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High Resolution 20kV Transmission Electron Microscopy of Nanosystems: First Results Towards Sub Ångstrøm Low Voltage *EM (SALVE* – Microscopy)

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For imaging all points of a large object field with the same optimum instrumental resolution at voltages down to 20kV, the components of the transmission electron microscope need to be newly specified and designed; here the axial chromatic aberration dominates resolution. In particular chromatic and spherical aberration must be eliminated by a suitable corrector. The aim of the *SALVE* (Sub Ångstrøm Low Voltage Electron Microscopy) project is the development of ultra-high-resolution, dose-optimized transmission electron microscopy for electron radiation-sensitive materials. Those materials cannot be investigated at their atomic level with present technology [1].

Here we report our first experimental results on the route towards *SALVE* microcopy, testing the performance of a standard LIBRA 200 microscope platform at 20kV. The instrument is equipped with a monochromator (an electrostatic spectrometer of Ω-type), an in-column Ω -type energy filter, and a CETCOR corrector for spherical aberration correction [2] aligned for 20kV operation. By employing the Young's fringes method, our instrument showed an information transfer up to 250 pm. From the zero-loss peaks of the EELS spectra at 20kV, the energy spread was measured to be 100eV with an exposure time of 1s.

Figures 1 (a) and (b) show raw HRTEM images of [110] Si (a) and platinum islands on a thin amorphous carbon foil (b) at 20kV with 2µm energy slit (ΔE_{fwhm}= 0.15eV), zero-loss filtered, and an exposure time of 1 s. Fig. 1b was acquired under tilted illumination condition (beam tilt of 18 mrad) for resolution enhancement [3]. The first order reflections (Si_{111} and Pt_{111}) are clearly transferred. Higher transfers down to 196 pm (Pt_{200}) can also be seen, however, non-linear transfer has to be assumed because of strong dynamic interactions.

Single-layer graphene and functionalized endohedral fullerenes in carbon nanotubes are challenging objects with respect to both resolution and contrast at 20kV. In Figure 2 we show as an example (Nd@C_{82})@DWNT metalofullerenes. The double walls of the carbon nanotube with a separation width of 340pm are clearly visible. Under the 20keV electron beam the fullerenes are extremely stable; a dose of 10^9 e/nm^2 could be applied without noticeable beam damage. Why, however, the Nd atoms do not show up with higher contrast, is a matter of current investigation.

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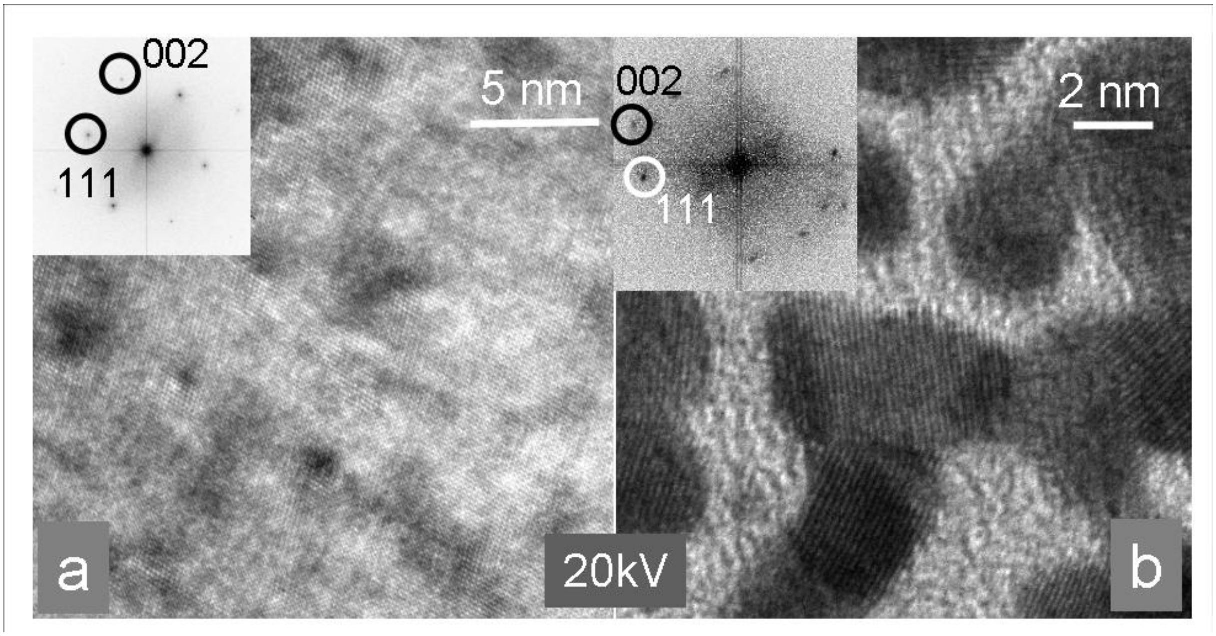

FIG 1: (a) Monochromated 20kV raw HRTEM image (a) Si[110] and (b) Pt on thin carbon foil. In both images lattice fringes are clearly transferred (see the Fourier Transform in the inserts). Image (b) was acquired using tilted illumination to increase the transfer.

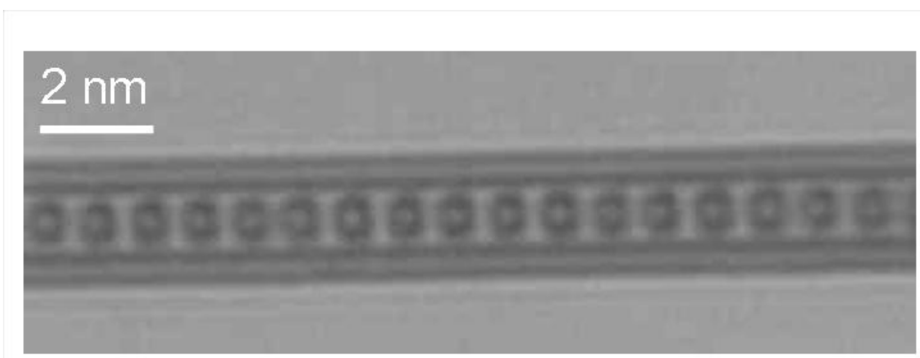

FIG. 2 Monochromated 20kV HRTEM image of Nd@C82@DWNT. It is composed of 100 cross-correlated images for signal/noise enhancement. The double walls (distance 340pm) are clearly separated. Under the 20keV electron beam the fullerenes were extremely stable; a dose of 10^9 e/nm^2 could be applied without noticeable beam damage.

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