Angular momentum resolved EELS by energy filtered nanobeam diffraction

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Electron energy-loss spectrometry (EELS) is a powerful and nowadays well-known tool to investigate materials. In the low-loss range, it provides information about the loss function $\mathrm{Im}(-1/\varepsilon)$, and after specific treatment of the data, it is possible to retrieve the dielectric constant $\varepsilon(\omega)$. Using angular resolved electron energy-loss spectrometry, one can even obtain the whole 4D information $\varepsilon(\omega,\mathbf{q})$ [1].

In the following, we will show a special way of performing angular resolved EELS acquisition. Our lab is in possession of a JEOL 2200 FS equipped with an in-column Ω filter, which allows us to take advantage of the energy filtered transmission electron microscopy (EFTEM) technique. Indeed, at the dawn of angular resolved EELS, the momentum loss information was acquired by manually selecting the area of interest with an appropriate aperture in the back focal plane. More precisely, in diffraction mode, it was necessary to acquire several EELS spectra by shifting the aperture for different momenta, which is both labour-intensive and rather imprecise. Using EFTEM instead gives the possibility to take one data cube with the complete set of possible angular resolved vectors. By doing so, the data set is much more complete than using the “aperture shift” method. Furthermore, EFTEM preserves the parallel illumination of the sample while creating the 3D data cube resolved in diffraction angle, which is crucial for identifying the momentum loss information. Nevertheless, there is a price to pay, in this case a loss of energy resolution (given in EFTEM EELS by the width of the filter entrance slit) to the benefit of angular momentum resolution.

Because the energy-dispersion of the Ω filter is image-coupled in diffraction mode, an EELS spectrum taken from a selected area diffraction pattern is convolved with the area-selecting aperture, which limits energy resolution to >5 eV. To overcome this constraint, nanobeam diffraction is instead being used. By doing so, the illumination beam is still parallel while the energy dispersion is convolved with a much smaller image object. In this way energy resolutions of 1–2 eV should be feasible. Data from preliminary experiments demonstrating the principle of this technique are shown in Figures 1 and 2. The further advantage of using a microscope with in-column filter is that imaging plates can be used instead of the CCD for recording the data, allowing for a much higher dynamic range to be captures.

The advantage of obtaining a complete set of angular resolved spectra in a single data cube while using EFTEM combined with NBD, which allows to overcome the issue of convolution between EELS spectrum and area-selecting aperture, leads us to the conclusion that energy filtered NBD provides a very promising route for angular resolved EELS studies. This will be used, for instance, to compare simulation and experimental studies of the plasmon wake of various reference materials.

References

[1] A Alkauskas *et al*, Ultramicroscopy **110** (2010) p1081

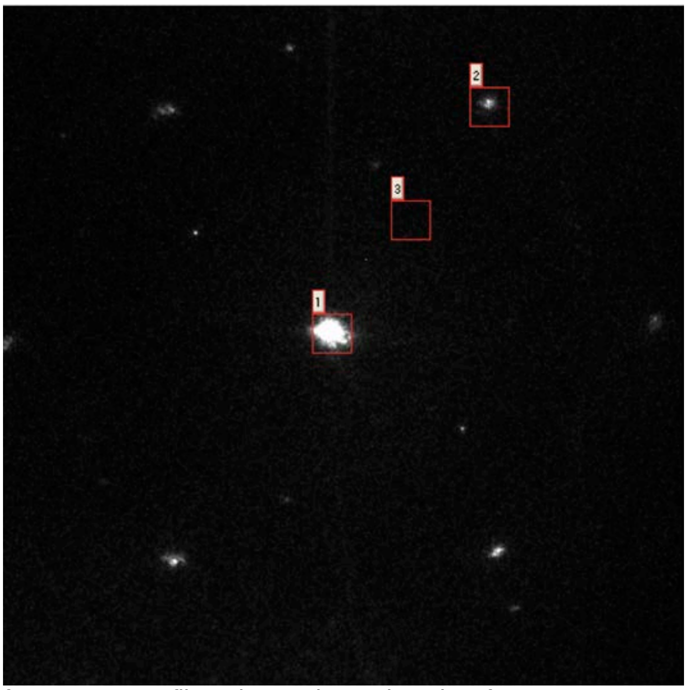

Figure 1. *"Zero Loss" image from an energy filtered NBD data cube taken from -10 eV to 10 eV at a camera length of 80 cm. The sample is polycrystalline silver, prepared by sputtering onto rock salt.*

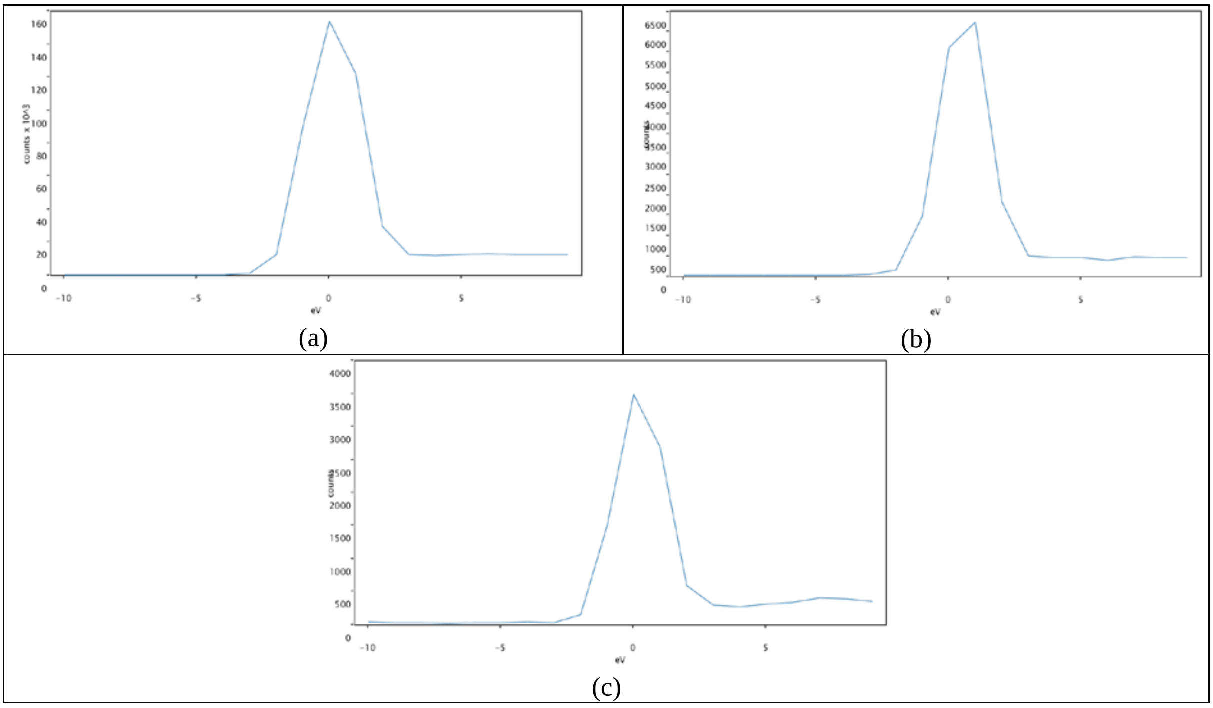

Figure 2. *Extracted spectra from the data cube of figure 1. (a) is the spectrum from the transmitted beam (square N^{o} 1), (b) corresponds to the [02-2] diffraction spot and (c) is a spectrum with an arbitrary **q**.*