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Dye-Sensitized Solar Cell Using Natural Dye Extracted from Damakase (Ocimum Lamiifolium) and Dambursa (New Plant)

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Abstract: Dye Sensitized solar cells were made using two locally available plants, Damakase (Ocimum lamiifolium) and Dambursa (New plant) used to extract the natural dye. The pigment was extracted using four solvents, ethanol, methanol, 0.1M hydrochloric acids and distilled water. Then to construct the DSSCs indium tin oxide immersed in the natural dye were used asa counter electrode and Nano crystalline ZnO were act as a working electrode, iodide/tri iodide were placed in between as an electrolyte. The absorption peak and its corresponding wavelength were measured, and then by varying the resistance value, the open circuit current and potential was calculated. Finally from the results the fill factor, performance efficiency and the incident photon conversion efficiency (IPCE) were calculated. At the end the calculated value revealed that, a pigment extracted from Dambursa leaf using solvent ethanol have relatively maximum efficiency and current densities with a value of 0.3675 and 0.264mAcm^{-2} respectively.

Keywords: Natural Dye, Solvents, Electrode, Fill Factor, IPCE

1. Introduction

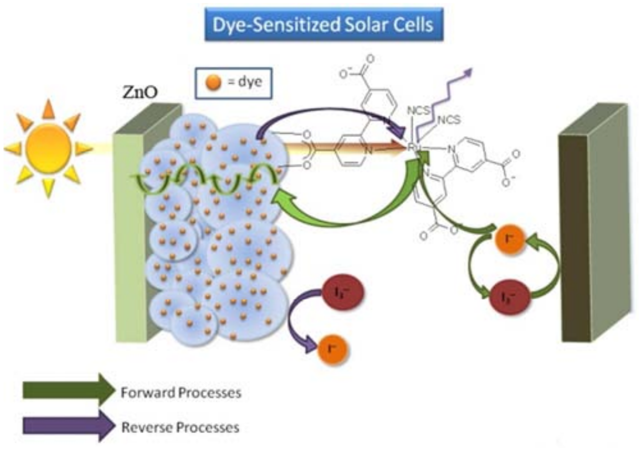
Dye-sensitized solar cell (DSSC) has recently penetrated research and development lines of renewable energy, exploited as a promising concept and simple alternative power source [1]. DSSC offers advantages of low fabrication cost, easy preparation methods, and minimal recombination losses as the role of the semiconductor in the DSSC device is merely to conduct the injected majority charge carriers [2] while the minority carriers are carried by the electrolyte.

Recently, ZnO, with similar band gap to that of TiO_2, appears to be an alternative material for the fabrication of high efficiency DSSCs. A DSSC is composed of a transparent conductive oxide substrate, a wide band gap semiconductor, photosensitizer (dye), a redox electrolyte (usually comprised of iodide/tri-iodide) or p-type semiconductor and a counter electrode [3-6]. Due to their aforementioned unique properties they have been proposed as alternative photo electrodes in DSSCs in order to achieve better performance [7-8]

However, the efficiencies of these cells were found unsatisfactory compared to those of liquid electrolyte. The two main reasons are: the low conductivity of molten salts, organic polymers and polymer electrolytes and bad contact between the dye and ZnO porous film surface and the p-type semi-conductor for solid DSSCs.

1.1. Operational Principle and Structure of DSSC

The dye-sensitized solar cell, DSSC, consist of a photo active working electrode and a counter electrode contacted by a liquid redox electrolyte.



(Source: photochemistry.wordpress.com)

Figure 1. *Schematic illustration of DSSC [9].*

The working electrode is Nano-porous ZnO placed on conducting glass and only separated by a thin layer of electrolyte solution from the counter electrode. The dye is chemisorbed onto the ZnO surface. The counter electrode also made of conducting glass with thin transparent platinum sputtered on to it catalyzes the regeneration process of mediator. Like the chlorophyll in plants, a monolayer of dye molecules (sensitizes) absorbs the incident light, giving rise to the generation of positive and negative charge carriers.

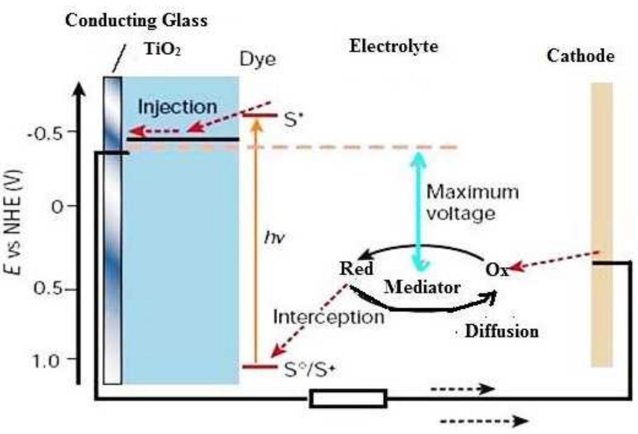


Figure 2. *Schematic diagram of Dye Synthesized Solar Cell of* TiO_2 *[10].*

1.2. The Chemical Reaction Undergoes in the DSSCs

The above diagram clearly indicates that the chemical reactions going in the cell can be [11] summarized as: - [$S=S^o$- the ground state of the dye] [S^*- the excited state of the dye] [S^+- the oxidized State of the dye]

1. Dye is excited by light and the electrons jump to the excited state from the ground state.

$$S + h\nu = S^*$$

2. Electron inject into the conduction band of semiconductor from the dye excited state.

$$S^* = e^- \text{ (in } TiO_2 \text{ conduction Band)} + S^+$$

3. Electrolyte redox couple reaction is

$$S^+ + 3I^- = S + I_3$$

4. Recombination between electrons in TiO_2 conduction band and oxide dye occurs

$$S^+ + e^- \text{ (in } TiO_2 \text{ conduction band)} = S$$

5. Electrons in conduction band conduct to outer circuit

$$e^- \text{ (in } TiO_2 \text{ conduction band)} = e^- \text{ (Back contact)}$$

6. Electrons in nano- crystalline semi-conductor combine with I_3-ions

$$I_3^- + 2e = 3I^-$$

1.3. Current-Voltage Characteristics

The current-voltage characteristics are monitored under illumination by varying an external load from zero load (short-circuit condition) to infinite load (open-circuit condition). The maximum power generated is when the product of the current and voltage is maximum, since the electrical power is given by current (J) times voltage (V), i.e P=JV [12]. The degree of the squared shape of the JV-curve is given by the fill-factor (FF). Taking all those listed parameters into consideration the researcher construct a dye sensitize solar cell using a natural dye.

2. Materials and Methods

2.1. Materials

To achieve the objective of the research electronics beam balance, measuring cylinder, magnetic stirrer, centrifuge to separate liquid dye from residue, to measure absorption spectra UV-Vis Spectroscopy (UV-330), and solvents like Ethanol, Methanol, Distilled water and 0.1M HCl, similarly for extraction of ZnO iodized water, Indium tin oxide (ITO), counter electrode and working electrode were used. Finally Electrochemical analyzer with computer control (Model-CHI-630A) without monochromater were used to analyze Potential Vs Current (V-I) curve, and with monochromataer to measure IPCE%, Iodied/tri iodide used as electron donor, Denver instrument XE-50 to measure mass of dye, drying materials (Compact 1300), twister to pick the absorbed dye and to measure the efficiency of the sample, electrochemical analyzer with computer control together with monochromator, lamp horizon (Model 66182, Ser No, 227, MFD11/94) and Zinc acetate, potassium hydroxide and chloroform to extract ZnO were used.

2.2. Methodology

2.2.1. Extraction of Dye and Measuring the Absorption Spectra of the Dye

Two samples; Damakase leaf (Ocimum lamiifolium) and Dambursaleaf (New plant) were collected from Southern region of Ethiopia, Wolayta Zone, placed in a clean and dry area for twenty five days at room temperature, then grinded using Mortar and pestle to make it powder, then the powder with a mass of 1gm were mixed with the mentioned four solvents and mixed using magnetic stirrer for about 12hr. Finally using centrifuge the residue was separated from the dye.

2.2.2. Preparation of ZnO

To prepare ZnO, dehydrate zinc acetate with 3.35mMol (735.2915mgm) were first dissolved in methanol with 31.25ml solution, then potassium hydroxide solution was added drop wise to zinc acetate solution at 60°C under vigorous stirring. After 1:30hr nanoparticles started to precipitate and the solution becomes turbid, after cooling the solution for 2:00hr, the ZnO particles settled at the bottom and the mother liquid removed. Then the precipitated washed six times with methanol (12.5ml). the precipitate then dispersed in 12.5ml of methanol and 2.5ml chloroform, the dispersed solution were placed in translucent container and allowed to stay for 2 weeks, then it were put in to oven for some times to get powder ZnO. Then to private the formation of ZnO aggregate first 0.1gm of poly ethylene glycol and 5ml distilled water and shacked together for some times, and then placed in hot plate and stirred with magnetic stirrer to mix them. At the end poly ethylene glycol and di iodized water mixed in to ZnO using drop by dropand mix it for several times, and finally pure form of ZnO were prepared.

2.2.3. Preparation of Working and Counter Electrode and Building Dye Sensitized Solar Cell

The ITO with 2.5cm by 1.5cm were covered with ZnO using glass rod then the covered ITO were immersed in to extracted dye for 24hr. and taking quasi solid electrolyte and put in ITO using glass rod which can act as counter electrode. Then the researcher Put the electrode which absorb the dye previously in to ethanol and dried using drying materials. Then after the electrolyte (iodide/tri iodide) placed in between counter electrode and working electrode and bind them together using mastics to get Dye Synthesized solar cell.

3. Result and Discussion

3.1. Absorption Spectra

The absorption spectra of the two leafs in different solvents were measured using UV-Vis spectrophotometer the graph of absorption versus wavelength showed that extracted by ethanol and methanol have relatively good peak than others.

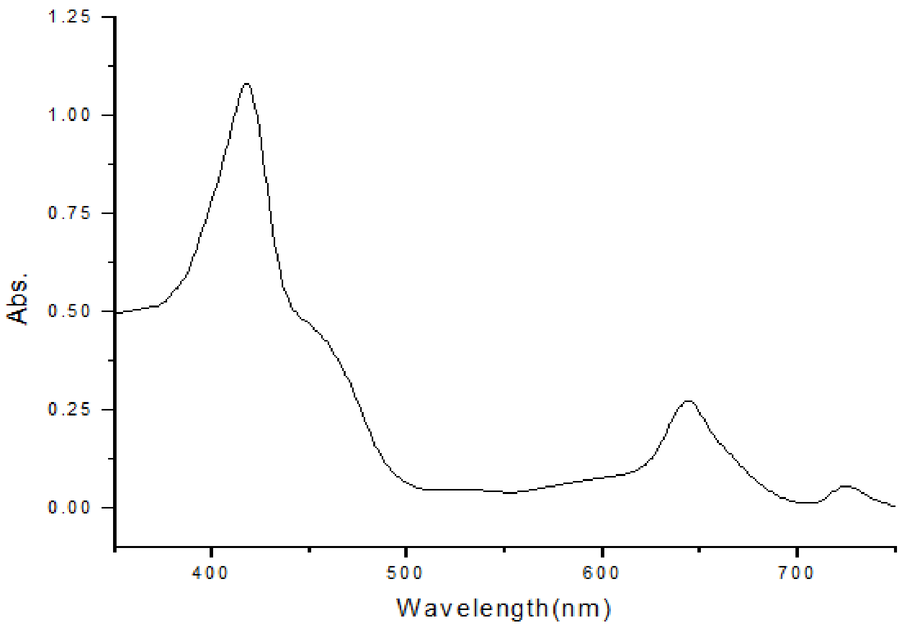


Figure 3. *Damakase (Ocimum lamiifoliu) leaf extracted by Methanol.*

Figure 3 indicates Ocimum lamiifolium leaf extracted by methanol exhibits the maximum peak occurs at the wavelengths of 418nm, 644nm and 725nm with a respective absorption of 1.08096, 0.27212 and 0.05662 respectively. Whereas figure 4 indicates the same leaf (Ocimum lamiifolium) extracted by ethanol exhibits many peaks. Out of the peaks the noticeable three peaks are having a wave length of 432nm, 421nm and 417nm with the respective absorptions of 1.0345, 0.9978 and 0.9985.

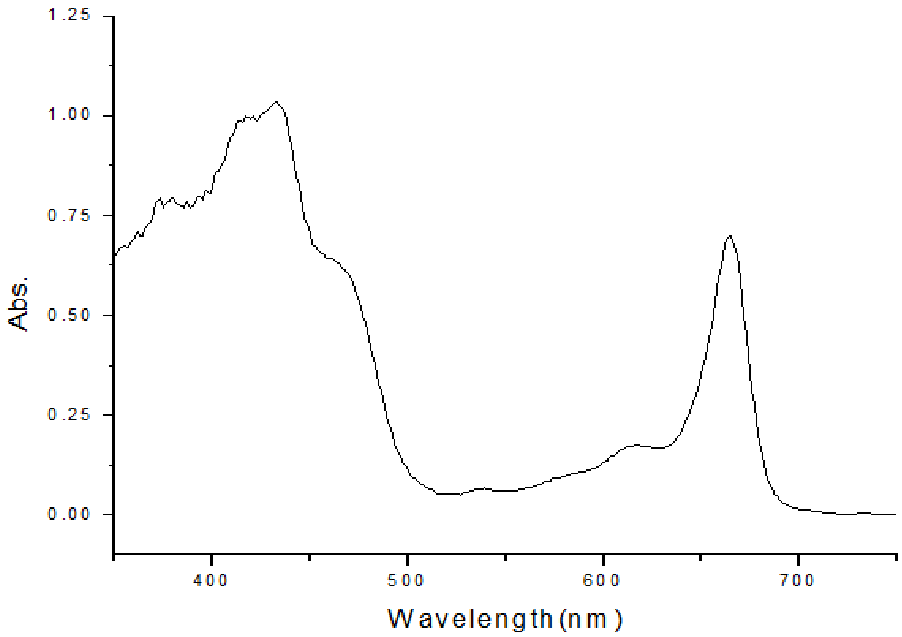


Figure 4. *Damakase (Ocimum lamiifoliu) leaf extracted by Ethanol.*

In the same way the second plant that means Dambursa leaf (New plant) shows maximum peak when it is extracted by methanol and ethanol. That means Dambursa leaf (New plant) extracted by ethanol shows maximum absorption peak at 1.4965, 1.5242, 1.6197 and 1.0128 with a corresponding wavelengths of 413nm, 421nm, 434nm and 644nm respectively. Whereas the Dambursa leaf (New Plant) extracted by methanol exhibit peaks at 418nm and 644nm with a peak absorption of 1.1428 and 0.2577 respectively.

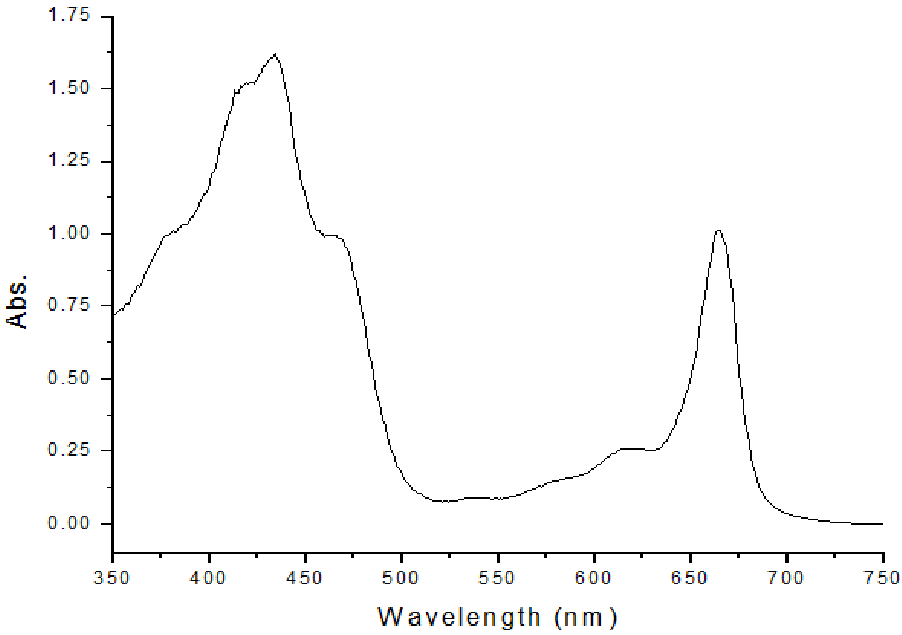


Figure 5. *Dambursa leaf extracted by Ethanol.*

Generally, the absorbed spectra detected by each leafs extracted by different solvents were listed below indicates *(Ocimum lamiifolium)* leaf extracted by distilled water and Dambursa leaf (New plant) extracted by 0.1M HCl indicates no peak absorption spectra.

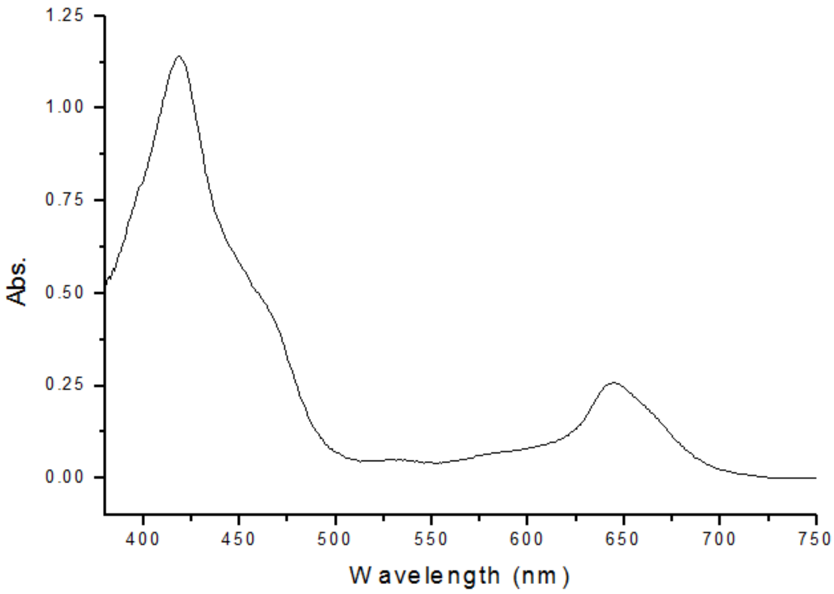


Figure 6. *Dambursa leaf extracted by Methanol.*

Table 1. *Summary of the absorption spectra of dyes of the two plants extracted by different solvent.*

Natural dye extracted from	Extracted by	λ_{max} (nm)
(*Ocimum lamiifolium*) Leaf	Ethanol	472
	Methanol	418
	Distell water	No
	0.1M HCl	667
Dambursa (New Plant) leaf	Ethanol	434
	Methanol	418
	Distell water	676
	0.1M HCl	No

3.2. Current-Voltage Curve

The I-V curve of the cells were measured by setting the resistance at different value and the record voltage, and current I_{sc} obtained at V = 0 and Voc obtained at I = 0. From the results, the research clearly showed that (Ocimum lamiifolium) leaf extracted by ethanol and distilled water has a good potential versus current density curve. That means in the case of the leaf extracted by ethanol, the short circuit current density and open circuit voltage becomes 0.26mAcm^{-2} and 0.38V. Whereas the leaf extracted by water becomes 0.046mAcm^{-2} and 0.36V. And the voltage at maximum power point and current density were obtained 0.22V and 0.151mAcm^{-2} for ethanol and 0.21V with current density of 0.0268mAcm^{-2} for water.

In similar manner for the case of Dambursa (New Plant) leaf extracted by ethanol and water showed a short circuit current density and open circuit voltage of 0.264mAcm^{-2} and 0.35V for ethanol and 0.15mAcm^{-2} and 0.36V for water. At the same time the maximum power were exhibited at a current density of 0.175mAcm^{-2} with a potential of 0.21V for ethanol and a 0.20V with current density of 0.0882mAcm^{-2} for water.

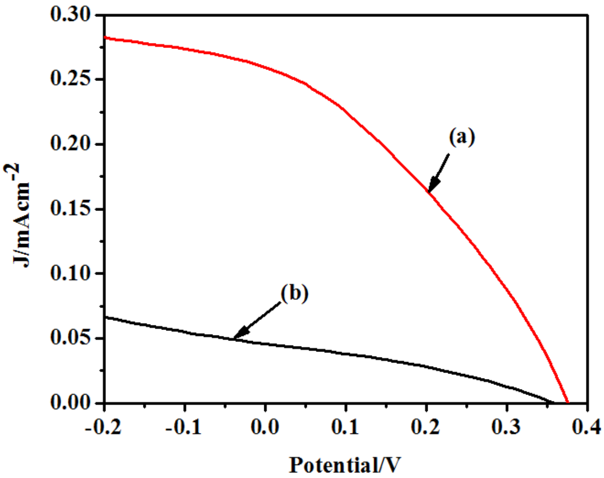


Figure 7. *Voltage Vs Current Density curve of Ocimum lamiifolium Leaf in (a) Ethanol (b) Water.*

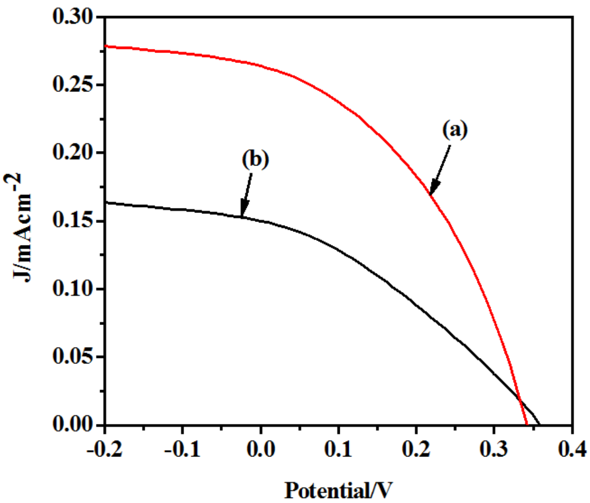


Figure 8. *Voltage Vs Current Density curve of Dambursa (New Plant) Leaf in Ethanol (b) Water.*

3.3. The FF, η, IPCE, of DSSCs

The fill factor (FF) which indicate the degree of squared shape of the current density versus potential, the coefficient of performance (η) which is the efficiency of the solar cell which can be considered in terms of power input and output and the incident photon to current conversion efficiency (IPCE) were calculated using the data collected using the formulas listed below.

$$FF=\frac{I_{mpp} \cdot V_{mpp}}{I_{sc} \cdot V_{sc}}$$

$$\eta = \frac{P_{output}}{P_{input}}$$

and the IPCE can be calculated by

$$IPCE = \frac{(^{h}/_{\lambda})J_{sc(mAcm^{-2})/q}}{P_{in(nwcm^{-2})}} = \frac{1240J_{sc(mAcm^{-2})}}{\lambda(nm)P_{in(nwcm^{-2})}}$$ where his plank constant and c is speed of light

Using the above formula, the maximum power point current density, and potential, the corresponding short circuit current density and its potential were listed in table 2. Whereas the maximum power point current density and its corresponding fill factor, the coefficient of performance and Incident photon to electric current conversion efficiency results are summarized in the table 3 below

Table 2. *Summery of current density and potentials.*

Natural dye extracted from	J_{mpp}	V_{mpp}	$J_{sc}(\frac{mA}{cm^2})$	$V_{oc}(mv)$
(*Ocimum lamiifolium*) leaf Extracted by Ethanol	0.151	0.22	0.26	0.38
(*Ocimum lamiifolium*) leaf Extracted by Water	0.0268	0.21	0.046	0.36
Dambursa Leaf extracted by Ethanol	0.175	0.21	0.264	0.35
Dambursa leaf extracted by water	0.0882	0.2	0.15	0.36

Table 3. *Summery of FF%, coefficient of performance and IPCE.*

Natural dye extracted from	FF%	η%	IPCE%
(*Ocimum lamiifolium*) leaf Extracted by Ethanol	0.33623	0.03322	31.88109
(*Ocimum lamiifolium*) leaf Extracted by Water	0.33986	0.00563	14.2866
Dambursa Leaf extracted by Ethanol	0.39773	0.03675	78.01458
Dambursa leaf extracted by water	0.32667	0.01764	45.3197

4. Conclusion and Recommendation

In this experiment all the extracted dyes using different solvent seems to have a better absorption peak in a visible wavelength region. The absorption peak does not indicate the best coefficient of performance efficiency as well as current density. The final result indicates the larger efficiency for Dambursa leaf extracted by ethanol with a value of 0.39773 and has also relatively larger Jsc with 0.264mAcm^{-2}.

But the experimental result indicates even if the efficiency and current density results found with this experiment are not as such satisfactory, there are potentials in the natural dye to construct a dye sensitize solar cells using natural pigment.

References

[1] B. O'Regan and M. Grätzel, "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films", *Nature*, vol. 353, pp. 737-740, 1991.

[2] G. E. Tulloch, "Light and energy-dye solar cells for the 21st century", *Journal of Photochemistry and Photobiology A: Chemistry*, vol. 164, pp. 209-219, 2004.

[3] G. G. G. M. N. Hemamali and G. R. A. Kumara, "Dye-sensitized solid state solar cells sensitized with natural pigment extracted from the grapes", *International Journal of Scientific and Research Publications,* vol. 3, pp. 1-3, 2013.

[4] S. Rani, P. Suri, P. K. Shishodia, and R. M. Mehra, "Synthesis of nanocrystalline ZnO powder via sol-gel route for dye-sensitized solar cells", *Solar Energy Materials & Solar Cells*, vol. 92, pp. 1639-1645, 2008.

[5] D. -I. Suh, S. -Y. Lee, T. -H. Kim, J. -M. Chun, E. -K. Suh, O.-B. Yang and S. -K. Lee, "The fabrication and characterization of dye-sensitized solar cells with a branched structure of ZnO nanowires", *Chemical Physics Letters*, vol. 442, pp. 348-353, 2007.

[6] K. Keis, E. Magnusson, H. Lindström, S. -E. Lindquist, and A. Hagfeldt, "A 5% efficient photoelectrochemical solar cell based on nanostructured ZnO electrodes", *Solar Energy Materials & Solar Cells*, vol. 73, pp. 51-58, 2002.

[7] C. Zeng, S. Xie, M. Yu, Y. Yang, and X. Lu, Facile synthesis of large-area CeO_2/ZnO nanotube arrays for enhanced photocatalytic hydrogen evolution, ‖*J. Pow. Sour.*, vol. 247, pp. 545-550, February 2013.

[8] N. H. Alvi, M. U. Ali, S. Hussain, O. Nur, and M. Willander, ―Fabrication and comparative optical characterization of n-ZnO nanostructures (nanowalls, nanorods, nanoflowers and nanotubes)/p-GaN white-light-emitting diodes, ‖ *Scr. Mater.*, vol. 64, pp. 697-700, April 2011.

[9] Ashenafi Belete, Dye sensitized solar cell using natural Pigment, Maters Thesis (Unpublished), 2012.

[10] Michael Gratzel, Review Dye-sensitize solar cells, Elsevier, Journal of photochemistry and photobiology, 4 (2003) 145-153.

[11] G. P. Smestad, “Education and solar conversion: Demonstrating electron transfer”, *Solar Energy Materials and Solar Cells*, vol. 55, pp. 157-178, 1998.

[12] Khwanchit Wongcharee, Vissanu Meeyooand Sumaeth Chavadej, Dye-sensitized solar cell using natural dye extracted from rossela and blue pea flowers, Elsiver, B. V, 2006.