14C1/2005G022

Sensitivity of X-ray phase imaging by Talbot interferometry

Atsushi MOMOSE*, Wataru YASHIRO, Yoshihiro TAKEDA
Graduate School of Frontier Sciences, Univ. Tokyo, Kashiwa, Chiba 277-8561, Japan

Introduction

We compared the sensitivity of X-ray phase imaging based on X-ray Talbot interferometry (XTI) [1] with the sensitivity of absorption-contrast method. It is known that the interaction cross-section of X-ray phase shift is about a thousand times larger than that of absorption for low-Z elements. High sensitivity corresponding to the difference is attained only by two-beam interferometry with a crystal X-ray interferometer. In the case of XTI, the advantage of X-ray phase imaging is more prominent when smaller structures are observed with smaller pixels.

Experimental

We performed a differential-phase imaging experiment with several polymer spheres in water. X-rays monochromatized at 25 keV were introduced into an X-ray Talbot interferometer, which consisted of a phase grating and an amplitude grating with a pitch of 5.3 µm. The sphere samples were located in front of the phase grating. X-ray images were acquired with a flat-panel sensor (Hamamatsu Photonics, C9727DK) whose pixel size was 50 µm.

Figures 1(a) and 1(c) show differential-phase images of polyoxymethylene (POM) and polypropylene (PP) in water, respectively. Corresponding absorption-contrast images are shown in Figs. 1(b) and 1(d).

Discussion

The sensitivities of XTI and the absorption-contrast method are compared under the common X-ray flux. Assuming the detection of a spherical material with a diameter a and a refractive index $1-\delta_c+i\beta_c$ in a surrounding medium with a refractive index $1-\delta_m+i\beta_m$, we found a criterion:

$$|\Delta\delta| = \frac{\sqrt{c_0}\sqrt{aD}}{\sqrt{2}\,pdc_1}|\Delta\beta|, \qquad (1)$$

where $\Delta\delta = \delta_c-\delta_m$ and $\Delta\beta = \beta_c-\beta_m$. D is the pixel size of the image detector and d is the pitch of the gratings. p is a half integer when a $\pi/2$ phase grating is employed, and in this experiment $p = 0.5$. c_0 and c_1 are the Fourier coefficients of moiré fringes generated by the Talbot interferometer.

When the coefficient in eq. (1) is smaller, XTI is effective for wider range of materials. Note that the advantage of X-ray phase imaging based on XTI is more prominent when smaller structures are observed with smaller pixels.

Figure 2 shows plots of $\Delta\delta$ versus $\Delta\beta$ for various polymer spheres in water and air with criterion lines calculated using eq. (1). The points of POM/water and POM/air are located in the region above the criterion lines. Therefore, the observation of POM is expected to be easier by XTI than by the absorption-contrast method. Actually, Fig. 1(a) depicts structures more clearly than Fig. 1(b) particularly for small features in voids. As for PP, the point of PP/air is located above the criterion lines while the point of PP/water is between the criterion lines of a = 1 mm and 10 mm. Actually, the boundary between PP and water is clearer in Fig. 1(d) than Fig. 1(c) while the images of voids are clear in both images.

Thus, the usage of XTI is for instance as follows: larger structures is depicted by the absorption contrast, which can also be obtained from the data set measured by XTI, and inside smaller structures can be depicted simultaneously with a help of the differential phase contrast.

This study was financially supported by Japan Science and Technology Agency (JST).

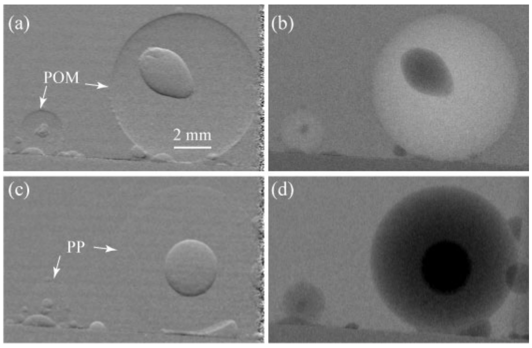

Fig. 1 (a, c) Differential-phase images obtained by XTI for PP and POM spheres with voids inside, and (b,d) corresponding absorption-contrast images. The spheres were observed in water.

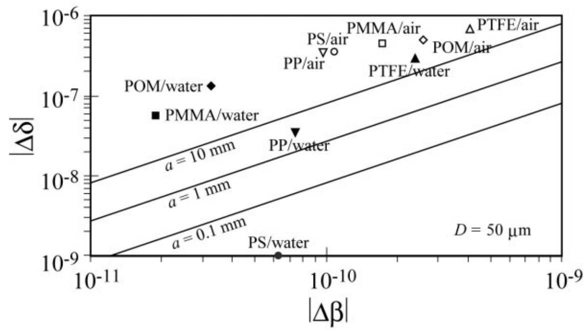

Fig. 2 Plots of $\Delta\delta$ versus $\Delta\beta$ for various polymer spheres in water and air with criterion lines.

References

[1] A. Momose et al., Jpn. J. Appl. Phys. 42, L866 (2003).

* momose@mml.k.u-tokyo.ac.jp