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Performance Evaluation of Dye-Sensitized Solar Cell Using Bougainvillea Flower Extract

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Abstract: The readily availability of energy is the center on which all technology relies. The solar energy, being the mother of energy need, to be harness by various applications on which Dye-Sensitized Solar Cells (DSSCs) is a very cost-effective way to tap into this natural renewable energy. This study explores the viability of Bougainvillea flower dye extracts as sensitizers in DSSCs for efficient solar energy conversion. The study focuses on extracting dye compounds from Bougainvillea flowers and integrating them into DSSCs. The efficiency of these solar cells is evaluated through various parameters, including performance, stability, and photovoltaic characteristics. The energy conversion efficiencies of Bougainvillea flower were found out to be 0.13%. This phenomenon arises from the interaction between the carbonyl and hydroxyl groups of the anthocyanin molecule in dye extracts and the surface of the TiO2 porous film.

Keywords: : *Solar energy, energy management, low cost solar cell, natural dyes*

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I. INTRODUCTION

The world will continue to change in the area of energy production and consumption as it relates to technological advancement. The significance of sustainability of energy production and consumption that is economically viable and ecologically friendly cannot be overemphasized. As the world population continues to increase, so will energy demand, which will continue to be overstretched. Various ways to harness environmentally friendly sources of energy production have been a challenge and a prospect for researchers worldwide. Solar energy has the potential to solve the world energy problem as it is pollution-free [1].

Electrical energy is an indispensable element of human productive life [2]. Without it, there is no modern technology, economic development, and quality of life [3]. Nigeria as a developing nation has been facing electrical energy generation challenges for decades without meeting up with the demand for power supply. Most electricity from Nigeria comes from natural fuels like oil, natural gas, and dams. These fuels must go through combustion before being converted into electrical energy [4]. Pollution from combustion, including wastewater and other wastes, can also take the form of gases, dust, and smoke. This harms the ecosystem and contributes to the greenhouse effect, among other things [5]. Overuse of nonrenewable energy in Nigeria has caused various environmental issues, including pollution, acid rain, layer loss,

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and temperature change. Nonrenewable resources such as fossil fuels cannot be replenished quickly after they are used to supply our ever-increasing energy demands [6]. More than 80% of Nigeria's businesses rely on power from fossil fuels. Renewable energy that comes from the sunlight, wind and tides can replace or reduce the use of non-renewable like fossil fuels. Photovoltaic systems (solar cells) convert sunlight into electricity. It holds a significant position among various renewable sources [7]. This energy is applicable on a regular basis in structures and vehicles exposed to prolonged sunlight. It is cost-effective with reduced industrial waste. Fossil fuels contribute significantly to climate change [8] and the danger posed by these fossil fuels to the environment gives solar cells an edge in the generation of energy.

Various research findings have explained the efficacy of dye-sensitive solar cells (DSSCs) in harnessing energy from the solar system [9]; [10]; [11]; [12]; [13]; [14]. Sharma K., Sharma V., and Sharma S.S. [15] opined that dye-sensitized solar cells fit in to the category of thin-film solar cells that was developed by O'Regan and Gratzel [16].

To convert a photon into electricity in DSSCs, an electron must be introduced into the wide-band gap of the semiconductor; attaining this involves the excitation of the dye molecule. As a result of the environmental friendly nature of organic dyes when compared to inorganic, it is therefore imperative that the fabrication of DSSCs is a sure bet in harnessing the solar energy. Bougainvillea dye contains pigment, which can be extracted from plants bougainvillea flower [17]. The dye is a sensitizer that plays the role of absorbing sunlight and transforming solar energy into electricity [9]; [18]. It is evident that natural dyes contain chlorophyll, carotenoids, anthocyanin, and crocetin that are freely available in plant leaves, flowers, and fruits and are potential sensitizers [19]; [20]. Exploration of natural dyes, such as cyanine, anthocyanins, have made DSSCs to emerged as a promising and sustainable technology for harnessing solar energy. These cells utilize organic dyes to capture sunlight and convert it into electricity through a process inspired by natural photosynthesis. One intriguing avenue in DSSC research involves exploring natural dyes derived from various plant sources, such as the flower of bougainvillea plant, for their potential application in solar cell technology.

The Bougainvillea flower, known for its vibrant and diverse pigments, presents a unique opportunity as an organic dye source for DSSCs. The pigments taken out of flower of Bougainvillea plant which can potentially enhance the absorption of light rays and electron transfer efficiency within the fabricated solar cell, contributing to improved overall performance. This novel approach aligns with the growing interest in sustainable and eco – friendly alternatives to conventional solar cell technologies.

The study objectives is to assess the recital efficiency of DSSCs by making use of Bougainvillea flower dye extracts as sensitizers. This study aims to investigate the feasibility of utilizing Bougainvillea pigments in DSSCs, considering the aspects of light absorption spectra, electron injection efficiency, and overall energy conversion efficiency. In addition, we discussed the rationale behind selecting Bougainvillea flower dye extracts as potential sensitizers and outline the specific parameters that will be investigated in the performance evaluation. The main advantages of the cell made of dye pigment while comparing with the conventional PV cells are better performance in low light as well as with the diffused radiation, it is also cost effective and eco – friendlier. In this research. the DSSCs where made, using natural pigments extracted flower of Bougainvillea pant. The efficiencies and fill factor of the dyes are discussed. The findings from this study may contribute valuable insights to the development of efficient and environmentally friendly dye-sensitized solar cell technologies, paving the way for sustainable energy solutions. Photoelectrical and optical properties of DSSC sensitized with organic dyes were also discussed.

II. MATERIALS AND METHOD

A. *Materials*

The materials and reagents used in executing this study are Dry bougainvillea flowers, Ethanol, Water, Digital balance, Measuring cylinder, Laboratory mortar, FTO conducting glass substrate, Iodolyte N50 (electrolyte) Titanium diode paste, Platinum paste, Spectrophotometer, Whitman filter paper Centrifuge, Test tubes, Petri dish etc.

B. *Method*

1) Extraction solvent : The dye sensitizer was extracted using a mixture of ethanol and distilled water. The content consists of 70ml of ethanol and 30ml of distilled water.

2) Extraction of dye sensitizer from bougainvillea flower :The dye sensitizer from the dried bougainvillea flower was extracted using physical extraction method, the following procedures were followed. Using a digital balance the total weight of bougainvillea flower was measured to be 1.34g out of which 1.00g of the flower was put into a laboratory mortar and properly crushed. Then, 20ml of the solvent was added and vigorously mixed together. The mixture was filtered into a test tube using the Whitman filter paper. The extract was then subjected to centrifuged set at revolutions per second to remove tiny particles.

3) Preparation of photo anode and cathode :The photo anode and cathode (counter electrode) were well prepared by using screen printing method or technique. Fluorine doped tin oxide (FTO) conducting glass substrate was properly cleaned using ethanol and allowed to dry. An area of 0.25cm2 (that is 5mm x 5mm) was mapped out using masking tape. Afterward, a squeegee was used to screen print TiO2 paste onto an active area and then heated to 500 degree Celsius so that all other elements present in the paste are burnt out leaving the TiO2 semiconductor in its pure and compact form. After cooling, it was treated with titanium tetra chloride (TiCl4) solution for 30 mins. Then it was later immersed in the dye extract over night to ensure proper discoloration.

The cathode also known as counter electrode was also prepared by screen printing platinum paste (platisol T/SP Solaronix) on the same active area and then heated and allowed to cool.

4) Solar Cell Assembly :The photo-anode and cathode were put together to Overlap within the active area, forming a sandwich configuration and sealed using a glue called meltonix and then the electrolyte (iodolyte N50) was injected into the cell from its periphery using a syringe. The electrolyte smoothly spread over the whole surface of the active area of the fabricated solar cell.

5) Testing :The current - voltage simulation was done using Oriel Class A solar simulator under solar light intensity of 1000W/m2 (that is 100W/cm2) and A.M 1.5 Spectrum. The current – voltage results obtained for the final made solar cell are presented in graphs in figure 1, 2, 3 and 4.

III. RESULTS AND DISCUSSION

A. Result of optical absorbance

The absorbance data of the dye sensitizer and the anode were measured from wavelength 230 nm to1100 nm using a UV/Vis spectrophotometer and results are presented in fig. 1 and fig. 2 respectively.

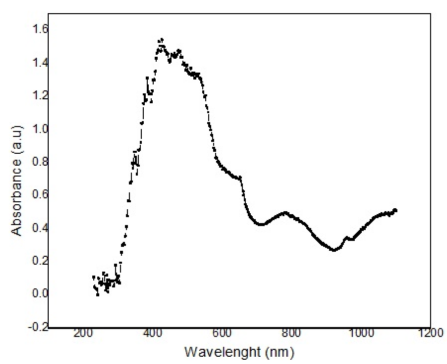

Fig. 1. Graph of absorbance against wavelength of bougainvillea dye extract

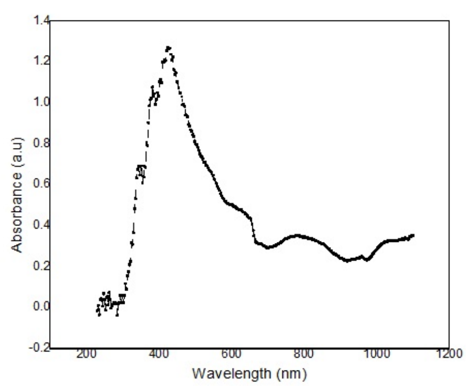

Fig. 2. Graph of absorbance versus wavelength of bougainvillea dye extract absorbed on the TiO_2 surface.

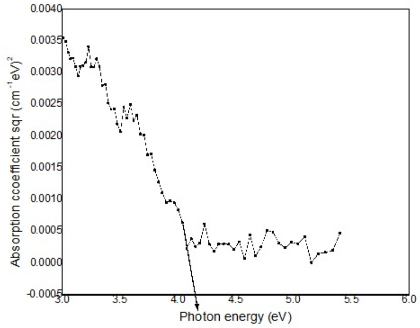

Fig. 3. Graph of absorption coefficient against photon energy bougainvillea dye extract

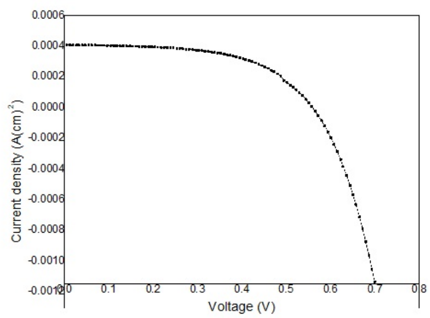

Fig. 4. The J-V characteristics graph of the made DSSC sensitized with bougainvillea extract

IV. DISCUSSION OF RESULTS

From fig. 1, bouga villa extract exhibited a very good light absorbance within the visible region and in the infrared region (between wavelengths of 401.35 nm to 518. 07nm). A maximum peak of 1.5304 was recorded at a wavelength of 418.35 n min the visible region of the electromagnetic spectrum. Another peak of 1263 was seen at a wavelength of 786.77 nm which increases as the wavelength increases.

Only one absorption peak was recorded in the visible region at wavelength of 426.66 nm of the EM spectrum when TiO2 was absorbed into the surface.

The energy band gap of the bougainvillea extract was found to be 4.16eV.as shown in the graph of absorption coefficient versus photon energy by assuming a direct band transition. The electrochemical parameters of the cell were deduced from fig. 4 and are presented in the table below:

TABLE 1
ELECTRICAL PARAMETERS OF THE FABRICATED DYE-SENSITIZED SOLAR CELL.

Dye source	Jsc(mA/cm^2)	V_{oc} (V)	J_{max}. (mA/cm^2)	V_{max}(V)	P_{max} (mW/cm^2)	Fill Factor	Efficiency (%)
Bougainvillea	0.4091	0.6994	0.08161	0.3949	0.1289	0.45	0.13

V. CONCLUSION

Dye derived naturally from dried bougainvillea flower was successfully employed as a sensitizer to produce a dye- sensitized solar cell. The extract demonstrated a broad light absorption within the visible region of the electromagnetic light spectrum. The anode also has a maximum peak in the visible region. Both samples exhibited good absorption across infrared region with improved light absorption as we approach longer wavelengths. A wide energy band gap of 4.16eV was obtained for the extract of bougainvillea flower. The dye sensitized solar cell produced has fill factor of 0.45 and light conversion efficiency of 0.13%. The dye extracted from dry bougainvillea flower can thus, be employed as a photosensitizer in making of solar cells.

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