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Characteristics of Dye-Sensitized Solar Cells Using Dye from Pitaya Fruit

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Abstract. Dye-sensitized solar cell (DSSC) consists of TiO_2 nanoporous coating which acts as a photo electrode, a sensitizer of dye molecules soaked in the TiO_2 film, liquid electrolyte and a counter electrode. This paper focuses on the usage of a sensitizer from the Pitaya fruit. Pitaya or commonly known as dragon fruit (Hylocereus polyrhizus) was extracted and used as a sensitizer to fabricate the dye sensitized solar cell (DSSC). The photoelectrochemical performance of Pitaya based solar cell shows an open circuit voltage (V_{OC}) of 237 mV, short circuit current (I_{SC}) of 4.98 mA, fill factor (FF) of 0.51, solar cell efficiency (η) of 0.70 % and has a peak absorbance rate of 2.7 at 550 nm. The photoelectrochemical and UV-Visible light absorbance performance of Pitaya-DSSC shows good potential in future solar cell fabrication.

Introduction

A typical dye sensitized solar cell (DSSC) or 'Gratzel cell' offers an average photon to electrical efficiency of 11% through the usage synthetic inorganic dyes as an alternatives to silicon based solar cell. Synthetic dyes are commonly used because the molecular sensitizer presents intense visible metal to ligand charge transfer [1] but due to expensive in costing and hard to synthesize, natural pigments which belongs to betalains [2] pigments is chosen because it is easily extracted, has abundance in resources and clean to environment. Sensitizers are used to absorb sun light and the electrolyte which contains the iodide/tri-iodide redox-couple provides electrons flow in the oxidised sensitizer [1]. Sensitization allows electrical generation with the energy level of irradiation lower than the bandgap of semiconductor in which light attracting dye molecules are adsorbed [3]. DSSC uses synthetic dye from ruthenium complex together with the wide band gap semiconductors oxides but the limitation is due to its costly and complicated preparation. The complexes also contain heavy metal end product which could pollute the environmental [4]. This resolves to the usage of natural dyes which are cheap, renewable, non-carcinogenic, and non-toxic [5]. Natural dyes are also abundant, easily extracted and safe materials [6]. In this paper, a dye sensitized solar cells (DSSC) is fabricated by employing Pitaya fruit dye into TiO_2 film and sandwiched with counter electrode that consist of a sketch graphite on ITO glass. Photoresponse of the cell was investigated by recording its I-V characteristics, UV-Vis absorption and charge generation properties.

Preparation of Pitaya fruit extract

10 g of Pitaya fruit is crushed with mortar and 10 ml of ethanol is added with a ratio of 1:1 at room temperature. Pitaya extract is filtered and then centrifuge for 25 minutes with speed of 2500 rpm.

Pitaya fruit's dye which was extracted resulted in deep maroon coloured solutions. The preparation of dye from Pitaya fruit is shown in Fig 1.

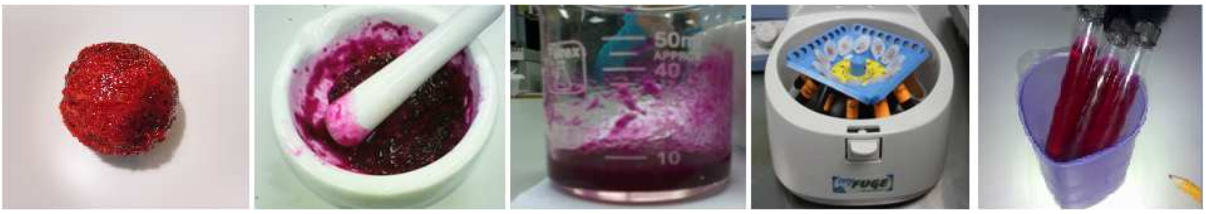

Fig.1 Preparation of Dye from Pitaya Fruit

Preparation of TiO_2 paste

3.5 g of TiO_2 nano-powder is added in 2 ml of Triton X-100. Solar bath it at least for 20 minutes. The preparation of TiO_2 paste is shown in Fig. 2.

Fig. 2 Preparation of Titanium dioxide adhesive

TiO_2 coating preparation by screen printing method

Scotch tape is applied on four corners of the conducting side of ITO glass; the scotch tape thickness is measured by using electronic digital caliper. The TiO_2 paste is added on to the ITO glass and is smeared with a razor blade on one side of the ITO glass. ITO glass is annealed on top of a hot plate to approximately 450 ºC for 30 minutes. After 30 minutes, the ITO glass is left to be cold at room temperature before it is soaked into the dye solution. As for the counter electrode, carbon from battery is smeared on to the ITO as TiO_2 using Dr.Blade's method. The TiO_2 and dye electrode is removed from the dye solution and is rinsed with ethanol to remove debris. The spacer is placed on the TiO_2 and dye electrode and some drops of the electrolyte solution is drip onto the TiO_2 and dye layer. Both the electrode and counter electrode is combined facing each other by a binder clips. Using binder clip, the solar cell is sandwich together [7]. The procedures are shown in Fig 3.

UV-Vis Measurements

The absorption spectra were performed by Evolution 201 UV-Vis spectrophotometer. The light source is conducted by using halogen lamp produced about 512 W/m^2. The parameters of solar cell are measured using Data Logger (Graphtec) and multimeter. The indoor testing is covered by using black box during measurement process to prevent the influence of surrounding light that could affect data collection.

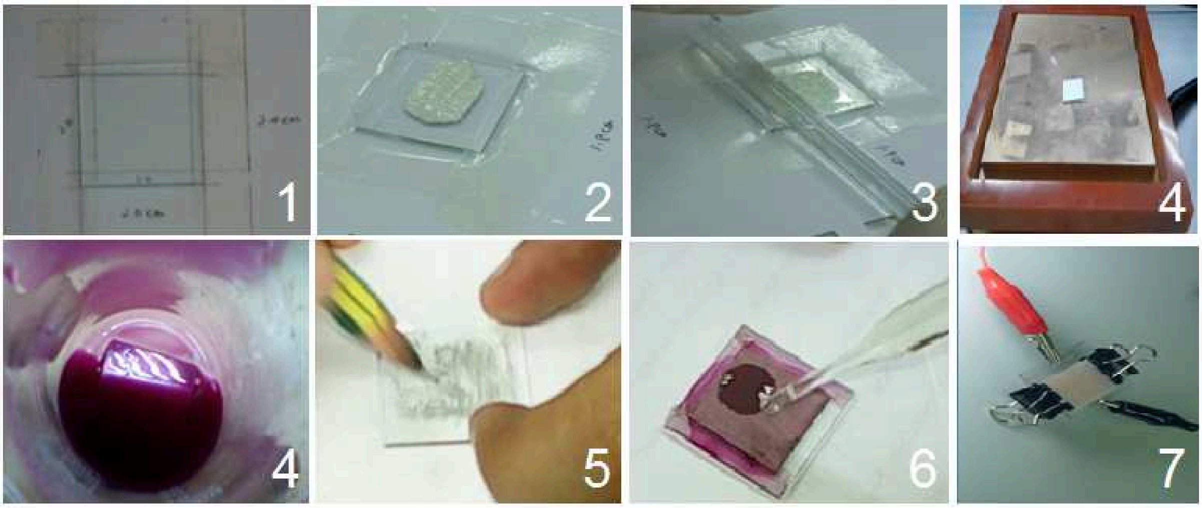

Fig. 3 Process of fabricating DSSC

Absorption Spectra of Pitaya Dye

Fig. 4 shows the absorption spectra of Pitaya dye with ethanol and absorbed into TiO_2. Maximum absorption of wavelength obtained by Pitaya's dye is about 550 nm at peak of 2.7 and slightly red shifted. The dye also excites at broader wavelength. This result shows possible existence of betalains pigments in Pitaya dye sample. The binding of TiO_2 surface with organic dye through carbonyl and hydroxyl group are capable to form a chelate with TiO_2.

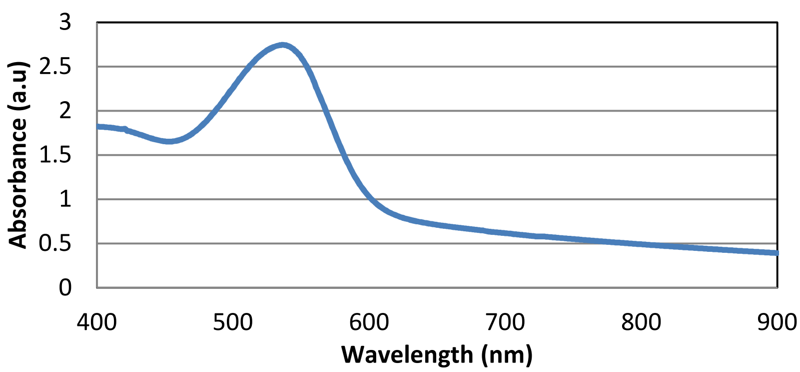

Fig. 4 UV-Vis Absorption spectra of Pitaya fruit's dye

Performance of Dye Sensitized Solar Cell (DSSC)

The performance of DSSC is monitored through its electrical current and voltage output using halogen lamp. Table 1 presents the values of I_{sc}, V_{oc}; fill factor (FF) and solar cell efficiency (η) by using Pitaya as dye sensitizer. The thickness of TiO_2 will affect the performance of DSSC because thicker TiO_2 film tends to increase the amount of dye adsorption which also causes higher material resistance of electron transport and decrease the performance of DSSC. Fig. 5 shows the current-voltage curve obtained with solar cells by using Pitaya dye as dye sensitizer. Fill factor of DSSC is shown to be above 50% and the efficiency is about 1.15%. This result shows that by using natural sensitizer from Pitaya extract, absorbed into TiO_2 will absorb the visible light and promote electron transfer across the dye/semiconductor surface. Photocurrent values also are affected by the acidity of dye solutions [1].

Table 1 Photoelectrochemical parameters of DSSC

Dye	Light Intensity (mW/cm^2)	Voc (mV)	Isc (mA/cm^2)	FF	η (%)
Pitaya	100	273	4.98	0.51	0.70

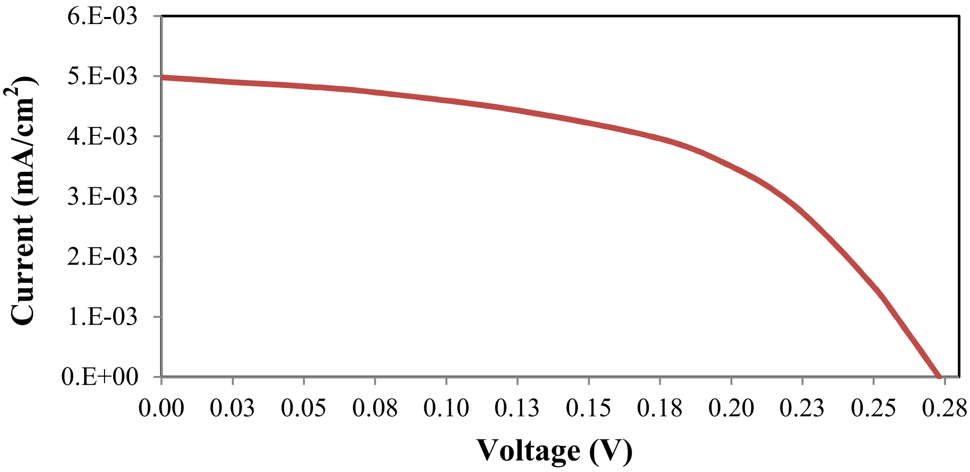

Fig. 5 Current-voltage curve for DSSC using Pitaya dye

Conclusion

The spectral response of TiO_2 to visible light is enhanced by using pitaya fruit dye as a sensitizer. Pitaya dye present good light harvesting properties and perform charge transfer sensitization of TiO_2 surface. The photoelectrochemical performance of Pitaya based solar cell shows an open circuit voltage (V_{OC}) of 237 mV, short circuit current (I_{SC}) of 4.98 mA, fill factor (FF) of 0.51, solar cell efficiency (η) of 0.70 % and has a peak absorbance rate of 2.7 at 550 nm. The implementation of natural sensitizer as an alternative to synthetic based dyes with a simple extraction and environmentally friendly method could be the future of green technology based solar cell that is non hazardous to health yet could generate the right amount of electricity.

Acknowledgements

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