Practical approach to the STEM setup parameters influencing the sensitivity of differential phase contrast image

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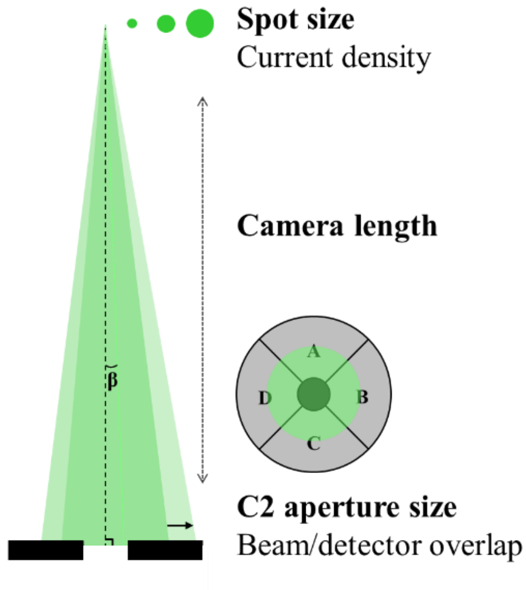
As devices become miniaturizing and integrating, a significance of characterization on unexpected physical phenomena in nanostructured materials has been rapidly growing. Especially, transmission electron microscopy (TEM) is one of the powerful instruments to observe the nanoscale structural and the electromagnetic features of materials simultaneously. So far, Lorentz TEM (LTEM) and electron holography have been widely used to visualize the magnetic and electronic structure. Differential phase contrast (DPC) imaging in scanning transmission electron microscopy (STEM) has been suggested as a new method to visualize nanoscale electromagnetic features of materials recently.

By the way, successful acquisition of DPC data is challenging since the image contrast is very sensitive to the beam alignment, setting parameters and sample conditions such as thickness, crystal orientation, field strength and etc. As a result, recent papers report possible effective parameters based on calculation and simulations. However, those theoretical approaches have several practical limitations. Thus, more practical and systematic investigation in the real facility and materials is necessary.

Here, we experimentally investigated the independent as well as combinatory effect of the STEM setup parameters such as camera length, spot size and C2 aperture affecting the sensitivity of DPC imaging. A schematic of proposed detector setup and major STEM setup parameters affecting the sensitivity of DPC imaging is shown in the figure below. A four segmented annular detector system which is installed in Talos TEM (Talos F200X; FEI) was used for DPC imaging. Individual signals from each detectors (A, B, C and D) were acquired, and then calculated an imbalanced signal of A-C or B-D for DPC image.

When the overlap between the diffraction disk and detector is same, current density of the electron beam does not affect significantly to the sensitivity for DPC imaging. In addition, increasing camera length improved the sensitivity for DPC imaging since the shift of diffraction disk rise linearly as the camera length jump. On the other hand, each calibration parameters may not be controlled separately in general STEM setup. Thus, the optimum experimental condition from various combinations of calibration parameters need to be determined before DPC imaging, and it can be suggested from our experimental results.



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