Carbon Nanotubes/TiO_2/Prussian Blue thin films nanocomposites: synthesis, characterization and application as photovoltaic materials

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Introduction

Nowadays the problems related to energy production, consumption and pollution are well known. Among alternative energy resources, solar energy has the best potential of efficient large application. Solar energy can be used in different ways, with photovoltaic devices (PVD) being one to convert it in electric energy. Dye sensitized solar cells (DSSC) are one type of PVD. On a DSSC, light absorption is done through a photosensitizer (dye) that, under excitation, promote an electron to the semiconductor (TiO2), in contact with the anode (FTO or ITO). The dye is reduced by an electrolyte (I^-/I_3^-) that is regenerated by the cathode (Pt), in contact with the anode to generate current. The total efficiency of a PVD is directly related with the efficiency of each process of transfer and transport of the exciton.[1] Besides that, stability, lifetime and costs should be consider for a viable PVD. Carbon nanotubes (CNT) have been used as a substitute of Pt electrodes, as well as a semiconductor or photoanode in different arrangements with TiO2, showing great increase in efficiencies. In order to lower costs and increase lifetime, the typical DSSC dye (a Ru complex) can also be substitute for other materials. Prussian blue (PB) is an iron-cyanide complex ($Fe_4[Fe(CN)_6]_3$) with well known electrochromic properties. Due to its intense blue color, PB can be used as a dye in DSSC. In our group, an innovative route for CNT/PB nanocomposites (NC) synthesis was developed through a heterogeneous reaction between iron species from CNTs cavities and $[Fe(CN)_6]^{3+}$ aqueous solution. This NC showed both great stability and performance as electrochromic material and H_2O_2 sensor.[2] This route could also be adapted to CNT/PB analogues synthesis.[3] In this work, the same route was modified to produce thin films of CNT/TiO_2/PB and PB analogue nanocomposites that were further applied as PV materials.

Results and Discussion

CNT/TiO_2 thin films nanocomposites were synthesized through interfacial route developed in our research group.[4] Two approaches were applied for the NC synthesis. One with both CNT and TiO_2 dispersed together in organic phase and another with CNT and TiO_2 dispersed in the organic and aqueous phases, respectively. The morphology and distribution of the species along the film were evaluated. The films showed clear differences, with the best interaction between both materials when they were dispersed in different media. CNT/TiO_2/PB were obtained through voltammetric modification by the method described above, in $[Fe(CN)_6]^{3+}$ aqueous solution.[4] The same method was used to synthesized a ruthenium PB analogue (ruthenium purple – PR), using $[Ru(CN)_6]^{4+}$ aqueous solution, leading to a CNT/TiO_2/PR NC. All nanocomposites were characterized by SEM, EDS, XRD, UV-Vis and Raman Spectroscopy, besides electrochemical characterization. Stability of the nanocomposites in support electrolyte (KCl 0,1 mol L^{-1}) and I^-/I_3^- were also evaluated. Photocurrent response of the nanocomposites was measured through potentiometric method in different applied potentials, besides OCP (open circuit potential). A 1.5 AM filter was used among the lamp to simulate atmosphere irradiation losses, with a total solar lightning of 100 W/m^2. The typical I^-/I_3^- electrolyte was used with KCl aqueous solution. Both nanocomposites showed great photocurrent responses, specially CNT/TiO_2/PB, with current densities at the order of 120 $\mu A\ cm^2$.

Conclusions

Thin films of CNT/TiO_2/PB nanocomposites could be successfully synthesized by interfacial method and electrochemical modification. All NC were testes as PV materials, showing great photocurrent responses.

Acknowledgments

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