The fabrication of DSSC TiO$_2$ transparent thin layer with natural dye sweet potato (*Ipomoea batatas* L.)

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Abstract. TiO$_2$ semiconductor materials as working electrodes are commonly used in DSSC fabrication. One type of TiO$_2$ used in DSSC fabrication is a paste form. In this study aims to determine the effect of the viscosity level of TiO$_2$ paste. The deposition of a TiO$_2$ transparent thin film using spin coating method with 450 °C heating temperature. Preparation of TiO$_2$ paste was done by mixing TiO$_2$ and ethanol by comparison (1:1, 1:3, 1:5). DSSC fabrication is characterized by an I-V test to determine the efficiency value. Sweet potato dyes used from the anthocyanin type. Preparation of sweet potato dye by mixing the sweet potato into a mixture of solution between methanol, distilled water, and acetic acid with the ratio of solution (1:3:5). UV-Vis spectrophotometer characterized the results of sweet potato extraction. In the test results I-V the most significant efficiency value is obtained at a 1: 1 ratio with an efficiency value of 1.92 x $10^{-2}$ and the absorbance peak obtained at 532 nm wavelength.

1. Introduction

The sun is a considerable energy where the average of sunlight radiation in the earth's atmosphere is 1366 W / m$^2$. But in 2001, the utilization of solar energy is still very minimal that is around 0.1% of the world's electricity needs. It is estimated that by 2050 energy demand will increase twice or even three times by the end of this century [1-2].

In 1991 began to develop research to utilize the sun to meet energy needs on earth in the form of DSSC. At the beginning of development, DSSC uses a TiO$_2$ semiconductor material with dye made silicon ruthenium. As technology progresses, many researchers are beginning to develop DSSC with natural dye [3-5]. In its development, DSSC is divided into three generations where the first generation is solar cell silicon, second generation thin layer solar cell, and the third generation is Dye-Sensitized Solar Cell (DSSC) [6-9].

In this study the semiconductor material used is TiO$_2$ 18 NR-T transparent which is dissolved with ethanol. The mixture of TiO$_2$ paste 18 NR-T and ethanol with three comparisons of 1: 1, 1: 3, 1: 5. While the natural dye type of antoianin used is purple sweet potato. The anthocyanin, the total content of anthocyanin extract containing other phenolic ingredients has been determined by measuring the absorptivity of the solution at a single wavelength. This is possible because anthocyanins have a typical absorption band at 490-550 nm [10].
2. Experimental Methods

2.1. Preparation of TiO$_2$ Transparent Paste
The TiO$_2$ paste is prepared by dissolving TiO$_2$ 18 NR-T with ethanol and stirring using a magnetic stirrer at 350 rpm. The making of this paste is made of three variations (1:1, 1:3, 1:5).

2.2. Preparation of Natural Dye Sweet Potato
Natural dye extraction using sweet potatoes was done by mixing 15 grams of sweetened sweet potatoes with a mixture of 45 ml of methanol solution, distilled water, and acetic acid. Dye is stirred with a magnetic stirrer at 450 rpm for 1 hour and then filtered by whatman number 42.

2.3. Fabrication of DSSC
The deposition process of working electrode on DSSC using glass Flouro Tin Oxide (FTO) with active area of 1 x 1 cm. The process of deposition using spin coating method with a speed of 1000 rpm for 15 seconds. Then the sample was heated with a furnace (Carbolite 1100) to a temperature of 450 °C with a 30 minutes holding time and than the sample was immersed into the dye for 24 hours. The counter electrode was prepared by heating the FTO glass above the hot plate at 250 °C. for 15 minutes then gradually dripping the platinum solution. The active area of the counter electrode is the same as the working electrode. Characterization of DSSC performance is done by measuring I-V and UV-Vis. Measurements of I-V are performed to determine the efficiency value of the confluence of electrical energy generated by DSSC. While UV-Vis testing conducted to determine the absorbance value of natural sweet potato extract.

3. Result and Discussion

3.1. UV-Vis Test
UV-Vis measurements were performed using the Lambda 25 UV / VIS Spectrophotometer. The result of measurement of absorbance value is shown as in figure 1.

![Figure 1. Absorbance of Dye Sweet Potato (Ipomoea batatas L.)](image-url)
Figure 1 indicates that the absorbance value is in the 460-560 nm range with the peak value being at 532 nm wavelength. The result of preparation dye shows that absorbance spectrum of anthocyanin according to the references [10].

3.2. Performance DSSC
The DSSC performance was tested using a Keithley 2620A with a illuminati lamp source 1000 W/m². The characterization and efficiency of the I-V test is shown in Figure 2 and Table 1.

![Figure 2. Curve of Current-Voltage (I-V).](image)

Figure 2 shows the curve between DSSC performance testing in the dark (no light) and in the light. In the DSSC with the ratio of TiO₂ and ethanol 1:5 has a curve that almost coincides with the curve in the dark. While the ratio of 1:1 there is a very wide distance when compared with the ratio of 1:3 and 1:5. For the efficiency value of DSSC shown in table 1.

| Comparison | \(I_{\text{max}}\) (mA) | \(V_{\text{max}}\) (mV) | \(I_{\text{sc}}\) (mA) | \(V_{\text{oc}}\) (mV) | \(\eta\) (%) |
|------------|----------------|----------------|----------------|----------------|-------------|
| 1:1        | 0.00021        | 0.09094        | 0.01516        | 0.19701        | 0.01934     |
| 1:3        | 0.00015        | 0.10604        | 0.00013        | 0.24247        | 0.01544     |
| 1:5        | 0.00004        | 0.30306        | 0.00006        | 0.36365        | 0.01148     |

Table 1 shows the difference in efficiency values in dssc of the three variations of the composition of TiO₂ 18NR-T ratio with ethanol. The highest yield resulted from a composition ratio of 1:1 with an efficiency of 0.19%. The greater the composition ratio between the TiO₂ paste and the ethanol, the lessened efficiency decreases. This can be seen in the table where the ratio of 1:3 value of efficiency decreased to 0.15% and decreased in the ratio 1:5 where the efficiency becomes 0.11%.

The decreasing value of the resulting efficiency may be due to the greater ratio between the transparent TiO₂ NR-T paste and ethanol. Because the greater the ratio makes the solution of TiO₂ paste to be dilute. This has an effect on the deposition of TiO₂ paste on the FTO glass. The dilute TiO₂ paste solution makes the DSSC deposition layer very thin as if there is no TiO₂ paste layer on the FTO glass.
4. Conclusion
DSSC fabrication with composition ratio of TiO$_2$ 18NR-T and ethanol paste has been successfully performed. From the results of the study, the greater the composition of TiO$_2$ and ethanol to make TiO$_2$ paste more dilute resulting in TiO$_2$ layer on the glass substrate FTO thinner. This has resulted in the declining performance of the DSSC. The highest efficiency value is 0.19% in the composition ratio of 1:1.

5. Acknowledgement
This Research was partly supported by Higher Education Project Grant with contract no. 543/UN27.21/PP/2018.

6. References

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