Resolving Power of a Zone Plate Monochromator of Soft X-ray Microscope at BL-12

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At BL12, soft X-ray microscope beam line, a condenser zone plate (CZP) is used as a dispersing element of monochromator in which the spectrum is scanned by means of a linear axial displacement. It is considered for use as a wavelength-encoded linear displacement transducer and is shown to be both effective and simple to construct. When ZP is used as an optical element of the monochromator, the first-order focal length *f*, can also be written as $f = r_1^2 / \lambda$, where r_1 is the first radius of ZP, and is the wavelength [1–3]. Thus, the observed wavelength is determined by the focal length.

In 2004, an automated CZP positioning system was introduced [4]. Now, it is used for daily observation and shows good performance. Many good images were obtained. However, since the ZP was put on the position, which was calculated geometrically, an accurate wavelength/energy estimation was required when an image was taken at different wavelengths

The accurate wavelength estimation was carried out using an X-ray micrograph. Since this microscope put a specimen stage under atmospheric pressure, the air path was used as a sample. The estimated wavelength region was 2.1－3.3 nm, since X-ray absorption edges of oxygen and nitrogen are included. The X-ray micrographs were taken at each 0.015 nm step in the region. Figs. 1 show X-ray micrographs of viewing fields at several wavelengths. The contrast depends on X-ray transmission rate at each wavelength. The 2.4 nm illumination provides as a homogenous and bright distribution of illumination across the viewing field. The X-ray transmission value was numerated in the homogenous illuminated area, which was cut out from the micrograph. The value was normalized by a beam current.

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Experimental results are presented by white circles in Fig.2. The theoretical transmission profile (solid line) was calculated by an interactive calculation tool at a web site [5]. The absorption at 2.3 nm is oxygen absorption edge and at 3.1 nm is nitrogen absorption edge. As shown in Fig. 2, the experimental transmission profile has 2 absorption edges. In comparison with the theoretical profile, the experimental value is in good agreement with it. CCD gate structure contains layers of silicon dioxide to isolate the gates from the substrate as well as to separate different clocks from each other. This implies a complicated X-ray response at energies close to the oxygen K_α absorption edge [6]. More detailed quantitative analysis shows that oxygen line consists of the wider line at 2.36 nm and a sharper component at 2.35 nm [6]. Though it is impossible to distinguish them, a sharpness of oxygen absorption edge, 0.024 nm, is experimentally estimated as 0.03 nm. The value is twice larger than that of the resolution power of the optical configuration, $\lambda/\Delta\lambda$=160. The results present that the ZP based optical system shows good performance, expecting from a design.

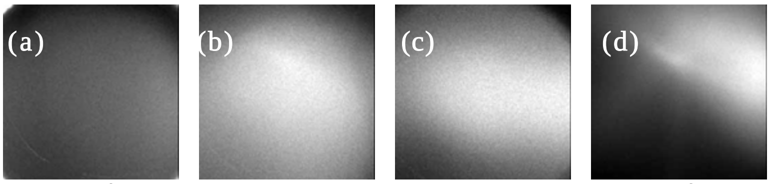

Fig.1. X-ray micrographs of viewing fields. (a)2.1 nm, (b)2. 4nm, (c)2.8 nm, (d)3.3 nm. Exposure time was 60 s.

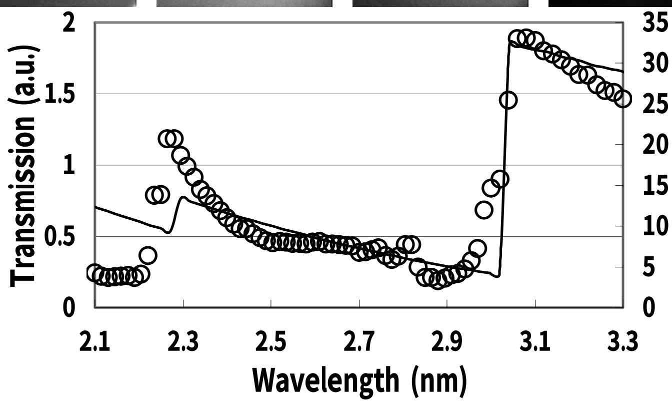

Fig. 2 The transmission ratios of x-rays for the air path. White circle: experimental data. Solid line: theoretical transmission profile.

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