Effect of Transparency of CNT counter electrodes on the Efficiency of DSSCs

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Abstract : Carbon Nanotubes (CNT) on flexible indium tin oxide (ITO) PET films were prepared for dye-sensitized solar cell (DSSC). These CNTs were prepared by spray coating method for various amount of light transparency. Also, Pt counter electrode was prepared by electro deposition method. All TiO_2 electrodes were deposited on ITO-PET films by spray coating method. Micro structural images show that CNT counter electrodes prepared by spray-coating have more dense structure with increasing spraying time (0 to 60 seconds). DSSC consisting of TiO_2 electrode and CNT counter electrode was fabricated with various amount of light absorption. DSSC have higher light energy conversion efficiency with increasing the thickness of CNT counter electrode. CNT counter electrode is at least compatible to that of Pt counter electrode.

Key Words : CNT, dye-sensitized solar cell, TiO_2, spray coating, ITO-PET film

1. INTRODUCTION

Many studies on mesoporous oxide electrode, dye and electrolyte for dye sensitized solar cells (DSSCs) have been carried out until now[1]. However, counter electrodes have not much studied so far. In this reason, we need to understand its microstructure and effect of CNT counter electrode on the efficiency of DSSCs.

The transparent conductive oxide(TCO) coated PET filmis presently used as a cathode in DSSCs. However, TCO itself has extremely poor catalytic property for iodine reduction;[2,3] . In this reason, it is required to modify TCO with good catalytic materials such as platinum, carbon, etc. Until now, Pt electrode has been widely used as a catalyst. In this case, it is essential for electrodes to promote electron-transfer reaction, not to degrade its electro-chemical property and to retain low voltage during redox coupling, and to have high electrical conductivity and low charge transfer resistance. Also, it requires large effective area for good catalytic reaction. Especially, 3D structure of catalytic material is expected to enhance electron-transfer reaction within electrolyte through enlarged effective reaction area. However, it is difficult to fabricate platinum in 3-dimensional (3D) configuration.

In order to overcome such limit, carbon nanotubes (CNTs) offer very promising materials due to their novel physical and electrochemical properties, which have caused considerable excitement. This material system can be easily fabricated in the form of 3D electrode. In this respect, we report novel method for fabricating 3D CNT electrodes in conjunction with ITO-PET films. DSSCs are made up of spray-coated CNT counter electrode and TiO_2 on ITO-PET films. I-V characterization of DSSCs is carried out to compare DSSCs having CNT-coated counter electrode with DSSCs having Pt-electroplated counter electrod.

2. EXPERIMENTAL PROCEDURE

2.1 TiO_2 ELECTRODE PREPARATION

In order to fabricate TiO_2 electrode, nano-crystalline TiO_2 (P25) powders (Degussa AG co.) was used. First, slurry of TiO_2 powder and alcholwas prepared, second, spray coating was conducted on ITO-PET films(<10 ohm/sq, 80% transmittance in the visible, 0.196 cm^2 active area of TiO_2 in diameter), third, TiO_2 -coated ITO-PET films was thermally treated below 200°C for 30min. In order to sensitize TiO_2 films, TiO_2 electrodes were immersed in a solution of 0.02 mg/ml red dye (RuL2(NCS)2[L=2,2'-bipyridine-4, 4'-dicar boxylic acid] in ethanol for 24h at room temperature. The cleaning process was followed with pure ethanol.

2.2 COUNTER ELECTRODE

CNT counter electrode was deposited on ITO-PET films by spray coating. First, slurry of CNT powder based on 3% CMC added-water was prepared, second, spraying was conducted on ITO-PET films, third, CNT-coated ITO-PET films was thermally treated on 100°C for 30min. Also, Pt-counter electrodes were prepared, using electroplating in $H_2Cl_4Pt_6$ solution.

2.3 CELL CONSTRUCTION

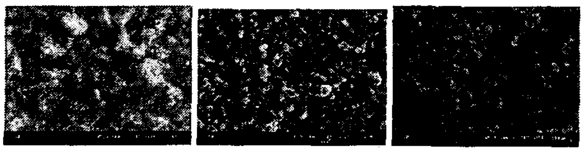
In order to assemble dye sensitized solar cells with 0.196 cm^2 active area, the structure of solar cell were design. The CNT counter electrode and the dye-adsorbed TiO_2 electrode were sandwiched with approximately 50 m spacers, using alligator clips. The electrolyte containing I^-/I^{3-} redox couple was introduced into the dye sensitized solar cell by capillary effect in the space gap area. Silver paste was put on the side edge of both TiO_2 and CNT counter electrodes. Assembled dye-sensitized solar cells having an active area of approximately 0.196cm^2 was fabricated.

2.4 CHARACTERIZATION

Light transmittance and absorption of CNT-spray coated and Pt-electroplated counter electrodes were measured with monochromator in variation of preparation process of counter electrode. Photoelectric property of DSSCs having TiO_2 electrode and Pt counter electrode was measured, using solar simulator and Keithley 2400 source meter in order to measure short-circuit photocurrent (Jsc), open- circuit voltage (Voc), fill-factor (FF) and cell efficiency. Also, we need to investigate the efficiency of dye-sensitized solar cells in variation of the preparation process of Pt counter electrode. Microstrucural investigation of mesoscopic TiO_2 electrode and Pt counter electrode were carried out, using FE-SEM(field emission scanning electron microscope) and sheet resistance was measured with 4-point probe.

3. RESULTS AND DISCUSSION

3.1 MICROSTRUCTURE OF ELECTRODES



(a) (b) (c)

(a) Pt-electroplate(transparent,60%), (b) CNT-spray coated (no-transparent,0%), (c) CNTspray-coated (transparent, 40%)

Fig. 1. FE-SEM micrographs of Pt-electroplated and CNT-spray coated counter electrodes with two different transparency

Fig. 1 shows photographs of Pt-electroplated and CNT-spray coated electrodes. Semi-transparent CNT counter electrode can be fabricated by changing spraying time within 30-60 sec. From light absorption measurement, surface area in CNT counter electrodes increased with increasing light absorption. Here, so many tubes in the surface of CNT counter electrode are randomly tangled with a plenty of open pores. We expect that tangled CNTs within the counter electrode can be in 3-dimensional configuration. This means CNT counter electrode with large surface area can be fabricated, by using spray coating. Figs. 1(b)(c) show FE-SEM micrographs as a function of spraying time within 30-60 sec. With increasing spraying time, the surface area of CNTs in counter electrode also increased.

3.2 Photocurrent and voltage curves of DSSCs

Fig.2 shows photocurrent-voltage curves in variation of light transparency in CNT electrode, in comparison with Pt-electroplated counter electrodes. Assembled dye sensitized solar cell was exposed to simulated sunlight with AM1.5 spectral distribution. Light intensity was 100mW/cm^2 and the active surface area of solar cells was approximately 0.196cm^2.

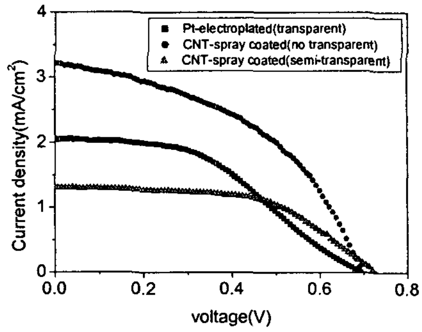


Fig. 2. Photocurrent-voltage curves of DSSCs

As a result, in the case of 100% light absorption of CNT-spray coated counter electrode, max. efficiency of DSSCs was observed in comparison with the case of DSSCs having transparent Pt-electroplated counter electrode.

In the case of CNT counter electrode, enhanced efficiency of dye-sensitized solar cells was observed with increasing light absorbtion of CNT counter electrodes. This means that catalytic behaviours of CNT-electrode increased with increasing light absorbtion of CNT counter electrodes, since the surface area of CNT in the case of 100% light absorbtion counter electrode is more than that in the case of low light absorbtion counter electrodes.

4. CONCLUSION

Efficiency of three dye-sensitized solar cells (DSSC) with two Carbon Nanotube (CNT) counter electrodes and one Pt-electroplated counter electrode was investigated. These CNT layers on ITO-PET films were prepared by spray coating for various amount of light transparency. Also, Pt counter electrode was prepared by electroplating. All TiO_2 electrodes were deposited on ITO-PET films by spray coating. DSSCs consisting of TiO_2 electrode and CNT counter electrode were fabricated in variation of its light absorption. DSSC have higher light energy conversion efficiency with increasing the thickness of CNT counter electrode. CNT counter electrode is at least compatible or exceeded to that of Pt counter electrode.

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