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FABRICATION, PERFORMANCE TEST AND EFFICIENCY OF ELECTRICAL ENERGY OF DYE SENSITIZED SOLAR CELLS (DSSCs)

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Abstract

Dye-Sensitized Solar Cells (DSSCs) were fabricated with three naturally occurring anthocyanin dyes extracted from naturally occurring seeds found in western African viz: raspberry, blackberry, pomegranate seeds as sensitizers. Extraction of anthocyanin was done using acidified ethanol. The highest power conversion efficiencies (η) of 0.3 % was achieved for the DSSCs fabricated using anthocyanin extracts of the seeds. The widespread availability of these seeds, high concentration of anthocyanins in them, and ease of extraction of anthocyanin dyes from these commonly available seeds render them novel and inexpensive candidates for solar cell fabrication. This study also synthesized conductive transparent glass as a substrate on which fabrication of solar power panels which after production is expected to generate <0.1 KvA to demonstrate the importance of these Soda Lime Glass (SLG). Twelve (12) Solar cells of averagely 300 mV and 0.02 A were fabricated. Equivalently these cells gave 3.51 volts averagely as peak voltage during the day and 2.08 volts as the lowest voltage during the lowest temperature. Although there were voltage variations when compared with standard silicon solar cells, the production could be improved upon if other metalloids that are economical are used for the production, or by increasing the number of cells.

Keywords*:* Performance Test, Anthocyanin, DSSCs, Kilovolt-Ampere (KVA), Metalloids

1. Introduction

Electrical energy utilization is pivotal to the socio-economic development of any nation and it is directly linked with any healthy growth, nationally. Nigeria is one of the countries with the largest deposit of renewable energy sources in the world still struggles to generate adequate electricity to support its economy. Regular and reliable electricity supply has been the bane and major concern in the country power sector where only about 40% of her total population is connected to the national grid. The alternative power supply in the present day Nigeria seems like a task without a solution; the inadequacies at exploring the available human and material resources to combat this challenge have not been given due attention. Nigeria has one of the largest deposits of fossil fuels as renewable energy sources in the world but unfortunately, these fuels remain underutilized as evident in her electricity generation which remains a major challenge in the country (Iwayemi, 2008). Kaseke and Hosking (2013) enumerated the importance of the utilization of electrical energy to national development especially on socio-economic growth and technological advancement. Aliyu *et al.*, (2013) showed that only about 40% of the total Nigeria population are connected to the national grid with the possibilities of getting electricity supply

which hovers around 3000megawatts distribution from a peak generation of about 7000 mW in recent years. It has been suggested that Nigeria's power generation needs to generate >45,000 mW to adequately cater for her growing economy and population otherwise; there would be a major developmental setback. Most unfortunate Nigeria still struggles with the generation of 10,000megawatts of electricity not to talk 40,000 mW. Therefore, every other avenue that would bring succor in the provisions of electricity supply not necessarily relying on the provisions of the Nigerian government should be encouraged to ease electricity challenges in every Nigerian home (Aliyu *et al.*, 2013). The Nigeria power sector is faced with enormous challenges in electricity generation and especially distribution owing to insincerity, inadequate funding, lack of focus and misplaced priority, inadequate human and material resources, large-scale corrupt and sharp practices, and undue awards of contracts (Adenikinju, 2011). Several types of research have been carried out to help reposition the power situation in Nigeria both at the generation and the distribution sectors but the results of the researches have not been given the desired consideration. One such suggestion is the diversification from hydro-based power generation to other sources of electricity generation: fossil fuels, wind, solar, natural gases, etc, and sustaining the adequate requirements in the distribution of the total electricity that is generated. Fossil fuels: natural gas, coal, oil, remains the most tapped into energy sources in the world. Renewable energy has an important role to play in meeting future energy needs and achieving sustainability. However, its diffusion and deployment are slow due to the high cost of implementation, and the adverse environmental impacts these fuels could cause if not properly managed; although, various financial and technical constraints have limited the use of renewable energy in Nigeria (Oyedepo, 2012). The impacts of global warming are increasingly becoming evident in the form of intensifying weather calamities, disappearing glaciers, and increasing water levels in the oceans. The impact hereof has equally led the world gearing towards "green" energy technologies where photovoltaic cells or solar cells which convert sunlight directly into electricity are becoming the in it in power generation. The sun is a mass of hot gaseous matter that radiates at an effective temperature of about 6,000°C and emits enormous quantities of energy that is adequate to supply the energy requirements needed for most functionalities in every man's developed system. The possible use of solar energy may fall into three categories: thermal processes, photochemical processes, and photoelectric processes. In thermal processes, the radiant energy is absorbed as heat by a receiver substance which then undergoes an increase in temperature, vaporization, or other heat-absorbing processes. Photochemical processes are those in which light energy causes a chemical process, and photoelectric processes are involved in the direct conversion of radiation to electrical energy. In the field of photoelectric processes, the Bell 'Solar Battery' has given conversions of solar energy to the electric energy of 11 percent. It employs silicon cells: other similar developments have been made with cadmium sulphide cells. Solar energy does not refer to single energy technology but rather a diver set of renewable energy technologies that are inexhaustible and powered by the Sun's heat. Some solar energy technologies, such as heating with solar panels, utilize sunlight directly. Other types of solar energy, such as hydroelectric energy and fuels from biomass (wood, crop residues, and dung), rely on the Sun's ability to evaporate water and grow plant material, respectively. The most commonly considered uses of solar energy are those which are used as thermal processes. They include house heating, the distillation of seawater to produce potable water, refrigeration and air conditioning, power production by solar-generated steam, cooking, water heating, and the use of solar furnaces to produce high temperatures for experimental studies. Silicon-based solar cells are the most renowned and the oldest photovoltaic technology; there are, however, plethora of non-silicon-based solar cells available today and many are still being researched. Solar cells can be generally divided into two broad categories depending on the type of the photoactive material used viz: inorganic and organic solar cells. Inorganic solar cells are the first generation solar cells and are based on silicon technologies, while the second generation solar cells are based on thin films deposition of amorphous silicon (a-Si), chalcogenides such as cadmium selenide (CdSe), Copper indium gallium selenide (CIGS), cadmium telluride (CdTe), etc. Organic solar cells form the third generation of photovoltaic technology and could be further divided into three subdivisions: dye-sensitized, small molecules, and polymer solar cells. Polymer solar cells (PSCs) are the most recently used technology primarily because of the few numbers of materials required, and the low production cost. This study is however explored to develop an alternative power supply through the production of a dye-sensitized solar cell using some semiconductor materials. Whereas alternative power supply in present-day Nigeria seems like a task without a solution, since the inadequacies at exploring the available human and material resources to combat this challenge have not been given due attention, this study embarks on the production of conductive transparent glass as a means of generating solar power panels which after production is expected to generate <0.1KVA just to demonstrate the usefulness of these glasses which are readily available in our environment. Equally, as a subject of concern, Indium Tin Oxide (ITO) is the most commonly used material for the production of transparent heaters and solar panels, but the production cost is relatively high and whereas the indium resources tarnish fast. Recent studies showed Tin (II) oxide could serve as an alternative to ITO in this regard with its high-temperature stability and could be made to conduct. This paper aims to fabricate dye-sensitized solar cells (DSSCs) using soda-lime glass (SLG) substrates and to actualize synthesize of conducting soda-lime glass (DSSCs) substrates, fabrication of DSSCs capable of generating an electric current (0.01 A) using the CSLG and to evaluate the performance test and the efficiency of the DSSCs.

2. Materials and Methodologies

Twelve Soda Lime Glass (SLG) substrates with dimension (25.4 x 76.2 x 1.2) mm were washed and rinsed with toothpaste (a source of Fluorine) to make the SLG mildly abrasive. The toothpaste was later washed off using soapy water, also with isopropyl alcohol, and finally with deionized water. The SLG was allowed to air-dry at room temperature. About 5 cm^3 of Tin (II) Chloride ($SnCl_2$) powder was applied on one edge of the SLG and heated to about 400 ^oC in an electric furnace to make them conductive and that during the heating process, the powdery $SnCl_2$ turns to a liquid state and as such smears upon the surface of the SLG, while a blower was used to aid the smearing with the emergence of a rainbow color on the surface of the SLG which indicates the final stage of the conductive processes of the SLG and they were allowed to cool before testing for their conductivity using a Multimeter of range 0-20 Ω (ohms). Thus, conducting soda-lime glass (CSLG). The conducting sides of the CSLG were identified and taped on three sides to the center to serve as a control for the thickness of the yet to be applied Titanium (II) Oxide (TiO_2) on the CSLG surface. A tissue wet with ethanol was used on the CSLG to wipe off any fingerprints or oils or any impurity on the surface of the CSLG. 0.5 g of the finely powdered TiO_2 was dissolved in 10 cm^3 of dilute acetic acid to obtain a colloidal suspension of the TiO_2 to make TiO_2 paste. The paste was applied on the surface of the conducting side of the CSLG and quickly spread across the surface of the CSLG and the paste was allowed to air-dry on the CSLG. The tapes were carefully removed without scratching the TiO_2 coating. The slide was later heated on a hot plate inside a fume hood for about 10-20 minutes which turned the conducting surface of the CSLG brown and this indicates the presence of white or green sintered Titanium Dioxide coating. The CSLG was air-dried and immersed into a 250 cm^3 beaker containing the juice of the pomegranate seed which serves as the dye sensitizer (an activator of the semiconductor in the presence of light) on the CSLG and this turned the TiO_2 paste purple and this indicated the end of that stage. The activated CSLG substrates were removed and rinsed with ethanol to remove any solid impurities or water on the slide. One of the twelve CSLG substrates was taken and coated with a carbon suit by applying a flame on the slide using a candle as the source of the flame. The CSLG substrates were connected (to form the panel) and ensured that the conducting sides of the CSLG substrate face each other such that the initial area where the $SnCl_2$ was applied were both left out. A drop of potassium iodide (KI_3) solution (an electrolyte) which was made from 0.5 M potassium iodide (KI) and 0.05 M iodine (I_2) dissolved in anhydrous ethylene glycol/ethyl-1, 2-glycol, was applied to the opposite edges of the panel, the solution spreads (via capillary action) between the two CSLG (the panel). The solution could corrode the alligator clips that were used to connect the panels, therefore the excess solution of the KI_3 on the panel was voided. Thereafter, the voltage generated and the corresponding current by the panel were tested with aid of a Multimeter. Finally, the panel was placed under the sun's ray intensity to show its capability and workability.

Result

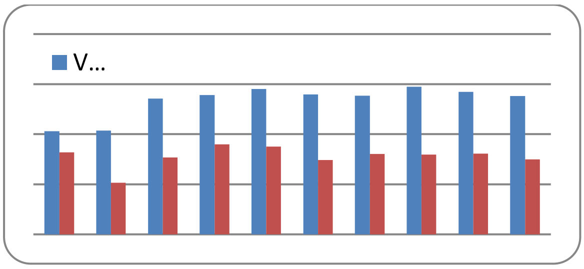

Figure 1: Time variation of standard solar cell voltages and the DSSCs for Day 1

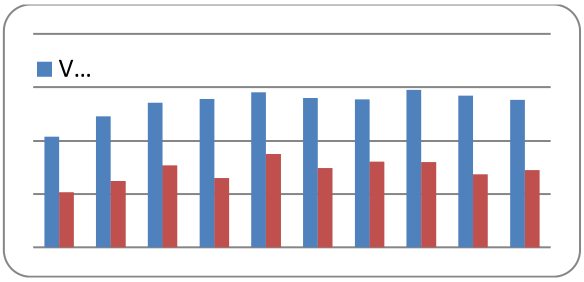

Figure 2: Time variation of standard solar cell voltages and the DSSCs for Day 2

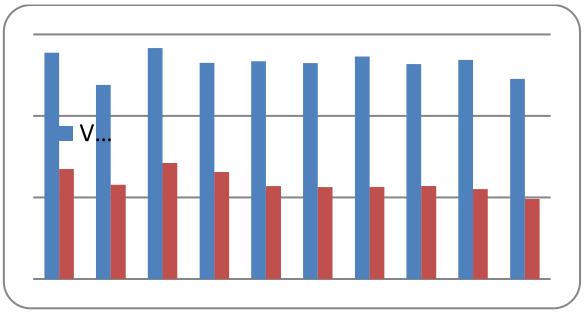

Figure 3: Time variation of standard solar cell voltages and the DSSCs for Day 3

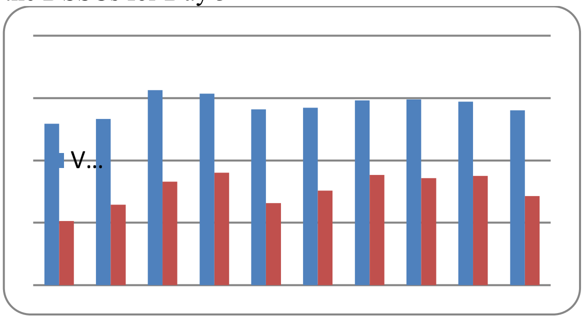

Figure 4: Time variation of standard solar cell voltages and the DSSCs for Day 4

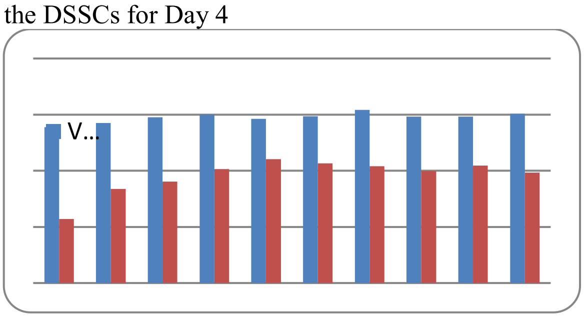

Figure 5: Time variation of standard solar cell voltages and the DSSCs for Day 5

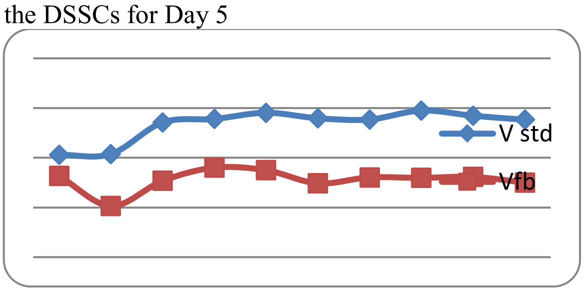

Figure 6: Day 1 Time variation with standard voltage and total voltage of all fabricated solar cells.

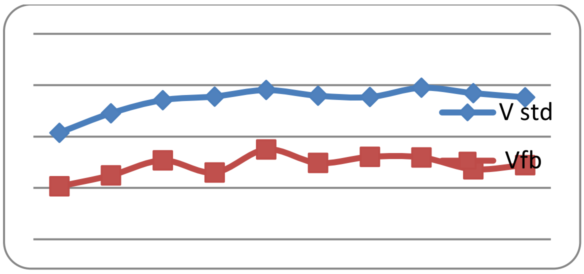

Figure 7: Day 2 Time variation with standard voltage and total voltage of all fabricated solar cells.

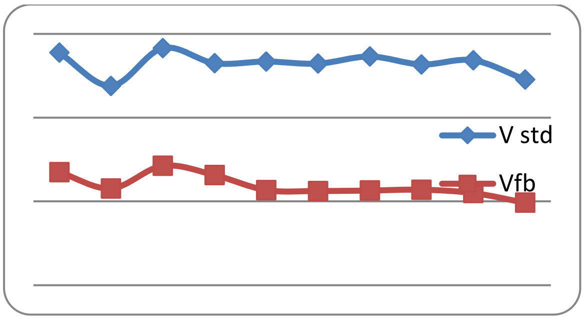

Figure 8: Day 3 Time variation with standard voltage and total voltage of all fabricated solar cells.

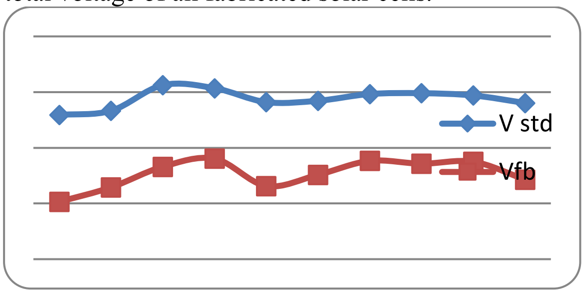

Figure 9: Day 4 Time variation with standard voltage and total voltage of all fabricated solar cells.

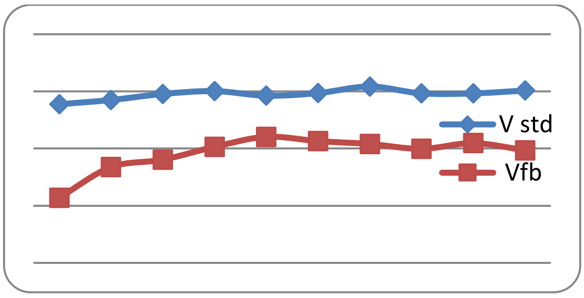

Figure 10: Day 5 Time variation with standard voltage and total voltage of all fabricated solar cells.

4. Discussion

This study fabricated twelve (12) Dye-Sensitized Solar Cells (DSSCs) of averagely 300 millivolts, and 0.02 amperes which is equivalent to 0.006 watts on average. To generate additional power in watts, it then implies more of the cells should be produced. At room temperature of about 27 °c, the minimum voltage recorded on the cells was 200 millivolts and 0.02 amperes, whereas 500 millivolts with 0.04 amperes were recorded at a high intensity of the sun rays of about 35°c temperature. Since the rate of reaction is supported with an increase in surface area, therefore it is believed that should the surface area of the solar cells produced be ten times larger, a wattage of 40 W would be produced. If 1000 cells were produced, then minimally (0.004 x 1000) watts should be generated which is 4 W. In this case the voltage or watts produced will be determined by the area of the SLG used. Generally, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (DC) electricity.

The solar-to-electrical energy conversion efficiency (η) of the cell is calculated using:

$$\eta = \frac{Pmax.}{Pin} x\ 100 \qquad 1$$

The pin is the solar power input and P_{in}= Ps x A
where: Ps = Irradiance in watt and A = Area of cell in cm^2
Ps = 1 Kw or 100 mW = 1000 W {This is the theoretical value of Ps under sunlight illumination at noon}. Therefore, power in spectrum is 1 kW/m^2 or 100 mW/cm^2. The energy conversion efficiency (η) obtained was 0.3 %. And the fill factor, FF is 29.031.

Dye-sensitized solar cells (DSSCs) were fabricated, tested and the energy conversion efficiency was calculated. Figures 1-5 compared the fabricated DSSCs with a polycrystalline solar cell, the fabricated DSSCs exhibited voltages in the range of millivolts as compared with the standard solar cell given voltage values in volt. However, on-time and ambient temperature variation, the voltages for standard cells increased with an increase in temperature, so also the voltages for the fabricated cells also increase with an increase in temperature. Figures 5-10 showed a similar pattern in all the voltages giving positive correlation coefficient values.

5. Conclusion

The dye-sensitized solar cell, though not as efficient as Silicon standard solar cell, it is a novel ideal to show case that solar energy could be generated using the Dye-sensitized method. This research could be improved upon using dye obtain through another source rather than raspberry, blackberry, pomegranate seed, thereby increasing the efficiency of the DSSCs energy more than the one achieved in this study.

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