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Adsorption and Performance Study of Dye Sensitized Solar Cell Based Mangosteen Dye

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Abstract: In the solar cell system electricity did not be produced if there was no dye because there would be no electron flow in the conduction band, where the dye on the surface of the thin layer of TiO_2 acted as an electron injector in the conduction band. The number of dyes adsorbed on TiO_2 was influenced by several factors, including dye concentration, immersion time during the adsorption process, and thickness of the TiO_2 layer. The performance of DSSC was studied by measuring currents with voltage variations. The best conditions for the dye adsorption process of mangosteen peel extract on TiO_2 semiconductors were obtained at a concentration of 25%, immersion time of 120 minutes, and thickness of TiO_2 of 5 times of coating. The best efficiency was also obtained at a concentration of 25%, immersion time 120 minutes, and thickness of TiO_2 of 5 times coating.

Keywords: Solar Cell, Mangosteen Dye, Adsoption, Efficiency.

I. INTRODUCTION

Photovoltaic cells are a system that can convert solar energy into electrical energy. Photovoltaic cells generate electrical energy from direct sunlight through several stages of the energy conversion process. Photovoltaic cells are able to operate well in almost all parts of the sun's illuminated hemisphere without producing pollution that can damage the environment so that it is more environmentally friendly. Dyes Sensitized Solar Cells (DSSC) with the TiO_2 thin layer were first developed by Gratzel et al. (1991). This system is based on sensitization of TiO_2 semiconductors by dyes adsorbed on the surface of TiO_2.

Sunlight produces 5% of the spectra in the ultraviolet region and 45% in the visible light region. TiO_2 only absorbs ultraviolet light (350-380 nm). In order to increase the absorption of TiO_2 spectra in the visible light region, sensitizer is needed to absorb visible light on TiO_2. From a number of studies, it was known that the use of the ruthenium complex as a dye that functions as a photosensitizer produced high efficiency but it was not environmentally friendly [1]. The use of sensitisers in DSSC has changed from synthetic dyes to natural dyes because environmental reasons. Flavonoids such as anthocyanin ($C_{15}H_{12}O_6$) can be used as a sensory replacement for the ruthenium complex. The maximum uptake of anthocyanin extracts ranges from 510-548 nm depending on the fruit or solvent used.

Organic dyes may be bonded to solids through functional groups that bind to dyes. The carboxyl group is very effective for forming these bonds like phosphonate bonds. Hydroxyl and carbonyl groups in dyes can build coordination with atoms on the surface of solids. The mangosteen peel contains anthocyanin which belong to the class of flavonoid compounds [2]. Flavonoids are polyphenol compounds that have many OH groups so that they can be used to bond with TiO_2 effectively.

The adsorption process is strongly influenced by several variables such as the amount of adsorbent, the concentration of the adsorbate and the time of adsorption interaction. There are certain conditions of each variable to achieve optimum adsorption..

II. EXPERIMENTAL METHOD

The first step was to prepare TiO_2 thin layer on the glass substrate using slip casting technique with variations of thin layer coating as much as 1x, 3x, 5x, and 8x. Extraction of dyes from the mangosteen peel was carried out using ethanol solvent. The results of the extract were adsorbed on TiO_2 thin layers with variations in initial extract concentration in %, interaction time, and thin layer coating. The quantitative analysis process was carried out using a UV-Vis spectrophotometer.

Solar cells were made in a sandwich system, where working electrodes were made with thin layers of TiO_2 on a conductive glass substrate which had adsorbed dyes extracted from the mangosteen peel. The working electrode was made based on the process of optimization of dye adsorption on TiO_2 thin layers. The counter electrode was made by

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graphite on the conductive glass substrate, while the electrolyte solutions were made from potassium iodide and iodine in acetonitrile solvents.

The performance of DSSC was studied by measuring currents with voltage variations. The measurement circuit in the construction of a solar cell sandwich system was carried out using a power supply, a digital multimeter and a halogen lamp 50 Watt. In this measurement, the voltage entering the cell was varied and the current read on the amperemeters was recorded..

III. RESULT AND DISCUSSION

A. Adsorption of Mangosteen Dye in TiO_2 Layer

In the solar cell system, electricity would not be produced if there was no dye because there would be no electron flow in the conduction band, where the dye on the surface of the thin layer TiO_2 acted as an electron injector in the conduction band. The number of dyes adsorbed in the TiO_2 thin layer was influenced by several factors, including dye concentration, immersion time during the adsorption process, and thickness of the TiO_2 layer.

1) *Effect of Initial Extract Concentration to Adsorption of Sensitizer*

In this study the initial extract concentration variations were 5%, 10%, 15%, 20% and 25% with thin layers of 1x coating and 30 minutes of immersion time.

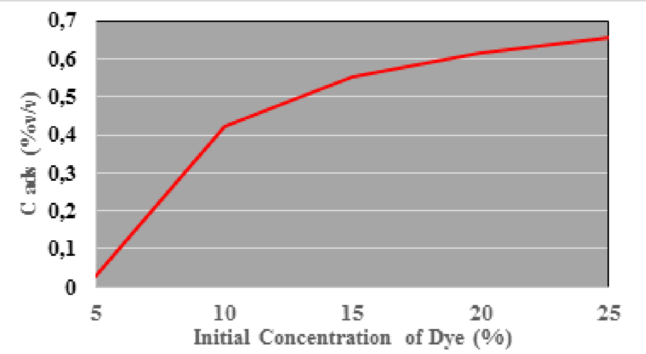

Fig 1. The Relationship of The Initial Extract Concentration of Mangosteen Peel To Adsorbed Concentration of Dye on TiO_2

From the figure 1. It could be seen that as the initial extract concentration of mangosteen peel increased, the dyed adsorbed on TiO_2 increased. But at the concentration of 5% mangosteen peel extract obtained the concentration of dye adsorbed 0.03% and experienced a significant increase in the concentration of 10% mangosteen peel extract with a value of 0.42%.

The anthocyanin adsorption on TiO_2 could occur as a result of the condensation process between alcoholic protons and OH found on the surface of TiO_2 so that it was likely that the group was used in forming bonds between dyes and TiO_2 [3]. The hydroxyl group (-OH) is an auxochrome group, where the auxochrome group was a group which when bound to a chromophore would cause changes in intensity and shift in electronic absorption. The dyes contained in the skin of the mangosteen fruit were a class of flavonoids that contain many hydroxyl groups [4]. With the increasing concentration of mangosteen peel extract, the hydroxyl group was increasing so that the formation of the bond between the dyes and TiO_2 gets stronger.

The initial concentration of the best mangosteen peel extract in this study was 25%. Where the greater the initial concentration of mangosteen peel extract, the more the concentration of the dye absorbed on TiO_2.

2) *Effect of Immersion time to Adsorption of Sensitizer*

In this study the immersion time variations were 30 minutes, 60 minutes, 90 minutes, 120 minutes and 150 minutes with a thin layer of 1x coating and the initial extract concentration of the mangosteen peel was 25%.

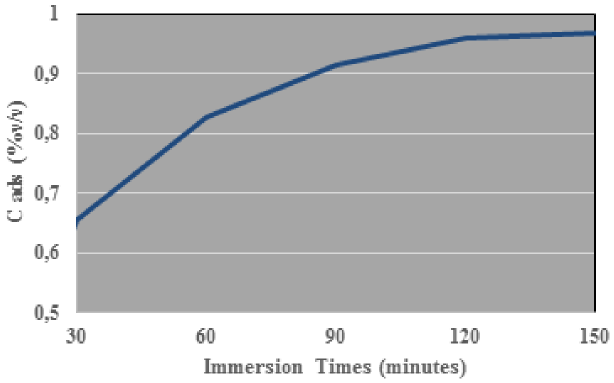

Fig 2. The Relationship of The Immersion Times of Mangosteen Peel To Adsorbed Concentration of Dye on TiO_2

In Figure 2 it could be seen that the longer the immersion time of TiO_2 in the dye solution, the concentration of the adsorbed dye in TiO_2 increased. But at 120 minutes - 150 minutes there was almost no increase, this was because equilibrium occured at 120 minutes.

3) *Effect of Electrode Thickness to Adsorption of Sensitizer*

In this study thickness variations were 1 x coating, 3 x coating, 5 x coating, and 8 x coating with the initial extract concentration of the mangosteen peel was 25% and immersion time was 120 minutes.

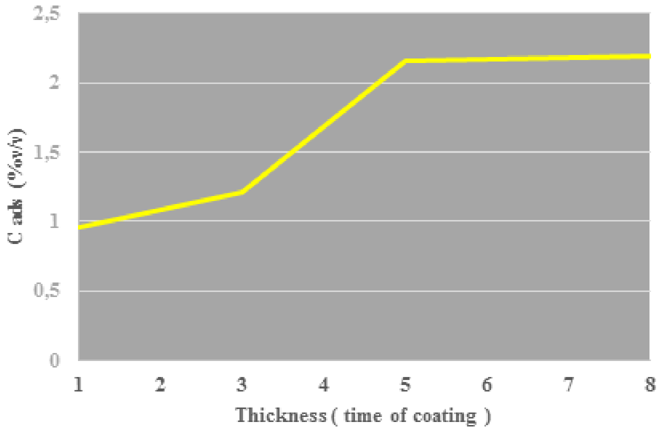

Fig 3. The Relationship of The Electrode Thickness To Adsorbed Concentration of Dye on TiO_2

In figure 3. it could be seen that the thicker the TiO_2 electrode, the more concentrated dyes absorbed. But the thickness of 8x coating did not increase compared to 5x coating, where thin layers with 8x coating had a denser pore structure. A more tight pore structure caused an increase in surface area not proportional to the increase in thin layer coating, so that adsorbed dyes did not increase significantly.

B. DSSC Performance

DSSC would be effective in generating electric current if there was visible light radiation whose energy was suitable to initiate electron injection through the process of electron transition from the base state to the excited state of the dye. The occurrence of electron injection into the TiO_2 semiconductor band was facilitated by the presence of dye bonds with TiO_2. Fermi level shifts under light irradiation were related to increasing stored free energy from injected electrons and producing voltage generation on external circuits [5].

1) *Effect of Initial Extract Concentration to DSSC Efficiency*

The effect of photosensitization was significantly affected by the concentration of the sensitizer which played an important role in the number of electrons transferred from excited to the semiconductor conduction band. The effect of photosensitization increased with increasing of concentrations of sensitizers.

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Table 1. DSSC Performance with Initial Concentration Variations

Initial Concetration (%)	**Isc**	**Voc**	**Imax**	**Vmax**	**FF**	**η**
5	0,71	0,147	0,58	0,1	55,6%	0,055%
10	0,91	0,14	0,6	0,1	47,1%	0,057%
15	0,74	0,14	0,6	0,1	57,9%	0,057%
20	0,7	0,14	0,6	0,1	61,2%	0,057%
25	0,84	0,14	0,61	0,1	51,8%	0,057%

From table 1. it could be seen that at the initial dyes concentration 10% DSSC efficiency increased compared to the initial concentration of 5% dyes. Anthocyanin molecules in the mangosteen peel dye had carbonyl and hydroxyl groups which were bound to the semiconductor surface of TiO_2, which helped in the excitation and transfer of electrons from anthocyanin molecules to the conduction band of TiO_2 which would make the bond between the dyes and TiO_2 be stronger [6]. Anthocyanin had the ability to be adsorbed on the surface of TiO_2, absorbing visible light. and injected electrons into semiconductor conductive bands [7]. So that with the increasing number of anthocyanin concentrations, the ability of DSSC in absorbing visible light was getting better.

The higher concentration may have caused the phenomenon of coloring aggregation. Aggregation of dyes, which caused energy transfer between molecules, was considered as one of the factors that reduce photovoltaic performance [8]. In our case, the aggregation of dye molecules did not at least increase the efficiency of the system where the initial concentration of dyes of 10 - 25% did not experience increased efficiency. The excessive concentration of dyes was not matched by the surface thickness of TiO_2 which was only 1 time coating. The excess sensitivity in the solution would be excited but could not be injected towards the photocatalyst conduction band [9].

2) *Effect of Immersion Time to DSSC Efficiency*

In this study, the value of Isc at 30 minutes of immersion time was 0.84 mA and tended to increase along with the immersion time of TiO_2 electrodes in the dye solution.

Table 2. DSSC Performance with Immersion Time Variations

Immersion Time (minutes)	Isc	Voc	Imax	Vmax	FF	η
30	0,84	0,14	0,61	0,1	51,8%	0,058%
60	0,77	0,144	0,64	0,1	57,7%	0,061%
90	0,86	0,148	0,74	0,1	58,1%	0,070%
120	1,24	0,156	0,78	0,1	40,3%	0,074%
150	1,26	0,156	0,8	0,1	40,7%	0,076%

In table 2, the longer immersion would increase the efficiency of DSSC. At the time of 30 minutes the efficiency of the DSSC produced was 0.058%, increasing at 60 minutes immersion by 0.061% and until finally increasing at 150 minutes immersion time by 0.076%. The longer the immersion time of TiO_2 in the dye, the more dye adsorbed to TiO_2 electrodes. The amount of light absorbed by the solution was proportional to the number of particles [10].

3) *Effect of Electrode Thickness to DSSC Efficiency*

Table 2. DSSC Performance with Immersion Time Variations

Times of Coating	Isc	Voc	Imax	Vmax	FF	η
1	1,24	0,156	0,78	0,1	40,3%	0,074%
3	1,21	0,23	0,8	0,115	33,1%	0,088%
5	1,29	0,23	0,82	0,18	49,7%	0,141%
8	1,34	0,23	0,87	0,114	32,1%	0,094%

In table 3, it could be seen that the thicker the electrode, the efficiency of DSSC increases. The thickness of electrode with the number of coatings is 8 times the efficiency of the DSSC had decreased. Non-uniform layer thickness would affect the inhibition of the electron discharge process. So that the resulting output voltage was not optimal. Too thick

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the coefficient of TiO_2 made it difficult to penetrate dye into TiO_2 in a deeper position and too thick of TiO_2 wiould block light towards the outermost TiO_2 particles [11].

IV. CONCLUSION

In this study, the greater the initial concentration, immersion time, and electrode thickness, the more adsorbed dyes on TiO_2. The greater the initial concentration, immersion time and electrode thickness, the greater the efficiency of DSSC. But on the thickness of the electrode with 8 coatings, the adsorbed dyes did not increase and even caused the efficiency of the DSSC to decrease. The best conditions for the dye adsorption process of mangosteen peel extract on TiO_2 semiconductors were obtained at a concentration of 25%, immersion time of 120 minutes, and thickness of TiO_2 of 5 times of coating. The best efficiency was also obtained at a concentration of 25%, immersion time 120 minutes, and thickness of TiO_2 of 5 times coating.

REFERENCES

[1]. Yusoff, A., Kumara, N.T.R.N., Lim, A., Ekanayake, P., and Tennakoon, K. U. Impacts of temperature on the stability of ropical plant pigments as sensitizers for dye sensitized solar cells. *Journal of Biophysics , Hindawi Publishing Corporation*, 2014.

[2]. Ratanamarno, S., Uthaibutra, J., dan Saengnil, K., Effects of Bagging and Storage Temperature on Anthocyanin Content and Phenylalanine Ammonialyase (PAL) Activity in Mangosteen (*Garcinia mangostana L.*) Fruit Pericarp During Maturation, *J. Sci. Technol*., 27, 711-717. 2005.

[3]. Polo, A.S., and Murakami Iha, N.Y., Clean and Renewable Energy From Dye-sensitized Solar Cell Using Fruits Extracts, *World Climate and Energy Event*, Rio de Janeiro. 2003.

[4]. Dai, Q. and Rabani, J.,Photosensitization of Nanocrystalline TiO_2 Films by Pomegranate Pigments with Unusually High Efficiency in Aqueous Medium, *Chem. Commun*., 1, 2142-2143. 2001.

[5]. Durrant J. R., Haque S. A. and Palomares E., ‘Photochemical energy conversion: from molecular dyads to solar cells’, *Chem. Comm*., 3279–3289, 2006.

[6]. Ludin, N. A., Mahmoud, A. A. A., Mohamad, A. B., Kadhum, A. A. H., Sopian, K., and Karim,N.S.A. Review on the development of natural dye photosensitizer for dye-sensitized solar cells. *Renewable and Sustainable Energy Reviews*, 31, 386-396. 2014.

[7]. F.Teoli, S.Lucioli, P.Nota, A.Frattarelli, F.Matteocci,A.Di Carlo, E.Caboni, and C.Forni, Role of pH and pigment concentration for natural dye-sensitized solar cells treated with anthocyanin extracts of common fruits, *Journal of Photochemistry and Photobiology A: Chemistry*. 2015.

[8]. Hara, K. and Arakawa, H. Dye-sensitized Solar Cells, In: Handbook of Photovoltaic Science and Engineering, A. Luque and S. Hegedus, (Ed.), Chapter 15, pp. 663-700, *John Wiley & Sons*, Ltd, ISBN: 0-471-49196-9. 2003.

[9]. Puangpetch, T., Sommakettarin, P., Chavadej, S., and Sreethawong, T. Hydrogen Production from Water Splitting over Eosin Y-Sensitized MesoporousAssembled Perovskite Titanate Nanocrystal Photocatalysts under Visible Light Irradiation, *International Journal of Hydrogen Energy*, 35, 12428–12442. 2010.

[10]. Hemalatha, K.V., Karthick, S.N., Raj, C. J., Hong, N.Y., Kim, S.-K., dan Kim, H.-J. Performance of Kerria Japonica and Rosa Chinensis Flower Dyes as Sensitizers for Dye-Sensitized Solar Cells, *ElsevierJournal of Ectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 96, 305–309. 2012.

[11]. Kumaraa, G.R.A., Kanekoa, S., Okuyaa, M., Agyeman, B.O., Konno, A., Tennakone, and K. Shiso. Leaf Pigments for Dye-Sensitized Solid-State Solar Cell, *Elsevier Journal of Solar Energy Materials and Solar Cells*, 90, 1220–1226. 2005.