National Conference on "Recent Trends in Mathematical Modeling, Simulation Methods, Computations, and Physical Sciences"
(MMSCP-2019), Organised by Hislop College, Nagpur, Maharashtra, India
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 4 | Issue 4 | ISSN : 2456-3307

Dye Sensitized Solar Cell Using Basella Alba (Red Vine Spinach) Sensitizer Nanocrystalline TiO2 Photoanode

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ABSTRACT

In the present work, dye sensitized solar cell is fabricated using Basella Alba (Red Vine Spinach) as sensitizer on nanocrystalline TiO_2 photoanode. TiO_2 photoanode film is deposited on transparent fluorine doped tin oxide (FTO) substrate using doctor blade method. Using UV- Vis spectrometer, optical absorption analyses is carried out for Basella Alba .The DSSC is fabricated by assembling Basella Alba sensitized photoanode and graphite coated counter electrode. The photoelectrochemical performance of the Basella Alba fruit dye extract showed an open ciorcuit voltage(Voc) of 0.8 mV, Short circuit current 10 mA Fill factor 0.63, and conversion efficiency 0.50%.

Keywords : Dye sensitized solar cell(DSSC), Titanium dioxide, Basella Alba dye.

I. INTRODUCTION

Among all other renewable energy sources, solar energy is safer and inexhaustible source of energy and it has greatest potential [1]. Photovoltaic's convert sunlight directly into electricity [2]. from the last three decades, The solar cell market is dominated by silicon based devices [3].However, recently DSSC have gained increasing interest due to its simple and low cost manufacturing process[4].A DSSC constitutes a photoelectrode and a catalytic electrode with an electrolyte between them. In 1991, O'Regan and Gratzel developed DSSC that work on the principle of plant photosynthesis and the efficiency of these cell was reported as 7.1% and 7.9% [5]. Usually, dye sensitized solar cells consist of a mesoporous titanium dioxide film, which is sensitized by a dye, in combination with a liquid or solid-state material. In hybrid solar cells the acceptor-type material is replaced by inorganic semiconductors like TiO_2, CdS, CdSe, PbS, PbSe, ZnO, or SnO_2 [6-12] .The DSSC sensitized by Ru compound absorbed onto nanoscale TiO_2 is most efficient and has efficiency 11-12% [13].

But ruthenium dye, including N3 and N719 are costly and hazardous to environment, thus other numerous metal free organic dyes have been used in DSSC [14]. Thus the natural dyes extracted from different parts of plant like leaves, fruits, flower, root, seed have been used as a sensitizer for DSSCs.

G. Calogero et al. [15] reported that Betaline pigment containing red turnip has highest efficiency of 1.70% . H. Zou et al. [16] have studied mangosteep pericap as a sensitizer with efficiency 1.17%. W. Lai et al.[17] have used Rhoeo Spathacea as a natural sensitizer and reported its efficiency as 1.02%. Bayron Cerda et al.[18] have used Maqui, Black Myrtle, Spinach and spinach black myrtle as natural sensitizer to increase the efficiency of DSSC and concluded that black myrtle has more efficiency as 0.040% among them.

Lawrence Amadi et al.[19] have studied the creation of natural dye sensitizer solar cell using vegetable dye from Red Cabbage, Green Cabbage, Spinach, Red Potato, Radish and concluded that green cabbage give the cell efficiency as 0.1% while red cabbage as 0.09% and radish and Potato as 0.06%. S.Rajkumar and K. Suguna [20] used Beet root and Pomegranate fruit to enhance the efficiency of DSSC. Monzir S et al. [21] used fifteen different dyes to study DSSC and found that schinus Terebinthifolis Leaves shows best performance for DSSC with photoelectrochemical parameter of J_{sc}= 2.40mA/cm^{2}, V_{oc}=0.68, FF=0.44 and efficiency ŋ= 0.73%.

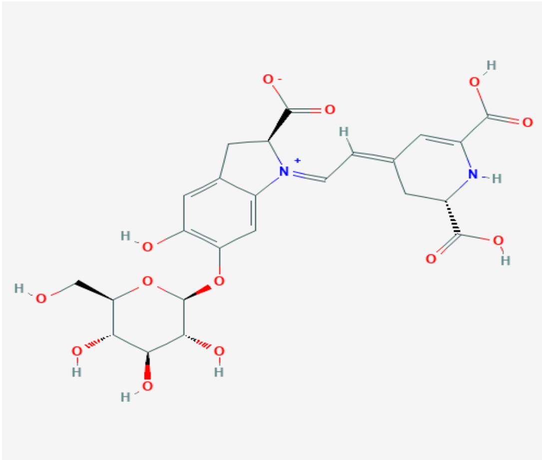
It has been observed that there is a lot of work to be done in order to improve quantum efficiency of dye-sensitized solar cell. The advantages of natural dyes as photosensitizers are large absorption coefficients, high light-harvesting efficiency, no resource limitations, low cost, simple preparation techniques and no harm to the environment.

Fig.1 B.Alba Vine

Fig.2 Fruits of B.Alba

In the present work we used Basella Alba (Red Vine Spinach) as a sensitizer. . Basella Alba (Figure 1), bearing deep-green leaves, is commonly grown and harvested as a novel leafy vegetable in tropical and non tropical region, particularly during the summer season when the production of other leafy vegetables is short. Grown into the fall and winter seasons, the vines produce a substantial quantity of fleshy and dark blue fruits, which are usually discarded by farmers. The estimated production of fresh fruits is approximately 2 kg per plant. Value-added use of the natural pigments from the fruits as colorants and bioactive ingredient in related product development deserves research interest.

Basella Alba Fruit Red Pigment Analysis at Various Maturities concluded that three red-violet pigments were detected in ripe B. alba fruits. Gomphrenin I was identified as the major pigment [22]. The structural formula for Gomphrein I ($C_{24}H_{26}N_2O_{13}$) is shown below.



In addition to gomphrenin I, betanidin-dihexose and isobetanidindihexose were also detected. B. alba fruits could be regarded as a potent source of natural colorant[22].

Experimental Section

A. Preparation of TiO_2 paste

TiO_2 paste was prepared from homogeneous mixture of TiO_2 nanopowder and Ethyl cellulose. TiO_2 nanopowder and ethyl cellulose was mixed in morter for about 30 min to make the homogeneous mixture and α-terpnol and ethanol was added gradually. Few drops of acetyl acetone were added to the mixture. The slurry obtained is then kept for ultrasonication for 1h.

B. Extraction of dye

The fresh fruits of basella Alba(Red Vine spinach) were rinsed in distilled water to remove dust and soluble impurities. 30g of the fruits were kept in 30mL of ethanol the beaker is covered with aluminum foil and kept it for 24 hrs. After that the fruits were filtered out and filtrate obtain was stored in a sample bottle covered with aluminium foil.

C. Preparation of TiO_2 photoanode

The photoanode is composed of conducting glass substrate of sheet resistance 15Ω/cm^2 (20 x20 mm^2) coated with FTO (fluorine doped tin oxide). The 10 x10 mm^2 active area of substrate was coated with titanium dioxide with the help of Doctor blade method. The coated film of TiO_2 on FTO glass was annealed for 1 h at 450 °C. After that the glass slide is left dipped into dye for 24 hr so that the adequate adsoption of dye occure into the TiO_2 film. The electrode was then taken out of dye solution and rinsed with distilled water and ethanol, and used as photoanode for solar cell.

D. Assembling complete Dye sensitizrd solar cell

TiO_2 coated glass Slide was used as photoanode while graphite coated FTO glass slide was used as counter electrode. The counter electrode was kept on working electrode and to avoid the direct contact between them, the spacer was inserted between them. The space between working and counter electrode is filled with electrolyte. To couple the electrode the binder clips on opposite sides were used.

II. RESULT AND DISCUSSION

A. UV-VIS Analysis of Natural sensitizer

The extracted Basella Alba (Red vine spinach) was characterized using UV-Vis. UV-Vis spectra that provide the information about frequencies at which the dye absorb photon. Fig.1 shows the absorbtion wavelength Basella Alba dye is from 450nm to 580nm, which falls in the visible region.

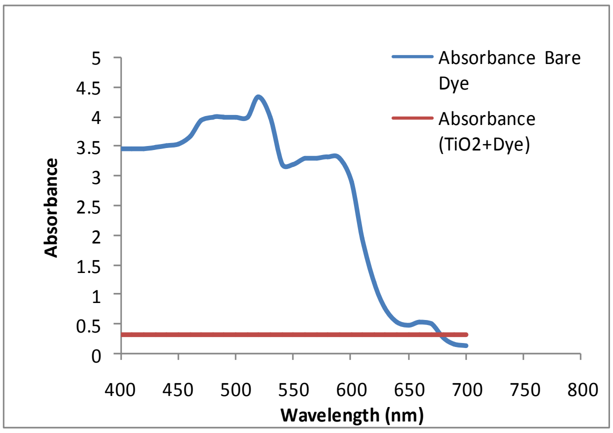


Fig. 3 Absorption spectrum of dye extract from Basella Alba (Red vine spinach) and TiO_2+dye

It is observed that the spectra of TiO_2 photoanode does not absorb visible light, but the absorbtion for Basella Alba sensitized TiO_2 photoanode is extended in the wavelength region 450-600nm.

B. Photovoltaic performance of DSSC.

The photovoltaic performance of the fabricated DSSCs employing metal free natural dye Basella Alba as photo-sensitizers are evaluated by recording the current and photovoltage (IV) . The sample was illuminated direct to sunlight and active area of the cell is exposed to light was 1cm x 1cm. From the recorded IV curve, the photovoltaic parameters such as open circuit voltage (V_{oc}), short circuit current (Isc), fill factor (FF) and the photo-conversion efficiency (ŋ) were calculated using the following empirical relation

$$\text{PCE}, \quad \eta = \frac{Voc \times Isc \times FF}{Pin} \times 100$$

The fill factor of the assembled stack calculated using

$$FF = \frac{P\max}{Voc \times Isc}$$

Fig.5 represent the I-V characteristic of DSSC sensitized by Basella Alba(red Vine Spinach) .

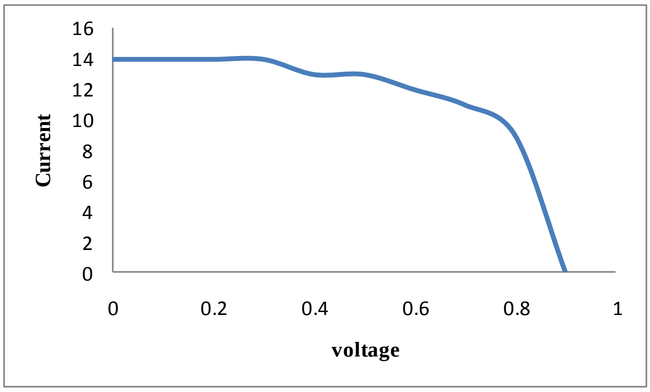


Fig.4- I-V characteristic of DSSC with Basella Alba (Red Vine spinach) extract Dye

Dye solution	I_{max} (mA)	V_{max} (mV)	I_{sc} (mA)	V_{oc} (mV)	FF	ŋ (%)
Basella Alba	14	0.9	10	0.8	0.63	0.504

III.CONCLUSION

We have successfully fabricated DSSCs using cost effective and naturally abundant metal free photo-sensitizer extracted from Basella Alba (Red Vine Spinach). The absorbance property of the extracted natural sensitizers was examined using UV-Visible spectroscopy. From the photovoltaic studies, it showed the Photovoltaic parameter such as V_{max}, I_{max}, Voc, Isc, FF, PCE (ŋ) was O.9mV,14mA, 0.8mV, 10mA, 0.63, 0.5% respectively. High efficiency may be attributed to rich adsorption of dye molecule on to TiO_2 particle. For the betterment of the device, further optimization of various parameter is required which is future challenge in the field of DSSC.

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