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The Analysis of Pyrostegia Venusta Flower Mediated Dye as Sensitizer for TiO_2 Based Dye Sensitized Solar Cells

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ABSTRACT

Since no vacuum systems or expensive equipment are needed in their fabrication, dye sensitized solar cells (DSSCs) are anticipated to be one of the effective solar cells of third generation delivering green energy at low production costs. The structure and operating principles of the dye-sensitized solar cell (DSSC) are reviewed in this work. Optical characterization and extraction of detail is provided on pyrostegia venusta. The preparation steps, dye-based optical and electrical characterization of the DSSC, are all covered. The sensitized solar cell having maximum conversion efficiency (1.99%) is capable of producing an open circuit voltage V_{oc} (1.94V) and a short circuit current i_{sc} (1.804mA) when exposed to solar irradiation.

Keywords: Dye sensitized solar cells, Photo potential, Photocurrent, Fill factor, Conversion efficiency.

INTRODUCTON

After Gratzel and others, first invented the DSSC in 1991, the scientific community became very interested in the DSSC because of its low costs of production and its ecological advantage[1]. The DSSCs sensitized by the ruthenium-complex dye (N719) in TiO_2 were analyzed and compared with maximum efficiency of 11–12%[2,3]. Despite the relatively great efficiency that these DSSCs have offered, using this inorganic dye has several drawbacks. These chemical inorganic dyes were difficult to fabricate, expensive, and non-ecofriendly. In order to manufacture affordable and environmental friendly solar cells, it is preferable to use cheap carbon black as the auxiliary electrode and low-cost catalytic materials in place of Platinum[4]. Contrarily, organic dyes not only offer a more affordable substitute but also have been shown to be up to 9.8% efficiency[5]. However, organic dyes have some drawbacks, like lesser yields and difficult purification techniques.

Due to their accessibility, low price, non-hazardous, and eco-friendliness, organic plants-based DSSCs have gained importance. Natural dyes absorb sunlight and convert sunlight into electrical energy and serve as sensitizers. Currently, DSSCs have used organic plant dyes as sensitizers, such as cladode of cactus and aloe Vera[6], rosella flowers and pawpaw leaves[7], shiso leaf pigment[8], curcuma launga[9], cyanin[10-15], rose bengal[16], caumarin[17,18].

According to reports, the conversion efficiency of natural plant dyes is ranges from 0.03-2.09%. Further more, Wang *et al.,*[17,18] has modified the structural properties of coumarines and used coumarine dyes as DSSC sensitivity agents, achieving an efficiency of 7.6%. Many advances have been made each year, and natural dyes have also been studied to improve conversion efficiency in DSSC[19–28]. The aim of this study is to explore natural pigments made of non-hazardous plants that can thrive in a dry environment and are abundant in nature using easy and affordable extraction techniques. In addition, look for ways to produce DSSCs by the combinations of natural plant dyes.

Using organic plant-based dyes that were derived from flowers of Pyrostegia venusta, also known as flame vine or orange trumpet vine, we explore a reasonably cheap and straight forward way to create DSSCs in this paper. On the basis of literature review, this is the first time that natural dyes from these plants have been identified as DSSC sensitizers. The design of the DSSC is sensitive to natural plant dye extracts using titanium dioxide nanopowder (TiO_2), which serves as an electron carrier and offers a wide band gap. UV-Vis absorption spectroscopy is used to evaluate the optical properties of dyes. pyrostegia venusta mediated flower dye was not used previously in TiO_2 based Dye sensitized solar cells, therefore present was undertaken for analysis of photovoltaic properties and improving the energy efficiencies of cells.

EXPERIMENTAL

MATERIALS AND METHODS

Conductive glass plates (fluorine-doped SnO_2, FTO glass overlayer,sheet resistance 7Ω/sq-50mm* 50mm* 2mm, made by SIGMA Aldrich) served as the substrate for the platinum counter electrode and precipitated porous TiO_2 layer. All of the chemicals and solvents were analytical-grade, and they weren't further purified before usage. Collection of dye Pyrostegia venusta flowers collected from western region of Jodhpur, Rajasthan. Using a porcelain mortar and pestle, the flowers were crushed before being added to the solvent. The mixtures were centrifuged and all solutions were shielded from direct sunlight.

Formation of nanocrytalline TiO_2 film

FTO conductive glass was first cleaned for 15 min in an ultrasonic bath with a detergent solution then rinsed with ethanol and water followed by drying. In an agate mortar, combine 2 g of TiO_2 powder, and 2 mL of acetic acid to make uniform TiO_2 paste. After grinding the two together for another 30 min, 3 cc of ethanol and then, 1 drop of Triton X-100 was ultimately added gradually as the mixture was still being processed. The paste was then applied on clear conducting glass that had been coated with fluorine-doped tin oxide. Using the doctor-blade process, TiO_2 pastes were applied to the FTO conductive glass to create a layer with a 10 m thickness and 0.25 cm^2 area. The TiO_2 film was preheated for 10 min at 200°C, sintered for 30 min at 450°C, and then allowed to cool at room temperature naturally. Next, the natural dye solution has been created, and for 24 h a sintered TiO_2 thin film was submerged there. This made it possible for the natural dye molecules to adhere to the TiO_2 nanoparticles' surface.

Preparation of auxiliary electrode

The FTO glass was cleaned with ethanol to get it ready for the counter electrode. The conductive surface of the FTO glass is then paint with the H_2PtCl_6 and calcine it at 350°C for 30 minutes. To make liquid electrolytes, 0.127 g iodine and 0.83 g potassium iodide were combined in beaker with 10 mL ethylene glycol. Using a glass rod, the mixture was blended until there were no remaining grains of potassium iodide and iodine.

Dye treatment of TiO_2 film

Cathode electrode was submerged in the dye solution for more than 24 h in order to create the dye solution. Measured amounts of dye are first dissolved in an appropriate solvent. To make sure that no additional dye was left at the edge of the FTO surface, the TiO_2 photo electrode's surface was then washed with solvent.

DSSC assembly

A space was created at the end of each electrode when the cathode and anode electrodes were joined together and overlapped. At the electrode's end, three drops of iodide solution were then added and the solutions were evenly distributed throughout the electrode. After that, a cotton swab was used to remove any residual iodide solution.

After the electrodes had been secured using a binder clip, the multi-meter was used to test it, and matching readings for voltage, capacitance, and current were taken. Sunlight was used to conduct the experiment. For the other dyes, the same process was used.

RESULTS AND DISCUSSION

Optical characterization of dye

The spectra of UV-Visible absorption of natural dyes were evaluated with a Systronics PC scanning double beam UV-Vis spectrophotometer 2202. Analysis of the absorption spectra was done in a particular wavelength range from 200-800nm for the dye solvent extracts of pyrostegiavenusta.

It was found that the absorption peak of pyrostegiavenusta dye extracts is about 450, 500, 450nm in water, ethanol and DMSO solvent. The distinct differences in the absorption properties of various solvents in which the solubility of dye differs and color of the extracts.

It was concluded that the peak of a dye's wavelength where it absorbs photons the best were 500, 500, 400nm in water, ethanol, DMSO containing cobalt nitrate.

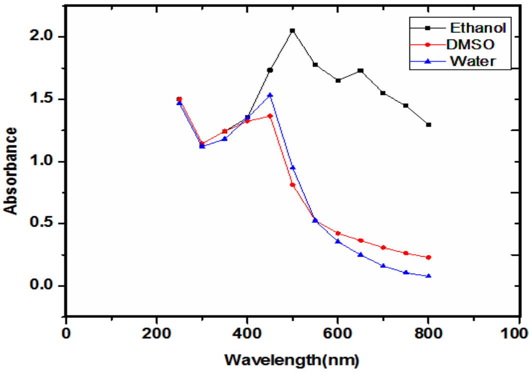

Fig. 1. Absorbance graph of Pyrostegia venusta dye in different solvent

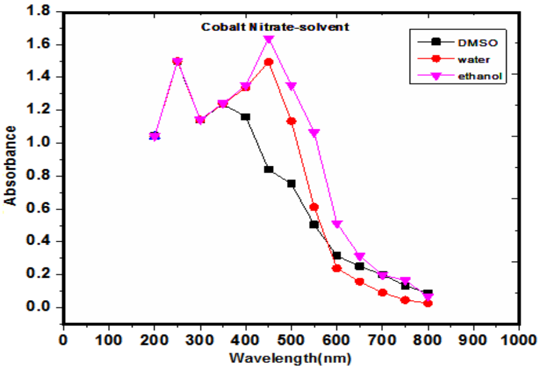

Fig. 2. Absorbance graph of Pyrostegia venusta dye in Cobalt Nitrate with different solvent

Current –potential (i-v) characteristics of DSSC :

The figure shows the current-potential (i-v) curve generated by the solar simulator irradiating 100 mW/cm^2 of DSSC samples with Pyrostegia venusta dyes. The electrical parameters of solar cells, such as open circuit voltage (V_{oc}), short circuit current (i_{sc}), fill factor (FF), conversion efficiency (η), and from these curves, can be obtained as shown in Table 1.

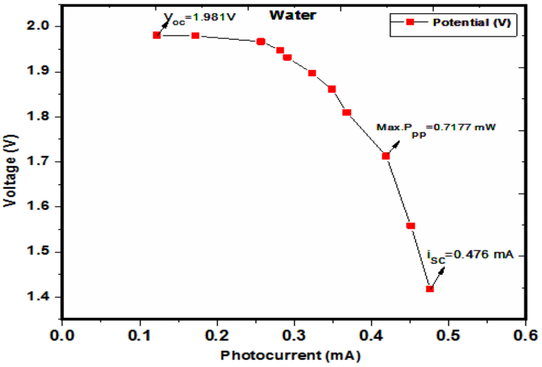

Fig. 3. Graph of (i-v) characteristics of pyrostegia vanusta dye in water solvant

Table 1: Electrical parameters of photosensitizer

Sr. No	Solvent system	Cobalt nitrate	V_{oc}(V)	i_{sc}(mA)	FF(%)	η%
1	Distilled Water	x	1.981	0.476	0.76	0.716
		✓	1.972	0.365	0.779	0.56
2	Ethanol	x	1.772	1.813	0.49	1.57
		✓	1.94	1.804	0.57	1.99
3	DMSO	x	1.238	1.012	0.53	0.66
		✓	0.882	0.338	0.59	0.17

The voltage ranges from 1.981 to 1.972 V, the short circuit current (i_{sc}) from 0.476 to 0.365 mA and maximum power output 0.7177 to 0.5658 mW in dye-water and dye-water-salt system. Sensitization by the dye solvent extract of Pyrostegia venusta, the DSSC presented a power conversion factor of 0.716%, and 0.56% respectively.

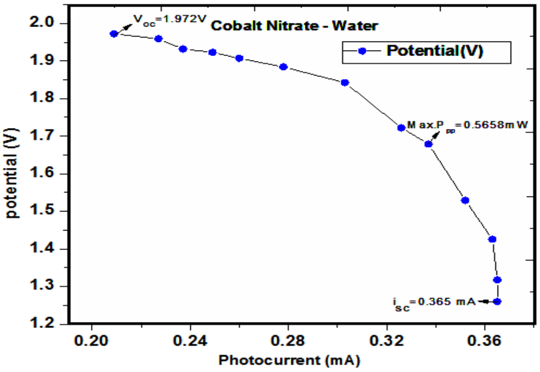

Fig. 4. Graph of (i-v) characteristics of Pyrostegia vanusta dye of Cobalt Nitrate with water solvent

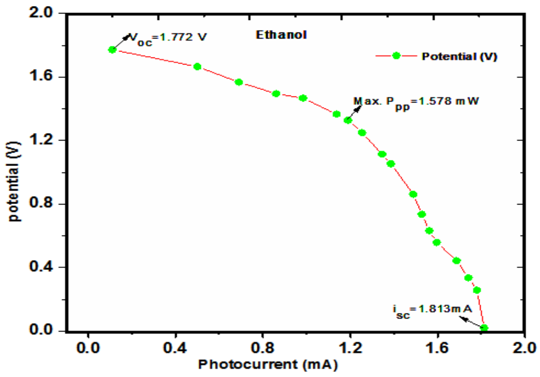

Fig. 5. Graph of (i-v) characteristics of Pyrostegia vanusta dye in ethanol solvent

The voltage ranges from 1.772 to 1.94 V, andthe short circuit current(i_{sc}) from 1.813 to 1.804 mA, and maximum power output 1.578 to 2.01 mW in dye-ethanol and dye-ethanol-salt system. Sensitization by the dye solvent extract of pyrostegia venusta, the DSSC presented a power conversion factor of 1.57%, and 1.99% respectively.

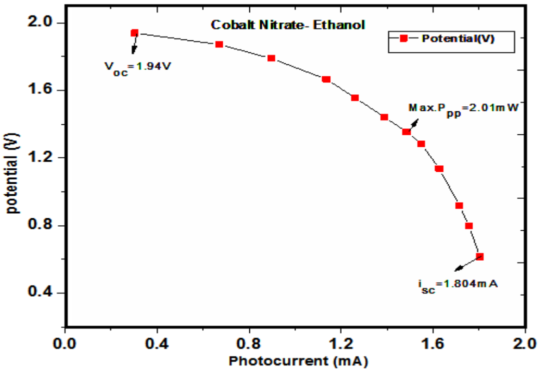

Fig. 6. Graph of (i-v) characteristics of pyrostegia vanusta dye of Cobalt Nitrate with ethanol solvent

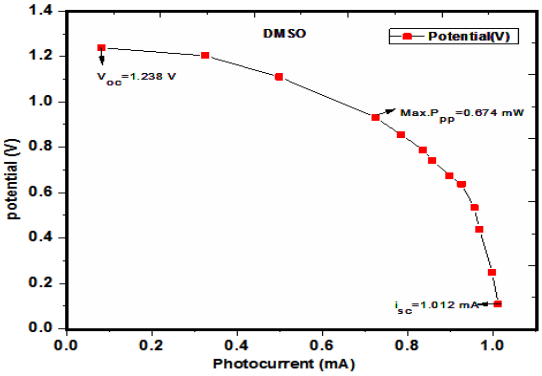

Fig. 7. Graph of (i-v) characteristics of pyrostegia vanusta dye in DMSO solvent

The Voltage ranges from 1.238 to 0.882 V, and the short circuit current (i_{sc}) from 1.012 to 0.338 mA, and maximum power output 0.67 to 0.1784 mW in dye-DMSO and dye-DMSO-salt system. Sensitization by the dye solvent extract of Pyrostegia venusta, the DSSC presented a power conversion factor of 0.66%, and 0.17% respectively.

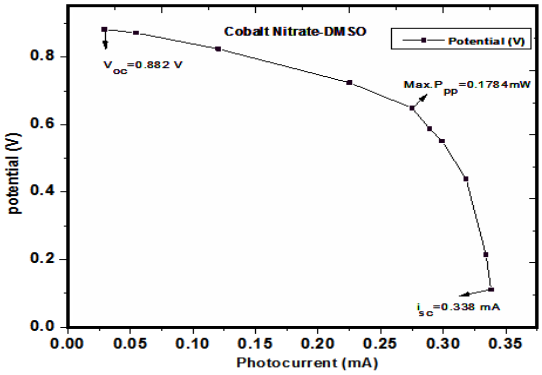

Fig. 8. Graph of (i-v) characteristics of Pyrostegia vanusta dye of Cobalt Nitrate with DMSO solvent

The following equation was used to obtain the total Conversion efficiency (η) from the photocurrent-potential (i-v) curves:

$$\text{Conversion Efficiency} = \frac{i_{SC} \times V_{OC} \times FF}{P_{input}} \times 100\%$$

Where the P_{input} is the radiation power on the cell, i_{sc} is the short-circuit current generated under the illumination, and V_{oc} is the open circuit voltage and FF is Fill factor. The formula for determining the fill factor is:

$$\text{Fill Factor} = \frac{V_{PP} \times i_{PP}}{V_{OC} \times i_{SC}}$$

Where V_{pp} is the voltage (V) and ipp is the current (mA) at maximum power output point.

CONCLUSION

Dye sensitized solar cells is a modern photovoltaic technology to convert the abundantly accessible solar energy into electrical energy source. The potential of natural dyes as a photosensitizer are explored in up to date to increase the conversion efficiency of the cell. It was demonstrated that pyrostegia venusta flower extracts could make a dye-sensitive solar cell more sensitive. The energy conversion factor (η) of the cells comprised of these dye extract was

0.716%, 1.57% and 0.66% when water, ethanol and DMSO (Dimethyl Sulphoxide) was used as the extraction solvent respectively while in the system having $Co(NO_3)_2$ along with these solvent shows the conversion efficiency 0.56%, 1.99%, and 0.17% respectively. From the above data we can conclude that pyrostegiavenusta flower dye shows max efficiency in ethanol as compare to other solvents or more precisely in ethanol containing $Co(NO_3)_2$.

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Conflict of interest

The author declares that we have no conflict of interest.

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