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Phase Tomography of Biological Samples by Using an X-ray Microscope with a Foucault Knife-Edge Scanning Filter

Norio Watanabe*, Yuji Tsuburaya, Akihiro Shimada and Sadao Aoki
University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan

1 Introduction

X-ray phase tomography is very attractive for the observation of weakly absorbing material, such as biological samples because phase-contrast is much higher than absorption contrast. In order to realize phase tomography, quantitative phase measurement is required. We have been developing a differential phase-contrast microscope with a Foucault knife-edge scanning filter. Introducing a scanning knife-edge filter at a back focal plane of an objective zone plate, a fairly quantitative phase image could be obtained [1, 2]. Then, phase tomography has become possible by using this microscope. 3D phase images of several biological samples could be observed with good contrast.

2 Experiment

The optical system is shown in Fig. 1. An objective zone plate (NTT Advanced Technology Inc.) had the outermost zone width of 50 nm and the diameter of 330 μm. Monochromatic parallel x-rays of 5.4 keV were used. The magnification ratio was 48. A gold wire of 250 μm in diameter was used as a knife-edge. The edge was scanned ±5 μm around the back focal point of the zone plate. A differential phase image was derived from the two images obtained by scanning the edge in the opposite directions to each other [1]. Exposure time of each image was 4 s. A 3D phase image was reconstructed from 360 projection images of different angles of view over the range of 360 degrees.

3 Results and Discussion

Figure 2 shows x-ray phase images of a human hair. Figure 2(a) is the differential phase image and Fig. 2(b) is the section image of the reconstructed phase. The cortex and medulla of the hair could be clearly observed. Figure 2(c) is the volume rendering of the phase image. Figure 3 shows images of a pollen of morning glory.

By replacing the knife edge with a Zernike phase plate, this differential phase microscope can be easily converted to a Zernike phase-contrast microscope. The Zernike phase-contrast microscope has slightly better contrast than this microscope. But it is not suitable for phase tomography because it cannot measure phase quantitatively. These results show that this differential phase microscope with the scanning filter is very suitable for phase tomography of microscopic samples.

* watanabe@bk.tsukuba.ac.jp

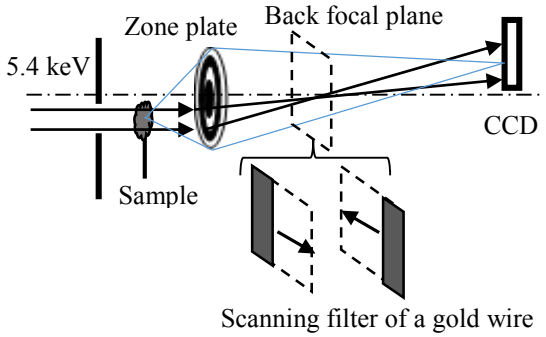

Fig. 1: Microscope system. A differential phase image was obtained by placing a scanning filter of a gold wire at the back focal plane of a zone plate.

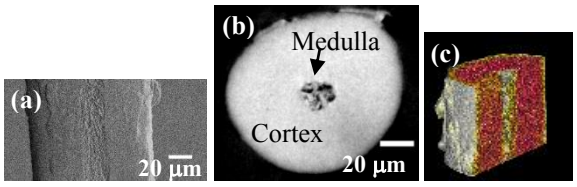

Fig. 2: (a) Differential phase image of a human hair. (b) The section image of the reconstructed phase. (c) The volume rendering phase image.

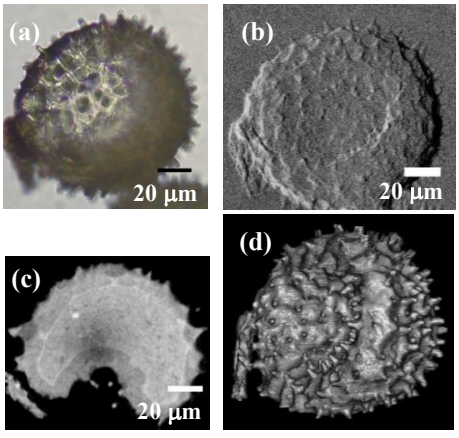

Fig. 3: Images of a pollen of morning glory. (a) Visible light image. (b) The x-ray differential phase image. (c) The section image of the reconstructed phase. (d) The volume rendering phase image.

References

[1] N. Watanabe et al., J. Phys.: Conf. Ser. 463 (2013) 012011.
[2] N. Watanabe, X-ray Imaging Optics (Japanese), 39 (2014) 1.