

The effect of ZnO-coating on the performance of a dye-sensitized solar cell

Chuen-Shii Chou^{a,b,*}, Feng-Cheng Chou^b, Yi-Geng Ding^b, Ping Wu^c

^a Research Center of Solar Photo-Electricity Applications, National Pingtung University of Science and Technology, Pingtung 912, Taiwan

^b Powder Technology R&D Laboratory, Department of Mechanical Engineering, National Pingtung University of Science and Technology, Pingtung 912, Taiwan

^c Engineering Product Development, Singapore University of Technology and Design, 20 Dover Drive, Singapore 138682, Singapore

Received 30 September 2011; received in revised form 3 January 2012; accepted 3 February 2012

Available online 28 February 2012

Communicated by: Associate Editor Sam-Shajin sun

Abstract

This study investigates the effect of a ZnO-coated TiO₂ working electrode on the power conversion efficiency of a dye-sensitized solar cell (DSSC). This electrode was designed and fabricated by dipping the TiO₂ electrode with the TiCl₄ treatment in a solution of zinc acetate dehydrate [Zn(CH₃COO)₂·2H₂O] and ethanol. The effects of the concentration of Zn(CH₃COO)₂·2H₂O and the duration of dipping on the band gap of a working electrode and the power conversion efficiency of a DSSC were also examined. The band gap of the working electrode increases to 3.75 eV [TiO₂ electrode dipped in 0.05 M Zn(CH₃COO)₂·2H₂O for 3 min] from 3.22 eV (TiO₂ electrode). Interestingly, the power conversion efficiency of the DSSC with a Zn-coated TiO₂ electrode (6.7%) substantially exceeds that of the conventional DSSC with a TiO₂ electrode (5.9%), and it may be originated from an increased energy barrier between ZnO and TiO₂ that reduces the electron recombination rate.

© 2012 Elsevier Ltd. All rights reserved.

Keywords: Dye-sensitized solar cell; ZnO-coated TiO₂ electrode; Band gap; ZnO energy barrier; Power conversion efficiency

1. Introduction

In order to relieve the energy crises, environment pollution and global warming, the development of accessible renewable energy productions has received substantial attention. Solar power is the most noteworthy among renewable and sustainable energy resources because it is a clean and unlimited resource of energy and has the global availability. In recent years, several alternatives to Si-based solar cells or photovoltaic (PV) cells have become available, and considerable research is ongoing towards

substantially reducing the cost of electricity generation (Thavasi et al., 2009). The dye-sensitized solar cell (DSSC), as proposed by O'Regan and Grätzel (1991), is an attractive alternative because of its properties, such as low production cost, the various choices of substrates that can be used, and low environmental impact during fabrication (Lewis, 2007; Kim et al., 2008; Caramori et al., 2010). However, a comparison with conventional solid-state junction devices made of crystalline silicon indicates that the DSSC has lower power conversion efficiency (Chou et al., 2008).

Decreasing the recombination of electrons in the dye or electrolyte may be one of promising approaches to enhance the performance of a DSSC. However, research on decreasing the recombination of electrons in the dye or electrolyte

* Corresponding author at: Research Center of Solar Photo-Electricity Applications, National Pingtung University of Science and Technology, Pingtung 912, Taiwan. Tel.: +886 8 7703202x7016; fax: +886 8 7740142.
E-mail address: cschou@mail.npust.edu.tw (C.-S. Chou).

by creating an energy barrier in the working electrode has been less studied. For example, Su et al. (2007) fabricated Au nanoparticles layer-by-layer onto the working electrode as a Schottky barrier in a water-based DSSC using chemical reduction method. Chou et al. (2009) investigated the use of a layer of TiO_2/Au (or TiO_2/Ag) composite particles as a Schottky barrier, and Chou et al. (2011) presented a layer of TiO_2/NiO composite particles as a n–p junction electrode. Further, the p-type oxide semiconductors, such as NiO (Sumikura et al., 2008a), CuAlO_2 (Bandara and Yasomane, 2007), and CuO (Sumikura et al., 2008b), were suggested as a hole collector and a barrier for charge recombination. The n–p junction electrodes, such as SnO_2/NiO (Bandara et al., 2004) and TiO_2/NiO (Bandara et al., 2005), were fabricated using the chemical process to promote the performance of the DSSC, and (Bandara et al., 2005) with researchers claimed that the efficiency of the TiO_2/NiO solar cell increases 30% more than that of the bare TiO_2 . Accordingly, reducing the electron recombination in the dye (or electrolyte) becomes an important issue in increasing the power conversion efficiency of a DSSC.

Aside from this, Wu et al. (2008) fabricated DSSCs based on ZnO-coated TiO_2 electrodes by RF magnetron sputtering, and the power conversion efficiency was increased from 4.76% to 6.55%. However, its highly efficient TiO_2/ZnO biphasic working electrode was obtained using an expensive vacuum technology that required a sophisticated process control. In contrast, this study used a simple dip coating method to fabricate a ZnO-coated TiO_2 electrode by immersing a FTO-glass (Fluorine doped tin oxide, $\text{SnO}_2:\text{F}$) substrate with a TiO_2 film in the solution of zinc acetate dehydrate [$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] and ethanol. Effects of the concentration of $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ and the duration of dipping on the band gap of a working electrode and the power conversion efficiency of a DSSC were noted. A comparison of a DSSC with the proposed working electrode (Fig. 1) with the conventional DSSC was also made.

2. Experimental details

The TiO_2 particles (P-25) of 30% rutile and 70% anatase with a particle size range (<100 nm) and the zinc acetate dehydrate [$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] with a purity of 98% were used in this study. Test conditions in the preparation of a solution of TiCl_4 and the solution of zinc acetate dehydrate [$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] and ethanol are presented in Table 1.

2.1. Preparing the working electrode

The procedure for fabricating a ZnO-coated TiO_2 working electrode of a DSSC (Fig. 1) consists of two stages. The first stage of preparing this working electrode included the following steps: (1) a FTO-glass substrate was immersed in the 0.05 M solution of TiCl_4 (Table 1) at a temperature of 70 °C for 30 min; (2) the colloid of TiO_2 particles (P-25)

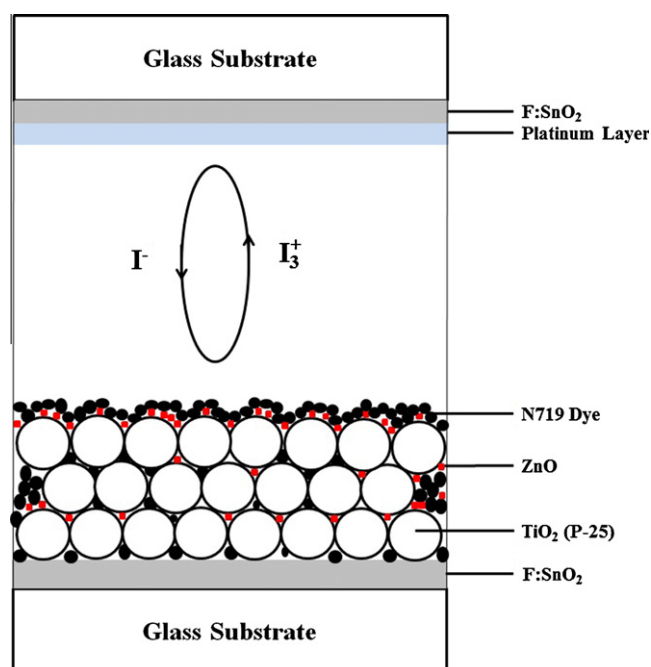


Fig. 1. Schematic of the DSSC with a ZnO-coated TiO_2 electrode.

Table 1

Test conditions of preparing TiCl_4 and $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ solutions.

	Material	Mass (g)	Solution	mol/L
B1	TiCl_4	0.95	100 mL DI water	0.05
B2	$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$	0.56	50 mL ethanol	0.05
B3		0.056		0.005

was prepared by mixing 2 g TiO_2 particles with 8 mL ethanol, 0.8 mL acetylacetone, and 0.1 mL Triton X-100, and the colloid was then homogenized in an ultrasonic homogenizer for a certain duration; (3) the colloid of TiO_2 particles was deposited on top of a FTO-glass substrate with the TiCl_4 treatment using the spin coating method; and (4) this substrate was then sintered at a temperature of 450 °C for 1 h in a high-temperature furnace (Thermolyne, 46100) (Table 2).

The second stage of preparing this working electrode included the following steps: (1) the surface of TiO_2 film on the FTO-glass substrate was modified by immersing this substrate in the solution of TiCl_4 and sintered at a temperature of 450 °C for 1 h (Table 3); (2) this substrate was then immersed in the solution of zinc acetate dehydrate [$\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$] and ethanol at a temperature of 25 °C for a preset duration of soaking, and the concentration of solution used in this step was either 0.05 or 0.005 mol/L (Tables 1 and 3); and (3) finally, this substrate was sintered at a temperature of 450 °C for 0.5 h (Table 3). Lu et al. (2010) prepared an electrode of ZnO nanoparticles synthesized via a direct precipitation method, and they indicated that an optimal annealing condition for a porous

Download English Version:

<https://daneshyari.com/en/article/1551085>

Download Persian Version:

<https://daneshyari.com/article/1551085>

[Daneshyari.com](https://daneshyari.com)