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APPLICATION OF NATURAL DYE FOR IMPROVING PERFORMANCE OF DYE SOLAR CELL

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ABSTRACT

In this paper, Hibiscus rosa-sinensis is used as natural dye for the fabrication of natural dye solar cell (DSSC). The Hibiscus is utilized effectively as a dye sensitizer to turn solar energy into electricity. The DSSCs are fabricated using two dissimilar types of semiconductor electrodes: TiO2 P25 and R-5566 TiO2. The dye solar cell using TiO2 P25 as semiconductor shows a short circuit current of up to Jsc=1.58 mAcm-2, an open circuit voltage of Voc = 0.49 V, fill factor of 0.41 and power energy conversion efficiency of 0.11% was achieved. The UV-Vis absorption spectra show natural Hibiscus dye has maximum absorption at 545nm in visible range of solar spectrum. This study offers an intriguing preliminary analysis for the creation of alternative energy that promotes sustainable energy sources by utilizing abundant biodiversity. The capabilities of the various TiO2 structures, as well as the method and the limitations, are covered in this article.

KEYWORDS: Dye solar cells, TiO2, Hibiscus, Performance parameter, P25 and R-5566

INTRODUCTION

The need for cleaner, sustainable, and renewable energy is being driven by rising energy consumption as well as increased environmental awareness. Solar energy has a great deal of potential to overtake fossil fuels as the most plentiful renewable energy source. Solar energy can be collected using solar cells, commonly known as photovoltaic cells (PV) [1-4]. But this procedure is only practical since this method is inexpensive, long-lasting, and reasonably efficient. Three fundamental generations of solar cells (SCs) are often taken into account. The first generation of photovoltaic cells, sometimes referred to as silicon wafer-based solar cells, are labor-intensive and costly to produce, and their efficiency ranges from 6% to 10% [5]. In recent commercial production, amorphous silicon SCs contains a lot of silica (SiO2), which is used to make silicon [6]. Nevertheless, the process of producing pure silicon requires a lot of energy [7]. Thin-film solar cells are simple to make in ambient circumstances, including thin- film dye-sensitized solar cells (DSSCs). Because DSSCs can be composed of both organic and inorganic components, the cells do not need to be extremely pure [8-10]. Due to their favourable economic and environmental characteristics, ease of production, and atomic design possibilities that allow for the modification of optical properties, dye-sensitized solar cells (DSSCs) are being investigated as a viable alternative to conventional solar cells [11- 12]. The dye is essential to extending the phantom reaction of the cells, which is the basis for the photosynthetic process that powers DSSCs. The excited electrons are transferred through a cascade process after photoexcitation of the sensitizer dye, which causes charge separation and quick regeneration of the oxidised dyes [13-15]. Because of the toxic, hazardous, and radical components, synthetic dyes produce polluted water, which poses serious environmental risks. Protective measures were therefore needed to bind the amount of dye in order to approach the global stream disaster and associated hazards. Because of the toxic, hazardous, and radical components, synthetic dyes produce polluted water, which poses serious environmental risks. Protective measures were therefore needed to bind the amount of dye in order to approach the global stream disaster and associated hazardsNatural dyes come from readily available natural resources[16-19]. These eco-friendly and cost-effective dyes might serve as a good substitute for dangerous synthetic dyes. These dyes are derived from various plant parts and effectively work as a photosensitizer for dye-sensitive solar cells [20- 24]. Anthocyanins are the natural pigments and provide various colors with different plants that have varying degrees of sensitivity. Many research teams from all around the world have worked hard to use natural dyes from different plant components as solar cell sensitizers. The red Hibiscus bloom has high anthocyanin concentration, could make it a useful as natural dye for SCs [25].

The research on the effectiveness of dye-sensitized solar cells made from hibiscus flowers is still missing, nevertheless. Hibiscus rosa-sinensis flowers were used to extract hibiscus dye, for DSSCs. Figure 1 reveals natural dye solar cell using anthocyanin dye. Thin uniform layer films were prepared using two different types of titanium dioxide (TiO2) namely P25 and R- 5566, and their respective efficiencies were recorded. The manufacturing units of dyes for DSSCs could benefit from this discussion.

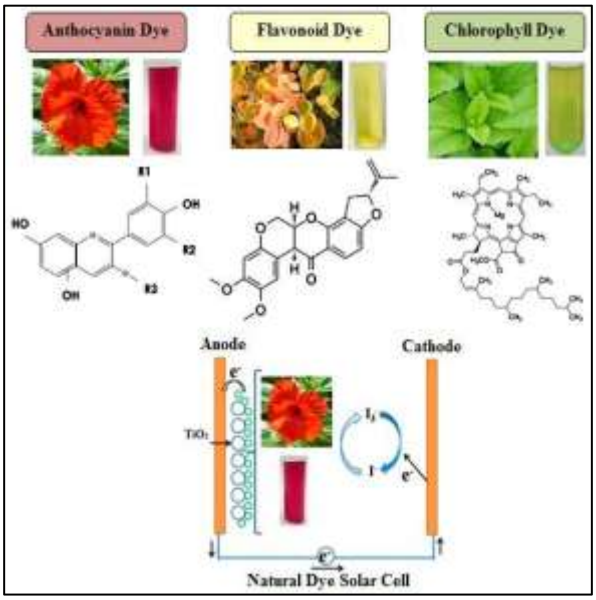

Fig.1. Structural diagram of natural dye solar cell

2.Experimental Details

The Titanium dioxide (TiO2) suspension was made with only minimal alterations in accordance [26]. First, 6g of measured TiO2 powder were taken in a mortar. The mixture was then homogenized by grinding. The suspension was then placed in a little plastic bottle and given fifteen minutes to acclimate before being sealed. The suspension that was left over was then spread out on a glass plate to create a thin, even layer. The film was then dried and baked for 30 minutes at 150°C, then cooled to room temperature. Hibiscus petals were utilized to extract the anthocyanins, which were then used to make the natural dye sensitizer employed in this study. Using a mortar and pestle, first, 10 g of the flower petals from Hibiscus rosa-sinensis were crushed into tiny pieces. Then, 200 ml of a 95% ethanol solution was used to the crushed petals, and the mixture was allocated to settle at normal temperature. The extract was then over night in a dark, covert container as shown in figure 2. The next day, the natural dye was boosted to create a slurry paste on a hot plate at 40°C.

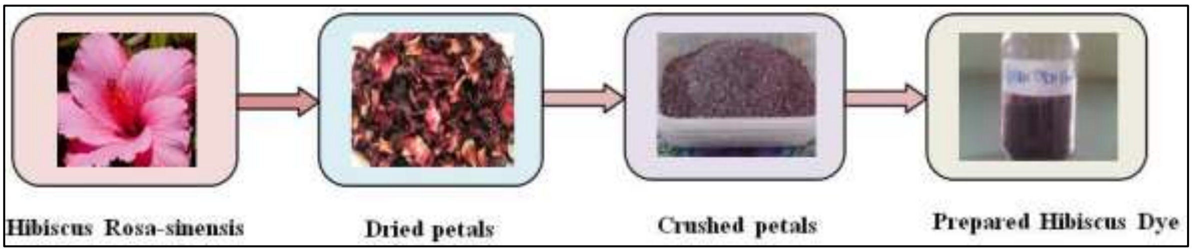

Fig.2. Preparation of Hibiscus dye

Two slides, an electrode and a counter electrode were created to construct the DSSC. The preparation of titanium dioxide paste is as shown in figure 3.

Fig.3. Preparation of TiO2 Coated FTO

The anode was created by immersing the titanium dioxide coated slides in the dye for an hour. In this process, the appearance of the TiO2 layer alters from white to a light purple. After that, ethanol and water were used to rinse the discoloured film. After that, tissue paper was used to gently blot dry the dye-stained slide. A carbon layer was created onto FTO to prepare the graphite-coated slide. After applying black paint to the carbon-coated side, the glass plate was placed in the flame of a candle. After being heated for 15 minutes at 150°C on a hot plate, the carbon-coated glass plate was then removed and left to cool to room temperature. The graphite-coated slide was then assembled by setting on top of the side coated in TiO2 that had been dyed. Two binder clips were then positioned on the edges of the slides to gently hold them together. Then, iodide/iodine electrolyte solution were applied to each side of the plate [27]. The overall cell preparation mechanism is shown in figure 4. Following that, the multi-meter was attached to the clips that were secured to the protruding ends. The positive and negative terminals were coupled with the graphite (counter electrode) and titanium dioxide (electrode)-dyed slides. A potentiometer was utilized as the variable load to monitor the electrical output and cell performance. At each incremental resistance value, point-by-point current and voltage measurements were collected. The morphologies of the samples were evaluated using scanning electron microscope (SEM) [28]. The dye's absorption spectra were examined with UV-Vis spectrophotometer.

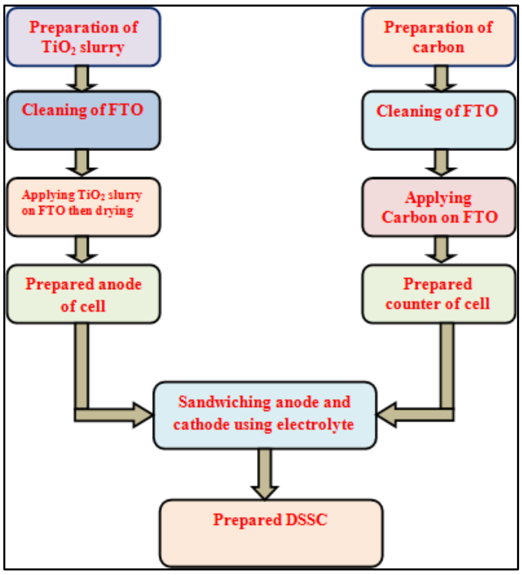

Fig.4. Fabrication steps for DSSC

3. RESULTS AND DISCUSSION

3.1 Performance of DSSCs

The hibiscus dye extract's UV–Vis absorption spectra, which span 400–780 nm, are displayed in Figure 5. The hibiscus dye's absorption peak was measured at about 498 nm. The Hibiscus rosa-sinensis dye's absorption spectra, which were obtained by extracting it from acidified ethanol and yielding an absorption peak at 550nm. Variations in the absorption characteristics were brought on by the varied functional group structures on the anthocyanins and the colors of the extracts. Furthermore, the variations in our results could have been brought about by the presence of certain contaminants or particles. The amount of light that dye sensitizers absorb from the visible light spectrum determines which ones are ideal. Therefore, below a threshold wavelength of about 870nm, all light should be absorbed. Greater energy conversion to electricity is correlated with absorbed spectrum ranges that are wider. As can be seen from the hibiscus extract's absorption spectra, the spectrum's range was 400–800 nm [29]. The potential of extracted natural dye from Hibiscus sabdariffa using three dfferent solvents i.e. ethanol, methanol and distilled water, used to inspect the performance of cells. And it is observed that with ethanol the DSSC reveals highest performance as discussed in Table 1.

Fig.5. Absorption spectrum.

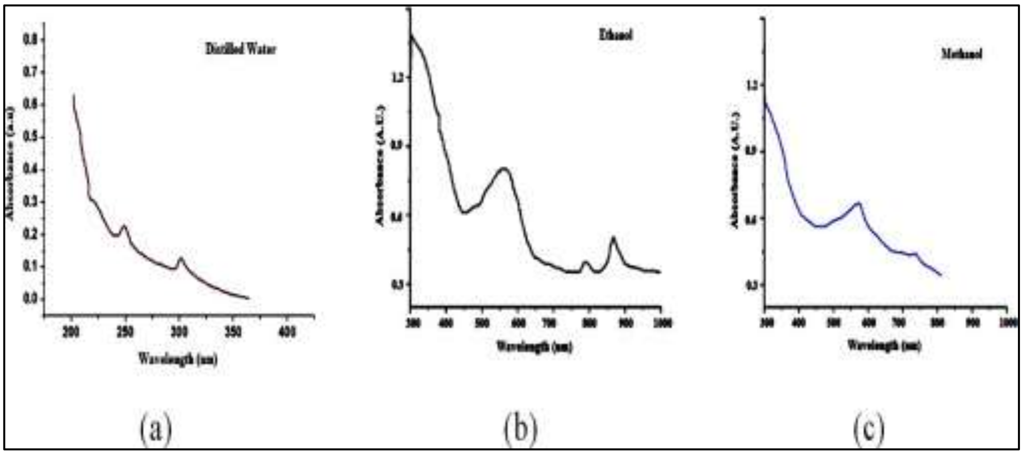

Table 1 Absorbance of dye with different solvents

Solvent Maximum	Absorbance (nm)	Reference
Ethanol 545	545	Present work
Methanol	570	Present work
Distilled Water	246	Present work
Ethanol	540	[30]

3.2 Scanning electron microscopy and energy dispersive spectroscopy of TiO2

The TiO2 film was scratched, which may be the cause of the morphological damage and the inconsistent SEM pictures of the film. Other methods, such coating the TiO2 sheet, are suggested for further investigation. Additionally, getting superior analysis results depends greatly on the film's homogeneity. The SEM picture of TiO2 (R-5566), which includes several agglomerates and a wide particle size distribution. The size of the particles ranged from 20 to 100μm. Furthermore, Figure 3 displays the TiO2 P25 powder's SEM picture. In this instance, the TiO2 particles had a restricted range of particle sizes and were evenly distributed. Nevertheless, none of the analyses carried out for this study provided evidence for this outcome. The crystallite particles had sizes of around 20nm. Furthermore, a large contact area was considered and strong bonding in between the TiO2 particles are necessary to provide appropriate connection in the TiO2 particle network [31]. The TiO2 photo-anode film surfaces on FTO conductive glass substrates are homogenous, porous, and contain well distributed nanoparticles of the size range of 30–60 nm, according to the SEM pictures. The increased dye loading on the TiO2 surface was made possible by high surface porosity and the resulting increase in surface area as shown in figure 6. Greater electrical conductivity in between particles and effective photon-to-electron conversion are expected outcomes of sufficient connection. Because of the shape that was lost when the TiO2 film was smashed, the image of the films might not be steady. For further research, other techniques such coating the TiO2 sheet are advised. Additionally, getting superior analysis results depends greatly on the film homogeneity.

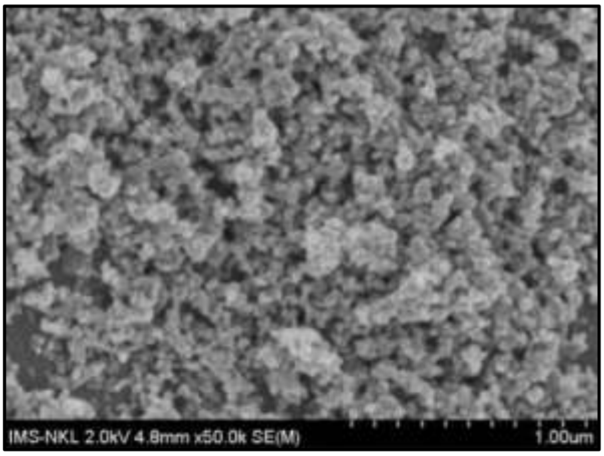

Fig.6. SEM of TiO2 layer

3.3 Solar Cell Analysis

TiO2 based solar cell performed worse than the P25 TiO2 coated solar cell. For the DSSC utilizing TiO2 (R-5566) under direct sunlight, a voltage of 0.4 V and an electric current of 0.04mA were recorded. When employing an overhead projector (OHP), the voltage experienced a significant reduction, dropping to approximately 0.2 V. The DSSC coated with R-5566 TiO2 exhibited an I-V output. Figure 7 illustrates the I-V curve for the outdoor studies conducted using P25 TiO2. The diminished particle size of P25 TiO2 was instrumental in its enhanced performance.

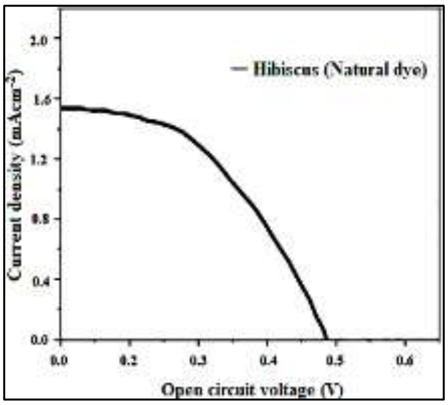

Fig.7. Current-Voltage Characteristics

The smaller TiO2 nanoparticles could be more efficiently packed onto the substrate surface due to reduced distances between particles. This size reduction provided a larger surface area for maximum dye sensitizer adsorption on the semiconductor, potentially resulting in a faster photoresponse and higher electron collection efficiency. Furthermore, P25 TiO2 demonstrated greater porosity compared to TiO2 (R-5566), facilitating increased electrolyte penetration. The improved porosity of the TiO2 film enhanced the regeneration of oxidized dye and charge transport. Despite the reported low efficiencies in solar energy conversion in this study, the results suggest that hibiscus dye holds potential for

photovoltaic energy conversion, with one possible factor influencing efficiency being variations in the thickness uniformity of the TiO2 layer, a critical determinant of solar cell module efficiency.
Moreover, charge recombination may happen if the film thickness is uneven, which will lower the DSSC's energy conversion efficiency. Ineffective electron transport was caused by the study's TiO2 film thickness, which ranged between 30 and 60 m. This resulted in poor cell performance. The dye adsorption was improved with increased the efficiency of the TiO2 films up to a thickness of 15m [32]. The TiO2 thin films stabilized and nearly decreased efficiency after being thickened later. This result was due to the longer electron transport path in the thicker layer. Recombination of the electrons with the electrolyte ions is also conceivable during electron transport across a long channel. As a result, the performance of the DSSC is significantly influenced by the TiO2 layer's thickness. The efficiency, current density, and dye adsorption are all affected by changes in film thickness. The electrolyte of this cell was an organic solvent and an I-/I3- redox pair. Vaporization and leakage are to blame for the low long-term stability of this electrolyte. The corrosive nature of the electrolyte damages the used metals. To maintain high conductivity, these problems should be avoided, and for maximum effectiveness, there has to be good interfacial contact between the porous TiO2 layer and the counter electrode [33]. The performance of dye solar cell using different semiconductors is discussed in Table 2.

Table 2 Performance of dye solar cells using different semiconductor materials

Semiconductor	**Voc**	**Jsc**	**FF**	**η**	**Ref**
Material	(V)	(mAcm-2)		(%)	
TiO2 P25	0.382	0.82	0.47	0.15	14
TiO2 P25	0.42	2.69	0.37	0.41	2
TiO2 P25	0.49	1.58	0.41	0.11	Present
					work
R-5566 TiO2	0.46	1.38	0.41	0.09	Present
					work

The suboptimal efficiency observed in this experiment may be attributed to the cumulative defects in the fabricated hibiscus extract dye-sensitized solar cell (DSSC). Notwithstanding the challenges encountered, this research marks the inaugural utilization of hibiscus extract as a dye sensitizer. The study specifically explores the incorporation of local products in the development of dye-sensitized solar cells, reflecting an innovative and region-specific approach to harnessing natural resources for renewable energy applications. While the experiment revealed certain inefficiencies, it serves as a pioneering step towards unlocking the potential of hibiscus extract in the realm of solar energy, paving the way for future refinements and advancements in utilizing indigenous materials for photovoltaic technologies. Furthermore, the least expensive source of anthocyanin, hibiscus dye, can be utilized to make inexpensive, environmentally acceptable DSSCs.

4.CONCLUSION

In this work, dye was extracted from Hibiscus rosa-sinensis flowers and then utilized to produce DSSCs. At 545 nm, the dye's UV-Vis absorption peak was visible. The DSSCs were fabricated using two dissimilar types of semiconductor electrodes: TiO2 P25 and R-5566 TiO2. The results shows smaller particle size with P25 TiO2 thin film while on the other side, the R-5566 TiO2 semiconductor revealed larger particle size caused greater I-V characteristics. Notable performance metrics were reached by the DSSCs that incorporated P25 TiO2 that shows a voltage of 0.49 V, an electric current of 1.58 mA cm-2, a fill factor of 0.41, and an efficiency of 0.11%. On the other hand, the I-V output of the DSSC for the R- 5566 TiO2 thin film prevented the efficiency of the device from being measured. These results emphasize the impact of the kind of semiconductor electrode on the power conversion efficiency and long term stability of DSSCs and emphasize the significance of selecting materials carefully.

Highlights

- Fabrication and characterization of DSSC using natural dye with two different semiconductors is done
- Power conversion efficiency is still hindered by the natural dyes.
- Performance parameters of dye solar cells are studied.
- Current density of 1.58% is achieved by the prepared DSSC.
- Natural dye from Hibiscus Rosa Sinensis is used to fabricate DSSC.

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