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Fabrication and Characterization of Dye Sensitized Solar Cell Using Anarcardium Occidentale Sensitizer

Oviri O. Kelvin* and Ekpunobi

Physics Department, Faculty of Physical Sciences, Nnamdi Azikiwe University, P.M.B 5024, Awka, Anambra State Nigeria.

ABSTRACT

DSSC was fabricated using Anacardium occidentale, a reddish dye extracted from its bark. The cell was assembled without a co-absorbent. The reddish extract from Anacardium occidentale containing a mixture of distilled water was used without purification. The Anacardium occidentale extract sensitized cell gave a remarkably high open circuit voltage of 0.20994V, a high fill factor of 0.5635 but a modest short circuit current (Sc = 1.63mA/cm^2) corresponding to a solar to electrical power conversion efficiency of0.48% with an absorption spectrum of peak at366.3nm. The measurement was carried out under Air Mass 1.5. The possible significance of these findings is discussed.

Keywords: Fill factor, Open circuit voltage, Current density, Doctor Blade.

INTRODUCTION

With the ever increasing population of the earth, the demand for energy becomes the most important problem for the next 50 years [1][6]. Most energy is provided at present by burning fossil fuel, but the extensive usage of fossil fuel produces also a greatly increased concentration of atmospheric CO_2 that causes global warming[2]. A search for a clean and sustainable source of energy free of carbon has therefore become an important issue for scientists. The most obvious source is the sun, which supplies energy about ten thousand times what all mankind consumes currently [1]. Solar photovoltaic cells, capable of directly converting sunlight into electrical power are the best candidates for a clean and renewable future source of energy. Although a silicon-based solar cell has been developed and commercialized for more than 30 years, a most promising photovoltaic cell is a dye-sensitized solar cell (DSSC). The idea of this DSSC was initiated in the early 1970's and was invented by Michael Grätzel and Brian O'Regan at the ÉcolePolytechniqueFédérale de Lausanne in 1991 and is also known as Grätzel cells [3]. Michael Grätzel won the 2010 Millennium Technology Prize for the invention of the Grätzelcells[4]. The fabricated DSSC is composed of a porous layer of nano-titanium dioxide [Solaronix T37/SP] covered with a molecular Anacardium occidentale dye that absorbs sunlight, like the chlorophyll in green leaves. The n-TiO_2 is immersed under an electrolyte solution above which is a platinum-based catalyst [Solaronix Pt-catalyst T/SP]. As in a conventional alkaline battery, a photoanode (the n-TiO_2) and a cathode (the platinum) are placed on either side of the electrolyte [Solaronix iodolyte]. Sunlight passes through the transparent electrode into the dye layer where they can excite electrons that flow into the titanium dioxide. The electrons flow toward the transparent electrode where they are collected for powering a load. After flowing through the external circuit, they are re-introduced into the cell through the cathode, flowing into the electrolyte. The electrolyte then transports the electrons back to the dye molecules. This cell is extremely promising because it is made of low-cost materials and does not need elaborate apparatus to manufacture. In bulk, it should be significantly less expensive than older solid-state cell designs. It can be engineered into flexible sheets and is mechanically robust, requiring no protection from minor events like hail or tree strikes. The European Union Photovoltaic Roadmap forecasts that DSSCs will be a potential significant renewable power source by 2020[5]. But, the technology still suffers from a number of technical challenges which has hindered large scale deployment. Notable among them are difficulty in scale up, low efficiencies and stability.

Recent improvements in materials and technology have led to certified efficiencies exceeding 11.1%[6][7][8].Trying to increase the efficiency and performances of the DSSC, several researches are on-going in order to get an efficient sensitizer ranging from the natural dyes to synthetic dyes[9][10][11]. In as much as we have a whole lot of plants which is so for the dyes, this research work which is on Anacardium occidentale dyeis going to throw a new light to the database of natural dyes used as sensitizers for Dye Sensitized Solar Cells (DSSCs).

MATERIALS AND METHODS

The conductive glass plates (FTO glass, fluorine-doped SnO_2, sheet resistance $15\Omega/cm^2$) TCO22-15, the titanium oxide (TiO_2) nanopowderTi-Nanoxide T37/SP (20 nm),Ti citrate complex (iv) solution and the electrolyte used is liquid electrolyte (Iodolyte PN-50). All reagents were of analytical grade and were used as received from Solaronix SA.Sensitizer which was chosen for this experiment is Anacardium occidentale.

1.1Dimensioning of (TCO) Substrate

Dimensioning of (TCO) substrate transparent fluorine-doped tin oxide (FTO) coated glass substrates (Solaronix TCO22-15) with a sheet resistance 15Ω/sq),were used as substrates[12]. The conducting side of the glass was detected by the use of a multimeter as the non-conducting side does not give any reading. Alternatively, the side that feels hazy when passing gently with the finger is the conducting side of the glass. The TCO glasses were not handled with bares fingers rather with hand gloves to avoid contamination.The 5cm by 5cm substrate was cut into 2.5cm by 2.5cm by the use of glass cutter. Hence the cell active area of the substrate is 3mm by 14mm ($0.42cm^2$).

1.2 Preparation of Electrodes

In the preparation of the photo anode which consists of several layers, the blocking layer is the first of such layers to be deposited.The blocking layer was prepared by spin coating[13] the obtained Ti citrate complex (iv) solution deposited on the FTO firstly at 300rpm for 10sec to disperse it and then coated at 3000rpm for 60sec. In this manner, two layers were deposited with each of the layers being tested by a multimeter respectively to see if it reads. Each layer was followed by a heat treatment at 300^oC for 10min after the final layer, the film is sintered at 450^oC (15°C/min) in a carbolytetubler furnace for 30min and thereafter, allowed to cool down uniformly. The blocking layer was introduced to block or reduce back recombination reactions.Subsequently, place the FTO (after the blocking layer application) unto the screen printer[14] for the application of the nanocrystalline n-TiO_2. The deposition was done by screen printing from a 70 count polyester mesh. Two such layers were sufficient to give a film thickness of 7.6μm. The film was sintered in air for 30min at 450 Â°C. After the deposition of the nanocrystalline $TiO_{2,}$ propan-2-ol (BPH-ANALAR) was used to clean the remnant of the n-TiO_2 on the screen printer in order to pave the way for the deposition of the scattering layer. The scattering layer is composed of the deposition of the n-TiO_2 (Solaronix D37/SC)using the screen printer on the n-TiO_2 layer (Solaronix T37/SP). After the screen printing, it was heated gently with an electric heater at 100^oC for 10mins so as to get the layer dried. Thereafter, the screen printed FTO was loaded into the furnace and heated to 450^oC for 30mins. The thickness was confirmed by a profilometer (DECTAC).

The counter electrode was prepared using doctor blade method[15]. A multimeter was used to test the surface of the FTO glass to determine the conductive surface. After then, I mapped out an area equal to the active area on the photoanode with a celotape. A platinum catalyst gel (Solaronix Pt-Catalyst T/SP)[12] unto the area mapped out on the conductive glass (Solaronix FTO), before drying at 100 °C for 10 min on an electric heater and firing at 450 °C for 30 min in the furnace. After heating, put off the furnace and let it cool down uniformly to prevent the cracks on the deposit.

1.3Preparation of dye Sensitizer Solution

Fresh cashew-bark was crushed in a porcelain mortar with little quantity of distilled water added to increase the fluid content. The resulting extract was filtered, placed in a petridish and used immediately without further purification.

1.4 Sensitizer Impregnation Using Anacardium occidentale

The sintered photo anode, a little bit warm, was slowly immersed (its face-up) in the dye extracted; and kept at room temperature overnight in a petri-dish to complete the sensitizer uptake. It was subsequently rinsed with ethanol and dried.

1.5 Assembling of DSSC

The dye sensitized solar cell (DSSC) was assembled accordingly by the procedure outlined below): the photoanode was pressed against the platinum coated counter electrode in such a way that the conductive surfaces of both the photoanode and counter electrode were placed against each other to enable electrical connection. The cell was sealed by a 25μm thick surlyn polymer foil (Solaronix Meltonix 1170-25PF). Sealing was done by keeping the structure under a hot-press iron at 140°C for 15-30 seconds. The liquid electrolyte Iodolyte AN-50 (composed of ionic liquid, lithium salt, pyridine in acetonitrile solvent) was introduced by using a pipette into the cell gap through a slit cut into opposite ends during sealing of the cell with the hot melt foil. The gap was then covered with epoxide based glue.

1.6 Measurements

The cell was characterised for their electrical performance in the dark by a digital Keithley 236 multimeter connected to a computer and photocurrent measurement were carried out by using a class A solar simulator, (orieel 6) at air mass 1.5(AM1.5) and irradiance (100W/cm^2). Electron micrographs of the porous TiO_2 films are taken with a LEO-1400 model Scanning Electron Microscope (SEM). The absorption spectrum of the dye was recorded on a Perkin-Elmer L20 spectrophotometer; cell active area was 0.42cm^2. Thickness measurement of 7.6μm were obtained with a Dectac Profilometer, SEM analysis and EDX measurement were carried out with Zeiss SEM equipped with EDX supplied by oxford instruments. Sheet resistance of 13.4726Ω/sq was obtained with a Cffg brand four point probe.

RESULTS AND DISCUSSION

The electrode sheet resistances (Solaronix TCO22-15) were measured using the cffg four point probe system. The sheet resistances measured are 13.347Ω/ ■, 13.469Ω/ ■, 13.703Ω/ ■, 13.511Ω/ ■ 13.333Ω/ ■ at a constant current source of 4.999504E-04A.

Calculation of the Mean of Sheet Resistances.

Mean = summation of values / number of values

$$\text{Mean} = \frac{13.347+13.469+13.703+13.511+13.333(\Omega/\blacksquare)}{5}$$

Mean sheet resistance = 67.369/5

= 13.4726 Ω/■

I-V Characteristics

Using a standard solar illuminator specifically a Class A solar simulator (Orieel 6) at 1.5A.M, 1000W/M^2 of illumination was generated; current and corresponding voltage readings were taken.

Calculation of Fill Factor and Efficiency of DSSC

$$\text{Fill Factor (FF)} = \frac{J_{mp}V_{mp}}{J_{sc}V_{oc}} \quad \ldots\ldots (i)$$

J_{mp} is the maximum current density corresponding to V_{mp}.

V_{mp} is the maximum voltage corresponding to J_{mp}.

J_{sc} is the short circuit current.

V_{oc} is the open circuit voltage.

J_{mp}= 1.35mA/cm^2
V_{mp}= 0.142837V
J_{sc} = 1.63mA/cm^2
V_{oc}=0.20994V

$$\text{Therefore FF} = \frac{1.35 * 0.142837}{1.63 * 0.20994} = 0.5635 = 56\%$$

$$\text{Efficiency } (\eta) = \frac{J_{sc}\, FF V_{oc}}{P_{in} * A} \quad \ldots\ldots (ii)$$

P_{in} is the power of incident light on the cell
A is the photoactive area of the cell

$$\eta = \frac{1.63 * 0.20994 * 56}{100 * 0.42}$$

η = 0.48%

The dye sensitized solar cell (DSSC) sensitized with the Anacardium occidentale has a low efficiency and photocurrent; this may be explained in terms of the narrow photo absorption window of the dye centred at an absorption peak of 366.3nm. As shown in figire.2 the absorption at 300nm-450nm with a peak at 366.3nm is much too narrow for the generation of high photocurrent. For efficient light harvesting, the spectra overlap with the solar spectrum should be maximized so that much of the sun’s energy could be utilized in exciting the dye and promoting a high density of electrons into the excited state. [16][17][18] To achieve efficiencies >15%, DSSC will need to absorb about 80% of light between 350-900nm which is the visible light region[19][20].

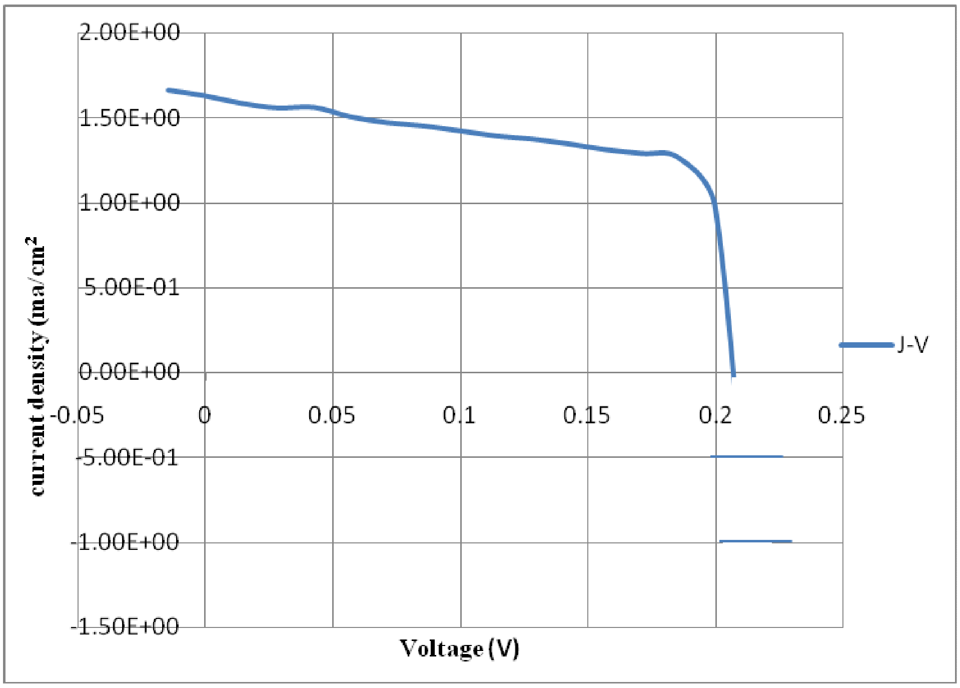

Figure 1. plot of current density(mA/cm^2) against voltage(V)

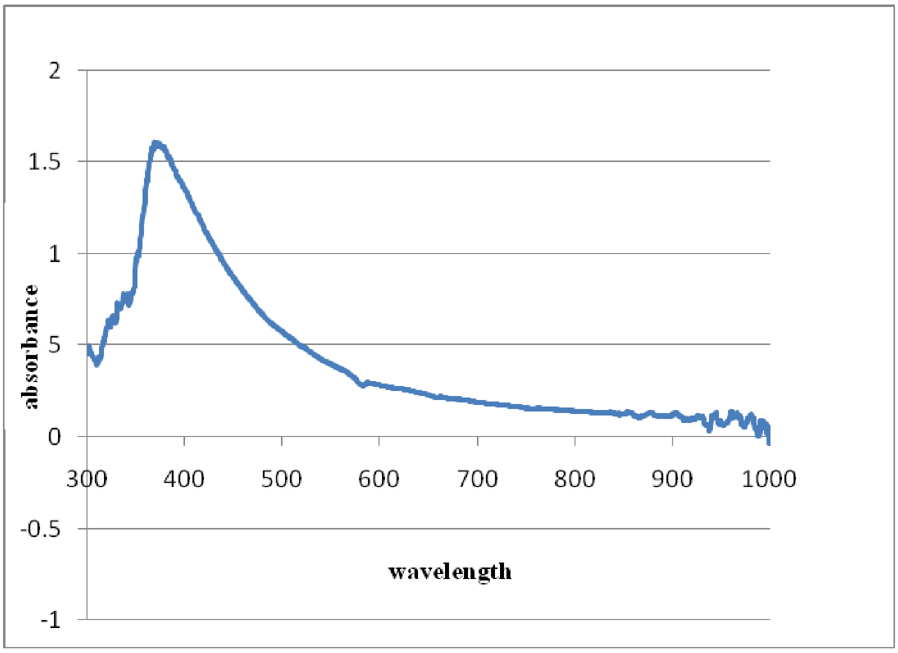

Figure 2. The absorption spectra of Anarcardium occidentale sensitized DSSC with an absorption peak of 366.3nm.

Figure 2 shows the representative UV–VIS absorption spectra for the water extract of the Anacardium occidentale which exhibit an absorption peak of 366.3nm in the ultraviolet region whereas no obvious maximum absorption peak in the visible light region was observed.

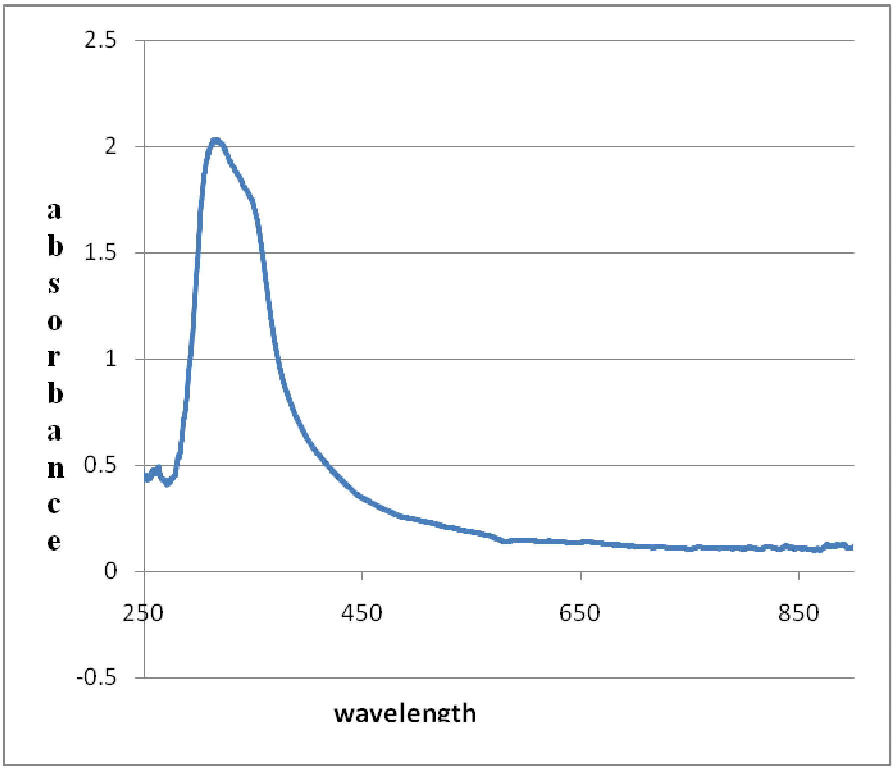

Figure 3. The absorption spectra of n-TiO_2 on the FTO glass with an absorption peak of 307.2nm.

Shown in figure 3 is the absorbance of n-TiO_2 on the FTO glass. The value shows that the n-TiO_2 still absorb a fraction of light rays. The absorption spectra of n-TiO_2 on the FTO glass had an absorption peak of 307.2nm.

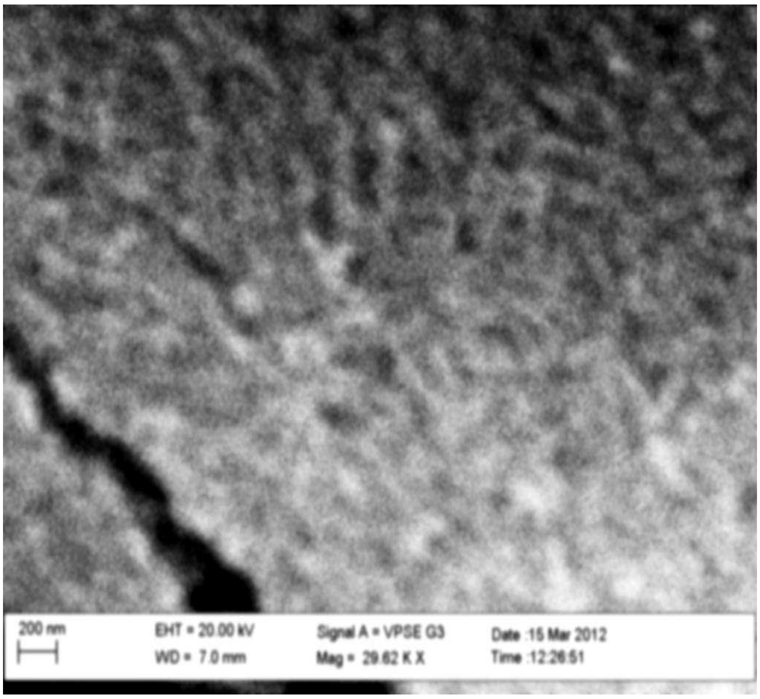

Figure 3 Scanning electron microscope images of n-TiO_2 layer, (the sample was annealed at 450°C for 30min).

CONCLUSION

The Anacardium occidentale sensitized dye solar cell exhibited a very high fill factor which suggests efficient packing at the TiO_2 electrolyte interface. The results are encouraging as the Anacardium occidentale therefore offers the potential as a useful sensitizer for dye solar cells especially when combined with other dyes to expand the absorption window or combined with energy relay dyes of superior absorbance. Further studies will be focused on identifying the active components of the extract.

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