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Quantitative investigation on density resolution in X-ray diffraction-enhanced imaging method

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Introduction

X-ray diffraction-enhanced imaging (DEI) method is a powerful method for observation of light materials [1]. The method has been successfully used, and is seeing excellent and rapid progress as a diagnostic tool in medicine and materials science [2]. However, almost all investigations thus far have been limited to qualitative observations. A few quantitative studies, such as the determination of activation energies of physical phenomena, have been reported [3]. In particular, there have been no previous reports about the ability to resolve differences in the refraction index, i.e., density differences. We have therefore designed and fabricated a standard test piece (phantom) for determining the density-change resolution of the DEI method, and used it to evaluate the density-change resolution of a DEI apparatus constructed in a precise X-ray diffraction station in KEK-PF.

Experimental

Design of phantom

The real part of the refractive index n is shown in

$$n(x,y) = 1-\delta(x,y) \qquad (1).$$

In homogeneously dense sample, given by

$$N(x) = \int_0^l \delta(x,y)dy = l\delta \qquad (2).$$

Here, l is thickness of the sample. We designed the phantom shown in Fig. 1. According to optical inspection, the angle of refraction $\Delta\theta$ is written as:

$$\Delta\theta = \frac{dN(x)}{dx} = \delta \tan\alpha \qquad (3),$$

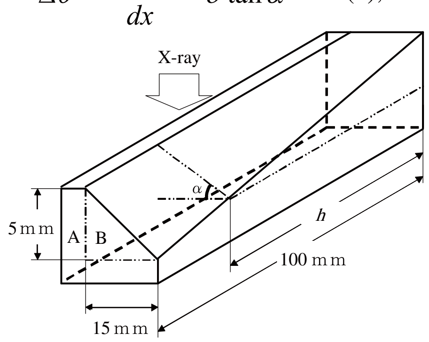

Fig. 1 External shape of the phantom (acrylic resin).

where α is an angle in Fig.1. Moreover, the relation of

$$\Delta\theta(h) = \frac{\delta}{100}h \qquad (4).$$

is approved from the shape of phantom. The incident X-ray beam on area B in Fig. 1 is refracted according to the inclined angle α. On the other hand, the incident X-ray beam on area A is not refracted. If the refracted angle is larger than the angular resolution, we can observe the contrast of the refracted beam after diffraction using an analyzer crystal.

Experimental procedure and results

The present investigations were performed at the vertical-wiggler beam line, BL-14B, at the Photon Factory. The X-ray energy was tuned to 30 keV. The analyzer was adjusted close to the symmetric 440-diffraction condition. Images were stored on an X-ray CCD camera (Photonic Science Inc., XFDI).

Fig. 2 shows the observed refraction image of the phantom at the high-angle side of analyzer. The boundary between areas A and B is clearly recognized at large angles of α (h = 20~45 mm).

Fig. 2 Diffraction-enhanced image of the phantom.

Discussion

From Fig.2, the minimum value of h, that the contrast can be observed between A and B was 13 mm. The density-change resolution of the DEI apparatus constructed in BL-14B at KEK-PF was thus determined to be $dN/dx = 3.8\times10^{-6}$.

References

[1] E. Foester, K. Goetz and P. Zaumseil, Krist. Tech. **15**, 937 (1989).
[2] J. Kirz, Q. Rev. Biophys., **28**,33 (1995).
[3] K. Mizuno, Y. Furuya, K. Hirano, and H. Okamoto, phys. stat. sol. (a) **204**, 2734 (2007).

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