

Decorating carbon nanotubes with CdTe nanoparticles

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Introduction

Many areas of nanotechnology application, especially in the creation of biomedical devices and sensors, require the creation of interfaces (transitional structures) that connect nanomaterials or nanoobjects with microscopic devices or tissues. One of the approaches to creating such interface nanostructures is the use of carbon nanotubes, modified with various nanoparticles (NP) [1]. In this work, a microwave irradiation method, which is widely used to activate or accelerate chemical reactions [2], was used to modify COOH-functionalized single-walled carbon nanotubes (SWCNT) with CdTe nanoparticles stabilized by thiols.

Materials and methods

The SWCNT with diameter about 1.5 nm were dispersed in separate containers in 1 ml of deionized water and 1 ml of CdTe NP suspension was added. The size of CdTe NP was about 2.6 nm and 4.9 nm. After that the containers were closed and loaded into a microwave equipped with a 700 W magnetron operating at 2.45 GHz. To minimize overheating of the solvent and increase the pressure in the closed vial, cyclic microwave exposures were performed with an on time of 30 s at 100% power, separated by 10-s off time intervals, with a total duration of 2400 s. The X-ray photoelectron spectra of the core levels of elements of the analyzed compounds were taken on the PERKIN ELMER PHI 5600 X-ray spectrometer, using Al K α radiation and a monochromatized beam. The beam diameter was set to 400 μ m. An electron gun was used to compensate for sample charging. The vacuum level during the experiment was at least 10⁻⁷ Pa. The energy resolution was equal to 0.1 eV. The calibration of binding energies was carried out using the 1s line of carbon of hydrocarbon residuals on the surface of the samples. The resulting energy is 284.0 eV. Deconvolution XPS spectra were carried out by XPSPeak software.

Results and discussion

The analysis of the X-ray photoelectron spectra of the studied samples made it possible to clearly interpret the energy relationships prevailing at the SWCNT - CdTe NP interface formation. The 1s carbon spectrum (Fig. 1) represents the binding energy of carbon in different conformations: sp², sp³, C-O, C=O, π - π^* , and does not change significantly because of the interaction of SWCNT with CdTe nanoparticles regardless of the size of the particles.

Significant changes are observed for the 1s spectra of oxygen (Fig. 2). For pure SWCNT, the O1s spectrum is characterized by two peaks at 531.6 eV and 533.3 eV, corresponding to chemical bonds C=O and C-O (C-OH) respectively. When SWCNT are treated with microwave irradiation, the C=O peak decreases and a new peak at 535.2 eV appears, which is most likely responsible for broken oxygen bonds formed as a result of the interaction of radiation with COOH functional groups on the surface of nanotubes. The interaction of SWCNT with CdTe nanoparticles (2.6 nm) under microwave irradiation leads to a significant decrease in the peak intensity, which is responsible for the connection C-O (C-OH). It should be noted that the peak near 535.0 eV is not observed in this case. A different situation is observed for SWCNT/CdTe (4.9 nm) samples. In addition to a significant decrease in the intensity of the peak responsible for the C-O (C-OH) bond, a peak at 535.5 eV is observed, but it is less intense than for SWCNT samples after microwave treatment. The shift of this peak by 0.3 eV in the direction of increasing binding energy indicates the outflow of electron density from oxygen atoms.

The following interaction mechanism can be assumed (Fig. 3): during microwave irradiation, broken oxygen bonds are formed, to which CdTe nanoparticles are non-covalently attached and SWCNT - CdTe NP hybrid nanostructures are formed. At the same time, the electronic transport of the charge from the functional groups directly to the carbon nanotube occurs, which increases the conductivity of such hybrid nanostructures compared to pure SWCNT.

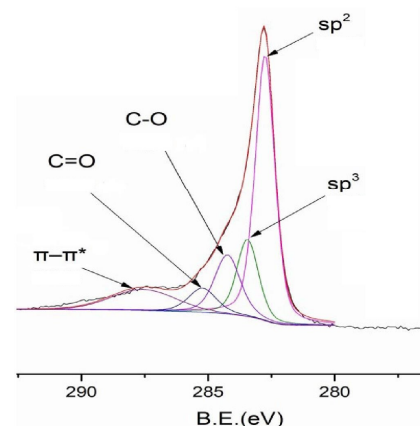


Fig. 1. XPS C1s spectra of the pure SWCNT.

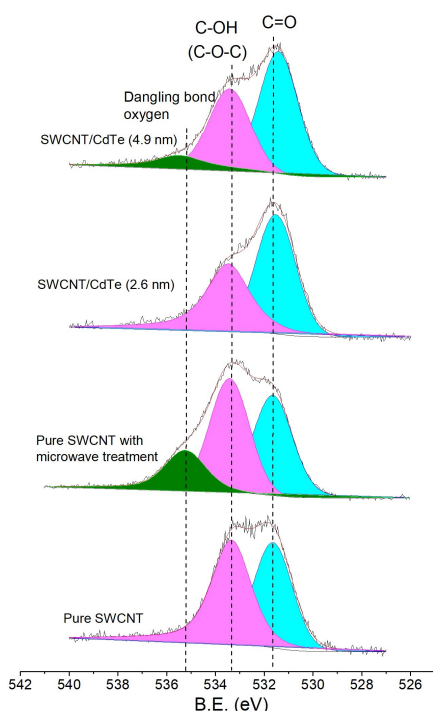


Fig. 2. XPS O1s spectra of the samples.

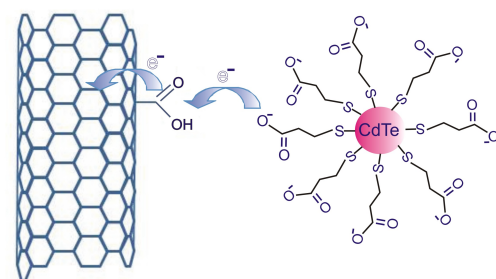


Fig. 3. Schematic interpretation of the noncovalent attachment of SWCNT with CdTe nanoparticles.

Conclusions

It was established that for pure SWCNT, the 1s spectrum of oxygen is characterized by two peaks at 531.6 eV and 533.3 eV, corresponding to the chemical bonds C=O and C-O (C-OH), respectively. When SWCNT are treated with microwave irradiation, the C=O peak decreases and a new peak at 535.2 eV appears, which is most likely responsible for broken oxygen bonds formed as a result of the interaction of radiation with COOH functional groups on the surface of nanotubes. A significant decrease in the intensity of the peak responsible for the C-O (C-OH) bond was observed during the interaction of SWCNT with CdTe NP. This reduction is due to the decrease in the number of C-O (C-OH) bonds in the formation of carbon bonds with CdTe nanoparticles. The mechanism of electron transport during the formation of SWCNT - CdTe NP hybrid nanostructures is described.

References

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