X-ray analyzer-based phase-contrast computed laminography

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Introduction

In x-ray imaging, volume reconstruction is usually carried out by computed tomography (CT). There are, however, several problems with the standard CT methods. The first problem is that the sample size must be smaller than the field of view (FOV) of the detector and beam size, which is generally a few centimeters when using synchrotron radiation (SR). This limitation has hindered the application of SR-CT to large samples. The second problem is that the thickness of the sample must be small enough for measuring the intensity of transmitted x-rays with sufficient accuracy. To mitigate these problems, synchrotron-radiation computed laminography (SR-CL) was developed by adopting the principles of tomosynthesis. While the standard CT methods are characterized by tomographic rotation around an axis perpendicular to the beam path, SR-CL is characterized by the more general geometry of an inclined rotation axis. Thanks to this generalized geometry, SR-CL is applicable to a wider variety of samples compared to SR-CT. For example, SR-CL is especially effective for observing regions of interest (ROIs) in laterally extended samples such as flip-chip bonded devices, leaves and thin organic objects.

Since its development, SR-CL has been applied to phase-contrast imaging based on propagation and grating interferometry. Recently it was shown that analyzer-based phase-contrast imaging provides a better sensitivity than these techniques. Therefore, we have introduced the SR-CL to analyzer-based phase-contrast imaging for observing ROIs in laterally extended flat samples of weak absorption contrast. [1)]

Optical Setup

To verify the feasibility of x-ray analyzer-based phase-contrast computed laminography, we performed experiments at the vertical-wiggler beamline BL-14B of the Photon Factory.

The optics consisted of an asymmetrically cut first crystal (collimator) and a symmetrically cut second crystal (analyzer) arranged in a nondispersive (+, −) diffraction geometry. The incident monochromatic x-ray beam was collimated and expanded by the first crystal and propagated through the sample. The refraction caused by the sample was analyzed by the second crystal. The beam diffracted by the second crystal was observed by an x-ray area detector.

The rotation-axis (ϕ-axis) of the sample was tilted at angle α with respect to the vertical direction (Fig. 1). In the experiments, we fixed the α angle at 30°.

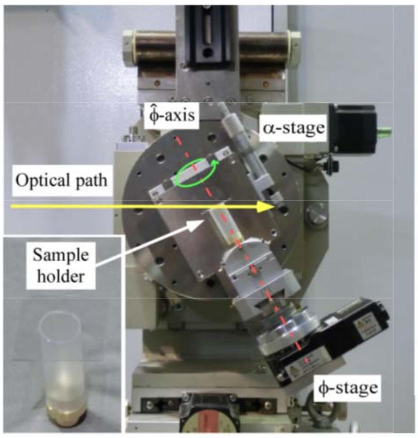

Fig. 1 Photograph around the sample. The α -axis was in the horizontal plane and was perpendicular to the optical path. The ϕ-stage was mounted on the α-stage so that the ϕ-axis would always become perpendicular to the α-axis, and perpendicular to the optical path at α = 0°. The lower-left inset is a photograph of the sample holder.

Results

As the sample, we used a nylon mesh. The period of the mesh was about 1 mm. From the set of obtained refraction maps, we calculated the phase-contrast sectional image of the sample as shown in Fig. 2. This result shows that both of our optics and algorithm work well. In this image, a strong circular artifact is also observed. This artifact originates from the joint of the sample holder. Due to this artifact, the FOV was limited to about 6 mm in diameter. Clear phase-contrast sectional images can be obtained as long as the ROI is located inside this FOV. We will be able to expand the FOV by replacing the polypropylene tube of the sample holder with a larger one.

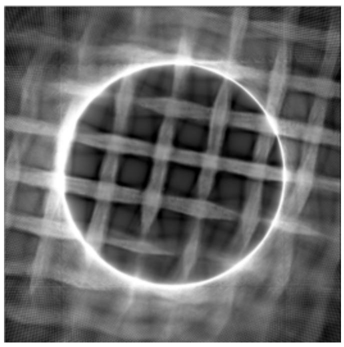

Fig. 2 Reconstructed phase-contrast and absorption-contrast sectional images of the nylon mesh. The size of the image is 8.9 mm (H) × 8.9 mm (V).

Summary

We have developed x-ray analyzer-based phase-contrast computed laminography for imaging ROIs in laterally expanded flat specimens of weak absorption contrast. In the experiments performed at the vertical-wiggler beamline BL-14B of the Photon Factory, we successfully obtained phase-contrast and absorption-contrast sectional images of the nylon mesh at the wavelength of 0.0733 nm.

References

1) K. Hirano, Y. Takahashi, K. Hyodo and M. Kimura: J. Synchrotron Rad. **23**, doi:10.1107/S1600577516014831.

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