Electrostatic Layer-by-layer Assembly of Amphoteric Titanium Dioxide Nanoparticles for Dye-sensitized Solar Cells

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Using nanocrystalline TiO_2 (nc-TiO_2) as amphoteric charged particles, and two weak polyelectrolytes: poly(allylamine hydrochloride) (PAH), poly(acrylic acid, sodium salt) (PAA) and two strong polyelectrolytes: poly(dimethyldiallylammonium chloride) (PDAC), poly(sodium 4-styrenesulfonate) (PSS) as charged binders respectively, nanocomposite polyion/nc-TiO_2 multilayered films were prepared via the electrostatic layer-by-layer (ELBL) technique. The layer-by-layer assembly of these nanoparticles proceeds linearly as shown by sequential UV-vis absorption and thickness measurements. The morphology of these assemblies was characterized using atomic force microscopy (AFM). The nanoscopic polyion/nc-TiO_2 films were sintered at 550 °C and then used as working electrodes for *cis*-di(thiocyanato)-N,N-bis(2,2'-bipyridyldicarboxylate)-ruthenium(II) (N3) sensitized solar cells. The I-V characteristics of the solar cells made by the sintered polyelectrolyte/nc-TiO_2 electrodes show several interesting results. (1) The short-circuit current (Isc) does not linearly increase with the thickness of the nc-TiO_2 electrode, even though the adsorption behavior of the N3 dye follows the linear principle. This indicates that there is a limited distance in which efficient charge transport occurs in the solar cell. (2) The precursor polyelectrolytes play a major role in the photovoltaic performance of the solar cell. The preliminary results show that the thermal stability of the polyelectrolyte may have a direct effect on the overall device efficiency. (3) The photovoltaic performance of these solar cells, made by the ELBL method, is comparable with other methods such as spin casting, but offers unsurpassed control over final device thickness. Device efficiencies of 6.2% were obtained for the $(PDAC/nc\text{-}TiO_2)_{200}$ solar cells, under 1 sun insolation at simulated AM 1.5D, using a redox I_2/I^- based semi solid-state [poly(ethylene oxide) (PEO)] electrolyte.