High-resolution TEM imaging and energy loss spectroscopy at low acceleration voltages

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We report on structural and electronic properties of low-dimensional objects obtained by analytical low-voltage aberration-corrected high-resolution transmission electron microscopy (AC-HRTEM). As results need to be confirmed by image calculation, for high-resolution TEM images the contribution of inelastic scattering must be taken into consideration [1]. For energy-filtered images of low-Z materials at low voltages, the contributions of elastic and inelastic scattering to the image intensity cannot be separated from each other because the inelastic scattering amplitudes are influenced by elastic scattering, and vice versa [2]. As signal-to-noise is limited for beam-sensitive materials, we show an approach to work with noisy images [3], to sandwich beam-sensitive objects in-between two graphene layers [4,5], and how to get graphene clean [6].

We show that lowering the energy of the electrons down to 20kV prevents various metal clusters and molecule inside CNTs from electron-beam stimulated damage [8]. The exchange of the isotopes of the molecules (deuterium instead of hydrogen) also enhances the stability against knock-on damage independent on the voltage [9]. We discuss the discovery of new structures such as 2D square ice [10] (see Fig.1) and crystalline AuC [11] (see Fig.2).

Moreover, we show that the monochromatic low-energy electron beam enables the acquisition of EELS spectra with exceptionally low background noise. In addition to the energy of electronic excitations, information on the momentum transfer can be obtained in the analytical TEM. We determine the dispersion behaviour for π and $\pi+\sigma$ plasmons in free-standing single-layer graphene and multilayers as benchmark experiments confirming earlier calculations [12].

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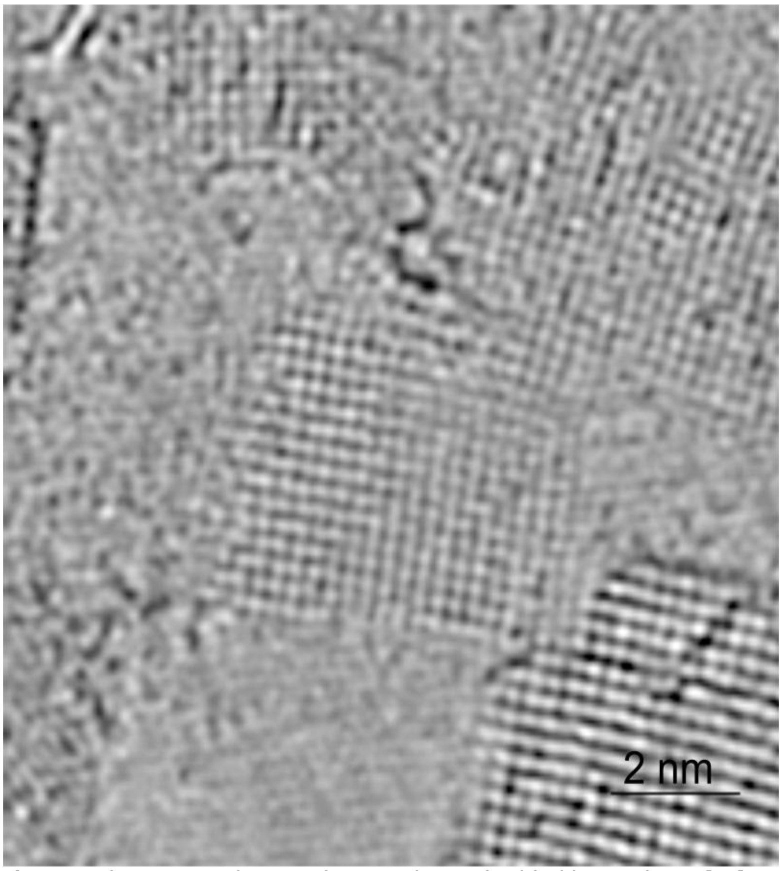

Fig. 1. 80 kV HRTEM image of square ice embedded in graphene [10]

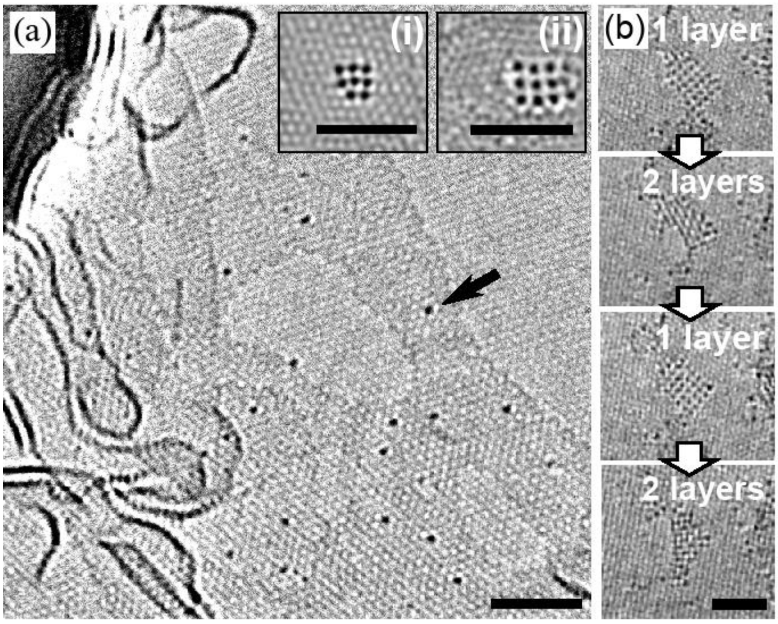

Fig. 2. (a) 80 kV HRTEM image of graphene at elevated temperature. The arrow marks a mobile Au atom embedded in graphene and the inserts show small Au clusters. (b) HRTEM images of single and double layer of AuC-clusters in a NaCl-crystal structure [11] (scale bars: 1 nm)