International Journal of Photochemistry and Photobiology
2021; 5(1): 1-6
http://www.sciencepublishinggroup.com/j/ijpp
doi: 10.11648/j.ijpp.20210501.11
ISSN: 2640-4281 (Print); ISSN: 2640-429X (Online)

Building a Solar Panel for Electricity Generation in the Fabrication of Dye Sensitized Solar Cell

Ezeh Marian Isioma[1, *], Okujagu Charity Ukpok-awaji[2], Ezema Fabian Ifeanyichukwu[3]

[1]Department of Physics, Delta State University, Abraka, Nigeria

[2]Department of Physics, University of Port-Harcourt, Rivers, Nigeria

[3]Department of Physics and Astronomy, University of Nigeria, Nsukka, Nigeria

Email address:

ezehmiriam@gmail.com (E. M. Isioma.), charityokujagu@gmail.com (O. C. Ukpok-awaji),
Fabian.ezema@unn.edu.ng (E. F. Ifeanyichukwu)

[*]Corresponding author

To cite this article:

Ezeh Marian Isioma, Okujagu Charity Ukpok-awaji, Ezema Fabian Ifeanyichukwu. Building a Solar Panel for Electricity Generation in the Fabrication of Dye Sensitized Solar Cell. *International Journal of Photochemistry and Photobiology*. Vol. 5, No. 1, 2021, pp. 1-6.
doi: 10.11648/j.ijpp.20210501.11

Received: November 18, 2020; **Accepted**: December 15, 2020; **Published**: March 10, 2021

Abstract: Dye sensitized solar cell have been fabricated since 19191 till date. In the previous year's seven cells were fabricated and arranged in series to build a solar module for electricity generation under which 2.0 volt diode bulb was lightened. Further study was carried out here where the electrolyte was improved upon using potassium iodide with F- centre factor that enhances light harvesting but in the course of the study the fabricated DSSCs exhibited in stability due to the delay in carrying out the I-V characteristics. Three of these dye sensitized solar cells were successfully fabricated using natural dye from Laali stem bark (Isoplumbagin) dye as sensitizer, with two metallic composition titanium doxide/ Zinc oxide (TiO_2/ZnO) on Flourine doped tin oxide as the substrate which comprises of the Anode or electrode and carbon soot as the counter electrode or the cathode. These three DSSCs were arranged in series to build a solar panel. From the results obtained, Current-voltage characteristics showed that current was 0.03A and voltage 2.0 m A with power output 0.06k watt and the curve showed a forward bias pattern as with the case of a diode. From the pattern of the curve showed that the DSSCs deviated from cells that display efficiency to a diode that operates with the PN theory.

Keywords: Panel, Anode, Dye, Sensitizer, Carbon Soot, cathode, Fabrication

1. Introduction

Dye sensitized solar cell is the 3rd generation solar cell where silicon germanium sensitizers are replaced with natural dyes being extracted from plants. In the fabrication process dyes from locally available plant are extracted and it serves as the sensitizers, metallic oxides such as zinc oxide increases wider surface of absorptivity. An ideal dye sensitized solar cell comprises of a substrate, electrode and counter electrode this is as shown in figure 1 below. Dye sensitized solar cell was first fabricated in the year 1991, where Gratzel won a noble prize [1]. Since then various sensitizers-plants have been sourced to fabricate DSSC. From 2013, students have fabricated a lot of DSSCs but had not been able to built panel for electricity generation [2]. In 2014, some students from the department of Physics Delta State University, Abraka fabricated seven DSSCs using tomatoes fruit and zobo leaves [3-7]. While in the year 2015 another group of students arranged these cells in series to build a solar panel in which seven cells arranged in series was able to light up a diode bulb. In which the built solar module of 2.79 V was used to power a 2.0V LED bulb like that of the Christmas tree [8]. Since two edible dyes were used, this work looked to the fact that non-edible dye can be used for this purpose. Along the processes, there was a delay in carrying out the current voltage characteristics of the cells fabricated and so the conductivity properties were affected which is part of the limitation in this study. The natural dyes chosen for this work is Isoplumbagin dye from Laali stem bark, which have been studied previously for the fabrication of DSSC cells [9]. Dye-sensitized solar cells (DSCs) are well researched globally due to their potential to be a low-cost photovoltaic (PV) device, especially suited for building and automobile integrated PV and portable or indoor light harvesting applications. Large monetary and intellectual investments for developing them into a deployable technology created a wealth of knowledge on nano-interfaces and devices through an increasing numbers of research reports since 1991 [1]. In response to those investments, the dawn of the new millennium witnessed the emergence of a corporate sector on DSCs. Advances in their device designs, their incorporation on flexible substrates, development of solid state modules, enhanced stability under outdoor exposure, and the advancements in their scalable fabrication tools and techniques elevated the DSCs from laboratory to real-life applications [10]. Although the long term stability problem is yet to be address fully, the already fabricated cells can be arranged into a solar module for light-harvesting system. One of the major limitations in this study is the volarity of the liquid Electrolyte Potassium Iodide. When left for a long time depreciate but was for its F-factor characteristics which enhances light harvesting. In this study, therefore DSSCS will be fabricated using Laali stem bark as the sensitizers and to ascertain its structural properties and build DSSC solar module for electricity generation. For every solar cell you assemble, you will need an anode and a cathode. The anode will contain the dye and titanium dioxide molecules. Photons will excite the dye molecules' electrons, and the electrons will jump from the dye molecule to the titanium dioxide to the glass anode through diffusion. The electrons will subsequently travel through a circuit that connects the two electrodes and return to the cell through the glass cathode. To complete the circuit, an interstitial electrolyte solution facilitates the flow of electrons back to the anode's organic dye molecules [13]. Since emphasizes is laid on improving the voltage the DSSCs were connected in series. In reference [14] it was established that Anode or electrode thickness and annealing temperature have significant effect on the energy conversion of the dye sensitized solar cells. Furthermore in reference [15] a work was carried out on the mechanism of thermal stability of an electronic device (diode) to know how temperature change affects semiconductor device. Actually it was observed that indeed temperature increases between the regions of 300C and 650C which affects the component output parameters like the output voltage and current. Reference [10] in 2014 studied the perspective of building a solar module and Eko in 2015 actually built a solar module which was observed to light up a 2.0 volt LED Diode bulb at 2.79 volt under high intensity from the sun [8]. These achievements were the background for this study. Comparing with the latter, the built solar module achieved 2.0Volt, 0.03mA and a power of 0.06 watt with three cells arranged in series. This study experiences set back due to its limitations. The study in 2015 lighted 2.0 V LED diode bulb at 2.79 V solar module but this study could not achieve that reasons being that: the dye sensitized solar cells were left for six month before characterization, three dye sensitized solar cells as against seven cells were used to build the solar module.

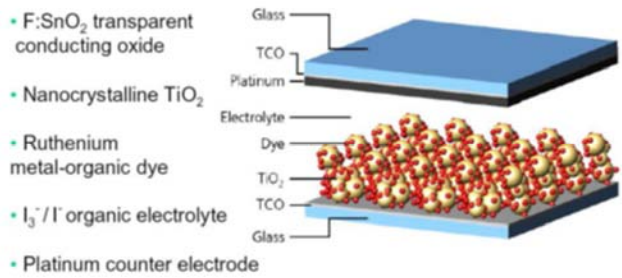


Figure 1. *A typical structure of a dye sensitized solar cell source: [1].*

2. Materials

These materials are sourced locally from the environment [13]

1) Dyes (Isoplumbagin)
2) TCO glass (Fluorine doped tin oxide FTO)
3) Two metallic oxides (Zinc Oxide ZnO and Tiatanium dioxide TiO_2)
4) Hand gloves/Hand spray
5) Weighing balance
6) Paper cellotape
7) Thermometer
8) Chemicals (Acetone, Liquid Electrolyte)
9) Oven dryer
10) Hot oven
11) Digital multimeter
12) Transparent Perplex glass/White Aluminum
13) Driller
14) Connecting wires
15) White gum
16) Candle/lighter/clip

2.1. Laali (Isoplumbagin) Dye

The Laali stem bark, the extracted solution and the chemical structure are shown below.

(a) (b) (c)

Figure 2. *Laali stem bark, its Solution and Chemical structure of Isoplumbagin dye source: [11].*

2.2. Method

2.2.1. Fabricating the Dye Sensitized Solar Cells

Isoplumbagin dye was extracted from the stem bark as shown in figure 2 (a) using simple extraction method and the solution placed in a beaker as shown in figure 2 (b). A plain glass slide was place inside using chemical bath method to deposit the dye. Thereafter a separate ZnO/dye solution was prepared and glass slide inserted, after about three days there was adhesion of the solution thereby showing thin film. In order to fabricate dye sensitized solar cell for electricity generation. The physiochemical structure of Laali dye is as shown in figure 2 (c). One of the TCO glasses was fluorine doped tin Oxide FTO was used picture is as shown in figure 3. It was sterilized before using, to avoid impurities.

Figure 3. *FTO glasses.*

Two metallic oxides were used: Titanium oxide and Zinc Oxide, both were prepared in the lab and ready for use in its liquid state. In fabricating the cells, the already prepared titanium oxide was deposited on the FTO glass using screen printing method and annealed at 400oC then left to cool down thereafter, the already prepared ZnO solution was sprayed over it using a manual hand spray and annealed at 400°C. The already prepared Laali solution was deposited on it using syringe drop by drop and annealed at 400°C. The Electrode or anode is ready for coupling. The other pair of the FTO glass is placed over a burning candle and the soot which serves as counter electrode or cathode is evenly distributed. Both are sandwiched with an electrolyte solution Potassium iodide for electrical alertness. The fabricated DSSCs are as shown in figure 4 and ready for the building of the solar module.

Figure 4. *Fabricated dye sensitized solar cells.*

2.2.2. Building the Solar Module Procedure

The following procedure was considered in assembling the fabricated dye sensitized solar cells in series: [13]

1) Cut the Perspex glass to size depending on the number cells in place
2) Use an aluminium sheet to make corners
3) Use top band gum to make a rectangular bottom then drill hole on both ends
4) Pad the bottom with white sheet of paper then place the cells in series
5) Use a foil paper to hold the wires in place
6) Couple it by place a cover then leave in the sun to dry.
7) Ready for testing and readings.

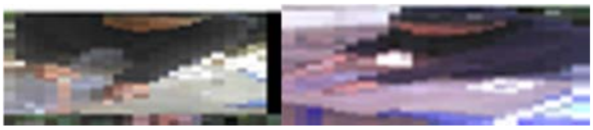
Note that the solar module was built with series connection of the fabricated dye sensitized solar cells

A digital multimeter is used to measure the amount of potential difference passing through the connecting wires inside the panels and the module

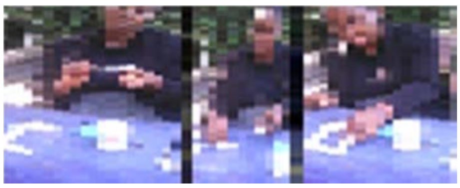
The relation I=V/R is used to ascertain the current within the panel and a table of values of Ambient temperature, Interval Time of 10minutes, Resistance, Potential difference (Voltage) and current will be achieved and a plot of Current versus Voltage.

2.2.3. The Building of the Dye Sensitized Solar Module

Having successfully fabricated the dye sensitized solar cell, these three cells were arranged in series. Reference [13] a simple method was followed in building a module which was employed in this study as listed above and the stages is observed in figure 5. In the first stage, perplex transparent glass was cut to a square size a pair figure 5 (a) and then two holes were drilled at both ends where the positive and negative wire can be inserted as in figure 5 (c). A four corner was cut and glued to the four sides of the squared perplex transparent glass as in figure 5 (a) and (b). A white sheet of paper was placed at the base to put the cells in place as seen in figure 5 (d). The polarities of the cells were tested and wires inserted positive to negative using foil paper to hold the wires to the cells, arranged in series as shown in figure 5 (e). Figure 5 (g) shows the three DSSCs arranged in series. Furthermore the sides are covered with the white aluminum sheet as shown in figure 5 (h) and the other pair of the perplex glass placed on top and the solar module is ready for testing as shown in figure (i). Figure 6 showed the digital multimeter used to measure the current and voltage of the solar module and a prototype solar module is placed side by side.



(a) Cutting the perplex glass (base and cover) and aluminum sides



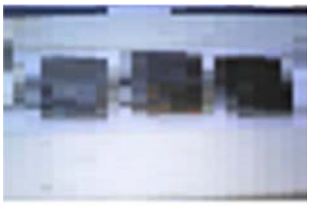
(b) Building the sides by using white gum

(c) Drilling a hole at the bottom for the wire

(d) Putting a white plain sheet of paper to sit the cells

(e) Passing a wire through the drilled hole

(f) Testing for polarity and placing the wires positive to negative (using foil paper to hold it in place)



(g) The DSSCs connected in series

(h) The sizes are placed on the base using white gum

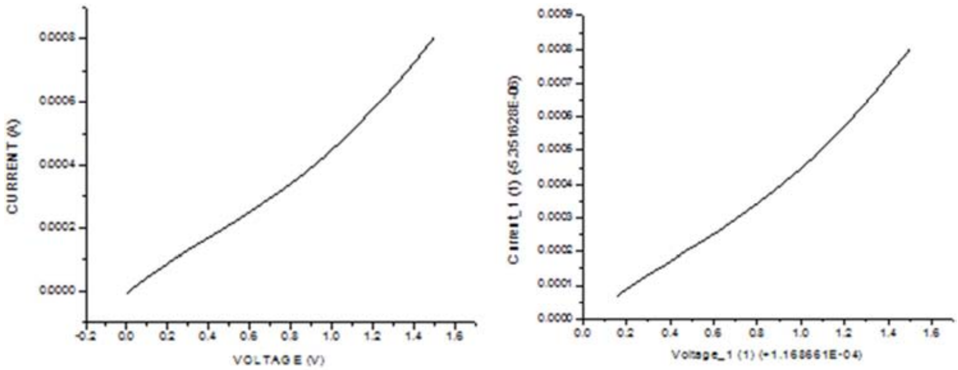
(i) The top perplex glass have been placed and solar module ready

Figure 5. *Assembling the DSSCs as solar panel.*

Figure 6. *The multimeter side by side with the fabricated solar module and a prototype conventional solar module as testing was in progress.*

3. Testing

The current, voltage measurements were obtain using digital multimeter under luminance for both the individual cell and the solar module.



Light

Dark

Figure 7. *I-V Curve of FTO/TiO_2/ZnO/Laali dye sensitized solar cell (Under Luminescence and dark).*

Table 1. *FTO/Laali dye sensitized solar module.*

Time (mins)	Time (s)	Temperature (°C)	Voltage (mV)	Resistance (10^6 ohms)	Current (A) ($X10^{-3}$)	Power x 10^{-6} (watt)
2:10pm	600	43	2.0	64.5	0.03	0.060
2:20pm	1200	43	1.2	58.8	0.02	0.024
2:30pm	1800	40	0.6	38.4	0.02	0.012
2:40pm	2100	41	0.5	35.1	0.01	0.010
2:50pm	2700	42	0.3	26.3	0.01	0.003
3:00pm	3300	39	0.2	15.8	0.01	0.002
3:10pm	3900	39	0.1	11.5	0.08	0.008

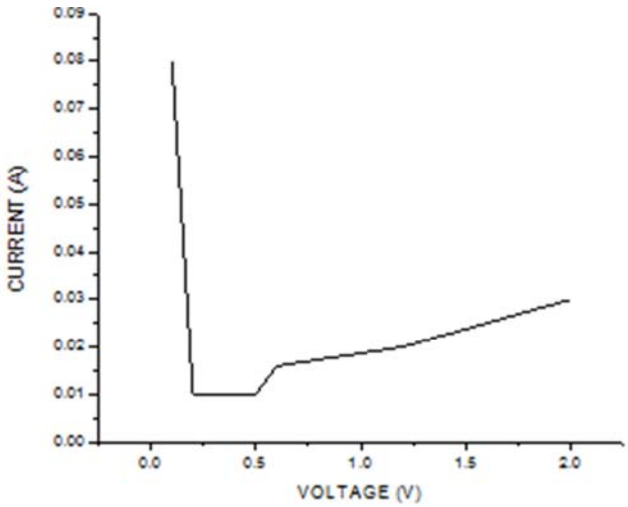


Figure 8. *I-V Curve of FTO/Laali module.*

3.1. Discussion

Figure 6 shows a prototype solar cell module which formed the basis of this study side by side with the fabricated solar module. In figure 7 the curve did not start exactly at zero likewise, that of FTO/TiO_2/ZnO/Laali showed a forward bias both under light and dark while FTO/Laali module showed a reverse bias at the positive axis instead of the negative figure 8. According to reference [16], when a diode is connected in a forward Bias condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material. If this external voltage becomes greater than the value of the potential barrier, approximately 0.7 volts for silicon and 0.3 volts for germanium, the potential barriers opposition will be overcome and current will start to flow. Although this was attain exactly as shown in table 1, but the barrier was overcome which is the reason for the flow of current in the solar module. Likewise from the graph in figure 8, the application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedance path through the junction thereby allowing high current to flow. The point at which this sudden increase takes place as represented in the I-V characteristics curve above (figure 8) at the knee point is 0.25 volts.

3.2. Limitation of Study

In the previous dye sensitized solar module built by the students in the year 2015, the current-voltage characteristics was carried out immediately which retain the activeness of the electrolyte on the cells. But with this study the current voltage characteristics was not carried out immediately due to the national strike embarked upon by the Researchers most especially the Engineering material development Institute, Akure Ondo state.(EMDI). This delay was for six months so as at the time it was taken for the analysis the electrolyte was no longer active and so the current and voltage was very low to power a LED diode bulb. However, a measure of current and voltage was observed but too low.

4. Conclusion

Arranging cells in series actually improves the voltage as seen in the results voltage was higher than the current. The materials used were at low cost which makes it advantageous over the traditional solar cells. Although this objective was not achieved due to the limitations the current-voltage curve showed a forward bias which is a characteristic of a diode both for the DSSCs and DSSC solar module and it agrees with Rayleigh's scattering theorem in optics. Due to its stability problems it would not issue out electricity as long as twenty years plus as would the traditional PV solar cells. This fabricated dye sensitized solar module showed an output power of 0.06 watt.

Acknowledgements

Profound appreciation goes to the staff of solar Laboratory University of Nigeria, Nsukka and staff of Engineering Material Development Institute Akure for their tireless support. Likewise to the scholarship body (ETF) for their financial support for the successful completion of this study.

References

[1] O'Regan B and Gratzel M (1991) A low-cost high efficiency solar cell based on dye-sensitized colloidal TiO_2 films Nature, 353: 737-740.

[2] Ezeh, M. I, Osuji R. U, Azi S. O and Egwuanunkwu D (2013) Comparison between the performance of Anthocaynin dye with Methythionium *Journal of Nigerian Association of Mathematical Physics* 24: 365-370.

[3] Eyekpegha O. F and Ezeh M. I (2014) Comparative Study between Zobo and Tomato Dye on the Fabrication of Dye Sensitized Solar Cell Using ITO/TiO_2/ZnO/Dye-Sensitized Proceedings of the 1st African International Conference/Workshop on Applications of Nanotechnology to Energy, Health and Environment, UNN, March 23 – 29, 2014, 38-46.

[4] Ezeh, M. I, Osuji, R. U and Ogbe E. J (2014) Fabrication of dye sensitized solar cell using FTO/TiO_2/Anthocyanin dye/ZnO *Nigerian Journal of Physics*. 25 (2): 107-116.

[5] Ezeh, M. I, Eyekpegha O. F and Mayiko O. L (2014) Fabricaion of dye sensitized solar cell using ITO/TiO_2/ZnO/Tomato dye natural dye sensitized *Journal of Nigerian Association of mathematical Physics* 27 (1): 341-346.

[6] Ezeh M. I, Dare, E. O and Eyekpega O. F (2014) Improving the efficiency and the long term stability of a dye-sensitized solar cells Proceedings of the 1st International workshop on Renewable Energy for sustainable Development in Africa (IWRESDA). 55-66.

[7] Ejuwevwo, S. O (2014) Comparision oF FTO/ITO and Lycopene/Anthocaynin dye doped ZnO and TiO_2 in the fabrication of dye sensitized solar cell (unpublished thesis).

[8] Eko, O. J, Omaghomi J, Madaugwu E. N, Oviosu C. U, Ogbuigwe S and Asunbye M. S (2015) Contruction of a solar Panel using locally available materials. Unpublished Thesis.

[9] Wasui B. A, Enock O. D, Damilola A. B, Samson O. A, Fatai O. O, Bukola O. B, Ezeh M and Osuji R. U (2017) "Dye-Modified ZnO Nanohybrids: Optical properties of the potential Solar Cell Nanocomposities" International Nanoletters Saudi. 7 (3): 171-179.

[10] Azhar F, Rajan J, Thomas M. B, Francisco F. S and Juan B (2014) A perspective on the production of dye sensitized solar module *Journal of Energy and Environment* 12: 1-72.

[11] Boyo O, Boyo O, Abdusalam T and Adeola S. (2012) Dye sensitized nanocrystaline titania solar cell using Laali stem bark (lawsonia inermis). *Transnational Journal of Science and Technology* 2: 60-68.

[12] Sanghoon Yoon, Sehyun T, Jinsoo K, Yongseok J, Kisuk K and Jiyoung P (2011) Application of transparent dye sensitized solar cells to build integrated Photovoltaic System Journal of building and Environment 46: 1899-1904.

[13] Philip Hurley (2006) Build your own solar panel Revised and expanded.

[14] Kamrul A. K (2017) Impact of Photo electrode thickness and annealing temperature on natural dye sensitized solar cell Sustainale Energy Technologies and Assessments Elsevier.

[15] Odike O. C and Sigalo F. B (2018) The mechanism of thermal staticstical of an electronic device (Diode) *Journal of scientific and Engineering Research* 5 (5): 131-138.

[16] Young, A. T. (2007). Rayleigh scattering. *Applied Opt*. 20, 522-535.