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Fabrication and Characterization of Dye Sensitized Solar Cells (DSSCs) for Energy Harvesting

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ABSTRACT Dye sensitized solar cells (DSSCs) have been intensively investigated. They are regarded as third generation latest photovoltaic technology in solar cells. This technology is found to be highly effective for low cost, more efficiency in low light conditions and its more absorption with different wavelengths across the visible light spectrum. The DSSC is commonly based on the extracted dye from flowers, roots and leaves of natural plants and trees. The natural dyes are collected from plants and trees to be used as natural photosensitizers for DSSCs. The cells are the fabricated using TiO_2 deposited on transparent fluorine doped tin oxide (FTO) conducting glass plate by using doctor blading method. The optical characteristics of the extracted dye solutions have been performed in between visible light range of 400nm to 780nm. Its photoelectrochemical performance for the cells has been studied. The (I-V) characteristic curves of all fabricated cells have been measured and further analysed for its better performance. Further, the impedance spectroscopy of the cells has been investigated for best performance analysis.

KEYWORDS Dye Sensitized Solar Cells, extracted natural dyes, Optical absorption of renewable source of light, TiO_2, Source meter, SMU instrument etc.

INTRODUCTION

Dye sensitized solar cells (DSSCs) are the latest new type of photovoltaic technologyinvented by Michael Grätzel and Brian O'Regan in 1991 [1]. They are also known as Grätzel cell. They employdyes to absorb the light from the sun and converting into electrical energyby photovoltaic effect. They are third generation solar cell technologiesbelonging to organic based photovoltaic cell. They are formed of a nano crystalline metal oxide semiconducting layer as TiO_2 deposited on transparent fluorine doped tin oxide (FTO) conducting glass, absorbed dye on the semiconducting material, counter electrode, and an electrolyte containing iodide and triiodide ions. In DSSCs, the absorbed dye acts as a photosensitizer [2-7].

The photosensitizers (such as anthocyanin, betalain, carotenoid, chlorophyll, β-carotene, flavonoid, etc.) have been extracted from natural sources (such as vegetables, fruits, flowers, leaves, roots, etc.), being the heart of DSSCs. Dyes have been extracted by using various extraction methods and are found to have an effect on the performance of the DSSCs. It is hypothesized that the strong mutual interaction between the method of extraction and optical absorbance or light harvesting efficiency (LHE) of the dyes. The LHE is indicative of the incident photon-to-current conversion efficiency (IPCE) of the DSSCs [8-12].

The main aim of research objective is to investigate the effects of extraction methods of natural dyes upon LHE for better performance of DSSC applications and scientific view projected on these studies. Since the invention of the nanostructured DSSC, a lot of theoretical and experimental works have been carried out to explain the surprisingly efficient operation of these solar cells. Finally, through the expected trend between the method of extraction and optical absorbance will contribute to bridge knowledge for applications and further research in DSSC technologies for energy harvesting.

In this paper, we employed a particular extraction technique for extraction of anatural dye such as betalain from bougainvillea flower has been extracted and used as DSSC photosensitizers [13-15]. The absorption spectra of these dyes have been carried out. The current-voltage characteristic curve of fabricated cell has been measured, plotted, and analysed.

EXPERIMENTAL ARRANGEMENT

At first, the natural dye was collected from plant and washed with distilled water. The raw material was left to dry at room temperature for a week. Fresh bracts of bougainvillea were handpicked and grinded using a mortar and pestle. 15 grams of these grinded bracts was put into 100 ml acetone and was further grinded using a grinder. The betalain dissolves in acetone to give the acetone a characteristic violet colour. The mixture was then subjected to centrifugation for 15 minutes at 4000 rpm. The heavier impurities settle down at the bottom and the betalain solution is taken out of the centrifuge. The UV-VIS spectrophotometer was used to carry out the absorption spectra of the extract in the visible range of 480nm to780nm.

Now with the conductive side facing up, in which two parallel strips of tape were placed on the edge of the glass plate, covering about 5 to 7mm of glass. The adhesive tape also holds the glass plate in position on the workbench and prevents the plate from moving during the deposition strokes. Titanium dioxide was deposited in the uncovered portion of the glass. The edges masked by the tape were used for sealing and making electrical contacts. Titanium dioxide powder, acetic acid and alcohol were stirred in motor and pestle to get a homogenous paste. A portion of paste was applied near the top edge of the FTO glass, between the two pieces of tape. A uniform coating of the paste was spread across the plate, between the strips of the applied adhesive tape, with the help of a slide. The coating of TiO_2 was sintered in a furnace at 500^0C temperatures for half an hour, subsequent to removal of the adhesive tape. The titanium dioxide was there after stained with extracted dye for 15-50 minutes. The cell was then dried in an oven at 80^0C for 5 minutes. A fine coating of carbon was rubbed on the conductive surface of the FTO glass. The electrodes were placed against each other so that the stained titanium dioxide faced the carbon of the counter electrodes. The conductive sides of each electrode, placed face to face, formed the inside the cell. Paper binder clips were used to hold the electrodes together. In order to fill the cell with an electrolyte few drops of IKI solution were administered at the interface of the two glass plates with a pipette. The liquid gets down into the cell by capillary effect. Finally, it was fabricated and used for laboratory viewing program.

The fabricated cell has been assembled in the sandwich configuration, which has illustrated in figure 1:

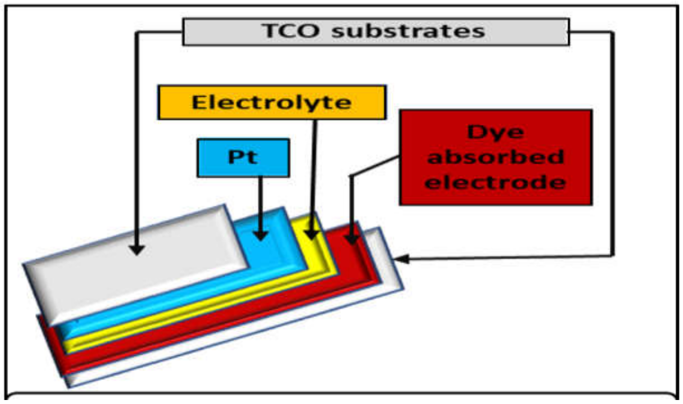

Figure 1: Typical elements of sandwich configuration of DSSC.

After illumination of the DSSC with 80 m W /cm² irradiation using high pressure mercury arc lamp, the cell was connected to Keithley 2450 source meter and was used for conduct the current-voltage curve.

RESULTS AND DISCUSSION

The photovoltaic parameters of solar cells are short circuit current density (J_{sc}), open current voltage (V_{oc}),wavelength at the absorption curve peak (λ_{max}), maximum power point (P_{max}), fill factor (FF),and efficiency (η). The wavelength of maximum absorption of the extract is determined from absorption spectra curve, which shown in figure 2. The current density and open current voltage are obtained with the help of (I-V) curve. The maximum power point is obtained from (P-V) curve [16-17]. The FF and η can be determined by the given equations:

Fill factor, $FF = \frac{I_{\max} . V_{max}}{I_{sc} . V_{oc}}$ (i)

Efficiency, $\eta = \frac{FF . I_{sc} . V_{oc}}{P_{in}} \times 100\%$ (ii)

where P_{in} is the power of incident photon light in watt / cm².

The pH-value, conductivity, absorption spectra characteristic curve of extracted dye has shown in figures 2 and 3 in below:

Common Name: Bougainvillea
Botanical Name: *Bougainvillea spectabilis*
Dye Found: Betalain
pH- value of Dye: 5.60
Conductivity: 3.56 mS/cm
Colour of Dye: Violet

Figure 2: Characteristics of Bougainvillea flower.

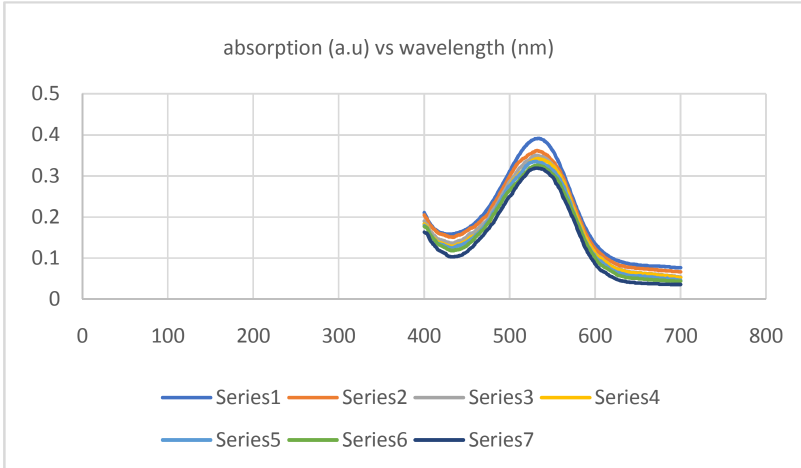

Figure 3: Absorption spectra curve of Betalain.

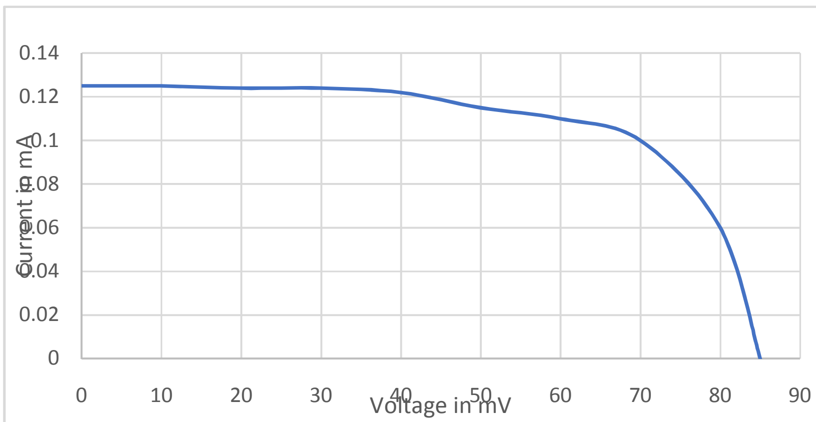

Figure 4: (I-V) characteristic curve of cell.

The Betalaine dye extracted from bougainvillea was subjected to UV-VIS spectroscopy and the UV-VIS was performed on Shimadzu UV-1800(figure-3). The wavelength of maximum absorption of the dye was obtained λ_{max} = 525 nm in the region from 400-700 nm. Further, the cell was connected to the Keithley 2450 source meter and after calculations and observations the values were obtained with the help of (I-V) curve (figure-4) by using ethanol and water on the extract as follows: J_{sc}=0.318 mAcm^{-2}, V_{oc}=0.445 V, FF=0.07 and η=0.006% respectively. The obtained efficiency is lowest than the reported earlier value for organic dye based DSSCs. The low efficiency may be attributed to poor absorption of dye molecules onto the TiO_2. Finally, the magnitude of measured quantities may be very significant for performance of DSSCs.

CONCLUSIONS

The betalain dye from bougainvillea flower was extracted and used as photosensitizers for the fabrication of DSSC, which has exhibited the lowest efficiency of current requirements for large scale practical applications. The result may be encouraging for the additional studies and inspiring for further work in the field.

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