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Performance and Application of Chromatic/Spherical Aberration-Corrected 30 kV Transmission Electron Microscope

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For characterization of carbon materials such as graphenes and carbon nanotubes, it is effective to apply a lower acceleration voltage to observe them free from knock-on damage originated from a probing electron beam on the specimen. Since a wavelength increases at a lower acceleration voltage, compensation of geometrical aberrations is important to yield atomic resolution. Compensating both spherical aberration (Cs) and six-fold astigmatism (A6) with a delta-type Cs corrector [1], we have achieved atomic resolution imaging [2] and succeeded in atom-by-atom spectroscopy of carbon materials [3,4] at 30-60 kV in a Triple C #1 microscope. For a next challenging target to further improve resolution at a lower acceleration voltage, we have uniquely developed a new type of chromatic aberration (Cc) corrector [5], and installed it on a 30 kV transmission electron microscope (TEM) with a delta-type Cs corrector. This paper reports results of performance tests and application data of Cc/Cs-corrected 30 kV-TEM.

Figure 1 shows a photograph of a developed microscope (Triple C #2). A Schottky field emission gun (FEG) is installed on the top of the microscope column and is to be replaced to a cold FEG to improve coherency of an electron source. A platform of the microscope is a JEM-ARM200F. Cc and Cs correctors, which were arranged in tandem, were installed between an objective lens and an intermediate lens. Using the effect of combination concave lens, generated from a thick electrostatic or magnetic quadrupole (two-fold astigmatism) field, Cc was compensated. Then residual (geometrical) aberrations were compensated with a delta corrector. All results reported here were taken at 30 kV. Figure 2 (a) and (b) show a Cc/Cs-corrected high-resolution TEM (HRTEM) image of Si[110] and its power spectrum. Lattice fringes of {002} and $\{2\bar{2}0\}$, corresponding to spacings of 272 pm and 192 pm, respectively, were clearly imaged in the TEM image. Clear spots of 125 pm and 105 pm can be seen in the power spectrum. Figure 3 (a) and (b) show a Cc/Cs-corrected HRTEM image of $SrTiO_3$[001] and its power spectrum. Lattice fringes of {110} and {200}, corresponding to spacings of 276 pm and 195 pm, respectively, were clearly imaged in the TEM image. Clear spots of 124 pm and 98 pm was observed in the power spectrum. These results demonstrate the stability of the Cc/Cs-corrected microscope at 30 kV and other application data will be reported.

References

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[6] This work was supported by Japan Science and Technology Agency under the CREST project.

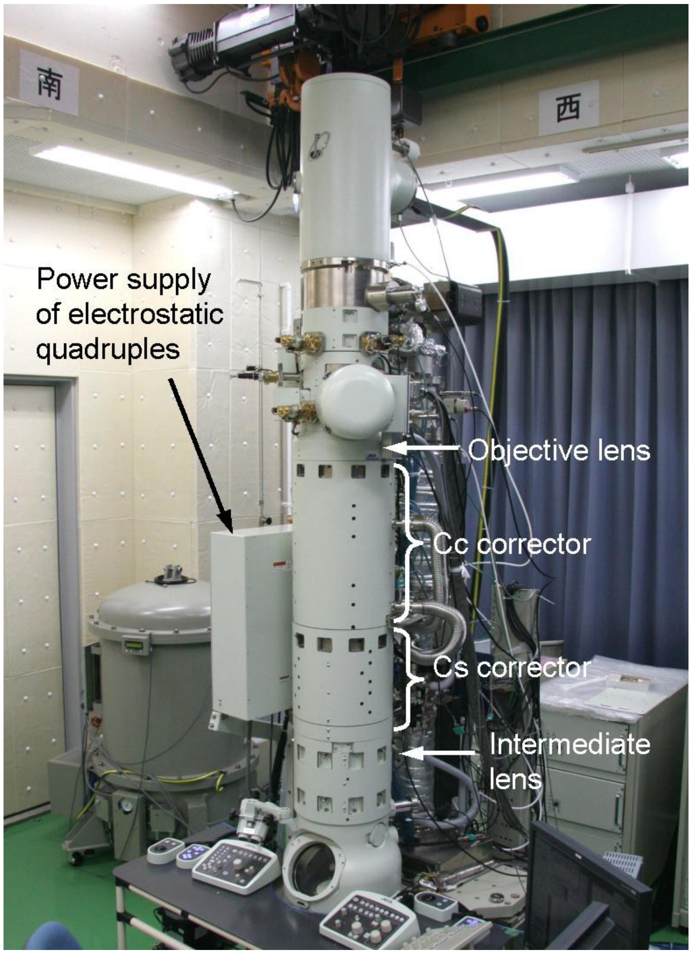

Fig.1 (a) Developed 30 kV TEM (Triple C #2) with delta-type Cs and new type of Cc correctors.

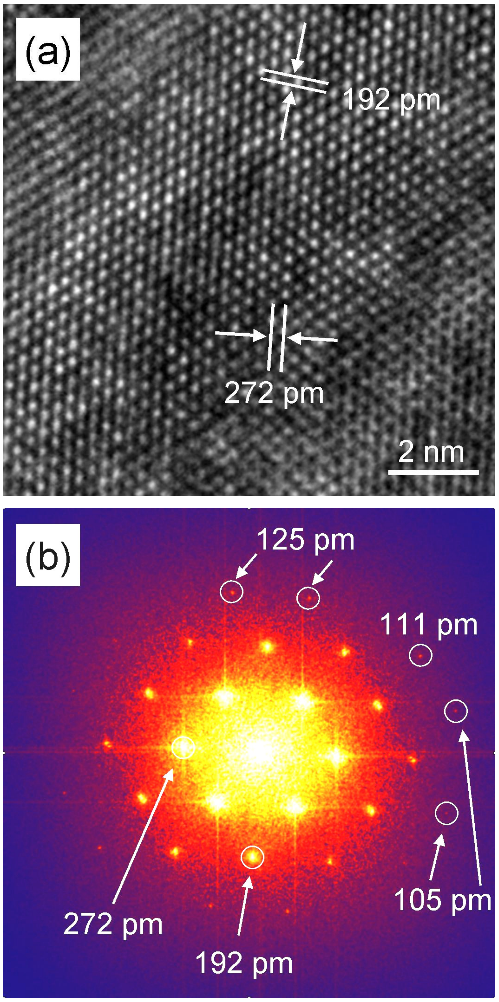

Fig.2 (a) Cc/Cs-corrected HRTEM image (raw data) of Si[110] taken at 30 kV and (b) its power spectrum.

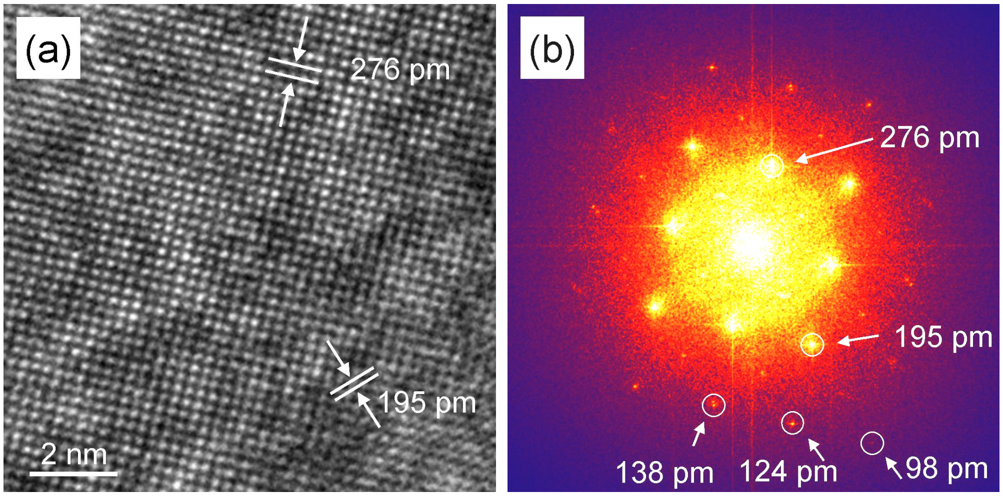

Fig.3 (a) Cc/Cs-corrected HRTEM image (raw data) of $SrTiO_3$[001] taken at 30 kV and (b) its power spectrum.