The effect of zinc oxide nanostructure on the performance of hybrid polymer/zinc oxide solar cells

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Abstract

Solar cells fabricated from composites of conjugated polymers with nanostructured metal oxides are gaining interest on account of the stability, low cost and electron transport properties of metal oxides. Zinc oxide (ZnO)/polymer solar cells are promising compared to other metal oxide/polymer combinations, on account of the possibility of low temperature synthesis, as well as the potential for controlling interface morphology through simple processing from solution. Here, we focus on the effect of surface morphology of ZnO films on photovoltaic device performance. We have successfully grown ZnO nanorods standing almost perpendicular to the electrodes on a flat, dense ZnO "backing" layer. We studied structures consisting of a conjugated polymer in contact with three different types of ZnO layer: a flat ZnO backing layer alone; ZnO nanorods on a ZnO backing layer; and ZnO nanoparticles on a ZnO backing layer. We use scanning electron microscopy, steady state and transient absorption spectroscopies and photovoltaic device measurements to study the morphology, charge separation and recombination behaviour and device performance of the three types of structures. We find that charge recombination in the structures containing vertically aligned ZnO nanorods is remarkably slow, with a half life of over 1 ms, over two orders of magnitude slower than for randomly oriented ZnO nanoparticles. A photovoltaic device based on the nanorod structure which has been treated with an ambiphilic dye before deposition of poly(3-hexyl thiophene) (P3HT) polymer shows a power conversion efficiency over four times greater than for a similar device based on the nanoparticle structure. The best ZnO nanorods: P3HT device yields a short circuit current density of 2 $mAcm^{-2}$ under AM 1.5 illumination ($100mWem^{-2}$) and peak external quantum efficiency over 14%, resulting in a power conversion efficiency of 0.20%.

Author keywords

Hybrid solar cells; Metal oxide; P3HT; Photovoltaics; Polymer; Rods; Transient absorption; ZnO

Indexed keywords

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