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Application of Low Voltage Transmission Electron Microscopy

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The fundamental aspects of electron microscopy all relate directly to the physics of the interactions between the electron beam and sample. Energetic electrons are described as “ionizing radiation” - the general term used to describe radiation that is able to ionize or remove the tightly bound inner shell electrons from a material. This is obviously an advantage for electron microscopy in that it produces a wide range of secondary signals such as secondary electrons and X-rays, but is also a disadvantage from the perspective that the sample is “ionized” by the electron beam and possibly structurally damaged, which depending on the accelerating voltage happens in a number of different ways. The advantages of using a lower accelerating voltage for the electron beam are that the energy is reduced and hence the momentum that can be transferred to sample from the electron is also reduced. This, however, has the unwanted effect of reducing the possible emitted signal; although, with recent improvements in detectors, cameras and the use of aberration correctors, the signal to noise and the resolution to produce a final image can not only be maintained but are actually improved.

Low-Voltage High-Resolution Electron Microscopy (LVHREM) has several advantages (and of course disadvantages), including increased cross-sections for inelastic and elastic scattering, increased contrast per electron and improved spectroscopy efficiency, decreased delocalization effects and reduced radiation knock-on damage [1,2,3]. Together, these often improve the contrast to damage ratio obtained on a large class of samples. 3rd order aberration correction now allows us to operate the TEM at low energies while retaining atomic resolution, which was previously impossible. At low voltage the major limitation to resolution becomes the chromatic aberration limit. Some applications require the imaging of the specimen with a large energy width ΔE. One example is the imaging of biological specimens. Here, due to radiation damage, one would like to work with the minimum dose. Unfortunately, a lot of electrons that carry useful object information due to the elastic scattering within the specimen, also undergo some inelastic scattering while passing through the sample and the embedding substrate (ice, carbon film, etc.). Inelastic scattering increases the energy width of the beam far beyond the initial energy width of the electron gun of only about 0.6 eV.

Using the spherical aberration corrector in conjunction with electron monochromator for example at 40 keV takes the user surprisingly close to the lower bound imposed by fifth-order spherical aberration, and enables imaging with an information limit better than 1Å, and a workable resolution of better than 1.4Å.

References:

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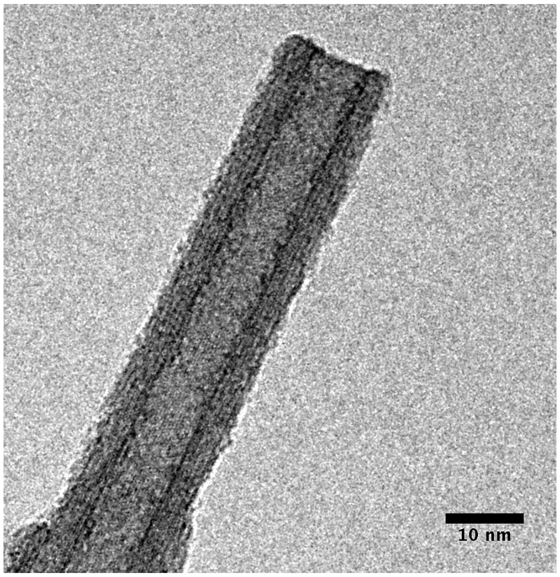

Figure 1. Optically variable pigment imaged at 40 keV.

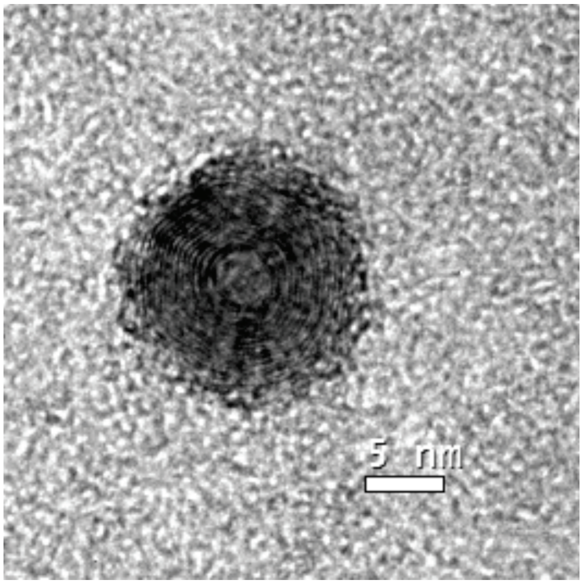

Figure 2. Carbon Nano-onion imaged at 40 keV showing clearly the carbon layers.