Sensitization Capacity of Fruit Extract of Malabar Melastome as Sensitizer in Dye Sensitized Solar Cell (DSSC)

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ABSTRACT

An alternative technology to convert sunlight into electricity that has drawn much attention in recent years is dye sensitized solar cell (DSSC). Sunlight can be converted into electrons and light absorption. This research used methanol and aqueous fruit extracts of *Malabar melastome* as dye sensitizer at the volumes of 0.100 mL, 0.125 mL and 0.150 mL. Results, indicated that the best performance on DSSC was shown by the treatment of aqueous fruit extract at the volume of 0.150 mL. Its electrical performance of V_{oc}, I_{sc}, FF and Efficiency of 227 mV, 0.038 mA, 0.457 and 0.987%, respectively.

Keywords: Dye sensitized solar cell, dye, Malabar melastome, substrate, solvent

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INTRODUCTION

Alternative energy continues to be developed to anticipate the increasingly limited non−renewable energy. One of alternative energy sources that is always available and potentially to be developed is solar energy. Sunlight can be used as heat energy and electrical energy. Utilization of solar energy into heat energy is easier than that of electrical energy. The conversion of solar beam into electrical energy has the potential to be developed due to the availability of solar light throughout the year (Wu *et al*., 2008). The need for electrical energy is increasing due to the increase of human needs that mostly depend on the electrical energy. One of the technologies for converting solar energy into developing electric energy is dye sensitized solar cell (DSSC). Solar energy can be converted into electrical energy which is caused by the effects of photovoltaic that depend on the formation of free electrons and light absorption.

DSSC consists of nanocrystalline semiconductors, photosensitizers, redox electrolytes and transparent conductive oxide (TCO) substrates. Initially, the dye sensitizer used was ruthenium polypyridyl complexes. Due to the expensive and limited of ruthenium, the natural dye extracted from plants was used instead of ruthenium. In addition, natural dye extract from plant is renewable as well as environmentally friendly. Dye sensitizer that is deposited in the TiO_2 paste on the surface of TCO substrate absorbs light and injects the electrons into the semiconductor. The sensitization process occurs due to dye absorption in the light spectrum which was converted to electrical energy (O'Regan and Gratzel, 1991: Gratzel *et al*., 2004). The performance of DSSC is dependent on many factors, including semiconductor materials, dye types, dye thickness deposited on transparent conductive oxide substrates, dye extracts, and long exposure to light (Gratzel, 2004; Jayaweera *et al*., 2008; Luo *et al*., 2009; Hernández−Martínez *et al*., 2012; Maabong *et al*., 2015)

One type of swamp vegetation that can be used as a dye sensitizer in the DSSC is the Malabar melastome (*Melastoma malabathricum* L.). The Malabar melastome can grow well in low lands because they are able to adapt well to acid soils. These plants are not yet used for human needs, although it has been known that the extract of its fruit contains anthocyanin which can use as antioxidant. The fruit of the population contains anthocyanin of 49.9 mg/L (Aishah *et al*., 2013). In addition to anthocyanin, the meat of the fruit contains antibacterial (Omar *et al*., 2012).

Utilization of fruit extract as a dye sensitizer for solar cells has the potential to be developed, especially in areas of South Sumatra, Indonesia that there are mostly swamps. With the potential availability of Malabar melastome fruit as sensitizer on solar cells, the conversion of solar energy into electrical energy will be sustainable. This paper focused on the output performance of the conversion of fruit pulp extract as a dye sensitizer in dye sensitized solar cells differing in substrate and carbon origin. The different substrate and carbon origin on the extract as sensitizer might affect the performance of the DSSC and the extract is affected by the solvent used. This research used polar solvent and non−polar solvent.

MATERIALS AND METHODS

Materials Used

The ingredients used are fruits of Malabar melastome (*Melastoma malbathricum* L.) obtained from swamp land in Jakabaring, Palembang, Indonesia. TCO glass area of 2.5 cm × 2.5 cm, ITO substrate (Sigma Aldrich) at the size of 2.5 cm × 2.5 cm, 70% methanol solvent. The equipment used was muffle furnace, oven, hot plate, lux meter, volt meter and potentiometer.

Fruit Extraction

The red ripe of fruits were selected which were indicated by the red fruit skin. The skin of the fruit was peeled, and the flesh was collected. The flesh was mashed in a blender and soaked in solvent. The two types of solvent used were aquadest and methanol. Immersion was performed for 24 hours and then filtered by using filter paper. The obtained filtrate was then concentrated by vacuum evaporator at 60°C for 30 minutes and it was used as a dye sensitizer.

Analysis of the absorbance of both extracts extracted with aquadest and methanol was performed using a spectrophotometer at a wavelength of 400 to 700 nm.

TCO Preparation (Non fabricated substrate)

Glass at the size of 2.5 cm × 2.5 cm was heated in a Muffle furnace at 700°C for two hours. During heating, the solution of $SnCl_4.5H_2O$ was prepared. After two hours of glass heating, the $SnCl_4.5H_2O$ solution was sprayed on the hot glass and reheated in the muffle furnace for two minutes (handmade−spray coating). Then the solution of $SnCl_4.5H_2O$ was re−sprayed onto the glass and reheated for two minutes. The treatment was repeated ten times. The resulting TCO was then left at room temperature until it reached room temperature and was ready for use.

TiO_2 Paste Preparation

TiO_2 was dissolved in acetic acid solution and stirred until it was evenly mixed to form a suspension. This suspension was applied to TCO by a doctor−blade technique on a certain extent on TCO that was limited by a scotch tape.

DSSC Assembling

A piece of TCO substrate that has been bordered with scotch tape on three sides is smeared with TiO_2 paste using a doctor−blade technique. The TCO substrate was then heated in an oven at the temperature of 100^{o}C for 30 minutes. The dried TCO substrate was then given dye extract with different volumes of 0.1 mL, 0.125 mL and 0.15 mL. After another ten minutes, it was rinsed with distilled water and methanol. The wet TCO edges are dried using filter paper. The dye−coated TCO substrate was subsequently sealed with a pre−prepared carbon−fiber TCO substrate. These two pieces of TCO substrate are clamped with a clip binder and then inserted with Iodine electrolyte between two pieces of the TCO substrate. The resulting DSSC sandwich was further tested for performance by exposure to the solar rays and halogen lamp.

RESULTS AND DISCUSSION

Dye Characterization

The absorbance analysis of the extracts was performed to determine the ability of the extract to absorb light in the wavelength range of light. The active ingredients extracted in the dye can be excited to a higher energy level. The results of absorbance analysis of extract with water solvent and methanol as presented in Figure 1.

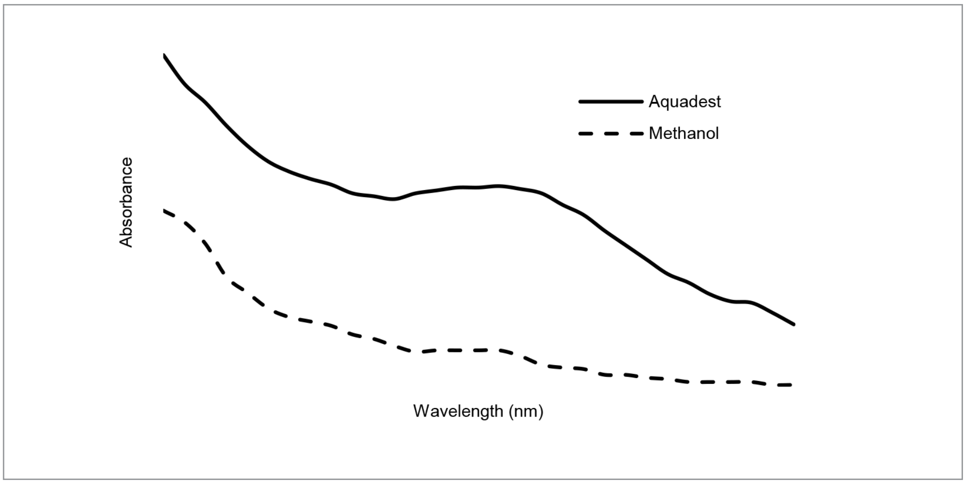
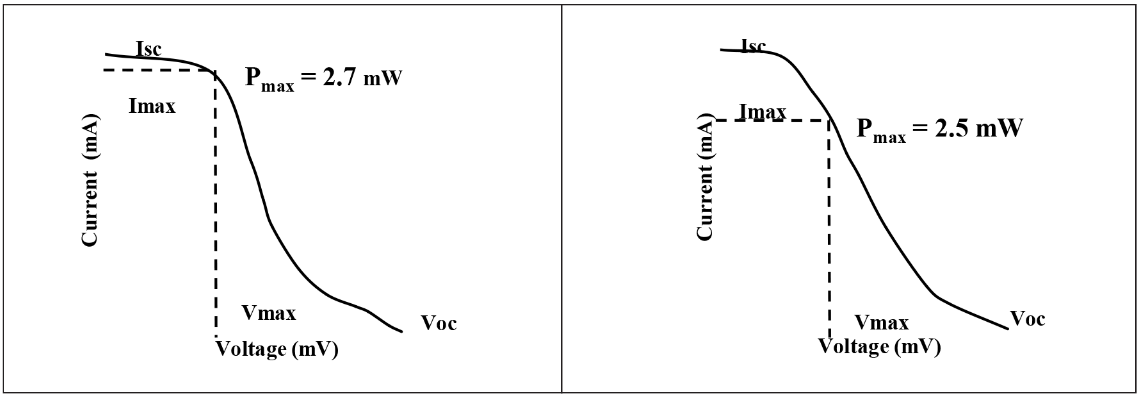


Figure 1 Absorbance of fruit extract of Malabar melastome

The fruit extract was not purified so it appeared that not only anthocyanins were in the extract. The active compound extracted from the plant part depends on several factors. In addition, methods and time of extraction, type of solvent; temperature; and the ratio of the sample to the solvent (Tiwari *et al*., 2011) could be the factors that affected the characteristics of the extract. Figure 1 shows two maximum peaks at the wavelengths of 400 nm and between 500−575 nm. The active compounds that can absorb at wavelengths between 500 and 575 nm are anthocyanin (Singh *et al*., 2014). This is consistent with the analysis of anthocyanin levels in water solvent−based extracts is 1.57% and with methanol solvent is 0.802%. The anthocyanin levels in the aquadest solvents were higher than those extracted with the methanol solvent because anthocyanins were more soluble in the distilled water compared to methanol (Tiwari *et al*., 2011).

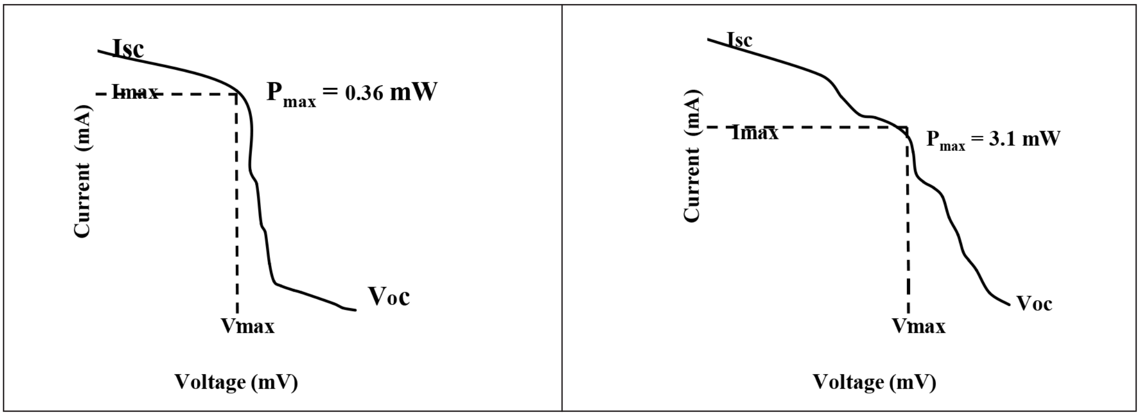
Electrical Characterization of DSSC

Analysis of I−V DSSC characteristic was done on dye extract of fruits extracted with water solvent and methanol. Each dye was applied to non−fabricated TCO of 0.1 mL, 0.125 mL and 0.15 mL with irradiation using solar energy. The results of the experimental characteristics are shown in Figures 2 to 5.



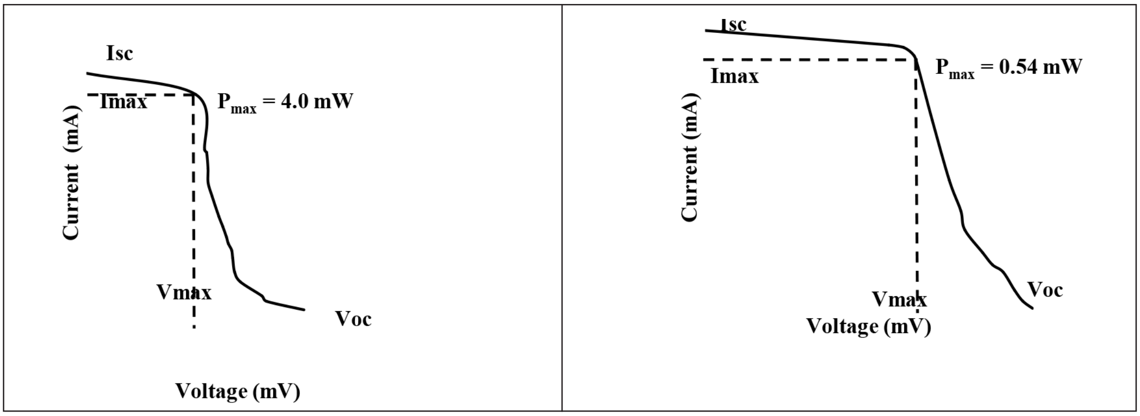
(a) 0.1 mL aqueous extract dye (b) 0.1 mL methanolic extract dye

Figure 2 I−V characteristics of DSSC on non−fabricated TCO substrate



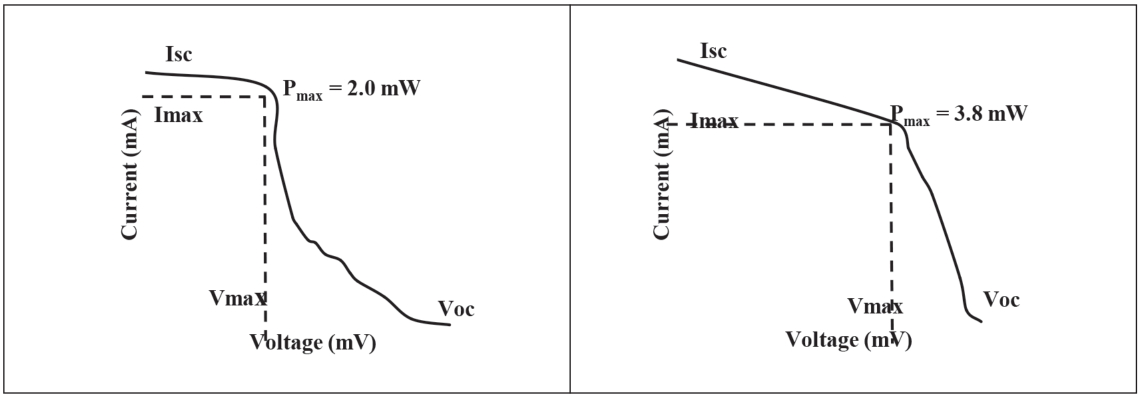
(a) 0.125 mL aqueous extract dye (b) 0.125 mL methanolic extract dye

Figure 3 I−V characteristics of DSSC on non−fabricated TCO substrate



(a) 0.150 mL aqueous extract dye (b) 0.150 mL methanolic extract dye

Figure 4 I−V characteristics of DSSC on non−fabricated TCO substrate



(a) Carbon of pencil (b) Carbon of burning of candle

Figure 5 I−V characteristics of DSSC on fabricated ITO (Sigma Aldrich) substrate

The I−V curve of the non−fabricated TCO substrate and the concentration variation of each extract are presented in Figures 2 to 4. The overall curve tends to be photovoltaic. This also occurs in the I−V curve (Figure 5) using ITO Sigma Aldrich substrate (fabricated substrate). The efficiency of solar cells using methanol solvents ranges from 0.431% to 0.825%. While the efficiency of solar cells using aquadest solvent ranged from 0.516% to 0.987%. Overall, however, the use of non−fabricated TCO substrate with carbon derived from pencil between aquadest solvent and methanol solvent was highest efficient in aquadest solvent with extract volume of 0.150 mL with an efficiency of 0.987%. This was due to the active compound of anthocyanin was extracted more by using aqueous solvent (1.570%) than by using methanol solvent (0.802%).

The efficiency of solar cells using both non−fabricated TCO and TCO substrate of Sigma Aldrich ITO with carbon derived from pencil showed no significant difference, each with an efficiency of 0.987% and 1.020%. Because the substrate surface of fabricated ITO substrate was relatively smoother than the non−fabricated TCO substrate, it was difficult for carbon derived from the pencil to stick on the TCO substrate. However, when compared with the fabricated ITO substrate with carbon from the burning of candle resulted in a significant difference. The efficiency of solar cell with carbon from burning of candle was 1.738%. This was due to the carbon derived from the burning of candle was more easily attached to the glass surface of the substrate. The results of the measurement of the electrical characteristics of the pulp extract as a dye sensitizer and the use of a handmade conductive transparent substrate on the dye sensitized solar cell are presented in Table 1.

Table 1 Electrical characteristics of Malabar melastome fruit extract as sensitizer

Solvent	Vol (mL)	P_{light} (lux)	V_{oc} (mV)	I_{sc} (mA)	P_{max} (mW)	FF	Eff. (%)
Methanol on TCO (non−fabricated)	0.100	98.40	271	0.032	2.532	0.290	0.673
	0.125	98.50	276	0.027	3.106	0.420	0.825
	0.150	32.50	401	0.023	0.535	0.580	0.431
Aquadest on TCO (non−fabricated)	0.100	104.10	259	0.032	2.781	0.336	0.699
	0.125	185.00	684	0.017	0.365	0.456	0.516
	0.150	107.00	227	0,038	4.039	0.457	0.987
ITO sigma−aldrich (carbon of pencil), aq	0.100	51.20	159	0.034	1.997	0.374	1.020
ITO sigma−aldrich (carbon of burning candle), aq	0.100	58.30	178	0.040	3.875	0.546	1.738

Note: aq = aqueous extract

CONCLUSION

Fruit extracts can be utilized as dye sensitizers to convert solar rays into electrical energy in dye sensitized solar cells. The active compound of anthocyanin is extracted more by using aqueous solvent (1.570%) than using methanol solvent (0.802%). The efficiency of solar cell using non−fabricated TCO substrate and fabricated ITO substrate with carbon pencil showed no significant difference, each with efficiency 0.987% and 1.020%, but on the fabricated ITO substrate with carbon from the burning of candle resulted in a relatively significant difference. The efficiency of solar cell from fabricated ITO substrate with carbon from the burning of candle was 1.738%. The characteristics of solar cell electricity using non−fabricated TCO substrate with 1.5 mL aquadest extraction on fruit as dye sensitizer for the V_{oc}, I_{sc}, FF and Efficiency were 227 mV, 0.038 mA, 0.457 and 0.987%, respectively.

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