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Electrical Performance of Dye Sensitized Solar Cell with the Extracts of Swamp Land Vegetation as Organic Dye Sensitizer

Tamrin[1*], Hersyamsi[1], H Hower[1], F Pratama[2]

[1] Study Program of Agricultural Engineering, Faculty of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatera, Indonesia
[2] Study Program of Agricultural Product Technology, Faculty of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatera, Indonesia

*tamrinlatief@gmail.com

Abstract. The electrical performance of dye sensitized solar cell with the extract of swamp land vegetation was conducted based on the extracts of bluebell (*Ruellia tuberosa* L.), flowers of *ulam raja* (*Cosmos caudatus* Kunth), and leaves of water spinach (*Ipomoea aquatica*). The electrical characteristics of DSSC was different for each dye sensitizer. The difference in electrical characteristics of DSSCs in the range of lighting source intensity 445 W/m2 - 845 W/m^2 generated from solar lighting sources is generally higher than that generated from halogen lamp. Efficiency (η) of the conversion of light into electricity produced by DSSCs whose lighting sources from halogen lamps tend to decrease with the decreasing intensity of lighting sources, except for extract leaves of water spinach. The efficiency of the conversion of light into electricity produced by DSSC for extract leaves of water spinach on halogen lamps with the intensity of lighting sources 445 W/m^2, 205 W/m^2, and 100 W/m^2, respectively 0.284%; 0.483%; and 0.983%.

1. Introduction

Energy crisis due to decreasing of fossil has an impact on finding alternative energy. Sun light is an abundant in tropical countries such as Indonesia. It is functioned as major energy for drying grains especially in rural areas. Sunlight is not only for transmitting heat but also can be converted into electric current. Alternatively, the renewable energy research is extensively studied, one of them is dye sensitized solar cell that is known as DSSC. Many studies have been carried out for increasing the efficiency of DSSC. Some of authors worked on the exploring dye as sensitizer [1][2], other works on the assembly of the substrate [3][4][5].

The conversion efficiency of by DSSC is low, however, there is endless study to increase its efficiency. The current study focused on using the local plants in south Sumatera of Indonesia that are mostly known as swamp vegetations. There are some swamp plants that are potential as dye sensitizer, they are flowers of bluebell (*Ruellia tuberosa* L.), flowers of *ulam raja* (*Cosmos caudatus* Kunth), and leaves of water spinach (*Ipomoea aquatica*). The blue colors in the flowers of bluebell reflected a substantial amount of anthocyanin in the flowers. Anthocyanin has been extensively reported as a potential plant pigment as dye sensitizer. The color n the flowers of *Ulam Raja* is yellow that indicated carotene pigment in the flowers. Carotene is reported by Suryana and Supriyanto [6] as dye sensitizer for DSSC; Darmokoesoemo et al. [7] worked on chlorophyll as dye sensitizer for DSSC.

Most of the earlier studies worked on effect of single light illumination on the efficiency of DSSC. Due to the abundant sun lights in tropical country including Indonesia, it is essential to conduct a comparative analysis between sun light and halogen lamp as artificial light on the conversion efficiency of DSSC into electric current by using the local abundant plant extract. The study aimed to conduct a comparative analysis between sun light and halogen lamps on the performance of natural dye sensitized solar cell (DSSC). The output of this study would contribute to save energy by using the natural light source for converting sun light into electric current.

2. Materials and Methods

2.1. Dye Preparation

The freshly picked flowers of bluebell and *ulam raja* as well as the leaves of water spinach were washed from dirt and mud. They were air-dried in the dark room for a day and manually crushed in a mortar by adding some distilled water. The ratio between flowers or leaves and water was 1:5. Acetic acid 0.1N was added to adjust to pH of 3.5. The mixture was filtered to separate the filtrate from the waste. The filtrate was kept in a dark bottle and stored in a refrigerator before use.

2.2. TiO2 Paste Preparation

The powder of TiO2 was weighed as amount of 0.5 g placed in a 20 mL of Beaker glass. Acetic acid was added as amount of 1 mL in the powder and evenly mixed.

2.3. Counter Electrode and DSSC Assembly

Counter electrode from a capacitive touch screen is made by shading the screen using a pencil 8B. The touch screens that has been deposited with TiO2 paste was soaked with dye for 2 hours, and then was placed in an oven at 105oC for 15 minutes. The touch screen with TiO2 paste was sandwiched with the counter electrode with an electrolyte solution (iodine) using a binder clip.

2.4. Characterization and Measurement

The absorption spectra of dye were recorded using a UV-VIS spectrophotometer (Jenway 6305). The light source was halogen light bulb (50 W) which was placed in a distance of 10 cm against the DSSC. Open circuit voltage (V_{oc}) of the fabricated DSSC device was measured using Multimeter (DT-830B) for 10 minutes under light source, while the photocurrent voltage was measured under light illumination 94,000 lux. The fill factor (FF) and efficiency (η) of DSSC were calculated using equations as stated in equation (1) and (2).

$$FF = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{oc}} \tag{1}$$

$$\eta(\%) = \frac{P_{max}}{P_{in}} \times 100\% \tag{2}$$

3. Results and Discussion

3.1. Absorption Spectra of Dye

Figure 1 shows the absorption spectra of dye solutions extracted from flowers of bluebell, *ulam raja* and water spinach. Dye that can absorb a wide range of wavelength is considered as a potential dye sensitizer. The crude extract of bluebell had a maximum light absorption at the wavelength of 510 nm and 560 nm. The maximum light absorption of *ulam raja*'s crude extract was 450 nm and 670, whereas for the water spinach was at the wavelength of 410 nm and 640 nm. The absorption spectra gave information for the possibilities of mixing of all those dye into a dye mixture that can absorb a wide range of light and therefore the light conversion into electric current is effective.

The crude extract of bluebell contained 5.86×10-3 mg/100g of anthocyanin. The carotene content in the yellow flower of *ulam raja* was 0.0082%, and the chlorophyll content in the leaves of water spinach was 6.90 mg/L for Chlorophyll A and 5.89 mg/L for chlorophyll B.

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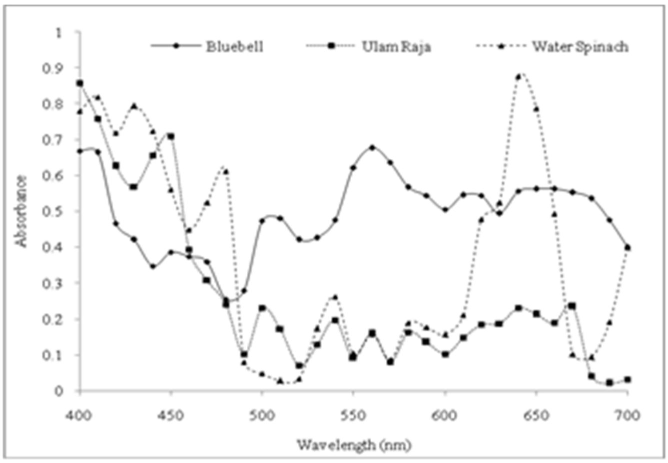

Figure 1. Absorption spectra of crude extract as dye sensitizer for DSSC.

3.2. The Electrical Performance of DSSC

The comparison on the electrical performance of DSSC by using various dye sensitizer and light sources as presented in Table 1. The different electrical characteristics as shown in Table 1 were due to different dye sensitizer and different light source. Differences in electrical characteristics produced by DSSC in the intensity range of the lighting source between 445 W/m2 to 845 W/m^2. Natural light sources such as solar lighting was generally higher than those generated from halogen lamp lighting sources, for example: halogen lamp. This could be due to a wider range of natural spectra of sun light compared to that of halogen spectra [8].

Table 1. Comparison of electrical performance of *DSSC* between light source of sun light and halogen lamps.

Light source	Light intensity (W/m^2)	*Dye Sensitizer*	V_{oc} (mV)	I_{sc} (mA)	V_{max} (mV)	I_{max} (mA)	P_{max} (mW)	*FF*	η (%)
Sun light	595	*Ipomoea sp.*	396	0.049	160.5	0.029	4.654	0.239	1.617
	845	*Cosmos sp.*	304	0.062	189	0.038	7.182	0.394	1.756
	650	*Ruellia sp.*	221	0.062	78	0.028	2.184	0.159	0.694
Halogen lamp	445	*Ipomoea sp.*	185	0.018	113.4	0.007	0.612	0.170	0.284
		Cosmos sp.	150,4	0.038	47.4	0.0303	1.436	0.316	0.667
		Ruellia sp.	152,7	0.057	43	0.023	1.006	0.211	0.467
	205	*Ipomoea sp.*	164	0.016	68	0.005	0.479	0.181	0.483
		Cosmos sp.	101	0.0174	37.3	0.015	0.556	0.250	0.560
		Ruellia sp.	131	0.013	62	0.006	0.366	0.137	0.369
	100	*Ipomoea sp.*	67	0.016	59.9	0.003	0.476	0.447	0.983
		Cosmos sp.	56.1	0.007	13.5	0.006	0.084	0.226	0.174
		Ruellia sp.	0.248	77.1	0.009	36	0.004	0.116	0.008

Efficiency (η) of the conversion of light into electricity produced by DSSCs whose lighting sources from halogen lamps tend to decrease with the decreasing intensity of lighting sources, except for the vegetation of Ipomoea sp. actually increases. The efficiency of the conversion of light into electricity produced by DSSC for Cosmos sp. on halogen lamps with the intensity of lighting sources 445 W/m^2, 205W/m^2, and 100W/m^2, respectively 0.667%; 0.560%; and 0.174%; for vegetation *Ruellia* sp. is 0.467%; 0.369%; and 0.008%; for *Ipomoea* sp. were 0.284%; 0.483%; and 0.983%. Some of The I-V characteristics curve of DSSC as depicted in Figure 2 and Figure 3.

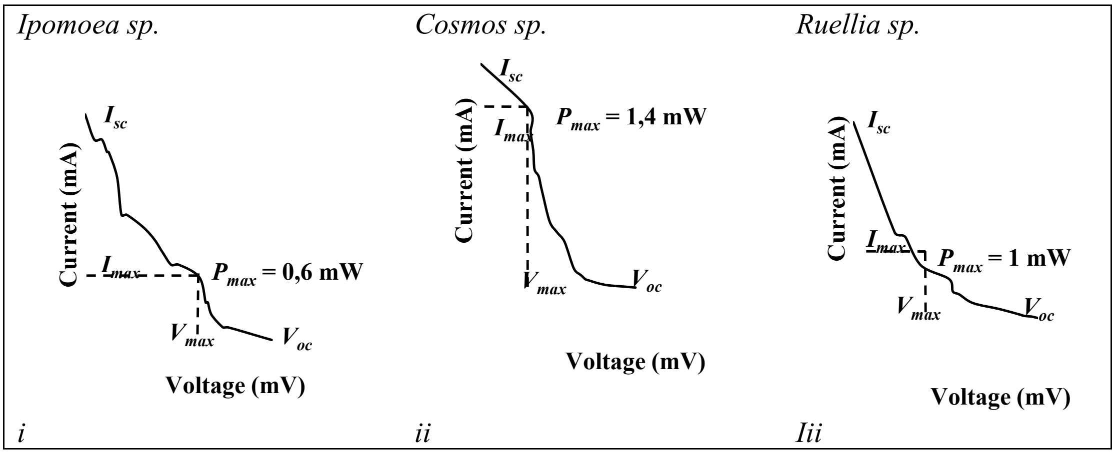

Figure 2. I-V characteristic curve with halogen lamp (100 W/m^2).

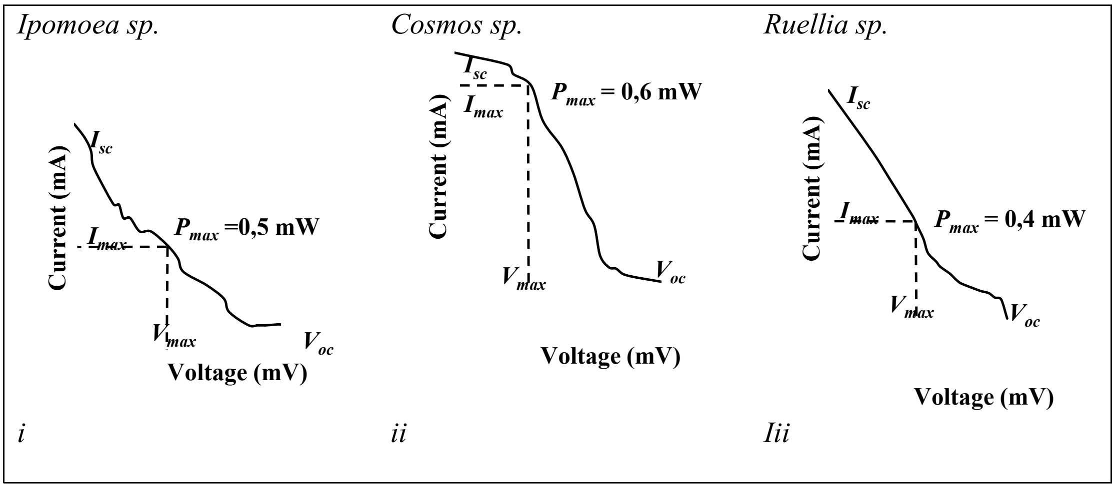

Figure 3. I-V characteristic curve with sun light as light source.

4. Conclusion

The difference in electrical characteristics produced by DSSCs in the range of lighting source intensity 445 W/m^2 - 845 W/m^2 generated from solar lighting sources is generally higher than that generated from halogen lamp lighting sources. Efficiency (η) of the conversion of light into electricity produced by DSSC's whose lighting sources from halogen lamps tend to decrease with the decreasing intensity of lighting sources, except for Ipomoea sp. The efficiency of the conversion of light into electricity produced by DSSC for Ipomoea sp. on halogen lamps with the intensity of lighting sources 445 W/m^2, 205 W/m^2, and 100 W/m^2, respectively 0.284%; 0.483%; and 0.983%.

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