Phase-contrast hard X-ray microscope with a zone plate

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Introduction

In x-ray region, phase-contrast is much higher than absorption contrast especially for a specimen that consists of light elements, such as biological specimens. Phase-contrast imaging offers observation methods of a specimen that is almost transparent for X-rays. We have been developing a Zernike-type phase-contrast x-ray microscope with a zone plate and a phase plate [1] [2]. Recently, the resolution of the objective zone plate was improved. The present status of the microscope is reported.

Experimental

Figure 1 shows the optical system. X-rays from the bending magnet source were monochromatized with a Si (111) double crystal monochromator. Parallel monochromatic x-rays at 9keV were incident on a specimen. The x-ray image was focused on a detector by a zone plate. The specifications of the zone plate were the followings; (diameter: 155µm, the outermost zone width: 0.1µm, pattern thickness: Ta 1µm, substrate: SiN 2.2µm, focal length at 9keV: 113mm). The magnification ratio was about 19. A CCD camera (Hamamatsu C4880, CCD: Texas Instruments TC-215, pixel size: 12 µm) and nuclear emulsion plates (Fuji EM G-OC 15) were used as a detector.

A phase plate was placed at the back focal plane of the zone plate. Two types of phase plates were tested. One was an aluminum phase plate of 5µm thickness, the center of which was a 12µmϕ pinhole. The phase shift is calculated to be a quarter wavelength for scattering x-rays from a specimen. Figure 2(a) is a bright field image of polystyrene latex beads (diameter: 2.8µm) without the phase plate, and Fig.2(b) is a phase-contrast image with the phase plate.

Another phase plate was a gold wire of 10µm diameter embedded in epoxy resin (Quetol 651). The slice of 7 µm thickness was cut down and used as a phase plate. The phase shift and the transmittance of 7 µm-thick gold is 1.9 λ and 13 %, respectively. The phase shift of the epoxy resin is 0.16λ, which is estimated from Quetol 651 monomer. Then, non-scattering x-rays from a specimen are advanced by approximately one and three quarter wavelength in phase. Figure 3 shows images of a tantalum test pattern. The specifications of the test pattern were the followings; (pitch 0.1~ 0.4µm, pattern thickness: Ta 0.5µm, substrate: 2.0µm SiN). The images were recorded on nuclear emulsion plates and displayed as photographic negative. Figure 3(a) is the bright field image without the phase plate and Fig. 3(b) is the phase-contrast image with the phase plate. Much better contrast could be obtained in the phase-contrast image. The horizontal 0.1 µm line and space pattern could be observed in Fig. 2(b).

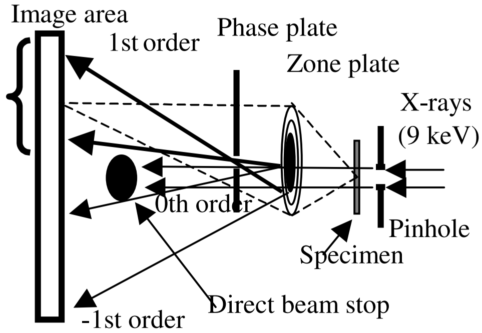
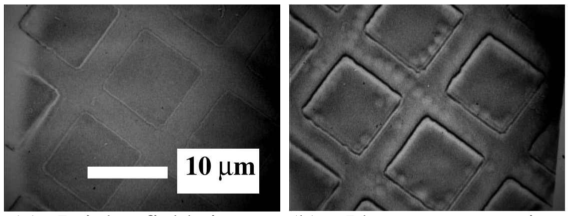
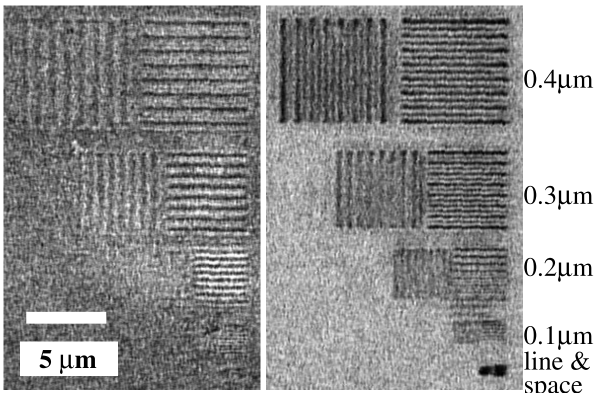


Figure 1: The optical system of the microscope.



(a) Bright field image. Exposure: 360 s. (b) Phase-contrast image. Exposure: 360 s.

Figure 2: X-ray images of the polystyrene latex beads



(a) Bright field image. Exposure: 60 s. (b) Phase-contrast image. Exposure: 240 s.

Figure 3: X-ray images of the tantalum test pattern

References

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