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Phase Plate STEM Imaging Using Two Dimensional Electron Detector

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Phase plate (PP) in Scanning Transmission Electron Microscopy (STEM) can modify phase contrast transfer function from sine type to cosine type to enhance phase contrast of biological molecules composed of light elements [1]. In phase plate STEM (P-STEM), we used a carbon PP with a center hole (Zernike PP). A mean inner potential of the film material provide a phase shift to the incident electron wave. We adjust the thickness of the carbon film to provide a half π phase shift to the electron wave with energy of 200KeV. Since we have to use the unscattered electron wave without phase shift and the scattered waves with phase shift to obtain higher contrast image in P-STEM, a detection aperture to choose electron waves with an appropriate optical condition should be used just above the detector. The electron waves with the appropriate P-STEM condition lands in the circle region indicated with "Out of plane" in Fig. 1.

In order to reconstruct the phase distribution of the phase objects, smaller hole is better because structural information with lower spatial frequency can be enhanced. This is one of the weakest points in conventional bright field (BF) TEM and STEM. However, the reconstruction of phase distribution using the PP with smaller hole requires smaller detector or smaller detection aperture to match the hole size of the PP as in Fig. 1. Using the PP with smaller hole reduces the total signals and this is undesirable to visualize beam sensitive samples. Recently, a two dimensional (2D) detector has been used in STEM imaging to reconstruct phase distribution [3]. STEM imaging using combination of a 2D detector and a pre-specimen PP was also reported [4]. In the present paper we applied the 2D detector to our Zernike type PP.

Figure 2 shows the comparison of the STEM images of InP/ZnS core shell quantum dots. JEM-2100F with P-STEM PP was used in the present study. The PTEM (Fig. 2(b)) provides higher contrast than conventional BF-STEM (Fig. 2(a)). Moreover, the P-STEM image with 2D detector (Fig. 2(c)) is clearer than the P-STEM image with conventional STEM detector (Fig. 2(b)). This shows that the 2D detector can be applicable to our Zernike type phase plate. Comparison of the power spectra also shows higher phase contrast transfer at low spatial frequency in P-STEM with 2D detector. Details results will be introduced in the presentation.

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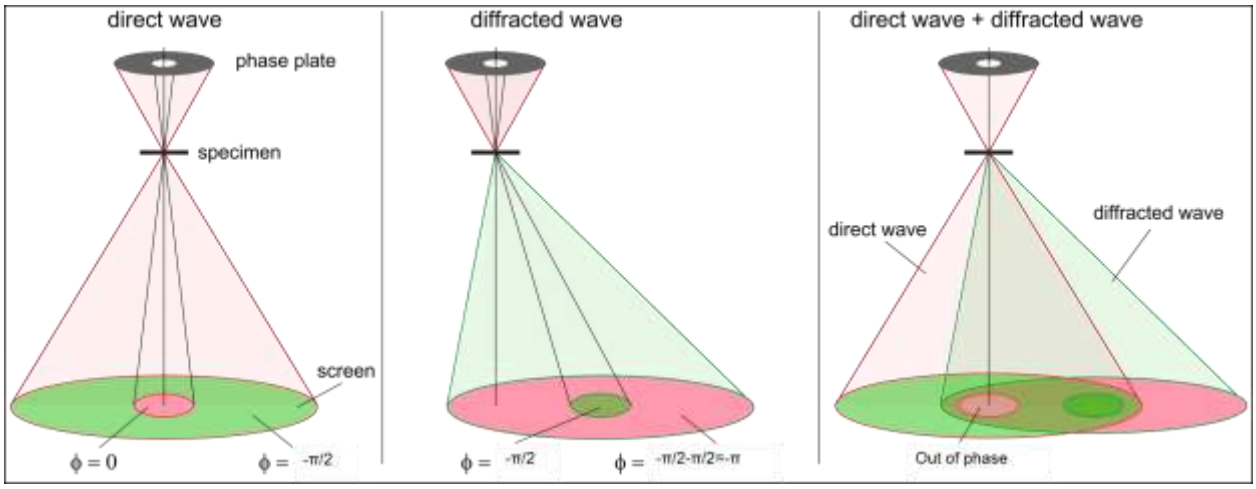

Figure 1. Principle of P-STEM imaging. Direct wave without phase shift and diffracted wave with phase shift are interfere to enhance phase contrast

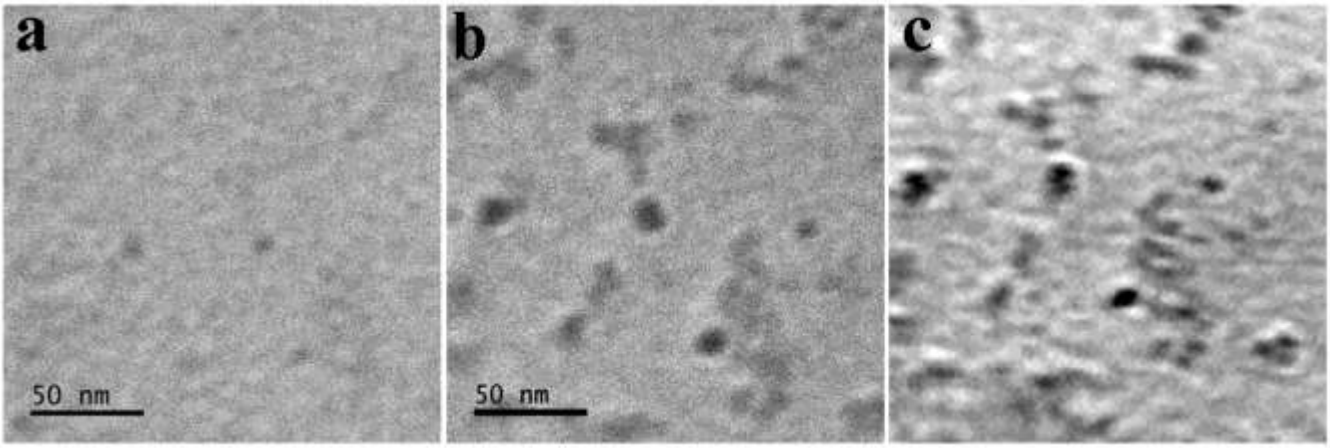

Figure 2. Comparison of the STEM images obtained using different condition. Bright field STEM image (a), P-STEM image with the conventional STEM detector (b) and P-STEM the image with 2D detector. PSTEM with 2D detector (c) shows the highest contrast.

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