Science World Journal Vol 13(No 1) 2018
www.scienceworldjournal.org
ISSN 1597-6343

PHOTOELECTRODE NANOSTRUCTURE DYE-SENSITIZED SOLAR CELL

Mohammed Isah Kimpa[1*], Jibrin Alhaji Yabagi[2], Haruna Isah[1], Taufiq Sulaiman[3], Aliyu Kabiru Isiyaku[4], Sani Garba Durumin Iya[5] and Auwal Mustapha Imam[6]

[1*] Department of Physics, School of Physical Sciences, Federal University of Technology Minna, P.M.B. 65, Minna, Niger State, Nigeria.
[2] Departments of Physics, Faculty of Sciences, Ibrahim Badamasi Babangida University Lapai, P.M.B 11, Lapai, Niger State, Nigeria.
[3] Department of Preminary Studies, Umar Waziri Federal Polytechnics, Birnin Kebbi, Kebbi State, Nigeria
[4]Department of Physics, Faculty of Science, Kaduna State University, P.M.B 2339, Kaduna State, Nigeria
[5]Power Equipment and Electrical Machinery Development Institute (PEEMADI) Okene, Nigeria
[6]Department of Physics with Electronics, Federal University Birnin Kebbi, 862104, Kebbi State, Nigeria

ABSTRACT
This study used *carica papaya* (pawpaw leaf) extracts as natural organic dye for dye sensitized solar cell (DSSC). Pawpaw leaf extract is rich in chlorophyll and was extracted using ethanol as the extracting solvent and serve as the sensitizer for DSSC. The specialty of the DSSC relative to other types of solar cells is the use of the dye. In addition, the self-developed photoelectrode nanostructure TiO_2 with an average particle size of 50 nm was synthesized through solution chemistry techniques and deposited on the fluorine doped tin oxide (FTO) glass substrate using screen printing procedure, forming a TiO_2 thin film of 12 µm thicknesses. This TiO_2 thin film underwent sintering at 450 °C to enhance the compactness of the film before impregnation into the dye solutions. This study further investigated the photoelectric conversion efficiency and the fill factor of the encapsulated DSSC. The experimental results show conversion efficiency of 0.030 % with fill factor of 0.5867, short circuit current density (**I_{Sc}**) of 15.7325 mA/cm and open circuit voltage (V_{oc}) of 0.5248 V. The photoelectrochemical performance of this extract demonstrated to be used as future alternative to application in solar cell.

Keywords: Carica papaya; dye-sensitized solar cell; photoelectrode; conversion efficiency; fill factor.

1. INTRODUCTION

As the world population continually increases, there is variable 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 (Hosseinnezhad *et al.*, 2017). 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 (Ramanarayanan *et al.*, 2017). The energy source based on mesoscopic semiconductors have shown strikingly high conversion efficiencies, which compete with those of conventional devices. This prototype devices is the dye-sensitized solar cell, which realizes the optical absorption and the charge separation processes by the sensitizer dyes as light-absorbing material having a wide energy band gap semiconductor (Kumara *et al.*, 2017).

Currently, photoelectrochemical solar cell based on a TiO_2 nanoparticle photoelectrode sensitizer with energy harvesting metal-organic dye is gaining high demand for commercialization potential. This could serve as 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 tremendously (Uwaisulqarni *et al.*, 2017).

The operational principle of dye sensitized solar cell begins from the charge separation which occurs at the interface of the titanium dioxide and the dye sensitizer. The interface is filled all over with the dye mesoporous layer. The dye molecules have the ability to absorb visible light. The dye molecules give up electron upon excitation and inject it into the titanium dioxide which was already impregnated onto it and serve as conducting electrode. The injected electrons migrate through the titanium dioxide particles and reach the transparent conducting oxide (TCO) glass of the anode (the negative terminal of the solar cell known as counter electrode). The load is connected and the electrons spontaneously move to the cathode (the positive terminal of the solar cell referred to as the conducting electrode) via the external circuit. Electric current occur due to the movement of electrons. Fig. 1 shows the schematic illustration of the working principle of DSSC (Kimpa *et al.*, 2012; Ayoub *et al.*, 2017; Isah *et al.*, 2016; Mohammed *et al.*, 2015).

In this study, natural dye from leaves of pawpaw (rich in chlorophyll) were used as photosensitizes for DSSC. The extracted dyes were characterized using UV–vis absorption spectra. The photo- electrochemical properties of the DSSC using these extracts as sensitizers were duly investigated in this work.

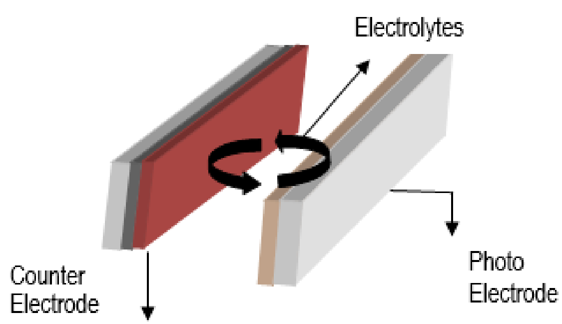

Fig. 1: Working principle of DSSC

2. 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 following the procedure describe elsewhere (Isah *et al.*, 2015). The filtrate is the sensitizer dye solution for the cell.

The FTO glass (40 mm thick and surface resistivity of about 20Ω) was cut into desired dimensions and shaped 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 TiO_2 paste, using a polyester mesh, was screen printed unto the conducting side of FTO glass and heated for 10 minute at 100 ºC on a hot plate. Progressive heating was adopted to ensure optimal adhesion of the titanium dioxide layer onto FTO glass until its colour changed from white to brown. TiO_2 undergoes sintering at 450 °C for 45min by heating the screen printed glass with a hot plate, and then it was 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 UV–Vis spectrophotometer (Ava-spec-2048 spectrophotometer) was used to characterize the absorbance of the dye in the visible range of the solar spectrum. For measuring the performance of the dye as sensitizer in DSSC, I–V characteristics were performed using solar simulator (Keithley 2400) under sun illumination source (AM 1.5). The cell has an active area of 0.021cm^2. The photo efficiency performance of DSSC is calculated following this relation:

$$\eta = \frac{FF \times I_{sc} \times V_{oc}}{P_{in}} \quad (1)$$

$$FF = \frac{I_{max} V_{max}}{I_{sc} V_{oc}} = \frac{P_{max}}{P_{in}} \quad (2)$$

Where *FF* is the Fill Factor, I_{sc} is the short-circuit current, V_{oc} is the open circuit voltage, P_{in} is the power input to the cell which defined the incident of the total radiant energy on the surface of the cell, I_{max} is the maximum current obtained along y-axis, V_{max} is the voltage at the maximum power output and P_{max} is the maximum power output.

3. RESULTS AND DISCUSSION

The absorbance spectrum of the dye is shown in Fig. 2. The absorption spectra of the pawpaw leaf extracts were within the wavelength of 300 to 550 nm with the maximum peak absorption value at 380 nm. It was observed that the dye absorbs photo best at a wavelength of about 380 nm, while the TiO_2 absorbs best within the range of 300 nm to 450 nm. We studied the TiO_2 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.

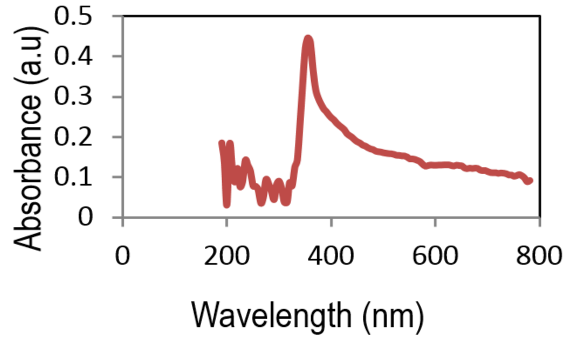

Fig. 2 Absorbance of dye on TiO_2 nanoparticles

Fig. 3 depicts the photo-electrochemical performance of DSSC using pawpaw leaf extracts as dye sensitizer. The performance was measured by current-voltage curves under solar irradiation with halogen lamb of 100 mW/cm^2. From the observed curve, the cell performance is relatively good with conversion efficiency of 0.030 %. Lower efficiency obtained from the extract of pawpaw leaf in this study could be as a result of extracting solvent which is ethanol. Similar work was carried out by Kimpa *et al.* (2012) and Isah *et al.* (2015). and water was used as the extracting solvent and the conversion efficiency was around 0.27 and 0.23 %, respectively. The transfer of poor charges between dye molecules and TiO_2 due to low growth kinetics can be responsible for the low conversion efficiency of cells. In fact, significant increase in efficiency can be achieved with greater caution on cell preparation and reassessment of materials and methods used. Based on this argument, ethanol can be replaced with other solvents as extracting material. Another reason for lower efficiency can be due to the electrolyte material used. Fast ethanol degradation as a solvent may be caused by highly volatile electrolyte which can eliminate dyes and destroy counter electrodes. Increasing the TiO_2 coloring attachment by introducing a carboxyl group and the use of solid / gel electrolyte also can address this problem so as to improve the efficiency of the conversion.

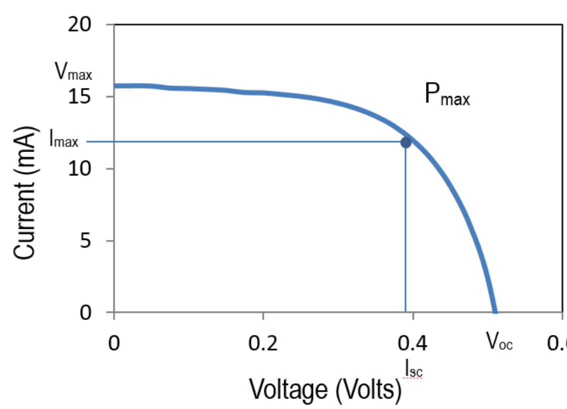

Fig. 3: Photoelectrochemical performance of DSSC extracts from pawpaw leaf

4. Conclusion

Sensitization of a dye solar cell using extract of pawpaw has successfully been fabricated. We observed a fill factor of 0.5867 for the pawpaw cell. The pawpaw leaf dye absorbs visible light in the range of 300 nm to 550 nm and its peak absorbance value was at 380 nm with a cell energy conversion efficiency of 0.030%.

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