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# Utilization of a Natural Pigment Extracted from Nilkatarolu Flowers as a Sensitizer in Photoelectrochemical Solar Cells

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## ABSTRACT

In this study natural pigment extracted from flowers of *Clitoria ternatea* (Nilkatarolu) was used as a sensitizer in photoelectrochemical solar cells. The pigment in the *Clitoria ternatea* flower is delphinidin which is blue in colour. The cells fabricated in the configuration of $TiO_2$/Delphinidin/electrolyte produced an open circuit photovoltage of 0.5 V and shorcircuit photocurrent of 160 $\mu$A with an energy conversion efficiency of 0.06 %. The energy difference between HOMO and LUMO levels of delphinidin was calculated from the onset of the absorption spectrum of the dye. The redox potential of the pigment was calculated from cyclic voltogram. It is evident that the electron injection from the excited state of the dye to the conduction band of $TiO_2$ is feasible with these findings.

## 1. INTRODUCTION

Solar energy is the most abundant energy source which is cheaply available and environmental friendly. There are many methods use to generate energy from sun. Solar cells are in fact large area semiconductor diodes which convert solar energy in to electric energy. A dye-sensitized solar cell (DSSC) is a relatively new class of low-cost solar cell. This cell was developed by Gratzal and co-workers as a practicable device which is an interesting field of research at present [1]. A DSSC consists of a transparent mesoporous film of nanocrystalline $TiO_2$ electrode coated with a dye, a platinum sputtered counter electrode and an electrolyte containing a suitable redox couple [2]. Dye sensitized solar cells differ from the conventional silicon based solar cells because light energy is absorbed by the dye and converted to electricity via injection of charge carriers to the bands of semiconductor which follows photosynthesis in natural plants [3]. Several natural pigments from leaves, flowers, fruits etc. have been used as the sensitizers of DSSCs. Here, dark blue pigment extracted from flowers of *Clitoria ternatea* (Nilkatarolu) has been reported as the sensitizer.

## 2. METHODOLOGY

Electrodes were prepared on a conducting tin oxide (CTO) glass plate by spreading a paste made of nanocrystalline $TiO_2$ powder. Then these films were sintered in a furnace at 450 $^o$C for 30 minutes. Photo electrodes coated with $TiO_2$ films were immersed in the pigment extract of the flowers for 24 hours. Pt sputtered CTO glass plate was use as the counter electrode. It was attached on the top of the dye coated film to assemble the cell. The pores of the dye coated film was filled with an electrolyte containing 0.5 mol dm$^{-3}$ of KI and 0.05 mol dm$^{-3}$ of $I_2$ which was dissolved in ethylene carbonate and acetonitrile at 4:1 ratio. Cells were characterized by illuminating with tungsten filament light (100 mW cm$^{-2}$) and a galvanostat potentiostat coupled to a computer .Absorption spectra was observed by using the Shimadsu UV-3000 spectrometer. Cyclic voltometry of the pigment coated $TiO_2$ films were studied in 0.5 M KCl solution under three electrode systems. The reference electrode was Ag/AgCl electrode and Pt was used as the counter electrode.

## 3. RESULTS AND DISCUSSION

The pigment of Nilkatarolu flower which is blue in colour mainly contains delphinidin dye. The structure of delphinidin is depicted in figure1. Delphinidin easily get attached to the $TiO_2$ films by the hydroxyl groups present on the molecule. The mechanism of attachment of the dye to $TiO_2$ is also shown in the figure.

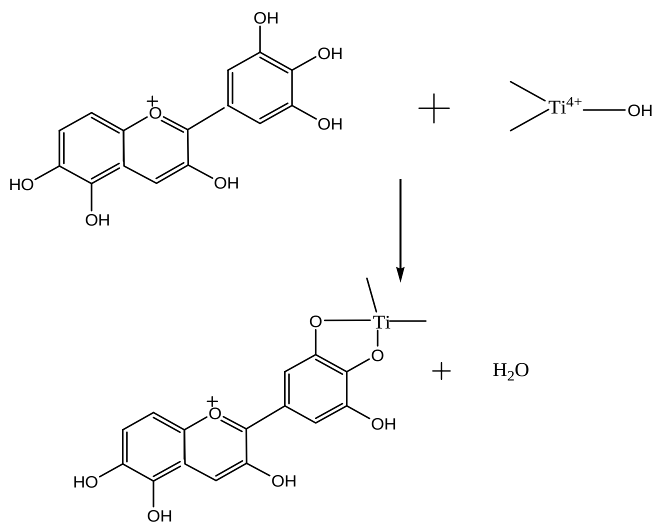


Figure 1. Mechanism of chelation of delphinidin with $TiO_2$

The absorption spectrum of delphidin extracted to an aqueous solution is illustrated in figure 2. The pigment exhibits an absorption band in visible region with a peak at 630 nm.

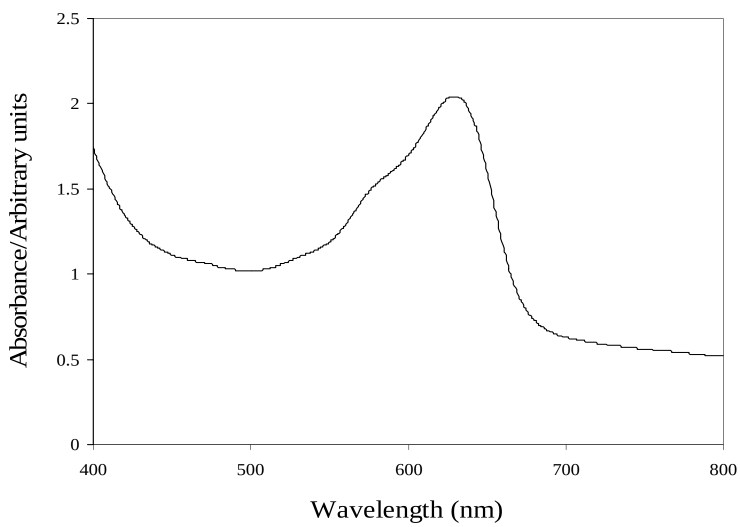


Figure 2. Absorption spectrum of the pigment

The colour of this pigment is more sensitive to the pH of the solition where it turns to red in acidic media and turns to green in basic media. The cyclic voltogram of the delphinidin coated $TiO_2$ electrode is shown in figure 3. When the electrode potential swept towards negative direction, the blue colour of the pigment changed to green and it turned to purple colour in positive electrode potentials. Reduction and oxidation of the pigment attached to the $TiO_2$ electrode may be the reason for this colour changes. The oxidation and reduction potential of the pigment can be found from the cyclic voltogram which is about -0.75 V vs the Ag/AgCl reference electrode.
The energy difference between the lowest unoccupied molecular orbital (LUMO) and highest occupied molecular orbital (HOMO) was calculated using the onset of the absorption edge of the dye in the absorption spectrum which is 1.9 eV. The oxidation reduction potential of the dye which coresponds to the energy of the LUMO level of the dye is 0.52 eV in vaccuum scale.
Since the energy of the excited state of the dye is above the conduction band of $TiO_2$, excited dye molecules could inject electrons possibly to the bands of $TiO_2$. Therefore conversion of light energy to electrical energy with this electrochemical system is feasible. The corresponding energy levels of the pigment, semiconductor and the $I^-/I_3^-$ redox couple is shown in figure 4.

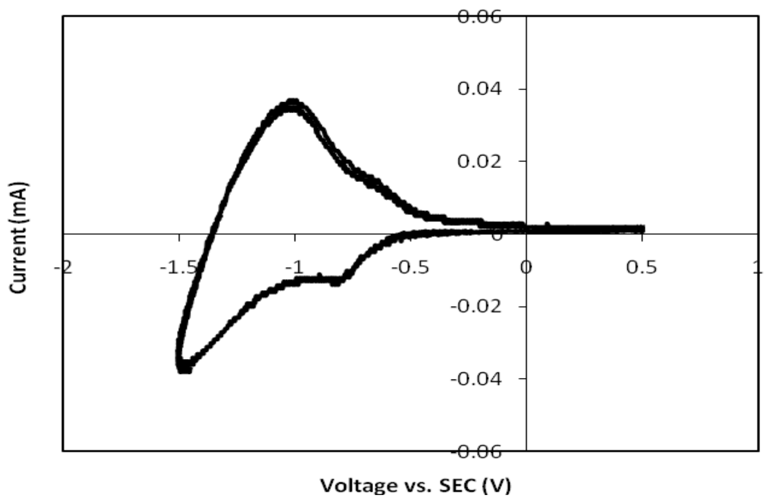


Figure 3. Cyclic voltogram of the delphinidin coated $TiO_2$ electrode

The I-V characteristics of the $TiO_2$/ delphinidin/ $I^-/I_3^-$ photoelectrochemical solar cell is shown in figure 5. The opencircuit photovoltage of the cell was 0.5 V and shortcircuit photocurrent was 160μA when illuminated with 100 mW $cm^{-2}$ tungsten filament lamp. The efficiency of the solar cell is arround 0.06 % and fill factor is 76.25 %.

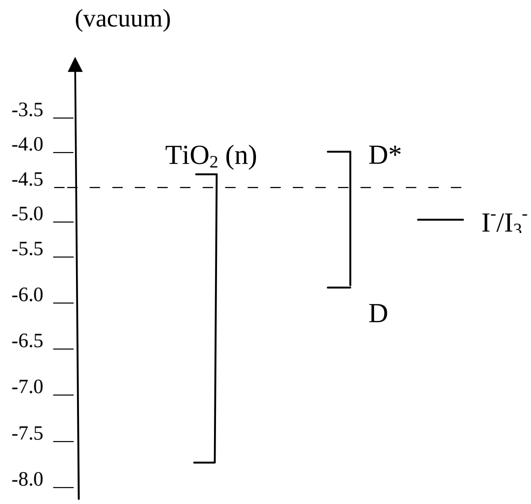


Figure 4. Energy level diagram of band position of $TiO_2$ and delphinidin.

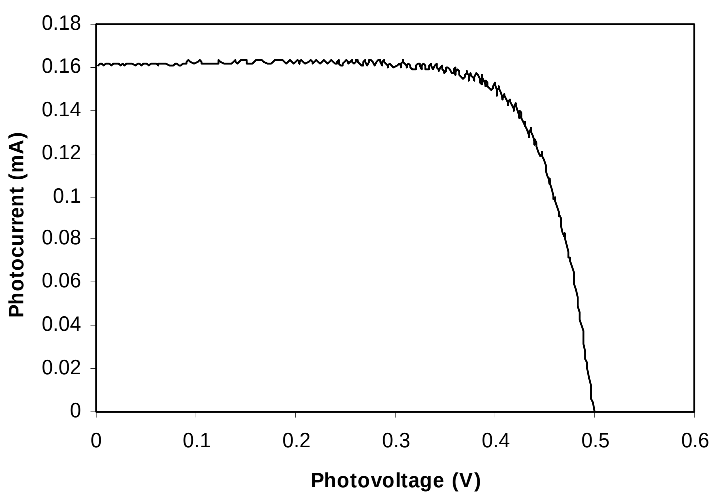


Figure 5. I-V characteristic of a solar cell sensitized with delphinidin.

This is an interesting electrochemical system to study that mimics the natural photosynthesis. Further work has to be done to develop this system practically viable.

## 4. CONCLUSION

Natural pigment extracted from Katarolu flower is used as a sensitizer in dye sensitized photoelectrochemical solar cell. The active pigment is delphinidin in the dye extract. It was evident that the pigment is capable of injecting electrons to the conduction band of $TiO_2$ generating a photocurrent. Although the conversion efficiency is insufficient for a practical device, the results are academically interesting. Therefore research work is under way to develop this solar cell practically viable.

**REFERENCES**

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