Phase-Contrast X-Ray Microscope with a Zone Plate

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Introduction

A Phase-contrast hard x-ray microscope makes it possible to observe a thick specimen that consists of light elements with high resolution, because phase contrast is much higher than absorption contrast in hard x-ray region. We have been developing a Zernike-type phase-contrast microscope. At first, a phase-contrast microscope with a Wolter mirror was developed, however, the only one-dimensional phase-contrast image could be imaged because of the figure error of the mirror [1]. As a next step, a zone plate was tested as an objective.

Experiment and results

The optical system is shown in Fig.1. Parallel monochromatic x-rays at 9keV were incident on a specimen through a pinhole of 100 μm in diameter. Transmitted x-rays through a specimen were focused on a detector by a zone plate. The zone plate was set off the optical axis to prevent –1 and 0 order x-rays from reaching the image area. The specifications of the zone plate were the followings; (diameter: 100 μm , the outermost zone width: 0.25 μm , pattern thickness: Ta 1 μm , substrate: SiN 2.4 μm , focal length at 9keV: 180mm). The magnification ratio was 9.8. An Au wire was used as a direct beam stop. A CCD camera (Hamamatsu , C4880, TC-215) and nuclear emulsion plates (Fuji EM G-OC 15) were used as a detector.

Figure 2 shows an image of a test pattern recorded by a nuclear emulsion plate. The specifications of the test pattern were the followings; (pitch 0.1~5 μm , pattern thickness: Ta 0.5 μm , substrate: 2.0 μm SiN). The microscope could focus a Ta line pattern of 0.3 μm (vertical) and 0.4 μm (horizontal) in width.

An Al foil of 5 μm thick with a pinhole of 10 μm in diameter was used as a phase plate for a phase-contrast microscope. The phase shift was 0.24 wavelength for transmitted x-rays through the phase plate. The Al pinhole was placed at the focused point of illuminating x-rays to obtain a phase-contrast image. Figure 3(a) is a bright field image of polypropylene fibres without the phase plate, and Fig. 3(b) is a phase-contrast image with the phase plate. These images were recorded by the CCD camera. The contrast of Fig. 3(b) is much higher than that of Fig.3(a). Several biological specimen could be observed by the phase-contrast microscope.

Next we tried to observe a wet specimen as shown in Fig.4. The specimen was sandwiched between two quartz glasses of 30 μm in thickness. Figure 5(a) is a bright field image of polystyrene latex beads (diameter: 2.8 μm) without the phase plate, and Fig. 5(b) is a phase-contrast image with the phase plate. These image were recorded by the nuclear emulsion plates.

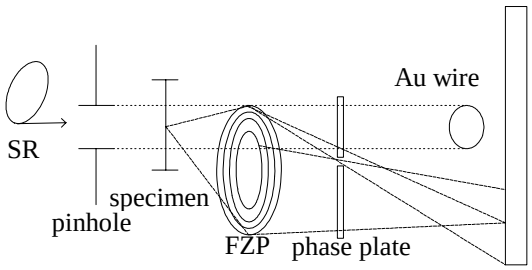

Fig. 1 Experimental set-up

Fig. 2 The image of test pattern

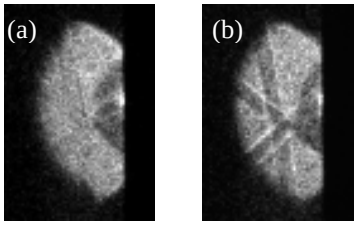

Fig. 3 The image of polypropyrene fibres (a) bright field (b) phase contrast

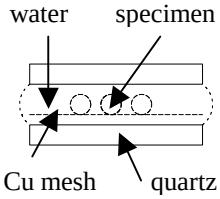

Fig. 4 Schematic diagram of the wet specimen

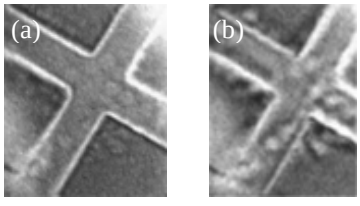

Fig. 5 The image of polystyrene latex beads (a) bright field (b) phase contrast

Acknowledgements

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References

[1] N. Watanabe, et al., in “X-Ray Microscopy”, eds. W. Meyer-Ilse, T. Warwick, and D. Attwood, AIP Conference Proceedings 507, p.84 (2000).

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