Photoelectric Performance of Organic Dye Sensitized Solar Cell on Various Thicknesses of TiO_2 Paste

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Abstract: ***Dye sensitized solar cells (DSSCs) were fabricated with various thicknesses of TiO_2 paste using the aqueous extract of dragon fruit pulp as photosensitizer. The thickness of TiO_2 paste was based on number of layers (2, 3, 4 and 5 layers) of Scotch tape on the conductive substrate. The fabricated DSSC was placed at a distance of 10 cm from halogen light bulb (100 W), and the photoelectric performance of the DSSC was measured after 10 minutes of the exposure period. Results showed that the characteristics of solar cell by using aqueous extract of dragon fruit pulp with three layers of Scotch tape (0.372 mm) was found to produce the best electrical performance with V_{oc}, I_{sc}, FF and efficiency were 245mV; 0.0271mA; 0.1190; and 0.2182%, respectively. The efficiency increased with increasing thickness of TiO_2 paste to some extent.***

Keywords: DSSC, dragon fruit pulp, photoelectric

1. Introduction

Dye Sensitized Solar Cell (DSSC) is a solar cell technology capable of converting solar energy into electrical energy with the help of photosensitizer [1]. This type of solar cell is easy in its fabrication process, fast and the materials used are environmentally friendly [2]. Photosensitizer or dye on the DSSC structure serves as a light absorber. Dye as the photosensitizer can be obtained from organic or inorganic materials. The widely used inorganic dye is the ruthenium complex [3]. However, the availability of inorganic dye is very limited, expensive and toxic; therefore organic dye is preferable [4-5]. Organic dye is obtained from the extraction process of roots, leaves, flowers or fruits. Natural plant pigments that can be used as dye in DSSC include chlorophyll, carotene and anthocyanin [6].

One of fruits that contains substantial amount of anthocyanin is red dragon fruit (Hylocereus polyrhizus); its thick covering peel is approximately 40% of total fruit’s weight. The red dragon peel is considered as waste after being consumed. The red dragon fruit peel has bright red in color; therefore it is potential as anthocyanin source. There has been some research carried out on using dragon fruit as a photosensitizer. Ali and Nayan [7] used natural dye of red dragon fruit flesh, and Setiawan et al. [8] used different concentrations of ethanolic pulp extract from red dragon fruit as dye sensitizer on DSSC. Unlike others, the natural dye used in this research was the aqueous extract of red dragon fruit pulp as photosensitizer for DSSC.

Light that is absorbed by dye molecules and separated charge by inorganic semiconductor that has wide band gap, i.e.: Titanium oxide (TiO_2). The efficiency of DSSC is associated with the optical absorption of dye, as well as its absorbance on TiO_2. The TiO_2 on the transparent conductive oxide glass is expected to absorb substantial amount of dye. It is used to be only a layer of TiO_2 paste which its thickness is similar to the thickness of masking tape used on the DSSC. The thickness of TiO_2 paste layer is one of the factors that can affect the efficiency of solar cells [9]. A layer of TiO_2 paste is considered too thin for TiO_2 to absorb dye; on the other hand too thick of TiO_2 paste might increase the resistivity of DSSC.

The thickness of the TiO_2 paste can be determined by the method of deposition of the paste such as spin coating, spray coating and doctor blade [10]. The doctor blade method is the simplest method which the active area on DSSC is given a border using a masking tape to draw a barrier for deposition of TiO_2 paste. In addition, the masking tape is served to control the thickness of the TiO_2 paste. The masking tape could be applied in multi layers on DSSC to increase the amount of TiO_2 paste. The TiO_2 paste is filled inside the border line of masking tape. Therefore, this study performs the analysis of photoelectric performance of DSSC at various thickness of TiO_2 paste deposited on a conductive glass substrate by using aqueous extract of dragon fruit (Hylocereus polyrhizus) as photosensitizer.

2. Materials and Method

2.1 Preparation of dye from dragon fruit pulp

The pulp was scraped out from red dragon fruit peel and blended in a blender. The ratio of pulp and water in the blender was 1:5. The pulp juice was separated from the fiber by using a filter paper, and added with acetic acid 0.1N to reach pH 4. The extracted dye was stored in a dark glass container and stored in a refrigerator to be used as a photosensitizer on DSSC.

2.2. Preparation of a capacitive touch screen as a conductive substrate

A capacitive touch screen is a glass substrate coated with a transparent metal oxide. The Dimension of the capacitive touch screen was 25 mm × 25 mm × 1.113 mm. The resistivity of touch screen was in the ranges of 0.73 to 9.6kΩ. The touch screen was then set for the active area for depositioning TiO_2 paste by a Scotch tape on the three sides of the touch screen (1.5 mm on the left and right; 3 mm on top of the touch screen). The dark side of touch screen as shown in Figure 1 was for the Scotch tape.

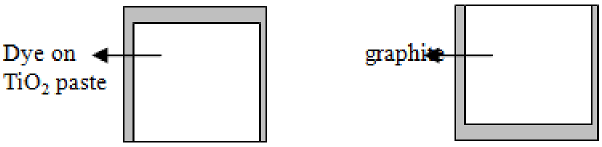

Figure 1: The active area for TiO_2 paste and graphite

There were 5 different layer of Scotch tape of the border line for deposition of TiO_2 paste i.e.: 2, 3, 4, and 5 layers. The thickness of a Scotch layer was 0.124 mm.

2.3 Preparation of TiO_2 paste and counter electrode

Titanium (IV) oxide (TiO_2) (Sigma Aldrich) was weigh as amount of 0.5 g and placed in a 100 mL beaker glass. Acetic acid 0.25 N solution as amount of 1 mL was added and mixed homogeneously. Counter electrode from a capacitive touch screen is made by shading the screen using a pencil 8B.

2.4 DSSC assembly

The touch screens that has been deposited with TiO_2 paste was soaked with dye for 2 hours, and then was placed in an oven at 105°C for 15 minutes. The touch screen with TiO2 paste was sandwiched with the counter electrode with an electrolyte solution (iodine) using a binder clip, as shown in Figure 2.

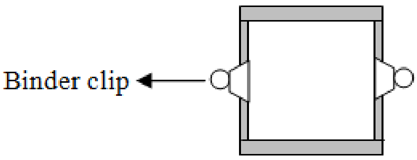

Figure 2: DSSC assembly

3. Characterization and Measurement

The absorption spectra of dye extracted from dragon fruit pulp 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).

$$FF = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{oc}} \quad (1)$$

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

4. Results and Discussion

4.1 absorption spectra of dye

Absorption spectra analysis provides information of the absorption transition between dye on the TiO_2 paste, excited state and the solar energy range absorbed by dye. The wavelength range will affect the type of light absorbed by dye. The wide range of wavelengths absorbed by the dye, the better of the dye is used as photosensitizer [11].

Titanium dioxide paste in the absence of dye can only absorb light in the short wavelength range from 350 to 380 nm [12]. Under these conditions, dye is needed to assist in increasing the wavelength range in absorbing solar energy precisely at the wider range of 400 to 700 nm [13].

The anthocyanin content in aqueous extract of red dragon fruit pulp was 1.535%. The anthocyanin content is higher than the anthocyanin content in the flowers of rose and Hibiscus rosa-sinensis extracts, but lower than that of in mangosteen and mangosteen peel [14-16]. Figure 3 shows the absorption spectrum of dye from red dragon fruit pulp.

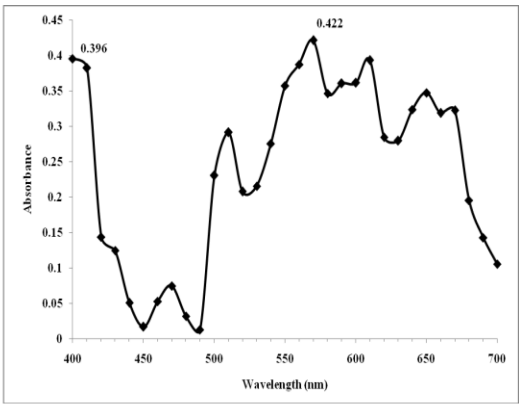

Figure 3: UV-Vis absorption spectrum of dye extracted from pulp of red dragon fruit peel

There was an increase of absorption spectrum in dye between the wavelength 520 nm to 570 nm, which indicated that there was an increase in dye capability in absorbing energy. The maximum absorbance peak of red dragon fruit dye extract was at the wavelength of 570 nm with a value of 0.422. The maximum absorbance of anthocyanin was in the wavelength ranges from 500 to 580 nm [16].

4.2 The electrical performance of the fabricated DSSC

The photovoltaic test on DSSCs using dye of dragon fruit peel pulp was performed by measuring the current-voltage (I-V) curves. The performance of dye was evaluated by open circuit voltage (V_{oc}), fill factor (FF) and energy conversion efficiency (η), as listed in Table 1.

Table 1: Photoelectrical performance of DSSC

	Thickness of TiO_2 paste based on number of Scotch tape applied on DSSC (layers)			
	2	3	4	5
V_{oc} (mV)	107	245	198	93.1
I_{sc} (mA)	0.0199	0.0271	0.0157	0.0112
V_{max} (mV)	58	37.1	78	34.6
I_{max} (mA)	0.0118	0.0213	0.0048	0.0062
FF	0.3214	0.1190	0.1204	0.2057
P_{max} (mW)	0.6844	0.7902	0.3744	0.2145

Note: 1 layer of Scotch tape = 0.124 mm

The electrical performance of DSSC with 3 layers of Scotch tape (0.372 mm in thickness) showed the best performance than others. It was indicated by the highest current, voltage and maximum power value compared to other thickness. The more layers of Scotch tape applied (>3 layers) resulted in lower current, voltage and power generated from DSSC. More layers would cause more TiO_2 in DSSC; therefore it would take longer time for the excited electrons traveled to anode electrode which was due to the thick TiO_2 paste [17]. In addition, a thick layer of TiO_2 paste would take a longer period for the TiO_2 paste to dry. Longer drying period would develop fissures in the TiO_2 paste and therefore it would inhibit the energy conversion process [18-19]. The typical I-V characteristics curve of DSSC with 2, 3, 4 and 5 layers of Scotch tape as shown in Figure 4 to 7.

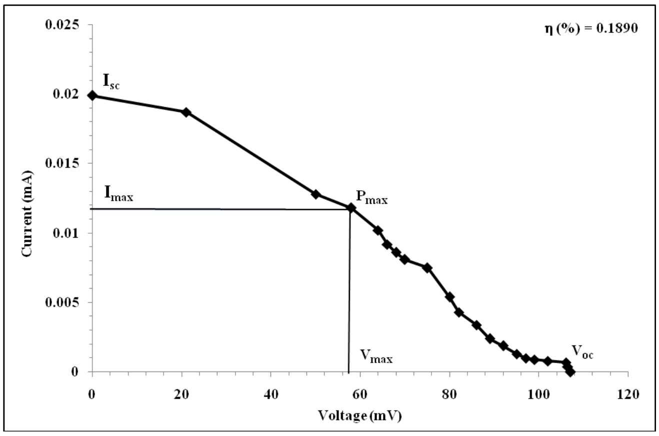

Figure 4: I-V characteristics curve (2 layers)

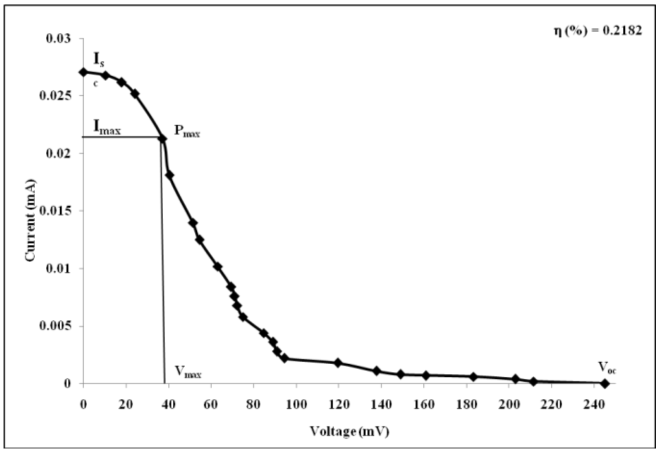

Figure 5: I-V characteristics curve (3 layers)

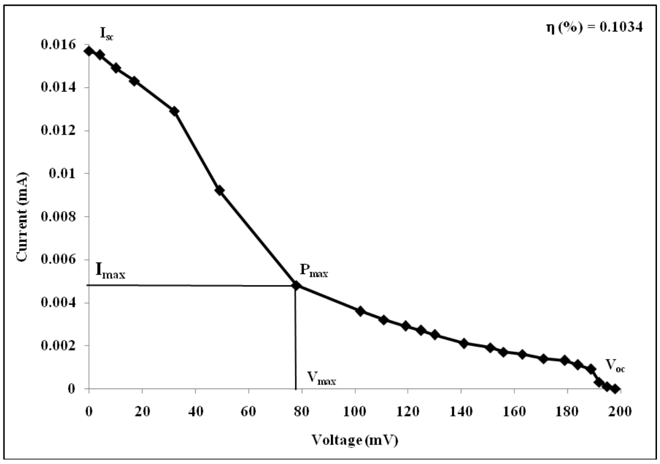

Figure 6: I-V characteristics curve (4 layers)

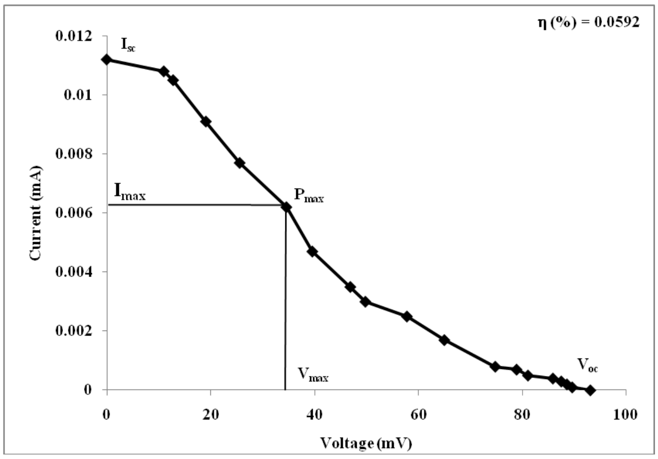

Figure 7: I-V characteristics curve (5 layers)

It is noteworthy that the efficiency (0.2182%) of DSSC with aqueous extract of dragon fruit pulp (3 layers) is closed to the efficiency (0.22%) obtained from DSSC with dye of ethanolic extract from dragon fruit flesh [7]. It indicated that dye in dragon fruit pulp is potential to be used as photosensitizer. This finding could be one of solution for the environmental issue resulted from agricultural waste. The aqueous extract of dragon fruit pulp showed better efficiency compared to ethanolic extract of dragon fruit pulp. The efficiency of the ethanolic extract (no dilution) was only 1.03×10^{-3} % [8]. It could be due to anthocyanin is more soluble in aqueous solution rather than in ethanol solution [20, 21]. In addition, the aqueous extract had better low cost of production compared to ethanolic extraction.

One of the weaknesses in DSSC is the poor stability; however increasing the thickness of TiO_2 paste could increase the stability due to more dye absorption into the paste. It was found that the dye inTiO_2 paste slowly faded during the exposure to the light source; therefore our future work will increase the anthocyanin concentration in the TiO_2 paste to increase the stability of solar cell in producing the electrical energy.

5. Conclusion

Increasing of the thickness of TiO_2 paste to some extent would increase the efficiency of the electrical performance of DSSC. The aqueous extract of dragon fruit pulp is potential to be used as a photosensitizer in the DSSC and its efficiency is 0.2182% at the thickness of TiO_2 paste of 0.372mm.

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