Hayat_2018_J._Phys.-_Conf._Ser._979_012062_2.pdf

by

Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Piper Ornatum and *Piper Betle* as Organic Dyes for TiO_2 and SnO_2 Dye Sensitized Solar Cells

To cite this article: Azwar Hayat *et al* 2018 *J. Phys.: Conf. Ser.* **979** 012062

IOP Conf. Series: Journal of Physics: Conf. Series **979** (2018) 012062 doi:10.1088/1742-6596/979/1/012062

Piper Ornatum and *Piper Betle* as Organic Dyes for TiO_2 and SnO_2 Dye Sensitized Solar Cells

Azwar Hayat[1], A. Erwin E. Putra[1], Novriany Amaliyah[1], Shuzi Hayase[2] and Shyam. S. Pandey[2]

[1]Mechanical Engineering Department, Faculty of Engineering, Hasanuddin University, Poros Malino Km. 6 Gowa, South Sulawesi, Indonesia.
[2]LSSE, Kyushu Institute of Technology, Japan, 2-4 Hibikino, Wakamatsu-ku, Kitakyushu-shi, Fukuoka, Japan.

E-mail: azwar.hayat@unhas.ac.id

Abstract. Dye sensitized solar cell (DSSC) mimics the principle of natural photosynthesis are now currently investigated due to low manufacturing cost as compared to silicon based solar cells. In this report, we utilized Piper ornatum (PO) and Piper betle (PB) as sensitizer to fabricate low cost DSSCs. We compared the photovoltaic performance of both sensitizers with Titanium dioxide (TiO2) and Tin dioxide (SnO2) semiconductors. The results show that PO and PB dyes have higher Short circuit current (Jsc) when applied in SnO2 compared to standard TiO2 photo-anode film even though the Open circuit voltage (Voc) was hampered on SnO2 device. In conclusion, from the result, higher electron injections can be achieved by choosing appropriate semiconductors with band gap that match with dyes energy level as one of strategy for further low cost solar cell.

1. Introduction

Solar energy is one of the greenest types of energy resources. It is free and abundant that makes this energy form one of candidate to replace fossil fuel. Silicon based solar cells have dominated the installed solar cell today. However, Silicon based solar cell required huge energy resources to purify the silicon and high production cost in order to achieve high efficiency as well. Low cost solar cells, such as Dye sensitized solar cells (DSSCs) are gaining more and more attention owing to their high efficiency and relatively lower cost of production [1]. A DSSC consist of two sandwiched electrodes, working and counter electrode, made from transparent conducting glass which mainly made of Fluorine doped tin oxide (FTO). Working electrode is made of thin layer of semiconducting material such as titanium dioxide (TiO_2), tin dioxide (SnO_2) Zinc oxide (ZnO) etc, coated with dyes as photo anode on top of FTO [2-9]. Counter electrode is made of FTO with thin layer of platinum or carbon [10-13]. Electrolyte is placed between both electrodes to connect and maintain electrons transfer. One of the main components to enhance the Photo-conversion efficiency (PCE) is dye sensitizer. The most widely used in DSSCs research area are Ruthenium based sensitizer. In the recent past Ruthenium based as well as metal free dyes have been reported having nearly quantitative photon harvesting mainly in the visible region of solar spectrum [14-17]. High quality ruthenium dyes are produced in sophisticated ways that increase the production cost of the DSSC. Most of sensitized dyes need anchoring groups in order to attach in nanoporous surface. Although attachment dyes on the nanoporous oxide semiconductor via a suitable anchoring group is common practice in DSSCs but introduction of such anchoring groups in dye structure at suitable position is synthetically cumbersome. In order to attach dyes on nanoporous oxide semiconductor surface, it could be achieved by several types of bonding, for example hydrophobic or electrostatic interactions and co-valent bonding [18]. Natural dye has widely used in textiles industry and recently in DSSC as sensitizer due to easier to prepare and low in cost [19-23]. In this works, the extracts of Piper ornatum and Piper betle as dye sensitizer in DSSC. The absorption spectra of PO and PB dyes solution in ethanol was measured with UV-VIS Spectrophotometer. The DSSC was made using two types of semiconductors which are TiO_2 and SnO_2. The current-voltage (I-V) characteristics ware measured along with Incident photon-to-current Efficiency (IPCE) to determine the photo-conversion efficiency and internal quantum efficiency.

2. Experimental

2.1. Dye preparation

The natural dyes used in this work extracted from Piper Ornatum (PO) and Piper Betle (PB) leafs. PO and PB fresh leafs was cleaned with distilled water and dried in shaded place for more than 3 weeks. After dried, the dried leaf ware crushed with Food grinder FTC-Z100 with output fineness 20-180 mesh. Powdered PO and PB ware diluted in ethanol. 1 gr of powdered leafs was immersed in 10 ml of ethanol and stored for 48 hours in dark place. After that, dye solution was filtered from remained powder using vacuum pump. Dye solution was kept in dark container to protect it from direct light exposure.

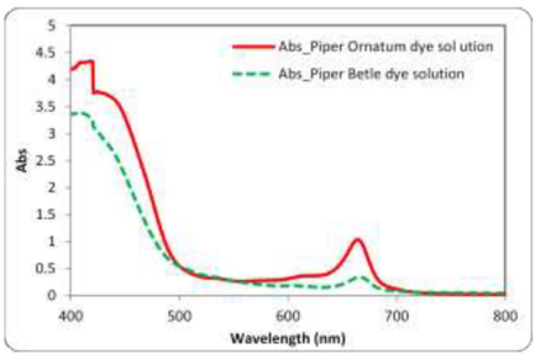

Figure 1. Absorption spectra of Natural dyes: Piper Ornatum in solution (red solid lines) and Piper Betle in solution (green dashed lines).

2.2. Preparation of dye sensitized solar cell

DSSCs ware fabricated with standard sandwich-like structure. Working electrode was prepared using Fluorine doped Tin Oxide (FTO) glass coated with 7 μM thick TiO_2 (30NRD) and SnO_2 followed by backing at 450°C for 30 minutes. Baked working electrode immersed in dye solution for 20 hours (figure 2). The cell area was 0.25 cm^2. The thickness of the spacer used to create a gap between working electrode and counter electrode was 25 μm (Solaronix Spacer). Counter electrode using Platinum (Pt) sputtered on FTO glass and electrolyte containing 500 mM LiI, 50 mM I_2, 600 mM Ethylmethylimidazolium dicyanoimide (MeEtIm-DCA), and 580 mM *tert*-butylpyridine (TBP) in Acetonitrile was used to fabricate the DSSCs. Natural dye solution in ethanol was used for sensitizer on the TiO_2 and SnO_2 surface. Photovoltaic characterization the DSSCs were made using a solar simulator (Bunko-Keiki Co. Ltd., Model Solar Simulator CEP-2000SRR) and black metal mask used to avoid the effect of optical reflection on photovoltaic measurement.

IOP Conf. Series: Journal of Physics: Conf. Series **979** (2018) 012062 doi:10.1088/1742-6596/979/1/012062

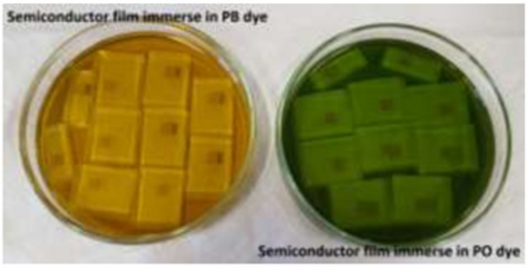

Figure 2. Immersion of semiconductor films on PO and PB dye.

3. Results and Discussions

Two kinds of Natural dyes (PO and PB) have been utilized as sensitizers in the present work. Two kind of semiconducting materials (TiO_2 and SnO_2) ware utilized to accommodate energy level of the dyes. Both PO and PB dyes used in the present work exhibits intense light absorption having absorption maximum at 667 nm and 671 nm in ethanol solution for the PB and PO dyes respectively. Light absorption spectra of dyes were characterized using UV-VIS spectrophotometer (Jusco V-670) to confirm the dye absorption (figure 1). Due to lower solubility of the natural dyes, it has been found that 48 hours are required to immerse in ethanol solution before proper usage in DSSC fabrication.

Table 1. I-V Characteristic of DSSCs with PO and PB dyes.

	PO-TiO_2	PO-SnO_2	PB-TiO_2	PB-$Sn0_2$
Efficiency [%]	0.032	0.022	0.034	0.014
FF	0.553	0.357	0.598	0.325
Voc[V]	0.463	0.238	0.455	0.202
Jsc[mA/cm^2]	0.124	0.261	0.125	0.207

Figure 3 exhibits the current-voltage characteristics of the DSSCs fabricated using these two dyes as sensitizer. It can be clearly seen that PO and PB exhibits relatively same PCE on TiO_2 as compared to the SnO_2 fabricated under similar experimental condition. This phenomenon occurred maybe due to deeper LUMO (Low Unoccupied Molecular Orbital) of these dyes that suppress the electron injection to semiconductor conduction band. The main factor controlling the efficiency is the short circuit density (Jsc) since open circuit voltage (Voc) and fill factors (FF) are nearly the same for PO and PB for each semiconductor. Table 1 shows result of PO-TiO_2 have Jsc of 0.124 mA/cm^2, Voc 0.463 V, FF 0.553 and PCE 0.032% and PB-TiO_2 have Jsc of 0.125 mA/cm^2, Voc 0.455 V, FF 0.598 and PCE 0.034% for device with TiO_2 semiconductor. The results were comparatively higher that dye from same genus reported before utilizing Piper Nigrum which was exhibit only 0.009% of PCE [24].

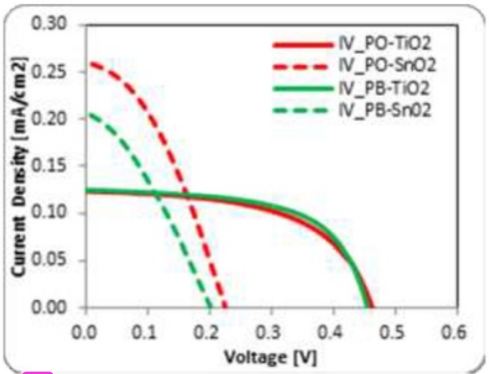

Figure 3. I-V Characteristic of DSSCs.

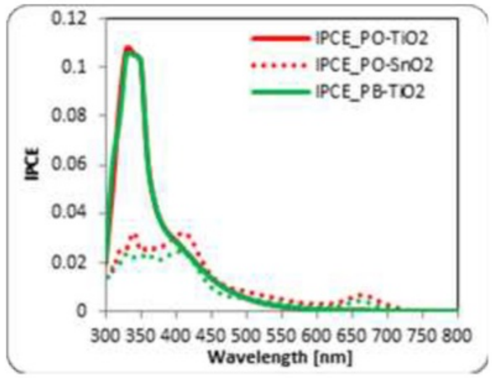

Figure 4. IPCE Spectra of DSSCs.

Device with SnO_2 semiconductor, PO-SnO_2 have Jsc of 0.261 mA/cm^2, Voc 0.238 V, FF 0.357 and PCE 0.022% and PB-SnO_2 have Jsc of 0.207 mA/cm^2, Voc 0.4202 V, FF 0.325 and PCE 0.014%. The results are interpreted in terms for facile dye regeneration in SnO_2 film was higher as compared to TiO_2 film due to its deeper conduction band. IPCE graph shown that photon to current density on SnO_2 film was higher. Higher electron injection was confirmed from peaks shown in 600 to 700 nm wavelength that agreed with absorption peak of the dyes shown in figure 4. Cells fabricated with SnO_2 film have lower Voc due to high traps on SnO_2 semiconductor lead to higher recombination that affect the Voc and FF.

4. Conclusions

DSSCs using Natural dyes Piper Ornatum and Piper Betle were fabricated for with two type semi conducting material Titanium dioxide and Tin dioxide. Fabricated cells produced relatively same PCE on TiO_2 film. Deeper conduction band of SnO2 compared to TiO2 lead to higher dye regeneration in SnO_2 film. IPCE graph confirmed that photon to current density on SnO_2 film was higher shown from peaks shown in 600 to 700 nm wavelength. Traps on SnO_2 semiconductor lead to higher recombination that affect the Voc and FF make both parameters lower compared on TiO_2 film. In conclusion, from the result, higher electron injections can be achieved by choosing appropriate semiconductors with band gap that match with dyes energy level as one of strategy for further low cost solar cell.

Acknowledgment

The work was part of Grand "PUPT 2017" from Indonesia Directorate General of Higher Education.

References

[1] Brian O and Grätzel M 1991 A Low-cost, High-efficiency Solar Cell Based on Dye Sensitized Colloidal TiO_2 Films *Nature* **353** 6346 737-740
[2] Chandiran A K, et al 2014 Analysis of Electron Transfer Properties of ZnO and TiO_2 Photoanodes for Dye-sensitized Solar Cells *ACS nano* **8** 3 2261-2268
[3] Ahn S H, et al 2013 One-Dimensional Hierarchical Nanostructures of TiO_2 Nanosheets on SnO_2 Nanotubes for High Efficiency Solid-State Dye-Sensitized Solar Cells *Advanced Materials* **25** 35 4893-4897
[4] Niu H, et al 2014 Dye-sensitized Solar Cells Employing a Multifunctionalized Hierarchical SnO_2 Nanoflower Structure Passivated by TiO_2 Nanogranulum *The Journal of Physical Chemistry C* **118** 7 3504-3513

[5] Thapa A, et al 2014 TiO_2 Coated Urchin-like SnO_2 Microspheres for Efficient Dye-sensitized Solar Cells *Nano Research* **7** 8 1154-1163
[6] Lv H, Xiaowei Y and Can C 2017 Enhancing the Photovoltaic Performance of Dye-sensitized Solar Cells by Modifying TiO_2 Photoanodes with Layered Structure g-C3N4 *AIP Conference Proceedings* **1820** 1
[7] Dongre J K 2017 A Comparative Study on the CDS Sensitized and Dye-sensitized ZnO Photoelectrodes Based on Solar Cell Performance *IJAR* **3** 3 504-507
[8] Abdalla J T, et al 2017 $TiCl_4$ Surface-treated SnO_2 Photoanodes for Self-powered UV Photodetectors and Dye-sensitized Solar Cells *Materials Technology* **32** 7 443-450
[9] Samsuri S A M, et al 2017 Influence of ZnO Growth Temperature on the Performance of Dye-sensitized Solar Cell Utilizing TiO_2-ZnO Composite Film Photoanode *Ionics* 1-12
[10] Ahmad I, et al 2014 Carbon Nanomaterial Based Counter Electrodes for Dye-sensitized Solar Cells *Solar Energy* **102** 152-161
[11] Zheng M, et al 2015 Flowerlike Molybdenum Sulfide/Multi-walled Carbon Nanotube Hybrid as Pt-free Counter Electrode Used in Dye-sensitized Solar Cells *Electrochimica Acta* **173** 252-259
[12] Ma J, et al 2014 3 D Single-Walled Carbon Nanotube/Graphene Aerogels as Pt-Free Transparent Counter Electrodes for High Efficiency Dye-Sensitized Solar Cells *ChemSusChem* **7** 12 3304-3311
[13] Arbab A A, et al 2017 A Complete Carbon Counter Electrode for High Performance Quasi Solid State Dye Sensitized Solar Cell *Journal of Power Sources* **343** 412-423
[14] Parisi A, et al 2017 Anomalous Performance Enhancement Effects in Ruthenium-based Dye Sensitized Solar Cells *Clean Electrical Power (ICCEP) 2017 6th International Conference on* IEEE
[15] Parisi A, et al 2017 Electro-optical Characterization of Ruthenium-based Dye Sensitized Solar Cells: A study of light soaking, ageing and temperature effects *Optik-International Journal for Light and Electron Optics* **135** 227-237
[16] Nagarajan B, et al 2017 Novel Ethynyl-pyrene Substituted Phenothiazine Based Metal Free Organic Dyes in DSSC with 12% Conversion Efficiency *Journal of Materials Chemistry A* **5** 21 10289-10300
[17] Chiu K Y, et al 2017 A New Series of Azobenzene-bridged Metal-free Organic Dyes and Application on DSSC *Dyes and Pigments* **146** 512-519
[18] Kalyanasundaram K and Grätzel M 1998 Applications of Functionalized Transition Metal Complexes in Photonic and Optoelectronic Devices *Coordination chemistry reviews* **177** 1 347-414
[19] Lim A, et al 2016 Co-dominant Effect of Selected Natural Dye Sensitizers in DSSC Performance *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **167** 26-31
[20] Jinchu I, et al 2016 Photovoltaic Parameters of DSSCs Using Natural Dyes with TiO_2 Nanopowder and Nanofiber as Photoanodes: A Comparative Study *Electrical, Electronics, and Optimization Techniques (ICEEOT) International Conference on* IEEE
[21] Teoli F, et al 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* **316** 24-30
[22] Sathyajothi S, Jayavel R and Dhanemozhi C A 2017 The Fabrication of Natural Dye Sensitized Solar Cell (DSSC) Based On TiO_2 Using Henna And Beetroot Dye Extracts *Materials Today: Proceedings* **4** 2 668-676
[23] Yoon S J, et al 2016 Deprotonated Curcumin as A Simple and Quick Available Natural Dye for Dye Sensitized Solar Cells *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* **38** 2 183-189
[24] Abdel-Latif M S, El-Agez T M, Taya S A, El-Ghamri H S and Batniji A Y 2015 Dyes Extracted

from Biota orientalis, Piper nigrum, and Glycyrrhiza glabra as Photosensitizers for Dye-Sensitized Solar Cells *International Journal of Renewable Energy Research (IJRER)* **5**(4) 1034-1040

Hayat_2018_J._Phys.-_Conf._Ser._979_012062_2.pdf

ORIGINALITY REPORT

%28	%14	%20	%20
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Brawijaya Student Paper	%9
2	Nyanda Madili, Alexander Pogrebnoi, Tatiana Pogrebnaya. "Theoretical Design of Complex Molecule via Combination of Natural Lawsone and Synthetic Indoline D131 Dyes for Dye Sensitized Solar Cells Application", Computational Chemistry, 2018 Publication	%3
3	Morimoto, Takuya, Naotaka Fujikawa, Yuhei Ogomi, Shyam S. Pandey, and Shuzi Hayase. "Parametric Optimization of Experimental Conditions for Dye-Sensitized Solar Cells based on Far-red Sensitive Squaraine Dye", Journal of Physics Conference Series, 2016. Publication	%3
4	ds.lib.kyutech.ac.jp Internet Source	%2
5	www.scribd.com Internet Source	%1

6	Submitted to Universiti Malaysia Sabah Student Paper	%1
7	Submitted to Universiti Malaysia Kelantan Student Paper	%1
8	Anders Hagfeldt, Gerrit Boschloo, Licheng Sun, Lars Kloo, Henrik Pettersson. "Dye-Sensitized Solar Cells", Chemical Reviews, 2010 Publication	%1
9	aip.scitation.org Internet Source	%1
10	www.ijrer.org Internet Source	%1
11	www.mdpi.com Internet Source	%1
12	pt.scribd.com Internet Source	%1
13	vdocuments.site Internet Source	%1
14	Submitted to Chungnam National University Student Paper	<%1
15	link.springer.com Internet Source	<%1
16	Mozhgan Hosseinnezhad, Kamaladin Gharanjig, Siamak Moradian, Mohammad Reza Saeb. "In	<%1

quest of power conversion efficiency in nature-inspired dye-sensitized solar cells: Individual, co-sensitized or tandem configuration?", Energy, 2017
Publication

---

17 "Advances in Solar Energy Research", Springer Nature America, Inc, 2019 <%1
Publication

---

18 Submitted to Yogi Vemana University, Vemanapuram <%1
Student Paper

---

19 www.tandfonline.com <%1
Internet Source

---

20 S. Sathyajothi, R. Jayavel, A. Clara Dhanemozhi. "The Fabrication of Natural Dye Sensitized Solar Cell (Dssc) based on TiO 2 Using Henna And Beetroot Dye Extracts", Materials Today: Proceedings, 2017 <%1
Publication

---

21 Soner Çakar, Mahmut Özacar. "The effect of iron complexes of quercetin on dye-sensitized solar cell efficiency", Journal of Photochemistry and Photobiology A: Chemistry, 2017 <%1
Publication

---

22 Brennan, Bradley J., Yick Chong Lam, Paul M. Kim, Xing Zhang, and Gary W. Brudvig. "Photoelectrochemical cells utilizing tunable <%1

corroles", ACS Applied Materials & Interfaces
Publication

23	Submitted to Indian Institute of Technology, Madras Student Paper	<1%
24	W MA, T HORIUCHI, C LIM, H OKAMOTO, Y HAMAKAWA. "Optimum design and its experimental approach of a-Si/ /poly-Si tandem solar cell", Solar Energy Materials and Solar Cells, 1994 Publication	<1%

EXCLUDE QUOTES	ON	EXCLUDE MATCHES	< 5 WORDS
EXCLUDE BIBLIOGRAPHY	ON		