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Energy Harvesting via Natural Photo-Sensitizer based Dye-Sensitized Solar Cell using Nanostructured Photo-Electrodes

Anand Kandacharya, Jagdhar Mandal*, P.L. Meena

Author's Affiliations:

Anand Kandacharya Research Scholar, University Department of Physics, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar 812007, India

Jagdhar Mandal Professor & Head, University Department of Physics, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar 812007, India

P.L. Meena Assistant Professor, Dept. of Physics, Deen Dayal Upadhyaya College, University of Delhi, Dwarka, New Delhi, Delhi 110078, India

***Corresponding author:** **Jagdhar Mandal,** Professor & Head, University Department of Physics, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar 812007, India
E-mail: jmandal1284@gmail.com

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ABSTRACT In this paper, we investigated the structural, chemical and photovoltaic characterization of commonly found natural dyes. The dyes have extracted from plant materials like the bougainvillea, yellow bells (piliya), golden shower (amaltas), hibiscus, peepal and mint. Based on the structure and properties of the dye, which the fact that "like extracts like", a suitable solvent has selected, in which the dyes have extracted efficiently. The extracted dyes act as natural photo-sensitizers, which has mostly used for the fabrication of dye sensitized solar cells (DSSCs). The cells have been fabricated by using TiO_2 as a semiconducting layer deposited on transparent fluorine doped tin oxide (FTO) conducting glass plate with the help of doctor blading method. The J-V characteristics curves of all fabricated cells were measured by using source-meter, SMU-instrument etc and further analysed for its better performance was investigated.

KEYWORDS Renewable energy, dye-sensitized solar cells (DSSCs), natural dyes, TiO_2, UV-visible spectroscopy, source-meter, SMU-instrument etc.

INTRODUCTION

Noble Laurate Richard E. Smalley tried to draw attention of human being topmost 10 problems [(i) Energy (ii) Water (iii) Food (iv) Environment (v) Poverty (vi) Terrorism & War (vii) Disease (viii) Education (ix) Democracy and (x) Population.] for the next 50 years in the 226th ACS National Meeting [1].Today, energy is the lifeline and status symbol of "civilized" societies. All nations have therefore embarked upon research and development programs of varying magnitudes to explore and effectively utilize renewable sources of energy in the field of science and technology.The renewable energy sources can play very significant role for reducing dependency upon non-renewable energy sources. Now in recent days, the new field of research comes on the surface on the development of alternative renewable energy resources. Of the wide range of renewable energy sources, solar energy is one of the most attractive [2-6]. The magnitude of solar energy as a potential energy is seen when one recognizes that the total solar energy falling on the surface of the earth is approximately 7.45×10^{17} kilo watt hour annually [7]. The solar energy considered to be the most promising one for meeting the energy needs of the future. However, capturing the solar energy and directly converted into electrical energy with the help of photovoltaic technology is challenging a task.

Among all the energy technologies, photovoltaic technology is considered to be the most promising one [8-9].The photovoltaic technology works on the principle of photovoltaic effect which converts the solar energy to electrical energy. Dye Sensitized Solar Cells (DSSCs) are regarded as the latest photovoltaic technology in solar cells, which have been recently investigated intensively for their low cost, more efficiency in low light conditions and its more absorption with different wavelengths across the visible light spectrum.Dye-sensitized solar cell (DSSC) was invented by Michael Grätzel and Brian O'Regan in 1991, also called as Grätzel cell. The heart of DSSC is the photosensitizer which has been extracted from natural sources such as vegetables, fruits, flowers, leaves, roots, etc. The dyes act as photosensitizers which have been extracted by using various extraction methods. They have been used for the fabrication of DSSCs.A new trend of nanotechnology has recently emerged also in the field of photovoltaic technology for the energy conversion also. On the development of material engineering, the scale of nanometer has activated into a new photovoltaic materials and systems that could potentially developed into low cost solar cell in future.

The main adjective of the proposed research work is to include a scientific temper and motivation for higher studies in the field of science and technology.The primary innovative part of the proposed research work is the identification, extraction, characterization of natural photosensitizer and their efficient use in dye sensitized solar cells (DSSCs) for energy harvesting. The secondary innovative parts have been describing the growth, characterization and suitable development of the photo-electrode for DSSCs for energy harvesting, which expected trend will contribute further research in DSSC technologies for energy harvesting.

In this present paper, we applied a particular extraction technique for the extraction of natural dyes have been extracted from different part of plants and employed for the best performance of DSSCs. The pH-value, conductivity and absorption coefficient of these dyes have been carried out. The current-voltage characteristic curves of fabricated cells have measured, plotted and analysed for the better performance.

EXPERIMENTAL

Extraction of Dyes: We employed a particular extraction technique for extraction of carotenoid dye from flower of golden shower (amaltas) by the descriptive flowchart has shown in figure 1 and the measured parameters mention in figure 2.

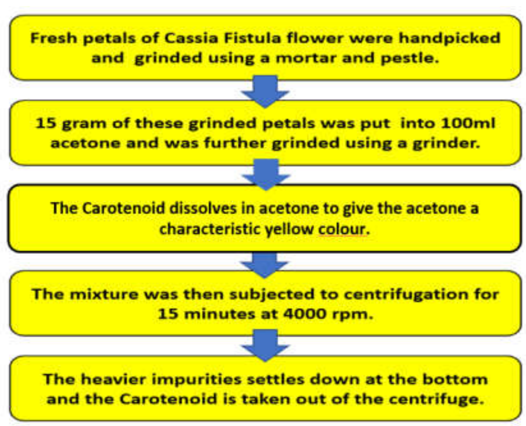

Figure 1: Flowchart for extraction of dye from amaltas

Figure 2: Determined parameters of amaltas

Preparation of TLC plates: The silica gel powder and plaster of paris was taken in a ratio of 4:1 in a container and was mixed with water in a ratio of mixture2:1. This mixture was thoroughly stirred in order to obtain a homogenous mixture. A thin layer of this mixture was evenly spread over a glass slide which was then dried in an oven. After all the water is evaporated, TLC plates were used for analysing the dye extracted from golden shower (Amaltas) illustrated in figure 3.

Figure 3: Preparation of TLC plates

Preparation of TiO_2 nanoparticle: Sol-gel technique used for the synthesis of pure TiO_2 by taking titanium isopropoxide (Sigma-Aldrich) as one of the precursor-solution and a mixture of distilled water with 2-propanol as another precursor solution. The synthesis process was started by the mixing 200 ml of double distilled water with 15 ml of 2-propanol. The pH of this first precursor solution was adjusted to 2 using decimolar nitric acid [11]. The second precursor titanium isopropoxide was taken as a 5 ml. The titanium precursor was added dropwise into the first precursor under continuous stirring in room temperature with equal interval of time. Formation of a white drop like precipitate was the immediate response from the reaction. After completing the drop wise addition of titanium precursor, the precipitation was washed several times in distilled water and then in methanol to remove the impurities. The precipitation was dried and fine white powder of TiO_2 was collected. The sol-gel processes with a simple modification for the synthesis of natural dye mixed TiO_2.

Construction of DSSCs:DSSC is composed of four elements, namely, the transparent conducting and counter electrodes, the nanostructured wide band gap semiconducting layer, the dye molecules (photosensitizer) and the electrolyte (usually composed of iodine/tri-iodine). The basis of solar cell is the semiconductor, which has the properties of enabling electron separation as well as transportation and which has obtained from sunlight (Shown in figure 4).

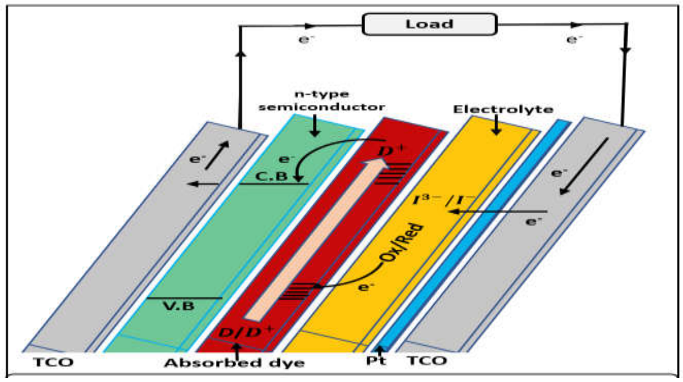

Figure 4: Typical configuration of DSSCs.

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 DISUSSION

In order to use the J-V characteristic curve to calculate the cell power output, conversion efficiency etc. be defined some quantities called the photovoltaic parameters, which 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 extracted dye has determined from absorption spectra curve, which shown in figure-5. The current density and open current voltage have obtained with the help of (J-V) curve. The maximum power point has obtained. The FF and η can be determined by the following equations:

Fill factor (FF) = $I_{max} \cdot V_{max} / I_{oc} \cdot V_{oc}$ (a)
Efficiency (η) =$FF.I_{sc}.V_{oc}/P_{in}$ (b)

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

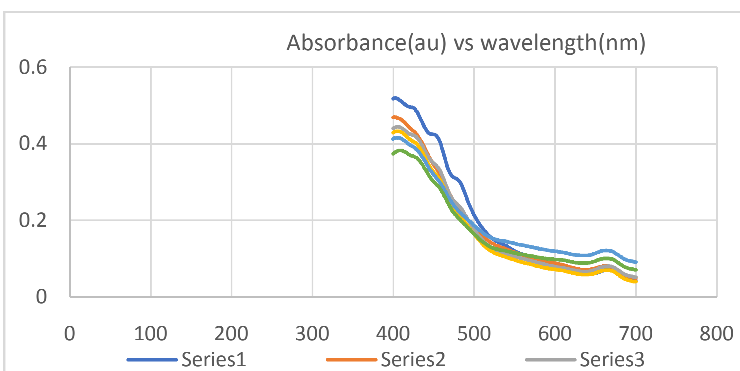

Figure 5: Absorption spectra curve of carotenoid (amaltas).

The carotenoid dye extracted from golden shower (amaltas) was subjected to UV-VIS spectroscopy and the UV-VIS was performed on Shimadzu UV-1800 (figure-5). The wavelength of maximum absorption of the extracted dye was obtained λ_{max} = 674 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 value was obtained as follows: J_{sc}=0.89 $mAcm^{-2}$, V_{oc}=0.254 V, FF=0.39 and η=0.010% respectively. The obtained efficiency is lower 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.

CONCLUSION

In this work we have reported about the studies carried out on different dyes easily available from plant as a natural photosensitizer for DSSC. Our work mainly carried out on carotenoid dye which was extracted from golden shower (amaltas) for DSSC although the efficiencies obtained from carotenoid dye is still below the current requirements for large scale practical applications, the results are encouraging and my initiate additional studies and in inspiration for further work in the field.

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