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Design and Fabrication of DSSC and Monitoring Using Embedded System

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Abstract - Fossil fuel shortages, increasing prices of crude oil, and the shunning of conventional energy sources (such as coal or nuclear power plants) are some of the factors that have made sustainable forms of traditional energy gain more attention. Some examples include hydropower, wind power, geothermal power, and biomass processing. Solar power is also a very important source of alternative energy. To comprehend such improving progress in achieving higher solar-to-electricity efficiency and improved long-term operating stability, the development process and basic principles for DSSCs should be understood. An FTO electrode with titanium dioxide (Tio2) is being used here, as part of which we grow dye tuned to give the required color and conductivity. It is called an anode. A pencil was used to graphite the other FTO glass, which would then serve as the cathode. We are presently working on using an iodide electrolyte. Also, current density and voltage were monitored by the ESP8266 kit.

***Key Words*:** Dye-sensitized solar cell; Carotenoid Extract; Electrolyte; ESP8266.

1. INTRODUCTION

Dye-sensitized solar cells (DSSCs) present a possibly positive alternative to conventional silicon-based solar cells. They are cheap, easy to produce, and adaptable to working under varying climatic conditions. The concept of these DSSCs is inspired by natural photosynthesis, which employs completely different ways of converting sunlight into electricity. The photoanode in the case of DSSCs is usually manufactured from a semiconductor material referred to as titanium dioxide (TiO_2). This light-absorbing molecule consists of a dye embedded within this porous TiO2 layer, acting as support for its attachment thereon. Some examples include carotenoids and dyes that possess excellent ability for gathering light due to their wider range of absorption and high molar extinction coefficient. When the carotenoid dyes absorb photons from sunlight, they create excited electrons that initiate charge separation in the cell. Another counter electrode completes it while an electrolyte solution acts between the photoanode and dye, thus making up for the DSSC system. Therefore, this continuous current flow occurs because this electrolyte enhances charge carrier mobility through a device involving both sides of the counter electrode and photoanode. The fabrication of DSSCs using them is dependent on the overall performance and stability of the electrolytes. Additionally, DSSC systems can also be embedded with electronic components to provide functions that keep up with the latest advancements, such as real-time monitoring and control. An excellent example is the ESP8266, which serves as an inexpensive Wi-Fi module for data acquisition and transmission. As a result, the DSSC modules are remotely connected to other researchers and engineers who monitor the voltage parameters, such as current density, in order to facilitate efficient optimization and maintenance of DSSC arrays, among others. This paper presents TiO2-based photoanode dye-sensitive solar cells (DSSCs) prepared by employing carotenoid dyes and electrolytes. Moreover, this paper delves into ESP8266 integration for continuous monitoring to improve DSSC performance, which will boost the efficiency, reliability, and scalability of dye-sensitized solar cell technologies in the future.

2. EXPERIMENTAL DETAILS

2.1 TIO2 PREPARATION

To obtain TiO2 particles through the hydrothermal method, titanium tetra-isopropoxide was employed. Fifteen minutes were required to grind a mixture of 50 µl of liquid detergent, ethanol (1 ml), 200 µl of acetylacetone, and a pinch of TiO2 powder in a mortar. Earlier, this paste was deposited on FTO-coated substrates with a sheet resistance of 15 Ω/cm2 and transmittance of about ~80% by the doctor blade method as a photoanode (Sigma Aldrich) square-sized 10x10 mm. Before coating them with TiO2 paste, these glasses were cleansed in series using alcohol, double-distilled water, and soap water. For example, this is rinsed with alcohol for ten minutes during the ultrasound cleaning process. After that, they were dried in an oven at 60°C for thirty minutes. Afterward, the FTO-coated substrates were further dipped in TiO2 slurry, then dried at 100 °C, followed by sintering at 450 °C for 45 min, respectively.

2.2 CAROTENOID EXTRACT PREPARATION

The bacterial strain was cultured in 1 L of nutrient broth for four days at 37 °C under optimum growth conditions with continuous shaking at 125 rpm to harvest biomass for pigment production. The yellow coloration of the broth took place after incubation. The biomass was separated from the broth by centrifuging at a speed of 7000 revolutions per minute (rpm) for a quarter hour while still at room temperature. Following air drying during the preceding night, these pellets were weighed. To ensure uniformity before starting pigment extraction, all harvested biomass was dissolved in 10 mL of a pure methanol solution (v/v) using a vortex. This showed that the pigment did not leave the centrifuged broth; hence, it could be said that it is located inside the cell, making it an intracellular pigment. Thereafter, dispersed cells of the recovered bacterial strain were sonicated in a bath sonicator for one hour. The solution cocktail underwent sonication before being subjected to centrifugation at 7000 rpm and room temperature for ten minutes, which resulted in a separation between the colored supernatant and the colorless pellet.

2.3 IODIDE ELECTROLYTE

To create an iodide solution, drop 0.127 g of iodine (I2) into 10 mL of ethylene glycol and then add 0.83g of potassium iodide (KI) into it, mixing it together. Ethylene glycol aids contents in dissolving. Potassium iodide is added so that the resultant solution cannot allow the re-crystallization of iodine. Stirring ensures that solute-solvent molecules are distributed uniformly and interact with each other. If light is shone on it, the dissolved iodine turns the solution brown and has to be kept in dark bottles to prevent decomposition through photochemical reactions. This process produces an iodide solution that has many applications, including chemical reactions and analytical procedures over time.

2.4 ASSEMBLE THE DSSC

The assembly of a dye-sensitive solar cell (DSSC) with components such as fluorine-doped tin oxide (FTO) glass, titanium dioxide (TiO2), carotenoid dye, and electrolyte involves several crucial steps. Initially, the FTO glass substrate is meticulously cleaned to remove all impurities and optionally treated with a thin layer of TiO2 for better adhesion. Then a paste containing TiO2 nanoparticles is prepared and applied onto the FTO glass using methods like spin-coating or doctor-blading, then annealed to ensure proper adhesion and solvent removal. The annealing process follows, where the dye molecules are fixed onto the layer of TiO2. The substrates must be thoroughly rinsed before they can be used as thermal templates for self-assembly or as building blocks in other devices that require highly ordered periodic arrays of nanoparticles. Subsequently, sandwiching the dye-sensitized substrate with another FTO glass substrate completes assembling the DSSC, leaving space for electrolyte injection. Therefore, this electrolyte solution is injected into this space while ensuring good coverage before sealing off the edges to avoid leakages. After completely drying, the assembled DSSC is subjected to testing in simulated sunlight or another appropriate light source to assess its efficiency and performance, often employing methods such as current-voltage measurements and spectral response analysis. Although this list of steps has been simplified, it outlines the key steps involved in making a DSSC and stresses the importance of being able to control exactly such parameters as voltage, current density, and solvent choice while also keeping within safety rules all through.

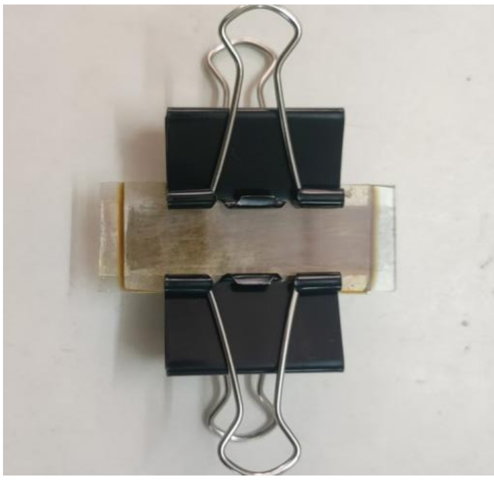

Fig -1

2.5 INTERFACING ESP8266 WITH A VOLTAGE SENSOR

Voltage and current density can be measured using an ESP8266 module and a voltage sensor. To start with, you have to pick up the right one and connect it to the ESP8266, making sure it is compatible and well-calibrated for accurate readings. Read voltage data through analog input pins while additionally incorporating other sensors for measuring the current. Convert voltage into current density whenever applicable. Process data and transmit it, keeping in mind power requirements and safety precautionary measures being considered. Thoroughly test that this setup is accurate as well as reliable enough; adjust hardware or software if necessary. While working with electrical circuits, always consult datasheets about proper wiring and operation in order to make sure that safety is given priority.

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3. RESULTS

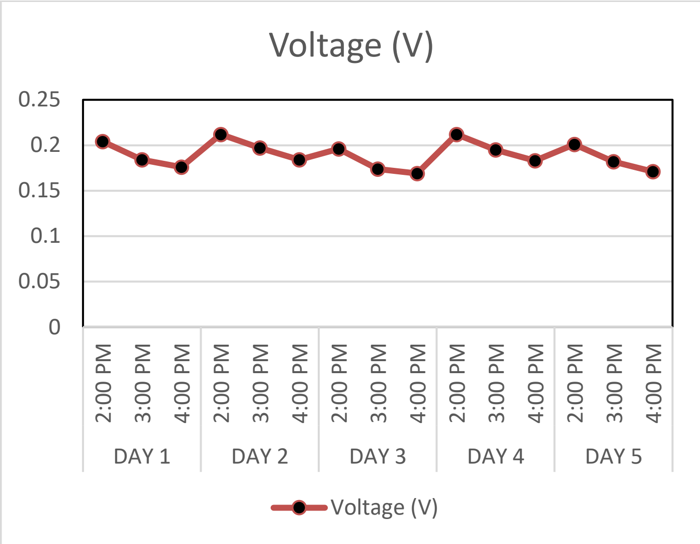
Table –1

Day	Time	Resistor	Voltage (V)	Current Density
DAY 1	2:00 PM	1000	0.204	1.6524E-07
	3:00 PM	1000	0.184	1.4904E-07
	4:00 PM	1000	0.176	1.4256E-07
DAY 2	2:00 PM	1000	0.212	1.7172E-07
	3:00 PM	1000	0.197	1.5957E-07
	4:00 PM	1000	0.184	1.4904E-07
DAY 3	2:00 PM	1000	0.196	1.5876E-07
	3:00 PM	1000	0.174	1.4094E-07
	4:00 PM	1000	0.169	1.3689E-07
DAY 4	2:00 PM	1000	0.212	1.7172E-07
	3:00 PM	1000	0.195	1.5795E-07
	4:00 PM	1000	0.183	1.4823E-07
DAY 5	2:00 PM	1000	0.201	1.6281E-07
	3:00 PM	1000	0.182	1.4742E-07
	4:00 PM	1000	0.171	1.3851E-07

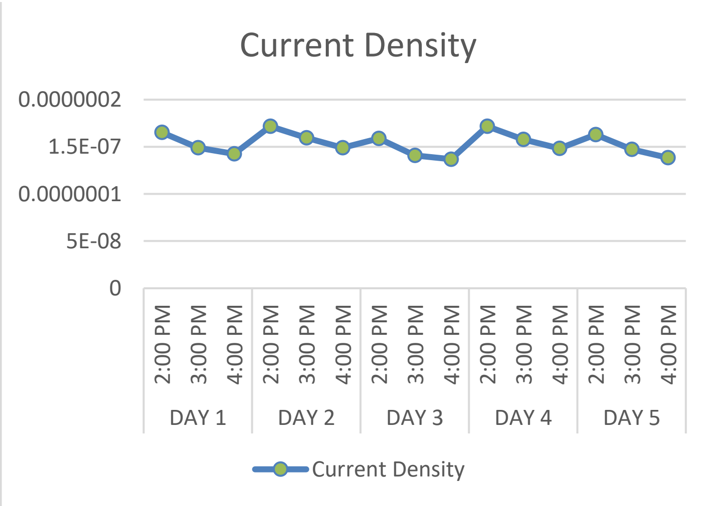
Three common times, 2:00 PM, 3:00 PM, and also at 4:00 PM, were used in the above analysis, for which five consecutive days of samples were collected. The used samples had a fixed resistor of 1000 ohms. Further, it is clear that different outputs are influenced by solar intensity levels. This particular time of day is characterized by the highest current density as well as voltage, which means that maximum energy conversion is taking place. Conversely, both current density and voltage have experienced a slight fall from their zenith at two o'clock to three o'clock in the evening. By four o'clock in the afternoon, there was the least current density and voltage values, implying reduced energy conversion efficiency due probably to diminishing sunlight towards evening.

This analysis brings out how output can vary according to changing daylight brightness within one day; therefore, this implies that whenever one wants to optimize his or her solar panel system for better utilization of solar power, he must consider such fluctuations. These results will help establish the best practices necessary to achieve optimal usable power generation from solar cells, thereby supporting sustainable development.

Charts 1



Charts 2



4. CONCLUSIONS

The dye-sensitized solar cells have been manufactured using natural pigments derived from carotenoids. We discovered that the DSSCs made of carotenoid extracts demonstrated maximum ISC and VOC of 0.212µA and 1.71V, respectively. Furthermore, we have proved that using carotenoid extracts as sensitizers is efficient, and the selection of counter electrodes also affects the design of environmentally friendly and cost-effective DSSCs significantly. By advancing further in the improvement of the electrolyte-inclusion mechanism, it will be possible to increase this efficiency to the desired levels. It is from this perspective that we are currently operating.

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