Spectroscopic TEM/STEM, EELS, EFTEM

IM4.P108
Spatially resolved EELS with an in-column Omega filter - from distorted recordings to corrected results

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Spatially resolved EELS (SR-EELS) [1] is a technique to preserve spatial information when recording EEL spectra. Using SR-EELS, many EEL spectra are recorded in parallel as a function of one spatial coordinate, perpendicular to the energy dispersive direction. This method is useful for investigating specimens like interfaces and layer systems. We will show that the used in-column Omega filter [2] introduces distortions to the SR-EELS images and we present a work flow to entirely correct these distortions.

As a test specimen we have used an iron chromium layer system on silicon oxide with a layer thickness of about 12 nm. Figure 1a shows the combination of three elemental maps of this specimen. A slit aperture at the filter entrance plane (see fig. 1b) is used for performing SR-EELS. Compared with a round aperture the intensity along the lateral axis is uniform, but we loose intensity as the slit is narrower. We operate the microscope in EELS mode, which means that the 2nd projector system images the energy dispersive plane onto the camera.

Using the default parameters for the energy filter excitations we obtain an SR-EELS image as shown in figure 1c. One distortion is clearly visible: the lateral extend decreases with increasing energy loss. A second distortion is harder to see: The lateral magnification decreases towards the top and the bottom of the spectrum. This results in a higher intensity at the borders. We can reduce the magnitude of these distortions by tuning the excitation of the last hexapol corrector of the energy filter. The second distortion can be removed almost completely. Additionally the lateral extend of the spectrum is increased and therefore the lateral resolution.

The final result is shown in figure 1d. The excitation was optimised and the remaining distortions have been corrected by software processing. The software processing requires to perform a characterisation measurement: The small filter entrance aperture is shifted along the lateral axis. At several positions a SR-EELS dataset is recorded. For each energy channel of these datasets we can extract the position of the curved aperture borders. Polynomials of 2nd and 3rd order are fitted to the data points. They are used to describe and correct both distortions. Detailed information about the characterisation and the correction can be found at [3].

High spatial resolution is possible using SR-EELS. The interfaces of the 15 nm thick layers are clearly resolved. Additionally we obtain a high energy resolution without the difficulty of correlating the obtained spectra with the investigated area, as in conventional EELS or STEM-EELS.

1. L. Reimer et al., Ultramicroscopy 24 (1988) 339-354.
2. S. Lanio, PhD thesis (1986), TH Darmstadt.
3. EFTEMj is available on GitHub: https://github.com/EFTEMj/EFTEMj/tree/master/MC2015

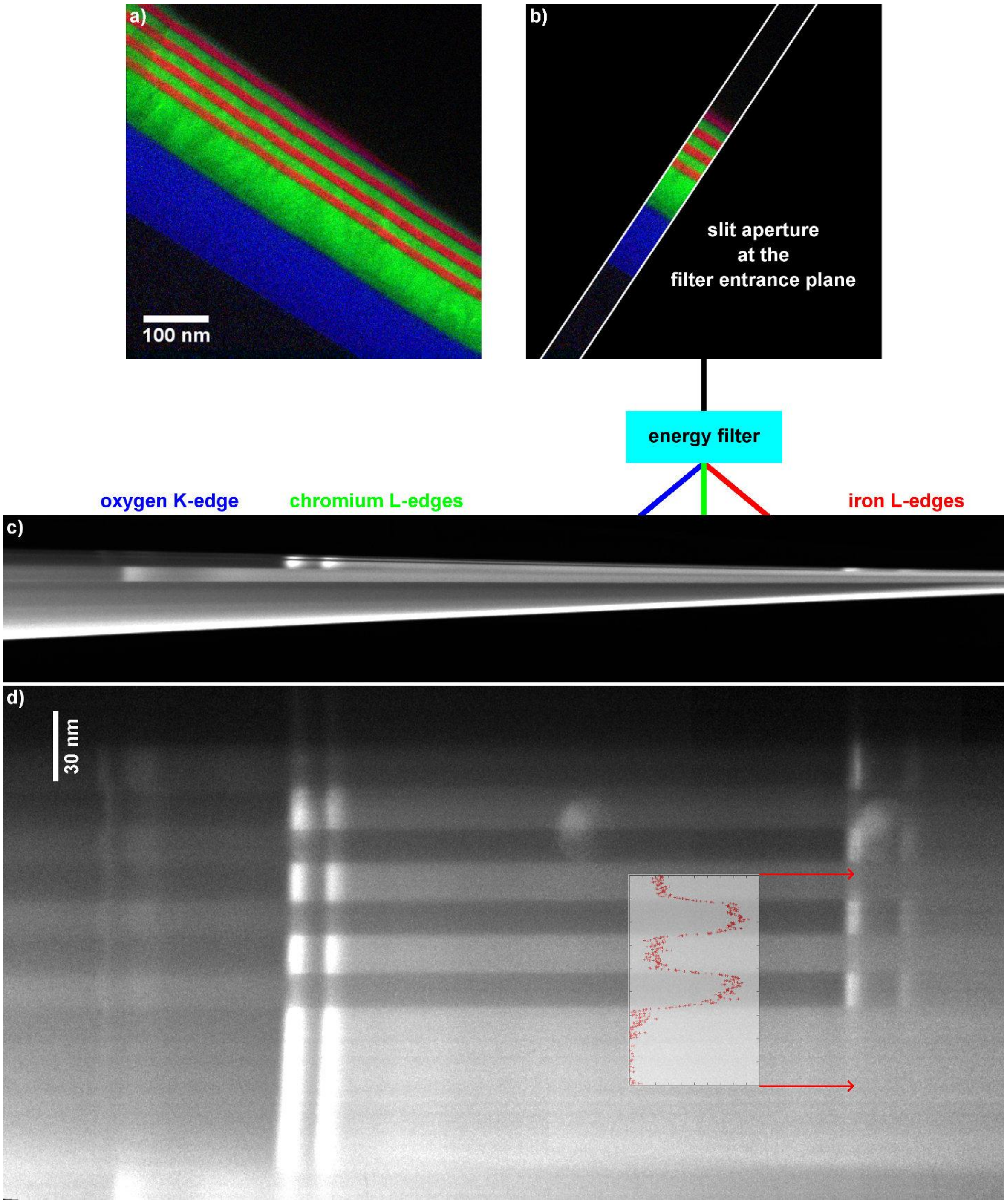

Figure 1. a) A combination of three elemental maps that shows the specimen (iron in red, chromium in green and oxygen in blue) used for SR-EELS measurements. b) This images shows how the specimen has to be aligned to perform a SR-EELS measurement. A slit aperture at the filter entrance plane is useful but not necessary. c) A SR-EELS measurement with default parameters for the energy filter excitations. The low lateral resolution and strong distortions are visible. d) The final SR-EELS image after optimising the energy filter excitations and post-processing of the recorded dataset with EFTEMj [3]. The inset shows the background subtracted iron L_3-edge signal. For a high resolution image visit [3].