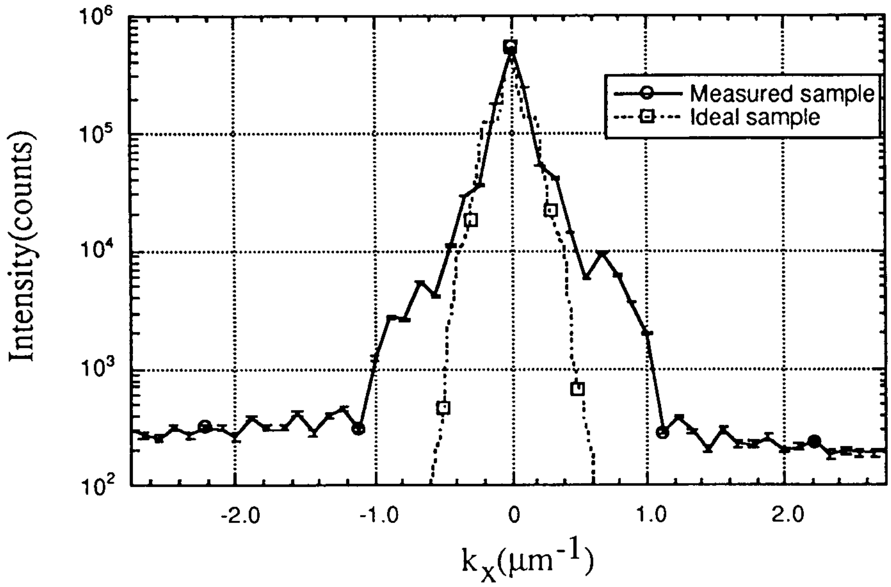

Fig.2 In-plane power spectrum from the multi-layer projected on the k_x axis.

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