Performance of MANDOLINE filter and Ω-type monochromator

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The MANDOLINE filter, proposed by Uhlemann and Rose [1] and developed by Zeiss, shows an extraordinary filter acceptance, isochromaticity, and energy resolution, even for large fields of view. This outstanding analytical performance is seen in the Zeiss SESAM microscope, which furthermore includes the CEOS electrostatic Omega-type monochromator [2,3], a highly stable 200 kV high voltage supply, and a highly stable current supply of the filter. The EEL spectra and CBED pattern in Figures 1 – 6 exemplify the analytical performance at 200 kV.

In Figure 1 the attainable energy resolution is shown to be 43 meV (FWHM) for 0.1 s exposure time with a small filter entrance aperture. At short exposure times, this is mainly limited by the energy window width of the smallest monochromator slit, which is about 40 meV. Although long exposure times and large fields of view lead to some degradation in the energy resolution due to instabilities and the filter's geometric aberrations respectively, the results are still excellent: Figure 2 shows an energy resolution of only 87 meV (FWHM) for an exposure time of a 100 s, which demonstrates the stability of both the high voltage and the MANDOLINE filter current.

With the small filter entrance aperture a region of 23 mm diameter can be illuminated on the SSCCD camera in the imaging mode, while the large filter entrance aperture can illuminate a region of 120 mm diameter on the viewing screen or entirely illuminate any other detector. Figure 3 demonstrates an energy resolution of only 52 meV (FWHM) with this large filter entrance aperture, which proves the success in correcting the aberrations of the MANDOLINE filter. Figure 4 shows a logarithmic plot of Figure 3 (after scaling the maximum to 10^6). The extreme steep drop of the zero-loss peak in Figure 4 establishes ideal preconditions for band gap measurements and investigations in the very low-loss region. Furthermore the good signal-to-noise ratio indicates the available high beam current in spite of 52 meV energy resolution, 0.1 s exposure time, and 530 Channels/eV.

The Comparison of zero-loss peaks for different monochromator slit widths in Figure 5 was carried out with identical microscope parameters for all three spectra. The steep slopes of the monochromated zero-loss peaks allow not only excellent energy resolution, but also yield almost the maximum possible current. At 126 meV energy resolution the mono-chromated zero-loss peak in Figure 5 has the same height as the unfiltered zero-loss peak and even at 48 meV energy resolution the height of the zero-loss peak drops only by 16%.

The CBED pattern of Si [100] in Figure 6 demonstrates the exceptionally high transmissivity of the MANDOLINE filter, which allows EFTEM Spectroscopic Imaging (EFTEM SI) with energy windows ≤ 200 meV.

References

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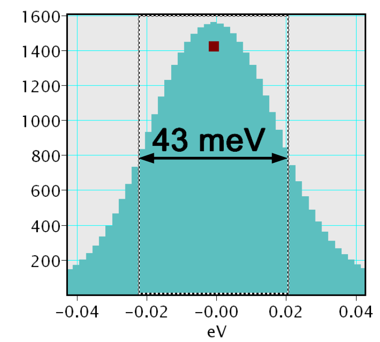

Figure 1. 43 meV energy resolution of the zero-loss peak for 0.1 s exposure time. (sum of 30 spectra; small aperture)

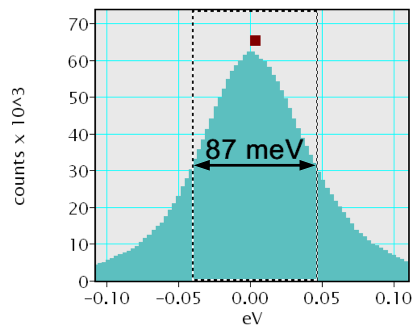

Figure 2. 87 meV energy resolution of the zero-loss peak for 100 s exposure time. (small aperture)

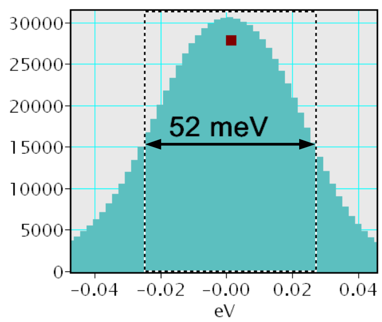

Figure 3. 52 meV energy resolution of the zero-loss peak for a large filter entrance aperture (0.1 s exposure time). With this aperture, the whole detector can be illuminated in the imaging mode.

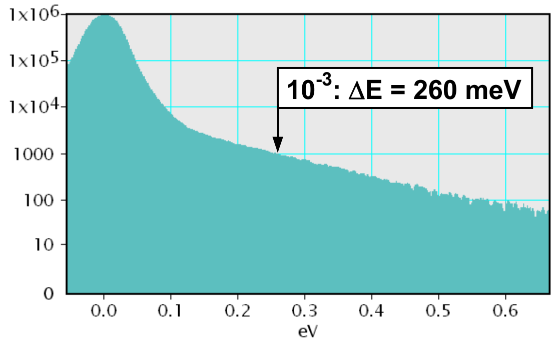

Figure 4. The zero-loss peak drops by 10 after 48 meV, 10^2 after 91 meV, 10^3 after 260 meV, and 10^4 after 570 meV.
(large filter entrance aperture, 530 Ch/eV, 0.1s exposure time, maximum scaled to 10^6)

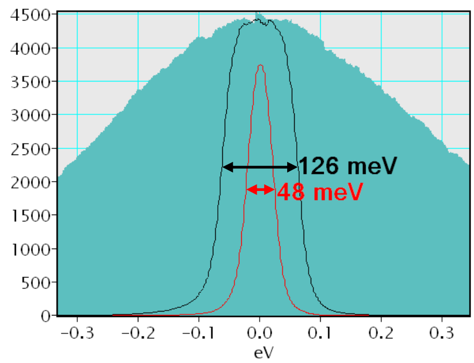

Figure 5. Comparison of zero-loss peaks for different monochromator slit widths and the unfiltered zero-loss peak (660 meV FWHM) with identical microscope parameters for all spectra.

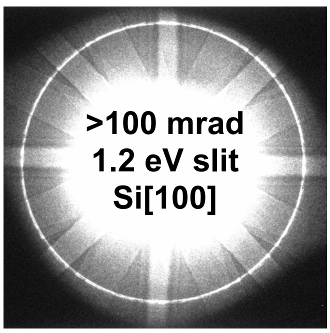

Figure 6. CBED pattern of Si [100];
>100 mrad are transferred at 1.2 eV energy slit width.

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