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MS-2-P-3372 Imaging of carbon nanostructures by low energy STEM below 5 keV

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Our work deals with the imaging of nanostructures composed of light biogenic elements, such as carbon nanotubes, by low energy scanning transmission electron microscopy (STEM). Compared to imaging at the voltages commonly used for TEM and STEM, low energy electrons seem very promising in terms of specimen damage that is caused by a number of elastic and inelastic collisions [1]. In carbonaceous materials, the most problematic is probably the knock-on damage, where the structure can be impaired by carbon atom displacement. To avoid this problem with structures composed of light elements, a reduction in beam voltage going down to 5 keV has recently been proposed [2]. The range below 5 keV has not been explored yet for this purpose, although electron scattering in matter is lower for these energies, which allows achieving a higher spatial resolution [3]. We aim to demonstrate that additional reduction of incident electron energy may yield interesting contrast features.

We used a FEI Magellan 400L microscope capable of high resolution imaging even at low and very low incident electron energies, equipped with a multi-segment, retractable STEM detector. Carbon specimens were prepared e.g. by depositing a solution of commercial Sigma Aldrich nanotubes, with dimethylformamide used as a solvent, on Agar S147 holey carbon mesh grids. Contrast features were recorded by secondary electron (SE), bright field (BF) and dark field (DF) detectors, including high-angle annular dark field (HAADF).

We have studied the aspects influencing the image information, such as incident electron energy, electron dose, sample thickness, the presence of the ubiquitous hydrocarbon contamination layer and other. The results were also tested using Monte Carlo simulations.

References:

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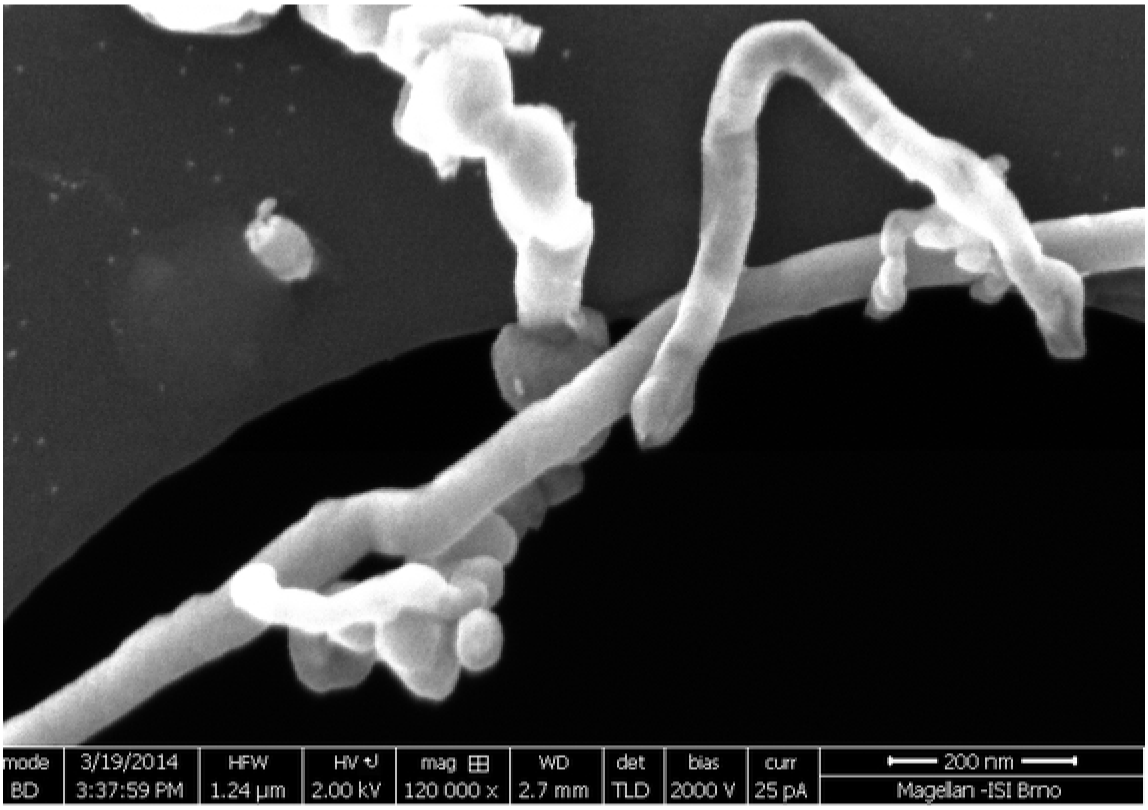

Fig. 1: Secondary electron image of carbon nanotubes at 2 keV incident energy.

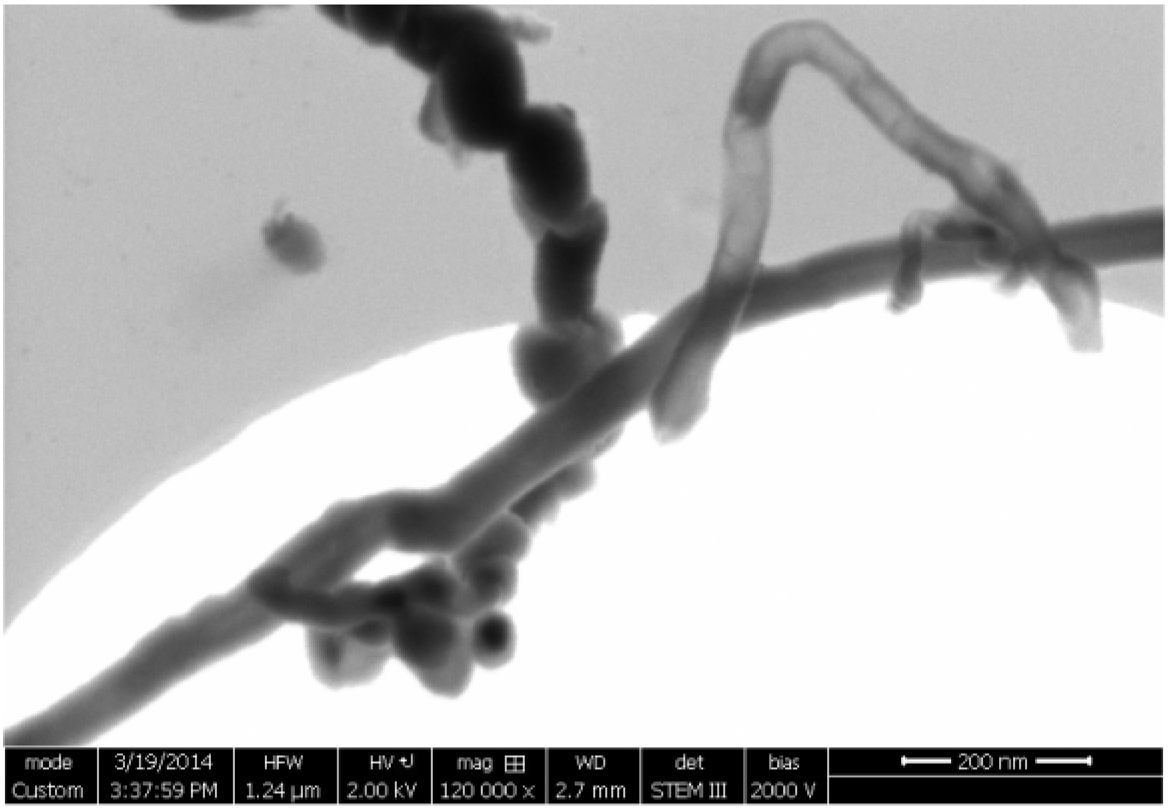

Fig. 2: Bright field STEM image of carbon nanotubes at 2 keV incident energy showing several thicknesses of multi-wall nanotubes, including embedded catalytic metal particles.