Improving the signal/noise ratio in elemental maps using spatial drift corrected EFTEM imaging

Tobias Heil and Helmut Kohl

Physikalisches Institut, Interdisziplinäres Centrum für Elektronenmikroskopie und Mikroanalyse (ICEM)
Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

tobiheil@uni-muenster.de
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In the energy filtering transmission electron microscopy (EFTEM) and the affiliated elemental mapping the spatial drift of the specimen during the image acquisition leads to blurring and a loss of spatial resolution in the image. To minimize this effect the acquisition time of the images is typically set to be as short as possible. However, depending on the signal intensity sometimes a sufficient signal/noise ratio (SNR) can not be achieved within a few seconds of exposure time and hence the loss of the spatial resolution can not be avoided with conventional imaging procedures. Although much effort is put into the mechanical stability of the electron microscope it is most likely that the spatial drift will always be a factor that limits the quality of the acquired images.

In order to alleviate this constraint one can divide the necessary exposure time of the camera onto several shorter exposed sub-images and merge them after a posteriori manual drift-correction [1]. With this method the influence of the spatial drift on the merged image is reduced to the influence on its sub-images. While the signal value of the merged image still equals an image with an exposure time equal to the product of the number of sub-images and their single exposure time, the blurring effect caused by the drift can be strongly reduced in this way, leading to an improved signal/noise ratio. However, in the described form this method still requires a reasonable SNR and consequently a certain exposure time per sub-image to define the drift between the single sub-images before merging. Also, the need for manual position fitting limits the number of sub-images that can reasonably be used. We have developed an extension of this method that is not limited to a certain SNR in each sub-image while simultaneously being able to use automatic routines for drift correction.

In order to obtain an image with good SNR from the merging of sub-images it is not necessary to have a signal distinguishable from the noise in each single sub-image as long as the spatial drift between these sub-images is known and corrected for. But with a very low SNR, these sub-images themselves can not be used for reliable drift calculations anymore. Instead, we now acquire one zero-loss filtered image immediately after every single EFTEM sub-image. These zero-loss filtered images offer a high SNR even with short exposure times (>1 sec) and are therefore, as long as some characteristic specimen structure is visible, highly suitable for automatic cross-correlation based drift calculation. This calculation can be done between the acquisition of two EFTEM sub-images, because its computation with sufficient accuracy takes only about one second. This drift value between two zero-loss filtered images can then be used to merge their associated EFTEM sub-images correctly before the next sub-image is acquired. If each of the above steps is done online there will be no need for any kind of post-processing or saving of other data afterwards apart from the desired EFTEM image.

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We developed a routine for our Zeiss Libra 200 FE microscope that works similar to the normal image acquisition software, except that the desired exposure time for the image can be divided onto a variable number of sub-images. The drift corrected merging of each sub-image reduces the influence of the spatial drift during the whole acquisition. Because of the readout time needed for each sub-image and the online drift calculation, this method increases the acquisition time for each image typically to between 150% and 200% of the pure exposure time, mainly depending on the number of sub-images chosen (Fig. 1). In return, the resulting images exhibit a better spatial resolution and SNR than conventional images with the same overall exposure time (Fig. 2). Another main advantage of this routine is the possibility to acquire a series of EFTEM images with different energy-loss values. These images will not only be drift corrected within themselves, but also among each other, thus eliminating any need for a posteriori drift correction. Furthermore, with the additional use of the image shift function of the microscope, it is possible to shift the illumination of the camera according to the measured drift between each sub-image, resulting in an enlarged usable field of view in all images and consequently for the resulting elemental map (Fig. 1,c).

1. K. Aoyama, R. Matsumoto, Y. Komatsu J. Electron. Microsc. **51** (2002) p257.
2. We are very grateful to Prof. Dr. G. Schmitz and his co-workers of the Institut für Materialphysik for invaluable discussions and their help with specimen preparation.

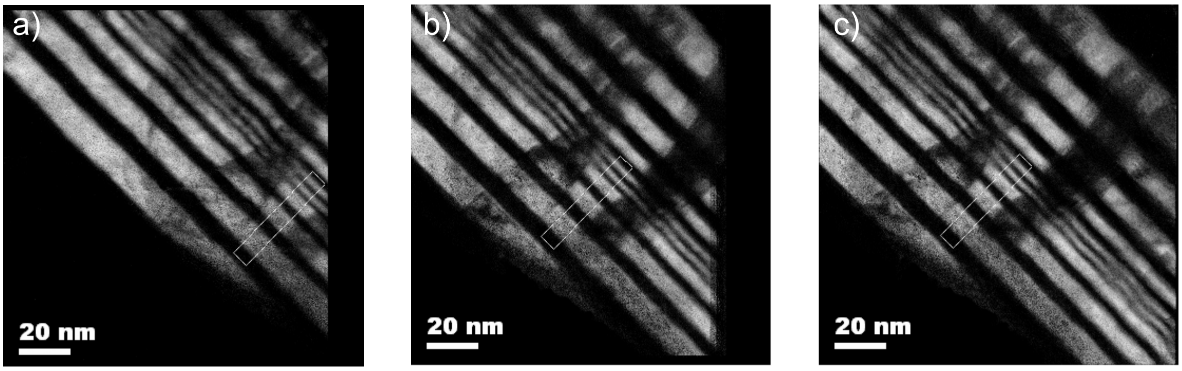

Figure 1. 4-window elemental maps (SNR) of chromium layers with an exposure time of 3 min per image, a) conventional, complete acquisition time: 15 min, b) with drift correction, 18 sub-images per image used, complete acquisition time: 27 min, c) with drift correction and additional used image shift, 18 sub-images used, complete acquisition time: 25 min.

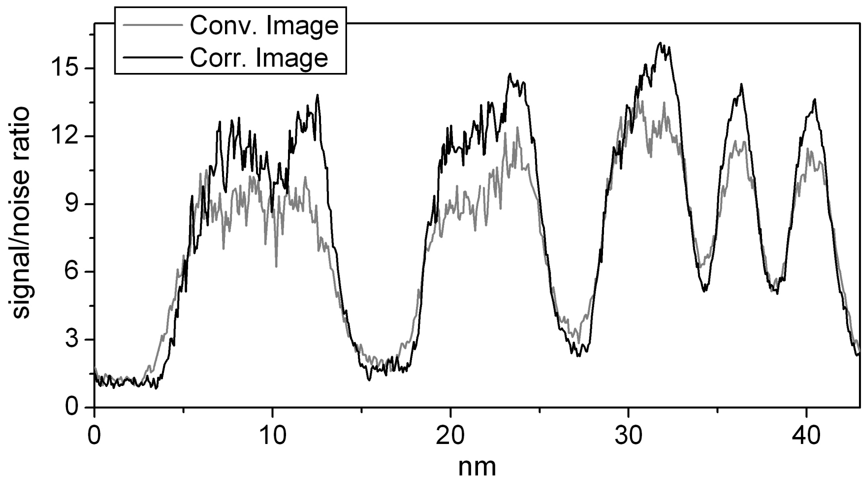

Figure 2. Profile of the signal/noise ratio of the conventional acquired map (grey) and the drift corrected map (black) from figure 1.

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