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Fresnel Diffraction Correction of Blurred image by Phase-considered Iteration Procedure in Soft X-ray Projection CT Microscopy

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Introduction

Soft X-ray gives a good contrast for wet specimens (living cell) because soft X-ray is in the spectral region of "Water-window". A projection microscope has a characteristic point to zoom in a specimen easily, while the specimen should be placed close to the light source that is located at the position of a pinhole with a diameter of 1-5μmϕ when the microscope raises its magnification. Therefore, the authors have exercised the ingenuity to hold and rotate a specimen close to the pinhole. The projection CT microscope has the advantage of the wide viewing area, while the diffraction effect cannot be negligible, resulting in a decrease of the image resolution. To obtain images with high-resolution, image processing is essential to eliminate the effect.

In this study, the images were corrected by an iteration procedure of Fresnel – inverse Fresnel transformation taking phase distribution of the specimen into account with the developed projection CT microscope.

Correction of blurred projection image

The experimental setup is shown in Fig.1[1]. Monochromatic soft X-rays were used at the wavelengths of 15 - 25 angstrom (0.83 - 0.50 keV in energy). The lateral magnification of the microscope was fixed at x107. An X-ray CCD camera was a back-illuminated type of 512x512 pixels (24.8μm/pixel). Its field of view became 114μm square at the magnification. The specimen, the rotation stage, and the imaging area of the CCD camera were in vacuum. The sample holder, which is attached on a center shaft of a rotating stage, was refined in its feature. The glass capillary with the diameter of 5-10 μm could be fixed and rotated in the view area of CCD. The authors improved the iteration procedure to correct the blur of the obtained projection image by considering the phase distribution of the specimen

In the burred image of a HeLa cell (Fig.2a), there were bright fringes around the cell and white spots in the cell. They are due to the influence of the Fresnel diffraction. In the corrected image (Fig.2b), they were thoroughly taken out. Figure 3 shows the images of a tapered hollow glass capillary. The apex was less than ϕ1μm. The several Fresnel fringes appeared around the capillary in the burred image of Fig.3a. In view of the pixel-size of the CCD detector and the microscope magnification, the physical resolution was estimated to be about 0.2μm. The thickness of the glass capillary was about ϕ0.5μm. The hollow structure was reproduced in the corrected image of Fig.3b. As a result, it was confirmed that the correction was adequate.

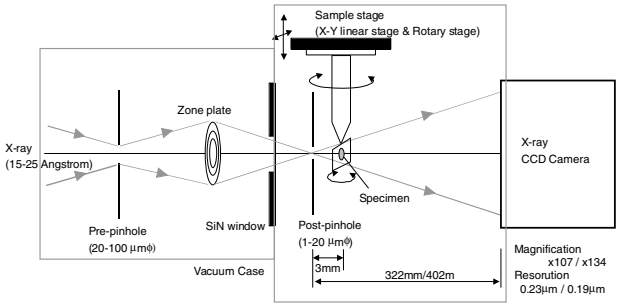
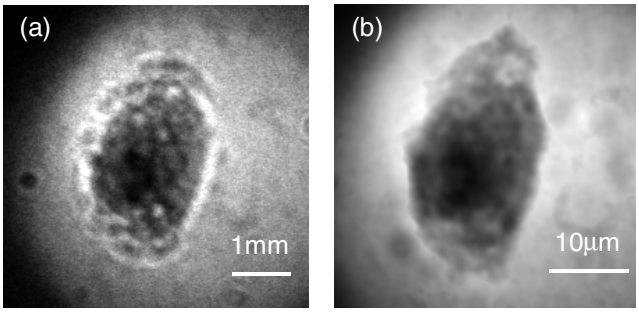
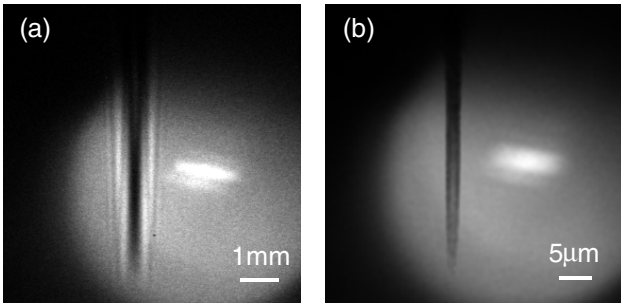


Fig.1 Soft X-ray projection CT microscope.



(a) Projection Image (b) Blur corrected image

Fig.2 Image processing with Fourier transformed iteration process (image of a HeLa cell on mylar film).



(a) Projection Image (b) Blur corrected image

Fig.3 Hollow glass capillary.

References

[1] T. Shiina et al., IMC16, p.1039, 2006

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