Journal of the Arkansas Academy of Science

Volume 68 Article 6

2014

Solid State Dye Sensitive Solar Cells Based on ZnO Nanowire as the N-type Semiconductor

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Running Title: Solid State Dye Sensitive Solar Cells on ZnO Nanowires

Abstract

We fabricated solid state dye-sensitized solar cells with ZnO nanorods as the n-type material and polypyrrole as the p-type material. The ZnO nanorods were grown on indium-tin oxide (ITO) glass by electrochemical methods for one hour. Scanning electron micrographs of the ZnO nanowire (NW) indicated a length of about 1 micrometer and a diameter of approximately 100-200 nm for the nanorods. Polypyrrole deposited on ITO/ZnO NW/dye and the fabricated device of ITO glass/ZnO nanorods/dye/polypyrrole/Ag showed a power conversion efficiency of 1.29%

Introduction

New concepts and devices that are challenging photovoltaic applications based on p-n junctions have been reported. Currently, exciton solar cells such as organic (Chen et al. 2012), hybrid organic-inorganic (AbdulAlmohsin et al. 2012) and dye sensitive solar cells (DSCs)(Kenneth et al. 2013) are promising devices for inexpensive, large scale solar energy conversion. The most commonly used types are TiO_2 nanoparticles and ZnO nanorods as working electrodes with CuSCN as a counter p-type electrode (Umang et al. 2012), however we are using polypyrrole as a counter electrode instead of CuSCN.

Here we report on a solid-state DSC consisting of ZnO nanorods as a wide band gap material, ruthenium dye (N719) and polypyrrole (PPY) doped by Li^+ as a hole transport conductor (Fig. 1). The mechanism of the device is that incoming light is absorbed in the dye monolayer and excites electrons from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO). The excited electrons are then injected into the conduction band of the ZnO by taking an electron from the HOMO level of the polypyrrole.

Methods

Glass coated with indium-tin oxide (ITO) was supplied by SPI supplies (West Chester, PA, U.S.A). The vertically aligned ZnO nanowire arrays were fabricated on ITO glass substrates (SPI Supplies) by a low temperature electrochemical method (Chen et al. 2011). The ZnO nanorod electrode was immersed in an 3mM ethanolic solution of ruthenium dye (N719) (Sigma-Aldrich) overnight, washed with ethanol and then introduced to deposit polypyrrole (PPY) by electrochemical polymerization using platinum wire as the counter electrode and 0.1 M of pyrrole monomer dissolved in acetonitrile and 0.1 M LiI salt with 2 volts as the applied voltage between counter and working electrode for 3 min. The PPY thin film deposited directly on the ZnO NW/dye. The electrode was then placed on top of the PPY using silver paste.

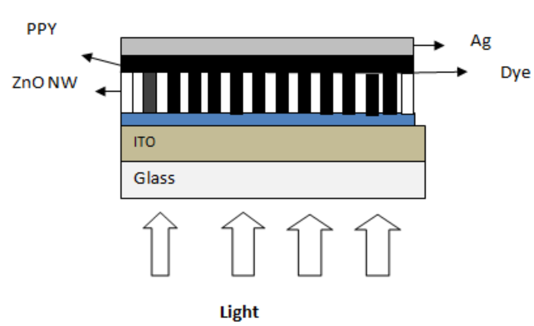

Figure1. Schematic of the ZnO/dye/PPY/Ag solar cells

Results and Discussion

Figure 2 shows a scanning electron microscope (SEM) top view image of a typical ZnO NW array grown by the electrochemical process. The nanowires had an average diameter of 100-200 nm and are vertically aligned on the substrate. The surface of the nanowire array is clean and free of particles and the roots of the wires separated from each other - both are important factors that affect the performance of the device of solar cells

In order to investigate the effects of dye on the optical properties of ZnO NWs, the UV-Vis absorption spectra were measured for ZnO NWs with and without dye N719 (Fig. 3). The ZnO NW/dye has strong absorption peaks around 434 nm, 522 nm, and 673 nm, the latter two being in the visible range. The modified ZnO NW with Dye N719 exhibit a strong increase in absorbance over the entire measured range relative to pristine ZnO NWs .

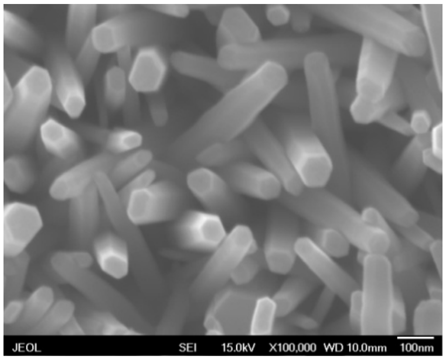

Figure 2. SEM cross-section image of ZnO nanowire arrays.

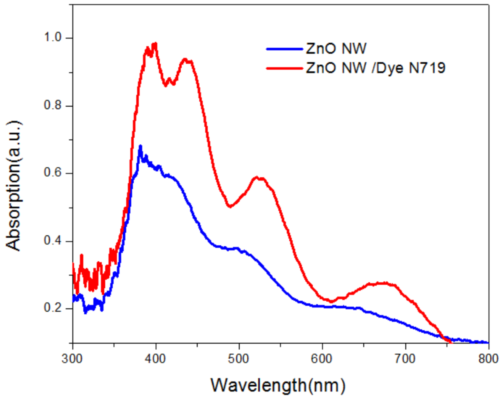

Figure 3. UV-Vis absorption spectra of ZnO NW and ZnO NW/Dye

The current density versus voltage curve shown in Fig. 4 indicates that the ZnO NW with Dye shows typical photovoltaic characteristics under illumination. An open-circuit voltage (V_{oc}) of 0.36 V and short-circuit current density of 7.3 mA/cm^2 was observed with a fill factor of 0.49. The overall power conversion efficiency of this solar cell is 1.29 % (Fig. 4). The high short circuit current leads to the higher power conversion efficiency due to the conductive polymer Polypyrrole acts as the hole-transport material in the solid State dye solar cells with N-type ZnO NWs.

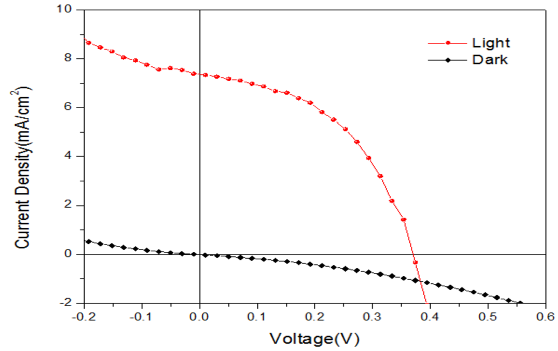

Figure 4. Current density – voltage curves measured on PPy/Dye/ ZnO nanowire

Conclusion

A solid-state dye sensitive solar cell has been fabricated using a vertically aligned ZnO nanowire array as the working electrode and polypyrrole (Li^+) as the hole-transport materials. The solid state dye cells give current densities of 7.3 mA/cm^2 and a voltage open-circuit voltage (V_{oc}) of 0.36 V. The power conversion efficiency is 1.29%, which is promising for a solar cell application.

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