Microsc. Microanal. 8 (Suppl 2) 2002
DOI 10.1017.S143192760210184X

Monochromized 200kV (S)TEM

P.C. Tiemeijer, J.H.A. van Lin, B.H. Freitag, and A.F. de Jong

FEI Electron Optics, P O Box 80066, 5600 KA Eindhoven, The Netherlands

FEI recently completed the development of a monochromator for a Tecnai F20ST by successfully installing a monochromized 200kV (S)TEM at the National Centre for High Resolution Electron Microscopy at the University of Delft. This instrument features a special 200kV supply, a dedicated High Resolution Gatan Imaging Filter (HR-GIF) [1], and a monochromator [2]. This instrument is primarily intended for high resolution Electron Energy Loss Spectroscopy (EELS), in order to enable analysis of bonding states on a nanometer scale, and chemical analysis on a sub-nanometer scale. When the monochromator is on, the system can do EELS with an energy resolution down to 0.10 eV at a spatial resolution $\lesssim$2 nm. When the monochromator is not used, the microscope has 0.50 eV resolution at a spatial resolution of 0.2 nm.

When the monochromator is off, the optics and performance of the microscope is very similar to that of a standard Tecnai F20ST. When the monochromator is switched on, the optics are as sketched in Figure 1. The Wien-filter type monochromator is located directly behind the field emission gun (FEG) and creates a small dispersed image of the source at its exit plane. The accelerator magnifies this dispersed image to the energy selection slit, which is integrated in the C1 aperture holder in front of the first condenser lens. The first condenser lens and objective lens can be used to demagnify the filtered image at the selection slit on to the specimen.

From the outside, this microscope looks just like a standard 300kV TEM: the HT supply has the size of a 300kV supply (because of additional RC filters which reduce the 25 kHz ripple of the high tension generator and its power converters down to 10 mV at 200 kV), the accelerator has the size of a 300 kV accelerator (in order to accomodate the monochromator), the monochromator and FEG supplies (redesigned in small SMD technology) all fit in the small vessel floating at HT close to the FEG at the back side of the column, and the monochromator controls are completely integrated in the Tecnai software.

The user aligns the monochromator as follows: first he sets the condenser system such that the dispersive plane is in focus. Next he sets the desired dispersion and monochromator potential. Beam shift and astigmatism in the FEG or monochromator or accelerator can be corrected with an electrostatic multipole in the monochromator. Astigmatism is judged simply by looking at the dispersed image. The shift and astigmatism can be stored such that they are automatically recalled when the same monochromator dispersion and potential are chosen again. With these, one can switch between monochromator off and on within fractions of minutes. After that, the energy selection slit of the monochromator is inserted and centered.

An important parameter for the performance of the microscope is the quality of its environment, especially with respect to stray magnetic fields and temperature variations. This is nicely illustrated in Figure 3 which shows the FWHM of the zero loss peak as measured as a function of exposure time. At the shortest exposure time (see Figure 2), the resolution is limited only by the HF ripple and the aberrations and point spread function of the monochromator and GIF. When the exposure time is increased, contributions of stray magnetic fields (especially 50 Hz and 150 Hz), noise and drift start to worsen the resolution.

Figures 4 and 5 show a typical example of how the information in an energy loss spectrum can be increased by the monochromator. Figure 4 shows the Ti-L_{23} peaks in rutile (TiO_2) as measured on a standard F20ST with 0.70 eV resolution, whereas Figure 5 shows the same peaks measured on the monochromized F20ST tuned to 0.25 eV resolution. As discussed in Ref. [3], the peaks visible in Figure 5 are caused by spin-orbit interactions, the crystal field effect, bonding symmetry breaking, and by transitions to a triplet state. In this way, with the improved EELS resolution a better understanding of local bonding states can be obtained.

References

1. M. Barfels et al., *elsewhere in these proceedings.*
2. P.C. Tiemeijer, *Inst. Phys. Conf. Ser.* 161(1999)191.
3. C. Mitterbauer et al., *contribution to ICEM15* (2002).

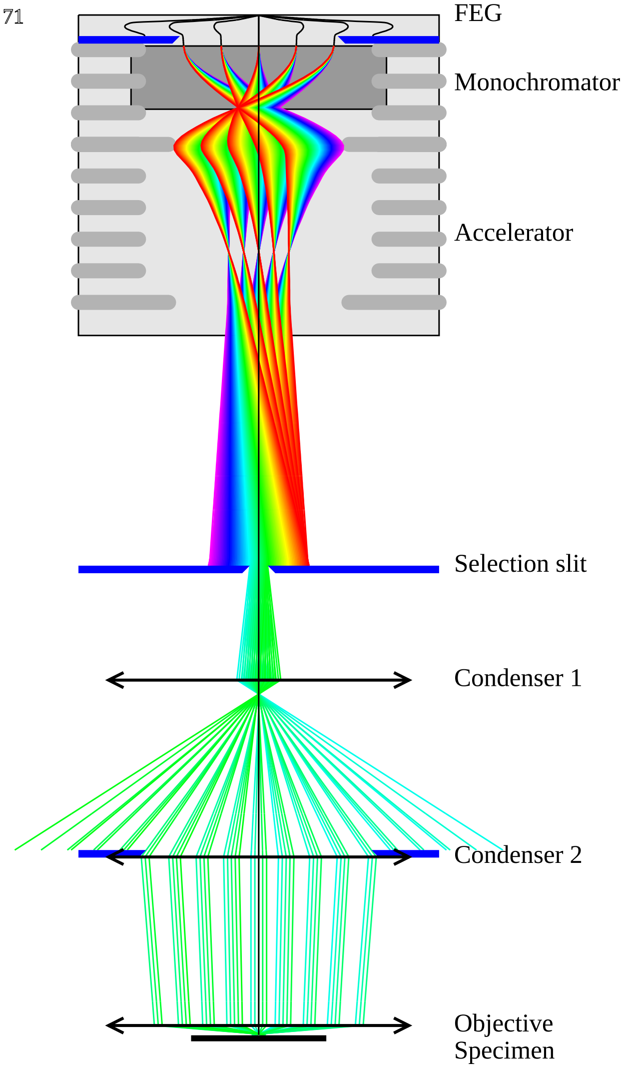

FIG. 1. Typical electron trajectories from source to specimen in the monochromized TEM. Different energies are indicated by different colors.

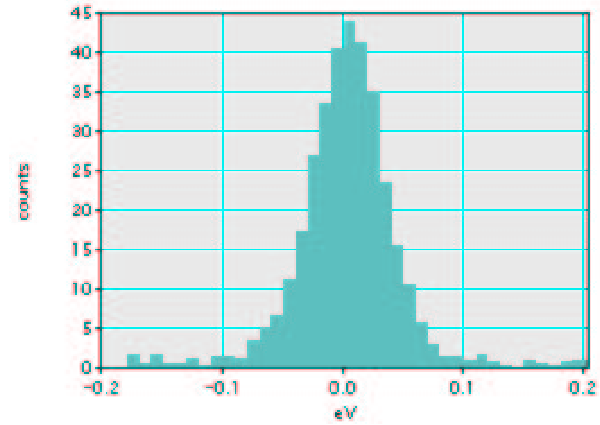

FIG. 2. Zero-loss peak measured at maximum dispersion of the monochromator, smallest GIF entrance aperture, and 1 ms exposure time.

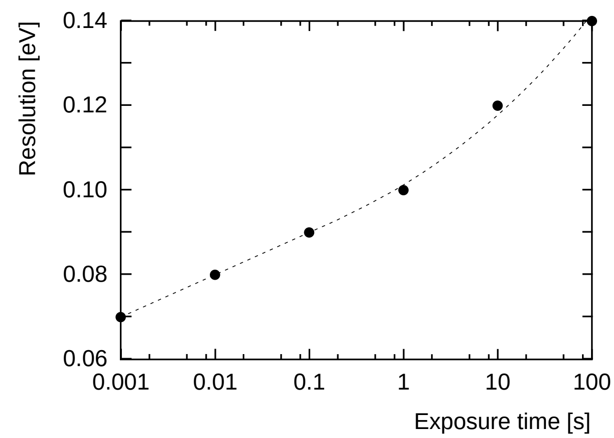

FIG. 3. Full Width at Half Maximum of the zero-loss peak as a function of exposure time, at maximum dispersion of the monochromator.

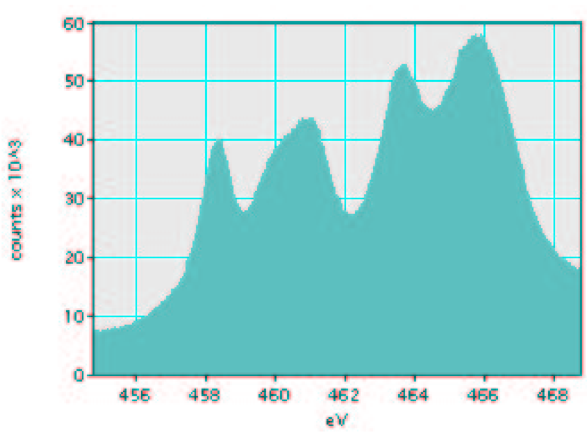

FIG. 4. EELS spectrum of the Ti-L_{23} peaks in TiO_2 measured on a standard Tecnai F20ST with 0.70 eV resolution.

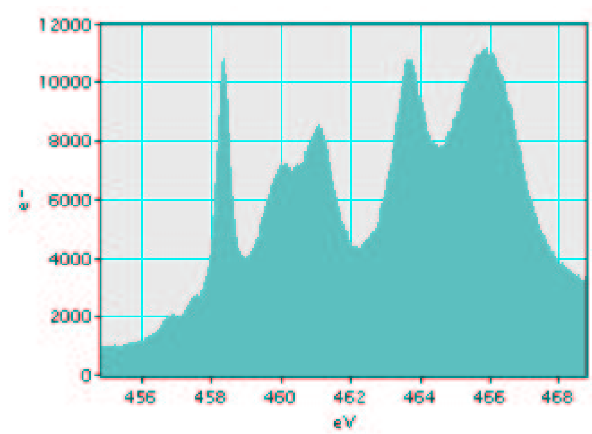

FIG. 5. EELS spectrum of the Ti-L_{23} peaks in TiO_2 measured on the monochromized Tecnai at 0.25 eV resolution (sample courtesy of F. Hofer, Felmi Graz).

https://doi.org/10.1017/S143192760210184X Published online by Cambridge University Press