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Synthesis and properties of bismuth oxide nanoshell coated polyaniline nanoparticles for promising photovoltaic properties

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A novel heterostructure made of polyaniline (PANI) nanoparticles coated by nanolayer of bismuth oxide Bi_2O_3 was synthesized. The structure was characterized by scanning electron microscopy, X-ray diffraction, and transmission electron microscopy. These characterizations showed that the bismuth oxide nanoshell was pure and crystalline, and has thickness in the range of 10 nm. The experiment on photoluminescence (PL) of Bi_2O_3 nanoshell coated polyaniline nanoparticle, at room temperature, shows an emission band peaked at around 385 nm. When compared with the PL spectrum of Bi_2O_3 nanoparticles, about 100 times PL enhancement was found in the PL spectrum of Bi_2O_3 nanoshell coated polyaniline nanoparticle. The current density versus voltage (*J–V*) measurements in dark and illumination showed that this heterojunction has 4 orders of magnitude rectification in the dark and 3 orders of magnitude rectification under illumination. The obtained power conversion efficiency of polyaniline nanoparticles coated by nanoshell of bismuth oxide ($\eta = 7.453\%$) was much enhanced compared with polyaniline alone ($\eta = 8.33 \times 10^{-4}\%$) this indicates that the prepared heterostructure represents a promising photovoltaic solar cell. Copyright © 2009 John Wiley & Sons, Ltd.

Keywords: bismuth oxide; polyaniline; nanoshell; photoluminescence; photovoltaic

INTRODUCTION

The science of organic/inorganic nanocomposites is extremely promising for applications in light-emitting diodes,[1,2] photodiodes,[3,4] photovoltaic cells,[5,6] smart microelectronic device,[7,8] and gas sensors among others.[9,10] The properties of hybrid nanocomposites can be easily adjusted by varying the composition. Their fabrication shares the same advantages of organic device technology such as low cost production and the possibility of device fabrication on large area and flexible substrates. Solar cells composed of hybrid conjugated polymers and metal oxides nanocrystal can combine attractive characteristics of bulk inorganic materials with the solution processability and low temperature chemical synthesis of polymers,[11] so have been extensively studied in recent years.

Conjugated polymers derive their semiconducting properties from having delocalized π-electron bonding along the polymer chain. The π bonding and π^* antibonding orbitals form delocalized valence and conduction wavefunctions, which support mobile charge carriers. One important approach is to construct heterostructure architectures, with two polymers used to transport either electrons or holes, with recombination forced to occur close to the heterojunction.[12] There has also been much work on the improvement of the process of charge injection at the two electrodes, and devices which retain the simple single-semiconductor-layer architecture can also show very high efficiencies.[13] To obtain high efficiency, it is necessary to have an interpenetrating network of electron-accepting and hole-accepting components within the device. Ideally, the microphase domain size should not exceed the exciton diffusion length, which is about 5–10 nm for most polymers.

In the present contribution, a new method was developed to prepare polyaniline nanoparticles coated by Bi_2O_3 nanoshell. Conducting polymers with function groups can act as self-assembling complex polymer to control disperse and crystal growth of Bi_2O_3. For the purpose, polyaniline was chosen as functional conjugated polymer, whose –NH groups at side chains could complex inorganic ions. In the process, bismuth salt and a polyaniline/PEG precursor aqueous solution were mixed to issue the complex reaction between Bi^{3+} ion and –NH of the PANI precursor. After addition of concentrated aqueous ammonia and subsequent heating treatment, polyaniline nanoparticles coated Bi_2O_3 nanoshell were obtained. This PANI/Bi_2O_3 hybrid heterojunction material can possess a high interface area for effective separation of excitons. The photoluminescence (PL) properties of the composite and application in photovoltaic devices are discussed.

EXPERIMENTAL

Materials

Aniline monomer was distilled under reduced pressure, ammonium peroxi-disulfate $(NH_4)_2S_2O_8$, hydrochloric acid (HCl), aqueous ammonia, ammonium hydroxide, nitric acid, urea, polyethylene

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