

A modular 100 keV vacuum sealed FEG for high resolution electron microscopy

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Recent advances in electron cryomicroscopy have found that an electron beam energy of 100 keV is preferable to higher beam energies in terms of the useful information obtainable from single-particle biological specimens [1,2]. A similar electron beam voltage requirement has been called for in electron beam lithography and some materials science applications [3,4]. A dedicated modular field emission electron gun (FEG) operational to 100 kV to address such a need is reported. The FEG's vacuum chamber is transported under ultra-high vacuum (UHV) to facilitate a fast exchange of a used emitter, thus avoiding baking the FEG unit to achieve the necessary operational base pressure, 10^{-10} mbar and hence reduce instruments being off-line for long periods. A manual isolation valve on the FEG's optical axis is used during transportation, whilst a differential aperture in the FEG vacuum chamber allows a pressure differential of $>10^{-2}$ times the base pressure to be achieved between the FEG and the microscope column.

The present design lends itself to integration onto existing high voltage electron columns, such as upgrading thermionically operated transmission electron microscopes (TEMs) or electron beam lithography (EBL) systems into FEG operation, as well as using it in research and development applications. The FEG vacuum chamber occupies a physical envelope of approximately 210 mm diameter and about 315 mm height (in addition to the high voltage plug and cable). In its current configuration, it has spherical and chromatic aberration coefficients (C_s and C_c) in the range of, $C_s = 45\text{-}55$ mm and $C_c = 25\text{-}27$ mm, at 100 keV over a range of working distances of 10 mm to 60 mm from the exit plane of the FEG unit.

A further requirement in high resolution field emission electron optical systems is that all the electrodes must have stable voltage and current supplies. A stand-alone 100 kV Power Supply Unit (PSU) together with a plug, cable and vacuum feedthrough has also been developed to operate the present FEG. The PSU has high stability for all its outputs with voltage ripples of less than 1 ppm on the beam potential at 100 kV. Further, an advantageous feature of this development is that the FEG, the feedthrough and the high voltage plug assembly do not require the use of SF₆ gas, as is customary for high voltage FEGs used on TEMs. This allows an easier 'hot swap' transition for emitter exchange.

Operation of the FEG has been demonstrated on a Tecnai 12 TEM (FEI), whereby the original thermionic hairpin electron source, the electron gun chamber and EHT unit were replaced with the aforementioned FEG unit. The sealed FEG chamber was installed on the column under a base pressure in the range of 10^{-10} to 10^{-11} mbar. To maintain UHV during operation, an intermediate vacuum chamber evacuated with an ion getter pump was added to the interface between the FEG chamber and the microscope column to achieve a base pressure in the range of 10^{-8} mbar at the entrance to the gun chamber.

Preliminary results show that an electron beam current stability of $< 1\%$ drift over 24 hrs and $< 0.5\%$ over 1 minute are achieved; operation in the voltage range of 30-100 kV has been demonstrated. Graphitic carbon as well as gold particles have been resolved confirming a resolution limit of better than 2.4 Å at 60-100 keV. The source brightness for this FEG has been estimated for an emitter operated at an angular current intensity of the order of 250-300 mA/str to be of the order of 150 times higher than the tungsten hairpin source which it replaced.

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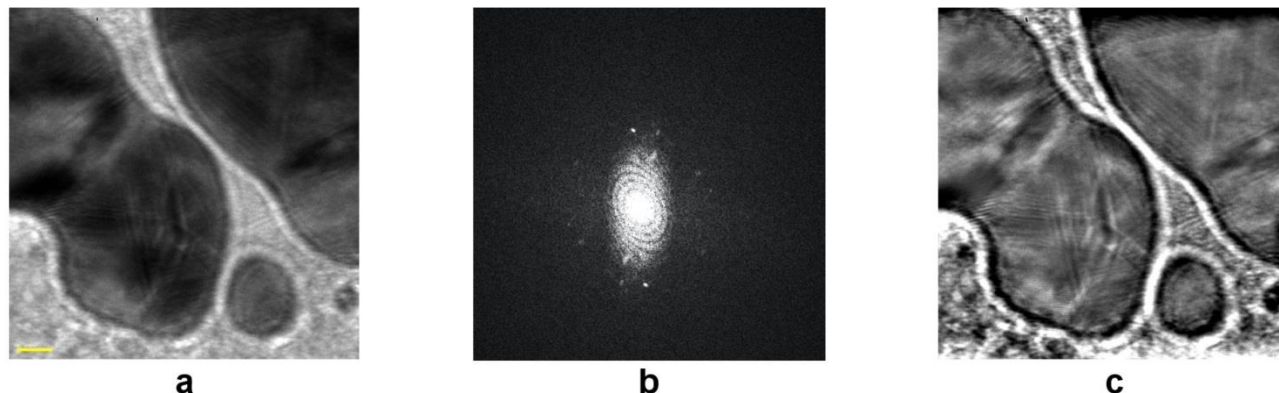


Figure 1. Figure 1: Bright field image of gold particles on amorphous carbon at 90 keV using modular FEG source. Nominal magnification was 570 kx on phosphor coupled CCD detector (Gatan Ultrascan 1000) binned 2×2 pixels, with exposure time 2 s using a beam current of 200 pA uniformly illuminating a region slightly larger than the image. Panel a is the original image, b is the FFT of the original image and, c shows the inverse FFT of the masked FFT. Scale bar is 100 Å.

References

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