Microsc. Microanal. 8 (Suppl. 2), 2002
DOI 10.1017.S1431927602105307

Effects of Detector Black Level in ADF-STEM Imaging

Z. Yu*, P. E. Batson** and J. Silcox***

***** Physics Department, Cornell University, Ithaca, NY 14853
****** IBM Thomas J. Watson Research Center, Yorktown Heights, NY 10598
******* School of Applied and Engineering Physics, Cornell University, Ithaca, NY 14853

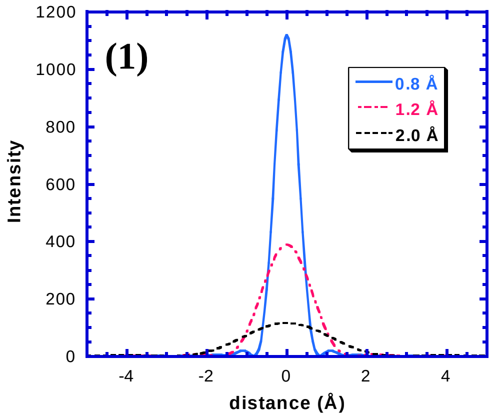
STEM high-resolution lattice images are formed by scanning an atomic scale focused probe over zone-axis oriented crystals and collecting the high-angle scattering with the ADF detector. For a uniform-thickness crystal, the highest ADF signal arises when the probe is on atomic column and the lowest signal when the probe is off atomic column. Recently with the successful implementation of a C_s corrector, the FWHM probe size has advanced into the sub-Å region.[1] This generates higher order (but weak) Fourier components in the image. Should the intensity be recorded with an experimentally introduced black level, there is a serious danger that artifacts may be introduced in the power spectrum of the lattice images. This is often used to identify important information (e.g., the resolution limit) in the image. We, therefore, have explored the possible effects of black level settings on ADF-STEM imaging with various probe sizes. This note presents an account of our multislice simulation results of ADF STEM imaging with an artificially introduced ADF detector black level for three different STEM probes.

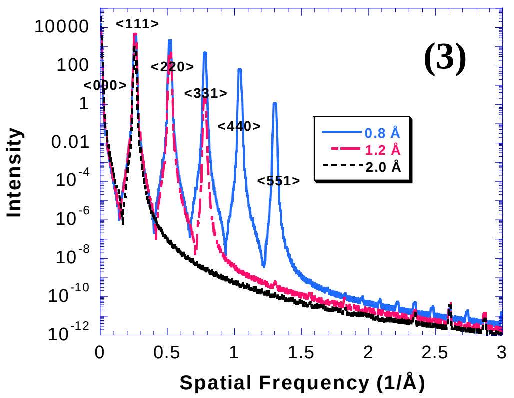
Multislice simulations which divide the sample into a sequence of thin layers and propagate the electron beam perpendicular to each layer, are important in electron microscopy in understanding the physics of the image or in predicting observations. The computer code realizing multislice simulation was written by Kirkland[2]. It has been successfully used to match the simulated CBED patterns with the experimental ones[3,4]. Three STEM probes with the FWHM size of 0.8 Å, 1.2 Å and 2.0 Å are generated respectively, as shown in Figure 1. A specimen with an average Z = 19 simulating a mixture of 70% Si and 30% Ge and a lattice constant of a = 5.43 Å was generated and oriented in such a way that the optical axis is parallel to the $<\bar{1}10>$ zone axis of the specimen. For each incident probe, a line scan along the <110> direction was done by displacing the incident probe along this direction over two unit cells and the resultant ADF intensity at each probe position was calculated, as shown by Figure 2.

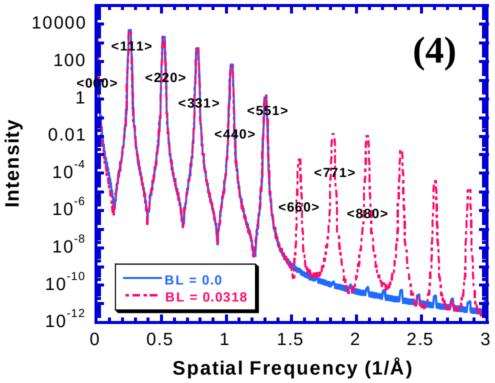
A power spectrum for Figure 2 were obtained by first extending the intensity profiles 32 times and then applying aTukey window to make the Fourier peaks in reciprocal space symmetric and sharp, as shown by Figure 3. Figure 3 confirms the validity of using power spectra to calibrate resolution since the high frequency limits are approximately the reciprocals of the probe sizes. A constant Black Level (BL) can be introduced to the real space line scan intensity such that intensities lower than the BL are registered as zero. Figure 4 shows the power spectrum of the line scan intensity for the 0.8 Å probe with two different black level values. It is evident that a BL can indeed introduce higher frequency artifacts beyond the resolution limits. Figure 5 shows the experimental lattice image and associated power spectra of a sample composed of 70% Si and 30% Ge obtained on the IBM VG STEM equipped with a C_s corrector[5]. The FWHM size of the experimental probe was estimated to be about 0.8 Å. The simulation result in Figure 4 shows that among all the artifact peaks, peak <660> is over 20 times lower than peak <771> or peak <880>. This explains the introduction of artifacts i.e., the presence of <771> and <880> peaks and the absence of the <660> peak, into the experimental images.

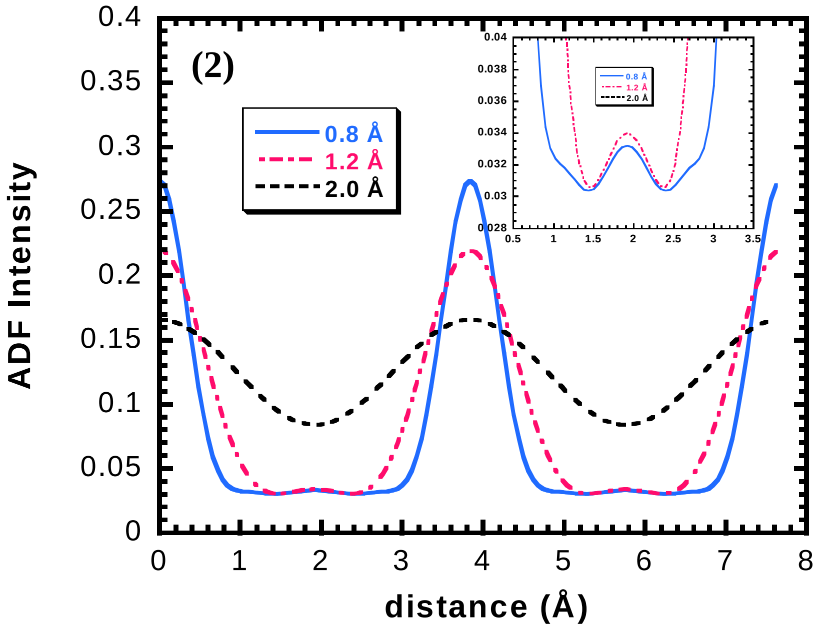
References:

1 *N. Dellby et al., Journal of Electron Microscopy 50 (2001) 177.*
2 *E. J. Kirkland, Advanced Computing in Electron Microscopy, New York (1998) 162.*
3 *R.F. Loane, P. Xu and J. Silcox, Acta Cryst. A47 (1991) 267.*
4 *D. A. Muller et al., Ultramicroscopy 86 (2001) 371.*
5 *P.E. Batson, O.L. Krivanek and N.Dellby, submitted for publication.*
6 *This work was supported by the Cornell Center for Materials Research (CCMR), a Materials Research Science and Engineering Center of the National Science Foundation (DMR-0079992).*









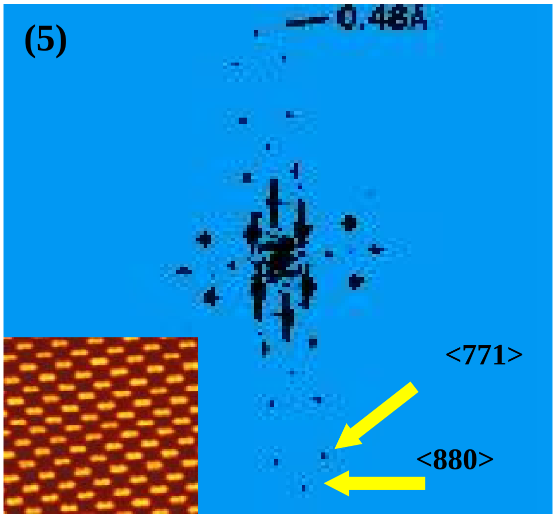


Fig. 1. Profiles of three simulated STEM probes with FWHM size 0.8 Å, 1.2 Å and 2.0 Å respectively. The parameters are:
V = 120 kV, C_5 = 10 mm, C_3 = -15 µm, a = 25 mrad and ?*f* =-28 ? for the 0.8 ? probe,
V = 120 kV, C_5 = 10 mm, C_3 = -15 µm, a = 14.3 mrad and ?*f* =-6 ? for the 1.2 ? probe,
V = 100 kV, C_5 = 0 mm, C_3 = 1300 µm, a = 8.9 mrad and ?*f* = 566? for the 2.0 ? probe.

Fig. 2. ADF line scan profiles along the <110> direction with three incident probes for a 600 Å thick sample. The inset is a blow up of the lowest intensity region.

Fig. 3. Power spectra of the line scan profiles in Figure 2 with Fourier peaks indexed. The <XX1> (X = 1, 3 and 5) indexes represent the projections onto the <110> direction of the corresponding peaks in two-dimensional reciprocal space.

Fig. 4. Power spectra of the line scan intensity for the 0.8 Å probe with two different black level settings.

Fig. 5. An experimental lattice image and its power spectrum.