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Minimizing 6-fold Symmetry and Chromatic Aberration by using Ultra High Resolution Lens in Cs-Corrected STEM

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Ultra high resolution HAADF-imaging and chemical analysis in the field of material science and nano-technology has been demonstrated by using Cs (spherical aberration)-corrected STEM. Also detecting single atoms by secondary electron imaging with Cs-corrected Cold FEG-STEM is reported recently [1]. In this field, Cs-corrected tool allow us to obtain 0.1nm in daily use.

Multi-pole type corrector is the most feasible tool to compensate the spherical aberration, however, the higher order aberration is introduced by the corrector. For example, Hexapole type corrector introduces 6-fold astigmatism (A5) in high angle component [2]. Chromatic aberration is more effective factor because chromatic aberration at 200kV by using 24mrad-convergence angle is around 0.1nm in case of Schottky emitter (Cc=1.7mm is assumed). To get sub-angstrom resolution routinely, we tried to minimize the A5 and chromatic aberration by using cold field emission gun (CFEG) and ultra high resolution lens (the original Cs and Cc is around 0.55mm and 1.1mm, respectively). This idea is to reduce residual A5 by decreasing Hexapole strength with small change of focal length.

Figure 1 shows calculated root mean square of residual aberrations including diffraction limit, chromatic aberration and 6-fold astigmatism with respect to UHR, HR and analysis objective lens at 200kV. The energy spread of 0.3eV for CFEG is used. The cumulative aberration shows 78pm, 68pm and 63pm for analysis, HR and UHR lens, respectively. This theoretical consideration supports the feasibility of UHR lens, and also means the other residual aberration should be eliminate completely to acquire 63pm-resolution at 200kV.

Figure 2 shows Ronchigrams taken with (a) HR lens and (b) UHR lens at 200kV. The 6-fold symmetry reduced at UHR lens in contrast to HR lens, and feature-free region extends from 35(HR lens) to 44mrad (UHR lens). This result means that UHR lens is effective to reduce A5 and chromatic aberration.

References

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[2] H. Mueller, S. Uhlemann, P. Hartel, and M. Haider, Microsc. Microanal. **12**, 442 (2006).

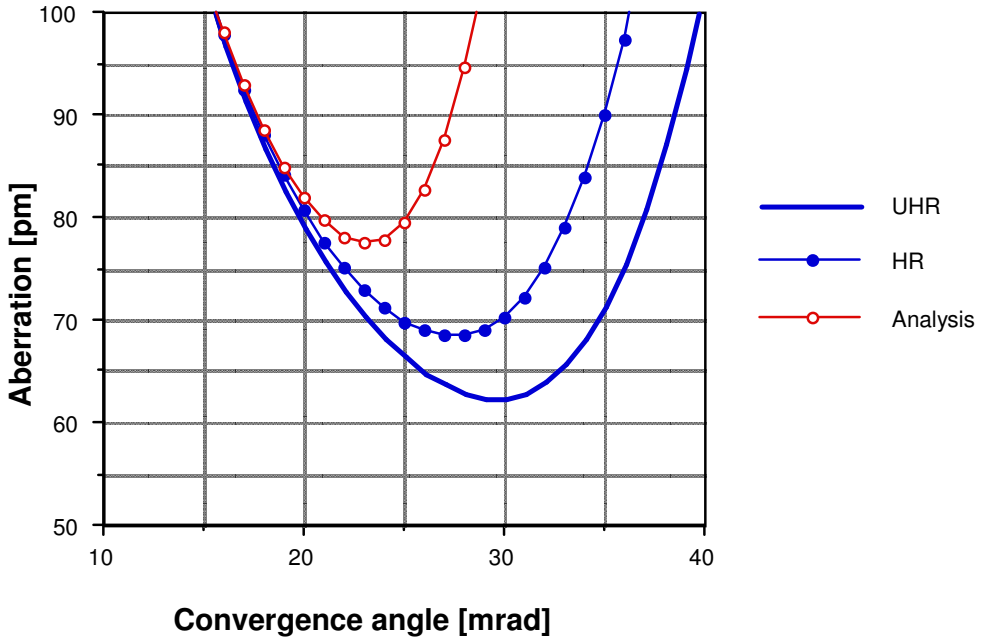

Fig.1 Calculated root mean square of residual aberrations including diffraction limit, chromatic aberration and 6-fold astigmatism with respect to UHR, HR and analysis objective lens at 200kV.

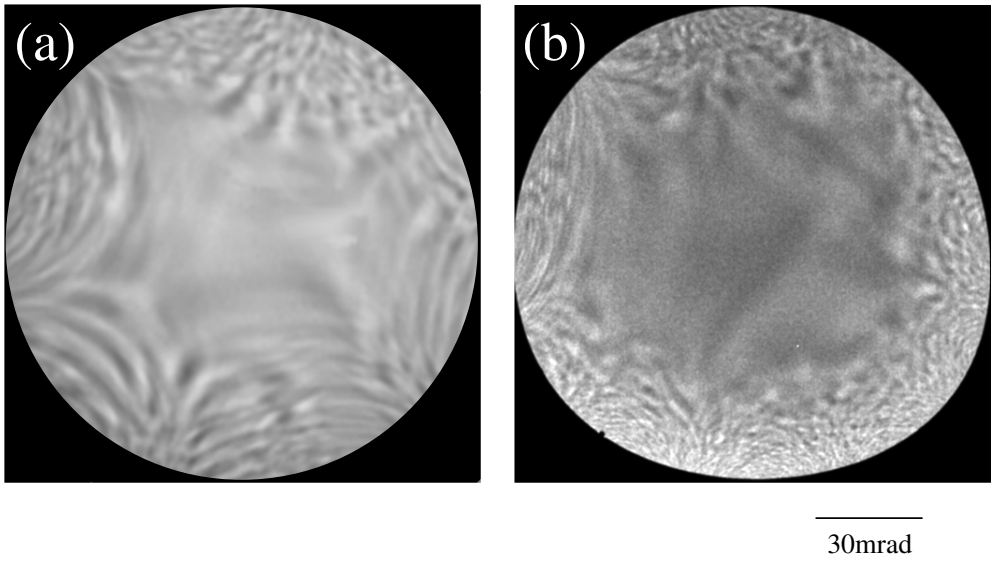

Fig.2 Ronchigrams taken with (a) HR lens and (b) UHR lens at 200kV.

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