

## **Design of phase plate for high contrast imaging in phase plate scanning transmission electron microscopy**

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We have been developing electron microscopy which can visualize biological materials composed of light elements. An optical condition for phase plate scanning transmission microscopy (P-STEM) was constructed and contrast enhancement of the nanomaterials were succeeded. We use a Zernike phase plate and it provides a phase shift to scattered waves. There is a hole at a center of the phase plate and a diameter of the hole corresponds to a cut-on frequency above which the phase shift is provided to the scattering electron waves. Smaller hole is desirable to enhance the phase contrast of the STEM image. A detector angle has to be adjusted to match a cut-on frequency or a cut-on angle. Thus, the smaller hole of the phase plate reduces the detection angle and the electron intensity.

Thickness of the phase plate is also important for high contrast imaging. Phase plate provides  $\pi/2$  phase shift modifies sine-type phase contrast transfer function to the cosine type. This should be ideal for contrast enhancement. However, thick film reduces the intensity or information of the scattering waves. Thus, the thinner phase plate may be effective for contrast enhancement. In the present paper design of the phase plate for high contrast imaging in P-STEM is discussed and effects of the phase plate whose corresponding phase shift is  $0.5\pi$ ,  $0.4\pi$  and  $0.3\pi$  are compared.