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The power spectrum of an EFTEM image recorded with low intensity levels

C. Kreyenschulte[1,2], H. Kohl[1,2]

[1] Physikalisches Institut, University of Münster, Münster, Germany
[2] Interdisziplinäres Centrum für Elektronenmikroskopie und Mikroanalyse, Münster, Germany

carsten.kreyenschulte@uni-muenster.de
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The power spectrum of electron micrographs can be used to evaluate the structure of the specimen quite accurately by determining its structure factor. By use of energy filtered transmission electron microscopy (EFTEM) it is even possible to determine the partial two particle structure factors by using elemental maps. We have done so for disordered structures [1]. Another use of the power spectrum can be the separation of detection noise from the specimen signal, allowing for a better distinction between signal and noise [2].

In order to get useful data the composition of the power spectrum needs to be understood. Considering a specimen signal , with **u** being the spatial frequency vector, the influence of the scattering process, the microscope and the detector, e.g. a CCD-camera, needs to be determined.

In Fourier space, the camera is usually characterized by the modulation transfer function , with being the modulus of , which is the Fourier transformed point spread function. It is either supplied by the camera manufacturer or can be determined by one of the methods described in [2].

In EFTEM the scattering process cannot be separated from the imaging process. Together, they are described by the inelastic transfer function which can be calculated theoretically [3,4]. and are shown in figure 1. These functions are cause a signal broadening in real space.

The noise of the detection system needs also to be taken into account. The noise power spectrum is a characterization of the statistical nature of the detection process [5]. It is also called noise transfer function or noise based modulation transfer function. In EFTEM or other low intensity applications it can be necessary to add the noise power spectrum from the dark current correction , which stems from the thermal fluctuation in the camera and is dependent on the recording time.

Combining all these functions the power spectrum of the recorded image can expressed as

When the flatfield image used to calculate is in the same intensity regime as the micrograph and the exposure time is sufficiently low, one can usually neglect .

Special care has to be taken when recording and evaluating elemental maps. In this case the difference in recording intensities and times can yield unexpected results. To avoid specimen drift, the overall exposure time for one image can be split into several shorter exposures which are summed up after drift correction [6]. Using the same dark current correction image for each of these shorter exposures will result in a recognizable increase of the noise power spectrum by a constant value over all spatial frequencies (figure 2).

Another problem can arise when the same illumination parameters are used for recording the flatfield images for the calculation of the noise power spectrum after recording a series of energy filtered images at higher energy losses. When using a full frame CCD camera, the recorded image is shifted line by line to the readout lane. If there is an afterglow due to high illumination intensities, the recorded images will show a signal broadening in readout direction showing the exponential decay of the scintillator. In Fourier space this will show as a symmetry breaking function for the noise power spectrum with being the spatial frequency in readout direction of the detector, the decay constant and the pixel size

.

This effect is more pronounced when using the binning function of the camera because of the much faster readout process. In figure 3 we show a fit of the above function to the quotient of an affected noise power spectrum by an unaffected one.

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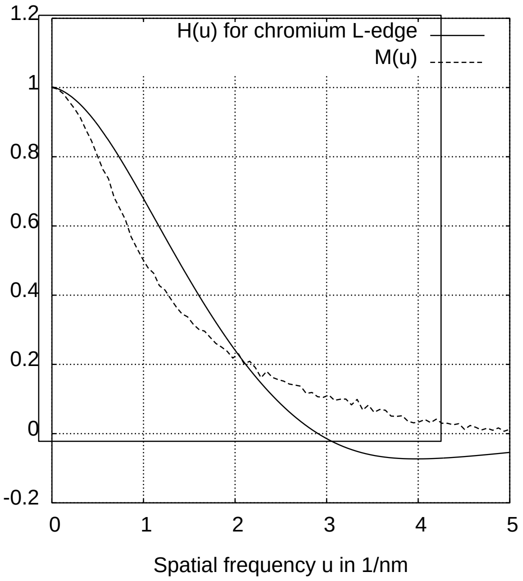

Figure 1. for the case of a CCD camera with a pixel size of and a magnification of 150k, calculated for an acceptance half angle of at an energy loss of , corresponding to an energy window on the chromium L-edge.

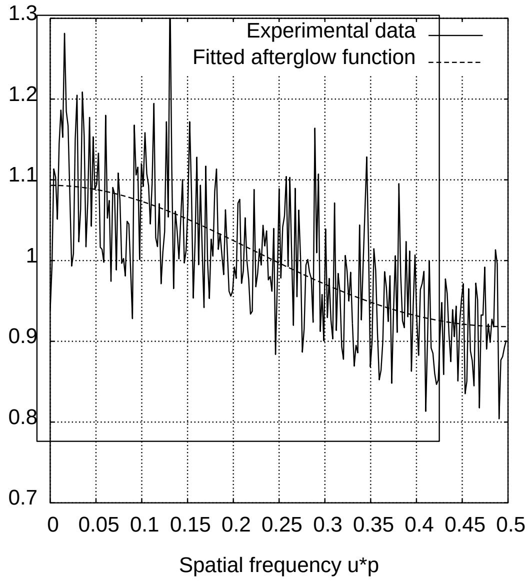

Figure 3. Afterglow function determined by dividing the noise power spectrum of a flat image recorded with high illumination intensity by the noise power spectrum of a flat image recorded by low illumination intensity. The decay parameter was found to be .

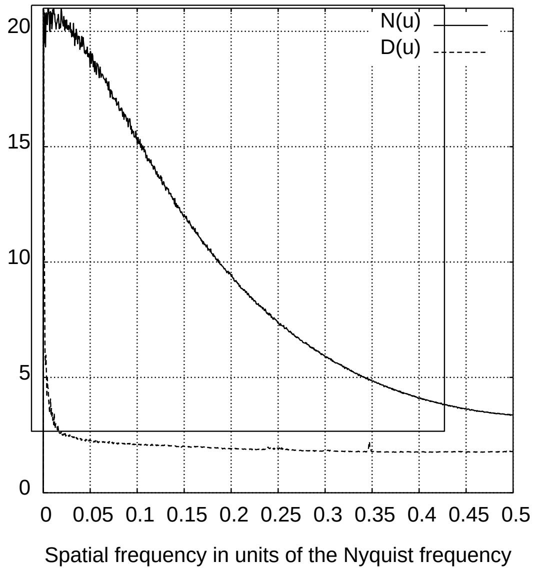

Figure 2. Noise power spectrum and dark noise for our CCD-camera, with a recording time of , at a low illumination intensity for the bright flat images.