Characterization of Nephelium Lappaceum Peel Extract as a Dye Sensitized Solar Cell

Joko Budi Poernomo¹,²,a; Ana Hidayati Mukaromah⁴; Hendri Widiyandari³; Putut Marwoto¹,b

¹ Program Pascasarjana Universitas Negeri Semarang
² Jurusan Pendidikan Fisika UIN Walisongo Semarang
³ Jurusan Fisika Universitas Diponegoro Semarang
⁴ Program Studi Analis Kesehatan Universitas Muhammadiyah Semarang

a) po3rnomoextra@gmail.com b) pmarwoto@gmail.com

Abstract. The world now is searching for a new renewable alternative energy. Nephelium lappaceum is a popular fruit in Indonesia that contains anthocyanin. Anthocyanin can absorb light on the range of visible light due to its conjugated double bonds. This finding makes Nephelium lappaceum as a potential Dye Sensitized Solar Cell (DSSC). The Nephelium lappaceum extract can be taken through extraction technique, called maserasi. The process of developing DSSC material was initiated by preparing TiO₂ photoanode using a conventional sintering procedure. It was, then, followed by doping TiO₂ on the Fluoride doped tin oxide (FTO) with resistance value of 10⁻²⁰ ohm/q. Finally, the electrode counter made of platinum paste was developed by implementing conventional sintering procedure. All of the above process were then continued by the DSSC assembly. In this process, the TiO₂ photoanode which has passed the absorption process for 24 hours, was doped on the counter electrode. After doping, the process was stopped by doing electrolyte solution filling into prepared electrode counter holes. In order to characterize the DSSC, a solar simulator connected to a computer was employed. Based on this characterization process, it was found that the maximum value of Voc was 0.29 V, the maximum value of current density was 0.56 mA / cm², the maximum power was 0.062 mW / cm² and efficiency of 0.063. Characteristics of Nephelium lappaceum peel extract is one of the DSSC cells using TiO₂ as a semiconductor material as a dye sensitizer that can convert light energy into electrical energy.

1. Introduction

Lack of energy supply is a major problem that the world faces until now where the scientists have been searching for. It is necessary for the world to look for the new, renewable and low-costed alternative energy sources for all levels of society. Then, the alternative energy must have these criteria: non-polluting, renewable, trustworthy and no need to buy. The one which meet the criteria is solar energy. The latest technology of using solar energy nowadays is using Dye Sensitized Solar Cell (DSSC). The working principle of DSSC includes three different processes, those are excitation of photosensitizer by photon, the utilization of the conduction band and the redox reaction in the electrolyte solution [1]. DSSC is the first breakthrough in solar cell technology since the silicon solar cells that known as conventional solar cells. In contrast to conventional solar cells, DSSC is a photoelectrochemical solar cells that use an electrolyte as a medium of charge transport.
When photons of sunlight impinge on the working electrode DSSC, the photon energy is absorbed by the dye particles attached to the surface of TiO$_2$ particles. So that the valence electrons from the dye obtain the energy to do excitation (D *). The Excitation of Electrons from the dye molecules then will be injected into the conduction band of TiO$_2$ where the TiO$_2$ acts as an acceptor / electron collector. The abandoned dye molecules then oxidized (D +). Photon electrons injected into the TiO$_2$ molecules will move to the diffusion along the top of the working electrode in the form of a transparent conductive layer of FTO (Fluorine-doped Tin Oxide).

This study uses *Nephelium lappaceum* peel extract as a natural dye which contains anthocyanin (substance which gives color to flowers, fruit and leaves of green plants) due to the arrangement of its long conjugated double bonds, so it can absorb light in the visible light range maximally [2]. This *Nephelium lappaceum* is popular fruit in Indonesia that available in every year.

2. Methods

The study began by preparing materials such as dye extracts of *Nephelium lappaceum* peel with a variety of solution concentration and means of glass including FTO (Fluorine-doped tin oxide), Platinum Paste (Dysol, Pt Queanbeyan NSW 2620, Australia), acetic acid, *Nephelium lappaceum* peel, thermoplastic sealent (Dysol, Pt Queanbeyan NSW 2620, Australia), electrolytes and distilled water. While the equipment used, among others, are magnetic stirrer, beakers, petri dish, mortar pestle, spatula, thermocouples, filter paper, aluminum foil, bottles drip, hotplate, solar simulator, cable clamps, conventional sintering (furnace) and a spectrometer to determine the characteristics of dye *Nephelium lappaceum* peel extract. The first step is making preparations of Photo anode TiO$_2$ through material sintering procedure of photoanode TiO$_2$ using a conventional sintering (furnace) tools at temperature 350°C for 5 min, 375°C for 5 min, 450°C for 15 minutes, 500°C for 15 minutes and then cooled at room temperature. The second step is to prepare conductive glass substrate types Fluorine-doped tin oxide with a resistance 10 ~ 20 ohm / sq. The third step is to prepare a counter electrode with platinum paste material through a sintering process. Sintering process of counter electrode layer is using conventional sintering at temperature of 450°C for 60 minutes. The fourth step is process of Assembly dye Sensitized Solar Cell (Sandwiching). Photoanode TiO$_2$ that has processed through the process of absorption with dye *Nephelium lappaceum* peel extract for 24 hours, then followed by the cleaning process and affixed to the counter electrode which has been prepared by thermoplastic sealant[3]. Next, fill electrolyte solution on photoanode and the counter electrode through the hole that was created on counter electrode layers[4]. The DSSC layers made by offset arrangement dye sensitized TiO$_2$ layer with counter electrode layer. Before it is offset-arranged, give liquid electrolyte first atop of the dye sensitized TiO$_2$ layer. The formed DSSC layers were characterized by current and voltage using a solar simulator which is connected to the computer program.

3. The Result of The Research and Discussion

In this research, the experiment was tested towards the dye characteristics of *Nephelium lappaceum* peel extracts and measuring the voltage and current toward time of DSSC that have been made.

Dye Characterization

Before being used as a sensitizer, *Nephelium lappaceum* peel extracts first tested its absorption spectrum using the spectrometer UV mini-1240 Shimadzu corp. The absorbance spectrum measured is on wavelength range 200-800 nm [5]. Test results shown in the following Figure 1a, 1b, 1c. Relationship Graph Absorbance of the initial *Nephelium lappaceum* peel extract to the wavelength.
Figure 1a. Shows UV Vis test on *Nephelium lappaceum* peel extract on wavelength between 400 nm - 500 nm. 

Figure 1b. Shows that the UV Vis test on the *Nephelium lappaceum* peel extract on the wavelength between 630 nm – 680 nm.

Figure 1c. Shows the experiment using UV Vis test on *Nephelium lappaceum* peel extract on wavelength 400 nm - 500 nm.

**Figure 1a** shows UV Vis test on *Nephelium lappaceum* peel extract on wavelength between 400 nm- 500 nm occurred noise because it was not visible light, while visible light wavelengths cover a range from approximately 500 nm - 800 nm with maximum absorbance value approximately 550 nm - 780 nm. While **Figure 1b** shows that the UV Vis test on the *Nephelium lappaceum* peel extract on the wavelength between 630 nm – 680 nm occurred noise because it is not visible light, while visible light occurs on wavelength between 680 nm – 800 nm. Great absorbance value was obtained on wavelength 690 nm – 780 nm. Similarly, **Figure 1c** shows the experiment using UV Vis test on *Nephelium lappaceum* peel extract on wavelength 400 nm - 500 nm occurred noise because it is not visible light, while visible light occurs on wavelengths 500 nm - 800 nm with maximum absorbance value on wavelength 550 nm - 780 nm with an absorbance value 4000. The best absorbance value in UV Vis spectrometer test on *Nephelium lappaceum* peel extract was on wavelength 550 nm – 780 nm, so that allowing the absorption of sunlight that can be done better by natural dye of *Nephelium lappaceum* peel extracts. These results indicate that the semiconductor sensitization using anthocyanin derived from natural pigment because of the presence of anthocyanin that has advantage more than chlorophyll as a DSSC sensitizer.

**Voltage and Current Measurement**

DSSC has been made then measured its voltage and current. Testing is done by using a solar simulator with input power of 100 mW / cm2. The process of testing and measurement used dye
variation with three samples, as well as the addition of an electrolyte solution in prevalent proportion to the entire surface area of TiO$_2$ paste and obtained results in the following Figure 2a, 2b, 2c.

On the first part, the leaf gives rapid reaction. It is needs about 4 to 6 second to close. It is shown clearly on the video analysis. The touch is shown given on 0,04200 seconds and the length of the leaf is 0,06617 x 0,05 m = 0,033 m = 3,3 cm. In short period, there is a movement of closing (move to horizontal line) to a movement of stop. This condition shown in Figure 2a, 2b, 2c. Relationship Chart voltage against current density on the sample; 1, 2, 3 and Figure 2d. Graph of current density - voltage (JV) between each sample (A) analysis of sample 1, sample 2 and sample 3 to test DSSC.

**Figure 2a.** Shows that the voltage and current values produced by variations of dye with HCL solvent, ethanol, distilled water generate current value o,56 mA and voltage 0,29 V

**Figure 2b.** Shows the test results and analysis that were obtained from voltage and current value of the dye with ethanol, citric acid and distilled water generate current value of 0.057 mA and voltage of 0.28 volts

**Figure 2c.** Shows the result of test and analysis of current and voltage value with the solvent dye acetate, ethanol and distilled generate current value of 0,056 mA and voltage of 0.29 V
While the figure 2d shows a comparison of the current and voltage characteristic by the third measurement data. Illustration of figure 2d shows that the current and voltage test data obtained in dye and HCL solution, ethanol and distilled water in figure 2a has a higher value and more stable than the observation data in figure 2b and figure 2c, this is due to HEA solution (first solution) has an electrolyte viscosity values used is higher than the ESA and the AEA solution. The more viscous electrolyte solution used, the voltage and current produced is more stable, but the more liquid electrolyte solution used then the current and voltage produced less stable or has low stability and drop quickly. This is due to the characteristics of volatile liquid solution and degraded by air.

Table 1 show the photovoltaic parameters of rambutan peel extracts (output current and voltage characterization of Dye Sensitized Solar Cells).

| Sample | Dye Concentration | Active area(cm²) | Photovoltaic Parameter |
|--------|-------------------|------------------|------------------------|
|        |                   |                  | Voc(V) | Jsc(mA/cm²) | FF  | η (%) |
| Sample 1 | HAE              | 1x1              | 0.29   | 0.56       | 0.38 | 0.0629 |
| Sample 2 | ESA              | 1x1              | 0.28   | 0.057      | 0.43 | 0.00695 |
| Sample 3 | AEA              | 1x1              | 0.29   | 0.0562     | 0.39 | 0.00629 |

Current density-voltage curves obtained above is in accordance with DSSC although as not ideal characteristics as expected, because the curve is sloping. It is caused by the internal resistance in the glass conductor (FTO) and a semiconductor layer of TiO₂ which is large enough so that it is possible for the electrons to be injected by dye and face obstacles were big enough and resulted in decreasing the maximum current that flows through the solar cell. The output characteristics of solar cells with high concentrations showed better performance than solutions that have medium and low concentrations in this study. The current output from solar cells at high concentration indicates the stability of the current output from the high cell than solar cells with medium and low concentration levels. But the efficiency value of each solution concentration was lower than previous research. This condition was caused by the low value of the conversion efficiency mainly due to the small current which produced. Characteristics of decreased DSSC solar cells performance with electrolyte is caused also by the low diffusion through the degradation of color and ease of evaporation of the solvent liquid electrolyte. This air electrolytic oxidation process also has the effect and accelerated by heat. This electrolyte degradation impede the regeneration of the electrons so that causing the flow and performance of solar cells decreased. Another factor which has the effect of causing the decline in stability and performance of solar cells is the damage of the dye by rambutan peel extracts which an organic substance is less stable. This dye damage cause disruption of the light absorption process so cell's ability in capturing photons decreased.
The result of this study shows relevance that the DSSC voltage generated from the difference in energy level conduction of semiconductor (TiO$_2$) electrode with redox electrolyte electrochemical potential partner, while the resulting current related to the number of photons involved in the conversion process and depends on the intensity of radiation and dye activity used. Although the value of the voltage generated is good enough and stable but the generated flow is less optimal. The magnitude of DSSC resistance results electrons injected from the dye run into obstacles, so that the amount of electrons that flow is dwindled, not optimal function of dye in the generation and injection of electrons to the electrode layer also provides influence. The intensity of the light source affects the output power of DSSC because the more the amount of photons involved in the conversion process, the greater the current is generated [6]. Another factor that affects the stability of the output current condition is the particle size and the thickness of the pasta TiO$_2$ deposited on FTO glass, long immersion of the dye, and the use of electrolyte[7].

4. Conclusion

Based on the results of research and finding, it shows that the use of *Nephelium lappaceum* peel extracts concentration as DSSC are able to produce output and performance of solar cells that good enough at high concentrations. *Nephelium lappaceum* peel extracts characteristics are able to convert light electric current density and voltage with the large of active area 1 cm$^2$ on the measurement of the efficiency, open circuit voltage and current density of each are 0.0629%, 0.29 V and 0.56 mA / cm$^2$, Characteristics of *Nephelium lappaceum* peel extract is one of the DSSC cells using TiO$_2$ as a semiconductor material as a dye sensitizer that can convert light energy into electrical energy.

Acknowledgments

The authors wish to thank to Dr. Rahmat Hidayat, M.Si. for all the helps and supports both material and immaterial.

References

[1] Smestad, G.P., and Gratzel M 2006 *Pore-Filling and Its Effect on The Efficiency of Solid State Dye-Sensitized Solar Cell Thun Solid Films* 500 p 293-301.

[2] Winefield, Chris 2008 *Anthocyanins: Biosynthesis, functions, and applications*. Springer. P 283-298.

[3] David M 2012 *Dye Solar Cell For Real* p 20 – 30.

[4] Meyer T. B., et al. 2001 Recent Development in Dye-Sensitized Solar Cell Technology, *Proceedings of SPIE, 4108, Organic Photovoltaics* p 8-16

[5] M J Keevers, T L Young, U Schubert, M A Green, 22nd 2007 *European Photovoltaic Solar Energy Conference, Milan, Sept.2007* p 1783-1790

[6] Günes S., Neugebauer H., Sariciftci N. S. 2007 *Conjugated polymer-based organic solar cells Chem Rev*, 107(4) p 1324-1338

[7] Longo, Claudia and De Paoli, Marco-A 2007 *Dye-sensitized solar cells: a successful combination of materials*. J. Braz. Chem. Soc. [online]. vol.14, n.6 p 898-901