Using Natural Dye as Sensitizers in DSSC

[1]Hara Prasad Tripathy, [2]Priyabrata Pattanaik, [3]Susanta Kumar Kamilla

Abstract--- *The "dye-sensitized solar cell (DSSC)" uses Roselle flower as a sensitizer. It is also known as Hibiscus Sabdariffa L. The ethanol (E) and distilled water (DI) is used for extracting solvent at 30° temperature at 37Hz by 'degas' mode for a time period of 30 minutes in ultrasonic cleaner. Fabricating titanium dioxide (TiO2) was done by the method of doctor blade on ITO glass. "Evolution 201 UV-Vis Spectrophotometer" was used for absorbing Roselle dye spectra in various extract solvent. In the extract dye, the active functional group was identified by "Fourier-Transform Infrared (FTIR)". The element in TiO2 thin film and surface morphology are characterized by "field emission scanning electron microscopy (FESEM)" and "energy-dispersive spectroscopy (EDS)".*

Index Terms--- *FTIR, Sensitizer, natural dye, DSSC, ethanol, solvent.*

I. INTRODUCTION:

The increasing human population demands higher electricity in coming thirty years. The major challenges are faced because of increasing power consumption. The environmental surroundings are highly affected by the excessive emission of greenhouse gases and increased consumption of fossil fuels [1][2][3]. The alternatives have been sought to combat the depleting fossil fuels and thus progress of renewable sources of energies has become a centre of focus. The solar cells are used for direct conversion of solar energy into electrical energy and thus, photovoltaic energy is the most promising and abundant source of energy[4]. Because of lower cost and easily fabricating technology are the reasons for dye-sensitized solar cell (DSSC) gaining popularity [5]. O'Regan and Gratzel were the first ones to introduce DSSC in year 1991[6]. The best dyes for DSSC were metal Ruthenium (Ru) because it has highest efficiency percentage of 10-12%. The environmental impact, high cost and a difficult purification method are the disadvantages of Ru[7]. Thus it becomes a necessity to replace Ru with natural dyes because of being environmental friendly and low-cost. The DSSC comprises of a photoelectrode, counter electrodes, substrate glass and electrolyte. The performance is affected by various factors. LK Singh et al compared extraction of solvent from ethanol and de-ionized water having 1.37% and 0.72% conversion efficiency. The cells whose fabrication is done in deionized water degrades slower in comparison with those in ethanol. It is because of lack of proper attachment of functional groups to TiO2 surface and lack of proper solubility of dye in ethanol. At temperature range between 250 °C to 500°C, an experiment was performed by M Murugiah et al [8]. The significant outcomes are produced by higher grade of ZnO having reduction in impurity level and higher annealing condition of temperature. The work by AKM Muaz et al here is a smaller band gap between valence and conduction bands at higher temperature of annealing and electrons excite from valence band to conduction band at small amount of energy[9]. The family of Malvaceae has a tropical plant namely Roselle[10]. Roselle is

Department of Engineering, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, haraprasadtripathy@soa.ac.in, priyabratapattanaik@soa.ac.in, sushantakamilla@soa.ac.in

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enriched with anthocyanins and it capable of the production of red colorant for food items. Cyanidin and delphinidin are the complexes obtained from anthocyanin derived from Rosella [11].

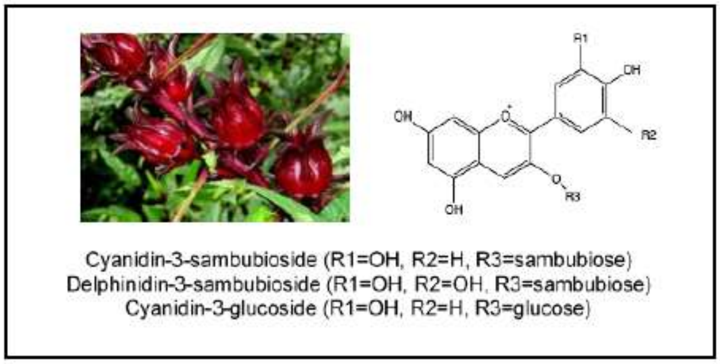

Fig.1 Structure of Cyanidin and delphinidin

II. WORKING

Figure 2 illustrates the cross section and process flow of DSSC.

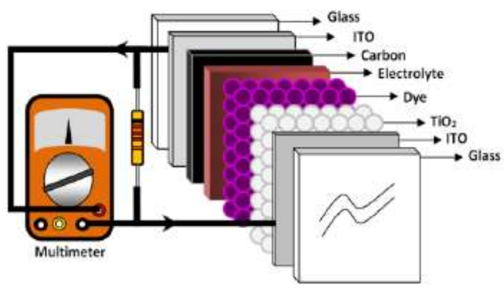

Fig. 2 DSSC cross section

The excited electrons are produced by the collection of photons by dry molecules whenever DSSC receives the sunlight. The dye molecules are excited when the light is passed through transparent anode. The electrons are injected by excited dye molecules into a conduction band of TiO2 layer behaving as semiconductor. The oxidation of those dye molecules those have lost electrons is done.

III. RESEARCH METHODOLOGY

III.I. Materials

The materials that are utilized in this work are distilled water (DI), paste of Titanium Dioxide(TiO2), ethanol, glass slide coated with Indium tin oxide (ITO). Some research works include the method of extraction and fabrication [12].

III.II. Preparation of extracts of natural dye sensitizer

A mortar was used for crushing Roselle dye of 10g into a paste after it is being chopped off into small pieces. A solvent at room temperature containing ethanol (E) and distilled water (DI) was used to immerse Roselle dye. Then an ultrasonic sensor is used for placing it as figure 4 illustrates. The coloured dye pigment is extracted by ultrasonic for a

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time period of thirty minutes at 37Hz by mode ‘degas’ at 30°C temperature[13].

The Roselle dye then immersed in the solvent which consists of distilled water (DI) and ethanol (E) at room temperature and then placed into the ultrasonic cleaner as shown in Figure 4. The ultrasonic is used to further extract coloured dye pigment for 30 minutes with a frequency of 37 Hz by using ‘degas’ mode at the temperature of 30°C.

Fig. 3 Roselle dye extract manufacturing

Fig. 4 Extraction of coloured dye by ultrasonic sensor

III.III.Manufacturing ITO glass

Figure 5 illustrates the cleansing and rinsing of ITO glass by ethanol. A mixture of TiO2 powder (5g) and Triton-100(3 drops) was mixed for preparing a paste of TiO2. A spatula was used for stirring the mixture to make it a homogeneous solution. The active area is fixed by pasting a scotch tape on conductive end of ITO. A glass stirring rod was used for spreading the suspension and TiO2 on ITO glass. This is called doctor blade method. At a hot plate having 450°C temperature two coated glass plates were placed for a duration of thirty minutes and fifteen minutes time was given to it for cooling. Out of the two ITO glasses, one was ITO titania dipped into an extract of Roselle dye for one day while other one was ITO glass having original pure TiO2[14].

Fig. 5 Preparation of TiO2 on ITO glass

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III.IV. Measurement and Characterization

"Evolution 201 UV-Vis Spectrophotometer" was used for testing the absorbed light's wavelength as illustrated in figure 6 which helped in the determination of absorption rate and composition of intensity of a dye colour. The equation 1presents a formula for determining the band gap of absorbed dye on the surface of TiO2, where h represents Planck's constant, λ denotes wavelength, c denotes speed and E represents photon energy [10]·

$$E = \frac{hc}{\lambda} \quad (1)$$

The level of penetration of light into a material before its absorption is determined by an absorption coefficient. The absorbance is divided by the wavelength that gives the value of absorption coefficient equation (2).

$$\text{Absorption coefficient, } \alpha = \frac{4\pi k}{\lambda} \quad (2)$$

Where λ (nm) is taken from the cutoff wavelength of the dyes and K is the Boltzman constant with value of 8.617×10^{-5} eV/K.

Fig. 6 UV-vis spectrophotometer

IV. RESULTS AND ANALYSIS

IV.I. Analysis of UV-VIS Absorption Spectra

The "UV-Vis spectrophotometer" is used to measure Roselle dye sample absorption spectra by diluting in ethanol (R-E) and distilled water (R-DI). A solution of red colour showed up while observing the extraction of Roselle dye by the use of distilled water. The wavelength of 400 to 600 nm is absorbed by R-DI having highest peak 490 m. The range 480 nm to 620 nm has R-E spectrum's peak of 540 nm. The existence of pigment anthocyanin is confirmed by absorption range 400 to 600 nm. Due to the presence of high amount of anthocyanin, Roselle is a good colorant and good source as well[15]ss.

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Table 1 Energy of photon and absorption coefficient of natural dyes

Dyes	Extract Solvent	Peak absorbance (nm)	Photon energy (eV)	Absorption coefficient (α) km^{-1}
Roselle	Distilled water	490	2.54	2.21
	Ethanol	540	2.30	2.01

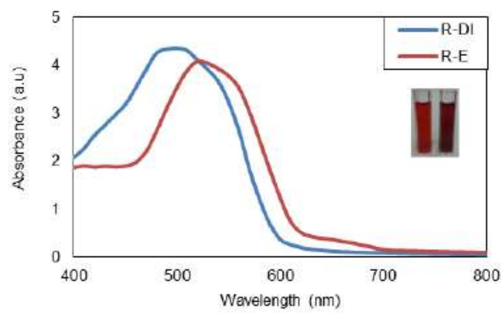

Fig. 7 Roselle water's absorption spectra

IV.II. FTIR Analysis

FTIR stands for "Fourier Transform Infrared Analysis". The ethanol (R-E) and distilled water (R-DI) formed solvent is use for confirming Roselle dye's functional group. The ketone structure having carbonyl group represents R-DI's sharp peak at "1639cm-1 corresponding to C=O stretching". The C≡O corresponds to peak at 2151cm-1. The presence of hydroxyl group (O-H) in Roselle dye gives broadest peak of absorption of 3366cm-1. The aromatics group (C-H) gives rise to peak at 879cm-1. The esters group (C-O) gives sharp peaks at 1087 cm-1 and 1046 cm-1. N=O bend is assigned band at 1382 cm-1. The ketone group is (C=O) gives a peak at 1646cm-1. When Roselle has dilution in ethanol solvent, peaks of absorption are at 2889, 2976 and 3366 cm-1 because of O-H stretching.

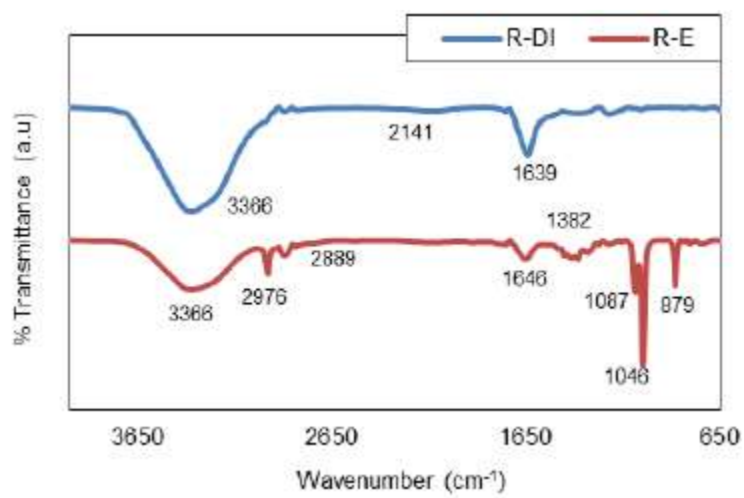

Fig. 8 FTIR spectrum

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V. CONCLUSION

The DSSC is implemented with Roselle dyes and it is a nature based dye. When the distilled water is used as extract solvent (R-DI), then maximum peak shown by absorption spectrum is 490 nm and when ethanol (R-E) solvent is used then maximum peak is 540 nm. The active functional group in the Roselle is identified by FTIR analysis. The efficiency of DSSC is enhanced because of hydroxyl (OH) group and carbonyl (C=0) group. Also the transfer of electron will be improved by this.

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