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Physics

# FABRICATION AND STUDY OF DYE SENSITIZED SOLAR CELL USING PERILLA FRUTESCENS EXTRACT

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**ABSTRACT** Dye-Sensitized solar cells are considered to be at the heart of our development of third generation photovoltaics due to their eco-friendliness and inexpensiveness. In this work, we have fabricated a solar cell by preparing a $TiO_2$ based Photo anode dipped and dried with the essence of purple coloured perilla frutescens (shiso) as natural dye senstizer. The as prepared working electrode was coupled with a graphite coated counter electrode intercalated by a polymer electrolyte. The following characterisation studies on UV-Vis, FTIR and I-V curve reveals that the shiso dye has the good absorption level of light in the range of 330 nm to 670 nm and showing greater energy conversion efficiencies at higher the temperature.

**KEYWORDS :** Dye Sensitized Solar Cell, Perilla frutescens, Shiso dye, energy conversion efficiencies.

## 1.INTRODUCTION

Dearth of fossil fuels, price hikes of crude oil and rejection of conventional energy sources diverts our attention towards solar energy. Dye sensitized solar cells or Gratzel cells are the new form of thin film cells found to have a good efficiency even under the low reflux of sunlight compared to the highly expensive traditional silicon cells[1-3]. A single junction dye sensitized solar cell Comprises a transparent Indium tin oxide (ITO) glass coated with a thin and uniform layer of highly porous $TiO_2$ nanostructure electrode, dye molecules, redox electrolyte and a graphite coated counter electrode. In DSSC, the molecular dye that is bounded to the photoanode absorbs the incident light and gets excited from the ground state, as a result the excited electrons gets injected into the $TiO_2$ nano coating and diffuse towards the transparent conducting oxide (TCO) glass of the anode and finally reaches the graphite coated counter electrode via external circuit[4,5]. This movement of electrons generate an electric current through which power is derived and the energy conversion efficiency is calculated.

In this work, we have utilised the purple perilla foliage leaf extract to enhance the performance of DSSC due to its broad spectrum of sensibility. An anatase phase of $TiO_2$ having a wider energy band gap of 3.2 eV shows a great photo-activity performance and hence it is preferred as a semiconducting material. The photoanode was prepared by spreading the paste of $TiO_2$ over the ITO glass and sintered at a temperature of $400^0$C to make a firm deposit, and then it is dipped into the dye at various temperatures and studies were made to analyse its photon capturing ability and energy conversion efficiencies.

## 2.EXPERIMENTAL PROCEDURE

### *2.1Materials and Drugs*

$TiO_2$powder (Anatase, Sigma Aldrich), Triton X-100 (Sigma Aldrich, for electrophoresis) Acetyl Acetone, Ethanol, Acetonitrile, potassium iodide and crystal Iodine were purchased and used without further purification. Indium doped tin oxide (ITO) conducting glass plates were used to coat the material and the organic dye extract was prepared from the Perilla Frutescens leaves.

### *2.2Preparation of organic dye sensitizer*

*Perilla frutescens*, commonly referred to as shiso, is a species of *perilla* in the mint family Lamiaceae. It is a food and traditional medicine in Asian countries, particularly Japan and China. These leaves are used in Chinese herbal medicine for symptoms of asthma and cough as it is enriched with calcium, iron, and vitamin C. Its seeds support healthy immune function and are a rich source of omega-3 alpha-linolenic acid (ALA) [6-9]. Fresh leaves of perilla frutescens were bought and cleansed several times with distilled water and grinded into a fine paste. It was then diluted with ethanol and filtered using the whatmann filter paper. The extract was then heated to attain the temperatures of $60^0$C, $70^0$C and $80^0$C to study its optical absorption.

### *2.3Preparation of $TiO_2$ based Photoanode*

A fine homogeneous paste of $TiO_2$ was prepared by adding and grinding the following mixture of 300mg of $TiO_2$ nanopowder, 1 ml of distilled water, 4 drops of acetyl acetone and 2 drops of trition x-100 using mortar and pestle for few minutes. Four edges of the ITO glass plate were covered with a layer of adhesive tape to control the thickness of the film and to mask the electric contact strips. The $TiO_2$ paste was spread uniformly on the substrate by sliding a glass rod along the tape spacer. After heating up the ITO glass coated with $TiO_2$ nanoparticle to $400^0$ C for about half an hour, the sintering process was completed and the $TiO_2$ deposit was cooled down from $100^0$ C to $60^0$ C at a cooling rate of $3^0$C/min to avoid cracking of the glass. After few hours the ITO glass plates was dipped into the dye at various temperatures for 1hour, so that it gets into the active sites of $TiO_2$ layer [10-12].

### *2.4Preparation of graphite coated counter electrode*

A dark HB pencil was used for coating a layer of graphite on the conducting side of the ITO glass sheet before the assembly of DSSC [13].

### *2.5Preparation of Redox Electrolyte*

The electrolyte solution was prepared by mixing 0.8 g of Potassium Iodide (KI), 10 ml of Acetonitrile and 0.127 g of Iodine $I_2$ in a conical flask and allowed to stir for 30 minutes and kept sealed in a container.

### *2.6Assembly of natural DSSC*

The $TiO_2$ based photoanode enriched by the purple coloured shiso dye essence and the graphite coated counter electrode was coupled together by facing each other with a spacer held in between provides a simple DSSC. The electrolyte solution was then fed into the spacer in drop wise. The assembled DSSC was exposed to the direct sunlight and the voltage across each cell was measured and tabulated [14, 15].

## 3.RESULTS AND DISCUSSION

### *3.1UV- Vis Spectroscopy*

The optical absorption behaviour and band gap energy of $TiO_2$ was studied by means of UV-Vis spectroscopy usin T90+spectro ph otometer. In Fig.(1), The apex at 359 nm shows the absorption level of $TiO_2$ nanopowder in UV region and its impotence to appear in the visible region.

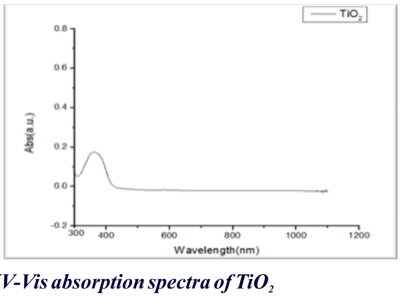


*Fig.(1): UV-Vis absorption spectra of $TiO_2$*

From the obtained result the hν (eV) vs$(\alpha h\nu)^2(eV)^2$ graph was drawn as shown in Fig.(2) and found that the band gap of $TiO_2$is 3.13 eV.

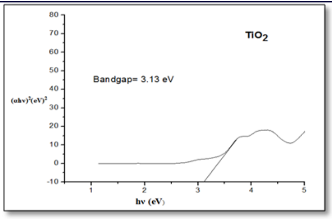


*Fig.(2): Band gap of $TiO_2$ nanoparticles*

The absorbance spectra of shiso dye at various temperatures 60$^0$ C, 70$^0$ C, 80$^0$ C shows a good absorption level between 330 nm to 670 nm as shown in Fig.(3). From the result it is understood that as the temperature of the dye rises, the rate of absorption of light gets higher. Hence the spectral sensitivity of the dye increases with increase in temperature.

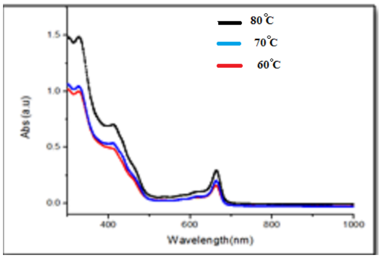


*Fig.(3): UV-Vis absorption spectra of shiso dye at various temperatures.*

*FTIR analysis of Shiso dye*

Fourier Transform Infra Red (FTIR) spectrum of the synthesized Purple Perilla Foliage dye (shiso dye) sample is shown in Fig.(4). The samples were prepared using the KBr pellet technology. The spectra were taken in the range from 3750 to 450 cm$^{-1}$. The peak at 3385cm$^{-1}$ corresponds to stretching vibration of O-H bond. The –C= C stretching of alkene and the presence of aromatic compound was observed from the peaks at 1631 cm$^{-1}$ and 1435 cm$^{-1}$ respectively. The stretching alkyl halide C-Br mode of vibration was observed at 694 cm$^{-1}$.

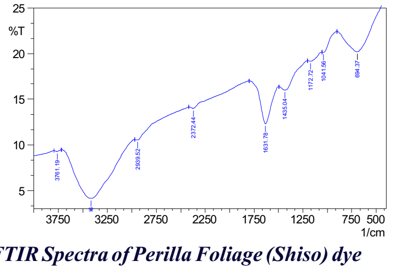


*Fig.(4): FTIR Spectra of Perilla Foliage (Shiso) dye*

*3.2Efficiency measurement of DSSC*

The photovoltaic study of the prepared DSSC with Purple Perilla Foliage extract as photo sensitizer was performed under irradiation with white light (100MW/cm$^{-1}$). The performance analysis of open-circuit voltage ($V_{OC}$), short-circuit current ($I_{SC}$), fill factor (FF), and energy conversion efficiency (η) were studied. The current-voltage characteristic curve of the prepared DSSC for different temperatures is shown in Fig.(5) and the corresponding photo electrochemical parameters of the Photovoltaic cell at different temperatures are summarized in Table.1. The calculated efficiencies of the DSSCs are 0.27%, 0.52% and 0.90% for the temperatures 60$^0$ C, 70$^0$ C and 80$^0$ C respectively. It clearly shows that the efficiency of the cell increases with increase in temperature. The natural dye used as photo sensitizers in DSSCs showed low conversion efficiencies compared with synthetic dyes.

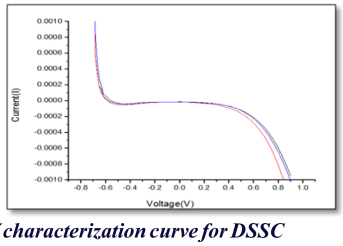


*Fig.(5): I-V characterization curve for DSSC*

**Table1. Photovoltaic parameter of the prepared cell**

| Temperature $^0$C | $V_{oc}$ (V) | $I_{SC}$ (µA) | $V_{max}$ (V) | $I_{max}$ (µA) | FF | Efficiency(η) % |
|---|---|---|---|---|---|---|
| 60 | 0.636 | 1.857 | 0.298 | 0.907 | 0.229 | 0.27 |
| 70 | 0.770 | 1.860 | 0.374 | 1.355 | 0.353 | 0.52 |
| 80 | 0.900 | 1.890 | 0.439 | 2.049 | 0.528 | 0.90 |

## 4.CONCLUSION

A simple and cost-effective photovoltaic cell enhanced with a purple perilla frutescens leaf essence was designed and fabricated. The optical absorption studies were made using UV-Vis, FTIR and I-V characteristic curve. It was found that light absorbing ability of the dye increases with increase in temperature and hence its power conversion efficiency also gets increased. The result of this work instigates the search of new natural sensitizers for the development of solar cell components compatible with such dyes. The work can be further done with other natural dye that may increase their efficiency to a greater extent.

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