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Mixed Dye From Nerium Oleander and Hibiscus Flowers as a Photosensitizer in Dye Sensitized Solar Cells

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Abstract : In the Present work, two natural dyes were extracted from flowers such as nerium oleander and hibiscus. The ethanolic extract of the dyes obtained were mixed in an equal proportion to prepare a mixed dye in order to observe the synergistic effect of the dyes and also to obtain the overall conversion efficiency. The ethanolic extract of the dye was subjected to uv-visible spectroscopic studies in order to understand its light absorption nature. The light absorption behavior in the uv-vis region makes it suitable as a photosensitizer in the development of DSSC technology.

The solar cell was fabricated with the dye prepared and tested under 85 mW/cm^2 Solar simulation to observe its photo response. The J-V Curve was recorded for the assembled cell. The combination of the dyes exhibited a short circuit current density of 0.451 mA/cm^2, an open circuit voltage of 0.462 mV, a fill factor of 0.269 and a conversion efficiency of 0.056% and did not show any significant increase on comparison with the single dyes obtained from the nerium oleander and hibiscus flowers.

Key Words— Dye-Sensitized Solar Cell, Natural Dyes, Absorption spectra, Efficiency

Introduction

The requirement for energy is always ever increasing due to the industrial growth and modernization. In the present world, though there are various positive aspects due to the advancement in technologies, on the other hand the development poses a serious threat to the environment thereby resulting in environmental degradation and unsustainable condition. Generation of greenhouse gases from the combustion of fossil fuels has led to the drastic changes in the climatic patterns. This present situation has led the researchers to explore the renewable energy sources in order to meet the ever increasing energy demands. Solar energy is the promising candidate in this regard and can be harnessed in many ways but still remains challenging to be harvested in a effective manner. Solar radiation is the abundant source of energy on earth. The conventional silicon based solar cells are not widely preferred due to their high production cost, and skilled manufacturing techniques[1.] Dye sensitized solar cells (DSSC's) have gained considerable attention due to their non polluting nature, attractive appearance, low cost fabrication and ease of manufacture. It is a growing and an intense research field with potential applications in the framework of non conventional energy technologies[2]. DSSC's are the modern devices used for the conversion of solar energy into electrical energy based on the photosensitization of the wide band gap semiconductor. It was first developed by Gratzel and his coworkers in 1991 at Swiss Federal Institute of Technology, Lausanne, Switzerland [3]. DSSC's basically belong to the third generation solar cells[4]. Different research groups work on the concept of DSSC with the prime aim of increasing the overall conversion efficiency .

Operating Principle of a Dssc

A Dye sensitized solar cell generally work on the principle of photosynthesis which is the naturally occurring cycle in plants that maintains the life on earth. Compared to the traditional silicon based solar cells, the nanocrystalline natured dye sensitized solar cell is a photoelectrochemical cell. The absorption of light from the light source by the dye molecule which acts a photosensitizer initiates the process of generating electric power. After the light absorption and excitation, an electron from the excited state of the dye molecule is injected into the conduction band of the Titanium dioxide semiconductor layer. The electrons that are injected travel through the semiconductor layer into an outer electrical circuit to generate electric current. The dye that has lost the electron is in turn regenerated and returned back to the normal state by the electron donation from the electrolyte that is used in the cell. The iodide is also regenerated by the reduction of the tri iodide at the counter electrode. The voltage that is produced in the DSSC is attributed to the difference between the Fermi level of the electron in the solid and the redox potential of the electrolyte[4,5].

Importance of a Photosensitizer

The dye is used as a photosensitizer in the performance of a DSSC. It serves as the absorber of sun's radiation and plays a pivotal role in increasing the efficiency of the cell. Much of the research in the identification and preparation of photosensitizers are involved in the suitability of it in the operation of a DSSC. A typical photosensitizer must possess the following requirements[4,5]

- Strong absorption in the visible region.
- It must carry suitable attachment chemical groups to bind itself with the semiconductor surface.
- Capable of injecting the electrons into the semiconductor layer upon excitation.
- It should be more stable in order to withstand many turnover cycles.
- Cost effective and eco friendly in nature.

Presently, ruthenium sensitizers were reported with their highest conversion efficiency exceeding 11%, the high efficiency is attributed to the wide absorption range in the NIR region[6,7]. With much research on ruthenium based sensitizers, considerable research interest is constantly focused on metal free organic dyes such as triphenylamine dyes with a reported efficiency of 9.1% [8], unsymmetrical squaraine dyes with a reported efficiency of 6.74% [9]. Additionally, importance is given to the naturally available dyes found in flowers, fruits and vegetables from which the extracts are obtained in a cost effective manner and tested for their performance in DSSC's. Anthocyanins , Betalains, Chlorophyll etc. which are generally found in the naturally available bright colored fruits, vegetables and flowers are successfully used as photosensitizers in the DSSC's.

Dyes from various natural sources, have been extracted and reported in recent years with different reported conversion efficiencies. Extracts from ivy gourd fruits and red frangipani flowers were used as sensitizers and the extract from red frangipani flowers were reported with a conversion efficiency of 0.30%[10]. Natural dyes were extracted from various sources such as raspberries, shami berries, grapes, hibiscus, chlorophyll etc and the combination of some of these dyes is reported with a better photovoltaic performance and with a overall conversion efficiency of 3.04%[11.] Natural dyes were extracted from wormwood and purple cabbage and their cocktail dye was prepared and reported with a best conversion efficiency of 1.95 % [12].

In the present work, natural dyes were extracted from flowers such as nerium oleander (Family: Apocynaceae, common name: Kaner, colour chosen: reddish pink), and hibiscus (Family: Malvaceae, common name: Gurhal, colour chosen: red), using the reported procedure[13]. The cocktail of the two dyes extracted were prepared in equal combination and tested onto the assembled DSSC and the conversion efficiency obtained was compared with the dyes that were used in single. The photo current - voltage (*J-V)* characteristics of the fabricated DSSC was also recorded in order to obtain the essential parameters such as short circuit current density (J_{SC}), open circuit voltage (V_{OC}), fill factor (*FF*) and the overall conversion efficiency (η).

Experimental Details

Extraction of natural dye

The chosen natural floral species such as nerium oleander and red hibiscus were collected freshly from the University Campus. The extraction was done as per the reported procedure[13]. Ethanol was used as a solvent for extraction. The ethanolic extract was used without further purification. The two extracts thus obtained were then mixed in an equal proportion and its light absorption characteristic was studied. The UV-Visible spectra of the prepared dye were recorded in a 10 mm length quartz cell by using JASCO V 630 spectrophotometer.

DSSC Assembling and Photovoltaic Measurement

All the materials required for fabrication of the DSSC were purchased from the Institute of Chemical Education, United States and used without any further purification. Nanocrystalline Titanium dioxide (TiO_2) powder (Degussa P25) was weighed and made into a smooth suspension in a mortar and pestle with dilute acetic acid (pH 3-4 in distilled water) which was added in drops until a lump free smooth suspension was obtained. To the TiO_2 paste obtained, 2 drops of clear detergent solution was added and left undisturbed for 15 min for the system to equilibrate. The square glass slide was cleaned with ethanol and the conducting side of the glass slide was identified with a multimeter. A smooth nanocrystalline TiO_2 layer was made on to the conducting side of the glass slide with a clean glass rod. The smooth film formed was air dried for a minute and heated in a furnace for 30 min at 450 $^{\circ}C$ and cooled. The ethanolic extract of the dyes were taken in a petridish and the glass with TiO_2 coated side was immersed in the dye solution for 24 hrs without exposure to sunlight and the same procedure repeated for the other two dyes as well. The carbon counter electrode was prepared by identifying the conductive side and coated with carbon using graphite pencil. The dye coated glass slide was washed gently with ethanol and dried for a minute. The electrodes were clipped together to form a complete cell and a drop of electrolyte was placed in between the electrodes and the response of the assembled cell was recorded [14]. The conversion efficiency was recorded under 85 mW/cm^2 condition using a solar simulator.

The photocurrent-voltage (*J-V)* curve was recorded with potentiostat / galvanostat (Autolab-84610) set up.

Results & Discussion

Absorption Spectra of the mixed Dye

Nerium oleander and hibiscus are reported for its anthocyanin content[15,16]. The dye in combination of both the floral extracts exhibited a sharp absorption peak at 380nm and a broad absorption peak in the visible region between 500 – 600 nm with a maximum wavelength at 540nm as in Fig 1.Since the dye shows intense absorption in the visible region, it is more suitable to be used as a photosensitizer in a DSSC.

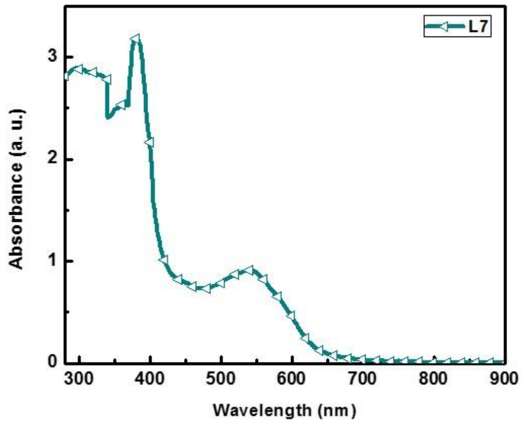

Fig 1

Performance of the DSSC with the mixed dye

The J-V Curve was recorded under 85 mW/cm^2 Solar Simulation conditions with potentiostat / galvanostat (Autolab-84610) set up. The essential cell parameters such as, short circuit current density (J_{SC}), open circuit voltage (V_{OC}), fill factor (*FF*) and the overall conversion efficiency, (η) for the mixed dye is summarized in the Table, and the corresponding photocurrent-voltage (*J-V*) curve is also shown for the sample in Fig 2. The open circuit voltage and the short circuit current play a vital role in determining the overall conversion efficiency of the cell. The cell constructed with the combination of both the dyes exhibited a conversion efficiency of 0.056% and there is a very less efficiency exhibited due to the poor interaction between the dye and the semiconductor layer.

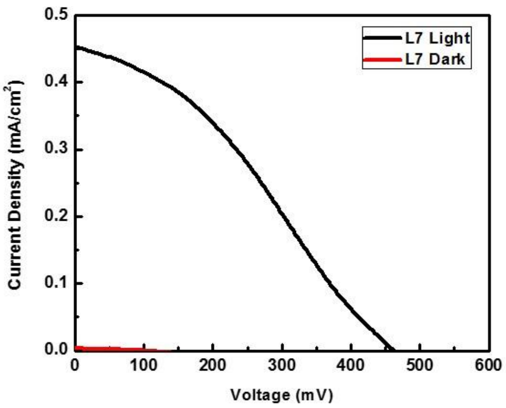

Fig 2 Photocurrent-voltage (*J-V*) curve of the Cell tested with the two dyes in combination

Table Photoresponse of the assembled DSSC

Dye Tested	J_{SC} (mA/cm^2)	V_{OC} (mV)	*FF*	η (%)	*Ref*
Nerium oleander (Reddish Pink)	0.421	0.525	0.274	0.061	[13]
Hibiscus (Red)	0.765	0.515	0.479	0.19	[13]
Mixed Dye (Reddish pink + Red)	0.451	0.462	0.269	0.056	Present Work

Conclusion

The natural dye prepared in combination(nerium oleander and hibiscus) exhibited a short circuit current density of 0.451 mA/cm^2, an open circuit voltage of 0.462 mV, a fill factor of 0.269 and a conversion efficiency of 0.056% . Though the Solar energy to electrical energy conversion is considerably less, the result obtained is academically interesting. To improve the efficiency, the ethanolic extracts obtained may be subjected to further purification techniques and then can be effectively used as a photosensitizer. Advanced fabrication procedures, by using platinum electrode, and other electrolytes may also contribute to better results. The present work can be extended by studying the influence of pH and the co-absorbers on the photosensitizers.

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