Raman spectra and calorimetric studies of MWCNTs

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Results

Calorimetric, DSC, XPS, NEAFS and Raman studies of multi-walled carbon nanotubes (MWCNTs) have been done. The experimental results are shown in Fig. 1-4. The heat capacity of MWCNTs in the temperature interval from 2 to 275 K was measured by the relaxation method using PPMS [1]. The size effects are observed in the temperature dependences of the specific heat of $C_P(T)$ for MWCNTs. The kinetic processes in MWCNTs were studied from room temperature to 500 K in a nitrogen flow using differential scanning calorimetry (DSC) on a Perkin - Elmer - 8000. It was found that all studied MWCNTs have a small number of defects, functional groups, and other impurities. The Raman measurements were performed in backscattering geometry using a Renishaw InVia Raman microscope equipped with a confocal DM 2500 Leica optical microscope and a CCD detector. In the Raman spectra of MWCNTs, defect-induced phonon mode so-called D band is observed near 1346 cm^{-1}. The high-energy G mode (1572 cm^{-1}), due to vibrations of carbon atoms in the walls of the nanotubes, is shifted toward the lower frequencies compared to the G mode of graphite (1580 cm^{-1}). The 2D band related with the two-phonon scattering is observed near 2688 cm^{-1}. The dependence of the I_D/I_{2D} ratio on the average diameter of MWCNTs is in good agreement with the data of [2]. $I_D > I_{2D}$ for MWNTs with an average diameter d <15 nm and $I_D < I_{2D}$ for MWNTs with d> 15 nm.

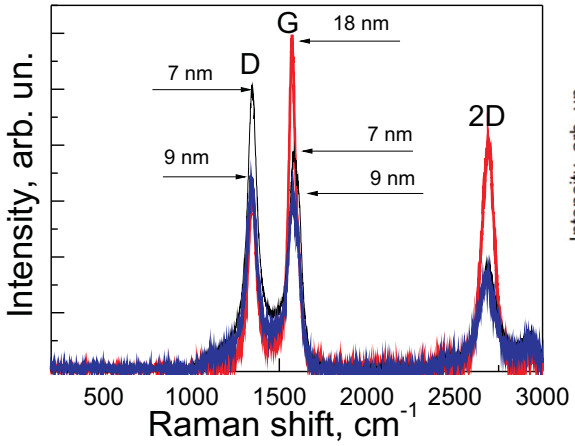

Fig. 1. Raman spectra for MWCNTs.

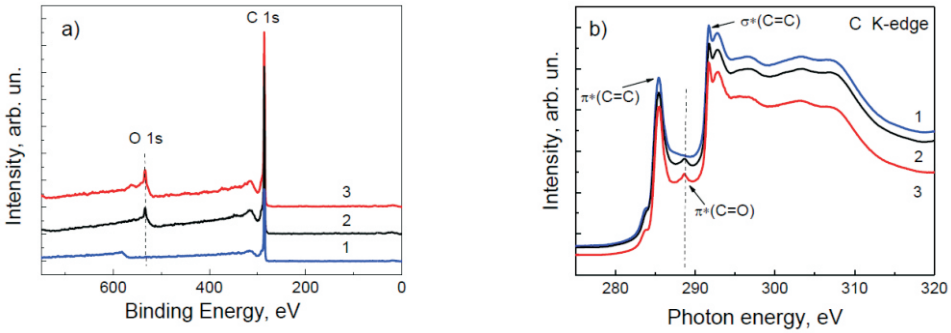

Fig. 4. XPS (a) and NEXAFS (b) spectra of initial (1), milled (2) and oxidized - then milled (3) multi-walled carbon nanotubes (18 nm).

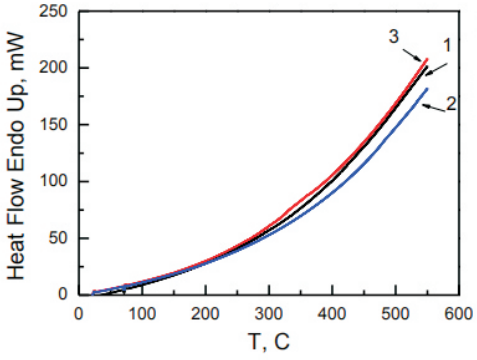

Fig. 2. DSC curves of MWCNTs with the average diameter 7nm (curve 1), 9nm (curve 2), and 18 nm (curve 3).

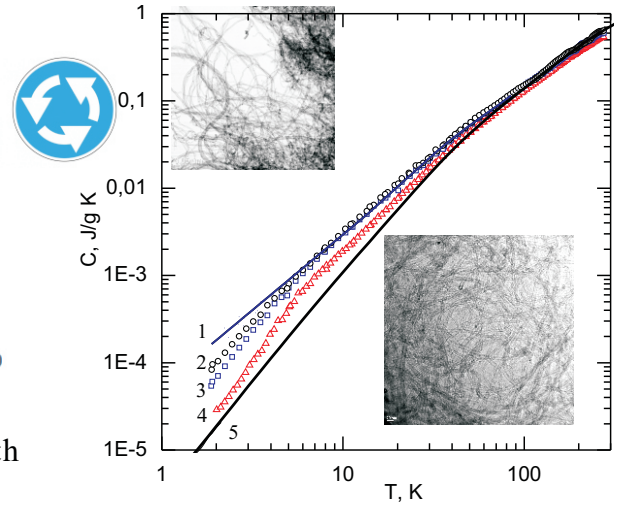

Fig. 3. The temperature dependences of the specific heat of the MWCNTs 7 nm (curve 2), 9 nm (curve 3) and 18 nm (curve 4) in comparison with specific heat of single-walled SWNT bundles (1) and graphite (5). The insert: TEM of MWCNTs 7 nm (up) and 18 nm (below).

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