Increasing the energy loss range in EELS at 80 kV

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Recently, we have shown that optimization of the post-specimen lens series for low camera lengths is essential to getting good quality EEL spectra above about 2000 eV loss for a 200 kV primary beam energy, especially when using the very short camera lengths required to couple the entire primary beam into a spectrometer on a probe-corrected microscope [1]. This optimization used the ideas developed previously for a simple dedicated STEM with two post-specimen lenses [2] and extended them to a four post-specimen lens system more common on modern TEM-STEM instruments. This brings clear benefits to performing EELS at higher losses, with excellent performance to at least 5 kV loss, and spectra possible up to over 10 kV loss [3].

In this work, we show that it is possible to do a similar optimization at 80 kV primary beam energy, although obviously the range of energy loss available will not be as large as at 200 kV as the rough figure of merit to consider is $\Delta E/E$, so at first glance, one would expect about 40% of the range possible as at 200 kV. Actually, we found it was possible to do a little better than this, and this is summarized nicely in Figure 1c. Prior to correcting the 2cm camera length, a cross-over is imaged onto the CCD at around 3500 kV. In other words, the EELS acceptance aperture has an effectively infinite acceptance angle at this energy, and all the high angle scattering in the spectrum, including that heavily affected by lens aberrations, is included in the spectrum. This will clearly add extra components to the background that are nothing to do with the regular continuum scattering underlying regular EELS edges. On the other hand, the optimized 2cmC camera length (where the "C" stands for Chromatically corrected) is still transferring information well into the spectrometer at 3500 eV loss, and finally reaches a crossover near 5500 eV. Seeing as the crossover previously observed for the optimized 200 kV version of the 2cmC camera length was at 9200 eV, so our results at 80 kV show that we are able to do rather better than a simple $\Delta E/E$ scaling would suggest. This difference in projector setup makes a huge difference to something practical - quantification of EELS edges of common semiconductors. Prior to optimizing this, there were huge problems in the 1-2 kV range due to excess intensity coming inside the EELS entrance aperture as the EEL stripe starts to fold inwards. This spoils the background subtraction for EELS edges like Si-K (as shown in Figure 1a, but similar problems would be encountered for Ga-, Ge-, and As-$L_{2,3}$ edges. The background behaves much better using the optimized 2cmC camera length and the power law extrapolation is followed very well. Further detailed characterization of the 2cm and 2cmC camera lengths will be presented including how acceptance angle and cutoff angle vary with energy loss in the two cases.

References

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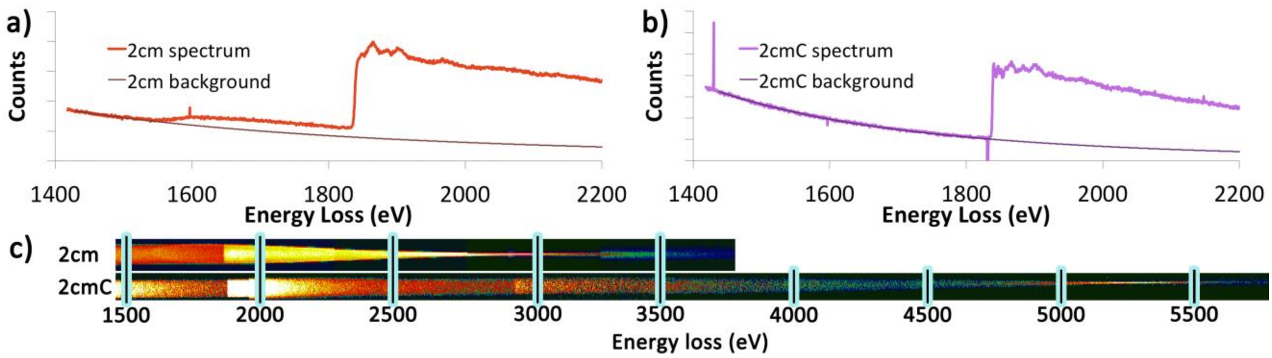

Figure 1: The effects of optimizing the 2cm camera length for best EELS performance at 80 kV: a) EEL spectrum of silicon recorded with the original 2 cm camera length, showing excess intensity in the background above about 1500 eV; b) EEL spectrum recorded in the same way from the same area using the optimized 2cmC camera length; c) a comparison of what the EEL spectra look like on the CCD as a function of energy loss.