DOI: 10.1017/S1431927605509802
Microsc Microanal 11(Suppl 2), 2005

Nion UltraSTEM™: An Aberration-Corrected STEM for Imaging and Analysis

N.J. Bacon, G.J. Corbin, N. Dellby, P. Hrncirik, O.L. Krivanek, A. McManama-Smith, M.F. Murfitt, and Z.S. Szilagyi

Nion Co., 1102 8th St., Kirkland, WA 98033, USA

Adding a Nion spherical aberration (C_s) corrector [1] to a Vacuum Generators (VG) scanning transmission electron microscope (STEM) typically improves its resolution by 2–2.5x, i.e. to better than 1 Å at 100 keV [2] and to about 0.6 Å at 300 kV [3]. This has resulted in many new applications for these instruments, such as numerous determinations of new structures, dynamic studies, and single-atom-sensitivity EELS (e.g. [4]).

VG STEMs have several attributes that make such performance possible when retrofitted with an aberration corrector. The chief one is the high quality of their cold field emission guns (CFEGs), whose brightness is typically $>10^9$ A/(cm^2 sr) at 100 kV. However, they also have weaknesses that create barriers to further progress. The VG condensers are difficult to align and drift for more than an hour if their current is changed. The objective lens in the 100 kV VG has a large upper bore, which prevents it from operating as a Riecke-type symmetric condenser-objective lens with minimized aberration parameters on both the entry and exit sides of the lens. Further, most 100 kV VGs have no sample height (Z) adjustment capability, and have a weak post-sample objective lens field. This saddles them with varying optical parameters when the sample tilt is changed, and with poor post-sample compression and consequently a hard-to-optimize EELS collection efficiency.

Addressing these problems is essential for further progress, and this is the path now pursued at Nion. Accordingly, we are developing a new STEM column, and also a new 200 kV cold field emission electron gun. The two projects presently proceed on separate tracks. New columns #1 and #2 are being assembled on top of existing 100 kV VG guns. They will be delivered in this configuration, with projected properties superior to any 100 kV VG. The new gun is being developed in a separate lab. In the long run, the new column and the new CFEG will be combined in an instrument named Nion UltraSTEM™.

The new column incorporates a new aberration corrector of fifth order aberration (C_5) in addition to C_s, described elsewhere in these proceedings [5]. It further has three condenser lenses (two round lenses plus a lens made from 3 quadrupoles) a symmetrical condenser-objective lens with C_s~C_c~0.8 mm, an ultra-stable 5-axis goniometer based on new construction principles, a detachable side-entry specimen cartridge that gives +/- 30° of tilt in all directions, two post-specimen round lenses, a quadrupole lens module for EELS coupling, and a variety of detectors including bright-field, high-angle and medium-angle dark-field detectors, a 1k x 1k CCD camera for Ronchigram and general diffraction pattern recording, and a parallel detection EELS (Gatan Enfina). Theoretical HAADF resolution at 200 kV is better than 0.4 Å [5].

Table 1 compares the key properties of the new STEM with the VG STEM and a typical modern TEM/STEM column. Fig. 1 shows a mechanical drawing of the entire UltraSTEM™ including the new CFEG. Fig. 2 shows the new column being tested at Nion.

In summary, a new dedicated STEM with a 200 kV CFEG, a C3/C5 aberration corrector, and several other new design elements is being developed at Nion. Results from its new electron-optical column will be presented at the meeting.

[1] N. Dellby et al., J. Electron Microscopy **50** (2001) 177.
[2] P.E. Batson, N. Dellby and O.L. Krivanek, Nature **418** (2002) 617.
[3] P.D. Nellist et al., Science **305** (2004) 1741.

[4] O.L. Krivanek et al., Proceeedings 2004 MRS fall meeting, in press.
[5] N. Dellby et al., these proceedings.

attribute	**VG STEM**	**typical TEM/STEM**	**Nion UltraSTEM**
gun type	CFEG	Schottky	CFEG
gun brigtness at 100 kV (A/(cm^2 sr)	1 x 10^9	2 x 10^8	> 1 x 10^9
vacuum sealing method	single or double o-rings (w. guard vac.)	single O-rings	metal seals (except for detectors)
sample-level press. (torr)	< 10^{-8} to <10^{-9}	~ 10^{-7}	< 10^{-9}
column bake temp. (°C)	120-140	not bakeable or 80	120
objective lens (OL) type	asymmetric (symm. at 300 kV)	symmetric condenser-objective	symmetric condenser-objective
typical OL aberration coefficients (mm)	$C_s = 1.3$ $C_c = 1.3$	$C_s = 0.5\text{-}1.2$ $C_c = 1.2$ (polepiece-dependent)	$C_s = 0.8$ $C_c = 0.8$
post-sample angular compression	3x (100 kV); 5-10x (300 kV)	50-100x	20-100x
sample holder	cartridge: top insertion (100); side ins. (300)	side entry rod	side insertion cartridge
sample Z-adjustment	no (100); yes (300)	yes	yes

Table 1. Key parameters of the new column compared to VG STEMs and modern TEM/STEMs.

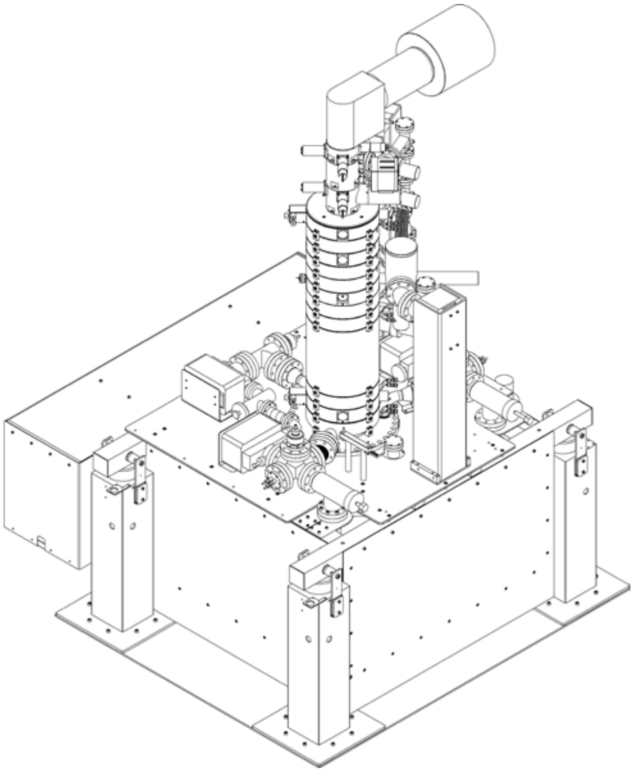

Fig. 1. Design drawing of the 200 kV CFEG Nion UltraSTEM™.

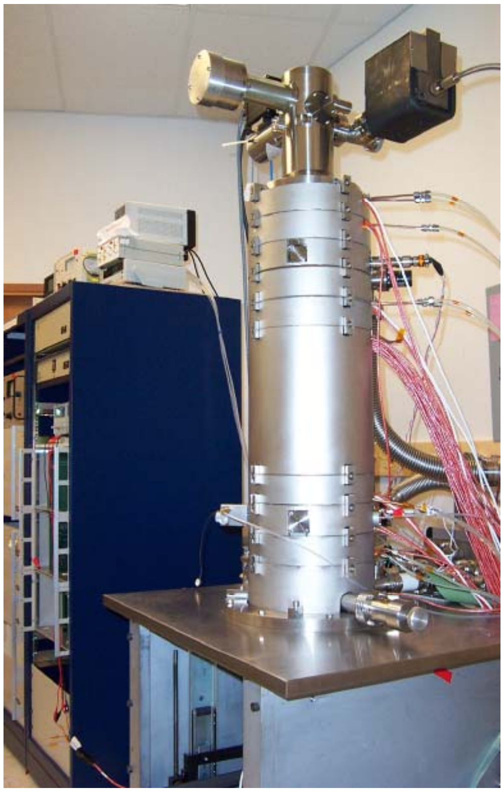

Fig. 2. The new column mounted on a 100 kV VG gun.