**Pawpaw Leaf And Flame Tree Flower As Natural Sensitizers For Dye Sensitized Solar Cells**

**M.I. Kimpa\*, K.U. Isah, M. Momoh, H.N. Yahya, M.M. Ndamitso and J.A. Yabagi**

Department of Physics, Federal University of Technology, Minna. Department of Physics, Usmanu Danfodiyo University, Sokoto. Energy Research Centre, Usmanu Danfodiyo University, Sokoto. Department of Chemistry, Federal University of Technology, Minna. Department of Physics, Ibrahim Badamasi Babangida University, Lapai, Niger State.

[\*kimpabala2@gmail.com](mailto:*kimpabala2@gmail.com) 08038654849

**Abstract**

Natural dyes of anthocyanin extract from flame tree flower (Delonix regia) and chlorophyll extract from pawpaw (Carica papaya) were used as sensitizer to fabricate dye sensitized solar cell (DSSC). The Photoelectrochemical performances of DSSCs obtained from I.V. curve showed conversion efficiency (η) of 80% for the dyes prepared by anthocyanin from flames tree flower, with open-circuit voltage (Voc) of 0.5249 mV, short-circuit current density (Isc) of 44.6191 mA/m2 and Fill factor (FF) of 0.5837. Chlorophyll dyes extract from pawpaw leaf has Voc of 0.5249 mV, Isc of 16.5283 mA/m2. FF of 0.5585 and a conversion efficiency (η) of 0.27 %. The conversion efficiency is 0.23 % for anthocyanin and chlorophyll as the dye mixture at ration 1:2 with Voc Isc and FF of 0.5500 mV, 14.2750 mA/m2 and 0.5206 and a conversion efficiency (η) of 0.26 %.

**Keywords:** Flame tree flower, Pawpaw leaf, spectrophotometer, absorbance, chlorophyll, anthocyanin.

**INTRODUCTION**

As the world population continually increases, there is variably increase in the consumption of energy which results in a high demand for energy. The major source of energy for humans has not being environmentally friendly, so this has propelled the necessity for alternative sources of energy. The alternative sources of energy are not based on fossil fuels but are either renewable or sustainable without depleting. It is therefore inevitable to strive for renewable source of energy that offers no harm to human life (Redmond, 2008).

Contrary to expectation, devices based on interpenetrating networks of mesoscopic semiconductors have shown strikingly high conversion efficiencies, which compete with those of conventional devices. The prototype of this family of devices is the dye-sensitzed solar cell, which realizes the optical absorption and the charge separation processes by the association of a sensitizer as light-absorbing material with a wide band gap semiconductor of naaocrystalline morphology (Michael Grätzel, 2003).

The most well known and studied unconventional renewable source of energy (photovoltaic system) is the dye- sensitized nanostructured solar cell developed by Professor Grätzel in 1991. At the moment this unique photoelectrochemical solar cell based on a TiO2 nanoparticle photoelectrode sensitized with a light-harvesting metallo-organic dye, is on the verge of commercialization offering an interesting alternative for the existing silicon based solar cells as well as for the thin film solar cells. At the same time the research activity as well as the industrial interest around the technology is growing fast (Haruna et al., 2015).

In DSSCs, dye molecules adsorbed on the oxide play a role of ‘‘antenna’’ for photon capturing. For this reason, accompanying with the development of DSSCs, organic dyes have been intensively studied with a focus on increasing the extinction coefficient and extending the optical absorption spectrum. However, a major problem confronting these cells is the low efficiency of conversion (Danladi *et al*., 2016).

**Components of dye sensitized solar cell**

A Dye Solar Cell is composed of two electrodes (the anode and the cathode), wide bandgap semiconducting layer (TiO2), sensitizing dye molecules, and the electrolyte. The electrodes are made from a specific glass that has a Transparent Conductive Oxide (TCO allows sunlight to enter the cell while its conductive surface collects charges) coating on one side. The TCO material is a thin layer of fluorine-doped tin oxide, also called FTO. The anode is the negative terminal of the solar cell. It essentially bears a continuous network of sintered titanium dioxide nanoparticles. This porous network offers an inner surface that is a thousand times greater than the equivalent flat area, and acts like a “light sponge” in which sunlight can get trapped. Titanium dioxide is a white semiconductor that is not sensitive to visible light. The titania particles have to be sensitized with a layer of dye molecules to absorb light in the visible spectrum. Some natural dyes can be employed, but the most efficient pigments were synthesized after intense scientific investigation. The positive terminal of the solar cell, also called the cathode, is coated with a catalytic material for electron transfer. In most cases, this catalyst is carbon or platinum. Since a very small quantity of catalyst is needed, the electrode remains transparent. The space left between the two electrodes is filled with an electrolyte that ensures charge transportation through a redox couple. Iodine/tri-iodide in a nitrile solvent is typically used for this purpose. Eventually, the two electrodes are sealed together to prevent the electrolyte solvent from evaporating. However, the assembly can remain open when simplicity is preferred over durability, such as during training courses or short run tests.

**Working principle of DSSC**

Martineau (2011) stated that nature likes to keep opposite charges together so that matter appears neutral. The photovoltaic effect is all about violating this rule. It creates a separation of charges in the solar cell under illumination. The resulting pairs of electrons and “holes” will strive to get together again, but we will only let them do so after a short trip through an external circuit.

In a Dye Solar Cell, this charge separation happens at the interface of the titanium dioxide and the dye. Remember that this interface is present all over the internal surface of the porous layer. This allows the Dye Solar Cell to form many, many separated charges which produces an electric current, for a given solar cell area. The structure of the Dye Solar Cell is one of the secrets of its efficacy.

The dye molecules have the ability to absorb visible light. As they are excited by this phenomenon, the molecules will give up an electron and inject it into the adjacent titanium dioxide. The charge separation occurs when the electron is injected into the titania and the “hole” is left behind on the dye molecule.

Not surprisingly, nature hates to have these charges separated. The electron must return to the oxidized dye molecule as soon as possible. That's were kinetics come into play: quick wins. The fastest route back to the dye for the electron is to travel through the external circuit. It might be a longer distance to take the highway, but it's faster than a footpath. Injected electrons migrate through the titanium dioxide particles and reach the TCO glass of the anode, the negative terminal of the solar cell.

When a load is connected, electrons spontaneously move to the positive terminal of the solar cell, the cathode, via the external circuit. This movement of electrons is what is called an electric current.



**Diagram illustrating the Working Principle of DSSC (Martineau, 2011)**

Thanks to the redox couple present in the electrolyte, electrons can finally be transported from the cathode's surface to the oxidized dye molecules. Now that the charges are together again, new cycles can be performed indefinitely as long as the sun shines. This is how a Dye Solar Cell produces electricity by photovoltaic separation of charges. The operation principle of DSSC is demonstrated in the diagram above.

**EXPERIMENTAL SECTION**

**Fabrication Process:** Pawpaw leaves were cut and pounded in ethanol using a porcelain mortar and pestle, the paste was squeezed in order to extract the dye. The filtrate is the sensitizer dye solution for the cell. The FTO glass (40mm thick, and surface resistivity of about 20Ω) was cut into desired dimension and shape from a non- conducting side of the glass to avoid the coated side been scratched or destroyed. To prepare working electrode (anode), a layer of nanocrystalline TiO2 paste, using a polyester mesh, was screen printed unto the conducting side of FTO glass and heated for 10minute at 100o C on a hot plate and progressive heating is then adopted to ensure optimal adhesion of the titanium dioxide layer onto FTO glass until its colour changed from white to brown. This is been referred to as blocking layer. Sintering of TiO2 was done by heating the screen printed glass with a hot plate at 450o C for 45minutes to 1hour and then allowed to cool uniformly. The impregnation process was carried out by gently immersing the electrode in the extracted dye at room temperature, for 18 hours so as to obtain complete staining. To prepare the counter electrode (cathode), FTO glass and Aluminium foil were immersed into Titanium III chloride solution and powered with a source meter (positive terminal connected to the FTO glass and negative terminal connected to the foil), facing each other. The cell was coupled, filled with the electrolyte solution and sealed. The cell is now complete and operational.

**Characterization**

The scanning electron micrographs of the nanocrystalline TiO2 films, showing the evaluation of morphological orientation of the surface of the TiO2, were taken with the SEM EVO I MA10. The current-voltage *(I-V)* data was obtained using a keithley 2400 source meter under AM1.5 (100 mw/cm2) illumination from a Newport A solar simulator. The absorption spectrum of the dye, spectra of various prepared slides with and without dye were recorded on Ava-spec-2048 spectrophotometer. The cell has an active area of 0.021cm2.

**RESULTS AND DISCUSSION**

Figure 2. Absorbance of dye on TiO2 nanoparticle

The absorbance spectrum of the dye is shown in the figure above. It was deduced that the dye absorbs photo best at a wave length of about 305nm, while the TiO2 absorbs best at a range about 300nm to 450 nm.

The Figure above shows the photocurrent current–voltage (*I* –*V*) curve of the DSSC. Based on the curve, the *fill factor (FF)* and solar cell efficiency (η)were determined following the equations:

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Where: **IMAX** = the current at the maximum power output

**VMAX** = the voltage at the maximum power output

**ISC** = the short-circuit current

**VOC** = the open-circuit voltage

**Pmax**= the maximum power output

**Pin** = the power input to the cell defined as the total radiant energy incident on the surface of the cell.

Imax

Isc

Voc

Vmax

Pmax

Figure 3. Photoelectrochemical performance of DSSC extracts from pawpaw leaf

The dimension of the cell fabricated is measured to be (0.03cm X 0.7cm) therefore; the area (**A)** of the cell is designed to be 0.03cm X 0.7cm = 0.021cm2**.**

From fig.4.5a, the value of the short circuit current **ISC = 15.7325** **mA/cm2** when the open circuit voltage **Voc** = **0V** while the value of open circuit voltage **Voc = 0.5248** **mV** when the short circuit current **ISC** = **0V**.

From figure above,

IMAX = 12.92210952mA/cm2

VMAX = 0.374951mV

PMAX = 4.845157W

PIN = 9.7076W

Fill Factor (FF) = = 0.5248

Efficiency (**η)** of the cell is therefore,



From the above results, the cell performance is relatively good using extracted dye from pawpaw leaf and compared to the using of other synthesized dyes like (ruthenium dyes). The efficiency (0.030%) could be compared with the result obtained by Kimpa *et al*., (2012) where 0.27% was obtained for the efficiency of mixture of flame tree flower and pawpaw leaf (with ethanol as the extracting solvent of the dye extraction). From the graph in figure above, the peak wave length of the dye on TiO2 is 400nm which is within the expected range (300nm to 850nm). We studied the TiO2 infused with electrolyte, under illumination and in the dark room for its conductivity. The conductivity of light intensity, wave length and voltage (applied) dependent were observed.

**Conclusion**

Sensitization of a dye solar cell using extract of carica papaya has successfully been fabricated. We observed a fill factor of (0.5867) for the carica papaya cell. The pawpaw leaf dye absorbs visible light in the range of 300nm to 800nm and its peak absorbance value was at 400nm with a cell energy conversion efficiency of 0.030%. Poor charge transfer between the dye molecule and the TiO2 due to low regeneration kinetics could be responsible for the low conversion efficiency of the cell.

In fact a significant improvement of the efficiencies can be achievable by means of more careful cell preparation and revaluation of the used materials and methods. DSSC work even in low-light conditions and, are therefore able to work under cloudy skies and non-direct sunlight, whereas traditional designs would suffer a “cut out” at some lower limit of illumination, when charge carrier mobility is low and recombination becomes a major issue. When the cut off is so low they are even being proposed for indoor use, collecting energy for small devices from the lights in the house (Patch, 2006).

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