

Extract From Leaf of *Epipremnum Aureum* on the Concert of Dye Sensitized Solar Cell

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Research Article

Keywords: Dye Sensitized Solar Cell, Eosin, Natural dyes, solvent ethanol, photoconversion efficiency

Posted Date: June 1st, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1278284/v1>

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Abstract

Sensitizers for Dye-Sensitized Solar Cell (DSSC) significantly impact the electron-hole pair for conduction to produce photocurrent. In this study, sensitizers from the leaf extract of *Epipremnum aureum* have been subjected to sensitize the solar cell with ethanol as solvent, and the photoconversion efficiency has been evaluated. Two dyes have been used, viz. The first dye is the natural dye alone, and the second is the cocktail of natural dye (dye from *Epipremnum aureum*) and synthetic eosin dye. The fabricated solar cells are subjected to UV-Vis, FTIR, XRD, SEM, and J-V characteristics to study the solar cell's performance and the effectiveness of the dye. The photoconversion efficiency of the solar cell with the cocktail of natural and synthetic dye is higher than the cell with natural and synthetic dye alone. It has been found that the cell with a cocktail of dyes has given an efficiency of 0.78%, which is higher than the solar with eosin or natural dye alone.

Full Text

Introduction

Electrical energy is indispensable for the people to do each and every domestic activities and industrial jobs. Though the demand for electrical energy is fulfilled in the present scenario by the utilization of coal, oil and natural gas, the sources will be exhausted soon and already consumed energy polluted the environment to a large extent. Due to the existing inconveniences, throughout the globe efforts are taken to switch over to an alternative energy resource which should be non-polluted and everlasting and deliver energy without any interruption. It is also found that solar energy is one of the alternate energy sources which is everlasting, cost-effectiveness and non-polluted. It is possible to utilize the thermal part of the solar energy by harnessing it using a absorbing surface and convert into thermal energy. The thermal energy is then converted in to electrical energy by various technology. In the same way, the solar energy may be directly into electrical energy by the photovoltaic method. In the photovoltaic method, solar cells play a vital role in producing electricity by absorbing the photons and transferring the photons energy to trigger the electrons to reach the counter electrode of the solar cell to constitute photoelectric current.

Among the various types of solar cell, Dye sensitized solar cell has significant impact due to the cost-effectiveness, sensitization capability of the dyes to trigger the electrons in the Transparent semiconductor oxide to move to the counter electrode via electrolyte. Researchers from various parts of the globe have undergone effective research to increase the efficiency of the Dye Sensitized Solar Cell (DSSC). Kyung Hee Park et al. (2013) have used the yellow and blue dyes from Gardenia Jasminoide Ellis and mixture of both in DSSC. It has been found that the mixture of dyes has shown enhanced efficiency rather than the single dye. Su Htike Aung et al. (2016) have presented the performance of carminic acid incorporated DSSC for the injection of electrons in the conduction band of TiO_2 for good performance. Rajitha Ramanarayanan *et al.* (2017) have used chlorophyll and Betalin rich dyes in DSSC and experimented for their performance. It has been found that DSSC with chlorophyll has shown higher efficiency. Geetham Richariya *et al.* (2017) have undergone a review regarding the natural dyes extracted

from plants, fruits and vegetables. Results of the various studies with the natural dyes have presented precisely. Mahmoud A.M. Al-Alwani *et al.* (2018) have undergone extraction of anthocyanin and chlorophyll from the leaves of *alternanthera dentata* and *musa acuminata* and used as sensitizer in DSSC. DSSC with anthocyanin has given photon-conversion to current efficiency of 42% higher than the chlorophyll pigment. Oluwaseun Adedokun *et al.* (2018) have used various solvents and natural dyes in DSSC and tested for the opt solvent. Results of the study revealed that ethanol, distilled water and dichloromethane are the good solvents. Wan Almaz Dhafina *et al.* (2018) have fabricated DSSC with ZnO nanoparticles and dyes extracted from *Ardisia Elliptica* and tested. Results have shown that good results obtained for dye loading time for 20 minutes. Rahul *et al.* (2018) have used dyes extracted from fruits and plants in DSSC and experimented to find the performance. It has been found that the performance is better than the synthetic dyes of N_3 , black and Ruthenium. Bashar *et al.* (2019) have fabricated DSSC with natural dyes extracted from beetroot (red dye) and Spinach (Green dye) with a different combination ratio and tested. The cell efficiency is higher for combination of red (80%) and green (20%) dyes compared to the dyes used alone. Charu Pathak *et al.* (2019) have used mixture of natural dyes extracted from leaves, vegetables and fruits in DSSC and tested for the performance. It has been found that the cell performance will be explored for better result. Suganya and Jaisankar (2019) have tested a DSSC with sensitizers of natural dyes and nanocomposite polymer electrolyte. Results have been compared and presented more precisely. Rajkumar *et al.* (2018) have extracted from the dyes from *Murraya Koenigii* fruit and *sabderifa* flower and used separately and cocktailed. Cocktail of dyes have shown better performance than the individual. Kabir *et al.* (2019) fabricated DSSC with dyes extracted from Malabar and red spinach and experimented. 80% and 20% of red and green dyes in DSSC has shown better efficiency than the individual. Aneesiya K. Rajan *et al.* (2019) have fabricated DSSC with dyes extracted from *Indigofera Tinctoria* and studied for the performance. It is found that, the cell has given maximum power conversion efficiency and efficiency of 0.114% and 0.022%. Ishwar Chandra Maurya *et al.* (2019) have extracted dyes from *Cassia Fistula* with ethanol as a solvent. The fabricated DSSC has given an efficiency of 0.21% with $V_{oc} = 0.549$ V and $J_{sc} = 0.51$ mA/cm².

Further Sutikno Madnasri *et al.* (2019) have extracted dyes from *Musa Acuminata* bracts with various mass fraction and used in DSSC. It has been found that the DSSC has given conversion efficiency of 4%. Sanjay *et al.* (2019) have used the dyes from the leaves of *Peltophorum Pterocarpum* using the solvents ethanol and water. It has been found that natural dyes are biodegradable and non-toxic. Sanjay *et al.* (2019a) have used ZnO photoanode for the DSSC incorporated with the dyes extracted from *Phytolacca Icosandra* and *Phyllanthus reticulatus*. Inferences of the study have been presented precisely. Sanjay *et al.* (2019b) have extracted dyes from *Phyllanthus Reticulus* and used in DSSC as sensitizer. Results of various studies have presented precisely. Tahmineh Jalali *et al.* (2020) have adopted solvent based extraction of dyes from saffron, red onion, mallow and oregano and used as sensitizer in DSSC. It has been found that carbonyl and hydroxyl groups present in dyes enhances the energy conversion efficiency. Carvalho *et al.* (2020) have fabricated DSSC with natural pigments of bixin and norbixin incorporated with an additive of 2,2' – bipyridine and tested. It is found that the additive has significant impact on the enhancement of voltage and current. Azimah Omar *et al.* (2020) have made a review of TiO₂ based DSSC

with natural dyes as sensitizers. The charge transfer mechanism, cell performance, architecture and novel materials for DSSC has been presented more precisely. Megala *et al.* (2020) have made an attempt to use dyes extracted from yellow rose and Moringa flower which are rich in flavonoids. Results of the DFT study revealed that, the dyes should be modified to give better results in DSSC. Mahmoud A.M. Al-Alwani *et al.* (2020) have undergone the study of utilizing different solvents and pH values and analyzed using D-optimal tool. It has been found that, the optimum parameters for dye extraction is 80°C with pH of 10 and solvent ethanol. Varsha Yadav *et al.* (2021) have utilized derivatives of Ruthenium Bipyridl and hardra fruit based dyes as sensitizer in DSSC and studied their performance. It is confirmed that DSSC with hardra fruit has given efficiency of 3.52% higher than the DSSC with commercial dye.

Maneesh Reddy Verumbaka *et al.* (2021) have studied the performance of DSSC with natural dyes and photoanode of TiO₂, Copper doped TiO₂ and nitrogen doped TiO₂. Results have shown the good performance with copper doped TiO₂ photoanode and natural dyes. Malihe Golshan *et al.* (2021) have extracted dyes from malva verticillate, syzygium cumini and acidified syzygium and their cocktails as sensitizers in DSSC and studied the performance. It has been found that DSSC with cocktail sensitizers has produced as fabricated efficiency of 52.51%. Shalini Singh *et al.* (2021) have used the dyes extracted from the petals of yellow and orange Nasturtium flower as sensitizers in DSSC. It has been confirmed that DSSC with dyes of orange petals has given 0.28% light to electricity conversion efficiency. Sakshi *et al.* (2021) have used natural dyes extracted from lemon, parsley, spinach, hibiscus-rosasiensis, pomegranate and beetroot separately and mixed form in DSSC and studied the performance. The absorption of energy is higher for the mixture of dyes which reflects the wider range of wavelength in the spectrum. Rahul *et al.* (2021) have fabricated DSSC with the dyes extracted from fruits incorporated with polymer electrolyte and counter platinum electrode. Results proved the light harvesting property of dyes from fruits and plants. Alfred Blaszczyk *et al.* (2021) have tested DSSC with natural dyes from juice, pomace and leaves of black chokeberries and synthetic N719 dye. It has been found that DSSC with dyes from black chokeberries has highest environmental performance. Sadia Muniza Faraz *et al.* (2021) have compared the performance of DSSC based on metallic and natural dyes. Impedance spectroscopic study of both the solar cells are used for the optimization of various components involved in the process. Prabhavathy *et al.* (2021) have used dyes extracted from astaxanthin pigments with anthocyanin and pluviah's cosensitizers in DSSC and experimented. It is observed that the efficiency is higher for the cell with TiO₂ nanorods as photoelectrode. Mona A. Almutairi *et al.* (2021) have used the extracts obtained from beetroot and found the photoconversion efficiency and other parameters with impedance characteristics. It is found that both V_{oc} and J_{sc} have shown linear variation at higher intensities of solar radiation.

In the present work, an effort has been taken to extract the dyes from *Epipremnum aureum* and used in DSSC to find the effectiveness of the dyes on the performance of solar cell. Characteristics study for the determination of fill factor, photon conversion efficiency has been carried out and various constituents in the dye has been found. Cocktail of Eosin-Y and natural dye has been used in the proposed cell and experimented.

Extraction of Dye – Experiment

Leaves of *Epipremnum aureum* have been plucked from the plant and care has been taken such that matured fresh leaves are plucked. 250 g of the fresh leaves are washed with ordinary water to remove the dust deposits on the leaves. Followed by the wash, deionized water is used to rinse the leaves for the removal of fine dust particles and dried in a shadow region. Fig. 1 shows the photograph of the *Epipremnum aureum* leaves. Mortar and pestle have been used to ground and make the dried leaves into a paste. The paste has been immersed in the solvent ethanol and kept for 24 hrs and filtered to get the pure leaf extract of *Epipremnum aureum*.

Preparation of photoanode

Fluorine doped Tin oxide (FTO) substrate has been bought with sheet resistivity less than 10 ohm/sq. and 0.2 g of TiO₂ nanoparticles in 1.5 ml nitric acid and 1 ml acetic acid has been made into a paste. The prepared TiO₂ paste is coated on the FTO substrate by Doctor Blade technique and subjected to annealing at 450°C in Muffle Furnace. XRD spectra for TiO₂ nanoparticles have been recorded for the structure confirmation and SEM photograph for the morphology of the nanoparticles has been carried out. Fig. 2 and Fig. 3 represents the XRD Spectra and SEM photograph of the prepared TiO₂ nanoparticles.

From XRD spectra, it is observed that the main peak matches with the JCPDS data of reference code 01-072-7058 and also it has the structure of anatase phase. From Debye Scherer formula, the grain size of the nanoparticles is found to be approximately 24 nm.

Electrolyte and counter anode

Lithium iodide of 0.65 g is mixed with 10ml acetonitrile and 0.11 g of iodine with a magnetic stirrer for 20 minutes. The mixture is taken as an electrolyte solution for the solar cell. The counter electrode is made by coating graphene from pencil on the FTO substrate which is thoroughly cleaned.

UV-Visible Spectroscopic study of the *Epipremnum aureum*, Eosin Y and cocktail of *Epipremnum aureum* and Eosin Y

The dyes are subjected for the UV- Visible spectroscopic study using the Shimadzu UV-Visible spectrometer of UV-1700 series and graphs have been plotted. From Fig. 4, Fig. 5, Fig. 6 shows the UV-Visible spectroscopic spectra of Eosin-Y, *Epipremnum aureum* and cocktail of *Epipremnum aureum* and Eosin-Y dye. For Eosin-Y dye, it is seen that the absorption peak at 300 nm and 520 nm are the prominent peaks and the dye has significant absorption of photons at the wavelength. Similarly, when the natural dye *Epipremnum aureum* and Eosin-Y dyes are cocktailed, from Fig. 6, prominent peaks are at 420 nm and 520 nm and it is clear that, the cocktail of natural dye from *Epipremnum aureum* and synthetic dye of Eosin-Y has maximum absorption in the visible region. From the spectra, the corresponding bandgap has been found and it is tabulated in Table 1. From the table, it is seen that, the bandgap energy for the

cocktail of natural and synthetic dye is 2.33 and 2.39 eV for the peaks at 420 nm and 520 nm. Therefore, the cocktail dyes have significant impact on the absorption of solar radiation in the visible region of the spectrum.

FTIR Spectroscopic Study

Fig. 7, Fig. 8 and Fig. 9 represents the FTIR spectra of Eosin-Y, *Epipremnum aureum* and cocktail of *Epipremnum aureum* and Eosin-Y dye. The peaks in the spectra have stretching and bending vibrations of O-H stretching, O-H bending and CO stretching in the respective wavenumber. It is seen that, for the Eosin-Y dye, only O-H stretching and bending vibrations are observed and anchoring of the dye with TiO_2 is not pronounced. In the case of *Epipremnum aureum*, O-H stretching and bending and CO stretching is present which is reflecting the best anchoring with TiO_2 coated on FTO substrate. In the case of cocktail of *Epipremnum aureum* and Eosin-Y dye, it is observed that O-H stretching and O-H bending has same contribution for the anchoring effect with TiO_2 . Moreover, CO stretching is more pronounced in the cocktail of *Epipremnum aureum* and Eosin-Y which is sole responsible for the strong anchoring of dye with TiO_2 . From the spectra, it is clear that, the functional groups present in the cocktail of natural and synthetic dye is anchored with TiO_2 and served as the potential sensitizer for the solar cell fabricated as shown in Table 2.

Dye Sensitized Solar Cell Fabrication

Epipremnum aureum, Eosin Y and cocktail of *Epipremnum aureum* and Eosin Y dyes have been taken in different beakers. The annealed TiO_2 coated FTO substrate i.e., photoanode is immersed in the dye solution and cocktail solution for 24 hours in dark region and shown in the Fig. 10. After 24 hours, the dyes formed a monolayer on the TiO_2 coated on the FTO substrate. Immersion hours of 24 is optimum, such that the monolayer of the dye will be acting as a potential sensitizer. If the substrate is allowed to immersed on the dyes for more than 24 hours, there will be a greater number of layers of coating of dyes on the substrate. This in turn, affects the sensitizing property and dyes will be trapping the photons energy and will not be transferring its energy to produce the excitons in Transparent Semiconducting oxide.

Followed, the substrate coated with Eosin-Y, *Epipremnum aureum* and cocktail of *Epipremnum aureum* and Eosin-Y are sandwiched with counter anode which graphene coated FTO substrate. Electrolyte prepared from Lithium Iodide, acetonitrile and Iodine has been injected between the two electrodes which are sandwiched. The photograph of the solar cell fabricated using Eosin-Y, *Epipremnum aureum* and cocktail of *Epipremnum aureum* is shown in the Fig. 11. The solar cells are subjected to J-V characteristic study to determine the performance and various parameters which represents the solar cell characteristics.

J-V Characteristics of Fabricated Solar cells

The solar cells fabricated with the dyes have been subjected to J-V characteristics study using Keithley 2400 Graphical Series SMU in which Xenon Lamp with illumination power of 100 mW/cm² is the source of light for the simulator. Current density (J) produced by the cells with varying voltage have been measured to plot J-V graph. Fig. 12, Fig. 13, Fig. 14 represents the J-V graph for the solar cell fabricated with Eosin-Y, *Epipremnum aureum* and cocktail of *Epipremnum aureum* and Eosin-Y dye.

From the graphs, maximum output of voltage (V_m) and current density (J_m), open-circuit voltage (V_{oc}) and short-circuit current (J_{sc}) are found and the significant parameter fill-factor and the efficiency of the three cells have been evaluated using the expression

$$FF = (J_m \cdot V_m) / (J_{sc} \cdot V_{oc}) \quad (1)$$

$$\eta \% = \frac{FF \cdot J_{sc} \cdot V_{oc}}{\text{Input power}} \cdot 100 \quad (2)$$

Various parameters of the DSSCs' fabricated have been tabulated in Table 3 along with the fill factor and efficiency.

From the results, it is observed that DSSC fabricated with the cocktail of *Epipremnum aureum* and Eosin-Y has given a maximum efficiency of 0.78462%. Followed DSSC with the natural dye extracted from *Epipremnum aureum* gave an efficiency of 0.4128%. This is because the constituents of steroids, terpinoids, alkaloids, saponins, tannins and flavonoids in *Epipremnum aureum* have good anchoring effect with TiO₂. The flavonoids and tannins in the dye has good photon to energy conversion efficacy and more number of excitons are produced. It is also seen that the natural dye from *Epipremnum aureum* and synthetic dye Eosin-y have done the process of photon to energy conversion effectively with good absorbing surface without losing its power of constituents. The open circuit voltage for DSSC with cocktail dye and *Epipremnum aureum* are 0.6919 V and 0.652 V which reflects the efficacy of the constitutes in the natural dye and the anchoring of the dye with TiO₂.

The energy absorbed by the dye is responsible for the movement of the excitons from through the electrolyte and reaching the counter electrode. Thus, the photocurrent flows between the electrodes without interruption. From the counter electrode, the electrons enter into the electrolyte, so that the process is repeated for the continuous flow of charges to produce photocurrent. Moreover, the anchoring of cocktail of natural and synthetic dyes are due to the stretching and bending of various functional groups present in the dye. The cocktail of dyes has high absorption in the visible region and also in UV region of electromagnetic spectrum. Therefore, radiation in visible as well as in the UV region will be best absorbed by the constituent of the dyes to transfer the energy for the production of excitons.

The fill factor for the cells fabricated with *Epipremnum aureum* and cocktail of *Epipremnum aureum* and Eosin-Y dye is greater than 0.5 which is acceptable for the good performance of the cell.

Conclusions

The following conclusions have been drawn from the study and are

- (i) Cocktail of natural (*Epipremnum aureum*) and Synthetic (Eosin-Y) dyes have given an efficiency of 0.78%.
- (ii) It is also observed that, natural dye from the leaf (*Epipremnum aureum*) 0.4128% which is almost same that of the similar results obtained by various researchers for natural dye based DSSC.
- (iii) Steroids, terpinoids, alkaloids, saponins, tannins and flavonoids in *Epipremnum aureum* have significant impact on the anchoring with TiO₂ nanoparticles due to the stretching and bending of functional groups present in dye.
- (iv) It is also recommended that the dyes prepared from cocktail of *Epipremnum aureum* and Eosin-Y has the efficacy of increasing the photon absorption and conversion of energy to trigger the exciton production to a large extent.
- (v) The pigments in the leaf have the substantial influence to act as a potential sensitizer for DSSC performance.

Declarations

Acknowledgements

I would say thanks a lot to Department of Science and Technology (DST, Delhi), Government of India for the award of DST-FIRST Level-1(SR/FST/PS-1/2018/35) scheme to the Department of Physics. Appreciations are grateful to the KLEF offering infrastructure, facilities, basic found (Perform basic instruments) and support to the current investigation.

Conflict of Interest

There is no conflict of interest among the authors.

Author Contributions

Dr. A. Kavitha

Synthesis and characterization of leaf extract of *Epipremnum aureum*

Dr. S. Karthick

Data validation, Editing of the manuscript

Dr. S. Pavithra

Analysis of results

Dr. N. S.M. P. Latha Devi

Data validation, Editing of the manuscript

Dr S. Shanmugan

Analysis of results, writing the manuscript, reviewing and editing the paper

Availability of Data and Material

The synthesized leaf extract of *Epipremnum aureum* and data of results of characterization are available.

Compliance with ethical standard

The research work is ethically complied.

Consent to participate

All the authors give their consent to having participated in the current work.

Consent for publication

All the authors give their consent for publication of this work.

References

1. Yadav, V., Negi, C.M.S., KishoreKumar, D.: Saral Kumar Gupta (2021). Fabrication of eco-friendly, low-cost dye sensitized solar cells using hard a fruit-based natural dye, Optical Materials Available online 22 November 2021, 111800
2. Venumbaka, M.R., Akkala, N., Duraisamy, S., Sigamani, S., Poola, P.K., Subba Rao, D.: Bhanu Chandra Marepally (2021). Performance of TiO₂, Cu-TiO₂, and N-TiO₂ nanoparticles sensitization with natural dyes for dye sensitized solar cells, Materials Today: Proceedings, <https://doi.org/10.1016/j.matpr.2021.09.281>
3. Malihe Golshan, S., Osfour, R., Azin, T., Jalali, Navid, R., Moheimani: Co-sensitization of natural and low-cost dyes for efficient panchromatic light-harvesting using dye-sensitized solar cells. J. Photochem. Photobiol., A. 417, 113345 (2021). <https://doi.org/10.1016/j.jphotochem.2021.113345>
4. Shalini Singh, I.C., Maurya, S., Sharma, S.P.S., Kushwaha, P., Srivastava, L.B.: Application of new natural dyes extracted from Nasturtium flowers (*Tropaeolum majus*) as photosensitizer in dye-sensitized solar cells. Optik. 243, 167331 (2021). <https://doi.org/10.1016/j.ijleo.2021.167331>
5. Sakshi, P.K., Singh, Vivek Kumar Shukla (2021). Widening spectral range of absorption using natural dyes: Applications in dye sensitized solar cell, Materials Today: Proceedings

<https://doi.org/10.1016/j.matpr.2020.12.287>

6. Rahul, S., Singh, P.K., Singh, S., Kakroo, D.M., Hachim, P.S., Dhapola, Zishan, H., Khan: (2021). Eco-friendly dye sensitized solar cell Sutikno Madnasri, Rieza Dwi Ayu Wulandar using natural dye with solid polymer electrolyte as hole transport material, *Materials Today: Proceedings*, 34(3): 760-766. <https://doi.org/10.1016/j.matpr.2020.04.775>
7. Alfred Błaszczuk, K., Joachimiak-Lechman, S., Sady, T., Tański, M., Szindler, Aleksandra Drygała: Environmental performance of dye-sensitized solar cells based on natural dyes. *Sol. Energy* 215, 346–355 (2021) <https://doi.org/10.1016/j.solener.2020.12.040>
8. Faraz, S.M., Mazhar, M., Shah, W., Noor, H., Awan, Z.H., Muhammad Hassan Sayyad: Comparative study of impedance spectroscopy and photovoltaic properties of metallic and natural dye based dye sensitized solar cells. *Physica B.* 602, 412567 (2021). <https://doi.org/10.1016/j.physb.2020.412567>
9. Tahmineh Jalali, P., Arkian, M., Golshan, M., Jalali, S. Osfour: Performance evaluation of natural native dyes as photosensitizer in dye-sensitized solar cells. *Opt. Mater.* 110, 110441 (2020). <https://doi.org/10.1016/j.optmat.2020.110441>
10. Carvalho, I.C., Barbosa, M.L., Costa, M.J.S., Longo, E., Cavalcante, L.S., Viana, V.G.F., Santos, R.S.: TiO₂-based dye-sensitized solar cells prepared with bixin and norbixin natural dyes: Effect of 2,2'-bipyridine additive on the current and voltage. *Optik.* 218, 165236 (2020). <https://doi.org/10.1016/j.ijleo.2020.165236>
11. Prabavathy, N., Balasundaraprabhu, R., Arne Kristoffersen, S., Balaji, G., Prasanna, S., Sivakumaran, K., Kannan, M.D., Svein, R.Erga, Dhayalan Velauthapillai: Enhanced photostability of anthocyanin dye for increased efficiency in natural dye sensitized solar cells. *Optik.* 227, 166053 (2021). <https://doi.org/10.1016/j.ijleo.2020.166053>
12. Azimah Omar, M.S., Ali, Nasrudin Abd Rahim: Electron transport properties analysis of titanium dioxide dye-sensitized solar cells (TiO₂-DSSCs) based natural dyes using electrochemical impedance spectroscopy concept: A review. *Sol. Energy.* 207, 1088–1121 (2020). <https://doi.org/10.1016/j.solener.2020.07.028>
13. Bashar, H., Bhuiyan, M.M.H., Hossain, M.R., Kabir, F., Rahaman, M.S., Manir, M.S., Ikegami, T.: Study on combination of natural red and green dyes to improve the power conversion efficiency of dye sensitized solar cells. *Optik* 185, 620–625 (2019)
14. Charu Pathak, K., Surana, V.K., Shukla, Pramod, K.Singh: (2019). Fabrication and characterization of dye sensitized solar cell using natural dyes, *Materials Today: Proceedings* 12: 665-670. <https://doi.org/10.1016/j.matpr.2019.03.111>
15. Megala, M., Jeyanthinath Mayandi, Beulah Rajkumar, J.M.: Optical absorption study of anthoxanthin based natural dyes for dye sensitized solar cells: Experimental and theoretical investigations. *Mater. Lett.* 276, 128089 (2020). <https://doi.org/10.1016/j.matlet.2020.128089>
16. Suganya, N., Jaisankar, V.: (2019). A Study on the effect of dye and polymer nanocomposite electrolyte on the performance of natural dye sensitized solar cells, *Materials Today: Proceedings* 14: 471-481. <https://doi.org/10.1016/j.matpr.2019.04.170>

17. Kabir, F., Bhuiyan, M.M.H., Manir, M.S., Rahaman, M.S., Khan, M.A., Ikegami, T.: Development of dye-sensitized solar cell based on combination of natural dyes extracted from Malabar spinach and red spinach. *Results in Physics*. 14, 102474 (2019). <https://doi.org/10.1016/j.rinp.2019.102474>
18. Mahmoud, A.M., Al-Alwani, H.A., Hasan, N.K.N., Al-Shorgani, Abu Baker, S.A., Al-Mashaan: Natural dye extracted from Areca catechu fruits as a new sensitiser for dye-sensitised solar cell fabrication: Optimisation using D-Optimal design. *Mater. Chem. Phys.* 240, 122204 (2020) <https://doi.org/10.1016/j.matchemphys.2019.122204>
19. Rajkumar, S., Nirmal Kumar, M., Suguna, K., Muthulakshmi, S., AshokKumar, R.: Enhanced performance of dye-sensitized solar cells using natural cocktail dye as sensitizer. *Optik*. 178, 224–230 (2019). <https://doi.org/10.1016/j.ijleo.2018.10.004>
20. Rahul, P.K.Singh, Bhattacharya, B., Zishan, H.Khan: Environment approachable dye sensitized solar cell using abundant natural pigment based dyes with solid polymer electrolyte. *Optik*. 165, 186–194 (2018). <https://doi.org/10.1016/j.ijleo.2018.03.099>
21. Dhafina, W.A., Salleh, H., Daud, M.Z., Mohd Sabri Mohd Ghazali: Low cost dye-sensitized solar cells based on zinc oxide and natural anthocyanin dye from *Ardisia elliptica* fruits. *Optik*. 172, 28–34 (2018). <https://doi.org/10.1016/j.ijleo.2018.06.041>
22. Maurya, I.C., Singh, S., Srivastava, P., Maiti, B., Bahadur, L.: Natural dye extract from *Cassia fistula* and its application in dye-sensitized solar cell: Experimental and density functional theory studies. *Opt. Mater.* 90, 273–280 (2019). <https://doi.org/10.1016/j.optmat.2019.02.037>
23. Aneesiya Rajan, K., Cindrella, L.: Studies on new natural dye sensitizers from *Indigofera tinctoria* in dye-sensitized solar cells. *Opt. Mater.* 88, 39–47 (2019). <https://doi.org/10.1016/j.optmat.2018.11.016>
24. Sutikno Madnasri, Rieza Dwi Ayu Wulandari, Syaikhul Hadi, Ian YuliantiaSukiswo Supeni Edi, Dhidik Prastiyanto (2019). Natural Dye of *Musa acuminata* bracts as Light Absorbing Sensitizer for Dye-Sensitized Solar Cell, *Materials Today: Proceedings* 13, 246-251. <https://doi.org/10.1016/j.matpr.2019.03.222>
25. Oluwaseun Adedokun, Y.K., Sanusi, Ayodeji, O., Awodugba: Solvent dependent natural dye extraction and its sensitization effect for dye sensitized solar cells. *Optik*. 174, 497–507 (2018). <https://doi.org/10.1016/j.ijleo.2018.06.064>
26. Sanjay, P., Deepa, K., Victor Antony Raj, M., Madhavan, J., Senthil, S.: (2019). Dye-Sensitized Solar Cells Using Natural Dye as Light-Harvesting Material Extracted From the Leaves of *Peltophorum Pterocarpum*, *Materials Today: Proceedings* 8(1): 123-129. <https://doi.org/10.1016/j.matpr.2019.02.089>
27. Sanjay, P., Isaivani, I., Deepa, K., Madhavan, J., Senthil, S.: The preparation of dye sensitized solar cells using natural dyes extracted from *Phytolacca icosandra* and *Phyllanthus reticulatus* with ZnO as photoanode. *Mater. Lett.* 244, 142–146 (2019) <https://doi.org/10.1016/j.matpr.2019.02.089>
28. Sanjay, P., Deepa, K., Madhavan, J., Senthil, S.: (2019). Natural Dyes Extracted from Fruits of *Phyllanthus reticulatus* as Sensitizers in ZnO Nanorods Based Dye Sensitized Solar Cells, *Materials*

Today: Proceedings 8: 284-293. <https://doi.org/10.1016/j.matpr.2019.02.089>

29. Mahmoud A.M.Al-Alwani, N.A.Ludin, Mohamad, A.B., Amir, A. H.Kadhum, Abduljabbar Mukhlus: Application of dyes extracted from *Alternanthera dentata* leaves and *Musa acuminata* bracts as natural sensitizers for dye-sensitized solar cells. *Spectrochim. Acta Part A Mol. Biomol. Spectrosc.* 192, 487–498 (2018).
30. Geetam Richhariya, A., Kumar, P., Tekasakul, B.G.: Natural dyes for dye sensitized solar cell: A review. *Renew. Sustain. Energy Rev.* 69, 705–718 (2017). <https://doi.org/10.1016/j.rser.2016.11.198>
31. Rajita Ramanarayanan, Nijisha, P., Niveditha, C.V., Sindhu, S.: Natural dyes from red amaranth leaves as light-harvesting pigments for dye-sensitized solar cells. *Mater. Res. Bull.* 90, 156–161 (2017). <https://doi.org/10.1016/j.materresbull.2017.02.037>
32. Aung, S.H., Hao, Y., Oo, T.Z., Gerrit Boschloo: Kinetic study of carminic acid and santalin natural dyes in dye-sensitized solar cells. *J. Photochem. Photobiol., A.* 325, 1–8 (2016). <https://doi.org/10.1016/j.jphotochem.2016.03.022>
33. Mona, A., Almutairi, Farooq, W.A., AlSalhi, M.S.,: (2021). Photovoltaic and impedance properties of dye-sensitized solar cell based on nature dye from beetroot, *Curr. Appl. Phys.* <https://doi.org/10.1016/j.cap.2021.07.010>
34. Park, K.H., Kim, T.Y., Park, J.Y., MeiJin, E., Yim, S.-H., Fisher, J.G., Lee, J.W.: Photochemical properties of dye-sensitized solar cell using mixed natural dyes extracted from *Gardenia Jasminoide* Ellis. *J. Electroanal. Chem.* 689, 21–25 (2013). <https://doi.org/10.1016/j.jelechem.2012.11.026>

Tables

Tables 1 to 3 are available in Supplementary Files section

Figures

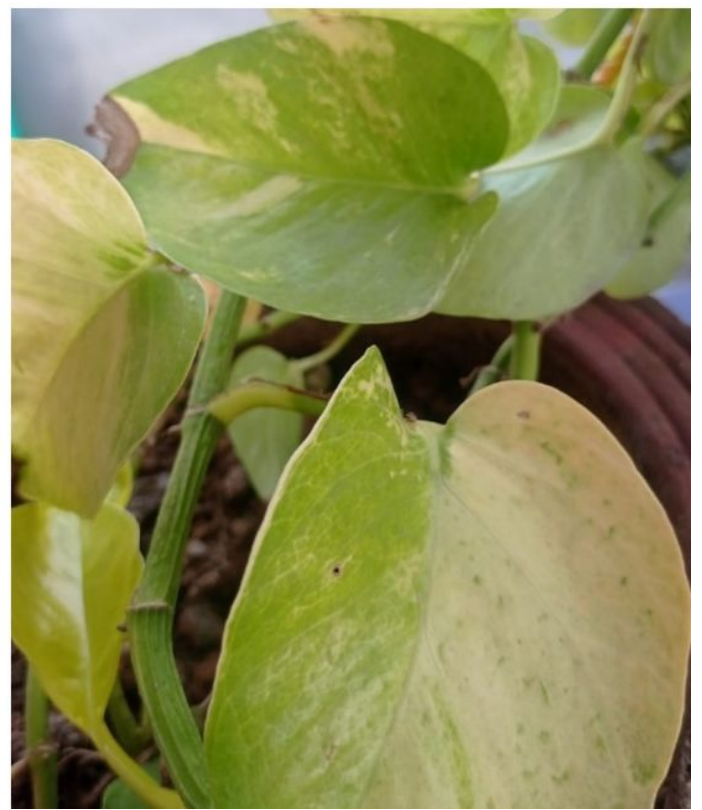


Figure 1

Photograph of the *Epipremnum aureum* leaves

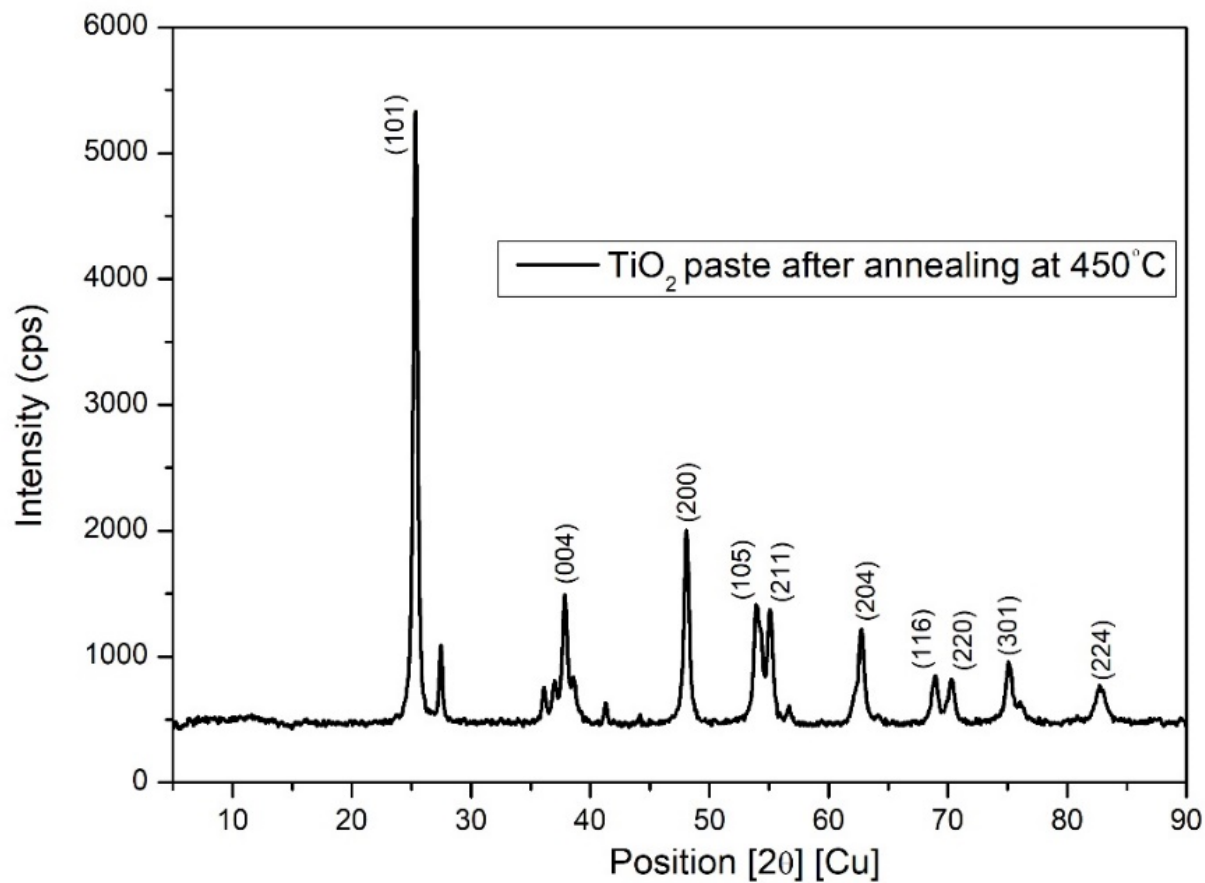


Figure 2

XRD Spectra of TiO₂ nanoparticles

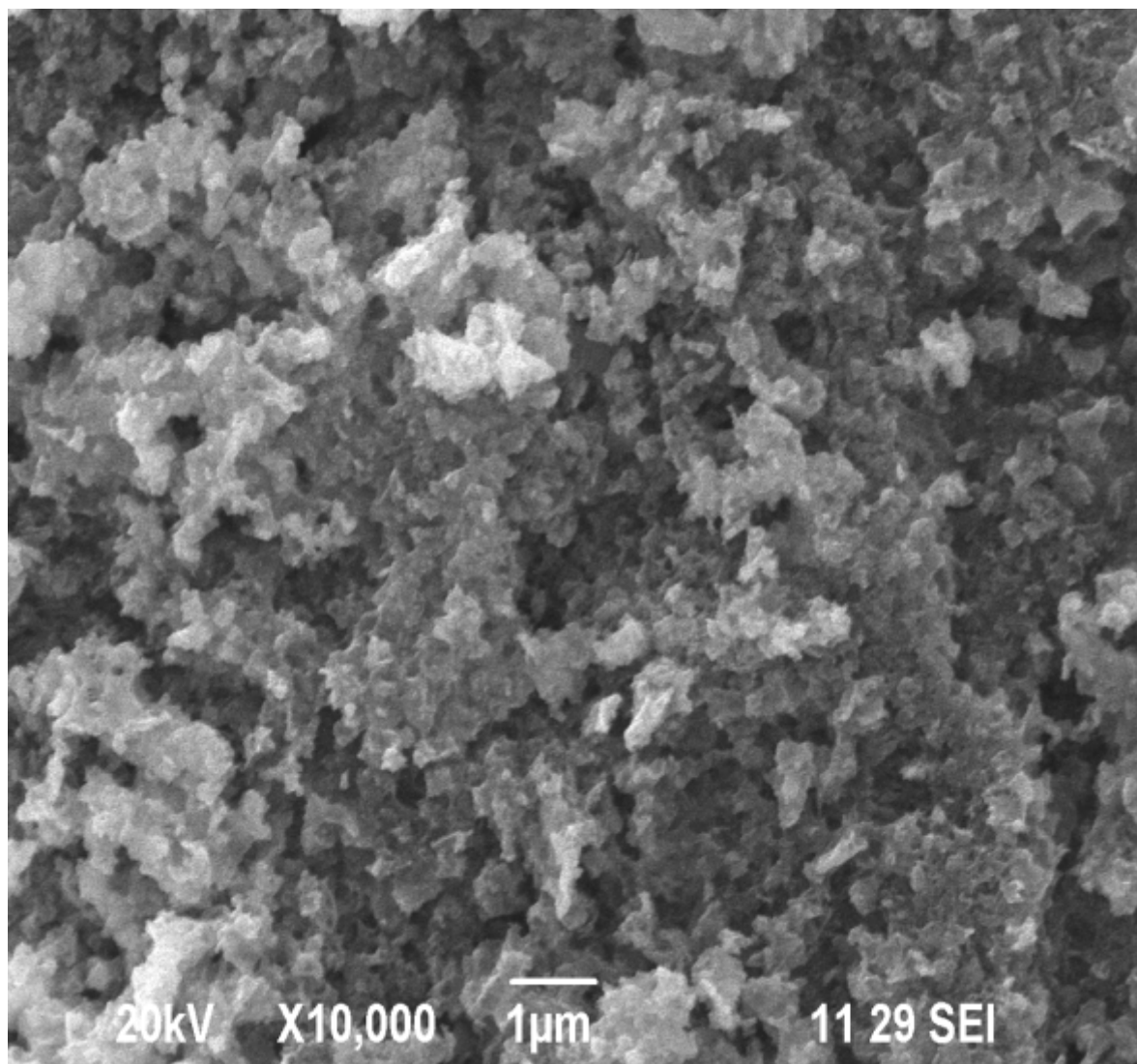


Figure 3

SEM photograph of the TiO₂ nanoparticle

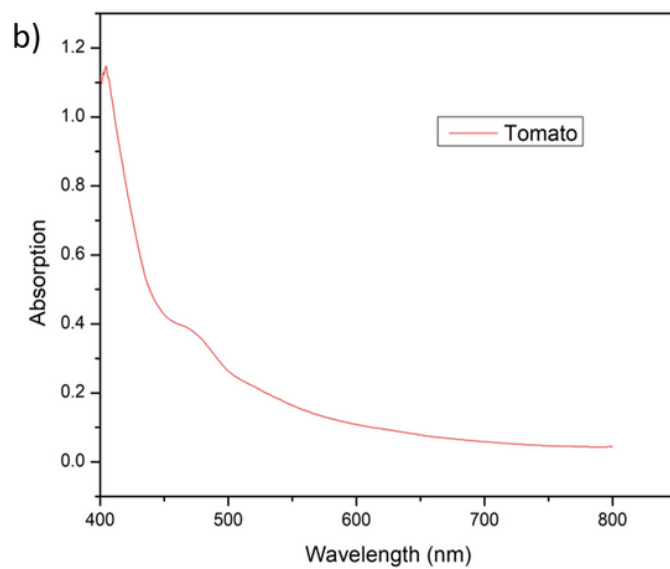
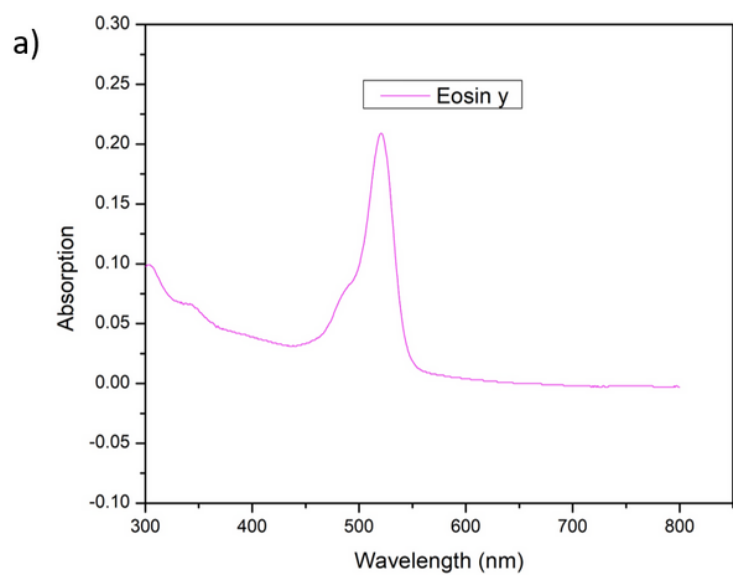


Figure 4

UV-Visible spectroscopic spectra of Eosin – Y dye

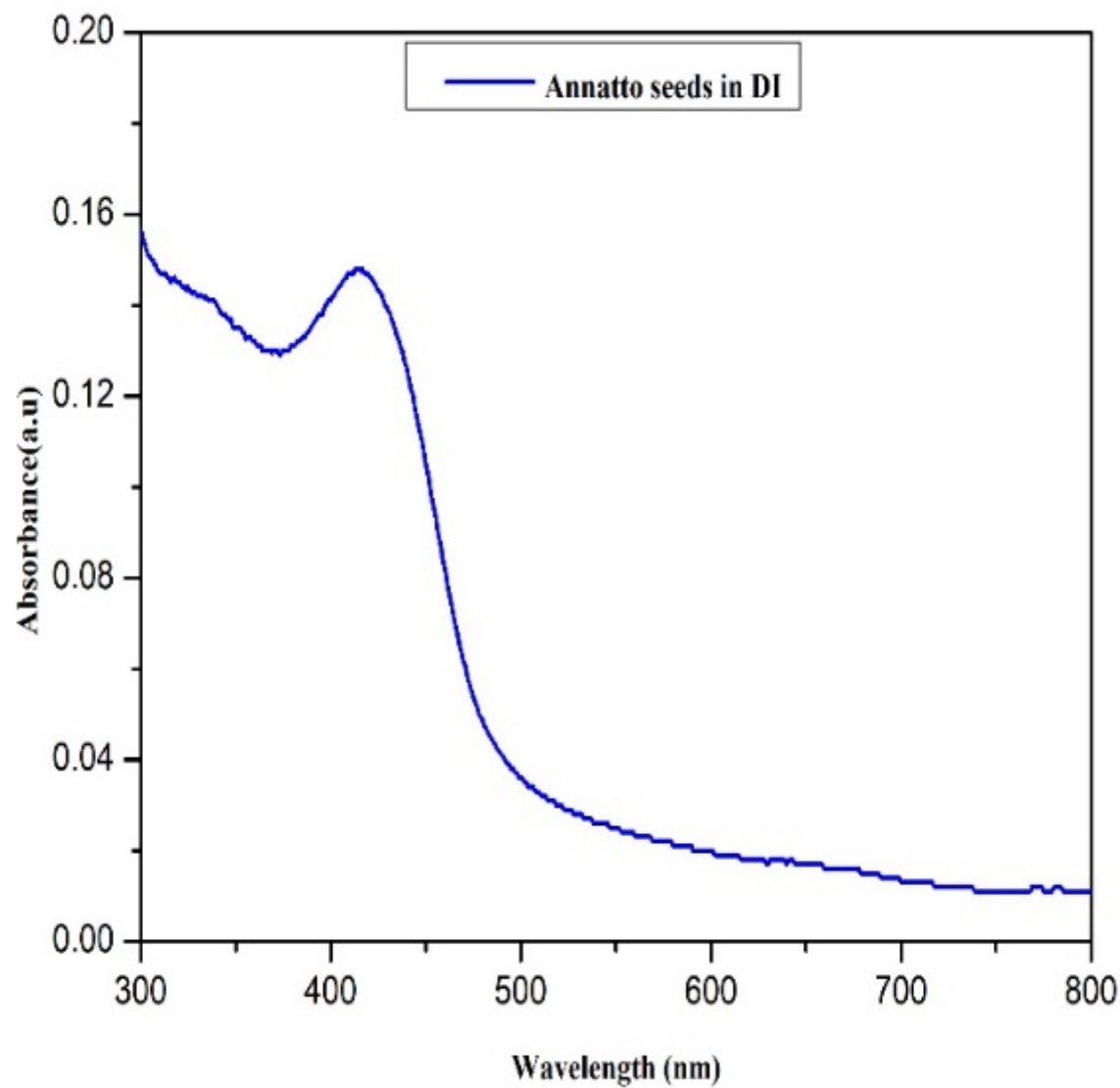


Figure 5

UV-Visible spectroscopic spectra of *Epipremnum aureum*

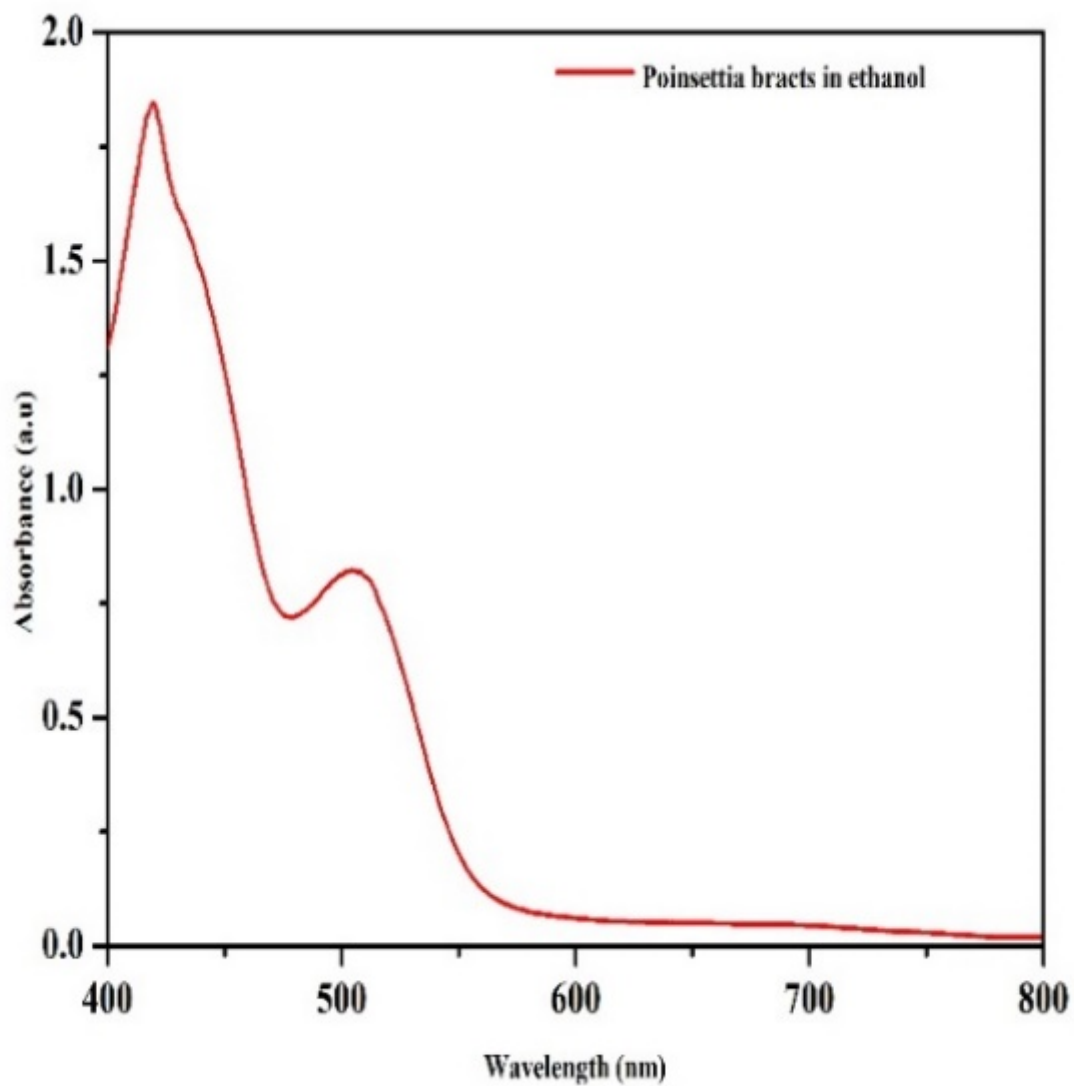


Figure 6

UV-Visible spectroscopic spectra of cocktail of *Epipremnum aureum* and Eosin-Y dye

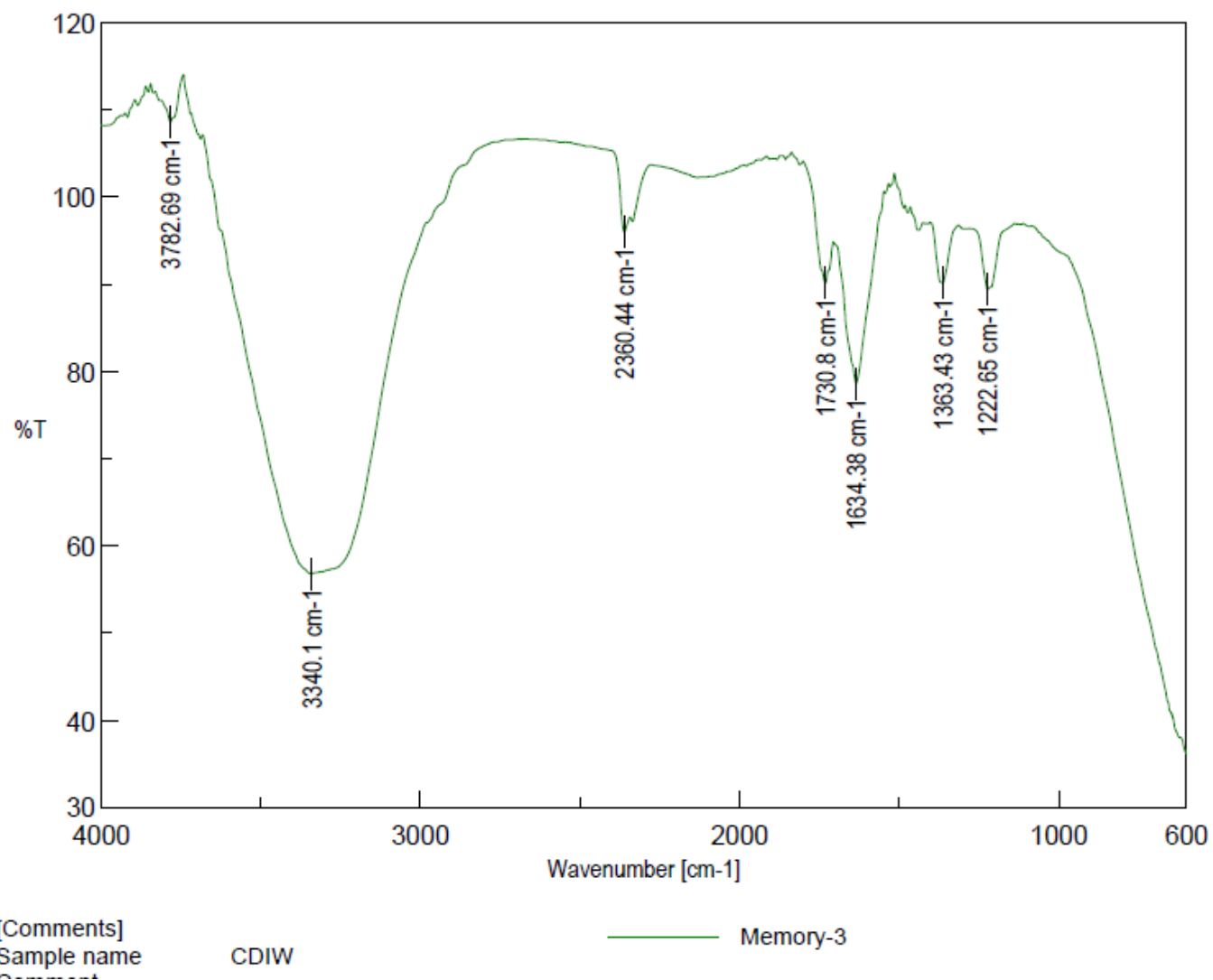
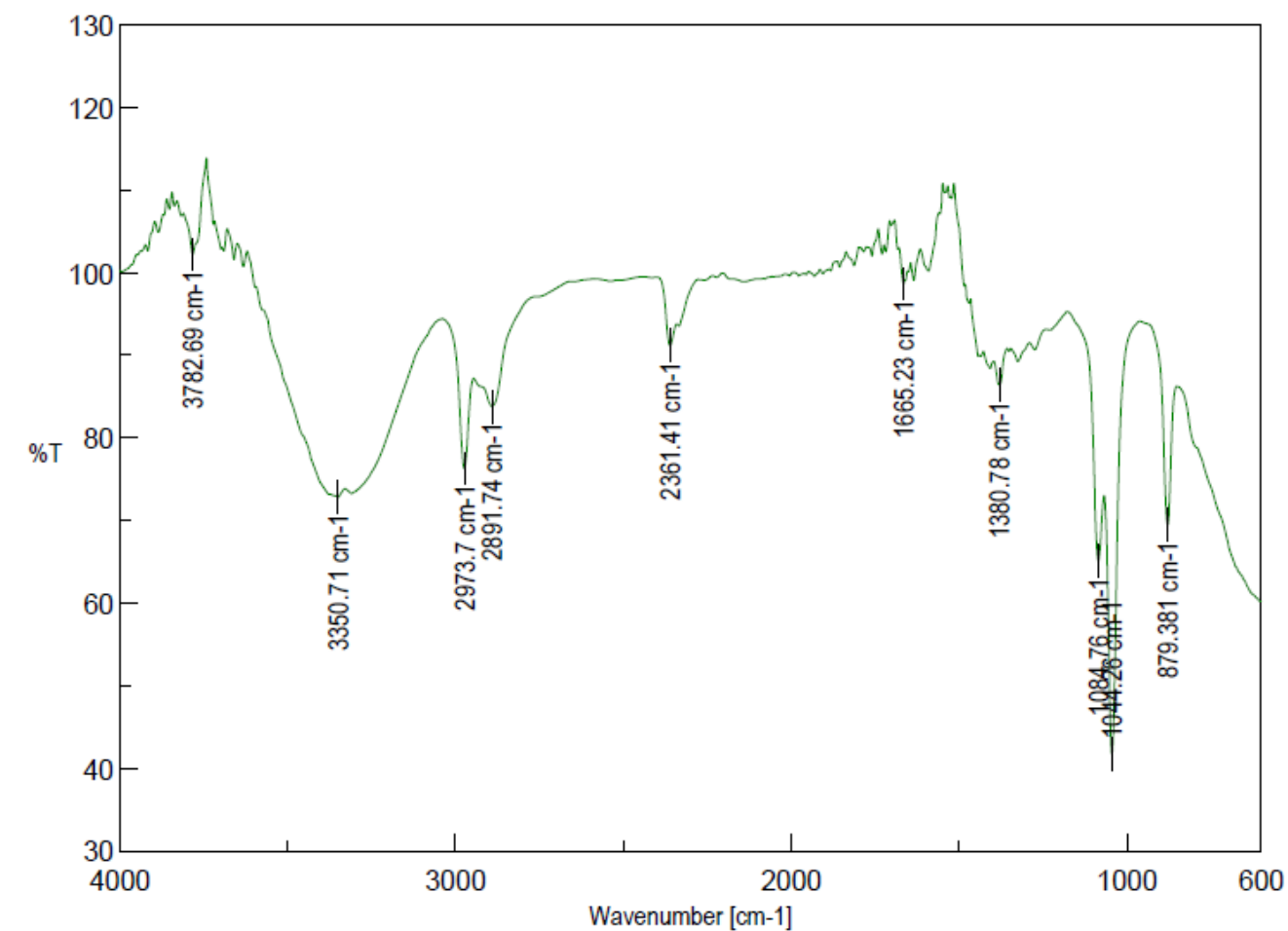


Figure 7

FTIR spectra of Eosin-Y dye



[Comments]
Sample name

CE

Memory-7

Figure 8

FTIR spectra of *Epipremnum aureum*

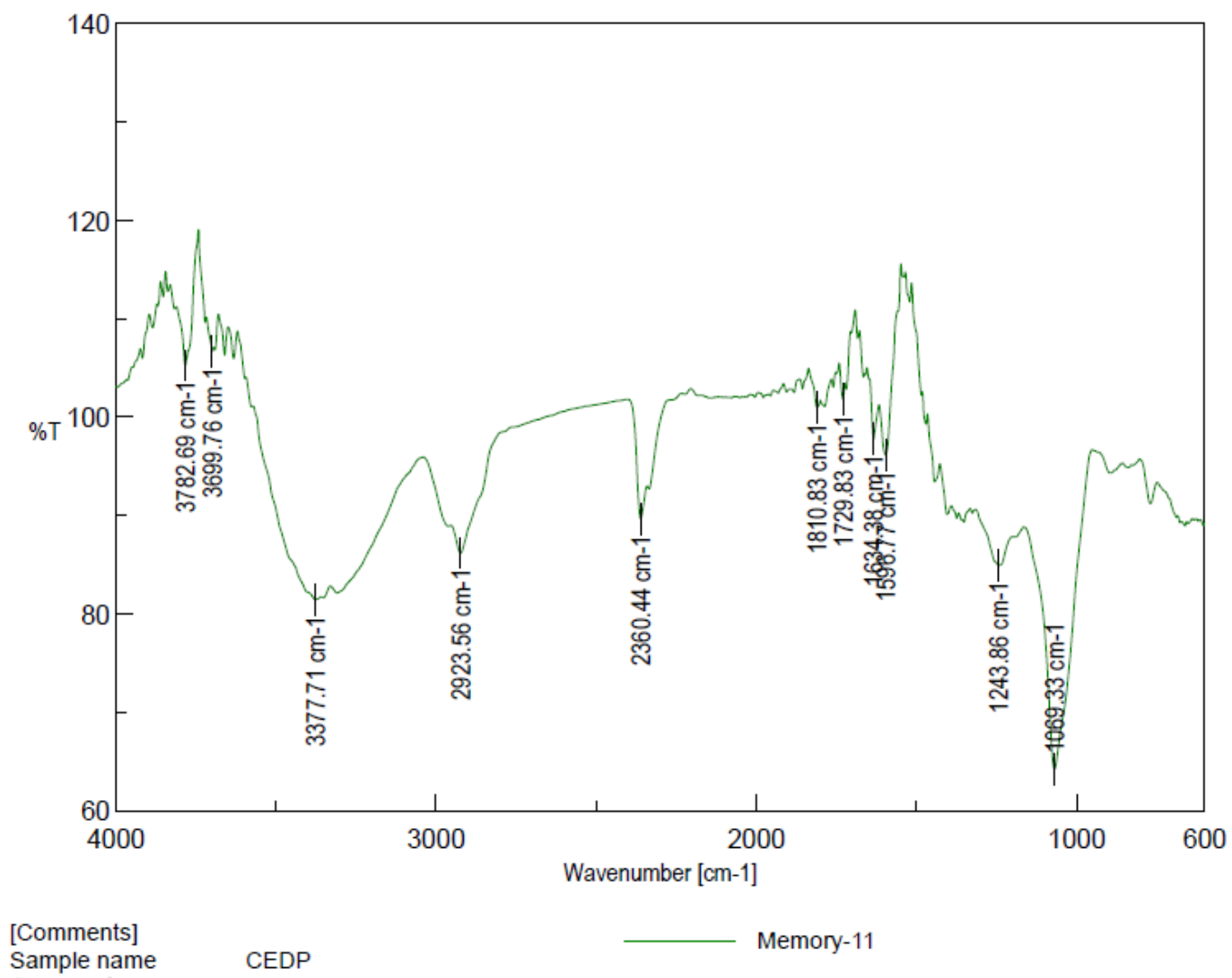


Figure 9

FTIR spectra of cocktail of *Epipremnum aureum* and Eosin-Y dye



Epipremnum aureum



Eosin-Y



Cocktail of *Epipremnum aureum* and Eosin-Y

Figure 10

Photograph of the TiO_2 coated FTO substrate immersed in the dyes

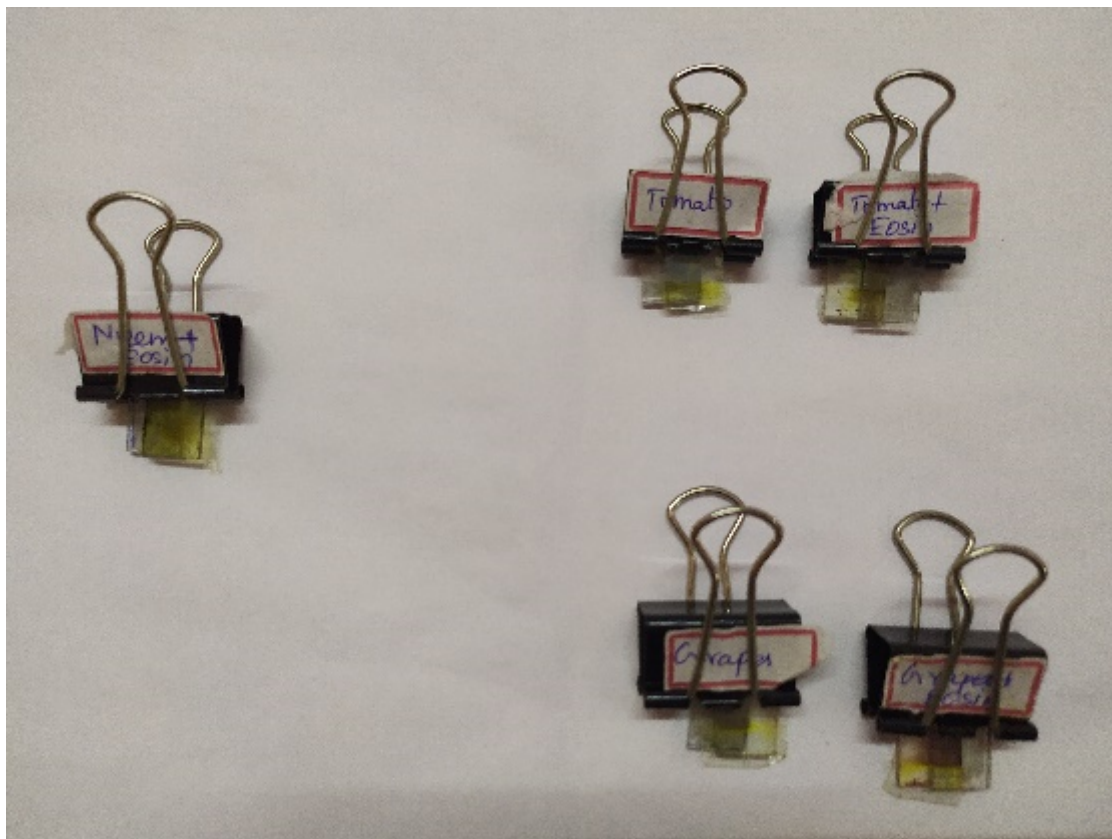


Figure 11

Photograph of the Dye Sensitized Solar Cells

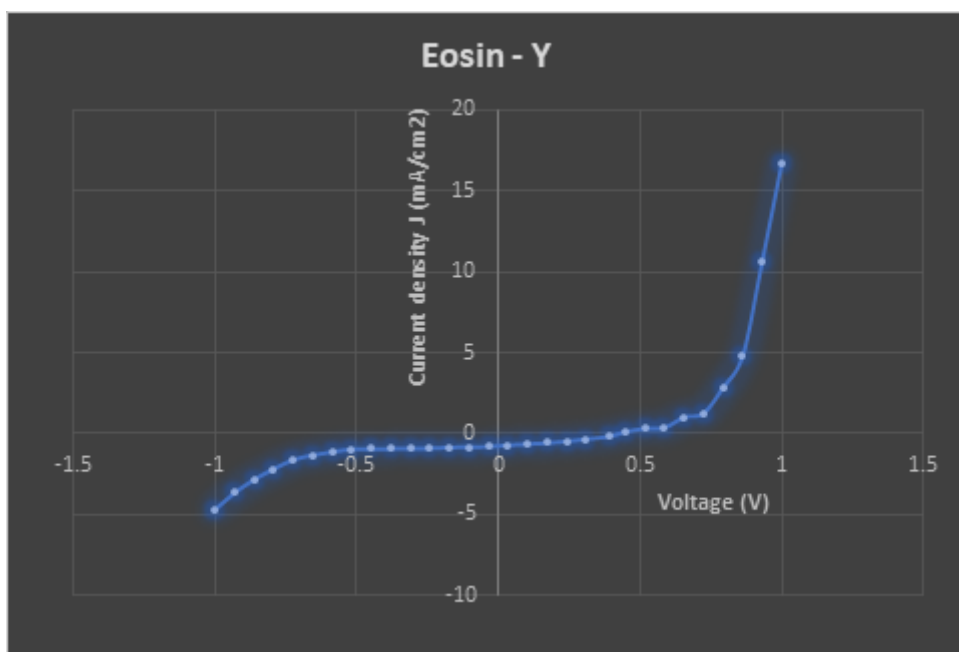


Figure 12

JV Graph for Eosin-Y dye

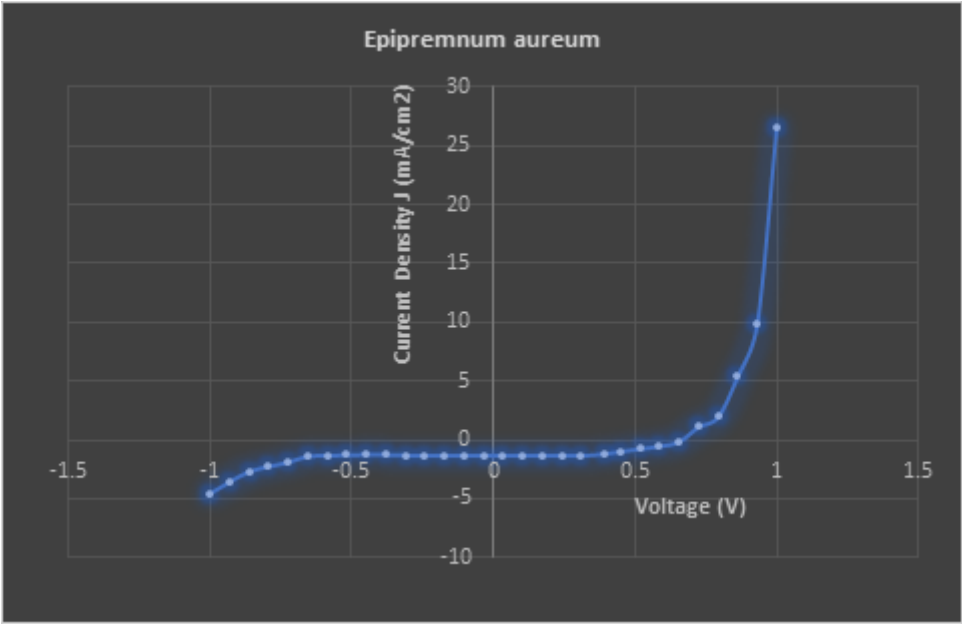


Figure 13

J-V Graph for Epipremnum aureum

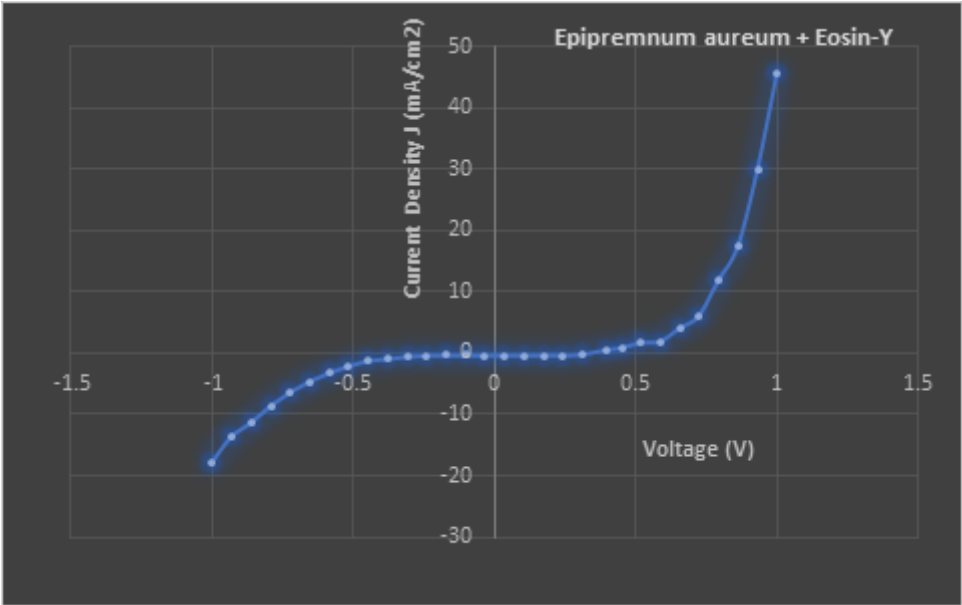


Figure 14

J-V Graph for cocktail of Epipremnum aureum and Eosin-Y

Supplementary Files

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- [T3.png](#)