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Optical and electrical properties of fabricated dye sensitized solar cells based on extract from kolanut (Cola Acuminta).

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ABSTRACT
Dye sensitized solar cells were successfully fabricated usingethanol and deionized wateras solvent to extract natural dye from Kola nuts (Cola Acuminta).Dr. Blade method was used to depositNanocrystalline titanium (iv) oxide (TiO_2) (solaonix SA) on the working electrode and screen printing methodwas employed to deposit Platinum catalyst on the counter electrodes. The optical characterizations of the fabricated dye sensitized solar cells were investigated with the aid of Ava Spec-2048 UV/Visible Spectrophotometer.Oriel Class A Solar Simulator was used to investigate theElectrical properties of solar cells. The I-V characterization of the solar cells was obtained in dark and illumination intensity and the illumination intensity used was at 100 m/W/cm^2. Under illumination intensity the open circuit voltage (V_{oc}) was 0.38 V, short circuit voltage (I_{sc}) was 0.28 mA, fill factor was 0.3.48%, and maximum power point is 0.004wM with a conversion efficiency of 0.004%. Under dark intensity (no halogen lamp), the open circuit voltage (V_{oc}) was -5.6x10^{-4}V, short circuit voltage (I_{sc}) was -0.28 mA, the fill factor was -1.40%, maximum power point was -0.0002wM with an efficiency of -0.0002%.
Keywords: dye sensitized, solar cells, Nanocrystaline Titanium, Platinum catalyst

I. INTRODUCTION

Constant energy supply is one of the major factors that determine the growth rate and economy of a developing country. Bankruptcy of energy supply has been the challenges of such developing countries;of which this has led to poor life style, lack of good health care facilities, industries, social amenities, low quality standard of education etc. These challenges bring the economy of such countries to zero level. In order to eliminate these challenges or to boast up the economy of such countries, constant energy supply must be in place.

According to O'Regan andGrätzel, 1991, there are two sources of energy: Renewable and nonrenewable energy.

Renewable energy is a clean and useful energy that is collected from renewable resources, which include;solar (from the sun), wind, water, geothermal (from the Earth) and biomass (from organic materials). They generate zero pollution, noise free, affordable, and easy to produce energy.

Nonrenewable or ''dirty''energy sources are fossil fuels formed when prehistoric plants and animals died and were gradually buried by layers of soil rock. These include natural gas, coal and oil. Nonrenewable energy cannot be replaced once they have been used up which is one of the limiting factors. The extensive use of fossil fuels is a contributor to greenhouse gas emissions, which include carbon dioxide, global warming, climate change and their cost of production is high (Hagberg 2009).

Out of other sources of renewable energy, solar energy is a widely and popularly source throughout the world due to its potentials. This limitless nature of energy from the sun makes solar cells very attractive for the production of electricity,(Lewis and Nocera, 2006).Among them, the dye sensitized solar cell (DSSC). The DSSC is a very attractive option for utilizing the solar energy, because ofits potentially; low cost of production. In contrast to conventional systems, where the semiconductor works as both the light absorber and charge carrier, the DSSC separates the two functions which facilitate the production of the device. They are very promising compared to silicon based solar cells because they are made from low-cost materials and do not need elaborate apparatus for their manufacture. (Alfa et al, 2012). As a result of these, natural dyes promises to be the best alternative as they can be used for the same purpose with acceptable and encouraging sufficiency,(Sekar and Chelot, 2010), (Ayyan and Karmaker 2011) and (Alhamedet al, 2012).

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II. EXPERIMENTAL DETAIL

2.1 Chemicals and materials

Below are the materials used, for the fabrication of dye sensitized solar cells;de-ionized water, ethanol, zinc oxide, platinium catalyst, hydrogen peroxide, ammonia solution, acetone, methanol, Titaniumtetrachlorite ($TiCl_4$), electrolyte, epoxy sealant and separator, con HCl, diluted HCl.

Florine doped tin oxide (FTO), Transparent Conductive Oxide (TCO 10-10), soda lime glass (SLG), kolanut (Cola Acuminta),DT 9205A digital multimeter, diamond glass cutter, nose mask, hot air blower, electric hot plate, scotch/masking tape, petri dish, beaker, ceramic mortar and pestle, squeegee, substrate holder, stirring glass rod, hand glove (latex), Carbolite 201tubular furnace, wooden clamp, film cupboard,

2.2 Identification of conductive side of the fluorine doped tin oxide (FTO)

Transparent fluorine-doped tin oxide (FTO) and soda lime glass (SLG) were used as the substrate. The conductive side of the FTO was determined with an aid of DT9205A digital multimeter, by placing the cable probe on the surface of the FTO, and the conductive sides were determined by observing some displays on the digital multimeter.

2.3 Cleaning of the FTO | Soda Lime Glass

The FTO and Soda lime glass were first cut to a size, using a diamond glass cutter, and then cleaned carefully with detergent, water and distilled water in that order. All the substrates were washed with Deconex and a soft sponge to remove dirty particles and as well decrease the surface tension. Immediately after washing of the FTO, some were squint with ethanol while some were rinsed with deionized water to avoid contamination. All the substrates were blown- dry with a hot-air blower to dry fast and were kept in petri dish. (Isi et al, 2021).

2.4 Dye Extraction

Kolanut (Cola Acuminta),were crshed using ceramic mortar and pestle. Some portions of the crushed kola nut were soaked with ethanol and deionized water respectively. And a sieve used to extract the pigment which forms our dye

2.5 Deposition of Blocking Layer

Fifty (50) milimoles of titanium tetrachloride (TiC_4) was deposited on the FTO using screen printing technique. A hot air blower was used to dry the electrode for five (5) minutes, after which it was heated with an electric hot plate for 90-100^{0}C. This deposited titanium tetrachloride (TiC_4) is dense layer and the layer was transparent. This was done to ensure adsorption of TiO_2 film that is yet to be deposited and to reduce or block the recombination reactions. (Isi et al, 2021).

2.6 Deposition of Titanium (iv) oxide Paste (TiO_2)

Nanocrystalline titanium (iv) oxide paste (TiO_2) was deposited on a plasma cleaned layer using Dr. Blade method. Prior to the deposition of titanium (iv) oxide paste, the active area of a 2.5 cm x 2.5 cm FTO was identified and covered on each of the two parallel edges with a double layer of masking tape to control the thickness of the TiO_2 film. The TiO_2 paste was applied at one of the edges of the FTO and was distributed with a squeegee sliding over the tape-covered edges (Ozuombaet al., 2011). Immediately after the deposition, a hot air blower was used to gradually dry the electrode for 2-3 minutes and the scotch tape was gently removed. The edges were cleaned with ethanol. The electrode was heated to dry at 75^{0}C on an electric hot plate (Ceramag Midi IKA^{R}WORKS USA) for ten (10) minutes. The electrode was immediately sent into furnace (carbolite 201 tubular furnace) to heat for 400^{0}C. This is to ensure complete combustion of organic additives and also ensure sintering of the materials which lasted for thirty (30) minutes. All these were done to enhance the electrical contact and mechanical adhesion on the glass. During the period of sintering, we observed some changes; at first, the white colour of the TiO_2 turned brownish and brownish fumes were released, after some time the same electrode also changed to black colour and finally turned to its initial colour (white). This white colour indicated that the electrode is now ready to be soaked in the dye. (Isi et al 2021)

2.7 Deposition of Platinum Catalyst Using Screen Printing

The counter electrodes were fabricated from the same substrate material and had the same dimensions as the working electrode. The cleaning was also done as in the working electrode.

The deposition was done by dipping a clean stirring glass rod in 0.5grams of platinum catalyst and was rolled on the conductive side of the FTO. The FTO was coated for five times while it was placed on an electric hot plate that was controlled at 90^{0}C. While the platinum electrode was still on the electric hot plate, a hot air blower was also used to enhance the drying process which

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lasted for ten (10) minutes. Thereafter, the platinum electrode was sent in a furnace (Carbolite 201 tubular) at 450^0C for thirty (30) minutes for sintering. The electrode was left in the furnace to cool gradually.

2.8 Sensitization of Titanium Dioxide by Natural Dyes

The sensitizers used are natural dyes extracted fromkolanut (Cola Acuminta). All the electrodes were preheated at 400^0C for ten (10) minutes. This process helps in the prevention of rehydration of TiO_2 surfaces or capillary condensation of water vapours from ambient air inside the nanopores of thin film. The presence of water in the pore decreases the injection efficiency of the dye.

The following procedures were followed to achieve a good result;

(i) The working electrodes were carefully put into the dye.
(ii) All the working electrodes were faced up inside the dye to avoid cracking.
(iii) The impregnation process lasted for forty eight hours for the dye molecules to naturally adsorb onto the titania particles.
(iv) All the dye-coated films were rinsed in ethanol and deionized water to remove excess dye and dried with an electric hot blower for three minutes.
(v) The dye-coated films were sealed with aluminum foil and were kept in a dark air tight case till the cell was assembled. (Isi et al, 2021)
(vi) All these were done at room temperature (300^0K).

2.9 Solar Cell Assembly

Before we assembled the dye-sensitized solar cell, we prepared a liquid electrolyte with I^-/I^{3-}redox couple by dissolving 0.5 M potassium iodide (KI) and 0.05 M iodide (I^2) into acetonitrile and anhydrous ethanol.

The cells were assembled since the working electrode, counter electrode, and electrolyte are ready.

The procedures for the assembling are as follows;

1. Permanent laminating films (Solaronix SX 1170-25PF) were cleaned with ethanol and were used to connect the working electrode and the counter electrode together and to avoid bridging.
2. The electrodes were kept in a way such that there will be room (gap) for the electrical connections on both electrodes.
3. They were heated under the pressure from two clips at 80^0C for 1 minute on a hot plate and allowed to cool for some minutes. The thickness of the laminating film was about 127 μm which decreased to 60 μm after heating.
4. Electrolyte (Iodolyte R-150 Solaronix SA) was introduced drop by drop at the gap between the two electrodes by capillary action.
5. Immediately after the introduction of the electrolyte, the edges of the electrodes were cleaned with acetonitrile and were sealed with Amoxil 4R sealant (BN011008SN, Solaronix SA).
6. Electrical contacts were made by applying silver paint on the conductive side of each electrode for optimal electrical connections.

All the assembled solar cells were kept in air tight container for proper characterization.

III. RESULTS AND DISCUSSION

Figures 1, 2, 3, and 4 displayed comparative studies of the optical properties of the fabricated dye sensitized solar cells which were extract from kolanut (Cola Acuminta) using deionized water and ethanol as solvent.

Figure 1 displayed Spectral Absorbance of Kola nut (Cola Acuminta)DSSCs and it revealed thatboth water and ethanol based cells displayed high absorbance both in the UV and VIS region, but the water based cell displayed higher absorbance than ethanol based cell in the infrared region ofthe electromagnetic spectrum that was covered in this research. This implies that water based cell absorbs more photon energy than ethanol based cell. Hence, water based solar cell is more efficient than ethanol based cell. This graph has a similar behavior with the absorbance result of Mbonyiryivuzeet al 2015.

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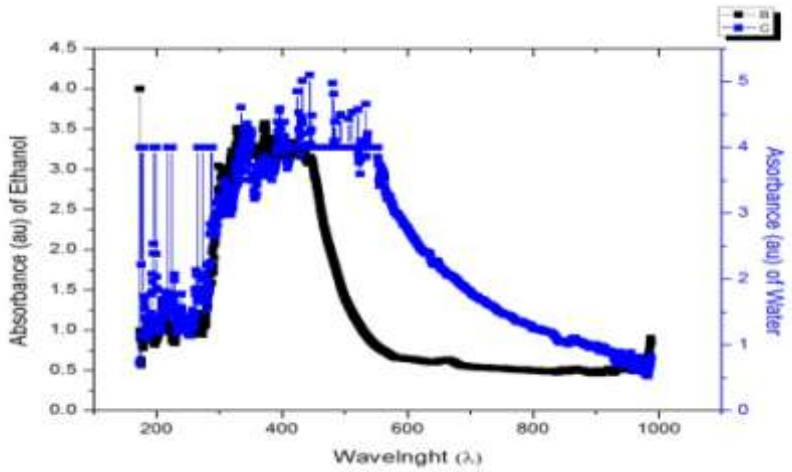

Fig. 1 Spectral Absorbance of kolanut (Cola Acuminta)of DSSCs extracted using deionized water and ethanol

Figure 2 reveals that ethanol based cell is highly reflective in all the regions of electromagnetic spectrum that was covered in this work. This is also an indication that water based DSSC is more efficient.

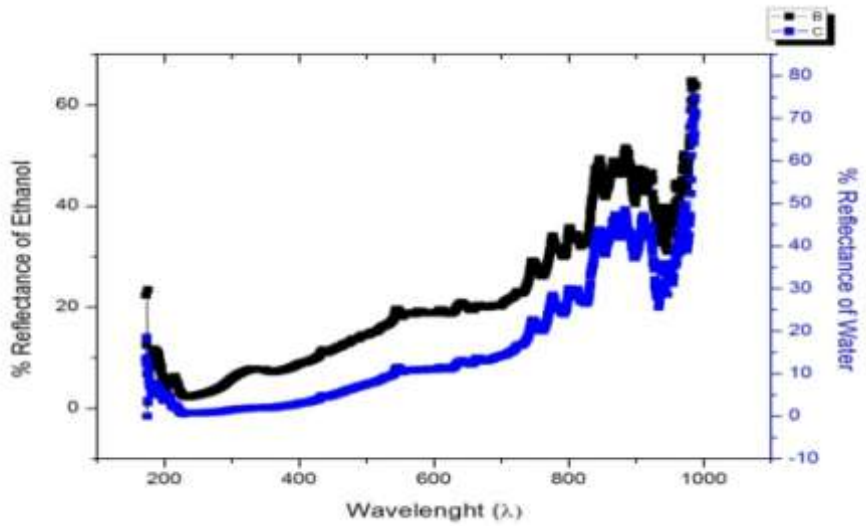

Fig. 2 Spectral Reflectance of Kola nut(Cola Acuminta)DSSCs extracted using deionized water and ethanol

Figure 3 displayed that ethanol based cell possessed low transmittance both in lower and higher wavelength of electromagnetic spectrum. This reveals that deionized water based DSSC is more efficient.

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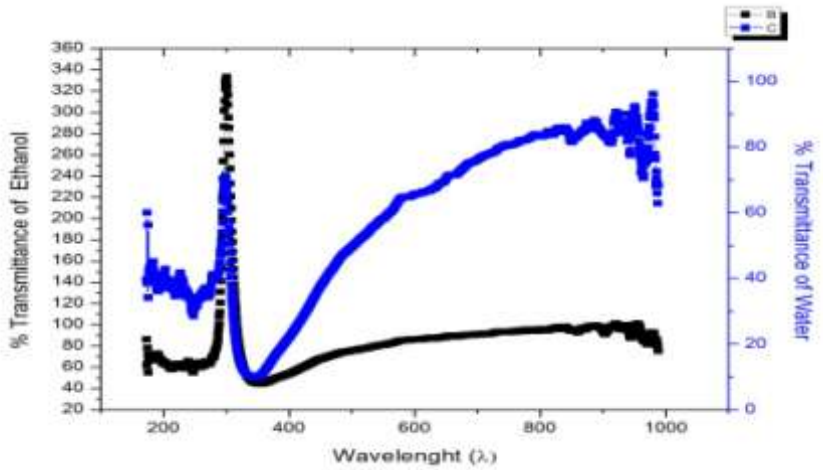

Fig. 3 Spectral Transmittance of Kola nut(Cola Acuminta)DSSCs extracted using deionized water and ethanol

Figure 4 showed the graph of absorption coefficient (nm^{-1}) against wavelength. The graph reveals that, the rate of absorption was very poor based on the unit of absorption coefficient (nm^{-1}). Notwithstanding, the absorption coefficient of water based DSSC is higher than that of the ethanol based DSSC. Thus the deionized water based DSSC is more efficient.

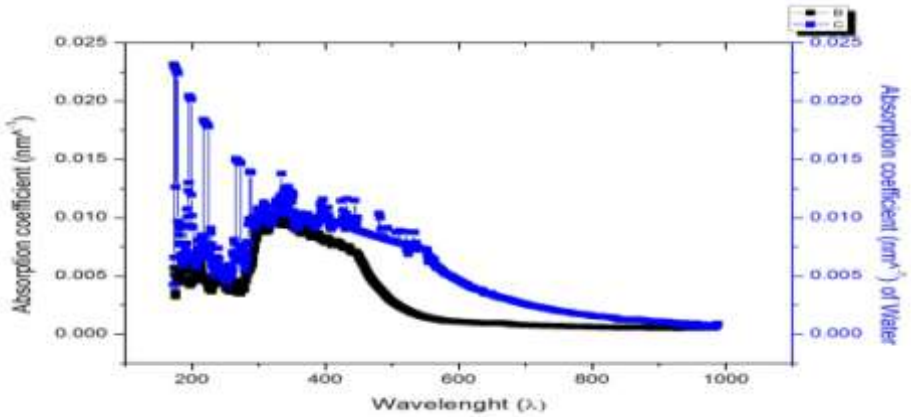

Fig. 4, the graph of absorption coefficient (nm^{-1}) against wavelength (nm) of Kola nut (Cola Acuminta) DSSCs extracted using deionized water and ethanol

The current and power response to external voltage was carried out on water based DSSC due its high efficiency. The I-V characterizations of the cell were measured under illumination intensity and dark (without halogen lamp) as indicated in figures 5 and 6 with an aid of Oriel Class A Solar Simulator. The illumination intensity used was at 100 mW/cm^2. Comparative studies of current density and power as a function of voltage were carried out at 100 mW/cm^2 and at dark. The photovoltaic parameters were calculated using; Isi et al, 2021.

$$FF = \frac{Vmp \times Jmp}{Voc \times Jsc} = \frac{Pm}{Voc \times Jsc} \text{ or } \frac{Vmp \times Imp}{Vsc \times Joc}$$

The photoelectric conversion efficiency was also calculated using;

$$\eta = \frac{Jmp \times Vmp \times 100}{Pin} = \frac{Jsc \times Voc \times FF \times 100}{Pin}$$

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Where, FF = Fill Factor
Pm = Vm x Jm = Maximum Power Point (mW)
I_{sc}= Short circuit current (mA),
V_{oc} = Open circuit voltage (Volts)
J = Current density (mW/cm^2)
Ƞ = photoelectric conversion efficiency

Figure 5 displayed the cell parameters obtained at 100mW/cm^2 are; open circuit voltage is 0.38 V, short circuit current is 0.28mA, fill factor of 3.50 %, maximum power is 0.004wMand photoelectric conversion efficiency of 0.004%.

Figure 6 showed the photovoltaic parameters at dark intensity (no Halogen lamp) are; open circuit voltage is $-5.6x10^{-4}$ Volts, short circuit photocurrent is-0.28 mA, fill factor of -1.40%maximum power is $-2.0x10^{-4}$ mW and photoelectric conversion efficiency of$-2.0x10^{-4}$%.

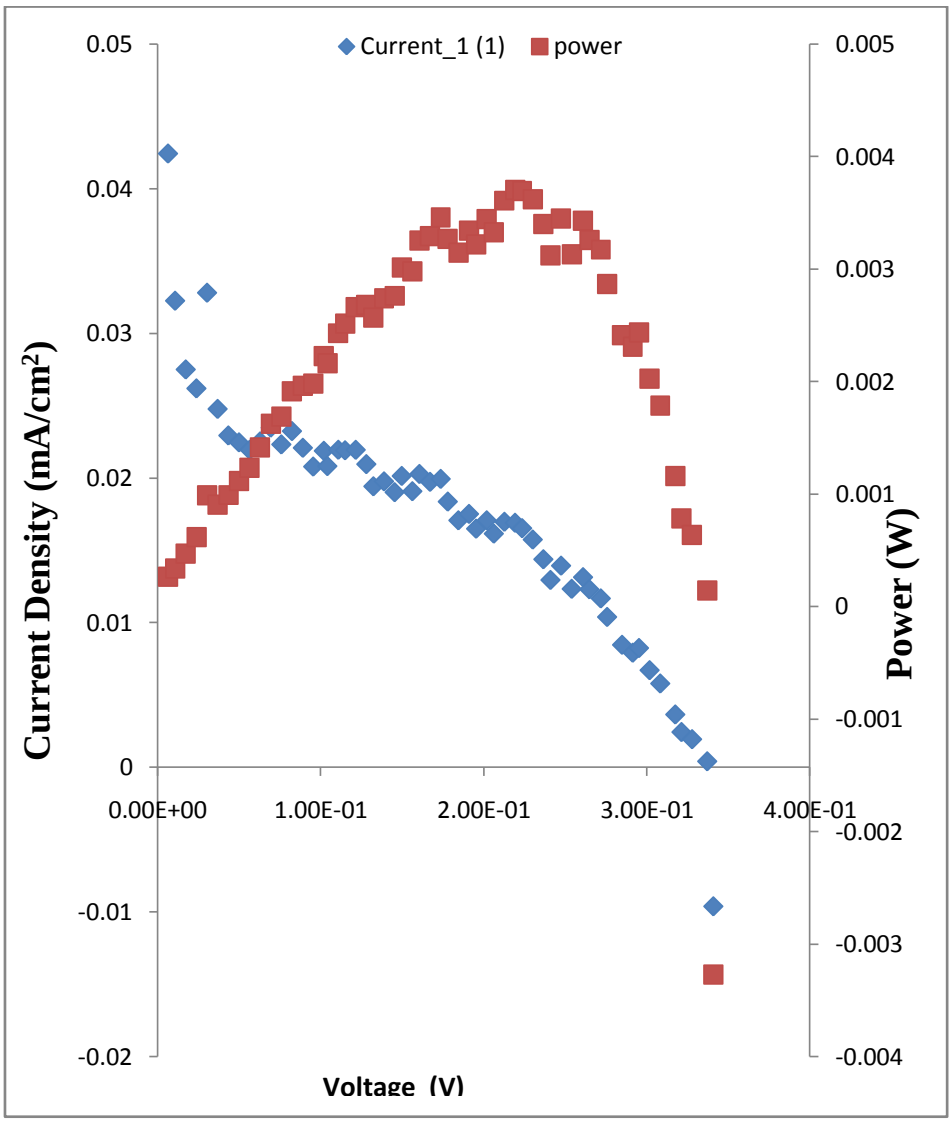

Fig. 5, I-V Curve of kola nut (water based) DSSC under light at 100 m/W/cm^2.

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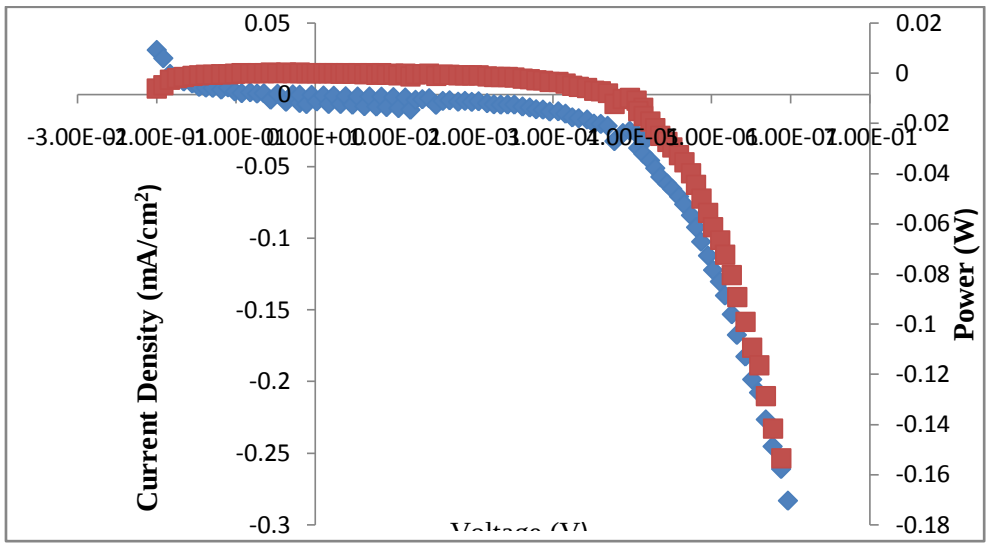

Fig. 6, I-V Curve of Kola nut (water based) DSSC under Dark

IV. CONCLUSIONS

Successful fabrications of dye sensitized solar cells have been carried out using various dyes extracted from Kola nut (Cola Acuminta). The technique employed for the depositions are Dr. Blade and screen printing deposition technique.Comparative studies were carried out for the DSSCs which extracted using ethanol and deionized water and their optical properties were also investigated using Avaspec 2.1 spectrophotometer.It was revealed that the water based dye sensitized solar cell absorbs more photon energy than the ethanol based dye sensitized solar cell in all the regions of the electromagnetic spectrum that were covered in this research.

Based on high absorption rate of the water based dye sensitized solar cell, an I-V characterization of the cell was investigated in dark (without halogen lamp) and illumination intensity at 100mW/cm^2 with an aid of Oriel Class A Solar Simulator. An efficiency of $-2.0x10^{-4}$%at dark (without halogen lamp) and $4.0x10^{-3}$% at 100mW/cm^{2}were obtained. Hence, DSSC is sensitized by short wavelength photons and water based cell is more efficient.

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