Hybrid polymer/zinc oxide photovoltaic devices with vertically oriented ZnO nanorods and an amphiphilic molecular interface layer

Ravirajan, P.[ad], Peiró, A.M.[b], Nazeeruddin, M.K.[c], Graetzel, M.[c], Bradley, D.D.C.[a], Durrant, J.R.[b] and Nelson, J.[a]

[a] Department of Physics, Imperial College London, Prince Consort Road, London SW7 2BW, United Kingdom
[b] Centre for Electronic Materials and Devices, Department of Chemistry, Imperial College London, United Kingdom
[c] Institute of Molecular and Biological Chemistry, Faculty of Basic Science, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
[d] Department of Physics, University of Jaffna, Jaffna, Sri Lanka

Abstract

We report on the effect of nanoparticle morphology and interfacial modification on the performance of hybrid polymer/zinc oxide photovoltaic devices. We compare structures consisting of poly-3-hexylthiophene (P3HT) polymer in contact with three different types of ZnO layer: a flat ZnO backing layer alone; vertically aligned 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, recombination behavior 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 several milliseconds, over 2 orders of magnitude slower than that for randomly oriented ZnO nanoparticles. A photovoltaic device based on the nanorod structure that has been treated with an amphiphilic dye before deposition of the P3HT polymer yields a power conversion efficiency over four times greater than that for a similar device based on the nanoparticle structure. The best ZnO nanorod:P3HT device yields a short circuit current density of 2 $mAcm^{-2}$ under AM1.5 illumination (100 mW cm^{-2}) and a peak external quantum efficiency over 14%, resulting in a power conversion efficiency of 0.20%.

Indexed keywords

Engineering controlled terms: Current density; Nanostructured materials; Power converters; Scanning electron microscopy; Surface chemistry; Zinc oxide

Engineering uncontrolled terms: Poly-3-hexylthiophene (P3HT); Power conversion efficiency; Zinc oxide photovoltaic devices

Engineering main heading: Photovoltaic cells