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Natural dye from phyllanthus reticulatus fruit as light –harvesting pigments for dye-Sensitized solar cells

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Abstract - *This study reports natural dye extracted from phyllanthus reticulatus fruit which may be used as low cost sensitizer for wide band gap semi conductors in dye sensitized solar cells. The fruit dye extracted in different solvents to analyze their characteristic absorption spectra. The optical properties of dye sensitized solar cell using natural pigments containing Anthocyanin was investigated in this work. Energy gap was calculated for the dyes extracted in solvents Ethanol, Methanol, Acetone. Calculated energy gap values are 2.85eV, 2.65eV, 3.09eV, 3.05eV, 2.64eV, 2.88eV from UV Visible absorption spectra. Then photoanode was prepared and its UV-Visible absorption characterization was analyzed for the application of dye sensitized solar cell.*

Key Words: **Phyllanthus Reticulatus, Ethanol, Methanol, Acetone, UV-Vis., Energy Gap.**

1. INTRODUCTION

Dye sensitized solar cell (DSSC) is one of the third generation photo voltaic. The major advantage of these solar cell are their economic viability that comes with simple manufacturing process, and eco-friendliness along with tunable optical properties [1,2]. These third generation solar cells aim to decrease the cost and/or to increase the efficiency [3].In DSSC, photon absorption and exciton transportation is accomplished separately through sensitizer and semiconductor [4] and this is one of the distinguished features against previous generation solar cells.

DSSC consists of dye sensitizer to absorb photons, metal oxide semiconductor to transport charge carriers, an electrolyte and counter electrode to regenerate the sensitizer [5]. However, stability of DSSC is the main challenge especially due to the use of liquid electrolyte and quality of sealing [6].Various dyes such as fluorescent dyes, phorphyrins, platinum complex, phthalocyanines [7] are being used as sensitizers. Though Ruthenium based dye is largely used and has demonstrated good efficiency up to approximately 11% [8,9], the demerits include less availability, high cost and toxicity [10]. To overcome this, natural dye obtained from several leaves, fruits and flowers is a better option due to ease of synthesis, economic factors, biodegradability, environment friendliness and availability [11, 12]. Natural dyes are obtained from flowers such as Begonia [13], Hibiscus surattensis [14] and from fruits like Raspberries [15] and Cherries [16] to name a few. Titanium dioxide (TiO_2) is highly investigated and explored semiconductor for DSSC due to its various properties like appropriate band gap [17], stability over wide pH range under irradiation, non-toxicity and chemical inertness [18]. Enhanced cell performance can be expected on using nano-structured materials that has influence on charge transport and charge separation ability [19]. The shape of the nanostructures plays an important role in determining the efficiency of solar cells.

In this context, this paper aims to carry out a comparative study on the UV-Visible spectra analysis of natural dyes extracted from phyllanthus reticulatus fruit in different solvent medium.

2. EXPERIMENTAL

2.1 Materials

The dye was isolated from the fruits of Phyllanthus Reticulates plant collected from Namakkal area, Tamilnadu, India. Titanium dioxide nanoparticles (TiO_2). Fluorine doped tin oxide (FTO-15Ω/cm^2) glass plat were from Sigma-Aldrich.

2.2 Preparation of Natural Sensitizer

The fruits of Phyllanthus Reticulatus were thoroughly washed using distilled water to remove the adhered dust particles. Seeds were removed and then remaining pieces of fruit specimen is taken in the mortar and pestle crushed. Then the sample was taken in three test tubes and 30ml of each solvent Ethanol Methanol and Acetone was added to the sample. Then the test tubes were

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covered with aluminium foil and kept for 24 hours in a dark place. After that the solid residues were filtered out using filter paper. Finally extracted dye was used for UV-Visible spectral measurements without further purification.

2.3 Preparation of photo anodes

TiO_2 paste was prepared by blending 5mg TiO_2 powder (P25-Degussa), 2ml Triton X100, and 0.5ml acetyl acetone agate in a mortar. Then the mixture was ground for 30minutes, finally 5ml polyethylene glycol was slowly added while grinding continuously for another 30minutes. FTO glass plates were cleaned using ethanol and acetone. The prepared TiO_2 paste was coated onto a FTO glass substrate by doctor-blade method. The film thickness was controlled by an area of 1x1 cm adhesive tape, and the paste was spread with a glass rod over the space between the tape strips. Films were heated at 450^{0}C for 1 hour and naturally cooled down up to 80^{0}C. Then electrode was immersed in dye solution for 24 hours. After 24 hours electrode was taken out and cleaned using ethanol.

3. RESULTS AND DISCUSSIONS

3.1 UV-VIS Analysis for Natural Sensitizer

Absorption spectra were carried out in Perkin Elmer Lambda 35 UV - Visible Spectrophotometer for the range 300nm-800nm. Figure-1 Shows the spectra for Phyllanthus reticulates dye in solvent medium, Ethanol, Methanol, Acetone. Phyllanthus reticulatus dye in Ethanol shows absorption peaks at a wave length of 435nm, 468nm. The dye in Methanol shows absorption peaks at wave length at 402nm, 407nm, 470nm. Also the dye in acetone shows absorption peaks at 431nm.

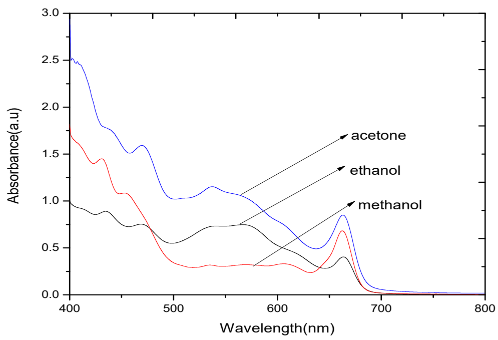

Figure-1: The absorption spectra for extracts of phyllanthus reticulatus fruit in acetone, ethanol and methanol solution.

3.2 UV-VIS Analysis for Photoanode

Figure 2 shows the absorption spectra of extracted dyes loaded onto the surface of TiO_2.The enhancement of absorbance and presence of peaks with dye loading shows the anchoring and chemical interaction of the dye molecules to the TiO_2 photoanode. The figure indicates that the phyllanthus reticulatus fruit dye extracted in solvent Acetone has adsorbed better on the surface of TiO_2 photoanode when compared to dye extracted in solvents ethanol and methanol.

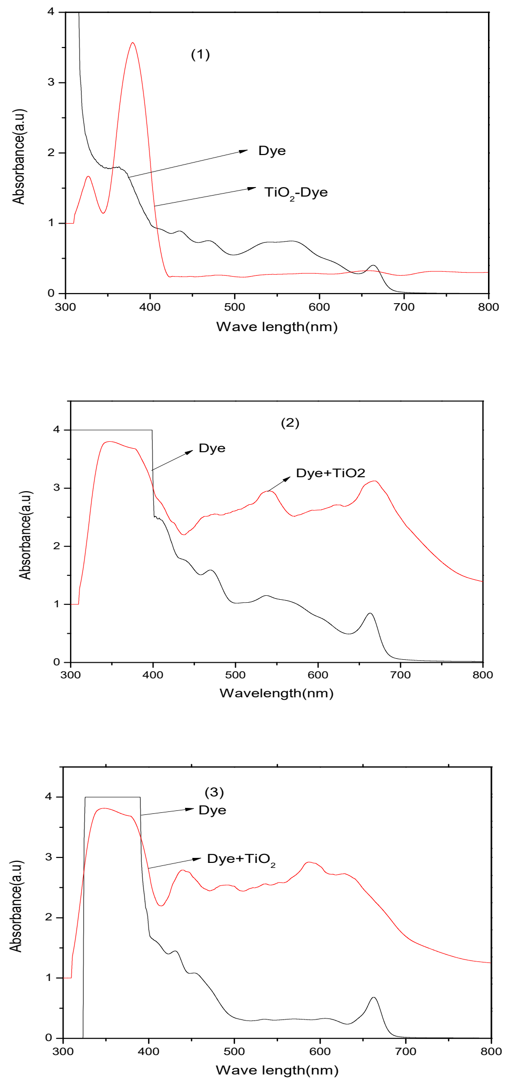

Figure-2: The absorption spectra of (1) TiO_2 -extracts of phyllanthus reticulatus fruit in ethanol solution. (2) TiO_2 - extracts of phyllanthus reticulatus fruit in methanol solution (3) TiO_2 - extracts of phyllanthus reticulatus fruit in acetone solution.

3.3 Optical properties

The bandgap of the dye samples from figure-1 estimated from Equation (1) is tabulated in Table.1

$\Delta E = hc/\lambda$ ---------------→(1)

Where, ΔE = Band gap (eV), h = Planck's constant = 6.626176 x 10^{-34} J/sec, c = Speed of light = 3 x 10^{8} m/s and λ = wavelength of light (nm)[20].

Dye	Solvents	Absorbance Wave length(nm)	Band gap (eV)
Phyllanthus reticulatus fruit	Ethanol	435 468	2.85 2.65
	Methanol	402 407 470	3.09 3.05 2.64
	Acetone	431	2.88

4.Conclusion:

The UV-Visible spectra analysis of natural dye extracts of phyllanthus reticulatus in solvent medium Ethanol Methanol and Acetone and UV-Visible spectra analysis of prepared photoanodes were carried out. The present study clearly concludes that each extract has its own absorption criteria in certain medium based on composition present in it. UV-Visible study shows that anthocyanin have maximum absorption in visible region. The rate of absorption of the reagents plays an important role in determining the conversion of light into electricity from solar energy which is in the visible region into its corresponding energies. The adsorption of dye molecules on the working electrode showed the broadening in the absorption spectra which enhances the light harvesting property of the pigments. Anthocyanin extract in solvent acetone may be used as natural potential sensitizer in the construction of Dye sensitized solar cell. In future we have planned to extend our work towards fabrication of DSSC and analyse the efficiency of the DSSC.

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