ESSENTIAL ROLE OF SURFACTANT ON TITANIUM DIOXIDE - ROSELLE DYE SENSITIZED SOLAR CELL

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ABSTRACT

In this approach the Blade-Method was employed to fabricate TiO_2-Roselle Dye Sensitized solar Cell with different surfactants by using the natural harvestable Roselle dye to replace ruthenium complex. The vinegar + gum acacia happened to be the best surfactants with overall short circuit current and open circuit voltage of I_{sc}=80.06µA and V_{oc}=0.41V, 22.87 µA and 0.18V under the sun and under illumination respectively.

Keywords**:** Dye Sensitized Solar Cell, Roselle, TiO_2, ITO, Gum Acacia

1 INTRODUCTION

Considering natural resources depletion and environmental demands, utilizing solar energy is certainly one of the most viable ways to solve the world's energy crisis. Dye-sensitized solar cells (DSSCs) have emerged as promising candidates for harvesting solar energy, owing to their low-cost, flexibility, ease of production, relatively high energy conversion efficiency, and low toxicity to the environment [1]. With all effort, significant progress has been achieved for Dye Sensitized Solar Cells by introducing some novel components such as dyes, electrolytes and surfactants, along with photo-anode having various morphologies for the semiconductor materials. It is apparent that the further improvement of DSSCs is a key factor to accelerating their industrialization. They are currently the most efficient third-generation solar technologies available, one major disadvantage in the DSSC design is the use of the liquid electrolyte, which has temperature stability problems: At low temperatures the electrolyte can freeze ending power production and potentially leading to physical damage [2]. Basically a solar cell, SC, consists of a junction of p- and n-type semiconductors [3]. At the interface the Fermi levels of both semiconductors are the same, generating depletion region, and therefore, a charge separation[4]. When photons are absorbed in the p-type region, an electron-hole pair is created. Each electron is then injected in the n-type region and the hole goes across p-type region. In the case of TFSCs the amount of material for the SCs production is considerably less, thus it reduces costs [5]. Some other advantages consist on the possibility of working with lighter materials and flexible substrates [6].

The working principle of dye sensitized solar cell is to convert solar energy into electricity which consists of two conductive glasses and sandwiched between; nanoscale titanium dioxide, dye and electrolyte. Dye is adsorbed on the titanium dioxide when it absorbs sunlight its electron will transit from ground state to the excited state then injected into the conductive layer of the titanium dioxide and the loop finally form current. The electrolyte is mainly to carry out the redox reaction.

In today's society, the use of natural pigment as sensitizer for the conversion of solar energy into electricity is very interesting owing to the fact that, they enhance the economical aspect and produced a significant benefits from the industrial point of view [7]. Natural pigments extracted from fruits and vegetables, such as chlorophyll and anthocyanins have been extensively investigated as Dye Sensitized Solar Cell sensitizer. The sensitization of wide band gap semiconductors using natural pigments is usually ascribed to some organic pigments, like anthocyanins and anthraquinones extracted from the leaves, flowers or other parts of the plant [8].

The third generation photovoltaic dye sensitized solar cell research gained significant interest in scientific and technological society. Advanced work by Michel Gratzel. reported the use of a Ruthenium-based dye with achieved efficiency of 10.6% [9]. However this compound is expensive, therefore people are interested to utilize inexpensive dye ingredients based on natural products such as fruits and vegetables having natural pigment which contains anthocyanin. Anthocyanin is a blue, red or violet pigment found in plants and able to absorb visible lights. Recently, some research group reported the usages of tamarillo extracts as dyes for DSSC and resulted in efficiency of 0.043% [10]. With all these efforts, Ozuomba et al. reported the incident solar light to electric energy conversion efficiency of 0.58% and 0.03% for the anthocyanin-dyed cell and the un-dyed cells respectively with Roselle extract [11]. Again, Adamu et al. used natural harvestable Roselle dye announced the energy conversion efficiency of 0.01% was achieved [5]. This accomplishment was demonstrated in a PEC device consisting of a nanocrystalline and mesoporous TiO_2 (anatase) thin-film electrode sensitized [8].

The resistivity ($\boldsymbol{\rho}$) and conductivity (σ) of the ITO glass slides was measured according to equation (2) and (3). Where R, t and L are the resistance, the thickness and the length of the ITO glass slides respectively [12].

$$R = \rho\frac{L}{A} = \rho\frac{L}{W\times t}\text{ , } for\ L = W\,(square)\ we\ have \quad (1)$$

$$\rho = R \times t \text{ and} \quad (2)$$

$$\sigma = \frac{1}{R\times t} \quad (3)$$

Hence, this paper presents several possibilities in forming a homogeneous layer of Titanium-Dioxide and Carbonated pastes on the glass slides for dye sensitized solar cell. In any case the cells were connected with Multi-meter to measure the performance of the DSSC.

2 EXPERIMENTAL DETAILS

2.1 Materials

Titanium Dioxide TiO_2 (79.89Mw, 99%) of Qualikems (T009111) For Laboratory Use obtained From CMAN NLT, Kabuga Kano Nigeria, Indium tin oxide coated (ITO) glass slide 25mm x 25mm with surface resistivity 10Ω/sq obtained from TECHINSTRO (TIX001) INDIA, VECSTAR Furnace from chesterfield U.K. (LF2 MOD, 2000W, 240V and 1200 max. temp), Adventurer OHAUS AR2740 digital weighing machine, 2 Digital DT9205A Multi-meters, voltmeter (EDM-14, 0-2V), ammeter (EDM-14, -20-100µA), micrometer screw gauge, Carbon soot, Gum acacia, White vinegar, Morning fresh, Swanglue obtained from Shopwell Kano, Roselle (Zobo), silver paste (EN06B8) from ENSON Japan. All chemicals used were purchased and employed without any further purification.

2.2 Preparation of Gum Arabic

Gum acacia was obtained from Taura LGA, Jigawa state, Nigeria. The samples were pulverized with the aid of mechanical blender (liquidizer). 20g of each pulverized sample was weighed using Adventure OHAUS Electronic weighing balance model AR2740 mixed with 50g of well blended powdered activated carbon soot and boiled with distilled water for 3 hours. The extract of the sample were decanted to remove the residual part of the samples Fig 1.

Fig1 Gum Arabic

2.3 Continuity Test of The ITO Glass slides

The conductive side of the indium-tin coated oxide (ITO) glass slides was identified by continuity test. The resistance of ITO glass slides was determined using Digital Multimeter Model-DT9205A and recorded in Table I. The Multimeter was connected across the square edges of the ITO glass slide shown in **Fig 2**.

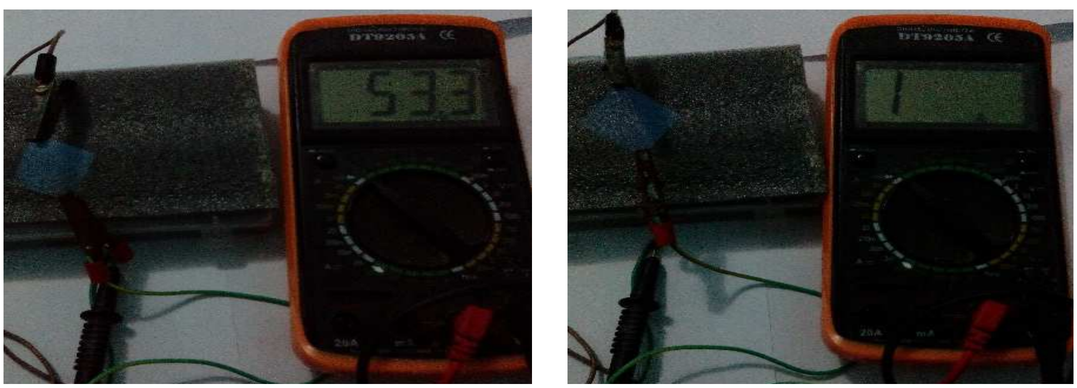
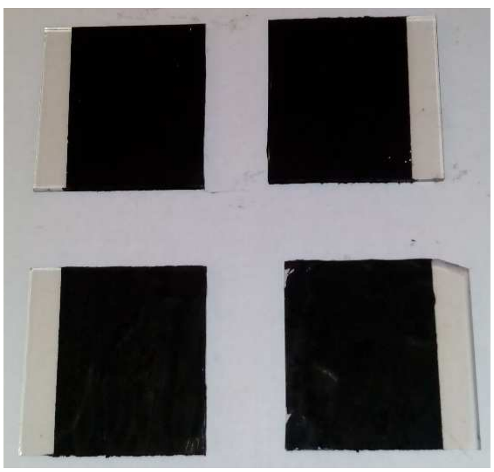


Fig 2: continuity test of conductive and non-conductive side of ITO glass slides

2.4 Fabrication of DSSC

In this work, an equal amount of well blended powdered activated carbon soot was mixed with different surfactant as counter electrode material. The deposition of our counter electrode on indium doped tin oxide (ITO) glass substrate was enabled through the doctor- blading method. The conducting side of a 2.5cm x 2.5cm ITO was identified and covered on each of the parallel edges with a sellotape of thickness 0.035mm to control the thickness of the TiO_2 film. Before deposition, the glass substrates were cleaned with isopropanol, then Ethanol. The carbon paste which was prepared through Doctor-blading method was applied at one of the edges of the conducting glass and distributed with a squeegee sliding over the tape-covered edges. The electrodes was kept on the safer side for about 24hours before removing the adhesive tapes. The edges were cleaned with ethanol Fig 3(a). Nanocrystalline titanium (iv) oxide was used as photo-electrode. The same blade method was adopted in depositing the TiO_2 layer and the film was allowed to dry naturally for five minutes before removing the adhesive tapes. The edges were also cleaned with ethanol. The electrodes was sintered for 30 minutes at a temperature of 400^0C using the Vecstar LF2 MOD furnace. The contained liquid of the paste burns away, leaving the Titania nanoparticles sintered together. This process ensures electrical contact between particles and good adhesion to the TCO glass substrate [13]. The furnace was allowed to cool down before removing the annealed electrode. This is because a sudden change in temperature can cause the glass to break [14]. The resulting nanoporous layer made from the sintered particles was stored in a sealed environment to avoid moisture absorption from ambient air. The TiO_2 photo-electrodes were immersed into a solution of the local dye for 15 minutes Fig 3(b). The binder clips was cleaned with ethanol before it was rightly placed on the dyed working electrode. The conductive side of the transparent electrodes was gently placed on top of conducting carbonized side of the counter electrodes[11]. We introduced 0.5ml drops of the electrolyte (Iodide/triiodide) through one of the gap left between the two glass plates by capillary action[15]. Electrical contacts were made by applying the silver paste (ENSON, EN06B8) along the conducting side of electrode.


a

b

Fig 3: (a) Carbon soot film deposited on ITO glass slides (b) TiO_2 film deposited on ITO glass slide

2.5 Photovoltaic Performance of DSSC

The performance of the DSSCs was determined using a Digital DT9205A Multi-meter, voltmeter (EDM-14, 0-2V) and ammeter (EDM-14, -20-100µA under the sunlight at 12:pm and under illumination of 100W bulb. The measurements were carried out for dilute nitric acid, vinegar, based DSSCs, the same method was employed with surfactant in the Titania paste in order to study the role of surfactants as shown in Table I.

3 Results and Discussion

It was observed that, the measured resistivity and conductivity of various glass slides (A-J) shown in Table 2. The resistance of the glass slides depend on the distance of separation between the two terminals of the multimeter. These result shows that the performance of the dye sensitized solar cell depends on the overlap area between the two conductive glass slides.

The effect of surfactant was observed in Table II. Dilute nitric acid + swanglue-based DSSC and Vinegar + swanglue-based DSSC shows poor performance with zero short circuit current in both the two situation. However, Dilute nitric acid + morning fresh-Based DSSC and Vinegar + morning fresh-based DSSC appreciates with short circuit current and open circuit voltage of; 50.21µA, 21.70µA and 0.18V, 0.07V and 35.10µA, 9.60µA and 0.17V, 0.04V under the sun and under illumination respectively. Finally, Dilute nitric acid + gum acacia and Vinegar + gum acacia-based DSSC gives a reasonable performance with short circuit currents and open circuit voltages of; 80.06µA, 22.87µA and 0.41V, 0.18V and 65.05µA, 22.87µA, and 0.41, 0.18V under the sun and under illumination respectively.

Experimentally it was observed that swanglue is a poor surfactant, this is because it cannot withstand any temperature above 50^{o}c unlike morning fresh and gum acacia which can work well ant higher temperature of 400^{o}c. Based on these results, vinegar + gum acacia are the best combination in forming the Titanium Dioxide-Paste.

Table I: Measured Resistivity And Conductivity Of Various ITO Glass Slides Of 1.1mm Thickness

Sample	Resistance (Ω)	Resistivity (Ωm)	Conductivity $(\Omega m)^{-1}$
A	67.7	0.07447	13.42823
B	67.6	0.07436	13.44809
C	67.5	0.07425	13.46801
D	67.3	0.07403	13.50804
E	58.9	0.06479	15.43448
F	57.7	0.06347	15.75548
G	57.0	0.0627	15.94896
H	54.2	0.05962	16.7729
I	53.3	0.05863	17.05611
J	51.4	0.05654	17.68659

Table II: Average Current-Voltage Obtained At 400^{0}c Roselle-Dye Sensitized Solar Cell For Various Surfactant Of TiO_2 Films.

Surfactant	V_{sun} (V)	V_{illum} (V)	I_{sun} (µA)	I_{illum} (µA)
Dilute nitric acid	0.1	0.05	30.00	10.07
Vinegar	0.13	0.09	44.80	16.30
Dilute nitric acid + morning fresh	0.18	0.07	50.21	21.70
Vinegar + morning fresh	0.17	0.04	35.10	9.60
Dilute nitric acid + swanglue	0.24	0.05	0	0
Vinegar + swanglue	0.27	0.06	0	0
Dilute nitric acid + gum acacia	0.30	0.10	65.05	21.12
Vinegar + gum acacia	0.41	0.18	80.06	22.87

4 CONCLUSION

Titanium Dioxide-Roselle Dye sensitized Solar Cells was successfully fabricated at constant annealing time of 30 minutes and temperature of 400^{0} in which the vinegar + gum acacia happened to be the best surfactant with overall short circuit current and open circuit voltage of 80.06µA and 0.41V, 65.05µA and 0.18V under the sun and under illumination respectively.

5 ACKNOWLEDGEMENT

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