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The Case for Lower Voltage TEMs: A 100 keV FEG for High Resolution Microscopy

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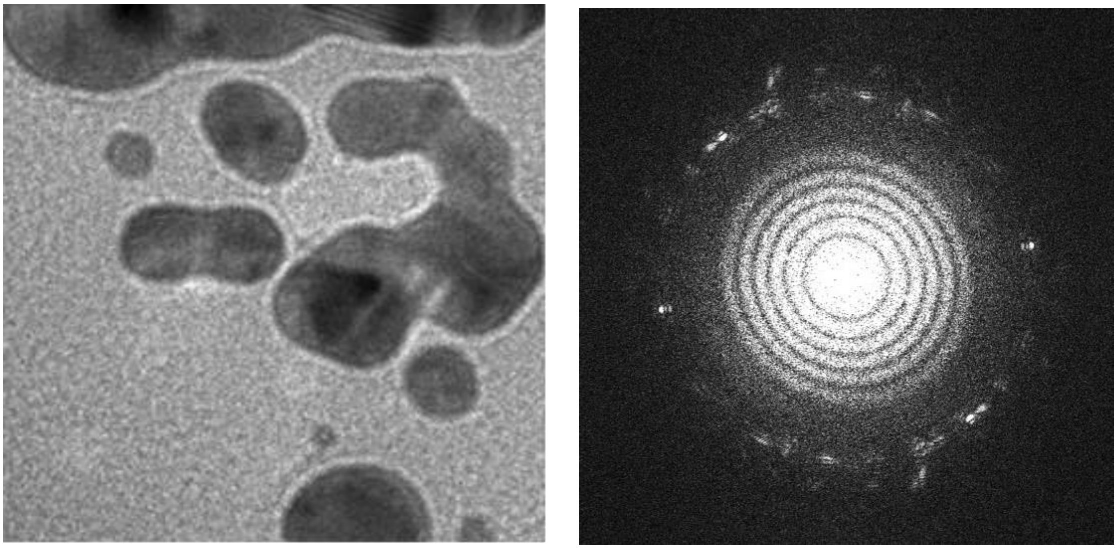
Whilst high voltage transmission electron microscopy (TEM) above 100 kV is useful in resolving atomic dimensions in many disciplines, and the imaging of thick specimens, it is often found that the majority of specimens being analysed dictate the opposite. An obvious and well documented case demonstrating this reality is electron cryomicroscopy (cryoEM) [1]. In cryoEM, this preference is based on corroborated studies showing that a beam energy of 100 keV is preferable to higher energy (300 kV) in terms of the useful information obtainable from single-particle biological specimens for the same amount of radiation damage [1]. Furthermore, inspection of the Protein Data Bank over the last 10 years or so, shows that the resolution of most of these reported structures are in the range of 0.3 nm to 0.9 nm; a modest resolution range in terms of what the current instrument capabilities can routinely achieve.

Electron beam damage is not only restricted to biological samples, though. Such a need for a moderate voltage instrument, 50-100 kV, is equally called for in material science as well as electron beam lithography [2]. It is obvious that even in the cases necessitating higher resolution, an electron energy below 100 keV could still be applicable, where it is suggested that alternative electron optical configurations, such as aberration correctors [3] or novel higher brightness and lower energy spread electron sources [4] should be used to achieve such a goal.

We will compare the advantages and complexities of TEMs based on their electron beam energy range. One important factor in achieving high resolution electron optical instruments has been the use of field electron emitter sources, in preference to thermionic based cathodes. It is now customary to find such instruments equipped with a field emission gun (FEG), but these have largely been for 200 kV to 300 kV instruments. Furthermore, conventional FEG designs necessitate the use of undesirable gases, such as SF_6, often in a dedicated chamber surrounding the FEG. Such designs place further constraints on the maintenance of the instrument, particularly when exchanging the electron source.

A stand-alone vacuum sealed 100 kV FEG together with its high voltage supply has been developed [5]. This design allows one to replace an existing thermionic gun with a FEG, to take advantage of its higher brightness and much smaller source size. The vacuum sealed FEG is of a compact design measuring about 310 mm in height and a 250 mm in diameter. This vacuum chamber is interfaced with an intermediate vacuum chamber between the TEM's main column and the FEG. It is estimated that there are around 7,000 thermionic based TEMs around the world, which could in principle take advantage of such upgrades to relieve the time constraints in using the more dedicated higher voltage TEMs in cryoEM applications.

Gold (111), 0.235 nm and (200), 0.202nm lattice fringes shown in Fig. 1 demonstrate the much-improved resolution of the stand-alone FEG, collected on a Tecnai T12 (Philips/FEI, now Thermo) and on a JEOL 1400HR. Further examples from cryoEM will also be given [6].



a) b)

Figure 1. Bright field image of gold particles on amorphous carbon at 90 keV using the modular FEG source on a JEOL 1400HR, where Gold (111), 0.235 nm and (200), 0.202nm lattice fringes are clearly resolved. Nominal magnification was 500 kX on phosphor coupled CCD detector (Gatan Orius SC600A) binned 4 x 4 pixels, with exposure time 2 s using a beam current of 500 pA uniformly illuminating a region slightly larger than the image. Panel a) is the original image, b) is the FFT of the original image.

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