P33: Low voltage transmission electron microscopy in Austria

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The term “low voltage” is not clearly defined in electron microscopy, neither for transmission electron microscopes (TEM), nor for scanning electron microscopes (SEM). Whereas 60 keV for (S)TEM was quite exotic a few years ago [1], it became a standard beam energy now-a-days. In general, low beam energies go hand in hand with a poorer spatial resolution since the De Broglie wavelength of the swift probe electron increases with decreasing kinetic energy. On the other hand, there are also some advantages as long as various threshold energies are not exceeded. There can be several threshold energies defined, like the one for knock-on beam damage [2], atomic displacements, or for Čerenkov radiation emission [3].
Table 1 gives a short overview over some threshold energies (in keV). Additionally, table 2 gives an overview over the available beam energies of TEMs used in Austria. It is remarkable, that most of the Austrian equipment can easily be used in the low keV range, at least for imaging.

	knock-on threshold	atomic displacement	Čerenkov limit
C-based materials	< 70 keV	<50 keV	-
semiconductors	100-200 keV	<100 keV	<60 keV
metals	180 – 1500 keV	<600 keV	-

Table 1: threshold energies in electron microscopy

TFS/FEI	Titan/Tecnai	30-300 keV/20-200 keV
JEOL	F200, NeoARM	20-200 keV
ZEISS	Libra 120, EM910	40-120 keV
NION	Hermes	30-200 keV

Table 2: possible beam energies of conventional TEMs operated in Austria

Austrian researchers are low voltage EELS (LVEELS) pioneers [4] and were associated members in the big German Sub-Ångstrom-Low-Voltage-Electron microscope (SALVE) project. The growing interest in low radiation energies can be seen from the fact that some publishers have already or are currently publishing special editions on this topic and that TEM manufacturers are also offering low-voltage alignments.

[1] Kaiser, U., Stöger-Pollach, M., Foreword to the special issue Low-Voltage Electron Microscopy, Ultramicroscopy (2014) 1-2
[2] Kaiser, U. et al., Transmission electron microscopy at 20 kV for imaging and spectroscopy, Ultramicroscopy (2011) 1239-1246
[3] Stöger-Pollach, M., Optical properties and bandgaps from low loss EELS: Pitfalls and solutions, Micron 39 (2008) 1092-1110
[4] Stöger-Pollach, M., et al., Čerenkov losses: A limit for bandgap determination and Kramers–Kronig analysis, Micon 37 (2006) 396-402