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Study of Dye Sensitized Solar Cell using Mirabilis Jalapa Flower Extract

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Abstract

Dye sensitized solar cells (DSSC) are a promising class of photovoltaic cells with the capability of generating green energy at low cost. No expensive equipment are required in their fabrication. In our work, we have constructed the solar cell with dye extracted from Mirabilis Jalapa (Four o'clock flower) as natural sensitizers.TiO_2 thin flim was coated on FTO conducting glass plate. The prepared dye was coated on it. A blend of KI, Ethylene glycol and iodine was used as an electrolyte. The prepared cells were characterised with FT-IR spectrometer and UV-Vis spectrophotometer. I-V characteristic curves were traced and its efficiencies were calculated. The efficiency of Dye sensitized solar cells (DSSC) was calculated.

Keywords: Dye Sensitized Solar Cells; Mirabilis Jalapa, dye, efficiency

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1. Introduction

Solar cells are the important applications of solar energy. It is an alternative energy source to produce energy from freely available solar radiation. Solar cell (SC) is one of several ways to convert solar energy into electrical energy. Dye sensitized solar cells (DSSCs) also known as Gratzel's cell was inverted by Gratzel and O'Regan and they first reported the DSSC in 1991[1-3]. (DSSC) have been intensively studied as a new type of solar cells which composed of nanocrystalline porous semiconductor electrode which absorbes dye, a counter electrode and an electrolyte of iodide-triiodide ions[4]. Solar energy is converted into electric energy through sensitization of wide-band gap semiconductors by using dye sensitized solar cells (DSSC)[5].This sensitization is due to the dye absorption of a part of the visible light spectrum. The sensitized dye works by absorbing the sunlight which then converts it into electrical energy [6-7].

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The natural dyes found in flower, leaves , fruits and seeds can be extracted and used. Due to their cost, efficiency, non-toxicity and complete biodegradation natural dyes have been a popular issue of research. DSSC have the advantages of simple fabrication, low cost and large area [8].

Titanium dioxide (TiO_2) coated with fluorine doped-tin oxide (FTO) transparent conducting glass is used as the photoanode. A dye molecular layer is coated on the exterior of TiO_2 layer to produce electricity. TiO_2 is the promising material for solar cell applications. TiO_2 is a wide band gap of 3.2 eV. Titanium's poor light harvesting capacity is increased by utilizing the sensitizer's strong absorption in the visible region of the solar radiation spectrum enhances to capture more solar radiation[9].

2. Experimental Procedure

2.1 Materials

TiO_2 powder (anatase titanium IV oxide, ALDRICH), Triton X-100 (SIGMA, for electrophoresis) Acetyl Acetone (A.R).ethanol, Ethylene glycol, potassium iodide(KI), Iodine were used as received without further purification. Fluorine doped tin oxide (FTO) conducting glass plates of size 25mmx25mm (7-10Ω) were used to coat the material. The flowers of Mirabilis Jalapa were collected from the garden. Experimental steps were done in three parts. First one is the preparation of the cathode electrode (TiO_2 photoelectrode), second is the preparation of the anode electrode (carbon counter electrode) and third is the preparation of the dye-sensitized solution[10].

2.2 Preparation of TiO_2 Paste

TiO_2 porous film (photo anode) was prepared by mixing 50 mg of TiO_2 powder (anatase) with 3drops of Triton X-100 in a mortar and pestle. Finely several drops of Acetyl Acetone was added under continuous stirring to form a TiO_2 paste [11].

2.3 Preparation of sensitizers using natural dyes

Mirabilis Jalapa, the **marvel of Peru** or **four o'clock flower**, is the most commonly grown ornamental species of Mirabilis plant, and is available in a wide range of colours is shown in fig.1. We have chosen the flower rich in pink colour because red dye is suitable for the Solar cells. The fresh flowers were got from the house garden at Periyakulam and were used. Mirabilis Jalapa is used for medicinal and ornamental purposes.

The Scientific Classification of Mirabilis Jalapa

Kingdom: Plantae
Clade: Angiosperms
Clade: Eudicots
Order: Caryophyllales
Family: Nyctaginaceae
Genus: *Mirabilis*
Species: *M.Jalapa*
Local name: Four o'clock flower
Used part: Flower

The fresh Mirabilis Jalapa flowers were washed with Distilled water, finely cut and soaked in 25 ml of ethanol for 30 minutes and filtered through Whatman filter paper and it was subjected to various temperature of 60˚C, 70˚C, 80˚C [12].

Fig. (1): Four o'clock flower (Mirabilis Jalapa)

2.4 Preparation of Electrolyte

0.127 gm of Iodine (I_2) was added to 10 ml of Ethylene glycol and stirred. Then 0.83 gm of Potassium Iodide was added to it and sonicated for 30 min for homogeneous mixing [13].

2.5 Preparation of Photo Anode

Fluorine doped Tin Oxide conducting glass plates of 2.5cm×2.5cm (7-Ω) was cleaned and was covered with scotch tape at the ends. The as prepared photo anode was coated on the conducting side of fluorine doped tin oxide (FTO) glass by doctor blade method. After drying, the tape was removed carefully and the coated cells were sintered at 450˚c for 30mins in a furnace and allowed to cool down to room temperature. The as prepared dye was placed in the beaker and the TiO_2 coated face of the FTO was immersed into the dye solution for 12 hours. After that it was washed with ethanol and distilled water and dried. The counter electrode was prepared by depositing platinum on FTO glass plate. The DSSC was assembled by sandwiching photo anode and counter electrode and the prepared electrolyte solution was injected between the two electrodes. It was clipped and the cell is ready for use. The Preparatio of dye sensitized photo anode shows in figures 2 and 3.

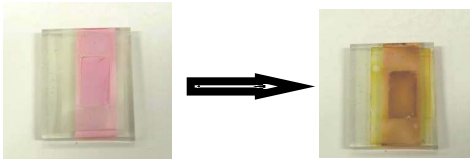

Fig.(2) Glass plate coated with TiO_2 and dye and then coated with electrolyte

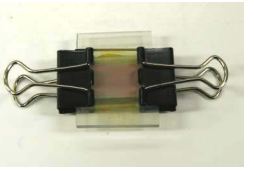

Fig.(3) Prepared Solar cell

3 .Results And Discussion

3.1 UV-Vis spectroscopy Studies

Optical absorption of Mirabilis Jalapa was studied by means of UV-Vis spectroscopy using the UV-Vis lambda 750 instrument. The absorption spectra of Mirabilis Jalapa subjected to various temperatures (60˚C, 70˚C, 80˚C) are shown in Fig.4. The absorption peaks are at 279nm for 60˚C, 218nm for 70˚C and 284nm for 80˚C. The band gaps of the dye calculated were 2.9 eV, 3.3eV and 3.9eV for the temperatures at 60˚C, 70˚C, 80˚C. It was found that the band gaps increased well with the rising temperatures.

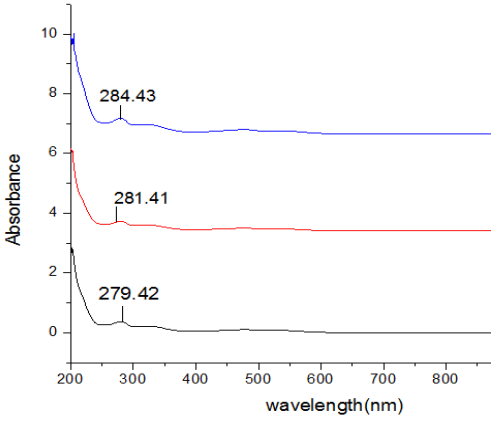

Fig.(4): UV-Vis absorption spectra of the prepared dyes at 60˚C, 70˚C, 80˚C

4.2 FT-IR Spectroscopy Studies

The FT-IR spectrum of the prepared dye is shown Fig.5. The observed frequencies are in the regions 3443-820cm^{-1}. The overall variations in intensities possible assignment of fundamental modes is given below. The possible frequencies of variations of different groups are reported. The frequency range of 3443.11 cm^{-1} exhibits O-H stretching mode of vibrations and it mainly occurs in alcohols. It is relative intensity is medium. The O-H stretching mode of vibrations is observed by the intense bands in the range of 2920.44cm^{-1} and mainly forms carboxylic acids. The frequency range 2842.23cm^{-1} is present in the aldehyde of C-H stretch. The C=C and C=H stretching mode of vibrations are observed by intensity range of 1641.77cm^{-1} and 1383.55cm^{-1} in the alkenes. The C=C stretching mode of vibrations are observed by the intensity range of 1056.88cm^{-1} in Ketones. The C-H stretching modes of vibrations are observed by the range of 820.44cm^{-1} in the Aromatics.

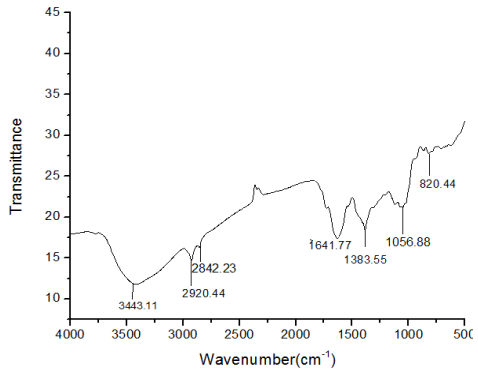

Fig. (5) : FT-IR spectra for the as prepared dye

4.3 I-V characterization Studies

The photovoltaic study of the prepared DSSC with Mirabilis Jalapa extract as photosenzitizer was performed under irradiation with white light (100 Mw/cm-1).The performance analysis of open-circuit voltage(Voc),short-circuit (I_{sc}), fill factor(FF), and energy conversion efficiency(η) were studied. The photocurrent-voltage characteristic curve is shown in Fig.(6) for different temperatures and the photo electrochemical parameters of the different temperatures are summarized in Table.1. The calculated efficiencies of the DSSC are 0.53%, 0.70%, 0.98% for the temperatures 60° C, 70° C, 80° C. The natural dyes used as photo sensitizers in DSSCs showed low conversion efficiencies compared with synthetic dyes.

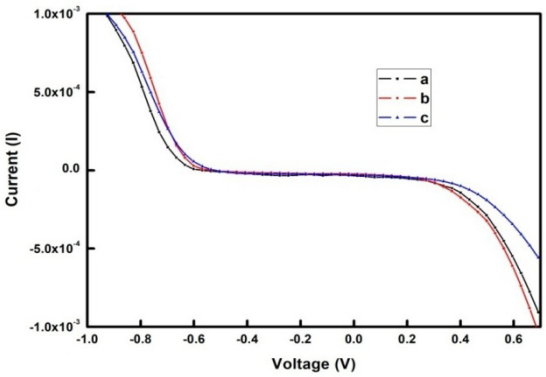

Fig. (6): I-V characterization curve for DSSC

Table.1. Photovoltaic parameters of the prepared cell

S.NO	Temperature	V_{oc}(V)	I_{sc}(μA)	V_{max}(V)	I_{max}(μA)	FF	Efficiency(η) %
1	60°C	0.30	2.3	0.23	2.3	0.696	0.54
2	70°C	0.33	2.9	0.24	2.9	0.7	0.70
3	80°C	0.40	3.5	0.28	3.5	0.8	0.98

5. Conclusion

DSSCs were constructed with the dyes extracted from the Mirabilis Jalapa flowers at three different temperatures. It was found that the band gaps increased well with the increase of temperatures which is suitable for solar cells. The I-V characterization study was done and calculated various photoelectrochemical properties and found that the highest efficiency was obtained for the cell prepared with dye at 80°C with efficiency of 0.98%.

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