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A NEW HIGH STABILITY, 4TH ORDER ABERRATION CORRECTED SPECTROMETER AND IMAGING FILTER FOR A MONOCHROMATED TEM

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During the development of a new high-resolution electron energy loss spectrometer prototype installed on a monochromated TEM a 100 meV energy resolution had already been achieved [1]. Recently this instrument was installed on a monochromated 200 kV Tecnai F20ST at the National Centre of High Resolution Electron Microscopy at the University of Delft. The latest developments of this spectrometer have been on using this instrument for energy filtered imaging with larger aperture sizes that increase the field of view for both diffraction and imaging. The first spectrometer of this type has been successfully installed at the Research Institute for Electron Microscopy at the Technical University of Graz.

In a conventional transmission electron microscope the energy resolution of electron energy loss spectra is limited by the energy spread of the electron source, under most practical conditions. The development, and recent commercial introduction, of monochromated TEMs [2] has greatly improved the energy spread of primary electrons. Realizing the possibilities of high resolution spectroscopy with a monochromated TEM, a new spectrometer has been designed with up to 4th order aberration corrected optics and high stability prism electronics yielding high resolution spectra with exposures on the order of minutes.

The energy resolution limiting spectrometer aberrations have been corrected up to 4th order with the addition of multipole lenses in front of the prism. Spectrometer aberrations cause electrons that enter the system under large angles to be offset with respect to electrons that enter the spectrometer under small angles. This effect gives rise to a degradation of energy resolution with increase in entrance aperture size. Using sophisticated software and automated tuning routines it is possible to analyze and correct electron optical aberrations by measuring the image isochromaticity. Figure 1 shows a 4th order corrected isochromaticity figure for both a 3mm and a 5 mm aperture. The squares inside the 3 mm and 5 mm aperture represent the CCD detector at the end of the energy filter onto which the image is projected. The equivalent spectral aberration can be calculated from these isochromatic figures. Figure 2 shows such calculations for an increasing order of aberration correction for a 2mm aperture. The equivalent full width at half maximum of the 4th order corrected zero loss peak aberration figure for a 2 mm aperture is 20 meV.

A larger entrance aperture allows for longer camera lengths and reduces convolution of spectral data with diffraction information, also known as spectrum diffraction mixing. The relationship between energy resolution, spectrum diffraction mixing, camera length and aperture sizes will be discussed in more detail. Furthermore, in imaging filter applications a larger entrance aperture simplifies the collection of data, such as for energy filtered CBED for which the collection angle is important. On the new spectrometer the effective aperture size has been doubled compared to the standard GIF and this was achieved without introducing greater distortions. Still larger aperture sizes may be realized in the future.

A high performance spectrometer requires high stability, low noise electronics for typical electron microscope room environment specifications. Long exposures are of greater importance for a monochromated electron source because of the decreased electron intensity. Therefore special attention has been paid to minimizing long-term drift with extensive electronic design work. Minimal broadening has been measured for a zero loss peak between 0.14 to 0.18 eV for exposure times on the order of minutes.

A preliminary measurement of a Si spectrum obtained with this instrument is shown in Figure 3. Already some high-resolution l-edge features from this raw measurement corroborate the processed or sharpened interpretation of the Si spectrum by P. Batson [3].

References

[1] HA. Brink et al., Proc. Microsc.Microanal. Vol 7, Suppl. 2 (2001) 908
[2] P. Tiemeijer et al., elsewhere in these proceedings.
[3] P.E. Batson, J.Microscopy 49 (2000) 268.

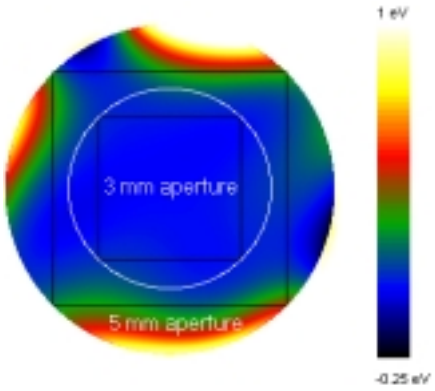

FIG. 1. Isochromatic surface of the 4th order corrected aberrations with the new spectrometer. The square inside the circle represents the image captured on the square CCD detector. All data outside of the outer square has been extrapolated.

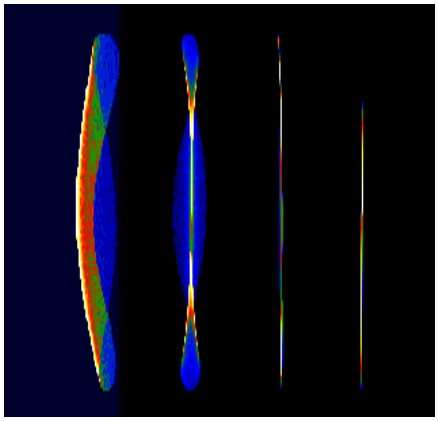

FIG. 2. Calculated spectral aberration figures from an isochromatic figure. The figures from left to right correspond to increasing orders of aberration correction from partial 2nd order up to 4th order.

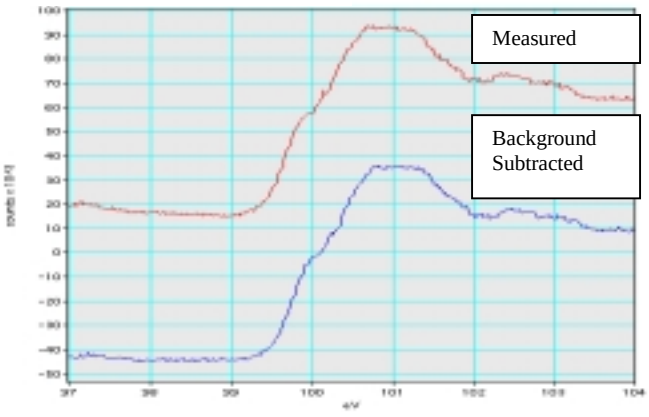

FIG. 3 Si spectrum collected with a 2 mm aperture at 200 kV on a monochromated TF20.

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