

Preparation of Platinum (Pt) Counter Electrode Coated by Electrochemical Technique at High Temperature for Dye-sensitized Solar Cell (DSSC) Application

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Abstract. Pt counter electrode was coated by electrochemical method. Electrolyte solution was synthesized by platinum (IV) chloride (PtCl_4) powder dissolved in hydrochloric acid solution. Pt films were deposited on the FTO substrate. Deposition time of 10, 30 and 60 minutes, the coating current of 5, 10, 15 and 20 mA and electrolyte solution temperatures for Pt layer synthesis of 25, 30 and 40°C were varied. Surface morphology and optical properties was analyzed by digital microscopic and UV-vis spectrophotometer. Pt films exhibit uniform surface area highly for all the conditions of coating current in the deposition time of 30 and 40 minutes at 40°C. Transmittance values of Pt films deposited on FTO substrate has approximately of 5 to 50 % show that occur high reflection corresponding to dye molecule absorption increases. DSSC device was fabricated from the TiO_2 standard and immersed in dye N719 for 24 hours. Efficiency was measured by solar simulator. Efficiency value obtains as high as 5.91 % for the coating current, deposition time and solution temperature of 15 mA, 30 minutes and 40°C. Summary, influence of temperature effects efficiency increasing. Pt counter electrode can be prepared easily and the suitable usefully for DSSC.

1. Introduction

The DSSC is photovoltaic which principle is similarly to light synthesis of leaves. Since 1994, M. Grätzel presented the DSSC concept [1]. After in 2008, the efficiency of DSSC was developed until to present which it can be increases as high as 10% under light intensity standard (100 mW/cm², AM 1.5). Special characteristic is the electrons transfer occurred under electric field and reduction and oxidation reaction inner cell. The counter electrode synthesis was made from the Platinum (Pt), graphite (C) and catalyst element but this research used popularly the Pt counter electrode [2-10].

This work, we interested increasing high surface area and catalyse by Pt counter electrode. Pt counter electrode was coated by electrochemical method. It focus is on influence of electrolyte solution temperature for Pt layer synthesis to DSSC cell efficiency.

2. Experimental

2.1 Preparation of the Pt counter electrode

Pt counter electrode was coated by electrochemical method which system consists of the dc power supply control, heating to electrolyte solution and substrate holder can adjust distance of electrode as shown in the Figure 1. Electrolyte solution was synthesized by platinum (IV) chloride (PtCl_4) powder (purity, 99.9%) dissolved in hydrochloric acid solution (HCl , 0.00156 M, purity of 99.99 %). Pt layer were deposited on the FTO substrate. Electrolyte concentration and the distance between positive and negative electrode (2 cm) were fixed under stir with magnetic stirrer continuously. The deposition time of 10, 30 and 60 minutes, the coating current of 5, 10, 15 and 20 mA and temperatures of 25, 30 and 40°C, respectively were varied.

2.2 Preparation of the TiO_2 working electrode

TiO_2 blocking layer was coated by spin coating technique which the solution was synthesized from Titanium diisopropoxidebis ($\text{C}_{16}\text{H}_{28}\text{O}_6\text{Ti}$) 0.5 ml mixed with Isopropanol 10 ml. The TiO_2 working electrode was prepared by screen painting method on TiO_2 blocking/FTO substrate (commercial TiO_2 powder particle size of 32 and 5 nm, Alfa Aesar, USA, 99.999% purity and Degussa P25, AEROXIDE). After, The TiO_2 layer on the TiO_2 -blocking-layer/FTO/SLG specimens were immersed in the sensitizer ruthenium 535 bis-TBA solution (N719 dye) face-up for 24 hours at room temperature and then rinsed with ethanol.

2.3 Cells assembly

Two sides of DSSC cell were glued together using, for example, Parafilms, gasket SX117-60PF (SOLARONIX) or Ethylene-vinyl acetate (EVA). The seal was cut to form a frame around the glass electrodes. Heat from a hot air gun was then applied to the cells, thus forming the seal. Then, the I_3^-/I^- -electrolyte (MPN-100, SOLARONIX) was injected into the cell. The area of the cell was typically $1.25 \times 1.25 \text{ cm}^2$ and $0.7 \times 1 \text{ cm}^2$. Finally, the photocurrent conversion under standard AM 1.5 radiation (100 mW/cm^2) was measured.

2.4 Characterization tools

The characterization tools are X-ray diffraction (XRD) (PANalytical, EMPYREAN), UV-vis spectrophotometer (UV-1800) and Solar simulator (PEC-L11) were used for its structural and optical properties and photocurrent conversion of cell.

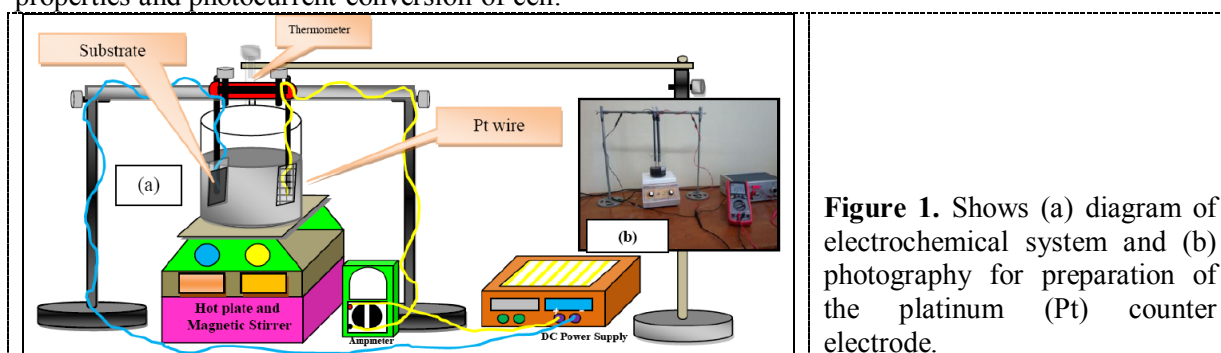


Figure 1. Shows (a) diagram of electrochemical system and (b) photography for preparation of the platinum (Pt) counter electrode.

3. Results and Discussion

Image of the Pt films on FTO substrate by electrochemical Method shows opaque light which it is black color as shown in the Figure 2. Surface area of Pt films can seen high uniform under the conditions of deposition at 40°C.

The structural characteristic of FTO substrate indicates in the Figure 3. It can be seen from the XRD pattern that the film has crystalline quality. The plane (hkl) of FTO exhibits at (110), (101), (200), (211), (310) and (301), respectively. A well-defined peak of FTO (110) at $2\theta = 26.52^\circ$ is observed. The plane explicitly of Pt film on FTO substrate is (111) which it confirm the Pt crystalline

layer. The XRD patterns of the FTO and Pt film on FTO substrate look like crystalline. This may due to the high crystalline quality lead to parameter such as the open circuit voltage (V_{oc}) increases. Moreover, electrons carrier of the counter electrode can be transfer continuously due to high crystalline.

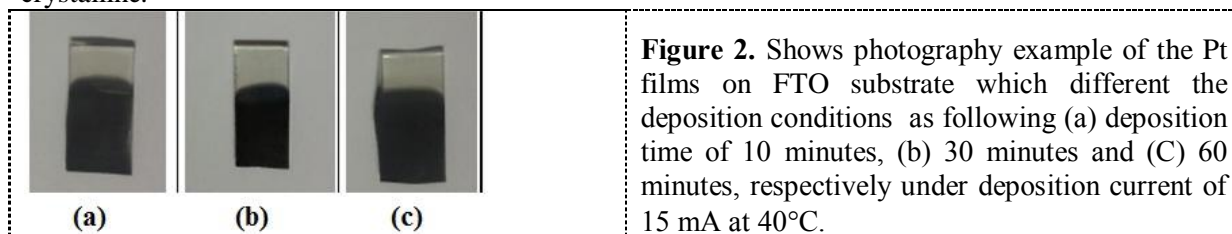


Figure 2. Shows photography example of the Pt films on FTO substrate which different the deposition conditions as following (a) deposition time of 10 minutes, (b) 30 minutes and (C) 60 minutes, respectively under deposition current of 15 mA at 40°C.

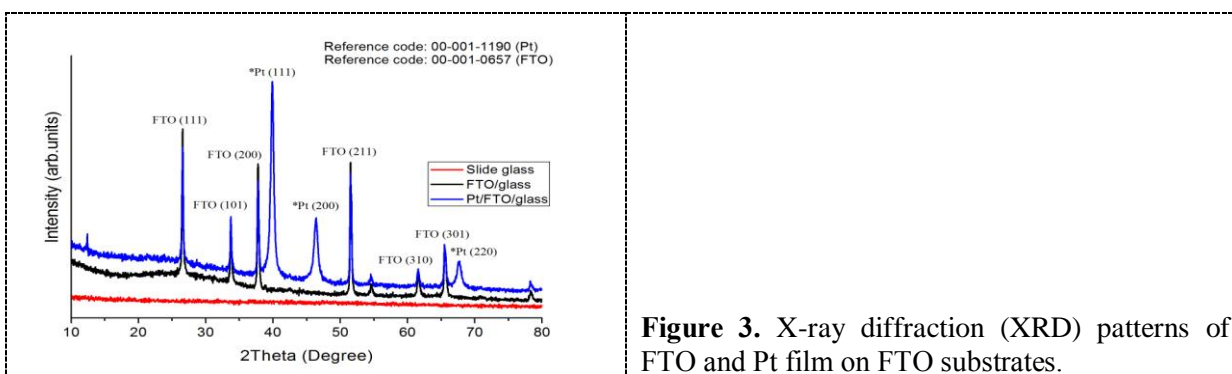


Figure 3. X-ray diffraction (XRD) patterns of FTO and Pt film on FTO substrates.

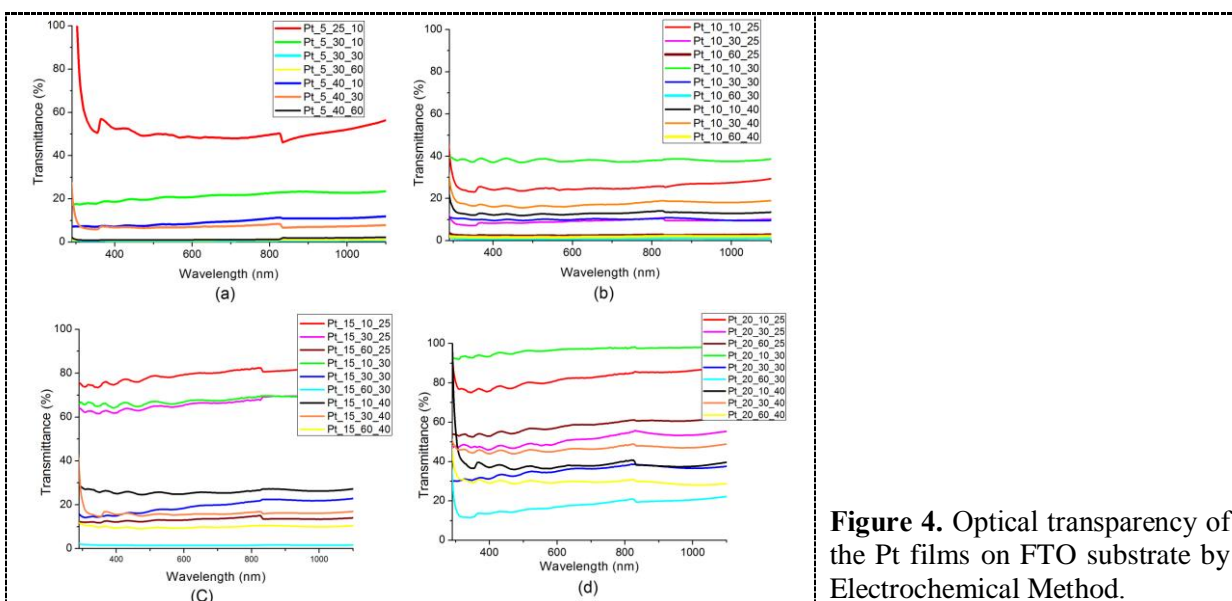


Figure 4. Optical transparency of the Pt films on FTO substrate by Electrochemical Method.

The transmittance spectra of Pt film shows in the Figure 4 which transmittance light has very less. On other hand, the transmittance spectrum obtains up to 5 - 50% for deposition time of 30 to 60 minutes. Show that, Pt counter electrode can be reflecting light into cell highly corresponding to increases photon absorption of dye-sensitizer. Thus, colour characteristic of Pt layer somewhat opaque light.

The photocurrent – voltage curve of DSSC device shows in the Figure 5. Parameter of performance has the current density (J_{SC}) are 11.70 mA/cm², the open circuit voltage (V_{oc}) of 0.77 V, fill factor (FF) of 0.65 and efficiency of 5.90% for the deposition current of 15 mA, deposition time of 30

minutes at 40°C which it can be generate highest current. However, the efficiency value nearly is the current density (J_{sc}) are 10.86 mA/cm², the open circuit voltage (V_{oc}) of 0.78 V, fill factor (FF) of 0.68. Main factor of the conditions are temperature and current deposition as shown in the Table 1.

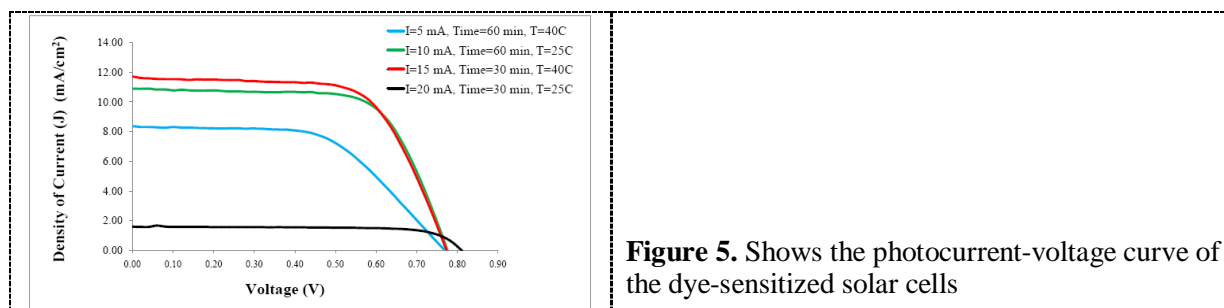


Figure 5. Shows the photocurrent-voltage curve of the dye-sensitized solar cells

Table 1. Shows parameter of photocurrent conversion of DSSC

| Coated Condition | Area(cm ²) | I _{sc} (mA) | J _{sc} (mA/cm ²) | V _{oc} (V) | FF | η (%) |
|--------------------------|------------------------|----------------------|---------------------------------------|---------------------|------|-------|
| 5 mA, t=60 mins T=40°C | 0.25 | 2.09 | 8.36 | 0.77 | 0.56 | 3.19 |
| 10 mA, t=60 mins T=25°C | 0.25 | 2.72 | 10.89 | 0.78 | 0.68 | 5.75 |
| 15 mA, t=30 mins T=40°C | 0.25 | 2.93 | 11.70 | 0.77 | 0.65 | 5.90 |
| 20 mA, t=30 mins, T=25°C | 0.25 | 0.39 | 1.58 | 0.81 | 0.74 | 0.95 |

4. Conclusion

Influence of temperature effects to efficiency increasing which highest efficiency of DSSC cell can be obtain as high as 5.90%. Therefore, Pt counter electrode coated by chemical method can be prepared easily and the suitable usefully for DSSC application. The plane explicitly of Pt film on FTO substrate is (111) which it confirm the Pt crystalline layer. XRD patterns look like crystalline. Pt counter electrode can be reflecting light into cell highly corresponding to increases photon absorption of dye-sensitizer. Thus, colour characteristic of Pt layer somewhat opaque light. Our results show that this simple preparation of Pt layer can be applied as a counter electrode for DSSCs.

References

- [1] M. Grätzel 2005 *Inorg. Chem.* **44** pp 6841 – 6851
- [2] Z.S. Wang, M. Yangida, K. Sayama, H. Sugihara 2006 *Chem. Mater.* **18** pp 2912 – 2916
- [3] Che-Yu Lin, Jeng-Tu, Chi-Cho Wan and Tzu-Chien 2011 *Electrochimica Acta* **56** pp 1941 – 1946
- [4] Chun-Chen Yang, Huan Qing Zhang, Yu Rong Zheng 2011 *Current Applied Physics* **11** pp S147 – S153
- [5] A. Hauch, A. Georg 2001 *Electrochim. Acta* **46** p 3457
- [6] M. Wang, Y. Lin, X. Zhou, X. Xiao, L. Yang, S. Feng, X. Li Mater 2008 *Chem. Phys.* **107** p 61.
- [7] N. Papageorgiou, W.F. Maier, M. Grätzel 1997 *J. Electrochem. Soc.* **144** p 876
- [8] X. Fang, T. Ma, G. Guan, M. Akiyama, T. Kida, E. Abe 2004 *J. Electroanal. Chem.* **570** p 257
- [9] K. Suzuki, M. Yamaguchi, M. Kumagai, S. Yanagida 2003 *Chem. Lett.* **32** p 28
- [10] Z. Huang, X. Liu, K. Li, D. Li, Y. Luo, H. Li, W. Song, L. Chen, Q. Meng 2007 *Electrochem. Commun.* **9** p 596

Acknowledgments

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