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The effect of titanium dioxide nanoparticles thin layer on overall performance of dye sensitized solar cells

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Abstract
This research studied the effect of TiO_2 thickness layer on Dye sensitized Solar cell DSSCs. Photo-anode was fabricated by depositing a TiO_2 paste on fluorine–doped SnO_2 (FTO) substrate glass and sintered at 500 °C for 2 hrs. Different thickness (3.6, 9, and 12) µm of TiO_2 layer has deposited on FTO glass. The thickness of the layer was measured using scanning electron microscope SEM .The results show that the thickness of 9 µm gives the best performance in term of short-circuit current I_{sc} as compared to other thickness layers due to the generation of photo electron.

Keywords: TiO_2 nanoparticles; $DSSC_s$; Thickness layers.

1. Introduction

DSSCs are Photo-voltaic devices convert visible light into electricity. DSSCs cost lower than Silicon solar cells, but its efficiency is 11.1% which is lower than Silicon solar cells [1, 2].Typically, a DSSC consist of:

1. Substrate glass coated with conductive oxide, such as FTO.
2. Semiconductor film deposited on FTO glass such as Tio2 nanoparticles to form photo-anode electrode.
3. Counter electrode usually formed by depositing Pt on FTO glass.
4. TiO_2 electrode immersed in a dye which absorb the light usually N_{719} dye.
5. The electrolyte contains a redox mediator, such as triiodide/iodine (I_3 /I) [3].

DSSC operates when the dye molecules absorbs the incident dye which transform to exciting state. The conduction band of TiO_2 injected by the excited electrons then to the FTO layer. Then, throw the external load, these electrons reach Pt electrode. Overall efficiency (Ƞ) of DSSC, depends on short-circuit current Jsc, open-circuit voltage, Voc, light intensity I_s, and fill factor (FF), as shown in this equation, [4],

$$\eta = Isc.Voc.FF/I_s \qquad (1)$$

Particle size of TiO_2, dye anchored to the dye, and the TiO_2 film thickness effected on performance of DSSC. Usually, when the thickness increases, the Isc is increased and Voc is decreased [5]. There are many researchers have studied the effect of TiO_2 film thickness on DSSCs performance. Sedghi has shown increasing in dye absorption due to increasing of the film thickness and obtained 7.51% of power conversion [6].

2. Experimental work

TiO_2 nanoparticle size and porosity were measured by using a Zeiss-Gemini FE-SEM. Photo-anode electrode was formed by depositing TiO_2 film layer on FTO glass using doctor-blade method. TiO_2 paste was prepared by adding 0.43 gram to 3.3 ml ethanol. In order to prevent the coagulation of the TiO_2 paste, 0.1 ml of acetyl-acetone was added to the paste. To make the spreading of the TiO_2 paste over the FTO glass, two drops of surfactant (triton X-100) was added to the paste, then the solution were stirred for 25 mins. After that, TiO_2 paste was uniformly deposited on FTO glass. The coating area was 2 cm^2. Each single depositing of TiO_2 paste $_{gives}$ 3 µm thicknesses. So, we got different thickness (3, 6, 9, and 12) µm by depositing the TiO_2 many times. Then, the electrode was dried in air for 45 mins and sintered to 500 °C for 2 hrs at heating and cooling rate of 10 °C/min. Sintering process forms higher crystalline TiO_2 and that enhances the interconnection between nanoparticles and makes the electrons movement through the TiO_2 film more easily. Finally, the electrode is immersed in a solution of 0.045 g of ruthenium dye in 100 mL of ethyl alcohol for 12 hrs at room temperature. Counter electrode was prepared by depositing 300 nm of Pt on FTO glass at rate of 34 nm/min. The electrolyte was prepared by mixing 0.6 M 1-butyl-3 methyleimidazolium, 0.5 M 4-tertbutyl-pyrodine, 0.1 M lithium iodide, 0.03 M Iodine, 0.1M guanidinium-thiocyanate in a mixture of 8.5 mL acetonitrile and 1.5 mL valeronitrile. Then, the cell was assembled by binding the two electrodes face-to-face with a binder clips. 40µm of Teflon is placed between the two electrodes to prevent the short circuit.

Then, electrolyte is inserted between the two electrodes by a capillary drawing action. Finally, a stainless-steel mask with a center hole 0.25 cm^2 area is placed on the TiO_2 electrode to expose a small area of film. Solar simulator (Xeon 300 W) was used for DSSCs measurements a under a light intensity 100 mW/cm^2 at 25 °C.

3. Results and discussions

Figure 1 shows that the average particles size of TiO_2 is about 20nm. The microstructure is fluffy with high porosity.

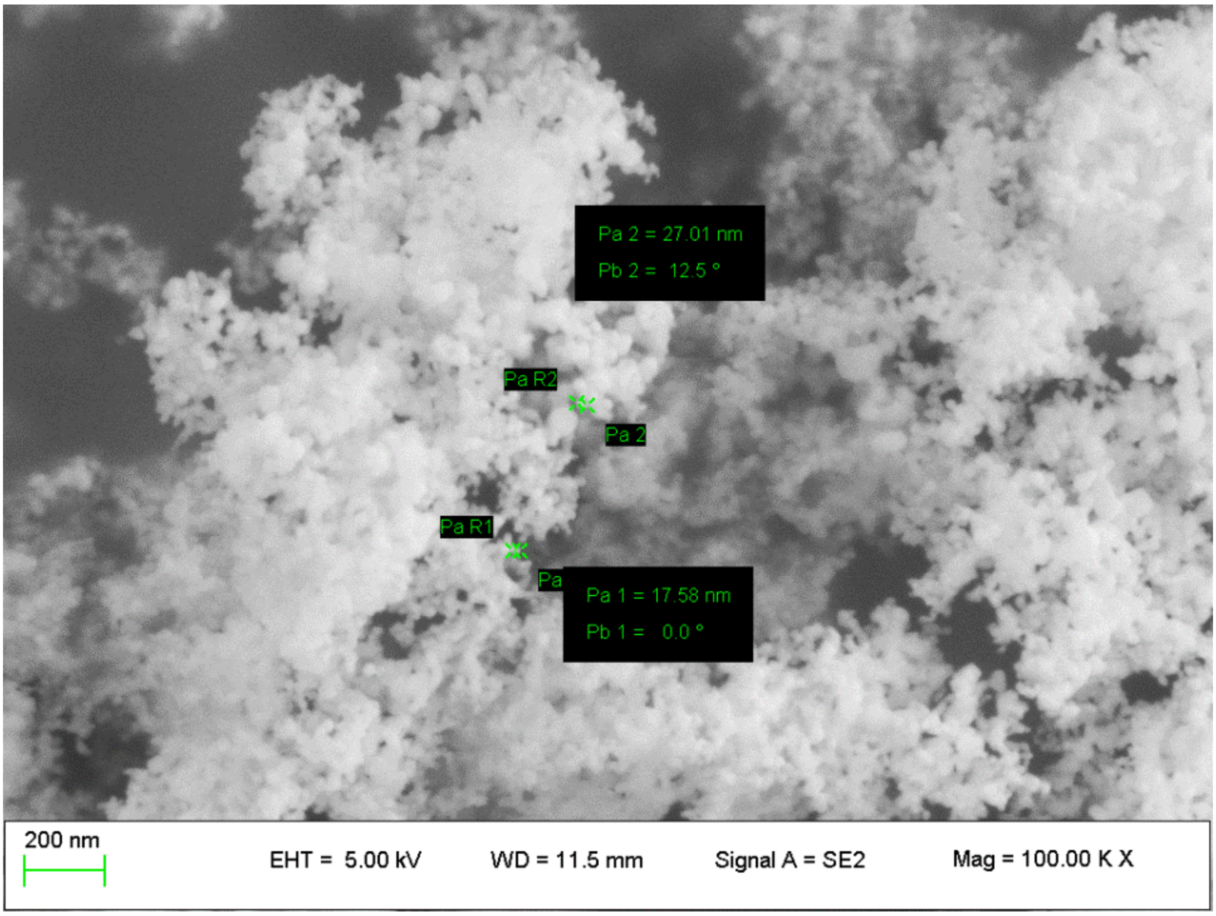

Figure 1. SEM image of TiO_2 nanoparticles.

The porosity will facilitate the movement of electrons to the FTO film. It's noticed that the TiO_2 nanoparticles are gathered as agglomerated form due to the collision between nanoparticles.
DSSCs measurements show in Table 1 and Figure 2 respectively.

Table 1. DSSCs measurements results.

Thickness layer (µm)	I_s (A)	V_{oc} (V)	FF	EFF
3	- 0.000740	0.61	0.534	1.026
6	- 0.000697	0.608	0.587	0.99
9	- 0.000541	0.53	0.541	0.63072
12	- 0.000612	0.56	0.804	0.586

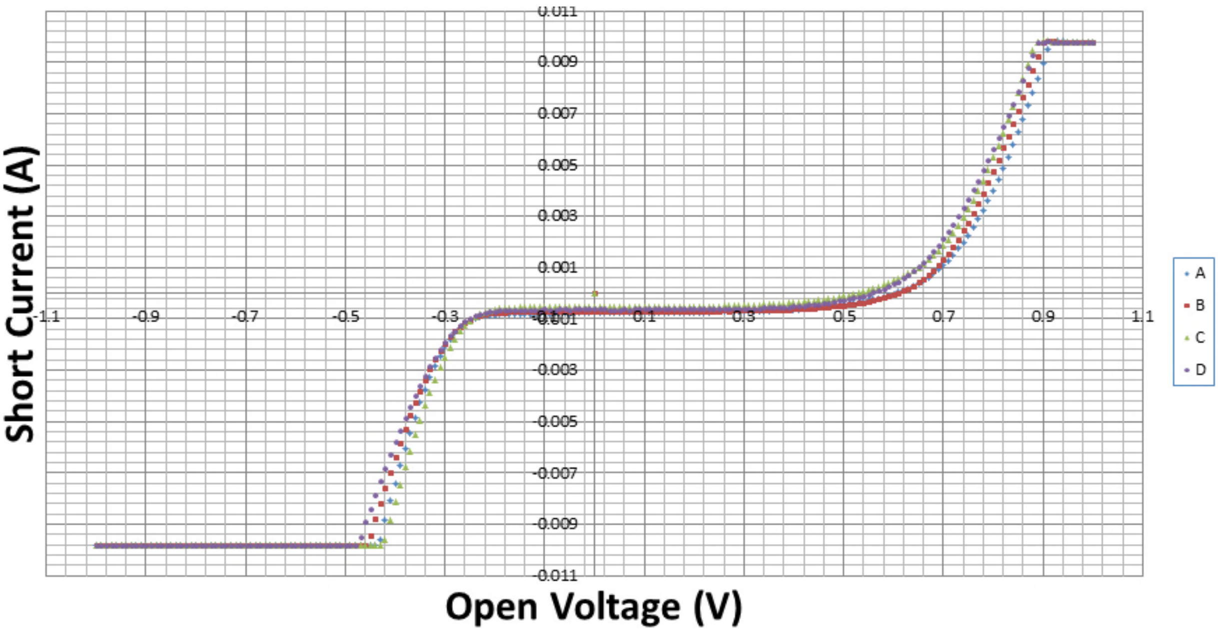

Figure 2. Current / voltage curves for different layers thickness of TiO_2: (a) 3 µm, (b) 6 µm, (c) 9 µm, and (d) 12 µm.

The experimental results shown that the Isc increase when TiO_2 film thickness increased due to the Photo-electron generation. When TiO_2 film thickness increase, the internal surface is increased and that enhance absorption of the dye. Therefore, a more photons can be absorbed by thicker electrode and has high I_{sc}. However, when the TiO_2 film layer is higher than penetration depth of the light, the generation of electron-photon reaches to a limit and Isc cannot be more increased. So, increase the thickness further than the light penetration depth leads to create recombination centers and cause losing in electrons generation and reduction of Isc. That explained the reason of 9 µm has higher Isc than 12 µm [6].
V_{oc} is decreased as the thickness increase. This behavior attributes to the decrease in light intensity (Is) as the light transmits into the electrode [5]. Also, the decreasing of Voc decreasing may attribute to the increasing of charge recombination [7]. As the consequence of the above results, the best efficiency was for thickness of 3 µm thickness layer of TiO_2 film.

4. Conclusions

TiO_2 film thickness effect of on performance of DSSCs was investigated in this paper. Different layer thickness (3, 6, 9, and 12) µm of TiO_2 were deposited on FTO glass and sintered at 500 C. The experimental results show that the Isc increase when TiO_2 film thickness increased due to the Photo-electron generation The best performance in term of Isc was shown in 9 µm film thickness due to increasing in generation of Photo-electron. Voc decreased as the thickness increase due to many factors such as reducing light intensity and creation of recombination centers.

List of symbols and abbreviations

η	overall efficiency of DSSCs
V_{oc}	open-circuit voltage
J_{sc}	short-circuit current
FF	Fill factor
I_s	light intensity
DSSCs	Dye sensitized solar cells
FTO	Flourine-doped Tin oxide

References

[1] Mathew A., Rao G. M., Munichandraiah N., Effect of TiO2 electrode thickness on photovoltaic properties of dye sensitized solar cells based on randomly oriented titania nanotubes, Materials Chemistry and Physics. 2011, 127, 95–101.

[2] Ihara M., Kanno M., Inoue S., Photoabsorption-enhanced dye-sensitized solar cell by using localized surface plasmon of silver nanoparticles modified with polymer, Physica E Low-dimentional Systems and Nanostructures. 2010, 42, 2867-2871.

[3] Nazeeruddin K., Baranoff E., Grätzel M., Dye-sensitized solar cells: A brief overview, Solar Energy. 2011, 85, 1172-1178.

[4] Narayan M. R., Dye sensitized solar cells based on natural photosensitizers, Renewable and Sustainable Energy Reviews. 2012, 16, 208-215.

[5] Balraju P., Suresh P., Kumar M., Sharma G. D., Effect of counter electrode, thickness and sintering temperature of TiO2 electrode and TBP addition in electrolyte on photovoltaic performance of dye sensitized solar cell using pyronine G (PYR) dye, Journal of Photochemistry and Photobiology A: Chemistry. 2009, 206, 53-63.

[6] Sedghi A., Miankushki H. N., The effect of drying and thickness of TiO2 electrodes on the photovoltaic performance of dye-sensitized solar cells, International Journal of Electrochemical Science.2015, 10, 3354-3362.

[7] Xu T., Nanoarchitectured electrodes for enhanced electron transport in dye-sensetized solar cells (Ed. Zang L.), p.p. 270-298, Springer, 2011.