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High-speed X-ray phase imaging with white SR and Talbot interferometer

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Introduction

X-ray Talbot interferometry[1] using transmission gratings has attracted increasing attention as a novel method for X-ray phase imaging. One advantage of this method is that it functions with a broad X-ray energy bandwidth. Therefore, extremely high-speed X-ray phase imaging is possible when white synchrotron radiation is used. This approach would advance X-ray phase imaging/tomography from a static observation method to a dynamic one.

Experimental

An X-ray Talbot interferometer under our configuration described below functions with a bandwidth of $\Delta E/E$ < 1/8 according to the Rayleigh's $\lambda/4$ rule. Even a broader bandwidth is available although moiré fringe visibility is degraded to some extent. For example, the X-ray Talbot interferometer functions with a W-target X-ray generator.

An X-ray Talbot interferometer consisted of a phase grating and an amplitude grating, which were aligned on the optical axis. The pitch of the gratings was 5.3 µm, and the separation between the gratings was set to 331 mm, which were optimal for 25 keV X-rays. An X-ray image detector, which consisted of a GOS (P46) phosphor screen, coupling lenses, and a CMOS camera, was placed behind the amplitude grating. The CMOS camera was operated with a frame rate of 500 f/s, and the exposure time per frame was 1 ms (1 ms blank between frames). The effective pixel size was 12.7 µm.

In order to obtain a differential phase image, the fringe scanning method is usually used. However, this method requires several images to produce a differential phase image, and therefore does not match with the present purpose. We adopted the Fourier transform method, which generates a differential phase image from a single moiré image with carrier fringes through the processes of Fourier filtering and argument extraction. Rotation moiré fringes were generated as the carrier fringes by inclining the grating about the optical axis. A sample, which was placed in front of the phase grating, was rotated continuously with a speed of 1 rps, and each frame was processed with the Fourier transform method. A phase tomogram was reconstructed from frames for 0.5 s.

Figure 1 shows an X-ray phase tomogram of a polystyrene (PS)/poly(methyl methacrylate) (PMMA) polymer blend, in which a bi-continuous phase separation structure is successfully revealed. This sample has ever been observed by X-ray phase tomography with monochromatic X-rays, and the scan time was several hours. Although the spatial resolution and image quality are better when monochromatic X-rays are used, the scan time has been shortened by a factor of 10^4.

Discussion

The presented result implies not only that the scan time is shorten extremely but also that dynamic observation of weakly absorbing object becomes possible in X-ray phase imaging and furthermore in X-ray phase tomography. We have already tried four-dimensional X-ray phase tomography measurements with some samples, such as polymer materials suffering radiation damage and living small worms. Four-dimensional X-ray phase tomography requires several Gbyte storage and massive calculation for image reconstruction, and the full analyses of the data will be disclosed elsewhere.

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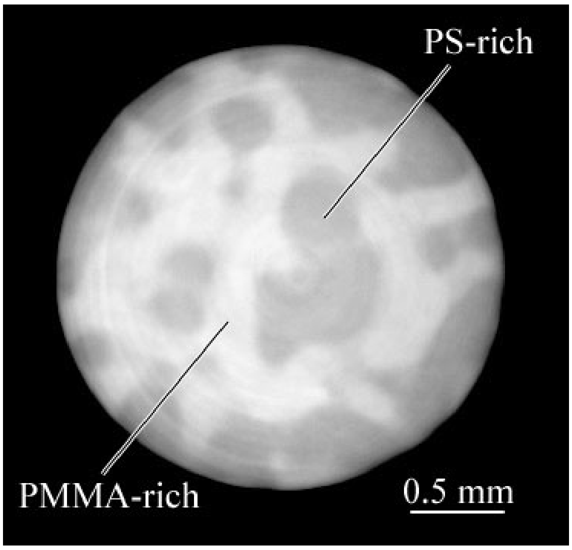

Fig. 1 X-ray phase tomogram of a PS/PMMA blend with a phase-separation structure. The total scan time was only 0.5 s.

References

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

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