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Study of dye sensitized solar cell using canna lily sensitizer nanocrystalline titanium dioxide photoanode

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Abstract

In the present work, dye sensitized solar cell is fabricated using canna lily as sensitizer on nanocrystalline TiO2 photoanode. TiO2 photoanode film is deposited on transparent fluorine doped tin oxide (FTO) substrate using doctor blade method. Using UV-Vis spectrometer, SEM, optical absorption analyses and photovoltaic characterization is carried out for Canna lily sensitized photoanode. The DSSC is fabricated by assembling canna lily sensitized photoanode and graphite coated counter electrode. The photoelectrochemical performance of the canna lily flower dye extract showed an open circuit voltage (Voc) of 1.6 mV, short circuit current 18 mA Fill factor, and conversion efficiency 0.20%.

Keywords: Dye sensitized solar cell (DSSC); Titanium dioxide; Canna Lily flower dye

1. Introduction

India 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

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that green cabbage gives 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.

1.1. The Flower of Canna Lily

The Canna lily is the most common garden plants with yellow and red color flower. Canna lily are easy to grow and low maintenance, and both flower and foliage offer long lasting color. The dye extracted from the red flower of it, four anthocyanin pigment detected namely Cyanidin-3-O-(6”-O- α-rhamnopyranosyl)-βglucopyranoside, Cyanidin-3-O- (6”-O- α-rhamnopyranosyl)-β-galactopyranoside, Cyanidin-3-O-βglucopyraoside and Cyanidin-O-β-galactctopyranoside [22]

2. Experimental Section

2.1. 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.

2.2. Extraction of dye

The fresh flowers of Canna Lily 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.

2.3. 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 ^{o}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.

2.4. Assembling complete Dye sensitized 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.

3. Results and discussion

3.1. Optical Characterization

The extracted Canna Lily was characterized using UV-Vis. UV-Vis spectra that provide the information about frequencies at which the dye absorb photon. The absorption spectra of *Canna lily* shown in fig 4.1a, shows broad absorption in range 400-535nm with average absorption 3.9342 followed by one more absorption peak at 553 nm with absorption 3.357.

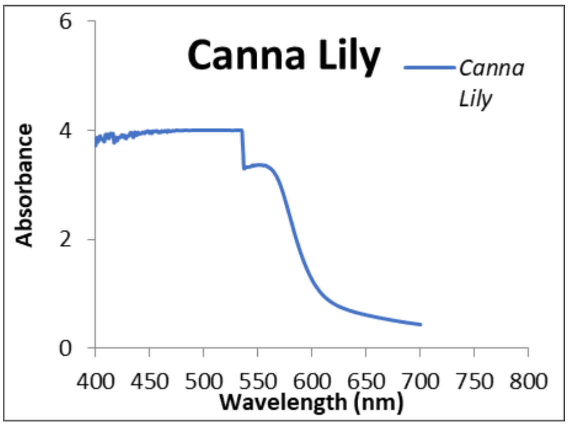

Figure 1 The absorption spectra for the extracts of Canna Lily

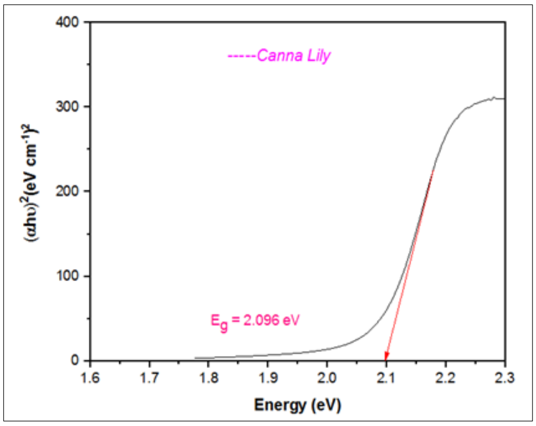

Figure 2 (Normalized absorption) ^{2}vs energy (eV) curve of *Canna lily* extract

Good sensitizers should have to absorb radiation from the visible region of the electromagnetic spectrum. As observed from the absorption spectrum, the range of the spectrum was from 400 to 700 nm.

The optical band gap of extracted colorant was calculated using Tauc's equation. The plot of normalized absorbance square vs. energy (eV) to calculate the band gap of colorant is 2.096 shown in Figure 4.1(b)

3.2. Morphological studies

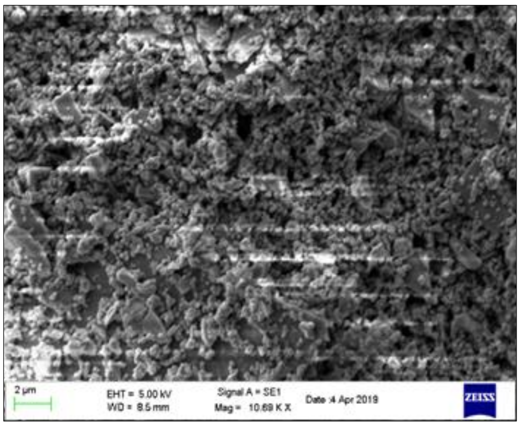

Figure 3 SEM micrographs of nanocrystalline TiO_2 films sintering temperature at 450^oC

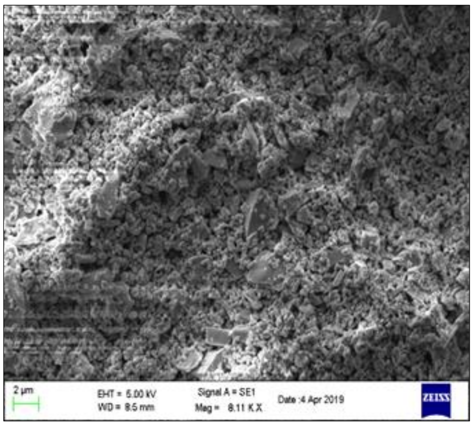

Figure 4 SEM micrographs of nanocrystalline TiO_2 films loaded with *Canna Lily*

Figure 4.2 a show the Scanning electron micrograph (SEM) of TiO_2films sintered at 450°C which has been coated on the top of FTO glass. The surface morphology shows TiO_2 nanomaterial had spherical forms and distributed almost uniformly. Some TiO_2 spheres stuck together to form small clusters. The uniform deposition and proper attachment between TiO_2 particles cause good grain to grain connectivity and reduction in the number of open pores facilitating dye adsorption and electron transport. While some particles are found to be agglomerated [23]. However significant changes are found for SEM images of dye adsorbed dyes (b- g). It is observed that most of mesopores and clearly visible, filled dye molecule [24, 25].

3.3. Photovoltaic performance of fabricated Dye sensitized solar cell

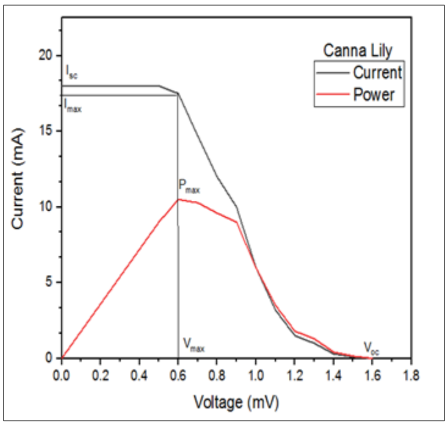

Figure 5 Represent the I-V characteristic of DSSC sensitized by *Canna Lily*

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

$$\text{PCE}, \ \eta = \frac{Voc \times Isc \times FF}{Pin} \times 100 \quad \text{...............(1)}$$

The fill factor of the assembled stack calculated using

$$\text{FF} = \frac{P\max}{Voc \times Isc} \quad \text{................(2)}$$

Table 1 Represents photovoltaic parameters of fabricated DSSC sensized with *Canna lily* flower extract

Dye solution	Imax (mA)	Vmax (mV)	Isc (mA)	Voc (mV)	FF	Ŋ (%)
Canna Lilly	18	1.6	17.5	0.7	0.425	0.20

3.4. Stability of fabricated devices

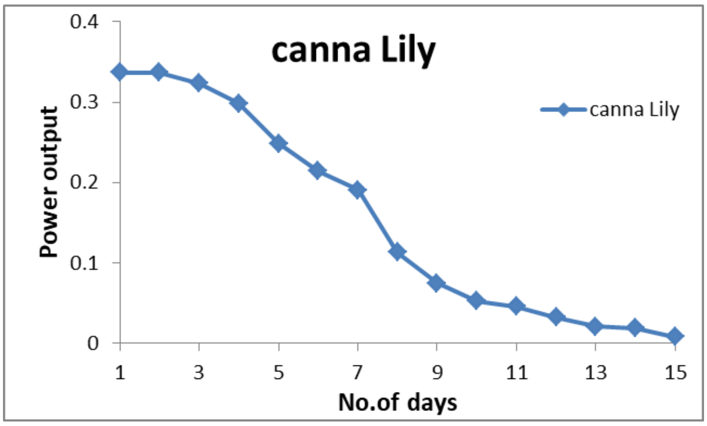

Figure 6 Variation of Power output with no. of days

To study the stability of fabricated device, each day, current and voltage values were fetched, under illumination direct sunlight. It was important to get current and voltage values all throughout the 15 days' time period, as it is a critical index for our cells aging study. The average power output of fabricated device sensitized with Canna Lily flower dye is obtained as 0.1547 Mw.

4. Conclusion

We have successfully fabricated DSSCs using cost effective and naturally abundant metal free photo-sensitizer extracted from *Canna lily*. 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 1.6mV,18mA, 0.7mV, 17.5mA, 0.425, 0.20% 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.

Compliance with ethical standards

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Disclosure of conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Declaration

I declare that the manuscript is original, and its content in some other form has not been published elsewhere previously by any of the authors and/or is not under consideration for publication in any other journal at the time of submission.

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