OPTIMASI KINERJA *DYE-SENSITIZED SOLAR CELL* DENGAN MENGGUNAKAN KOMBINASI *NATURAL DYE* SEBAGAI FOTOSENSITIZER

SKRIPSI

Diajukan untuk memenuhi salah satu syarat untuk memperoleh gelar Sarjana Sains Departemen Pendidikan Fisika Program Studi Fisika Konsentrasi Fisika Material

Oleh

Prima Fitri Rusliani

1800920

PROGRAM STUDI FISIKA
DEPARTEMEN PENDIDIKAN FISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA
BANDUNG

2022

OPTIMASI KINERJA *DYE-SENSITIZED SOLAR CELL* DENGAN MENGGUNAKAN KOMBINASI *NATURAL DYE* SEBAGAI FOTOSENSITIZER

Oleh

Prima Fitri Rusliani

Diajukan untuk memenuhi sebagian syarat dalam memperoleh gelar Sarjana Sains

Program Studi Fisika Departemen Pendidikan Fisika

Konsentrasi Fisika Material

FPMIPA UPI

LEMBAR PENGESAHAN

PRIMA FITRI RUSLIANI

OPTIMASI KINERJA *DYE-SENSITIZED SOLAR CELL* DENGAN MENGGUNAKAN KOMBINASI *NATURAL DYE* SEBAGAI FOTOSENSITIZER

Disetujui dan disahkan oleh:

Pembimbing I

Dr. Endi Suhendi, M.Si.
NIP. 197905012003121001

Pembimbing II

Dr. Eka Cahya Prima, S.Pd., M.T.
NIP. 199006262014041001

Mengetahui,
Ketua Program Studi Fisika

Dr. Endi Suhendi, M.Si.
NIP. 197905012003121001

ABSTRAK

OPTIMASI KINERJA *DYE-SENSITIZED SOLAR CELL* DENGAN MENGGUNAKAN KOMBINASI *NATURAL DYE* SEBAGAI FOTOSENSITIZER

oleh

Prima Fitri Rusliani

NIM 1800920

(Program Studi Fisika)

Dye-sensitized Solar Cell (DSSC) memanfaatkan proses fotoelektrokimia untuk mengubah energi foton menjadi energi listrik sebagai alternatif energi terbarukan yang ramah lingkungan dengan menggunakan *natural dye* sebagai fotosensitizer. Namun, kinerja piranti yang dihasilkan masih jauh lebih rendah dari *dye* sintetis. Penelitian ini difokuskan pada penentuan sifat optik dan sifat listrik kombinasi *natural dye* dari pigmen kurkuminoid (*Curcuma longa*), klorofil (*Justicia gendarussa*), dan antosianin (*Clitoria ternatea*), serta pengaruh kombinasi *dye* pada kinerja DSSC. Karakterisasi sifat optik diperoleh dari hasil karakterisasi absorbansi dan LHE menggunakan *UV-Vis Spectrophotometer*, sifat listrik diperoleh dari potensial redoks menggunakan *Cyclic Voltammetry*, sedangkan pengaruh kombinasi terhadap kinerja DSSC ditentukan oleh kelistrikan piranti DSSC yang meliputi J_{sc}, V_{oc}, *FF*, serta efisiensi menggunakan *Standard Solar Simulator AM 1.5 filter 100 mW/cm*^{2}. Hasil yang diperoleh yaitu spektrum absorbansi dan LHE kombinasi *dye* lebih luas dari *dye* tunggal. Sedangkan potensial redoks dye menghasilkan energi celah (HOMO/LUMO) yang tidak berbeda karena kesamaan pelarut yang digunakan untuk mengekstrak pigmen sekitar 1.76 - 1.79 eV. Sampel terbaik dicapai oleh kombinasi tiga pigmen, Kuning-Hijau-Biru, yang memiliki densitas arus *short-circuit* (J_{sc}) 32.5 mA/cm^2, tegangan *open-circuit* (V_{oc}) 0.94 V, FF 31.2%, dan efisiensi sebesar 9.54%. *Sehingga, kinerja DSSC tidak hanya disebabkan oleh banyaknya energi foton yang terabsorpsi dan teradsorpsi pada permukaan TiO_2 dan laju difusi elektron yang berlangsung secara cepat karena LHE yang besar dan energi celah yang sempit. Namun, dipengaruhi pula oleh* jarak antar potensial reduksi-oksidasi, pita konduksi TiO_2, elektrolit, serta komponen lain yang digunakan. *Oleh karena itu, kombinasi dari natural dye dapat meningkatkan kinerja DSSC secara optimal.*

Kata Kunci: dye-sensitized solar cell, kombinasi dye, fotosensitizer.

ABSTRACT

PERFORMANCE OPTIMIZATION OF DYE-SENSITIZED SOLAR CELL USING COMBINATION OF NATURAL DYES AS PHOTOSENSITIZER

by

Prima Fitri Rusliani

NIM 1800920

(Physics Study Program)

Dye-sensitized Solar Cell (DSSC) utilizes a photoelectrochemical process to convert photon energy into electrical energy as an environmentally friendly renewable energy alternative using natural dye as a photosensitizer. However, the performance of the resulting device is still much lower than that of synthetic dyes. This study focused on determining the optical and electrical properties of the natural dye combination of curcuminoid pigments (Curcuma longa), chlorophyll (Justicia gendarussa), and anthocyanins (Clitoria ternatea), as well as the effect of dye combination on DSSC performance. Characterization of optical properties was obtained from the results of absorbance and LHE characterization using UV-Vis Spectrophotometer, electrical properties were obtained from redox potential using Cyclic Voltammetry, while the effect of the combination on DSSC performance was determined by the electricity of the DSSC device which includes J_{sc}, V_{oc}, FF, and efficiency using Standard Solar Simulator AM 1.5 filter 100 mW/cm^2. The results obtained are the absorbance spectrum and the LHE of the dye combination are wider than the single dye. Meanwhile, the redox potential of the dye produces a gap energy (HOMO/LUMO) which is not different due to the similarity of the solvent used to extract the pigment around 1.76 - 1.79 eV. The best sample was achieved by a combination of three pigments, Kuning-Hijau-Biru, which has a short-circuit current density (J_{sc}) 32.5 mA/cm^2, open-circuit voltage (V_{oc}) 0.94 V, FF 31.2%, and an efficiency of 9.54%. Thus, the performance of DSSC is not only due to the large amount of photon energy absorbed and adsorbed on the TiO_2 surface and the fast electron diffusion rate due to the large LHE and narrow gap energy. However, it is also influenced by the distance between the oxidation-reduction potential, the TiO_2 conduction band, the electrolyte, and other components used. Therefore, the combination of natural dye can improve the performance of DSSC optimally.

Keywords: dye-sensitized solar cell, dye combination, photosensitier.

DAFTAR ISI

DAFTAR PUSTAKA

Abd El-Kodous, Mohamed. (2018). *C-Dots Dispesed Macromesoporous TiO2 Nanospheres as An Efficient Photocatalyst for Waste-Water Treatment* (Nomor May). https://doi.org/10.13140/RG.2.2.25280.38404

Abdel-Hafez, Salma M., Hathout, Rania M., & Sammour, Omaima A. (2021). Attempts to enhance the anti-cancer activity of curcumin as a magical oncological agent using transdermal delivery. *Advances in Traditional Medicine*, *21*(1), 15–29. https://doi.org/10.1007/s13596-020-00439-5

Abdel-Latif, Monzir S., Abuiriban, Mahmoud B., El-Agez, Taher M., & Taya, Sofyan A. (2015). Dye-sensitized solar cells using dyes extracted from flowers, leaves, parks, and roots of three trees. *International Journal of Renewable Energy Research*, *5*(1), 294–298. https://doi.org/10.20508/ijrer.13167

Abduljalil, Hayder M., Muhsen, Musa K., & Madlool, Hussein A. (2018). *Theoretical Study of the Electronic Properties of the Curcumin Molecule : Using Density Functional Theory*. *5*, 48–58.

Adedokun, Oluwaseun, Titilope, Kamil, & Awodugba, Ayodeji Oladiran. (2016). Review on Natural Dye-Sensitized Solar Cells (DSSCs). *International Journal of Engineering Technologies, IJET*, *2*(2), 34. https://doi.org/10.19072/ijet.96456

Agrawal, Saurabh, Dev, Pratibha, English, Niall J., Thampi, K. Ravindranathan, & MacElroy, J. M. D. (2011). First-principles study of the excited-state properties of coumarin-derived dyes in dye-sensitized solar cells. *Journal of Materials Chemistry*, *21*(30), 11101–11108. https://doi.org/10.1039/c1jm10953g

Al-Ghamdi, Ahmed A., Gupta, R. K., Kahol, P. K., Wageh, S., Al-Turki, Y. A., El Shirbeeny, W., & Yakuphanoglu, F. (2014). Improved solar efficiency by introducing graphene oxide in purple cabbage dye sensitized TiO2 based solar cell. *Solid State Communications*, *183*, 56–59.

https://doi.org/10.1016/j.ssc.2013.12.021

Al Qibtiya, Mariya, Prima, Eka Cahya, Yuliarto, Brian, & Suyatman. (2016a). pH influences on optical absorption of anthocyanin from black rice as sensitizer for dye sensitized solar cell TiO2 nanoparticles. *Materials Science Forum*, *864*, 154–158. https://doi.org/10.4028/www.scientific.net/MSF.864.154

Al Qibtiya, Mariya, Prima, Eka Cahya, Yuliarto, Brian, & Suyatman. (2016b). pH influences on optical absorption of anthocyanin from black rice as sensitizer for dye sensitized solar cell TiO2 nanoparticles. *Materials Science Forum*, *864*(August), 154–158. https://doi.org/10.4028/www.scientific.net/MSF.864.154

Anoua, Rania, Lifi, Houda, Touhtouh, Samira, El Jouad, Mohamed, Hajjaji, Abdelowahed, Bakasse, Mina, Płociennik, Przemysław, & Zawadzka, Anna. (2021). Optical and morphological properties of Curcuma longa dye for dye-sensitized solar cells. *Environmental Science and Pollution Research*, *28*(41), 57860–57871. https://doi.org/10.1007/s11356-021-14551-9

Arifin, Zainal, Soeparman, Sudjito, Widhiyanuriyawan, Denny, Suyitno, & Setyaji, Argatya Tara. (2018). Improving stability of chlorophyll as natural dye for dye-sensitized solar cells. *Jurnal Teknologi*, *80*(1), 27–33. https://doi.org/10.11113/jt.v80.10258

Bahtiar, Hafidz, Wibowo, Nur Aji, & Rondonuwu, Ferdy Semuel. (2015). Konstruksi Sel Surya Bio menggunakan Campuran Klorofil-Karotenoid sebagai Sensitizer. *Jurnal Fisika dan Aplikasinya*, *11*(1), 19. https://doi.org/10.12962/j24604682.v11i1.780

Bai, Yu, Cao, Yiming, Zhang, Jing, Wang, Mingkui, Li, Renzhi, Wang, Peng, Zakeeruddin, Shaik M., & Grätzel, Michael. (2008). High-performance dye-sensitized solar cells based on solvent-free electrolytes produced from eutectic melts. *Nature Materials*, *7*(8), 626–630. https://doi.org/10.1038/nmat2224

Bai, Yu, Mora-Seró, Iván, De Angelis, Filippo, Bisquert, Juan, & Wang, Peng. (2014). Titanium dioxide nanomaterials for photovoltaic applications. *Chemical Reviews*, *114*(19), 10095–10130. https://doi.org/10.1021/cr400606n

Brédas, J. L., Silbey, R., Boudreaux, D. S., & Chance, R. R. (1983). Chain-Length Dependence of Electronic and Electrochemical Properties of Conjugated Systems: Polyacetylene, Polyphenylene, Polythiophene, and Polypyrrole. *Journal of the American Chemical Society*, *105*(22), 6555–6559. https://doi.org/10.1021/ja00360a004

Cacace, J. E., & Mazza, G. (2003). Mass transfer process during extraction of phenolic compounds from milled berries. *Journal of Food Engineering*, *59*(4), 379–389. https://doi.org/10.1016/S0260-8774(02)00497-1

Cahyono, Bambang, Huda, Muhammad Diah Khoirul, & Limantara, Leenawaty. (2011). Pengaruh Proses Pengeringan Rimpang Temulawak (Curcuma xanthorriza ROCB) terhadap Kandungan dan Komposisi Kurkuminoid. *Reaktor*, *13*(3), 165. https://doi.org/10.14710/reaktor.13.3.165-171

Calogero, Giuseppe, Bartolotta, Antonino, Di Marco, Gaetano, Di Carlo, Aldo, & Bonaccorso, Francesco. (2015). Vegetable-based dye-sensitized solar cells. *Chemical Society Reviews*, *44*(10), 3244–3294. https://doi.org/10.1039/c4cs00309h

Calogero, Giuseppe, Sinopoli, Alessandro, Citro, Ilaria, Di Marco, Gaetano, Petrov, Vesselin, Diniz, Ana M., Parola, A. Jorge, & Pina, Fernando. (2013). Synthetic analogues of anthocyanins as sensitizers for dye-sensitized solar cells. *Photochemical and Photobiological Sciences*, *12*(5), 883–894. https://doi.org/10.1039/c3pp25347c

Cari, C., Khairuddin, K., Septiawan, T. Y., Suciatmoko, P. M., Kurniawan, D., & Supriyanto, A. (2018). The preparation of natural dye for dye-sensitized solar cell (DSSC). *AIP Conference Proceedings*, *2014*(September). https://doi.org/10.1063/1.5054510

Cho, Kun Ching, Chang, Ho, Chen, Chih Hao, Kao, Mu Jung, & Lai, Xuan Rong. (2014). A study of mixed vegetable dyes with different extraction concentrations for use as a sensitizer for dye-sensitized solar cells. *International Journal of Photoenergy*, *2014*. https://doi.org/10.1155/2014/492747

Cisse, Mady, Vaillant, Fabrice, Kane, Ale, Ndiaye, Oumoule, & Dornier, Manuel. (2012). Impact of the extraction procedure on the kinetics of anthocyanin and colour degradation of roselle extracts during storage. *Journal of the Science of Food and Agriculture*, *92*(6), 1214–1221. https://doi.org/10.1002/jsfa.4685

Dahlan, Dahyunir, Leng, Tjiauw Siaw, & Aziz, Hermansyah. (2016). Dye Sensitized Solar Cells (DSSC) dengan Sensitiser Dye Alami Daun Pandan, Akar Kunyit dan Biji Beras Merah (Black Rice). *Jurnal Ilmu Fisika | Universitas Andalas*, *8*(1), 1–8. https://doi.org/10.25077/jif.8.1.1-8.2016

Darwis, Darmawati, & Amrullah, Satrio. (2020). *Original article Dye-sensitized Solar Cells Fabricated Using Natural Dyes from Indonesian Plant as Sensitizers*. *09*(03), 63–66. https://doi.org/10.22487/25411969.2020.v9.i3.15369

Devadiga, Dheeraj, Selvakumar, M., Shetty, Prakasha, & Santosh, M. S. (2021). Recent progress in dye sensitized solar cell materials and photo-supercapacitors: A review. *Journal of Power Sources*, *493*(February), 229698. https://doi.org/10.1016/j.jpowsour.2021.229698

Erande, K. B., Hawaldar, P. Y., Suryawanshi, S. R., Babar, B. M., Mohite, A. A., Shelke, H. D., Nipane, S. V., & Pawar, U. T. (2020). Extraction of natural dye (specifically anthocyanin) from pomegranate fruit source and their subsequent use in dssc. *Materials Today: Proceedings*, *43*(xxxx), 2716–2720. https://doi.org/10.1016/j.matpr.2020.06.357

Ezike, Sabastine C., Hyelnasinyi, Clement N., Salawu, Mufutau A., Wansah, John F., Ossai, Amarachukwu N., & Agu, Nnabuike N. (2021). Synergestic effect of chlorophyll and anthocyanin Co-sensitizers in TiO2-based dye-sensitized solar cells. *Surfaces and Interfaces*, *22*, 100882. https://doi.org/10.1016/j.surfin.2020.100882

Fukui, Kenichi, Yonezawa, Teijiro, & Shingu, Haruo. (1952). A molecular orbital theory of reactivity in aromatic hydrocarbons. *The Journal of Chemical Physics*, *20*(4), 722–725. https://doi.org/10.1063/1.1700523

Gaal, Dennis A., McGarrah, James E., Liu, Fang, Cook, Jamie E., & Hupp, Joseph

T. (2004). Nonadiabatic electron transfer at the nanoscale tin-oxide semiconductor/aqueous solution interface. *Photochemical and Photobiological Sciences*, *3*(3), 240–245. https://doi.org/10.1039/b313694a

Ganta, D., Combrink, K., & Villanueva, R. (2019). Natural Dye-Sensitized Solar Cells: Fabrication, Characterization, and Challenges. *Energy, Environment, and Sustainability*, 129–155. https://doi.org/10.1007/978-981-13-3302-6_5

Gareso, Paulus Lobo, & Juarlin, Eko. (n.d.). Karakterisasi Lapisan Tipis TiO2 : Fe dengan Metode Spin-Coating. *Universitas Hasanuddin*, 2–4.

Ghann, William, Kang, Hyeonggon, Sheikh, Tajbik, Yadav, Sunil, Chavez-Gil, Tulio, Nesbitt, Fred, & Uddin, Jamal. (2017). Fabrication, Optimization and Characterization of Natural Dye Sensitized Solar Cell. *Scientific Reports*, *7*(January), 1–12. https://doi.org/10.1038/srep41470

Giuliani, A., Cerretani, L., & Cichelli, A. (2015). Colors: Properties and Determination of Natural Pigments. In *Encyclopedia of Food and Health* (1 ed.). Elsevier Ltd. https://doi.org/10.1016/B978-0-12-384947-2.00189-6

Gong, Jiawei, Liang, Jing, & Sumathy, K. (2012). Review on dye-sensitized solar cells (DSSCs): Fundamental concepts and novel materials. *Renewable and Sustainable Energy Reviews*, *16*(8), 5848–5860. https://doi.org/10.1016/j.rser.2012.04.044

Guidi, Lucia, Tattini, Massimiliano, & Landi, Marco. (2017). How Does Chloroplast Protect Chlorophyll Against Excessive Light? *Chlorophyll*, *June*. https://doi.org/10.5772/67887

Hanis, Syahida, & Siti. (n.d.). *Optimization of dye extraction from turmeric (curcuma longa l.) and henna leaves (lawsonia inermis l.) in dye sensitized solar cell*. 978–988.

Hao, Sancun, Wu, Jihuai, Huang, Yunfang, & Lin, Jianming. (2006). Natural dyes as photosensitizers for dye-sensitized solar cell. *Solar Energy*, *80*(2), 209–214. https://doi.org/10.1016/j.solener.2005.05.009

Hara, K., Horiguchi, T., Kinoshita, T., Sayama, K., & Arakawa, H. (2001).

Influence of electrolytes on the photovoltaic performance of organic dye-sensitized nanocrystalline TiO2 solar cells. *Solar Energy Materials and Solar Cells*, *70*(2), 151–161. https://doi.org/10.1016/S0927-0248(01)00019-8

Hardeli, Zainul, R., & Isara, L. P. (2019). Preparation of Dye Sensitized Solar Cell (DSSC) using anthocyanin color dyes from jengkol shell (Pithecellobium lobatum Benth.) by the gallate acid copigmentation. *Journal of Physics: Conference Series*, *1185*(1). https://doi.org/10.1088/1742-6596/1185/1/012021

Hariyadi, Asful, Swasono, Muhammad Aby, & Augusty, Anniza Cornelia. (2017). Combination of dragon fruit, hibiscus and bitterleaf as dye sensitizer to increase efficiency of DSSC. *International Journal on Advanced Science, Engineering and Information Technology*, *7*(3), 936–942. https://doi.org/10.18517/ijaseit.7.3.2445

Haryanto, Ditia Allindira, Landuma, Suarni, & Purwanto, Agus. (2014). Fabrication of dye-sensitized solar cell (DSSC) using annato seeds (Bixa orellana Linn). *AIP Conference Proceedings*, *1586*, 104–108. https://doi.org/10.1063/1.4866740

Hayat, Azwar, Putra, A. Erwin E., Amaliyah, Novriany, & Pandey, Shyam S. (2019). Clitoria ternatea flower as natural dyes for Dye-sensitized solar cells. *IOP Conference Series: Materials Science and Engineering*, *619*(1). https://doi.org/10.1088/1757-899X/619/1/012049

Hemmatzadeh, Reza, & Jamali, Abbas. (2015). Enhancing the optical absorption of anthocyanins for dye-sensitized solar cells. *Journal of Renewable and Sustainable Energy*, *7*(1). https://doi.org/10.1063/1.4907599

Henari, F. Z., Cassidy, S., Jasim, Khalil E., & Dakhel, A. A. (2013). Nonlinear refractive index measurements of curcumin with CW laser. *Journal of Nonlinear Optical Physics and Materials*, *22*(2), 1–8. https://doi.org/10.1142/S0218863513500173

Hidayat, Aldy Satria, Rokhmat, Mamat, Si, M., & Qurthobi, Ahmad. (2010). *Pengaruh Suhu dan Kecepatan Putar Spin-Coating terhadap Kinerja Sel*

Surya Organik Berbahan Dasar TiO2. *1*(1), 1–14.

Huang, S. Y., Schlichthörl, G., Nozik, A. J., Grätzel, M., & Frank, A. J. (1997). Charge recombination in dye-sensitized nanocrystalline TiO2 solar cells. *Journal of Physical Chemistry B*, *101*(14), 2576–2582. https://doi.org/10.1021/jp962377q

Hug, Hubert, Bader, Michael, Mair, Peter, & Glatzel, Thilo. (2014). Biophotovoltaics: Natural pigments in dye-sensitized solar cells. *Applied Energy*, *115*, 216–225. https://doi.org/10.1016/j.apenergy.2013.10.055

Husain, A. A. F., & Hasan, W. Z. Wa. (2017). Transparent solar cell using spin coating and screen printing. *Pertanika Journal of Science and Technology*, *25*(S), 225–234.

Ilic, Stefan, & Paunovic, Vesna. (2019). Characteristics of curcumin dye used as a sensitizer in dye-sensitized solar cells. *Facta universitatis - series: Electronics and Energetics*, *32*(1), 91–104. https://doi.org/10.2298/fuee1901091i

Jalali, Tahmineh, Arkian, Parisa, Golshan, Malihe, Jalali, Mandana, & Osfouri, Shahriar. (2020). Performance evaluation of natural native dyes as photosensitizer in dye-sensitized solar cells. *Optical Materials*, *110*(October), 110441. https://doi.org/10.1016/j.optmat.2020.110441

Kabir, F., Bhuiyan, M. M. H., Hossain, M. R., Bashar, H., & Rahaman, M. S. (2019). Optik Improvement of e ffi ciency of Dye Sensitized Solar Cells by optimizing the combination ratio of Natural Red and Yellow dyes. *Optik - International Journal for Light and Electron Optics*, *179*(September 2018), 252–258. https://doi.org/10.1016/j.ijleo.2018.10.150

Kabir, F., Bhuiyan, M. M. H., Manir, M. S., Rahaman, M. S., Khan, M. A., & Ikegami, T. (2019). Development of dye-sensitized solar cell based on combination of natural dyes extracted from Malabar spinach and red spinach. *Results in Physics*, *14*(June), 102474. https://doi.org/10.1016/j.rinp.2019.102474

Kabir, Fahmid, Nazmus Sakib, Syed, Shehab Uddin, Sheikh, Tawsif Efaz, Erteza,

& Farhan Himel, Md Tahmid. (2019). Enhance cell performance of DSSC by dye mixture, carbon nanotube and post TiCl4 treatment along with degradation study. *Sustainable Energy Technologies and Assessments*, *35*(June), 298–307. https://doi.org/10.1016/j.seta.2019.07.011

Katoh, Ryuzi, Hara, Mikiya, & Tsuzuki, Seiji. (2008). Ion pair formation in [bmim]I ionic liquids. *Journal of Physical Chemistry B*, *112*(48), 15426–15430. https://doi.org/10.1021/jp806578h

Katoh, Ryuzi, Kasuya, Motohiro, Kodate, Satoshi, Furube, Akihiro, Fuke, Nobuhiro, & Koide, Naoki. (2009). *2009 Effects of 4-tert-Butylpyridine and Li Ions on Photoinduced Electron Injection Efficiency in.pdf*. 20738–20744.

Kazuma, Kohei, Noda, Naonobu, & Suzuki, Masahiko. (2003). Flavonoid composition related to petal color in different lines of Clitoria ternatea. *Phytochemistry*, *64*(6), 1133–1139. https://doi.org/10.1016/S0031-9422(03)00504-1

Khalil Ebrahim Jasim, Seamas Cassidy, Feryad Zaki Henari, & Akil Aziz Dakhel. (2017). Curcumin Dye-Sensitized Solar Cell. *Journal of Energy and Power Engineering*, *11*(6), 409–416. https://doi.org/10.17265/1934-8975/2017.06.006

Kim, Hee Je, Kim, Dong Jo, Karthick, S. N., Hemalatha, K. V., Justin Raj, C., Ok, Sunseong, & Choe, Youngson. (2013). Curcumin dye extracted from Curcuma longa L. used as sensitizers for efficient dye-sensitized solar cells. *International Journal of Electrochemical Science*, *8*(6), 8320–8328.

Kimura, Mutsumi, Nomoto, Hirotaka, Masaki, Naruhiko, & Mori, Shogo. (2012). Dye molecules for simple co-sensitization process: Fabrication of mixed-dye-sensitized solar cells. *Angewandte Chemie - International Edition*, *51*(18), 4371–4374. https://doi.org/10.1002/anie.201108610

Kohjiro, Arakawa, Hironori, & Dssc, Cells. (2003). *Dye-sensitized Solar Cells*.

Kumar, K. Ashok, Subalakshmi, K., & Senthilselvan, J. (2016). Co-sensitization of natural dyes for improved efficiency in dye-sensitized solar cell application.

AIP Conference Proceedings, *1731*, 1–4. https://doi.org/10.1063/1.4947823

Kumara, N. T. R. N., Lim, Andery, Lim, Chee Ming, Petra, Mohamad Iskandar, & Ekanayake, Piyasiri. (2017). Recent progress and utilization of natural pigments in dye sensitized solar cells: A review. *Renewable and Sustainable Energy Reviews*, *78*(April), 301–317. https://doi.org/10.1016/j.rser.2017.04.075

Lee, Jung Kun, & Yang, Mengjin. (2011). Progress in light harvesting and charge injection of dye-sensitized solar cells. *Materials Science and Engineering B: Solid-State Materials for Advanced Technology*, *176*(15), 1142–1160. https://doi.org/10.1016/j.mseb.2011.06.018

Li, Bin, Wang, Liduo, Kang, Bonan, Wang, Peng, & Qiu, Yong. (2006). Review of recent progress in solid-state dye-sensitized solar cells. *Solar Energy Materials and Solar Cells*, *90*(5), 549–573. https://doi.org/10.1016/j.solmat.2005.04.039

Lichtenthaler, Hartmut K., & Buschmann, Claus. (2001). Chlorophylls and Carotenoids: Measurement and Characterization by UV-VIS Spectroscopy. *Current Protocols in Food Analytical Chemistry*, *1*(1), F4.3.1-F4.3.8. https://doi.org/10.1002/0471142913.faf0403s01

Lim, Andery, Haji Manaf, Noramaliyana, Tennakoon, Kushan, Chandrakanthi, R. L. N., Lim, Linda Biaw Leng, Bandara, J. M. R. Sarat., & Ekanayake, Piyasiri. (2015). Higher performance of DSSC with dyes from cladophora sp. As mixed cosensitizer through synergistic effect. *Journal of Biophysics*, *2015*. https://doi.org/10.1155/2015/510467

Lin, C. K., Yang, T. J., Feng, Y. C., Tsung, T. T., & Su, C. Y. (2006). Characterization of elecrophoretically deposited nanocrystalline titanium dioxide films. *Surface and Coatings Technology*, *200*(10 SPEC. ISS.), 3184–3189. https://doi.org/10.1016/j.surfcoat.2005.07.040

Liu, Yao, Hagfeldt, Anders, Xiao, Xu Rui, & Lindquist, Sten Eric. (1998). Investigation of influence of redox species on the interfacial energetics of a dye-sensitized nanoporous TiO2 solar cell. *Solar Energy Materials and Solar*

Cells, *55*(3), 267–281. https://doi.org/10.1016/S0927-0248(98)00111-1

Ludin, Norasikin A., Al-Alwani, Mahmoud A. M., Mohamad, Abu Bakar, Kadhum, Abd Amir H., Hamid, Norul Hisham, Ibrahim, Mohd Adib, Teridi, Mohd Asri Mat, Al-Hakeem, Tarik M. Al., Mukhlus, Abduljabbar, & Sopian, Kamaruzzaman. (2018). Utilization of natural dyes from Zingiber officinale leaves and Clitoria ternatea flowers to prepare new photosensitisers for dye-sensitised solar cells. *International Journal of Electrochemical Science*, *13*(8), 7451–7465. https://doi.org/10.20964/2018.08.04

M. Wang, C. Grätzel, S. M. Zakeeruddin, M. Grätzel. (2012). Redox Midiator.Pdf. *Energy & Environmental Science*, *5*(207890), 9394–9405.

Maddah, Hisham A., Berry, Vikas, & Behura, Sanjay K. (2020). Biomolecular photosensitizers for dye-sensitized solar cells: Recent developments and critical insights. *Renewable and Sustainable Energy Reviews*, *121*(November 2019), 109678. https://doi.org/10.1016/j.rser.2019.109678

Maleta, Hana Susanti, Indrawati, Renny, Limantara, Leenawaty, & Brotosudarmo, Tatas Hardo Panintingjati. (2018). Ragam Metode Ekstraksi Karotenoid dari Sumber Tumbuhan dalam Dekade Terakhir (Telaah Literatur). *Jurnal Rekayasa Kimia & Lingkungan*, *13*(1), 40–50. https://doi.org/10.23955/rkl.v13i1.10008

Maryani, Devi. (2012). *Jurnal Kimia Sains dan Aplikasi Penentuan Efisiensi DSSC (Dye-Sensitized Solar Cell) yang Dibuat dari Semikonduktor ZnO yang diemban Fe 3 + Melalui Metode*. *15*(1).

Md Fahim Hasan Khan. (2019). *Measurement of Open circuit voltage , Short circuit current , efficiency , Maximum power point and Fill factor for different solar radiation of a solar cell or module* (Nomor July).

Mohamad Sri, M. N. S., Buraidah, M. H., & Teo, L. P. (2017). Effect of 1-Butyl-3-Methylimidazolium Iodide on the Performance of Dye-Sensitized Solar Cell Having PEO-PVA Based Gel Polymer Electrolyte. *Materials Today: Proceedings*, *4*(4), 5161–5168. https://doi.org/10.1016/j.matpr.2017.05.022

Mondal, Satyajit, Ghosh, Soumen, & Moulik, Satya P. (2016). Stability of curcumin in different solvent and solution media: UV–visible and steady-state fluorescence spectral study. *Journal of Photochemistry and Photobiology B: Biology*, *158*, 212–218. https://doi.org/10.1016/j.jphotobiol.2016.03.004

Mosharraf Hossain Bhuiyan, Md., Kabir, Fahmid, Serajum Manir, Md., Saifur Rahaman, Md., Robiul Hossain, Md., Barua, Prosenjit, Ghosh, Bikram, Mitsugi, Fumiaki, Ikegami, Tomoaki, Huque, Saiful, & Ahmad Khan, Mubarak. (2021). Effect of Combination of Natural Dyes and the Blocking Layer on the Performance of DSSC. *Solar Cells - Theory, Materials and Recent Advances*, *April*. https://doi.org/10.5772/intechopen.94760

Muhimah, Luthviyah Choirotul, Yuwono, Rio Akbar, & Ernawita, Ernawita. (2017). Biophotovoltaic Tipe-N Dan Tipe-P Dengan Menggunakan Ekstrak Kulit Jeruk Dari Aceh. *Simetris : Jurnal Teknik Mesin, Elektro dan Ilmu Komputer*, *8*(2), 687. https://doi.org/10.24176/simet.v8i2.1580

Narayan, Monishka Rita. (2012). Review: Dye sensitized solar cells based on natural photosensitizers. *Renewable and Sustainable Energy Reviews*, *16*(1), 208–215. https://doi.org/10.1016/j.rser.2011.07.148

Nemala, Siva Sankar, Kartikay, Purnendu, Prathapani, Sateesh, Bohm, H. L. Mallik., Bhargava, Parag, Bohm, Sivasambu, & Mallick, Sudhanshu. (2017). Liquid phase high shear exfoliated graphene nanoplatelets as counter electrode material for dye-sensitized solar cells. *Journal of Colloid and Interface Science*, *499*, 9–16. https://doi.org/10.1016/j.jcis.2017.03.083

O'Regan, Brian, & Gratzel, Michael. (1991). © 19 9 1 Nature Publishing Group. *Nature Publishing Group*, *3523*, 737–739.

O'Sullivan, Colm T. (1980). Ohm's law and the definition of resistance. *Physics Education*, *15*(4), 237–239. https://doi.org/10.1088/0031-9120/15/4/009

Omar, Azimah, Ali, Mohd Syukri, & Abd Rahim, Nasrudin. (2020). Electron transport properties analysis of titanium dioxide dye-sensitized solar cells (TiO2-DSSCs) based natural dyes using electrochemical impedance spectroscopy concept: A review. *Solar Energy*, *207*(July), 1088–1121.

https://doi.org/10.1016/j.solener.2020.07.028

Ooyama, Yousuke, & Harima, Yutaka. (2012). Photophysical and electrochemical properties, and molecular structures of organic dyes for dye-sensitized solar cells. *ChemPhysChem*, *13*(18), 4032–4080. https://doi.org/10.1002/cphc.201200218

Pal, Kumaresh, & Rahaman, Chowdhury Habibur. (2015). Phytochemical and Antioxidant Studies of Justicia gendarussa Burm. F. an Ethnomedicinal Plant. *International Journal of Pharmaceutical Sciences and Research*, *6*(8), 3454. https://doi.org/10.13040/IJPSR.0975-8232.6(8).3454-62

Park, Kyung Hee, Kim, Tae Young, Han, Shin, Ko, Hyun Seok, Lee, Suk Ho, Song, Yong Min, Kim, Jung Hun, & Lee, Jae Wook. (2014). Light harvesting over a wide range of wavelength using natural dyes of gardenia and cochineal for dye-sensitized solar cells. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, *128*, 868–873. https://doi.org/10.1016/j.saa.2014.03.016

Park, Kyung Hee, Kim, Tae Young, Park, Ju Young, Jin, En Mei, Yim, Soon Ho, Choi, Do Young, & Lee, Jae Wook. (2013). Adsorption characteristics of gardenia yellow as natural photosensitizer for dye-sensitized solar cells. *Dyes and Pigments*, *96*(2), 595–601. https://doi.org/10.1016/j.dyepig.2012.10.005

Pathak, Charu, Surana, Karan, Kumar Shukla, Vivek, & Singh, Pramod K. (2019). Fabrication and characterization of dye sensitized solar cell using natural dyes. *Materials Today: Proceedings*, *12*, 665–670. https://doi.org/10.1016/j.matpr.2019.03.111

Prabavathy, N., Shalini, S., Balasundaraprabhu, R., Velauthapillai, Dhayalan, Prasanna, S., & Muthukumarasamy, N. (2017). Enhancement in the photostability of natural dyes for dye-sensitized solar cell (DSSC) applications: a review. *International Journal of Energy Research*, *41*(10), 1372–1396. https://doi.org/10.1002/er.3703

Pratiwi, D. D., Nurosyid, F., Ahliha, A. H., Nurosyid, F., Pratiwi, D. D., & Nurosyid, F. (n.d.). *The chemical bonds effect of anthocyanin and chlorophyll*

dyes on TiO 2 for dye-sensitized solar cell (DSSC) The chemical bonds effect of anthocyanin and chlorophyll dyes on TiO 2 for dye-sensitized solar cell (DSSC).

Pratiwi, D. D., Nurosyid, F., Kusumandari, Supriyanto, A., & Suryana, R. (2017). Performance improvement of dye-sensitized solar cells (DSSC) by using dyes mixture from chlorophyll and anthocyanin. *Journal of Physics: Conference Series*, *909*(1). https://doi.org/10.1088/1742-6596/909/1/012025

Prima. (2017). Studi Performansi Natural Dye Sensitized Solar Cell menggunakan Fotoelektrode TiO2 Nanopartikel. *Institut Teknologi Bandung*, *April 2013*. https://doi.org/10.13140/RG.2.2.11518.18245

Prima, E. C., Yuliarto, B., Suyatman, & Dipojono, H. K. (2016). Charge Transfer Dynamics of Highly Efficient Cyanidin-3-O- Glucoside Sensitizer for Dye-Sensitized Solar Cells. *Journal of Physics: Conference Series*, *739*(1), 4–11. https://doi.org/10.1088/1742-6596/739/1/012031

Prima, Eka Cahya, Al Qibtiya, Mariya, Yuliarto, Brian, Suyatman, & Dipojono, Hermawan Kresno. (2016). Influence of anthocyanin co-pigment on electron transport and performance in black rice dye-sensitized solar cell. *Ionics*, *22*(9), 1687–1697. https://doi.org/10.1007/s11581-016-1673-6

Prima, Eka Cahya, Nugroho, Harbi Setyo, Nugraha, Refantero, Gema, Panatarani, Camelia, & Yuliarto, Brian. (2020a). Performance of the dye-sensitized quasi-solid state solar cell with combined anthocyanin-ruthenium photosensitizer. *RSC Advances*, *10*(60), 36873–36886. https://doi.org/10.1039/d0ra06550a

Prima, Eka Cahya, Nugroho, Harbi Setyo, Nugraha, Refantero, Gema, Panatarani, Camelia, & Yuliarto, Brian. (2020b). Performance of the dye-sensitized quasi-solid state solar cell with combined anthocyanin-ruthenium photosensitizer. *RSC Advances*, *10*(60), 36873–36886. https://doi.org/10.1039/d0ra06550a

Prima, Eka Cahya, Yuliarto, Brian, Suendo, Veinardi, & Suyatman. (2014). Improving photochemical properties of Ipomea pescaprae, Imperata cylindrica (L.) Beauv, and Paspalum conjugatum Berg as photosensitizers for dye sensitized solar cells. *Journal of Materials Science: Materials in Electronics*,

25(10), 4603–4611. https://doi.org/10.1007/s10854-014-2210-x

Priya, M., Balakrishnan, V., Lakshmi, A. Kiruthika, Aruna, R., & Ravindran, K. C. (2014). Mercury Induced Oxidative Stress of Antioxidants in *Clitoria ternatea* L. *International Letters of Natural Sciences*, *23*(January), 1–8. https://doi.org/10.18052/www.scipress.com/ilns.23.1

Priyadarsini, K. Indira. (2009). Photophysics, photochemistry and photobiology of curcumin: Studies from organic solutions, bio-mimetics and living cells. *Journal of Photochemistry and Photobiology C: Photochemistry Reviews*, *10*(2), 81–95. https://doi.org/10.1016/j.jphotochemrev.2009.05.001

Qu, Sanyin, Hua, Jianli, & Tian, He. (2012). New D-π-A dyes for efficient dye-sensitized solar cells. In *Science China Chemistry* (Vol. 55, Nomor 5, hal. 677–697). https://doi.org/10.1007/s11426-012-4517-x

Rahul, Singh, Shruti, Singh, Pramod K., Kakroo, Sunanda, Hachim, Dhafer Manea, Dhapola, Pawan S., & Khan, Zishan H. (2019). Eco-friendly dye sensitized solar cell using natural dye with solid polymer electrolyte as hole transport material. *Materials Today: Proceedings*, *34*(xxxx), 760–766. https://doi.org/10.1016/j.matpr.2020.04.775

Richhariya, Geetam, Kumar, Anil, Tekasakul, Perapong, & Gupta, Bhupendra. (2017). Natural dyes for dye sensitized solar cell: A review. *Renewable and Sustainable Energy Reviews*, *69*(November 2016), 705–718. https://doi.org/10.1016/j.rser.2016.11.198

Ridwan, M. A., Noor, E., Rusli, M. S., & Akhiruddin. (2018). Fabrication of dye-sensitized solar cell using chlorophylls pigment from sargassum. *IOP Conference Series: Earth and Environmental Science*, *144*(1). https://doi.org/10.1088/1755-1315/144/1/012039

Rizali, Dede, Suryanto, Heru, & Sukarni, Sukarni. (2019). The Effect of Chlorophyll Concentration from Papaya Leaves on the Performance of Dye Sensitized Solar Cell. *Journal of Mechanical Engineering Science and Technology*, *3*(2), 59–69. https://doi.org/10.17977/um016v3i22019p059

Rodrigues, Marcelo Alatzatianou. (2020). *Fabrication of dye-sensitized solar cells using natural dyes extracted from Brazilian plants Master Thesis Fabrication of dye-sensitized solar cells using natural dyes extracted from Brazilian plants Marcelo Alatzatianou Rodrigues University of Freiburg ,. October*, 0–86. https://doi.org/10.6084/m9.figshare.12934526.v1

Rosikhin, Ahmad. (n.d.). *Eksploitasi Sifat Optoelektronik Graphene sebagai Lapisan Booster Pembawa & Media Efektif Transport Muatan pada Sel Surya Film*.

Ruhane, T. A., Islam, M. Tauhidul, Rahaman, Md Saifur, Bhuiyan, M. M. H., Islam, Jahid M. M., Newaz, M. K., Khan, K. A., & Khan, Mubarak A. (2017). Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period. *Optik*, *149*(September), 174–183. https://doi.org/10.1016/j.ijleo.2017.09.024

Sadikin, S. N., Rahman, M. Y. A., Umar, A. A., & Salleh, M. M. (2017). Effect of spin-coating cycle on the properties of TiO2 thin film and performance of DSSC. *International Journal of Electrochemical Science*, *12*(6), 5529–5538. https://doi.org/10.20964/2017.06.57

Sakthivel, S., Baskaran, V., & Mahenthiran, S. (2015). Dye Sensitized Solar Cell Properties and Fabrication Using Lawsonia Inermis. *An International Research Journal), www.chemistry-journal.org February*, *5*(2), 85–92. www.chemistry-journal.org

Santos-Buelga, Celestino, Mateus, Nuno, & De Freitas, Victor. (2014). Anthocyanins. Plant pigments and beyond. *Journal of Agricultural and Food Chemistry*, *62*(29), 6879–6884. https://doi.org/10.1021/jf501950s

Saputro, Aldhi, Mizan, Adlan, Sofyan, Nofrijon, & Yuwono, Akhmad Herman. (2017). Investigating the effect of various extracting solvents on the potential use of red-apple skin (Malus domestica) as natural sensitizer for dye-sensitized solar cell. *AIP Conference Proceedings*, *1826*(2017), 1–8. https://doi.org/10.1063/1.4979222

Sathyaseelan, B., Manikandan, E., Baskaran, I., Senthilnathan, K., Sivakumar, K.,

Moodley, M. K., Ladchumananandasivam, Rasiah, & Maaza, M. (2017). Studies on structural and optical properties of ZrO2nanopowder for opto-electronic applications. *Journal of Alloys and Compounds*, *694*, 556–559. https://doi.org/10.1016/j.jallcom.2016.10.002

Senthilkumar, Subramanian, & Rajendran, Annamalai. (2018). Biosynthesis of TiO2 nanoparticles using Justicia gendarussa leaves for photocatalytic and toxicity studies. *Research on Chemical Intermediates*, *44*(10), 5923–5940. https://doi.org/10.1007/s11164-018-3464-3

Septina, Wilman. (2007). *Pembuatan Prototipe Solar Cell Murah dengan Bahan Organik-Inorganik (Dye- sensitized Solar Cell) PENGHARGAAN PT . REKAYASA INDUSTRI Pembuatan Prototipe Solar Cell Murah dengan Bahan Organik-Inorganik (Dye-sensitized Solar Cell) Oleh : Wilman Septina D. May*.

Shafouri, M. Al, Ahmed, Naser M., Hassan, Z., Almessiere, Munirah Abdullah, & Jumaah, Maadh. (2018). Optical and structural properties of curcuminoids extracted from Curcuma longa L. for hybrid white light diode. *EPJ Applied Physics*, *84*(1), 1–10. https://doi.org/10.1051/epjap/2018180185

Shalini, S., Balasundara Prabhu, R., Prasanna, S., Mallick, Tapas K., & Senthilarasu, S. (2015). Review on natural dye sensitized solar cells: Operation, materials and methods. *Renewable and Sustainable Energy Reviews*, *51*, 1306–1325. https://doi.org/10.1016/j.rser.2015.07.052

Shanmugam, Vinoth, Manoharan, Subbaiah, Anandan, Sambandam, & Murugan, Ramaswamy. (2013). Performance of dye-sensitized solar cells fabricated with extracts from fruits of ivy gourd and flowers of red frangipani as sensitizers. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, *104*, 35–40. https://doi.org/10.1016/j.saa.2012.11.098

Sinha, Dola, De, Debasis, & Ayaz, Abdul. (2020). Photo sensitizing and electrochemical performance analysis of mixed natural dye and nanostructured ZnO based DSSC. *Sadhana - Academy Proceedings in Engineering Sciences*, *45*(1). https://doi.org/10.1007/s12046-020-01415-0

Supriyanto, A., Nurosyid, F., & Ahliha, A. H. (2018). Carotenoid pigment as sensitizers for applications of dye-sensitized solar cell (DSSC). *IOP Conference Series: Materials Science and Engineering*, *432*(1). https://doi.org/10.1088/1757-899X/432/1/012060

Suresh Reddy, Yanala, Chinnala, Krishna Mohan, Vamshi Sharath Nath, K., Madhan Mohan, E., Preethi, B., & Narender, B. (2015). In vitro evaluation of anti-oxidant activity of different extracts of Justicia gendarussa leaf. *Der Pharma Chemica*, *7*(8), 21–24.

Susanto Budi antoni Saputro, Khoirun Nisa, Nita Rosita, Agus Yulianto. (2014). Analisis Spektrum Absorbansi Pigmen Flavonoid Dari Daun Tanaman Andong (Cordyline Fruticosa L.) Sebagai Dye Solar Sel. *Jurnal Fisika Unnes*, *4*(2), 79687. https://doi.org/10.15294/jf.v4i2.3833

Syafinar, R., Gomesh, N., Irwanto, M., Fareq, M., & Irwan, Y. M. (2015a). Chlorophyll Pigments as Nature Based Dye for Dye-Sensitized Solar Cell (DSSC). In *Energy Procedia* (Vol. 79). Elsevier B.V. https://doi.org/10.1016/j.egypro.2015.11.584

Syafinar, R., Gomesh, N., Irwanto, M., Fareq, M., & Irwan, Y. M. (2015b). Potential of Purple Cabbage, Coffee, Blueberry and Turmeric as Nature Based Dyes for Dye Sensitized Solar Cell (DSSC). In *Energy Procedia* (Vol. 79). Elsevier B.V. https://doi.org/10.1016/j.egypro.2015.11.569

Tanaka, Hiromitsu, Takeichi, Akihiro, Higuchi, Kazuo, Motohiro, Tomoyoshi, Takata, Masakazu, Hirota, Nobuaki, Nakajima, Junji, & Toyoda, Tatsuo. (2009). Long-term durability and degradation mechanism of dye-sensitized solar cells sensitized with indoline dyes. *Solar Energy Materials and Solar Cells*, *93*(6–7), 1143–1148. https://doi.org/10.1016/j.solmat.2009.02.006

Tayyan, Ahmed A. El. (2011). Dye sensitized solar cell: parameters calculation and model integration. *Journal of Electron Devices, 11*, 616–624.

Terahara, Norihiko, Toki, Kenjiro, Saito, Norio, Honda, Toshio, Matsui, Toshiro, & Osajima, Yutaka. (1998). Eight new anthocyanins, ternatins C1-C5 and D3 and preternatins A3 and C4 from young Clitoria ternatea flowers. *Journal of*

Natural Products, *61*(11), 1361–1367. https://doi.org/10.1021/np980160c

Tonooka, K., Chiu, Te Wei, & Kikuchi, N. (2009). Preparation of transparent conductive TiO 2 :Nb thin films by pulsed laser deposition. *Applied Surface Science*, *255*(24), 9695–9698. https://doi.org/10.1016/j.apsusc.2009.04.056

Trihutomo, Prihanto, Soeparman, Sudjito, Widhiyanuriyawan, Denny, & Yuliati, Lilis. (2019). Performance improvement of dye-sensitized solar cell- (DSSC-) based natural dyes by clathrin protein. *International Journal of Photoenergy*, *2019*. https://doi.org/10.1155/2019/4384728

Tutunaru, Oana, Ion, Valentin, Simionescu, Octavian-gabriel, Romanit, Cosmin, Buiu, Octavian, & Avram, Andrei. (n.d.). *RF Magnetron Sputtering Deposition of TiO 2 Thin Films in a Small Continuous Oxygen Flow Rate*. 1–13.

Ubani, C. A., Ibrahim, M. A., Teridi, M. A. M., Sopian, K., Ali, J., & Chaudhary, K. T. (2016). Application of graphene in dye and quantum dots sensitized solar cell. *Solar Energy*, *137*, 531–550. https://doi.org/10.1016/j.solener.2016.08.055

Uddin, Jasim, Islam, Jahid M. M., Karim, Ejajul, Khan, Shuak M. M., Akhter, Shireen, Hoque, Enamul, & Khan, Mubarak A. (2015). Preparation and Characterization of Dye Sensitized Solar Cell Using Natural Dye Extract from Red Amaranth (Amaranthus sp.) as Sensitizer. *International Journal of Thin Films Science and Technology*, *4*(2), 141. http://dx.doi.org/10.12785/ijtfst/040212

Vijayakumar, Alagan Subbiah, Jerayaj, Mani, Kolanchinathan, Pachan, Selvakumar, Muniraj, & Praveenkumar, Dharmaraj. (2019). Molecular Identification of the Medicinal Plant Justicia Gendarussa (Burm) F. Using Its Gene. *Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences*, *5*(1), 663. https://doi.org/10.26479/2019.0501.55

Walley, H. D. (1964). Vertebrate resistance to pesticides. In *Audubon Bull* (Vol. 129).

Warkoyo, & Saati, Elfi Anis. (2011). the Solvent Effectiveness on Extraction Process of Seaweed Pigment. *MAKARA of Technology Series*, *15*(1), 5–8. https://doi.org/10.7454/mst.v15i1.850

Widiatmoko, Pramujo, Devianto, Hary, Nurdin, Isdiriayani, Adriaan, Adriaan, & Purwito, Henry Natanail. (2018). the Effect of Counter Electrode Preparation Methods Toward Dye Sensitized Solar Cell Performance. *Jurnal Teknologi Bahan dan Barang Teknik*, *8*(1), 1. https://doi.org/10.37209/jtbbt.v8i1.112

William, paul. (1985). Extinction Coefficients of Chlorophyll a and b in N,N - Dimethylformamide and 80% Acetone. *Plant Physiology*, *77*(2), 483–485. https://doi.org/10.1104/pp.77.2.483

Wu, Jihuai, Lan, Zhang, Lin, Jianming, Huang, Miaoliang, Hao, Sancun, Sato, Tsugio, & Yin, Shu. (2007). A novel thermosetting gel electrolyte for stable quasi-solid-state dye-sensitized solar cells. *Advanced Materials*, *19*(22), 4006–4011. https://doi.org/10.1002/adma.200602886

Yuliarto, Brian, Septina, Wilman, Fuadi, Kasyful, Fanani, Fahiem, Muliani, Lia, & Nugraha. (2010). Synthesis of nanoporous TiO2 and its potential applicability for dye-sensitized solar cell using antocyanine black rice. *Advances in Materials Science and Engineering*, *2010*. https://doi.org/10.1155/2010/789541

Zanjanchi, Farzaneh, & Beheshtian, Javad. (2019). Natural pigments in dye-sensitized solar cell (DSSC): a DFT-TDDFT study. *Journal of the Iranian Chemical Society*, *16*(4), 795–805. https://doi.org/10.1007/s13738-018-1561-2