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A COMPARATIVE STUDY OF THE PERFORMANCE OF DYE –SENSITIZED SOLAR CELLS BASED ON ANTOCYANIN LOCAL DYE AND RUTHENIUM DYE

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The performance of *anthocyanin* local dye as photosensitizer for dye-sensitized solar cell has been compared with that of Ruthenium-620 organic dye. *Anthocyanin* dye is an extract from hibiscus sabdariffa which is an edible plant called *zobo* by Nigerians. Optical absorbance measurements show that both *anthocyanin* and Ruthenium dye are good photosensitizers for titanium (iv) oxide. The dye-sensitized solar cell fabricated with Ruthenium-stained TiO_2 electrode showed a better photovoltaic performance but the *anthocyanin*-stained cell showed a similar fill factor. Also, the photoconversion efficiency of the cell fabricated with the local dye is not poor when compared with the result of the Ruthenium-stained cell and other existing results.

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1. Introduction

Dye-sensitized solar cells (DSSCs) offer the hope of fabricating photovoltaic devices with high efficiency at low cost [1,2]. Gratzel group has successfully developed a high power conversion efficiency of about 11% with thick spin-coated nanoporous TiO_2 as a photoelectrode [1,3].

Unlike solid-state photovoltaic devices, dye sensitized photoelectrochemical cells are based on interpenetrating networks. These cells feature a dye molecule chemisorbed on a porous, nanocrystalline TiO_2 film. The pores of the film are filled with a liquid electrolyte. Photo-excited dye molecules inject electrons into the conduction band of TiO_2, and redox species in the electrolyte reduce the oxidized dye molecules back to their original state. Recombination with oxidized species in the redox electrolyte is one factor that limits the efficiency of these cells. A recent strategy employed for mitigating this type of recombination involves adding certain components to the electrolyte that are believed to adsorb to and passivate the surface of the TiO_2 [4,5].

Nanoporous TiO_2 films have the capability of adsorbing a wide range of dyes. The sensitization process occurs via participation of only the conduction band of this semiconductor as was proposed by Mott and Gurney [6]. A DSSC was recently developed by sandwiching a natural pigment in between n-type and p-type semiconductors by a Sri Lankan research group [7]. The efficiency of this cell was less than 1%. Several natural pigments [7-10] and synthesized dyes [11-14] have been identified as suitable sensitizers for wide band gap semiconducting oxides. Sirimanne *et al* 2008 [15] obtained photoconversion efficiency ranging from 0.04% to 1.67% using three different dyes. Suri *et al* 2007 [16] obtained photoconversion efficiency of 1.43% using undoped ZnO as photoanode and Eosin-Y as an organic dye. Law *et al*, 2005 [17] fabricated

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DSSC with TiO_2 sensitized with $Ru(DobpyH)_2$ $(NCS)_2$ and obtained photo-conversion efficiency of 1.5% under a full sun intensity of $100mW/cm^2$. This work studies the photovoltaic performance of a DSSC fabricated with anthocyanin dye by comparing its characteristics with those of Ru-620 dyed solar cell. Anthocyanin dye is a local dye extracted from hibiscus sabdariffa.

2. Experimental Details

2.1 Electrode preparation

In this work, an equal amount of well blended powdered activated carbon (PAC) and a kind of natural graphite powder (NGP) was used as counter electrode for both cells. Carboxy ethyl cellulose (natrosol) and tin II chloride were used in a sol-gel process to produce our binder. The well blended carbon mixture was mixed with the binder in the ratio of 3g/ml to obtain our carbon paste for the counter electrode. The active area of a 2.5cm x 2.5cm fluorine-doped tin oxide conducting glass substrate (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 film. Before deposition, the glass substrate was cleaned with acetone, then methanol and etched through plasma treatment for 1min. The carbon paste was applied at one of the edges of the conducting glass and distributed with a squeegee sliding over the tape-covered edges. A hot air blower was used to dry the electrode for about 3 minutes before removing the adhesive tapes. The edges were cleaned with ethanol. The carbon electrode was sintered at 150^0C in a furnace (carbolite 201 tubular furnace) for about 15 minutes.

Nanocrystalline titanium (iv) oxide (Ti-nanoxide T/sp, Solaronix SA, Rue de e' duriette 128) was used as photo-electrode. The same blade method used in depositing the counter electrode was adopted in depositing the TiO_2 layer. The film was allowed to dry naturally without blowing before removing the adhesive tapes. The edges were also cleaned with ethanol. The electrode was sintered for 30 min at 400 ^oC using the same carbolite 201tubular furnace.

2.2 Dye sensitization

The *anthocianin* dye used in sensitizing the mesoporous TiO_2 film was extracted from hibiscus sabdariffa which is a common edible plant called zobo by Nigerians. Extraction of the pigment from hibiscus sabdariffa was achieved through this simple process:

(i) Blend the hibiscus sabdariffa using electric blender.
(ii) Add 90% ethanol and continue blending.
(iii) Use sieve to extract the pigment which forms our dye.

The TiO_2 photo-electrode was immersed into a solution of the local dye overnight. The electrode was preheated at 80 ^oC for 15 minutes before it was dipped into the dye solution. Another photo-electrode was sensitized using Ruthenium-620 organic dye.

2.3 Cell fabrication

Sealing gasket (SX 1170 – 60 PF, Solaronix SA) brings the ease of using a 60μm thick hot melt foil for sealing the cells. The sealing gasket was cleaned in ethanol before placing it on top of the dyed working electrode. The counter electrode was gently placed on top of the frame and held in position with a clamp with the conducting carbonized side towards the working electrode. The set up was held over a hot plate for 1 min at 150 ^oC before allowing it to cool for a few minutes. A few drops of the electrolyte (Iodolyte R-150, BN408/071008SN, solaronix SA) were introduced in between the electrodes and the cell was sealed using Amosil 4R sealant (BN011008SN, Solaronix SA). Electrical contacts were made by applying silver paint along one of the edges on the conducting side of each electrode. A second cell was assembled using the Ru-620 dyed TiO_2. The active surface area of the *anthocianin*-dyed and Ru-dyed cells were $1.54cm^2$ and $1.80cm^2$ respectively.

2.4 Measurements

The thickness of both electrodes was measured using Dektak stylus 7.0 surface profiler. The sheet resistance of the carbon counter electrode was measured using dual-Pro 301 (auto calculating 4 pt. Probe resistivity test system). The optical absorbance of the *anthocianin*-stained TiO_2 was measured using Avaspec 2.1 spectrophotometer. The I-V characteristics was measured using an Oriel class A solar simulator (AM 1.5, 100mW/cm^2).

3. Results and discussion

The thickness and sheet resistance of the carbon counter electrode were 4.2µm and 15.4 Ω/□ respectively. The thickness of the photo-electrode deposited using the same blade method was 6.2µm. *Anthocyanin*-stained TiO_2 electrode showed an outstanding optical absorption within wavelength range of 283 nm – 516 nm. Peak absorbance of 2.16 A.U., 2.26 A.U. and 2.38 A.U. were recorded in the UV region at 324.45 nm, 344.87 nm and 369.35 nm respectively (Fig.1). Appreciable absorbance was recorded in the visible region with two outstanding peaks, 2.26 A.U. and 2.16, occurring at 405.99 nm and 426.47 nm respectively.

Fig. 2 also shows that the Ru-stained TiO_2 has good optical absorbance over a wide wavelength range (313nm - 605nm) both in the UV and visible region but very poor absorbance at the infra-red region. The highest peak of 2.65 A.U was recorded in the UV region at the wavelength of about 370nm. The highest peak recorded in the visible region was 2.46 A.U at the wavelength of 415 nm. Another peak of 2.35 A.U was recorded at 427 nm.

Meanwhile, Lee and Kang, 2010 [18] studied an unstained nanoporous TiO_2 and obtained optical absorbance of 1.3A.U. and 1.2A.U. at 200nm and 350nm respectively but no absorption was recorded beyond UV region. Also, a bare TiO_2 nanowire studied by Meng et al, 2008 [19] showed no optical absorption beyond 400nm. Hence, the *anthocyanin* and Ruthenium dye greatly improved the optical absorption capacity of the TiO_2 electrode.

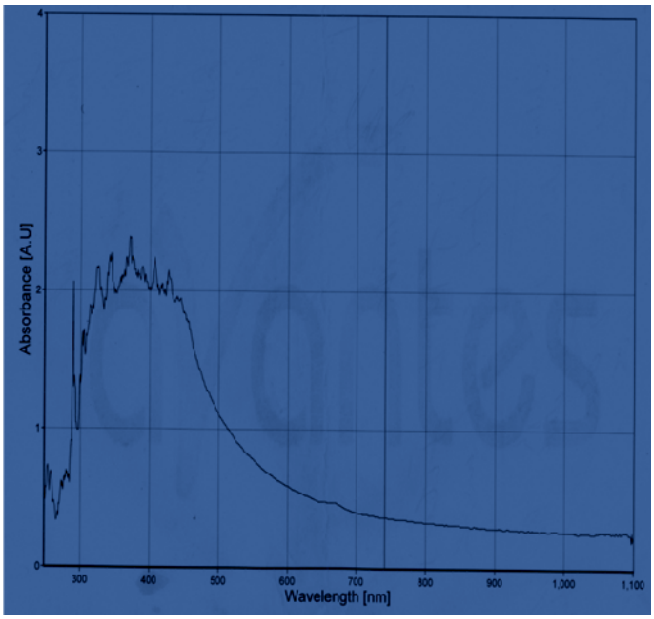

Fig. 1. Optical absorbance of anthocyanin-stained TiO_2

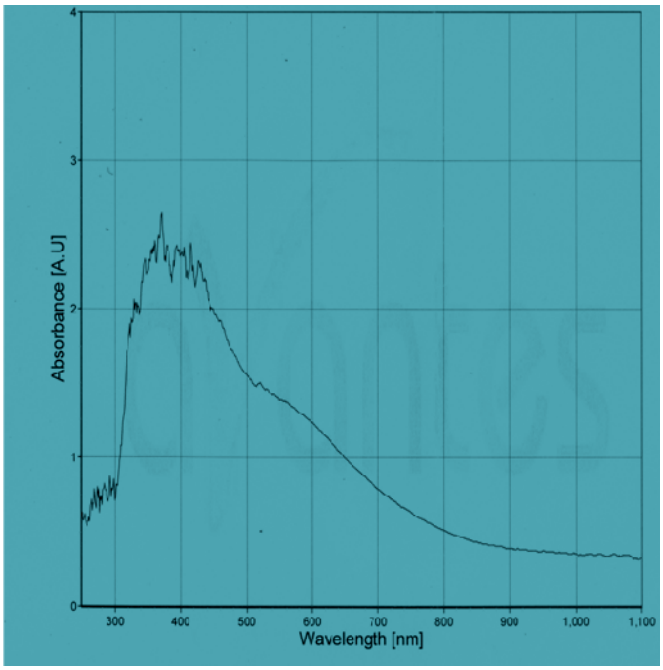

Fig. 2. Optical absorbance of Ruthenium-stained TiO_2

Fig. 3 and Fig. 4 are the photocurrent-voltage characteristics of DSSCs fabricated with the *anthocyanin*-dyed and Ru-dyed electrodes respectively. The cell parameters obtained for the *anthocyanin*-dyed electrode were; open circuit voltage (0.33V), short circuit photocurrent (2.60mA/cm^2), fill factor (0.68) and photoelectric conversion efficiency (0.58%) while the results obtained for the Ru-dyed cell were; open circuit voltage (0.52V), short circuit photocurrent (4.80mA/cm^2), fill factor (0.69) and photoelectric conversion efficiency (1.71%). The results were comparable to those of Sirimanne *et al*, 2008, Suri *et al*, 2007 and Law *et al*, 2005. The photovoltaic performance of our local *anthcyanin* dye could be compared to that of Rurhenium dye which is a conventional dye in the fabrication of dye-sensitized solar cells.

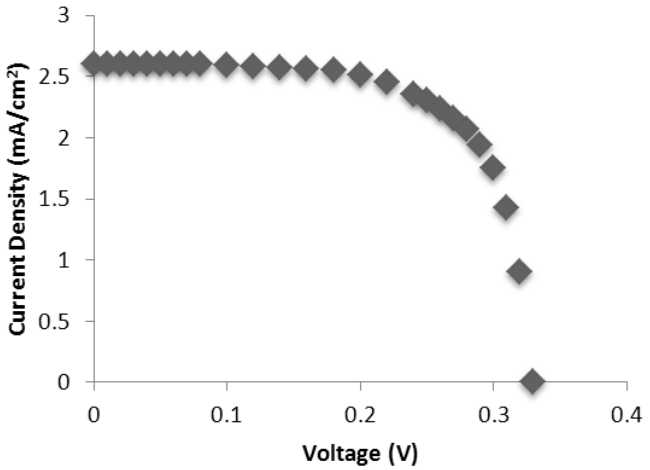

Fig . 3. The I-V curve for the cell sensitized with anthocyanin dye

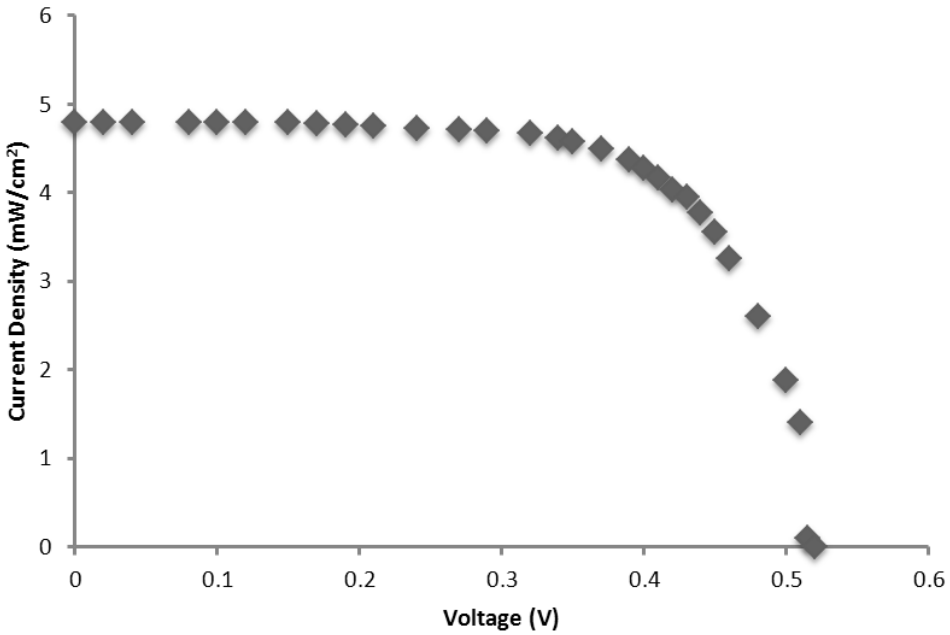

Fig. 4. The I-V curve for the cell sensitized with Ruthenium dye

4. Conclusion

Dye sensitized solar cells using *anthocyanin*-stained and Ruthenium-stained electrodes have been successfully fabricated. Although the optical absorbance of the Ru-stained TiO_2 electrode was better than that of *anthocyanin* dye, but the local dye greatly improved the optical absorption capacity of the TiO_2 electrode beyond the ultra-violet region. Also. the photocurrent conversion efficiency of the DSSC fabricated with the local dye was about three times lower than that of the Ru-dyed cell but both cells have similar fill factor. Hence, *anthocyanin* dye which is an extract of hibiscus sabdariffa is a viable alternative to Ruthenium which is a popular dye in the world of Dye Sensitized Solar Cells.

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