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Experimental Study of I-V Characteristics Dye Sensitizer Solar Cell Based on Carotenoid and Photoelectrode TiO_2

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ABSTRACT

Dye sensitizer solar cell (DSSC) is one of the photoelectrochemical cells consisting of photoelectrode, dye, electrolyte, and counter electrode. This article presents experimental data of I-V characteristics of DSSC made from carotenoid and photoelectrode TiO_2. Optimization of carotenoid concentration in ethanol and optimization of TiO_2 concentration in slipcasting method were investigated. It was found that TiO_2 concentration gave significant effect in slipcasting method. Current-voltage (I-V) characteristics of DSSC made from carotenoid produced open circuit voltage (V_{OC}) of 480 mV, short circuit current density (J_{SC}) of 28 μA/cm2, Fill Factor (FF) = 0.37 and photoelectric conversion efficiency (η) 5.07 × 10^{-3}%.

Keywords: Dye Sensitized Solar Cell (DSSC), Slipcating, TiO_2, I-V characteristics.

INTRODUCTION

Solar energy sources are an attractive and profitable investment that has been proposed as the most likely replacement for fossil fuels in the future. Nowadays the dominance of the photovoltaic field with inorganic devices is being challenged by the emergence of dye sensitized solar cells (DSSC). DSSC is the only solar cell that can offer both flexibility and transparency. Efficiency is comparable to amorphous silicon solar cells but at a much lower cost. Generally, DSSC consists of transparent conducting oxide (TCO) coated with dye TiO_2 electrodes, counter electrodes, and electrolytes containing iodide/tri-iodide ion redox pairs. Various efforts to improve the efficiency of DSSC have been made, one of which is increasing light trapping in TiO_2 electrodes (Shakeel Ahmad et al., 2017), and develop new dyes to expand the absorption spectrum from ultraviolet to a wider spectral range (Francis & Ikenna, 2021).
Dye molecules are placed on the TiO_2 layer to achieve higher energy efficiency in DSSC. Carotenoids are one of the dye sensitizers used in DSSCs made from natural organic materials because they absorb the visible light spectrum. Tio_2 is a semiconductor of choice with the advantageous properties of high chemical activity, simple band gap, cheap, abundant, and non-toxic (Al-Alwani et al., 2016); (Suhaimi et al., 2015). Various DSSC performance optimizations have been reported, including expanding the dye absorption spectrum from ultraviolet to visible light, photoelectrode morphology and conductivity, liquid, solid, and gel electrolytes, and counter electrode (Sharma et al., 2018);(Mahmoudi et al., 2018);(Mariotti et al., 2020).

This study aims to determine the effect of TiO_2 solution/gel concentration in the slipcasting process on the current-voltage (I-V) characteristics of DSSC made from natural caroteneoid which include short circuit current density (J_{SC}), open circuit voltage (V_{OC}), and efficiency Photoelectric conversion of DSSC.

METHODS

The research was conducted in the laboratory of the Physics Education, UPGRI Pontianak.

DSSC Preparation

The TiO_2 layer was made using the slipcasting method with optimization of the concentration of TiO_2 solution/paste in ethanol, to produce a TiO_2 layer with a thickness of 50 mm and an area of 1 cm × 1 cm. The annealing temperature of the TiO_2/FTO layer was at 400 ^{0}C for 60 minutes. The slipcasting method was also used for the counter electrode, namely, 3.5 grams of graphite powder was mixed with 15 ml of ethanol and a 1cm x 1cm graphite layer was obtained at an annealing temperature of 400^{0}C for 60 minutes. The assembly of the DSSC used a sandwich technique, namely the Tio_2 layer containing dye and the counter electrode was assembled into a DSSC by sandwiching the redox ion pair electrolyte to produce a DSSC structure that was ready to be measured (Suhaimi et al., 2015).

Current-Voltage (I-V) Characteristics of DSSC

As an introduction, the current and voltage method is used to determine the current-voltage (I-V) characteristics of a DSSC, namely by using two multimeters and a variable resistor.

RESULTS AND DISCUSSION

The current voltage method is used to determine the efficiency of photoelectric conversion of DSSC made from natural dye carotenoid. Then the current and voltage can be determined for each change in resistance value. The study observed the effect of carotenoid concentration on increasing current and voltage. Open circuit voltage (Voc), short circuit current (Jsc) and photoelectric conversion efficiency (η) are presented in Table 1.

Table 1 DSSC from carotenoid dye with different concentrations

Concentrations	***Voc* (mV)**	***Jsc* (μA/cm^2)**	***FF***	***η* (%)**
0,01 mg/ml	409	6.6	0.32	8.95×10^{-4}
0,5 mg/ml	485	5.5	0.39	9.55×10^{-4}
5 mg/ml	465	6	0.38	1.01×10^{-3}

The concentration of dye (5 mg/1 ml ethanol) produces an open circuit voltage (Voc) of 465 mV and a current density (Jsc) of 6 μA/cm^2. The study observed that the dye concentration mainly affects the increase in J_{SC}. This result is in accordance with theoretical studies that Jsc can be affected by dye. Furthermore, the study observed that increasing the concentration can reduce the photoelectric conversion efficiency (η) of DSSC, because the addition of dye concentration in ethanol solvent can increase the roughness of the dye solution which reduces the absorption of dye molecules into the pores of the TiO_2 electrode. To optimize the absorption of dye into the TiO_2 electrode, the effect of variations in TiO_2 concentration was then observed.

Table 2 Effect of TiO_2 solution/gel concentration on I-V DSSC

Concentrations	***Voc* (mV)**	***Jsc* (μA/cm^2)**	***FF***	***η* (%)**

3,5gr : 30 ml	480	28	0.37	5.07×10^{-3}
3,5gr : 45 ml	452	14.2	0.39	2.57×10^{-3}
3,5gr : 75 ml	465	6	0.38	1.01×10^{-3}

Table 2 shows the variation of TiO_2 concentration in ethanol solvent to obtain TiO_2 layer by slipcasting method which is then assembled into DSSC made from carotenoid dye (5 mg/1ml ethanol). Table 2 shows the current density (Jsc) and open circuit voltage (Voc) of DSSC measured using DT830B digital multimeter under Xenon lamp illumination of 100 mW/cm^2. The largest Voc is 480 mV and Jsc increases from 28 µA/cm2 (initial concentration of 3.5 gr/15 ml ethanol, before variation treatment) to 6 µA/cm^2 (concentration of 3.5 gr/45 ml ethanol). This is thought to be related to the properties of the semiconductor and the thickness of the resulting layer. Previous research shows that there are satisfactory results from DSSC research results (Zulkifili et al., 2015); (Bella et al., 2015); (Adedokun et al., 2016).

CONCLUSION

From the above results, it can be concluded that the slip casting method can affect the efficiency of DSSC. In addition, the conversion efficiency of DSSC increases with the optimization of TiO2 concentration in the slipcasting process. The results of photoelectric conversion measurements in the form of current and voltage make the dye sensitizer applicable to DSSC and can be increased by optimizing the TiO2 concentration in the slipcasting method.

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