

Fabrication of dye sensitized solar cell using TiO₂ coated carbon nanotubes

Tae Young Lee^a, P.S. Alegaonkar^{a,b}, Ji-Beom Yoo^{a,*}

^a Center for Nanotubes and Nanostructured Composites, Sungkyunkwan University, 300 Chunchun-Dong, Jangan-Gu, Suwon, 440-746, Republic of Korea

^b Department of Physics, University of Pune, Pune-411 007, India

Available online 20 November 2006

Abstract

We fabricated a dye sensitized solar cells (DSCs) using TiO₂ coated multi-wall carbon nanotubes (TiO₂-CNTs). Carbon nanotubes (CNTs) have excellent electrical conductivity and good chemical stability. We introduced CNTs in DSCs to improve solar cell performance through reduction of series resistance. TiO₂-CNTs were obtained by Sol–Gel method. Compared with a conventional TiO₂ cell, the TiO₂-CNTs content (0.1 wt.%) cell showed ~50% increase in conversion efficiency, which is attributed to the increase in short circuit current density (J_{sc}). The enhancement in J_{sc} occurs due to improvement in interconnectivity between the TiO₂ particles and the TiO₂-CNTs in the porous TiO₂ film.

© 2006 Elsevier B.V. All rights reserved.

Keywords: Dye sensitized; Carbon nanotubes; Passivation layer

1. Introduction

DSCs have been attracting considerable attention because of their high efficiency, simple fabrication process and low production cost. Cost effectiveness is an important parameter for producing DSCs as compared to the widely used conventional Si-solar cells [1]. Moreover, enhanced dye sensitized solar cell efficiency would provide enormous economical advantages [2–6]. Recently, TiO₂ nanoparticles have been used as a working electrode for DSCs due to their higher value of efficiency than any other metal oxide semiconductor. However, the highest conversion efficiency so far reported for this device is ~10% under air mass (AM) 1.5 (100 mW cm⁻²) irradiation when liquid electrolytes containing I⁻/I₃⁻ redox couples was used as conjunction [7,8]. Because, photo-generated charge recombination should be prevented for enhanced efficiency, solely enlarging the oxide electrode surface area is not sufficient. Strategies to enhance efficiency include the promotion of electron transfer through film electrodes and the blockage of interface states lying below the edge of conduction band. Interface states facilitate recombination of injected conduction band electrons with I₃⁻ ions. The efforts have been made to improve the conversion efficiency by modifying TiO₂ film.

CNTs are remarkable materials, which are being widely studied because of their extraordinary electronic and mechanical properties. Polymer composites with CNTs have recently been investigated for improved electrical conducting layer, optical devices and high strength composites. A composite of poly(*p*-phenylene vinylene) with CNTs in a photovoltaic device showed good quantum efficiency, owing to the formation of a complex interpenetrating network with the polymer chains [9]. CNTs also conferred electrical conductivity to metal oxide nanocomposites [10]. However, only few reports have been found in the literature where CNTs were used in TiO₂ films of DSCs, despite of their expected potential to enhance solar energy conversion efficiency due to favorable electrical conductivity. Thus, we introduce CNTs in DSCs to improve the electrical conductivity of TiO₂ film.

In this study, we incorporated TiO₂-CNTs in porous TiO₂ films. As a result, the value of the J_{sc} of DSCs was increased. To prevent leakage current in device, thin passivated layer was prepared between the transparent conducting glass (FTO) substrate and porous TiO₂ film.

2. Experimental

Multi-walled CNTs (MWNTs, supplied by ILJIN Nanotech) synthesized by the thermal chemical vapor deposition (thermal CVD) method were used in the present study. The raw powder contains MWNTs of diameter 25 nm, amorphous carbon, and

* Corresponding author. Tel.: +82 31 290 7396; fax: +82 31 290 7410.

E-mail address: jbyoo@skku.ac.kr (J.-B. Yoo).

carbon-encapsulated metal nanoparticles. MWNTs were oxidized in a hydrogen peroxide (H_2O_2) solution under ultrasonication condition for 24 h at the temperature 50°C to produce finely dispersed MWNTs terminated with carboxylic acid groups. The resulting solution was filtered by a polytetrafluoroethylene (PTFE) membrane with pore size $1\ \mu\text{m}$. At this step, the carbonaceous impurities were removed from the as-grown MWNTs. Raman spectrometer and Fourier transform infrared spectrometer (FT-IR) were used to identify the formation of carboxylic acid groups on MWNTs.

The Sol–Gel solution (SGS) was prepared using titanium tetraisopropoxide $\text{Ti}(\text{OPr}^i)_4$, isopropanol (IPA), nitric acid (HNO_3) and distilled water (H_2O). The weight ratio for the SGS preparation is kept as 1:10:1:0.2 for $\text{Ti}(\text{OPr}^i)_4$:IPA: H_2O : HNO_3 [11]. The solution was reflux at the temperature 80°C for a period of 1 h, using a magnetic stirrer. For each sample, 1 g of MWNTs were mixed with 100 ml of SGS and stirred in close vials for 3 h. The impregnated MWNTs were separated from the solution by filtration process. To obtain TiO_2 -CNTs, the filtrated nanotubes were dried in an oven at 80°C for 1 h under atmospheric conditions followed by thermal treatment at 450°C for 1 h.

The passivation layer was introduced between the fluorine-doped SnO_2 (FTO) substrate and porous TiO_2 layer. To obtain a uniform and flat surface, the Sol solution ($\text{Ti}(\text{OPr}^i)_4$:IPA: HNO_3 = 1:10:0.2) was spin coated. After being dried in air, the passivation layer was annealed for 1 h at 500°C , under atmospheric conditions. Scanning electron microscope (SEM) measurement revealed the thickness of the passivation layer 70 nm. This solution was also reflux at 80°C for 1 h, using a magnetic stirrer before spin coating.

Porous TiO_2 films were prepared by coating a passivated transparent conducting glass substrate (Solaronix; fluorine-doped SnO_2 overlayer; sheet resistance: $17\ \Omega/\text{sq}$) with viscous slurry of TiO_2 powder and TiO_2 -CNTs dispersed in an aqueous solution. Initially, TiO_2 -CNTs (0.1–0.3 wt.%) were added in IPA and sonicated during 1 h to obtain well dispersed solution of TiO_2 -CNTs in IPA. Commercially available TiO_2 powder (0.5 g, P25, Degussa) and IPA included TiO_2 -CNTs (1 g) were ground in a mortar with distilled water (1 g), polyethylene glycol (0.1 g, Aldrich, MW 2000) and polyethylene oxide (0.1 g, Aldrich, MW 100,000) to break up the aggregate into a

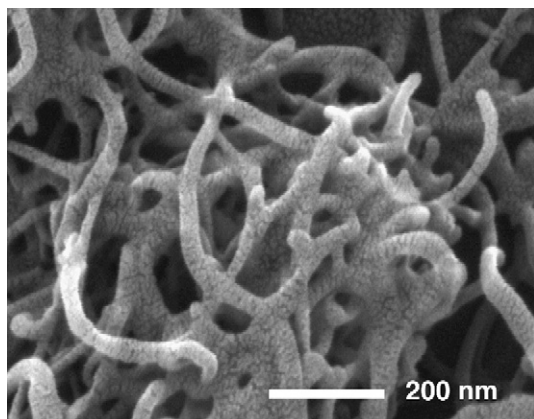


Fig. 1. SEM micrograph for TiO_2 coated MWNTs (TiO_2 -CNTs).

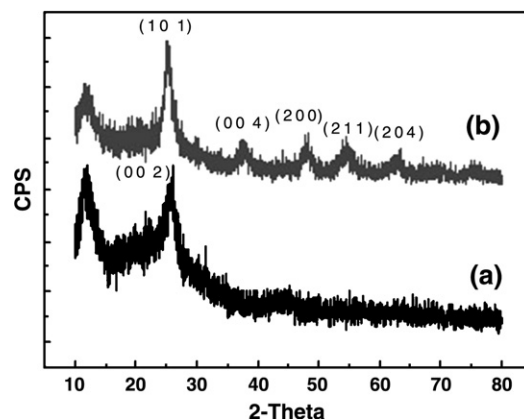


Fig. 2. XRD spectra for (a) pristine MWNTs and (b) TiO_2 -CNTs annealed at $\sim 450^\circ\text{C}$, under atmospheric conditions.

dispersed paste. Adhesive tape was placed on the edges of the conductive glass to form a guide for spreading the slurry using a glass plate. The film thickness was controlled by the amount of water in the slurry and by the thickness of adhesive tape. After being dried, the porous TiO_2 film mixed with TiO_2 -CNTs was annealed for 1 h at 500°C , under atmospheric conditions. The film thickness was 10–15 μm and measured with a Tencor Alpha-Step profiler.

Following this process, the resulting surface-modified TiO_2 films were immersed in absolute ethanol containing 0.3 mM $[\text{RuL}_2(\text{NCS})_2] \cdot 2\text{H}_2\text{O}$ ($L = 2,2'$ -bipyridine-4,4'-dicarboxylic acid; Solaronix) for 12 h at room temperature. The dye-covered electrodes were then rinsed with absolute ethanol and dried. Pt counter electrodes were prepared by spreading a drop of 5 mM hexachloroplatinic acid (Fluka) in IPA on the FTO glass followed by heating at 400°C for 30 min in air. The Pt electrode was placed over the dye-coated electrode, and the edges of the cell were sealed with 0.5-mm-wide strips of 100- μm -thick Surllyn (Dupont, grade 1702). The redox electrolyte consisted of 0.8 M lithium iodide (LiI), 40 mM iodine (I_2) and 0.2 M 4-*tert*-butylpyridine (TBP) in acetonitrile was introduced into the cell through one of the two small holes drilled in the counter electrode. The holes were then covered and sealed with small squares of microscope objective glass and Surllyn.

To analyze the crystallinity of TiO_2 -CNTs, X-ray diffraction (XRD) data was recorded. Investigations on film morphology were carried out by atomic force microscope (AFM) and field emission scanning electron microscope (FE-SEM). Current density–voltage (J – V) characteristics were recorded using Keithley (model 2400) as a source measure unit, which was connected between the FTO and Pt electrodes under an illumination of a 300 W Xe lamp (ILC technology Inc.). The voltage was scanned from -0.2 to $0.8\ \text{V}$ in steps of $0.05\ \text{V}$. The incident light intensity ($100\ \text{mW cm}^{-2}$) was calibrated using a Newport 818 UV photodiode detector.

3. Results and discussions

It is known that pristine MWNTs have hydrophobic surface and poor dispersion stability. To avoid these problems the

Download English Version:

<https://daneshyari.com/en/article/1676349>

Download Persian Version:

<https://daneshyari.com/article/1676349>

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