

EFFECT OF SnO₂ BLOCKING LAYER ON THE EFFICIENCY OF DYE-SENSITIZED SOLAR CELL

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Received 2 March 2017; Revised 12 June 2017; Accepted 26 June 2017

ABSTRACT

The effect of SnO₂ blocking layer prepared by using ultrasonic spray pyrolysis method on the performance of dye-sensitized solar cells (DSSCs) was studied. The SnO₂ blocking layer was coated on the transparent conducting oxide (TCO) layer before TiO₂ would be coated for improving the solar cell efficiency. The DSSCs structure consisted of TiO₂ working electrode with and without SnO₂ blocking layer, ruthenium (II) (N719) dye, lithium iodide electrolyte and Pt counter electrode. In this work, the SnO₂ blocking layer coated on TCO glass was deposited by various times. I-V characteristic was used to measure efficiency of DSSC.

KEYWORDS: SnO₂ blocking layer; Dye-sensitized, Solar cell

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INTRODUCTION

Dye-sensitized solar cells (DSSCs) have been examined extensively on manner of their improvement of high efficiency and low cost invention [1]. Conventional DSSCs consist of the dye/TiO₂ working electrode coated on a transparent conducting oxide (TCO) glass. Platinum coated on TCO glass is used as a counter electrode, and I⁻/I₃⁻ redox couple electrolyte is filled between the two electrodes. There are many methods to improve the efficiency of solar cell. The efficiency of DSSCs can be improved by coating a thin compact blocking layer on TCO glass substrate before coating of the TiO₂ film.

The DSSCs efficiency depends on kinetic competition between the black electron transfer and the dye regeneration processes. Electrons in TiO₂ can backward to recombination with dye cations and I₃⁻. In ideal, all dye cations are reduced by I⁻. Electrons can not transfer to I₃⁻ at short circuit. Electrons can transfer to I₃⁻ at open circuit. The blocking layer was applied to protect the backward electron transfer from TCO to lithium iodide electrolyte.

Various groups have reported procedures for coating blocking layer films with a different metal oxide such as MgO, ZnO and SnO₂. In SnO₂/TiO₂ DSSCs, the electrons are excited from dye

molecules then electrons transfer to TiO₂. Electrons can be transferred quickly in to the SnO₂ blocking layer which has the lower lying conduction band (E_{CB} = 0 V vs. NHE) compared with the conduction band of TiO₂ (E_{CB} = -0.5 V vs. NHE) [3].

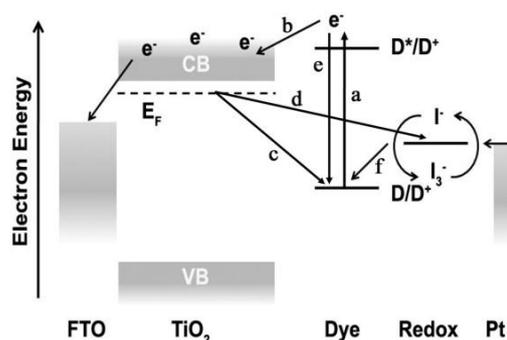


Fig. 1 Schematic representation of electron transfer processes in DSSC indicating excited electrons in the absorbed dyes (a), electron injection into the conduction band of TiO₂ (b), electrons at the conduction band of TiO₂ transfer to dye cations (c) and I₃⁻ (d), electron at lowest unoccupied molecular orbital of adsorbed dye transfer to highest occupied molecular orbital of adsorbed dye (e), electron at dye cations reduced by I⁻ (f) [2].

In this work, the SnO₂ blocking layer was deposited by using spray pyrolysis method on TCO/glass substrate for improving the performance of the DSSCs.

MATERIALS AND METHODS

For the DSSCs fabrication, the TCO/glass substrate was purchased from Nippon Sheet Glass. The TCO is SnO₂: F, fluorine doped tin oxide. The SnO₂: F electrode has thickness of 500 nm, and it has sheet resistance of 20 ohm/square with optical transmission about 70%. The substrate was washed by using acetone, alcohol and deionized water, respectively.

For TiO₂ electrode, the TiO₂ paste, commercial (P25) Dyesol Australia Pty. Ltd, with 20 nm diameter was used for TiO₂ working electrode that it was prepared by using screen printing method. The TiO₂ paste was screened on TCO/glass substrate for five times. The TiO₂ area was 0.36 cm². For TiO₂/SnO₂ electrode, SnO₂ blocking layer was prepared by spray pyrolysis method. Thin film of SnO₂ was prepared by using 0.1 M of tin (IV) chloride pentahydrate (SnCl₄·5H₂O) dissolved in 90 ml of methanol and 10 ml of deionized water. The substrate temperature was kept at 450 °C over the deposition process. The solution was put in the glass tube with the diameter of 26 mm that was covered by parafilm sheet. The glass tube was placed on the ultrasonic transducer to induce the mist of solution then the mist solution was flowed to the substrate at the constant compressed flow rate of 1.0 l/min. The TCO/glass substrate was placed 25 cm above the solution with double wall glass chamber as displayed in Fig. 2. The various deposition times were used at 15, 30, and 50 minute. After the SnO₂ blocking layer was deposited on the TCO/glass substrate, the TiO₂ paste was screened on the SnO₂/TCO/glass substrate. The both working electrodes were annealed at 500 °C for 50 min. The all working electrodes were immersed in standard ruthenium(II) (N719) dye at room temperature for 24 hour.

For Pt counter electrode, the 100 mg of hydrogen hexachloroplatinate (IV) (Cl₆H₂Pt) was mixed with 100 ml of ethyl cellulose 30 wt% in terpineol anhydrous then the solution paste was printed on TCO/glass substrate, and it was annealed at 500 °C for 50 min. The electrolyte was prepared by 0.5 M of tert-butylpyridine (TBP), 0.05 M of iodine (I₂) and 0.5 M of lithium iodide (LiI) then materials were mixed and dissolved in acetonitrile. The electrolyte solution was injected through predrilled holes on the anode electrode. The working and counter

electrodes were sealed by polymer sheet then electrolyte was filled pass the holes predrilled on the counter electrode then they were sealed by aluminum tape. The DSSC efficiency was calculated form the current-voltage graph that was measured under light with air mass of 1.5.

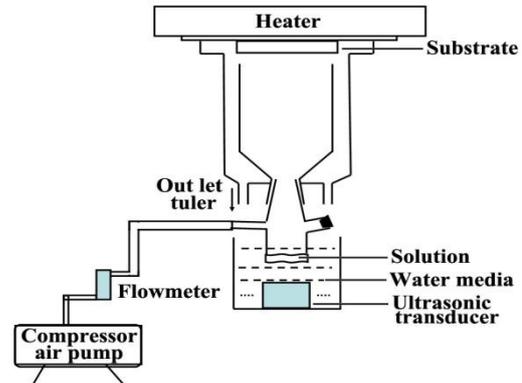


Fig. 2 Schematic diagram of ultrasonic spray pyrolysis system for preparing SnO₂ blocking layer.

RESULTS AND DISCUSSION

Figure 3 presented XRD patterns of SnO₂ thin film at various deposited times (6 min, 10 min and 20 min), and the peaks were compared with the commercial SnO₂: F thin film, the fluorine peak did not appear for the commercial film. The crystal structure of SnO₂ thin films at various deposited times was tetragonal rutile phase. The XRD peaks SnO₂ thin film were diffracted from the lattice planes of (110), (101), (200), (211), (220), (310), (301), and (321). It was also clear that the intensity of the preferred orientation increased as the deposition time increased. The dominate peaks of (110), (101), (200) and (211) were located at about 27, 34, 38 and 52 degree respectively.

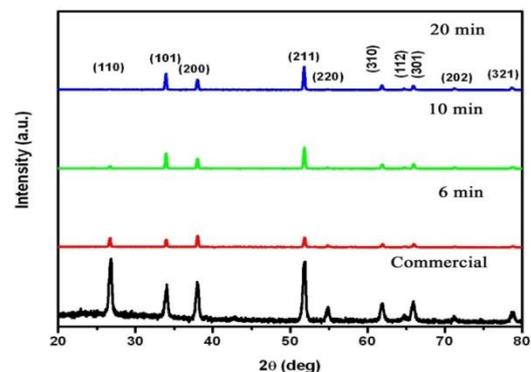


Fig. 3 XRD-patterns of SnO₂ thin films at different deposited time.

Figure 4 showed the UV/VIS spectra of SnO₂ thin films. The spray solution was deposited on glass substrates at various deposited times as the spectral was transmitted to the film in the range of 200 nm to 800 nm. The relation between the deposited time and the transmission could be seen. The transmission decreased as the deposited time increased. This decrease was due to the thickness of SnO₂ increase.

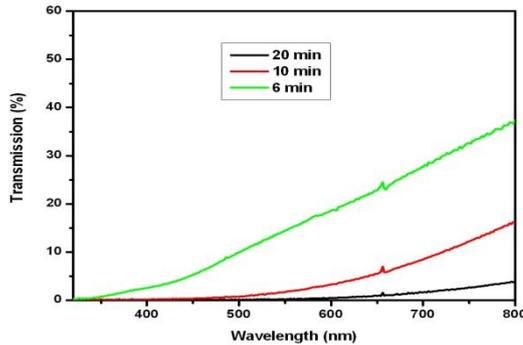


Fig. 4 Variation of transmittance with wavelength of SnO₂ thin films deposited on glass substrate.

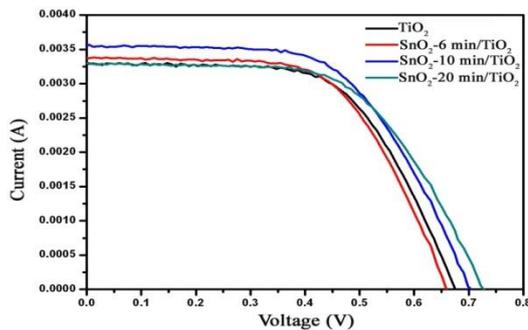


Fig. 5 Photocurrent-voltage characteristic of dye-sensitized solar cell measured at various deposited time of SnO₂ blocking layer.

Figure 5 showed the photocurrent-voltage characteristics of DSSC under light intensity irradiations. Short circuit current (I_{sc}), open-circuit voltage (V_{oc}), fill factor (FF), and conversion efficiency ($\eta\%$) of DSSCs were calculated from the photocurrent-voltage characteristics graph. It was remarked that overall conversion efficiency was in the following order: SnO₂-10 min/TiO₂ working electrode (4.06%) > SnO₂-20 min/TiO₂ working electrode (3.91%) > TiO₂ working electrode (3.75%) > SnO₂-6 min/TiO₂ working electrode (3.74%). The highest performance DSSC had the spray time of blocking layer of 6 min and it presented 3.38 mA of I_{sc} , 0.66 V of V_{oc} and 0.60 of FF. The DSSCs efficiency depended on kinetic competition between the black electron

transfer and the dye regeneration processes. The height efficiency due to the blocking layer was protected the backward electron transfer from TCO to lithium iodide electrolyte. While the spray time of blocking layer of 20 min efficiency decreased, the more thickness of blocking layer could block the light that come to dye for exciting electron.

Table 1 Photovoltaic parameters of dye-sensitized solar cell

Deposited Time of Blocking Layer (min)	I_{sc} (mA)	V_{oc} (V)	FF	$\eta\%$
0	3.30	0.67	0.61	3.75
6	3.38	0.66	0.60	3.74
10	3.57	0.70	0.59	4.06
20	3.30	0.72	0.59	3.91

CONCLUSION

The effect of SnO₂ blocking layer of dye-sensitized solar cell was studied by varying the spray times of SnO₂ blocking layer. The crystal structure and optical property were studied while the SnO₂ semiconductor was coated on glass substrate. The XRD pattern peak of SnO₂ film did not show other phase, and the XRD pattern peak agreed with SnO₂:F commercial film. The percent transmission of SnO₂ thin film was decreased when the spray time was increased. The highest performance DSSC was the spray time of blocking layer of 6 min and it had 3.38 mA of I_{sc} , 0.66 V of V_{oc} and 0.60 of FF. While the spray time of blocking layer of 20 min efficiency decreased, the more thickness of blocking layer could block the light that come to dye for exciting electron.

ACKNOWLEDGEMENTS

This work was partially supported by National Metals and Materials Technology Center, National Science and Technology Development Agency, Thailand. The author would like to acknowledge on the TGIST scholarship from National Science and Technology Development Agency, Thailand.

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