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Nature based dyes from blue pea flower as a potential sensitizer for dssc

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ABSTRACT

The new technological way of Dye-Sensitized Solar Cell (DSSC) similar to photosynthesis process has attracted much attention since its demonstrate a great potential due to the use of low-cost materials, ease of fabrication process and environmentally friendly sources of technology. This paper discovers the use of natural dyes from Blue Pea flower which act as a sensitizer in DSSC and in addition has a potential in absorbing visible light spectrum. The absorption spectra of the dyes have been investigated by UV-Vis Spectrophotometer. Fourier transform infrared (FTIR) is used to characterize the functional active group of dyes. Photovoltaic parameters reveal that the blue pea flower extract resulted in 0.19% energy conversion efficiency (η), short circuit current (I_{sc}) of 0.63 mA/cm^2, open circuit voltage (V_{oc}) of 0.60 V, and fill factor (FF) of 0.50.

Keywords - dye-sensitized solar cell, blue pea flower, distilled water, ethanol, spectrum

INTRODUCTION

Dye-Sensitized Solar Cell (DSSC) are the third era of photovoltaic technology that converts solar energy generated from the sun into electrical energy based on the sensitization of wide bandgap semiconductors[1]. This new class of solar cell can be said to resemble the process of photosynthesis since its use light energy absorption of dye[2][3]. DSSC sometimes referred to as Gratzel Cell was first innovated by O' Regan and Gratzel in 1991[4].

DSSC primarily consists of dye, photoelectrode, electrolyte, counter electrodes and substrates glass as shown in Figure 1. Dye act as a sensitizer plays an important role in absorbing sunlight and transforming solar energy into electricity[5]. Titanium dioxide (TiO_2) is chose as a potential semiconductor material in solar cell application because it offers superior characteristics, including chemical stabilities, wide band gap, fairly good thermal and excellent optical transmittance[6].

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Natural dyes usually from plants, fruits and flowers shows a variety of colors and contain several pigments such as anthocyanin, betalain and chlorophyll that can be easily extracted and then worked in DSSCs[7]. The structure of pigment used as sensitizer determines the strength of its attachment to the oxide surface of TiO_2. The pigment would bind strongly onto the surface of TiO_2 film, if the structure contains carboxyl and hydroxyl functional groups[8]. The interaction between TiO_2 and the dye would lead to the excited electron transfer from the dye molecules to the conduction band of the semiconductor TiO_2[9]. The ideal sensitizer should be stable and be able to attach to the surface of the electron-conducting material. They should able to absorb light at all wavelengths (λ) below 920 nm[10].

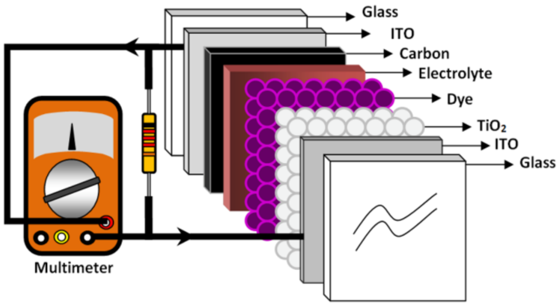

Figure 1: Cross section of DSSC [11]

RESEARCH METHODOLOGY

Materials

The materials used are Titanium Dioxide (TiO_2) paste, Triton X-100, ethanol (E), distilled water (DI), Indium tin oxide (ITO) coated glass slide.

Preparation of natural dye sensitizer extracts

For blue pea flower of weight 10 g were cut into small pieces and crushed using a mortar until a liquefied paste was formed. The blue pea dye then immersed in the solvent which consists of distilled water (DI) extract solvent and ethanol (E) extract solvent at room temperature and then placed into the ultrasonic cleaner. The ultrasonic is used to further extract colored dye pigment for 30 minutes at the temperature of 30°C by using 'degas' mode with a frequency of 37 Hz. The absorbance rates of blue pea dye in visible light spectrum were tested using Evolution 201 UV-Vis Spectrophotometer.

Figure 2: Preparation of blue pea dye sensitizer extract

Figure 3: Evolution 201 UV-Vis Spectrophotometer

Preparation of TiO_2 paste

The ITO glass was cleaned and rinsed using ethanol. In order to prepare a TiO_2 paste, 5 g of TiO_2 powder and 3 drops of Triton X-100 were mixed together. The mixture was stirred well until evenly distributed and turned into a homogenous solution using a glass rod or a spatula. The scotch tape was applied on each sides of conductive ITO glass to control and maintain the thickness of TiO_2. Then, apply the TiO_2 paste and the suspension was spread uniformly by using glass stirring rod on ITO glass. This method is known as doctor blade method. At a temperature of 350°C, the coated glass was placed on the hot plate for 30 minutes and was kept cooled for 15 minutes at room temperature.

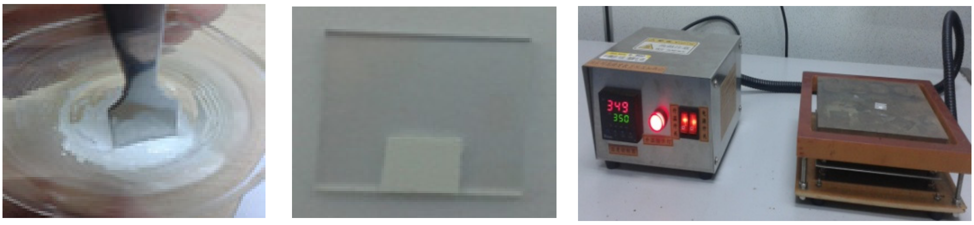

Figure 4: Preparation of TiO_2 paste

The assembly of DSSC

The dye-sensitized solar cells were assembled by combining the two electrodes which are photoanode and counter electrode facing each other by a binder clip. Photoanode contained TiO_2 paste with blue pea dye extract. Meanwhile, another ITO glass was sketched using graphite from the pencil and act as a counter electrode.

Figure 5: Full assembly of DSSC

RESULTS AND DISCUSSION

UV-Vis absorption spectra analysis

The visible absorption spectra of the blue pea flower were tested by using Evolution 201 UV-Vis Spectrophotometer. It's potential to absorb a photon from visible light using distilled water (BP-DI) and ethanol (BP-E) solvent is shown in Figure 6. Blue pea dye extracted by using distilled water shows deep blue colored solution meanwhile blue pea with ethanol resulted in light blue. The blue pea shows good absorption for both extract solvent which absorbs from 500 nm to 680 nm at peak 590 nm. Basically, this absorption is due to the anthocyanin present in blue pea extract sensitizer.

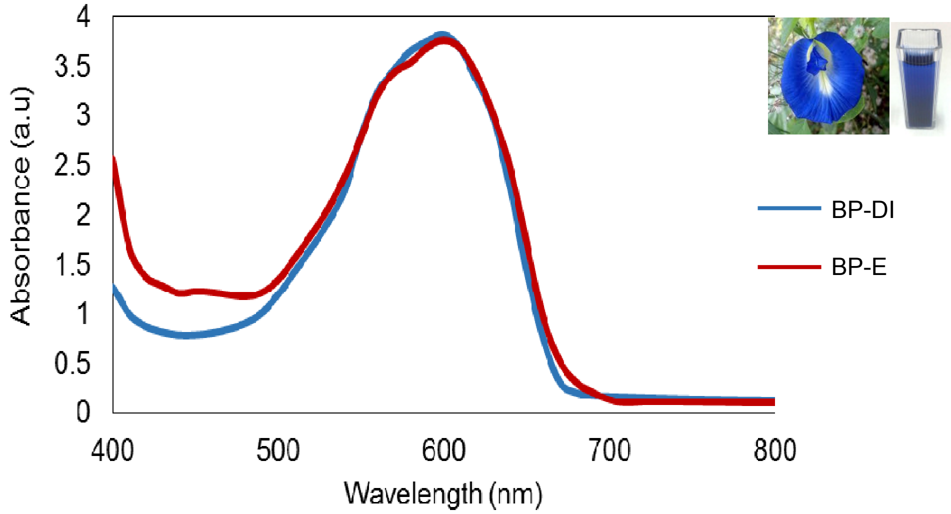

Figure 6: Absorption spectra of Blue Pea Flower extracted using Distilled Water (BP-DI) and Ethanol (BP-E)

FTIR analysis

Figure 7 shows the FTIR spectra of the blue pea dye extracted using distilled water (BP-DI) and ethanol (BP-E). For BP-DI, the peak at 1639 cm^{-1} represented C=O stretch. The broad absorption at 2115 cm^{-1} corresponds to the C≡C stretch. The two peaks at 2886 cm^{-1} and 3367 cm^{-1} attributed mainly due to the hydroxyl group which contain O-H stretching vibration.

For BP-E, the FTIR spectra starting from the peaks at 880 cm^{-1} arises due to the C-H stretching in the aromatic group. The sharp peak at 1047 cm^{-1} and 1088 cm^{-1} both correspond to the C-O stretching contained in esters group. A band at 1382 cm^{-1} attributed to the N=O bond. The presence of a peak at 2883 cm^{-1}, 2886 cm^{-1} and 3367 cm^{-1} confirms the presence of hydrogen bonding in blue pea flower which assigned as O-H bonding.

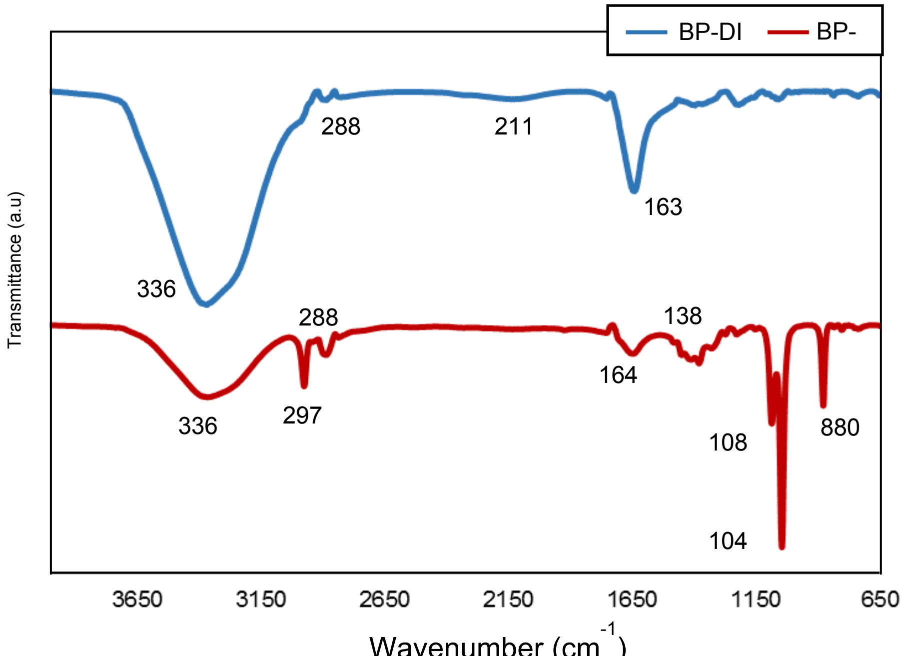

Figure 7: FTIR spectrum of Blue Pea Flower extracted using Distilled Water (BP-DI) and Ethanol (BP-E)

Photovoltaic Characteristics

Blue pea dye extract has been tested for their photovoltaic performance shown in Figure 8. The performance of DSSC was characterized in term of open-circuit voltage (V_{oc}), short-circuit current (I_{sc}), fill factor (FF) and energy conversion efficiency (η). The conversion efficiency (η) of the sensitized solar cell prepared from the dye extracted from blue pea flower is 0.190%, with open circuit voltage (V_{oc}) of 0.60 V, short circuit current (I_{sc}) of 0.63 mA/cm^2 and fill factor (FF) of 0.504 as shown in Table 1. The capability of the dye to absorb broader range in the visible spectrum, enhance a better interaction charge transfer between the anthocyanin dye from blue pea flower and TiO_2.

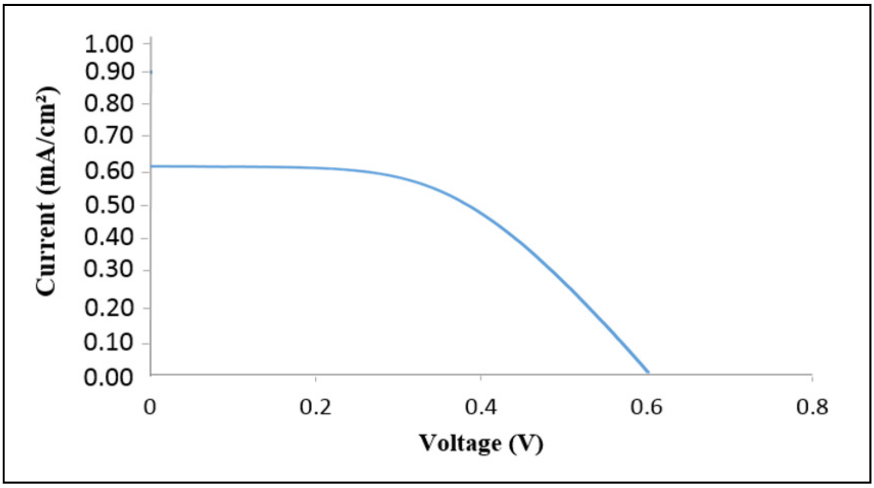

Figure 8: I-V Characteristics of blue pea sensitized solar cell

Table 1: Photovoltaic characteristic of blue pea dye extract

Dye	I_{sc} (mA cm^{-2})	V_{oc} (V)	FF	η (%)	Ref.
Blue pea	0.63	0.60	0.50	0.19	This work
Blue pea	0.37	0.37	0.33	0.05	[12]

CONCLUSIONS

In this study, the dye-sensitized solar cell was fabricated using titanium dioxide (TiO_2) by doctor blade method. Natural dyes from blue pea dye extract had been characterized in term of optical characteristics and photovoltaic characteristics. Optical characteristics which include the result from UV-Vis absorption spectra shows the potential of blue pea dye to absorb a photon in visible light spectrum. The dye absorbs in the range of 500 nm to 680 nm at a maximum peak of 590 nm for both extract solvent of distilled water (BP-DI) and ethanol (BP-E). The present of the hydroxyl group in blue pea was proven by the existing of O-H stretches vibration. Due to the widely used photovoltaic technology nowadays, the DSSC have a potential to be commercialized in global as it is available everywhere, ease of fabrication and considered as a low-cost sensitization material production.

REFERENCES

[1] R. S. Shelke, S. B. Thombre and S. R. Patrikar. (2013). Status and Perspectives of Dyes Used in Dye-Sensitized Solar Cells, *International Journal of Renewable Energy Resources*, 3: 12-19.

[2] H. Hug, M. Bader, P. Mair and T. Glatzel. (2014). Biophotovoltaics: Natural Pigments in Dye-Sensitized Solar Cells, *Applied Energy*, 115: 216-225.

[3] S. Sahare, N. Veldurthi, R. Singh, A. K. Swarnkar, M. Salunkhe and T. Bhave. (2015). Enhancing the Efficiency of Flexible Dye-Sensitized Solar Cells Utilizing Natural Dye Extracted from Azadirachta Indica, *Materials Research Express*, 2(10): 105903.

[4] O' Regan B. and Gratzel M. (1991). A Low-Cost Efficiency Solar Cell Based on Dye-Sensitized Colloidal TiO_2 Films, 353: 737-740.

[5] R. Syafinar, N. Gomesh, M. Irwanto, M. Fareq and Y. M. Irwan. (2015). Cocktail Dyes From Blueberry and Dragon Fruit in the Application of DSSC, ARPN Journal of Engineering and Applied Sciences, 10(15): 6348-6353.

[6] A. Arunachalam, S. Dhanapandian, C. Monoharan, M. Bououdina and G. Ramalingam. (2016). Influence of Sprayed Nanocrystalline Zn-doped TiO2 Photoelectrode with the Dye Extracted from Hibiscus Surattensis as Sensitizer in Dye-Sensitized Solar Cell, Ceramics International, 42(9): 11136-11149.

[7] H. Chang and Y. J. Lo. (2010). Pomegranate Leaves and Mulberry Fruit as Natural Sensitizers for Dye-Sensitized Solar Cells, Solar Energy, 84(10): 1833-1837.

[8] I. C. Maurya, P. Srivastava and L. Bahadur. (2016). Dye-Sensitized Solar Cell Using Extract from Petals of Male Flowers Luffa Cylindrica L. as a Natural Sensitizer, *Optical Materials*, 52: 150-156.

[9] M. A. M Al-Alwani, A. B. Mohamad, A. A. H. Kadhum and N. A. Ludin. (2015). Effect of Solvents on the Extraction of Natural Pigments and Adsorption onto TiO2 for Dye-Sensitized Solar Cell Applications, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 138: 130-137.

[10] A. I. Babatunde, M. O John, C. Isanbor, M. A. Olopade, A. Appl and S. Res. (2012). The Development of Eco-Friendly Photoelectrochemical Solar Cell Using Extract of Lonchocarpus Cyanescens as a Natural Sensitizer Department, *Pelagia Research Library*, 3(5): 3230-3232.

[11] N. Gomesh, Z. Arief, R. Syafinar, M. Irwanto, Y.M Irwan, M. R. Mamat, U. Hashima and N. Mariun. (2014). Performance Comparison Between Dyes on Single Layered TiO2 Dye-Sensitized Solar Cell, *Advanced Materials Research*, 1008-1009: 78-81.

[12] K. Wongcharee, V. Meeyoo and S. Chavadej. (2007). Dye-Sensitized Solar Cell Using Natural Dyes Extracted from Rosella and Blue Pea Flowers, *Solar Energy Materials and Solar Cells*, 91: 566-571