JOURNAL OF
NATURAL SCIENCES
AND
MATHEMATICS RESEARCH

Available online at http://journal.walisongo.ac.id/index.php/jnsmr

The Effect of Gel-Electrolyte on Dye Sensitized Solar Cell (DSSC) Prototype based on Nanosized-TiO_2 Using Mangosteen Pericarp as Absorber

Biaunik Niski Kumila[1], and Gontjang Prajitno[2]
[1]Department of Physics, Faculty of Science and Technology, Wallisongo State Islamic University
[2]Dapartment of Physics, Faculty of Mathematics and Natural Science, Sepuluh Nopember Institute of Technology

Corresponding author:
bnkumila@walisongo.ac.id

Recived: 05 April 2017,
Revised : 11 May 2017
Accepted: 15 June 2017.

Abstracts

Dye Sensitized Solar Cell (DSSC) with Fluorine deped Tin Oxide (FTO) substrat and nanosize-TiO_2 layer sensitized by "dye" ,mangosteen pericarp extract, was succesfully fabricated. Gel-Electrolyte as electron regenerator was synthesized by adding Polyethylene Glycol (PEG) 1000 to electrolyte solution while nanosize-TiO_2 was synthesized by co-precipitation method from $TiCl_3$ solution. The crystal size of TiO_2 characterized by X-Ray Diffraction is 10.5 nm in size. The solar absorbance of "dye" mangosteen pericarp was measured using UV-Vis Spectrophotometer and it showed that the dye can absorb photon at Near Ultraviolet (NUV) to yellow visible light. Nanosize-TiO_2 based DSSC with gel-electrolyte successfully reached short circuit current up to 30.9 μA, open circuit voltage 398.3 mV and performed the long term stability.

Key words: Dye-Sensitized Solar Cell (DSSC); Mangosteen Pericarp; Gel-Electrolyte; Nanosized-TiO_2

1. Introduction

Dye Sensitized Solar Cell (DSSC) was firstly fabricated by scientist from Switzerland, Michael Gratzel, in 1991 [1]. It was found to be the solution for low-cost solar power compared to silicon-based solar cell. DSSC generally consist of two electrodes (active electrode and counter electrode) and electrolyte for electron to transfer. Counter electrode was basically coated by Pt or carbon on its surface of substrate[2].

The mechanism of electron transfer of dye sensitized solar cell is described by Figure 1. The photon energy from the sun was absorbed by dye as a solar absorber to excite the electron from the ground state to excited state based on raction : S^0 + e -> S*[3]. The photoexcited dye transfers an electron to the semiconducting

TiO_2 layer via electron injection. The injected electron is then transported through the TiO_2 and collected by conductive glass. Within the electrolyte, the mediator (I^-/I_3^-) undergoes oxidation at the dye and regeneration at the catalyst-coated counter electrode as current flows through the electrical load [3]. DSSC as a low-cost solar cell device has achieved effeciency of 11% [1].

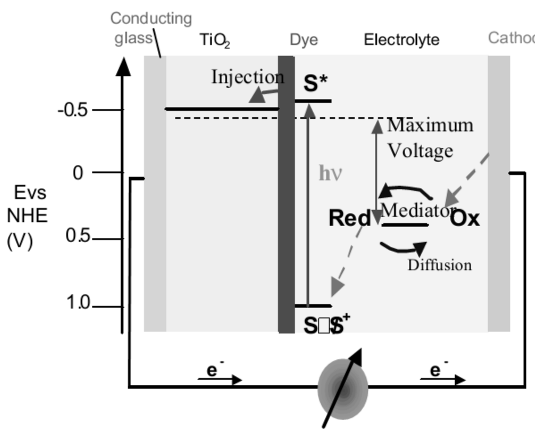

Figure 1. Mechanism of electron transfer within dye sensitized solar cell (DSSC)

DSSC has been attractive to be a substitute to previous silicon-based solar cell due to its higher efficiency and low-cost process. However, several issues such as electrolyte leakage in high temperature and short-term stability are main problems of liquid-electrolyte. This work is concerned to escalate DSSC performance by engangement of nanosize TiO_2 and gel-electrolyte to improve its stability.

2. Experiments Procedure

There are four general steps in fabricating DSSC, namely : synthesis of TiO_2, synthesis of dye solution, synthesis of gel-electrolyte and fabrication of DSSC device.

Nanosize-TiO_2

Nanozie-TiO_2 was synthesized by co-precipitation method of titanium triclhoride, $TiCl_3$. Solution of HCl:DI water with the ratio of 2:5 was stirred for 15 minutes. The 20 ml of titanium trichloride was then gradually added to the solution and stirred for 30 minutes. 50 ml of amonium hydroxide (NH_4OH) was gradually dropped to the solution and stirred for 1 hour. The suspension was further filtered and dried to gain nanosized powder of TiO_2.

Dye solution

Mangosteen pericarp was separated from its nut , cleaned and dried. It was then heated in oven at 60^0C for 6 hours to remove the contained water. The dry mangosteen pericarp was crushed and further grinded to obtain the powder and further dissolved in water to get dye solution. The dye solution was then characterized by UV-Vis Spectrophotometer to analyze the absorbance.

Gel-electrolyte

Electrolyte utiized in the experiment was redox solution of iodin and iodide (I^-/I^{3-}) from Potassium Iodide (KI) and I_2 solution. 3 gram kalium iodide was dissolved in 3 ml Iodine and stirred for 30 minutes. Furthermore, Polyethylene glicol (PEG) was employed to obtain gel electrolyte. The 2,5 gram of PEG was firstly dissolved in 5 ml chloroform and stirred for 30 minutes. The electrolyte solution was gradually added to it, stirred for minutes and maintained at 60^0C.

Fabrication of DSSC device

There are two types of electrodes, namely : active electrode and counter electrode.

Figure 2. Active elctrode consists of : TiO_2 layer, dye solution and gel-electrolyte

Thin TiO_2 layer was coated to FTO glass substrate by spin coater and it was further heated up to 450^0C and slowly cooled to 70^0C.

At that temperature, the layer was immersed in dye solution for 24 hours and further cleaned by DI water. Furthermore, the gel electrolyte was dropped to the cleaned pasta.

The counter electrode consists of FTO glass coated by carbon. The carbon layer gained by scretching the glass with carboneous pencil was heated up. The size of cell was (1 cm x 1 cm)

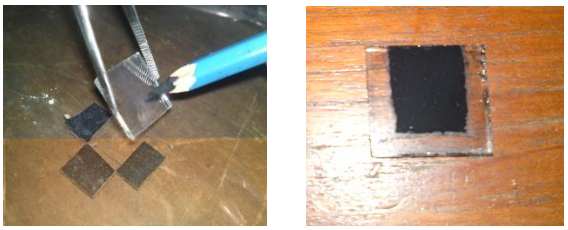

Figure 3. Scretched FTO glass by carbonaceous pencil (left), heated carbon layer (right)

Those two electrodes was then clipped to construct a prototype of DSSC device as described in Figure 4.

Figure 4. Prototype of DSSC device

The device was kept in dark room for 24 hours and further tested under yellow light illumination.

Figure 5. IV-characterization process of DSSC under yellow light illumination

3. Result and Discussion

The EM absorption capability of dye synthesized from mangosteen pericarp extract was examined by UV-Vis Spectrophotometer.

Figure 6 shows the absorbance range of dye was in the range of near Ultra-violet to blue-yellow visible light.

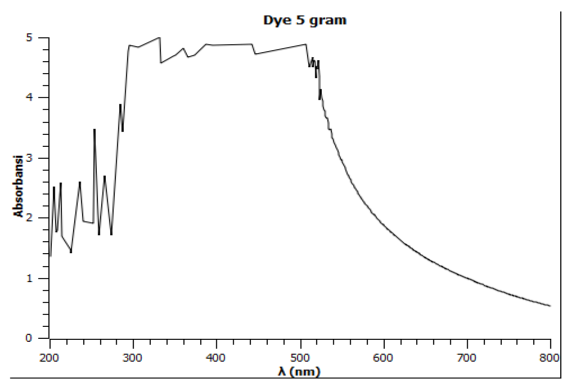

Figure 6. UV-Vis spectra of mangosteen pericarp extract

The best dye absorber is the dye which is able to strongly absorb the long range of electromagnetic (EM) energy from the sun. Meanwhile, the visible light (390-700 nm) is the highest intensity of EM recieved by the earth. Figure 6 shows the dye is able to strongly absorb the EM energy in the range of Near-Ultraviolet to yellow visible light, i.e 300-550 nm. Therefore, it conclude that the dye was potential to be performed in the DSSC device.

The TiO_2 phase and crystal size was characterized by X-ray diffractometer (XRD).

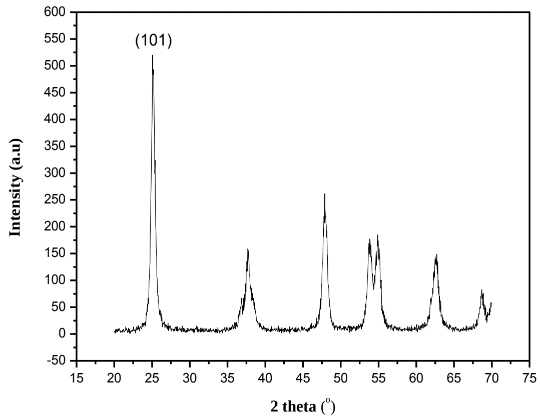

Figure 7. X-ray diffraction pattern of TiO_2

The TiO_2 anatase phase is assigned to diffraction angle of 2θ : 25.4° determining the (101) crytalline plane while rutile phase is assigned to diffraction angle of 2θ : 27.36° determining the (110) crytalline plane [4][5]. Figure 7 shows that the (101) is assigned to 2θ : 25.7° and the rutile peak is undetectable. The anatase phase formation occured at 450°C and that was apparently in agreement with previous work performed by Muneer and co-workers who analyzed the effect of heating temperature to TiO_2 phase formation. They stated that the rutile peak formation was appeared at heating temperature of 500°C.

The crystalline size of TiO_2 referring to (110) crystalline plane identified by Materials Analysis Using Diffraction (MAUD) was 10,5 nm in size. Nanosize-TiO_2 possesses higher specific surface area compared to microsize-TiO_2. The higher specific surface area of TiO_2, the more dye molecules embedded on TiO_2 surface.

The stability of the device was observed by screening for 180 minutes under yellow light illumination. The optimum performance of the device occured after illumination about 8 minutes (Figure 8). It inferred that the electron required sometimes to transfer. The performance was gradually decreased and remained stable at the minute of 120th due to the leakage and evaporation of electrolyte. However, the stability of device was better than that of the previous work utilizing liquid electrolyte performed by Rofiah [6].

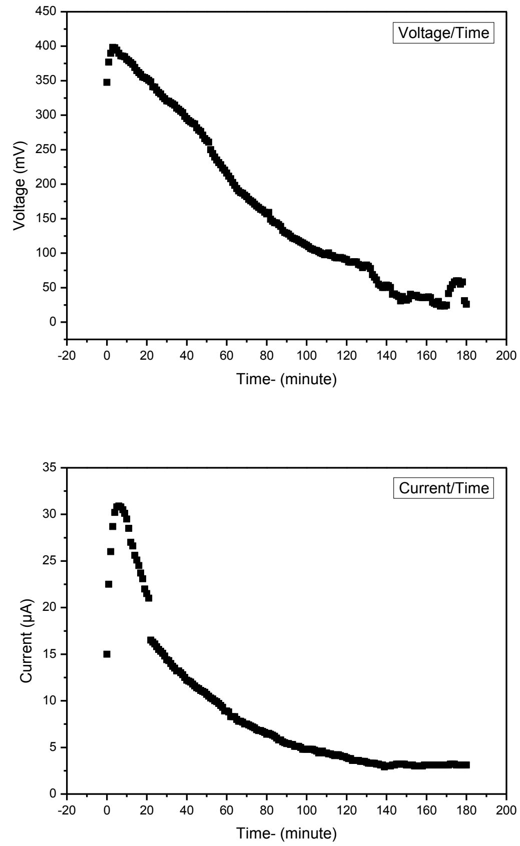

Figure 8. Screening of voltage (top) and current (bottom) over the time

The I-V curve (Figure. 9) shows the electrical performance of DSSC under light illumination.

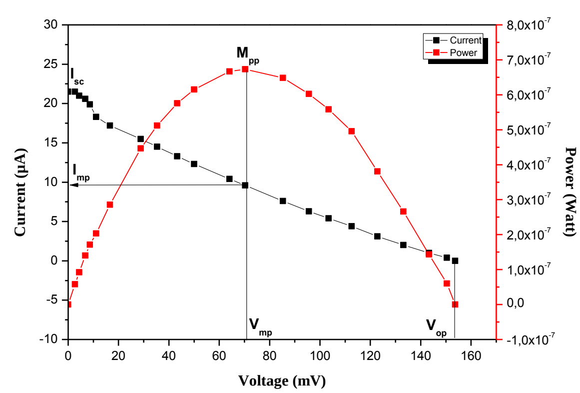

Figure 9. IV-curve of DSSC device

DSSC performance is well represented by the value of its efficiency and fill factor [7]. The efficiency of the photovoltaic cell is calculated from the maximum power of the cell divided by total power of illumination as described by Equation 1.:

$$\mu_{cell} = \frac{P_{max}}{P_{in}} \quad (1)$$

which power maximum (P_{max}) is equal to short circuit current (I_{sc}) multiplied by open circuit voltage (V_{oc}), while the value of fill factor is described by Equation 2.

$$\mu_{cell} = \frac{P_{max}}{V_{oc} I_{sc}} \quad (2)$$

Maximum voltage of 70,3 mV and maximum current of 9,6 μA was reached by the cell. The fill factor reached the value of 0.2. This number is higher compared to the fill factor of previous work utilizing microsized-TiO_2 which was performed by Rofiah [6]. Nanosize-TiO_2 possesses higher specific surface area than that of microsize-TiO_2. It affects the amount of dye molecules embedded on the TiO_2 surface. The higher amount of dye molecules on the TiO_2 surface is assumed to absorb higher amount of light source intensity which affect to the number of transferred electron within the cell.

4. Conclusion

In conclusion, these preliminary results suggest that Dye Sensitized Solar Cell (DSSC) based on nanosize-TiO_2 and gel elctrolyte using mangosteen pericarp as absorber was succesfully fabricated. The long-term stability was achived due to the utilization of gel-electrolyte which was able to minimize electrolyte leakage and evaporation. Furthermore, the engagement of nanosize-TiO_2 was able to improve the efficiency if it was compared to work done by Rofiah[6] due to the higher surface specific area compared to microsize-TiO_2.

Acknowledgment

The authors wish to thank Department of Physics, Wallisongo State Islamic University and Dapartment of Physics, Sepuluh Nopember Institute of Technology for supporting this work.

References

[1] B. Oregan and M. Gratzel, “a Low-Cost, High-Efficiency Solar-Cell Based on Dye-Sensitized Colloidal Tio2 Films,” *Nature*, vol. 353, no. 6346, pp. 737–740, 1991.

[2] A. Kay and M. Grätzel, “Low cost photovoltaic modules based on dye sensitized nanocrystalline titanium dioxide and carbon powder,” *Sol. Energy Mater. Sol. Cells*, vol. 44, no. 1, pp. 99–117, 1996.

[3] G. P. Smestad, “Demonstrating Electron Transfer and Nanotechnology : A Natural Dye – Sensitized Nanocrystalline Energy Converter,” *J. Chem. Educ.*, vol. 75, no. 6, pp. 752–756, 1998.

[4] M. M. . Ba-Abbad, A. A. H. . Kadhum, A. B. . Mohamad, M. S. . Takriff, and K. . Sopian, “Synthesis and catalytic activity of TiO 2 nanoparticles for photochemical oxidation of concentrated chlorophenols under direct solar radiation,” *Int. J. Electrochem. Sci.*, vol. 7, no. 6, pp. 4871–4888, 2012.

[5] K. Sakurai and M. Mizusawa, “X-ray Diffraction Imaging of Anatase and Rutile,” *Anal. Chem*, vol. 82, no. 9, pp. 3519–3522, 2010.

[6] I. Rofiah and G. Prajitno, “The effect of gel-electrolyte on the current and voltage DSSC prototype using dye extract mangosteen pericarp (garcinia mangostana L) as dye sensitizer,” Sepuluh Nopember Institut of Technology, 2013.

[7] M. Grätzel, “Perspectives for Dye - sensitized Nanocrystalline Solar Cells,” *Prog. Photovoltaics Res. Appl.*, vol. 8, no. 1, pp. 171–185, 2000.