Electrical Properties of *Roystonea regia* Fruit Extract as Dye Sensitized Solar Cells

Adenike Boyo, Olasunkanmi Kesinro, Henry Boyo, Surukite Oluwole

Abstract**—**Utilizing solar energy in producing electricity can minimize environmental pollution generated by fossil fuel in producing electricity. Our research was base on the extraction of dye from *Roystonea regia* fruit by using methanol as solvent. The dye extracts were used as sensitizers in Dye-sensitized solar cell (DSSCs). Study was done on the electrical properties from the extracts of *Roystonea regia* fruit as Dye-sensitized solar cell (DSSCs). The absorptions of the extracts and extracts with dye were determined at different wavelengths (350-1000nm). Absorption peak was observed at 1.339 at wavelength 400nm. The obtained values for methanol extract *Roystonea regia* extract are, I_{mp} = 0.015mA, V_{mp} = 12.0mV, fill factor = 0.763, I_{sc}= 0.018 mA and V_{oc} = 13.1 mV and efficiency of 0.32%. .The phytochemical screening was taken and it was observed that *Roystonea regia* extract contained less of anthocyanin compared to flavonoids. The nanostructured dye sensitized solar cell (DSSC) will provide economically credible alternative to present day silicon p–n junction photovoltaic.

Keywords**—**Methanol, Ethanol, Titanium dioxide, *Roystonea regia* fruit, Dye-sensitized solar cell.

I. Introduction

THE concept of dye sensitization of wide band gap semiconductors started in 1960s by the work of [1] and [2] together with their co-workers where they used ZnO as the semiconductor and different dyes such as rose bengal as photosensitizer. However, the efficiencies remained low for many years [3].The breakthrough in the field came when [4], [5] presented their results in 1991 with an impressive overall efficiency higher than 7%, using a ruthenium based sensitizer and a porous TiO_2 layer as the semiconductor material [5].

DSSC is a photo electrochemical solar cell [6] made up of four elements, namely, the transparent conducting and counter conducting electrodes, the nanostructured wide bandgap semiconducting layer, the dye molecules (sensitizer), and the electrolyte [7]. The transparent conducting electrode and counter-electrode are coated with a thin conductive and transparent film as shown in Fig. 1

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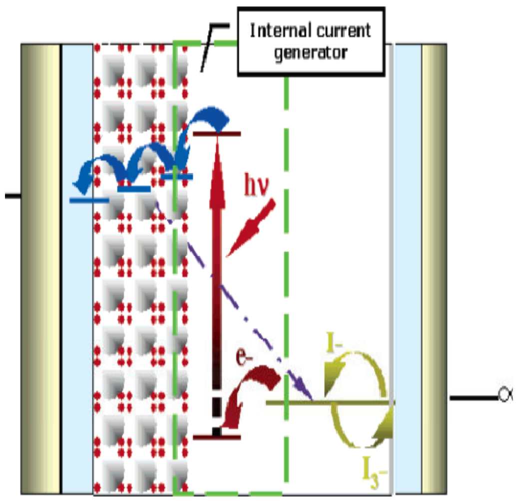

Fig. 1 Dye sensitized solar cell

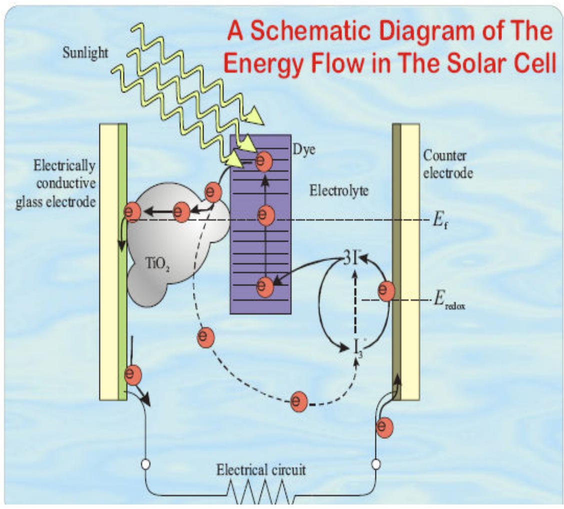

Fig. 2 The Energy flow in the solar cell

In the Energy flow (Fig. 2) of DSSC, an incident light excites electrons within the dye, giving them enough energy to travel in the conduction band of the TiO_2. The electrons flow through the TiO_2 onto the electrode, through an electric circuit, and then to the counter electrode. The electrolyte carries electrons back to the dye from the counter electrode. [8].

Dye + light ® Dye*
- + Dye* + TiO ® 2 e (TiO2) + Dye
- - e (TiO2) + C.E. ® TiO2 + e (C.E.) + energy
- - - ½ I3 + e (C.E.) ® 3/2 I + C.E.

C.E. is the counter electrode and Dye* indicates an excited state of the dye. In overall process, the DSSCs generate electric power from light without suffering any permanent chemical transformation [9].

The interest in DSSC is because it is cost effective –much less expensive than Silicon (p-n junction) solar cell, can be produce using layered coatings on glass and can be produce on flexible substrates. [10]. We are able to produce DSSC by using the dye extracted from *Roystonea regia* fruits which is available in Lagos state, Nigeria and determine the electrical properties of the Dye sensitized solar cell.

Roystonea regia is a large palm, which reaches a height of 20-30 m as shown in Fig. 3. The trunk is stout, very smooth and grey white in colour. The fruits are spheroid to ellipsoid in shape [11]. They are green when immature, turning red and eventually purplish-black as they mature. The seed is used as a source of oil and for livestock feed; leaves are used for thatching and the wood for construction [12]. They are used as treatment for diabetes [13].

Fig. 3 *Roystonea regia*

II. Extraction of Dye from Plants

The Fruits were collected from the banking area at Agbara, Ogun State., Nigeria. They are pulverized and 25g of the pulverized plant was soaked in 250mL of Ethanol and Methanol respectively. The soaked specimens were left for 24 hours and then filtered into labeled reagent bottles. Evaporation was done to separate the solvent with natural extracts. The pH of each extracted dye was recorded. The absorbance of each extracted dye, TiO_2 paste and mixture of each extracted dye with TiO_2 paste was measured from wavelengths of 350nm to 1000nm using a UV-VIS spectrophotometer (Spectrum lab 23A GHM Great Medical England). A phytochemical screening was carried out to determine the level of anthocyanins and flavonoids in the extracts.

III. Deposition of TiO_2 Film

The TiO_2 solution is prepared by the incremental addition of 20mL of nitric acid to 12g of colloidal TiO_2 powder in a mortar while grinding. The ITO (2.5cmx2.5cm) conducting glass was cleaned using methanol and left to dry. A voltmeter is used to check the conductive side of the ITO conducting glass and the reading was between 12 and 20 ohms. Adhesive tape is applied on the conductive side to mask 0.2cm at the four edges and drops of the TiO_2 solution are uniformly spread over the ITO conductive glass plate .The film is allowed to dry in air for five minutes, adhesive tape carefully removed and the film is sintered at 350^oC. The resulting TiO_2 thin film layer has a porous, sponge – like structure that enhances both the light absorption and electron collection efficiency. Another counter electrode is made from ITO conducting glass.

IV. Assembling the Solar Cell Device

The sintered TiO_2 thin film was immersed in the prepared various natural dyes extract. Adsorption of the dye to the surface of TiO_2 is rapid, forming a complex capable of electron injection. The dye stained TiO_2 thin film electrode and the counter electrode were assembled together. An iodide electrolyte solution (0.5M potassium iodide and 0.05M iodine) are then placed at the edges of the plates. The liquid is drawn into the space between the electrodes by capillary action. The completed solar cell electrical properties are then measured.

V. Measurement of the Electrical Properties of the DSSC

An indoor measurement of electrical properties of the solar cell was done by illuminating the cell with 50W, 12V tungsten halogen lamp equipped with integral parabolic reflector as the irradiation source. The current-voltage characteristics were determined by applying an external potential bias to the cell and measuring the photocurrent using a digital source meter.

From the I-V (current-voltage) curve, the following parameters can be obtained:

ISC (Short-circuit current): the cell current measured at an applied potential of 0 V. Isc is a function of the illumination intensity.

VOC (Open-circuit voltage): the cell potential measured when the current is 0 A.

IMP (Maximum power point): the point where the maximum power is generated.

FF (Fill factor): the ratio of the maximum power to the short and open circuit values.

FF = Imp x Vmp /IscxVoc

η (Efficiency): the ratio of the developed power to the light intensity. η = (Isc x Voc x FF)/Pin,

IPCE (Incident Photon-to-current conversion efficiency): the ration of the number of electrons generated in the solar cell to the photon flux on the photoactive surface area of the cell.

VI. Result and Discussion

Fig. 4 shows the representative UV–VIS absorption spectra for the extracts of *Roystonea regia*. The most striking feature that has been observed from this figure is that TiO_2 and TiO_2 with dye extracts have almost the same absorption peak. These indicate a proper chemical reaction between the dye and extract.

Fig. 5 I-V curve for *Roystonea regia* (methanol extract) indoor measurement we notice an erratic behavior in the I-V curve of the cells and this affect the efficiency of the cell.

Fig. 6 shows the X-ray diffraction spectra of the ITO. X-ray diffraction measurements (XRD) are usually used to confirm the formation of nanostructured TiO_2 layer. Analysis of the XRD data confirms the formation of nanocrystalline TiO_2 particles of sizes less than 50 nm [14].

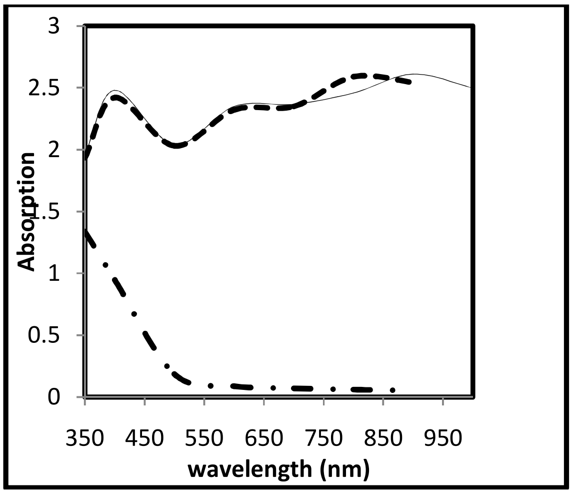

Fig. 4 Absorbance graph of *Roystonea regia* and TiO_2 (---), *Roystonea regia* dye (-.-.-.) and TiO_2 (—)

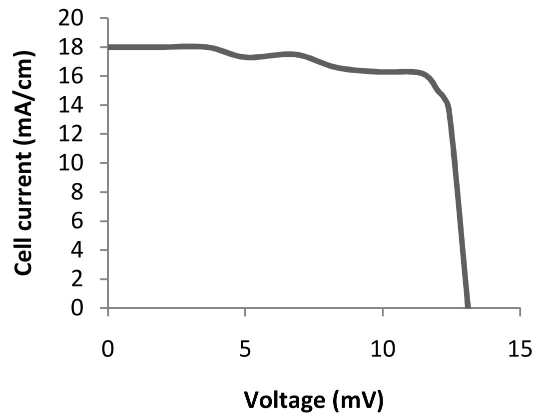

Fig. 5 I-V curve for *Roystonea regia* (methanol extract) indoor measurement

VII. Conclusion

In this research, we have discussed the electrical properties of one example of the third generation solar cells, called nanocrystallinedye sensitized solar cells DSSC [15], [16]. Nanocrystalline dye sensitized solar cell DSSC is classified as a low cost, environmental friendly, and capable of being highly efficient cell mainly due to materials, charge carriers generation and transport within the cell structure. We observed an efficiency of 0.32%. Which is very low and the absorbance of the cell is not in the visible range. All these might be due to the preparation and measurement of the cell electrical parameter. If we can use something other than the binder clips in holding the cell, then loss in the internal resistance of the cell will be reduce.

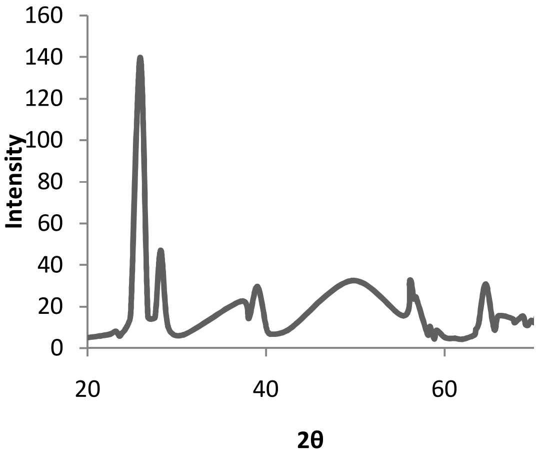

Fig. 6 XRD diffraction pattern of the fabricated in Dye sensitized solar cell

References

[1] H. Gerischer, M. E. Michel-Beyerle, F. Rebentrost, H.Tributsch, "Sensitization of charge into semiconductors with large band gap," Electrochim. Acta, 13(6), pp 1509-1515, 1968.

[2] H. Tsubomura, M. Matsumura, Y. Nomura, T. Amamiya, "Dye sensitized Zinc oxide: aqueous electrolyte platinum photocell, Nature,"261, pp 402, 1976.

[3] J. Desilvestro, M. Grätzel, L. Kavan,J. E. Moser, J. Augustynski, "Highly Efficient Sensation of Titanium Dioxide," J. Am. Chem. Soc. 107 (10),pp 2988-2990, 1985.

[4] M. Grätzel, "Photovoltaic and Photoelectrochemical conversion of solar energy," Philos. Trans. R. Soc. London, 365, pp 993-1005, 2007.

[5] B. O'Regan, M. Gratzel, "TiO- Based photovoltaics," Nature 353, pp 737-740, 1991.

[6] S. Ali,"Biomimicry in Solar Energy Conversion With Natural Dye Sensitized Nanocrystalline Photovoltaic Cells,"Department of Chemistry and Biochemistry Obelin College, Ohio,pp 1-22, 2007.

[7] A. Maddu, A. M. Zuhri.Irmansyah, "Use Red Cabbage Extract Anthocyanins As Fotosentizer In TiO_2 Nano crystal Solar Cells sensitized Dye," Makara journal of Technology, vol 1 (2),2007.

[8] Q. Wang, J. E. Moser, M. Gra1tzel, "Electrochemical Impedance Spectroscopic Analysis of Dye-Sensitized Solar Cells," J. Phys. Chem. B, 109, pp14945-14953, 2005.

[9] C. A. Kelly,G. J. Meyer, "Excited state processes at sensitized nanocrystalline thin film semiconductor interfaces," Coordination Chemistry Reviews. Vol. 211, pp.295, 2001.

[10] K. Hara, H. Arakawa, "Dye-sensitized Solar Cells," In: Handbook of Photovoltaic Science and Engineering (A. Luque and S. Hegedus, (Ed.))," (15), pp. 663-700, 2003.

[11] S. Zona K. Scoot, O. F. Cook, W. Bartram "proposal to conserve Oreodoxaregia , the Basionym of Roystonearegia (Kunth) against Palma elata. (Arecaceae)," Taxon 43,(4): pp 662-64, 1994.

[12] K. F. Connor, "Tropical tree seed manual," Washington DC: USDA Forest Service Agriculture Handbook 721, pp 698-700, 2002.

[13] D. F. Austin, "Florida Ethnobotany."CRC Press LLC, Boca Raton, FL. 2004.

[14] K.E. Jasim, A. M. Hassan, "Nanocrystalline TiO2 based natural dye sensitised solar cells," Int. J. Nanomanufacturing, Vol. 4, Nos. 1/2/3/4, pp.242–247, 2009.

[15] M. Gratzel, "Dye-sensitized solar cells," Journal of Photochemistry and Photobiology C: Photochemistry Reviews 4, pp. 145–153, 2003.

[16] M. Gratzel, "Solar Energy Conversion by Dye-Sensitized Photovoltaic Cells," Inorg, Chem., Vol. 44, pp. 6841-6851, 2005.