Performance Improvement of Flexible Dye-sensitized Solar Cells by Addition of Larger TiO_2 Particle as Scattering Layer

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Abstract

The performance of dye-sensitized solar cells (DSC) is affected by its components such as photoelectrode material, dye-sensitized, electrolyte, substrate and counter electrode materials. In this study, we investigated the effect the addition of larger TiO_2 particle as a scattering layer to the TiO_2 nanoparticle. The paste which containing the mixture of TiO_2 particle was deposited on flexible substrate of ITO-PET and followed by sintering at 120 ^oC. The surface morphology of photoelectrode TiO_2 films were observed using SEM and the optical properties were investigated by measure percent transmittance and absorbance of dye covered TiO_2 film using UV-Vis Spectrophotometer. The I-V characteristic of flexible dye-sensitized solar cells were measure using Sun Simulator with light source of Xenon at an intensity of 50 mW/cm^2. The results showed that the current density and the conversion efficiency of dye solar cell enchance with the addition scattering layer, there are 0.2 mA/cm^2 and 0.135% respectively.

Keywords: flexible dye-sensitized solar cells, I-V characteristics, TiO_2 particle, scattering layer.

1. Introduction

Dye-sensitized solar cells (DSC) have attracted much attention from the scientific and commercial community due to the low production cost, good stability and high energy conversion efficiency [1,2].

DSC is an electrochemical device based on light absorption by sensitizer dye molecules that attached on the surface of a wide band gap semiconductor, usually TiO_2 nanoparticles. This process is followed by dye regeneration and hole transportation to the counter electrode by the redox electrolyte to converting iodide (I-) into tri-iodide. Usually the substrate material of DSC is transparent conducting oxide (TCO) coated glass due to its excellent optical, electrical and compatibility with high-temperature processing [3]. Currently, one of DSC research has been focused on the development of flexible plastic substrates, such as indium tin oxide (ITO) coated polyethylene terephthalate (PET) or polyethylene naphthalate (PEN). The flexible DSC is very interest to develop because of its merits, such as light weight, good flexibility, simple process, and lower cost [4]. An attractively advantage of flexible DSC is the potential for roll to roll printing on polymer substrates so it very potential to commercial application such as mobile power source for portable electronic devices [5]. There are many innovation technology to improve of DSC performance have been done, like the new dyes which absorb a longer range of wavelength, modification of nanostructure titanium dioxide for increasing surface area [2]. Higher surface area is usually obtained with smaller particle size and the usual consequence is relatively transparent film so that poor light scattering. Ferber et.al have reported addition of particle of 125-150 nm to the smaller TiO_2 particles can increase efficient light collect in the device [6]. In his papers, Jeng el.al also have indicated different particle size effect of TiO_2 layer on efficiency of DSC using FTO substrate.

In this work, we investigate performance improvement of DSC with addition of the larger TiO_2 particle as scattering layer using flexible substrate. The TiO2 film was prepared on ITO coated PET by using a binder-free titania paste and followed by sintered at low temperature.

2. Experimental

ITO-PET substrates (60 ohm/sq, thickness of 0.1 mm, Aldrich product) were cleaned with mild soap and isopropyl alcohol (Merck) in an ultrasonic, and then rinsed with deionized water. The TiO2 paste were prepared with add 6 gr of TiO2 powder to the mixed solvent of 3 mL ethanol (Merck) and several drops of HCl (1M) dan Triton X-100 (Merck). The TiO2 powder is contain of TiO_2 nanoparticle (Dyesol, Swichzerland) for A paste and the mixture powders containing TiO2 nanoparticle (Dyesol, Swichzerland) and the larger TiO_2 particle (reflector Dyesol, Swichzerland) with ratio composition of 10 : 1 (**%wt)** for B paste. The TiO2 pastes ware deposited onto the substrate by doctor blade printing and followed by annealing of the TiO_2 film n a vacuum oven for 4 hours at 120 ^oC. All samples were subsequently immersed on a solution consisting Ruthenium complex dye $RuL_2(NCS)_2$:2 TBA (L = 2,2'-bipyridil-4,4'-dicarboxylic acid; TBA = tetrabutylammonium) known as N719 (Dyesol) for 24 hours on a dark place and continued all samples were rinsed on ethanol to remove the dye residues. A counter electrode was prepared by deposited a Pt onto ITO-PET substrate using sputtering technique. The reason for choosing sputtered-Pt as the catalyst has been explained in our previous work [7]. Platinum layer as counter electrode was deposited for 20 minutes with an initial pressure of $6.6x10^{-3}$ Pa, Argon gas pressure of $5.3x10^{-1}$ Pa, rotation speed 5 rpm and power 50 W. Both photoelectrode and counter-electrode were assembled into a sandwich structure and sealed up using a 60 µm thick thermoplastic sealant (Solaronix S.A). Dyesol liquid electrolyte EL-HSE was injected into the assembled samples.

The surface morphology of the TiO_2 layer were investigated using a Jeol Scanning Electron Microscope (SEM). Optical properties was analysed using UV-Vis Spectrophotometer. The photocurrent-voltage (I-V) characteristics of the DSC of 1 cm^2 active area cells were measured using a National Instrument I-V measurement under an irradiation of 50 mW/cm^2 supplied by a xenon light solar simulator.

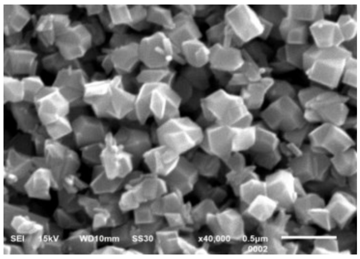
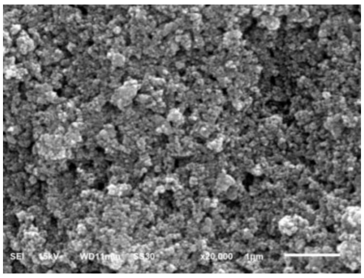
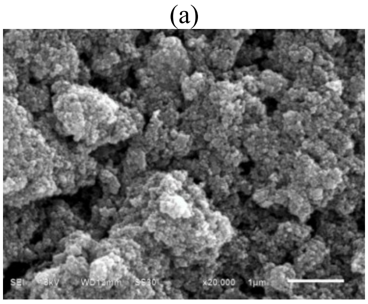


Fig.1. SEM Image of TiO_2 particle from reflector paste (Dyesol product) which used as a scattering layer.



(a)

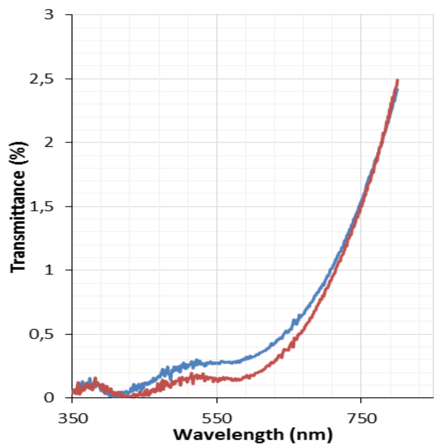


(b)

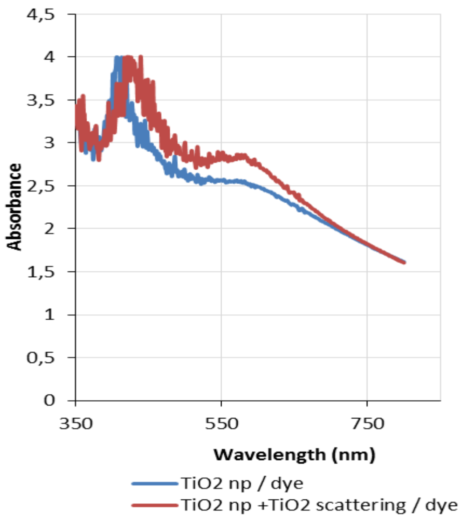
Fig.2. The surface view SEM image of TiO_2 photoelectrode film after sintering at low temperature of 120^oC ; the morphology of the anatase TiO_2 nanoparticle (a) and mixture of the anatase TiO_2 nanoparticle with scattered-anatase TiO_2.

3. Results and Discussion

Fig.1 indicates morphology of TiO_2 particle from reflector paste (Dyesol product) which has particle size of 150-250 nm. This particles were used as a scattering layer in the mixture of photoelectrode TiO_2 paste.



(a)



(b)

Fig.3. Optical properties of the dye covered TiO_2 film; percent transmittance (a) and absorbance (b).

Fig 2 shows the surface view SEM image of TiO_2 film after sintering at low temperature of 120 ^oC that deposited by blade printing. The images indicate the morphology of the anatase TiO_2 nanoparticle (A paste) and mixture of the anatase TiO_2 nanoparticle with scattered-anatase TiO_2 (B paste) for comparison. Deposition of A paste on the surface of FTO produces TiO_2 film, which have particle arrangement homogeneous and flat enough (Fig.3a). Whereas deposition of B paste produces TiO_2 film with particles of random-size agglomerated (Fig.3b). The agglomerates are formed from large particle of scattered-anatase TiO_2 and small particle of anatase TiO_2. This TiO_2 film has a pore size bigger than the film of TiO_2 nanoparticle.

The optical properties the TiO_2 film resulted was investigated through measurement of absorbance and transmittance. Fig. 3 shows that TiO_2 photoelectrode film which applied scattered-anatase TiO_2 results lower percent transmittance and higher absorbance. It is known that smaller particles of TiO_2 film have large surface area and can absorb more dyes. Hence, they have low contact resistance and high photocurrent [2]. In addition, the increasing of large particle will be happened reabsorption in the small particle size TiO_2. The light that contact on the surface of TiO_2 particle will be scattered and light transmition decrease (Fig.3a). Reduction light transmition can enhance light harvesting so the dyes can absorb more light. High absorpsion of dyes in the region 400 – 600nm is shown in the Fig.3b.

Using the large TiO_2 particle as scattering layer, increase dye absorption. The more light absoption can result higher photocurrent so conversion efficiency of solar cell resulted is also higher.

Fig 4 shows I-V curve of dye solar cell with active area of 1 cm^2 and the performance of parameters is described in Table 1. The dye solar cell which used scattering layer result current density of 0.2 mA/cm^2. It is higher of 30% than without scattering layer. Both cells result similar open-circuit voltage, that is 0.632V. The power conversion efficiency obtained is 0.095% and 0.135% for dye solar cell without scattering layer and with scattering layer, respectively. It indicates that the addition of scattering layer effect to current density and efficiency of cell resulted.

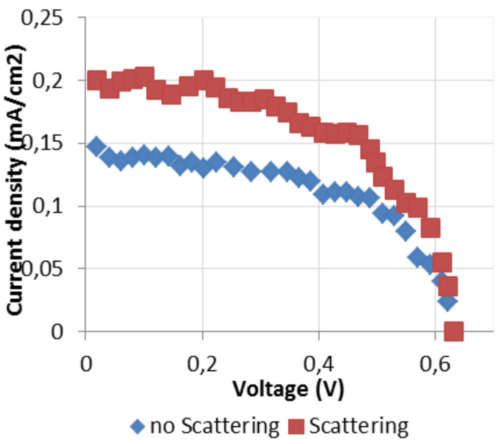


Fig 4. Current-Voltage characterictics of the cells with applied TiO_2 photoelectrode using and without scattering layer.

Table.1 The performance parameters of dye solar cells, active area of 1 cm^2.

Electrical Characterstics	Without Scattering	Using Scattering
V_{oc} (V)	0.632	0.632
J_{sc} (mA/cm^2)	0.14	0.2
P_m (mWatt)	5.17×10^{-2}	7.30×10^{-2}
FF	0.56	0.58
η (%)	0.095	0.135

4. Conclusion

The addition of the larger TiO_2 particle to mixture of the anatase TiO_2 nanoparticle can be function as a scattering layer on TiO_2 photoelectrode film. The scattering layer effect to Performance improvement of flexible dye-sensitized solar cells. The percent transmittance decrease and the absorbance increase with the addition of scattering layer. The current density and the conversion efficiency of dye solar cell enchance also, there are 0.2 0,2 mA/cm^2 and 0.135%.

Acknowledgements

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