Characterization of dye-sensitized solar cell (DSSC) with acid treatment by HNO3 in mangosteen peel dye

by Setia Budi Sasongko

Submission date: 27-Jul-2020 07:44AM (UTC+0700)

Submission ID: 1362505563

File name: 11_-_127_Yahya_ICSAS2019.pdf (359.95K)

Word count: 2803

Character count: 14753

Characterization of Dye-Sensitized Solar Cell (DSSC) With Acid Treatment by HNO_3 in Mangosteen Peel Dye

Agung Kurnia Yahya[1, a)] and Setia Budi Sasongko[1,b)]

[1]*Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, Jl. Prof Sudarto, Tembalang - Semarang, 50275, Indonesia*

[a)]Corresponding author : agungkurniayahya@gmail.com
[b)]another author : sbudisas@gmail.com

Abstract. The influences of acid treatment of dye sensitizer using HNO_3 on the characteristics of DSSC were investigated. The acid treatment using HNO_3 improved morphology of TiO_2, increased the amount of adsorbed dye molecules on TiO_2, and diffusion of redox electrolyte became easier. The values of Isc and Voc of DSSC increased with the addition of HNO_3 on dye sensitizers. They were caused by the charge collected by adsorption of anions on the surface of TiO_2. Without the addition of HNO_3 the efficiency produced is 0.141%. and with the addition of HNO_3 into the dye solution increased the efficiency by 0.201%

INTRODUCTION

The availability of fossil energy sources, especially petroleum, which is the main component of energy producers in Indonesia is decreasing along with increasing of industry development. One of the alternative energy that environment friendly and its abundant presence is solar energy, which will never run out of availability. The energy released by sunlight is actually only received by the earth's surface by 69% of the total radiant energy of the sun. The energy supply from sunlight received by the earth's surface was enormous, reaching 3 x 1024 joules per year, this energy is equivalent to 2 x 1017 Watts. The amount of energy is equivalent to 10,000 times the energy consumption in the world [1].

Dye-sensitized solar cells (DSSC) were third-generation solar cells developed in 1991 by Gratzel. DSSC was able to convert light energy into electricity using the principle of photoelectrochemistry [2]. The advantages of DSSC compared to other types were environment-friendly, low production costs, the amount of dye availability extensive, easy extraction, biodegradability, and no further purification process needed [3,4].

DSSC is composed of a transparent conducting substrate, mesoporous oxide semiconductor layers, dye sensitizers, electrolytes, and counter electrode [5]. The principle of DSSC operation starts with the absorption of photons by photosensitizer (S) which results in the excitation of photosensitizer (S*) and transfer electrons to the semiconductor conduction band by injection process. Photosensitizers that lose electrons are in the oxidized state (S^+). On the other side, oxidized dye is returned to the ground state by the mediator and electrolyte oxidation reaction occurs. Then the injected electrons flow through the semiconductor to the counter electrode and are received by the redox electrolyte mediator.

$$S + h\nu \rightarrow S^* \quad (1)$$

$$S^* \rightarrow S+ + e^- \quad (2)$$

$$S^+ + e^- \rightarrow S \quad (3)$$

$$S^+ + 3/2\ I^- \rightarrow S + ½\ I^{3-} \quad (4)$$

$$½\ I^{3-} + e^- \rightarrow ½\ I^- \quad (5)$$

Equation description:

(1) Excitation of dye during radiation
(2) Dye oxidation causes electron injection to TiO_2

(3) Dye is returned to the basic state by the mediator electrolyte
(4) Electrolyte oxidation reaction
(5) Electrolyte reduction reaction in the opponent's electrode

Some reactions that are not expected can cause a loss of DSSC efficiency. Among are caused by injected electron recombination on TiO_2 with photosensitizers oxidized or with oxidized redox pairs on the TiO_2 surface [6].

$$S+ + e^- \rightarrow S \qquad (6)$$
$$I^{3-} + 2e \rightarrow 3I^- \qquad (7)$$

Sensitizers are an important component in DSSC. In the application of DSSC, sensitizers are divided into three categories: natural organic dye, synthesis organic dye, and metal complex dye. In a previous study using metal dye complexes, the efficiency value was 15%, while organic dye and natural dye produced 9.5% and 0.70% efficiency respectively [7,8,9]. Some efforts were needed to improve the performance of DSSC including increasing dye stability with a long immersion method, dye purification [10], increasing the acidity of solvents [11], increasing extraction and use of various solvents [9], addition of acetic acid loading [12] and optimization of dye structures [3].

EXPERIMENTAL METHOD

Fabrication of Substrate Glass

20 gr $SnCl_2.2H_2O$ and 5 gr NH_4F were dissolved in 100 ml ethanol. Furnace was preheated to 200°C then the glass was put into furnace for 10 minutes. Then it was sprayed by a conductive solution. Repeated the steps for 4 times. After it, the temperature was raised to 400°C and the heating time was 60 minutes..

Coating of TiO_2 on Substrate Glass

TiO_2 paste made from 3.5 gr of TiO_2 powder was put into a glass beaker. Added 15 ml ethanol then stirred it for 10 minutes until homogeneous. TiO_2 paste was applied to the substrate glass. Then the substrate glass was inserted into the furnace for the sintering process. This process was carried out at 400°C for approximately 30 minutes.

Preparation of Dye

Mangosteen peel was smoothed using a blender to form a fine powder. The powder 25 gr was extracted using 100 ml of ethanol for 24 hours and stored in a dark place. The material is then filtered using filter paper.

Making Electrolytes

0.8 gr KI was dissolved in 10 ml of acetonitrile. Then 0.127 gr I_2 was added to the solution. The complete electrolyte solution is then stored in a bottle.

Dye Sensitization on TiO_2 Electrodes

The dye solution was placed in a vessel. Then HNO_3 was added to dye solution according to the variables (0%, 2%, and 5%). The glass oxide layer that had been sintered was dipped into the dye solution. The substrate glass was placed with the oxide layer facing up. Let soaked it in time according to 120 minutes. Then it was rinsed with distilled water, then was heated in an oven at ^{60oC} for 30 minutes to dry.

Characterization of Dye Sensitizer

UV-Vis spectrophotometry measurements were carried out to see the ability of light absorbance and peak absorption values of UV-Vis waves.

Characterization of DSSC

A DSSC prototype consists of two substrate glass. Namely a substrate glass that has been sensitized to dyes and substrate glass for the electrode counter. The DSSC assembly stages were as follows: Arranged the glass substrate to form a sandwich structure, gave an offset at the end of each electrode for electrical contact, pinched the edges of the DSSC cells that were not offset by clips so that the prototype is correctly attached, Added 2-3 drops of triiodide electrolyte solution from both ends of the DSSC prototype offset. Pinned the two edges of the DSSC cell that were not offset by clips so that the prototype was correctly attached.

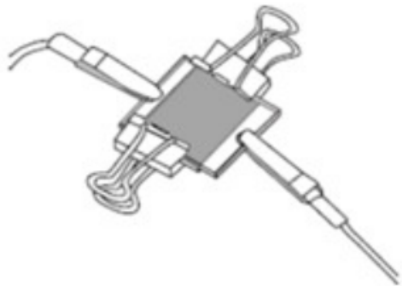


FIGURE 1. DSSC Structure

The DSSC layer formed is characterized by its current and voltage using a voltmeter (V) and an amperemeter (mA). The light source was directed perpendicular to the cell surface. Tests were carried out with halogen light sources.

RESULT AND DISCUSSION

Characterization of Dye Sensitizer of Mangosteen Peel

The study of dye absorption of mangosteen peel extract was carried out using UV-Vis spectrophotometry to see the ability of light absorbance and peak absorption values of UV-Vis waves.

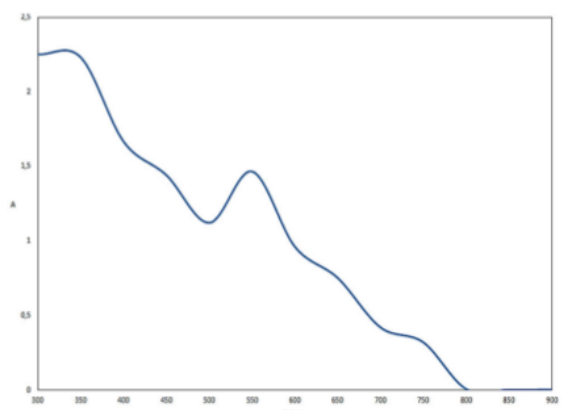
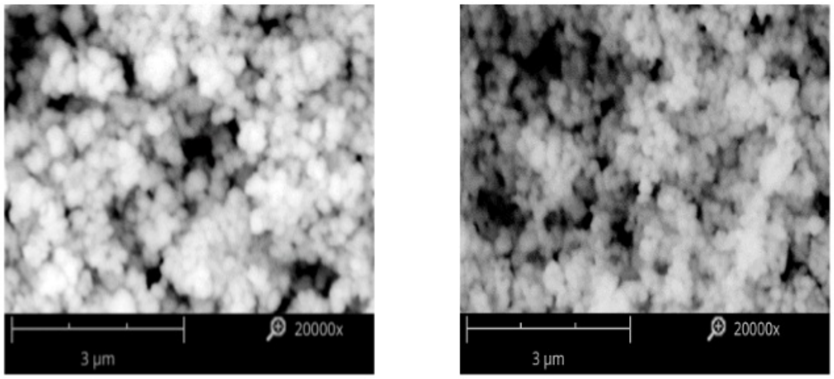


FIGURE 2. Absorbance of Mangosteen Peel Dye

From figure 2 , it can be seen that mangosteen peel extract has absorption peaks at a wavelength of 550 nm and has a wide enough absorption range. The absorption is quite extensive in the visible light region of mangosteen peel extract because it is possible in the extract not only to contain one type of dye but rather consist of several different dyes, so that the electronic absorption produced is the addition of various dyes [13].

Mangosteen peel extract is very potential as an effective sensator in solar cell systems because it has a wide range of electronic absorption so that the solar cells produced will have a spectral response with a wide enough range in the visible area.



(a) (b)

FIGURE 3. Morphology of TiO_2 After Immersion In Dye Solution. a) Soaked without the addition of HNO_3. b) Soaked with the addition of HNO_3.

Characteristics of TiO_2 Film

Analysis using scanning electron microscopy (SEM) was carried out to determine the morphology of TiO2 layers on glass substrates. TiO_2 films modified by HNO_3 showed larger pore size and higher porosity while TiO_2 films that were not treated showed greater particle aggregation [14]. That caused the amount of dye absorbed also increased and the redox electrolytes diffusion became easier. When compared between TiO_2 thin layers soaked in dyes solution with the addition of HNO_3 and without HNO_3 addition, the surface morphology of TiO_2 soaked with dyes by acid treatment showed a structure that formed a quite wide cavity resulting from the presence of HNO_3 absorbed in TiO_2.

From the figure 3, it can also be seen that the surface morphology of TiO_2 thin layer with acid treatment had a better cavity compared to the untreated TiO_2 thin layer so that the TiO_2 thin layer with acid treatment was more effective in adsorbing dyes, which later the dye could be reached by solution electrolytes so that the interaction between dye and electrolyte solutions became more effective. The existence of effective interactions between dyes and electrolytes could accelerate the process of regenerating dyes through the process of electron donation resulting from the oxidation of iodide to dyes that were positively charged because they had carried out electron injection.

Effect of HNO_3 Addition in Dye Sensitizer to Adsorption of Dye in TiO_2 Layer

In solar cell systems electricity will not be produced if there is no dye because there will be no electron flow in the conduction band, where the dye on the surface of the thin layer TiO_2 acts as an electron injector in the conduction band [15].

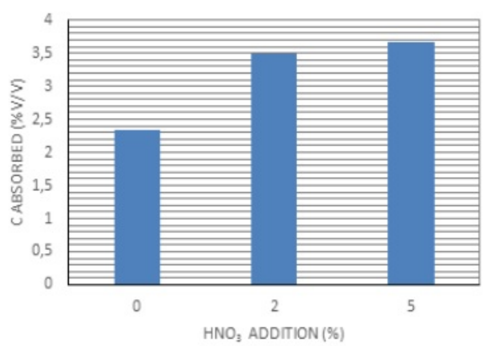


FIGURE 4. Results of Addition of HNO_3 to Adsorbed Concentration of Dye on TiO_2

In Figure 4, it can be seen that the addition of HNO_3 in the dye solution will cause the concentration of the adsorbed dye to increase. The addition of HNO_3 will cause the pH of the dyes solution to become more acidic. The addition of acids that had polar character resulted in a redshift in the peak of spectral absorption due to the interaction of the extreme groups of dye molecules with solvents and increased intensity of wave absorption [16].

The pH conditions greatly affect absorbance, in acidic conditions, anthocyanins are in the form of flavylium, which is able to coordinate more effectively with the Ti^{4+} site [17]. The adsorption power of a sensitizer is strongly influenced by surface charge. The surface charge of TiO_2 changes positively when it is acidic and is able to bind strongly to the negative molecule sensitizer, the surface charge of TiO_2 changes to negative under alkaline conditions and attracts positive sensitizer molecules [18]

The dye-immersed TiO_2 particles added HNO_3 cause the surface of TiO_2 to be positively charged, thus increasing particle dispersion due to electrostatic forces. TiO_2 films which were immersed with dyes plus HNO_3 showed higher porosity and larger pore size whereas TiO_2 films without HNO_3 showed more significant particle aggregation, so the number of absorbed dyes increased and diffusion of redox electrolyte became easier [14].

Effect of HNO3 Addition in Dye Sensitizer to Efficiency of Dye in TiO_2 Layer

From table 4.3 it can be seen that the increasing number of HNO_3 addition affects the performance of DSSC. Without the addition of HNO_3 the efficiency produced is 0.141%. After acid addition, using HNO_3 with the addition of 2% and 5% of HNO_3 into the dye solution increased the efficiency by 0.146% and 0.201%. In addition to increasing efficiency, adding acid in the dye solution used as a DSSC sensitizer will increase the value of Isc and Voc.

Table 1. Performance of DSSC with variations in the HNO_3 Addition

HNO_3 addition	0%	2%	5%
Isc (mA)	1,29	1,67	1,97
Voc (V)	0,23	0,29	0,3
Imax (mA)	0,87	1,18	1,51
Vmax (V)	0,18	0,13	0,14
% FF	49,7	31,6	35,7
% Efficiency	0,141	0,146	0,201

In solution, anthocyanins have 5 molecular types in chemical equilibrium:, color pseudo carbinol, red flavylium cations , purple quinoidal bases, yellow chalcone , and blue quinoidal anions [19], their stability and color are affected by pH of the dye solution. The more addition of HNO_3 resulted the dye solution was more acidic. According to Tedesse, et al, the flavylium cation was the dominant form at acid pH and it had a strong absorption. When the pH increased, the flavylium cation gradually changes to the quinoidal base by losing the proton [16].

The increase of Isc in the treatment of HNO_3 was caused by the charge collected by surface protonation of TiO_2, which was TiO_2 surface was more positively charged and attracted a negative charged of dye. It was also caused by electron transfer by adsorption of anions (NO^{3-}) on the surface of TiO_2. In the energy band theory, Voc is the maximum voltage generated by the difference between the quasi-fermi level of the TiO_2 and the redox electrolyte potential. The H^+ ions adsorption on the surface of TiO_2 caused the TiO_2 flat band potential may have shifted in a positive direction in the HNO_3 treatment of dye sensitizer [14].

CONCLUSIONS

The conclusion of this study was that the addition of HNO_3 would improve the morphology of TiO_2. TiO_2 films which were immersed with dyes added HNO_3 showed higher porosity and larger pore size while TiO_2 films without HNO_3 showed more significant particle aggregation, so the amount of absorbed dye increased and diffusion of redox electrolyte became easier. The addition of HNO_3 in a dye solution used as a DSSC sensitizer will increase the value of Isc, Voc, and efficiency of DSSC.

REFERENCES

[1] Gratzel, M. (2001) Photoelectrochemical Cells. Nature, 414, 338-344.

[2] Nazeeruddin, M.K., Baranoff, E., Gratzel, M., (2011) : Dye Sensitized Solar Cells: A Brief Overview, *Elsevier*

Journal of Solar Energy, 85, 1172-1178.
[3] Zhou, H., Wu, L., Gao, Y., dan Ma, T. (2011) : Dye Sensitized Solar Cells using 20 Natural Dyes as Sensitizers, *Elsevier Journal of Photochemistry and Photobiology A: Chemistry*, 219, 188–194.
[4] Singh R, Jadhav NA, Majumder S, Bhattacharya B, Singh PK.(2013). Novel biopolymer gel electrolyte for dye-sensitized solar cell application. *Carbohydr Polym*;91:682–5.
[5] Gong, J., Liang, J., dan Sumathy, K. (2012) : Review on dye-sensitized solar cells (DSSCs): Fundamental concepts andnovel materials, *Elsevier Journal of Renewable and Sustainable Energy Reviews,* **16**, 5848–5860.
[6] Kim, M.R., Park, S.H., Kim, J.Udan Lee, J.K. (2011) : Dye-Sensitized Solar Cells Based on Polymer Electrolytes, 223-225 *in* Kosyachenko, L.A., Eds, *Solar Cells - Dye-Sensitized Devices*, 492 p., InTech, Croatia.
[7] Lee, J.K., dan Yang, M., (2011) : Review Progress in Light Harvesting and Charge Injection of Dye Sensitized Solar Cells, *Elsevier Journal of Materials Science and Engineering B*, **176**, 1142-1160.
[8] Ooyama, Y.,dan Harima, Y. (2009) : Molecular Designs and Syntheses of Organic Dyes for Dye-Sensitized Solar Cells, *Willey Journal of Organic Chemistry,* 2903–2934.
[9] Wongcharee, K., Meeyooa, V., dan Chavadej, S. (2007) : Dye-Sensitized Solar Cell Using Natural Dyes Extracted from Rosella and Blue Pea flowers, *Elsevier Journal of Solar Energy Materials and Solar Cells*, **91**, 566–571.
[10] Lai, W.H., Sub, Y.H., Teoh, L.G., dan Hon, M.H. (2007) : Commercial and Natural Dyes as Photosensitizers for a Water-Based Dye Sensitized Solar Cell Loaded with Gold Nanoparticles, *Elsevier Journal of Photochemistry and Photobiology A: Chemistry*, **195**, 307–313.
[11] Senthil, T.S., Muthukumarasamy, N., Velauthapillai, D., Agilan, S., Thambidurai, M., dan Balasundaraprabhu, R. (2011) : Natural Dye (Cyanidin 3-O-Glucoside) Sensitized Nanocrystalline TiO_2 Solar Cell Fabricated Using Liquid Electrolyte/Quasi-Solid-State Polymer Electrolyte, *Elsevier Journal of Renewable Energy*, **36**, 2484-2488.
[12] Kumara, G.R.A., Kanekoa, S., Okuyaa, M., Agyeman, B.O., Konno, A., Tennakone, K. (2005): Shiso Leaf Pigments for Dye-Sensitized Solid State Solar Cell, *Elsevier Journal of Solar Energy Materials and Solar Cells*, **90**, 1220–1226.
[13] Dai, Q., Rabani, J., 2001, Photosensitization of NanocrystallineTiO_2 Films by Pomegranate Pigments with Unusually High Efficiency in Aqueous Medium, *Chem. Commun*., 1, 2142-2143.
[14] Park, K.H., Jin, E.M, Gu, H.M., Shim, S.E., Hong, C.K., (2009): Effects of HNO3 treatment of TiO_2 nanoparticles on the photovoltaic properties of dye-sensitized solar cells, *Elsevier Journal of Solar Materials Letter***.** **63**, 2208-2211.
[15] Smestad, G.P., 1998, Education and solar conversion : Demonstrating electron transfer, *Sol. Energy Mater. Sol. Cells,* 55, 157-178.
[16] Tadesse, S., Abebe, A., Chebude, Y.,Garcia, I.V., dan Yohannes, T. (2012) : Natural Dye Sensitized Solar Cells Using Pigments Extracted from Syzygium Guineense, *Journal of Photonics for Energy*, **2**, 1-10.
[17] F. Teoli S. Lucioli P. Nota A. Frattarelli F. Matteocci A. Di Carlo E. Caboni C. Forni. (2016): 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*.
[18] Luo, P., Niu, H., Zheng, G., Bai, X., Zhang, M., dan Wang, W. (2009) : From Salmon Pink to Blue Natural Sensitizers for Solar Cells: Canna indica L., Salvia splendens, Cowberry and Solanum nigrum L, *Elsevier Journal of Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 1-22.
[19] Dangles, O., Saito, N., Broullard, R. (1993): Anthocyanin intramolecular copigment effect. *Elsevier journal : Photochemistry*.

Characterization of dye-sensitized solar cell (DSSC) with acid treatment by HNO3 in mangosteen peel dye

ORIGINALITY REPORT

14%	7%	10%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Sebelas Maret Student Paper	1%
2	Park, K.H.. "Effects of HNO"3 treatment of TiO"2 nanoparticles on the photovoltaic properties of dye-sensitized solar cells", Materials Letters, 20091031 Publication	1%
3	aip.scitation.org Internet Source	1%
4	www.exxonenergy.com Internet Source	1%
5	Chiang-Yu Chien, Ban-Dar Hsu. "Optimization of the dye-sensitized solar cell with anthocyanin as photosensitizer", Solar Energy, 2013 Publication	1%
6	S. Silviana, H. Hadiyanto. "Preparation of sago starch-based biocomposite reinforced microfibrillated cellulose of bamboo assisted by mechanical treatment", AIP Publishing, 2017	1%

Publication

7	Submitted to Universiti Teknologi MARA Student Paper	1%
8	docplayer.fi Internet Source	1%
9	www.tnuniv.ac.in Internet Source	1%
10	A H Ahliha, F Nurosyid, A Supriyanto, T Kusumaningsih. " Optical properties of anthocyanin dyes on TiO as photosensitizers for application of dye-sensitized solar cell (DSSC) ", IOP Conference Series: Materials Science and Engineering, 2018 Publication	1%
11	Wang, Xiaoyi, Dainan Zhang, Jie Li, Zhiyong Zhong, Lijun Jia, Tianlong Wen, Huaiwu Zhang, and Yulong Liao. "A novel sol-gel method for preparing favorable TiO2 thin film", Materials Research Express, 2016. Publication	<1%
12	Submitted to University College London Student Paper	<1%
13	link.springer.com Internet Source	<1%
14	Supawadee Namuangruk, Jittima Meeprasert,	<1%

Siriporn Jungsuttiwong, Vinich Promarak, Nawee Kungwan. "Organic sensitizers with modified di(thiophen-2-yl)phenylamine donor units for dye-sensitized solar cells: a computational study", Theoretical Chemistry Accounts, 2014

Publication

15 Shahid, Mohammad, Shahid-ul-Islam, and Faqeer Mohammad. "Recent advancements in natural dye applications: a review", Journal of Cleaner Production, 2013. <1%

Publication

16 Submitted to University of Northumbria at Newcastle <1%

Student Paper

17 studentsrepo.um.edu.my <1%

Internet Source

18 pubs.rsc.org <1%

Internet Source

19 Submitted to Cranfield University <1%

Student Paper

20 Desi Heltina, Adel Fisli, Praswasti PDK Wulan, Slamet. "The Influence Surface Modification of CNT Using Surfactant to Formation of Composite", Journal of Physics: Conference Series, 2019 <1%

Publication

21	Submitted to Universiti Malaysia Sabah Student Paper	<1%
22	Hernández-Martínez, Angel, Miriam Estévez, Susana Vargas, and Rogelio Rodríguez. "Stabilized Conversion Efficiency and Dye-Sensitized Solar Cells from Beta vulgaris Pigment", International Journal of Molecular Sciences, 2013. Publication	<1%
23	Masato Ohmukai, Jun Kyokane. "Acetylacetone-Based Electrolyte in Dye Sensitized Solar Cell", World Journal of Engineering and Technology, 2017 Publication	<1%
24	Neha Patni, Pranjal Sharma, Shibu G. Pillai. "Newer approach of using alternatives to (Indium doped) metal electrodes, dyes and electrolytes in dye sensitized solar cell", Materials Research Express, 2018 Publication	<1%
25	Submitted to University of Bath Student Paper	<1%
26	Submitted to Institute of Graduate Studies, UiTM Student Paper	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

Characterization of dye-sensitized solar cell (DSSC) with acid treatment by HNO3 in mangosteen peel dye

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6