Implementation of Gyrinops Versteegii Gaharu Leaves as a Dye-Sensitized Solar Cell

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Abstract

Dye-Sensitized Solar Cell (DSSC) is a photoelectrochemical solar cell that uses electrolytes as the cargo transport medium. Gratzel developed it as an alternative resource through the discovery of the latest solar cell material by mimicking the photosynthesis process called photo-electrochemical reactions. According to the research of Saputra, flavonoids can be used as dyes in Dye-Sensitized Solar Cells, while Yanti in 2014 studied the agarwood leaf extract that contained flavonoids and chlorophyll. This study aimed to design, build, and test Dye-Sensitized Solar Cell by testing the light absorption, and the Performance of Dye-Sensitized Solar Cell using Agarwood Chlorophyll. This research extracted the Gyrinops versteegii that was grouped into young, medium and old leaves. With the same dose of extract, 15 grams of agarwood leaves were dissolved in 96% ethanol for 100 ml. The results showed that even though the maximum absorption power was the same, or 4.00, the medium leaves absorbed the light more than its wavelength range. The DSSC performance test results obtained the voltages of the young, medium, and old agarwood leaves that were 0.398 V, 0.399 V, and 0.369 V. The currents of those leaves were 0.01 mA, 0.01 mA, and 0.01 mA respectively.

Keywords
Dye-Sensitized Solar Cell, Voltage, Current, Agarwood leaf

1. Introduction

The solar cell is a semiconductor that produces direct electrical energy by conversion solar energy into electrical energy [1]–[3]. The conversion consists of several stages: (1) light absorption to the semiconductor, and (2) generates and separates the positive and negative charges through its terminals. This process commonly uses silicon solar cells due to its 24% efficiency. However, the production of this silicon solar cell is not environmentally friendly with the complicated assembly line. Besides, silicon solar cell has a limited supply of raw material because of the price rise following the demand of semiconductor industries. Nowadays, there is a more environmentally friendly solar cell that is Dye-sensitized Solar Cell (DSSC). The DSSC is a photoelectrochemical solar cell and uses electrolyte as the medium to transport the load. Gratzel developed this type of solar cell as an alternative power source by imitating the photosynthesis process that is called photoelectrochemical reaction [4]–[7]. The photosynthesis process converses the sunlight into a chemical reaction that is an essential technology development to converse solar energy into electrical energy in the Dye-sensitized Solar Cell. DSSC also has other advantages such as cheap material price, easy to obtain resources, and environmentally friendly.

DSCC consists of several components: oxide semiconductor, dye layer, counter electrodes and electrolytes. Dye becomes a vital part of the absorption process and converts it into electrical energy. Previous research used dye from Ruthenium complex compound and reached 11–12% efficiency [8]–[10]. However, since that dye is limited and costly, researchers turned into color pigment from plants, for example, using chlorophyll and plant flavonoids. Agarwood leaves is a plant with chlorophyll and flavonoid. Yanti, in 2014, researched the extract of agarwood leaves that consists of flavonoid and chlorophyll. Chlorophyll from the agarwood leaves absorbs the light and can be used as a dye in the DSCC due to its conjugated double bonds (organic compound bonds that the atoms covalently bonded singularly or double alternately). Other than chlorophyll, flavonoids can be used as a natural dye, as proved by the research of Saputra in 2014.

There was not any particular research that discusses the utilization of chlorophyll in the agarwood leaves as the natural dye in the Dye-sensitized Solar Cell (DSCC). The current development is using chlorophyll or pigment from other plants such as spinach leaves. However, based on current reality, spinach leaves are utilized as a food source in almost all regions in Indonesia. Thus, there needed an alternative plant to replace the spinach such as agarwood leaves. To date, the stems of agarwood often used as material to produce perfume. Meanwhile, the leaves are used as a particular material for tea. These occasions are not comparable with the availability of agarwood. Therefore, this research aimed to utilize agarwood leaves as the natural dye,

besides spinach leaves, by testing and analyzing the chlorophyll in agarwood leaves (young, medium, and old leaves) towards DSSC efficiency. This research tested the efficiency using characteristic I–IV tests with solar simulator equipment.

2. Research Method

This research covered three stages: designing, making and testing the Dye-sensitized Solar Cell.

A. Designing Dye-Sensitized Solar Cell

The design process was divided into two: chemical element composition design and DSSC shape design. The making of FTO conductor glass required $SnCl_2.2H_2O$, and NH_4 mixed with 96% ethanol. The making of TiO_2 paste needed 2.5 grams of TiO_2 powder and dissolved in 15 ml Aquades and 15 ml HNO_3. Moreover, the making of electrolyte solution required Potassium iodide (KI) and Iodine (I_2) for 0.83 gr, dissolved in 10 ml acetonitrile and stirred for 30 minutes. Designing DSSC in this research used a layered structure or sandwich structure where there were two FTO (fluorine-doped tin dioxide) conductor glasses with different compositions. The top layer was the carbon layer to pull the electron back from the conjunction back to the electrolyte. Meanwhile, the bottom layer or anode was Titanium dioxide and dye layer from the agarwood chlorophyll to trap and extract the electron. Figure 1 shows the design of DSCC in this research.

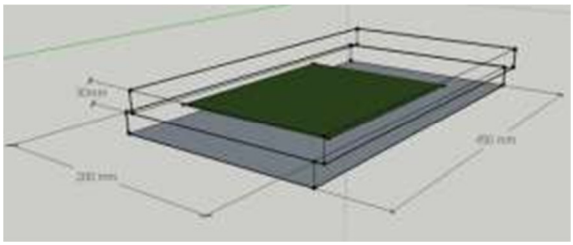

Figure 1. DSSC Design

B. Making Dye-Sensitized Solar Cell

After the design was validated, the next was to make the DSSC based on the design following the procedure from valid references such as journals and books. Based on the above figure, there were some stages in making the Dye-sensitized Solar Cell. First was preparing the instruments and materials that would be used in the process. The second was the extraction of agarwood leaves and light absorption test that was processed to take and test the chlorophyll in agarwood leaves. This made the conductive glasses (FTO) had low resistance as the conductors. The fourth was layering with TiO_2 as the area active to put the dye and as cathode pole. The fifth was making the anode pole (counter electrode) by layering the conductive glasses with carbon. Sixth was a sandwich structure by pinning both carbon-coated poles with the previous pole that was soaked with dye and was given an electrolyte (cathode). Last was the DSCC performance test to obtain the voltage and current values.

C. Dye-Sensitized Solar Cell Testing Stage

There were two tests on this research: light absorption test on agarwood leaves and performance efficiency test using solar cell simulator to obtain the voltage and current values. Light absorption test from the Gyrinops versteegii (young, medium, old leaves) was conducted after obtaining the extracts. The extract then was brought to the Mathematics and Natural Science Faculty laboratory, State University of Malang, to be tested using a UV-Vis spectrometer to observe the wavelength. If the result was around 400–700 nm (visible light), then the dye could be used for the next stage. DSSC performance test was conducted after all components were ready. The test's goal was to obtain the current and voltage from the DSSC. The test was performed in the conversion laboratory of the Electrical Engineering Study Program at the State University of Malang.

3. Result and Discussion

A. Light Absorption Test Result

This test used a UV-Vis spectrophotometer to find the wavelength that could be absorbed and the peak absorption of the three extracts.

1) Light Absorption Test Result of Young Agarwood Leaves. The resulted wavelength was 208–650 nm. Meanwhile, the peak absorption was 4.00 at several points, from 252 nm until 361 nm with the same amount of 472.5 nm.
2). Light Absorption Test Result of Medium Agarwood Leaves. The above figure shows the chart of medium agarwood leaves light absorption test. The resulted wavelength was 213–640 nm with the peak absorption was 4.00 at 239–288 nm and 306–362 nm. Although it had the same amount of wavelength with the young agarwood leaves, it had a longer wavelength.

3). Light Absorption Test Result of Old Agarwood Leaves. The absorption range was between 249–650.5 nm. The peak absorption was 4.00 nm, similar to the other two, but only at three points: 308 nm, 359 nm, and 476.5 nm.

TABLE I. COMPARISON OF LIGHT ABSORPTION TEST RESULTS

Type of Agarwood Leaves	Absorption Range (nm)	Peak Absorption (nm)	Peak Absorption Point (nm)	
Young	208-650	4.00	1. 2.	252 – 361 472.5
Medium	213 - 640	4.00	1. 2. 3.	239 – 288 306 – 362 479 - 486
Old	249 – 650.5	4.00	1. 2. 3.	308 359 476.5

Based on the comparison, all agarwood leaves types had the same peak absorption that was 4.00, but different wavelengths. Medium agarwood leaves had a longer peak wavelength compared to the other two. It showed that the medium agarwood leaves could produce better absorption. The young and old agarwood leaves, with shorted wavelength, still could produce absorption although lesser in quality.

B. DSSC Performance Test Results

The DSSC performance test was performed after the dye was tested using solar simulator equipment, as displayed in Figure 2.

Figure 2. DSSC Performance Test

TABLE II. DSCC PERFORMANCE TEST RESULTS

Agarwood Leaves Groups	Voltage (V)	Current (mA)
Young	0.398	0.01
Medium	0.399	0.01
Old	0.369	0.01

The test resulted in 0.398 V voltage and 0.01 mA current for the young agarwood leaves, but the medium leaves obtained 0.399 V voltage and 0.01 mA current. Moreover, last, the old leaves obtained 0.369 V voltage and 0.01 mA current.

4. Conclusion

The Dye-sensitized Solar Cell designation covered the chemical component design of conductive glasses (16 gr SnCl2.2H2O was mixed with 50 ml ethanol and was added 0.3 gr NH4 powder), TiO2 semiconductor TiO2 (2.5 gr TiO2 powder was dissolved in 15 ethanol and 15 ml HNO3). Meanwhile, the dimensions of the design were 4.5x2x0.3 cm. The making of DSSC covered the making of conductive glasses, layering them with TiO2 on anode pole, layering the cathode pole with carbon, and testing. The results were (a) peak absorption on young, medium, and old agarwood leaves were the same (4.00). The longer wavelength was on

medium agarwood leaves. (b) the current and voltage values from the DSSC performance tests stated that the medium leaves had the highest voltage (0.399 V) or best used as the dye.

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