Plasmonic effects of quantum size metal nanoparticles on dye-sensitized solar cell

ABSTRACT

Gel polymer electrolytes (GPEs) based on poly(ethylene oxide) (PEO) and phthaloyl chitosan (PhCh) for dye-sensitized solar cells (DSSCs) have been synthesized and characterized. The GPEs have been prepared using different weight fractions of PEO and PhCh that have been added to a fixed composition solution of tetrapropylammonium iodide (TPAI), dimethylformamide (DMF) and iodine (I2) crystals. The ionic conductivity behavior of prepared GPEs was studied using impedance spectroscopy. The sample having 70 wt.% PEO and 30 wt.% PhCh showed the highest ionic conductivity of 7.36 mS cm−1 at room temperature. The photoanode of the DSSC consists of two TiO2 layers. The first or compact layer has a thickness of ~5 μm and the TiO2 nanoparticles have an average size of 14 nm. The second layer of TiO2 nanoparticles has an average size of 21 nm. In order to adsorb dye molecules, the TiO2 photoanodes were soaked in anthocyanin and ruthenium 535 (N3) dye solutions. The GPE has been deposited between the dye/TiO2 photoanode and platinum (Pt) counter electrode in a sandwich-like structure. Results showed that the fabricated DSSC with an electrolyte containing 70 wt.% PEO:30 wt.% PhCh exhibited the highest efficiency for both anthocyanin and N3 dyes and the efficiency and ionic conductivity trend versus PEO content are similar. On addition of different amounts of Ag nanoparticles (0, 10, 20, 30, 40 μL), with average size of 10 nm to the second TiO2 layer, the performance of DSSCs with anthocyanin sensitizer and N3 dye improved. The cell with anthocyanin/(TiO2 + 10 μL Ag nanoparticles) showed a 21%, 17.2% and 39.6% increase in short circuit current density (Jsc), fill factor (FF), and light to electricity conversion efficiency (η) respectively compared to the cell without Ag nanoparticle. The DSSC fabricated with TiO2 photoanode containing 20 μL Ag nanoparticles soaked in N3 dye exhibits Jsc, FF, and η of 15.24 mA cm−2, 57% and 5.21% respectively. The incorporation of Ag nanoparticles has resulted in a 17% and 13% increase in Jsc, and η, respectively, for N3 based cells. This performance enhancement with the addition of Ag nanoparticles can be attributed to improvement of light scattering and charge transport as a result of plasmonic resonance.