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Enhancement of photovoltaic characteristics using a PEDOT interlayer in TiO_2/MEHPPV heterojunction devices

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Abstract

The effect of inserting a PEDOT interlayer between the MEHPPV layer and the Au electrode of a nanocrystalline ITO/TiO_2/MEHPPV/Au heterojunction device on the photovoltaic characteristics of the device has been studied. The MEHPPV layer has both a light-sensitizing role and a hole-transporting function. The overall conversion efficiency of the device with a PEDOT layer is better by more than 80% than that obtainable without a PEDOT layer. The modified device shows improved photocurrent density–voltage (J–V) characteristics, in that there is a strong reduction of the roll-over behavior in the forward bias region, and an increase in the fill factor. These improvements are due to the reduction of junction resistance across the MEHPPV/Au interface in the presence of the PEDOT interlayer, which results in improved hole injection.

Keywords: Photovoltaic device; Organic/inorganic interface; Heterojunction; Organic solar cell; PEDOT

1. Introduction

Dye-sensitized solar cells (DSSCs) based on nanoporous titanium dioxide particles and organic dyes have energy conversion efficiencies close to those of amorphous

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silicon solar cells, i.e., about 10% [1]. However, one limitation of the DSSC approach is its use of volatile liquid solvents as iodide redox mediators. The presence of liquid electrolyte in the cells can give rise to stability problems during long-term operation, in particular due to encapsulation difficulties. As an alternative to the use of liquid electrolytes, all-solid-state devices based on polymer gel electrolytes that conduct ions [2–5] or on hole-conducting organic materials [6,7] have been investigated. All-organic photovoltaic devices consisting of conjugated polymers have also been fabricated, producing electron donor–acceptor combinations similar to those of the p–n junction photovoltaics of semiconductors [8]. Most conjugated polymers with delocalized π-electrons share the characteristics of p-type semiconductors, which readily donate electrons to an electron acceptor. Hybrid devices consisting of conjugated polymers and fullerenes or n-type nanocrystalline semiconductors have also been studied [9,10]. However, the energy conversion efficiency of these devices is lower than that of conventional DSSCs due to the low charge mobility of conjugated polymers, which conduct charge carriers by hopping between localized states in disordered solids. The charge transport properties of a heterojunction of TiO_2 and poly(2-methoxy-5-[2'-ethyl-hexyloxy]-1,4-phenylenevinylene) (MEHPPV) have been investigated intensively as a function of polymer thickness, carrier mobility and morphology of the TiO_2/conjugated polymer interface by Breeze et al. [11], with a view to improving the conversion efficiency of such devices.

In all-solid-state multilayer devices, high performance requires good interfacial contact between the layers. In this paper, we report the modification of a TiO_2/MEHPPV heterojunction device by the addition of a poly(3,4-ethylenedioxythiophene) (PEDOT) layer, which enhances the performance of this photovoltaic device. The basic device structure of ITO/TiO_2/MEHPPV/Au is modified by inserting a PEDOT interlayer between the MEHPPV layer and the Au electrode. PEDOT has been widely used to modify the anodes of electronic devices, including those of organic light-emitting diodes [12], thin-film transistors [13] and photovoltaic devices [14], because of its excellent electrical properties.

We found that this modification of the device increases both its fill factor and its energy conversion efficiency. To elucidate the nature of these improvements, the interfacial characteristics of the devices were also analyzed using AC impedance spectroscopy, in particular their serial resistance.

2. Experimental

2.1. Device preparation

A compact TiO_2 layer was spin-coated onto indium–tin oxide (ITO) coated glass substrates from a sol–gel solution of titanium isopropoxide in ethanol followed by Ref. [15]. The compact TiO_2 layer avoids a direct contact between MEHPPV and ITO substrate which would short circuit the device. Nanocrystalline TiO_2 (Degussa, P25) paste was prepared according to the published procedure [16]. Sintered