The effect of polymer optoelectronic properties on the performance of multilayer hybrid polymer/TiO_2 solar cells

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Abstract

We report a study of the effects of polymer optoelectronic properties on the performance of photovoltaic devices consisting of nanocrystalline TiO_2 and a conjugated polymer. Three different poly(2-methoxy-5-(2'-ethylhexoxy)-l,4-phenylenevinylene) (MEH-PPV)-based polymers and a fluorene-bithiophene copolymer are compared. We use photoluminescence quenching, time-of-flight mobility measurements, and optical spectroscopy to characterize the exciton-transport, charge-transport, and light-harvesting properties, respectively, of the polymers, and correlate these material properties with photovoltaic-device performance. We find that photocurrent is primarily limited by the photogeneration rate and by the quality of the interfaces, rather than by hole transport in the polymer. We have also studied the photovoltaic performance of these TiO_2/polymer devices as a function of the fabrication route and device design. Including a dip-coating step before spin-coating the polymer leads to excellent polymer penetration into highly structured TiO_2 networks, as was confirmed through transient optical measurements of the photoinduced charge-transfer yield and recombination kinetics. Device performance is further improved for all material combinations studied, by introducing a layer of poly(ethylene dioxythiophene) (PEDOT) doped with poly(styrene sulfonic acid) (PSS) under the top contact. Optimized devices incorporating the additional dip-coated and PEDOT:PSS layers produced a short-circuit current density of about 1 mA cm^{-2}, a fill factor of 0.50, and an open-circuit voltage of 0.86 V under simulated AM 1.5 illumination (100 mW cm^{-2}, 1 sun). The corresponding power conversion efficiency under 1 sun was ≥0.4%.

Indexed keywords

Engineering controlled terms: Charge transfer; Correlation methods; Nanostructured materials; Optimization; Optoelectronic devices; Photoluminescence; Photovoltaic cells; Polymers; Quenching; Titanium compounds

Engineering uncontrolled terms: Multilayer hyprid polymers; Optoelectronic properties; Poly(ethylene dioxythiophene) (PEDOT); TiO2 solar cells

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