11th International Conference on Advanced Materials
Rio de Janeiro Brazil
September 20 - 25
ICAM2009

Carbon Nanotubes Decorated with both Gold Nanoparticles and Polythiophene: Influence of the Synthetic Variables, Characterization and Electrochemical Properties

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Abstract – This work reports a simple, one-step procedure to synthesize carbon nanotubes (CNTs) decorated simultaneously with gold nanoparticles and polythiophene, with and without previous CNT surface functionalization, and the influence of synthetic parameters on the final material. The method involves the reaction between $HAuCl_4$ and thiophene in an HCl aqueous dispersion of CNTs. The characterization of samples was made by Raman spectroscopy, UV-Vis spectroscopy, XRD and TEM. The electrochemical properties of these nanomaterials were investigated by cyclic voltammetry measurements

Nanocomposites composed of carbon nanotubes (CNTs) decorated with both metal nanoparticles and conducting polymer should present very interesting properties due the intimate contact between the components, with potential applications in photovoltaic and electrochromic devices. Recently we have reported a very simple, one-step procedure to synthesize carbon nanotubes decorated simultaneously with gold nanoparticles and polythiophene[1]. In this work we report the influence of some synthetic variables on the characteristics of the obtained material, the characterization of these systems and their electrochemical properties.

Multi-walled CNTs (MWCNTs) were obtained by pyrolisis of ferrocene, according our previous report[2]. Pristine and CNTs pre-treated with 30% (w/w) H_2O_2 aqueous solution [3] have been used for the synthesis of nanocomposites. Our approach was based on a procedure whereby the polymer and the metal nanoparticles are formed together in a CNT-containing medium, and CNTs act as seeds for the beginning of the reaction in a heterogeneous nucleation process in which both the Au nanoparticles and polythiophene grow directly on the CNTs surface. In a typical procedure, CNTs were mixed in HCl aqueous solution with $HAuCl_4$ and the monomer tiophene. Several different reactions were carried out employing the same procedure and varying the ratio of the precursors and the CNTs presence or not for control sample. All the samples were characterized by Raman spectroscopy, UV-Vis spectroscopy, X ray diffraction(XRD), and Transmission electron microscopy (TEM) and their electrochemical properties were studied by cyclic voltammetry.

The Raman spectra of the samples show a superposition of both spectra of pristine PT and pristine MWCNTs, indicating that the polythiophene was formed through the reaction between the $HAuCl_4$ solution and the tiophene, and that the CNTs were incorporated on the resulting material. The UV-Vis spectra shows signs related with CNTs and with the polythiophene. The X-ray diffractograms show, besides the amorphous halo characteristic of the polythyophene and the (002) peak at 0.34 nm attributed to the concentric MWCNTs layers, peaks characteristics of the fcc gold. The TEM images of the nanocomposites samples show that the MWCNTs were capped by a polymer shell in which gold nanoparticles are embedded. Previous MWCNT-treatment with H_2O_2 add surface modifications that permits better dispersion of large amounts of CNTs, which results in more homogeneous CNT/PT/Au NPs samples. It is important to note that variations in the CNT/$HAuCl_4$/thiophene ratios produced inhomogeneous samples, showing not only CNTs decorated with both gold nanoparticles and polythiophene but also other morphologies such as isolated gold nanoparticles, isolated polythiophene, and polythiophene mixed with gold nanoparticles but without CNTs.

Cyclic voltammetry was employed to estimate the HOMO and LUMO energy levels of the nanocomposites, and than the energy gap was deduced from these electrochemical measurements.

References

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