Synthesis of Natural Dye Sensitizer Local for Dye-sensitized Solar Cell (DSSC) Application

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Abstract

The DSSC has been the attractive for third generation of photovoltaic. Natural dyes were synthesized from the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively. Molecules of natural dye were distilled from ethanol, butanol and acetonitite which are solvent. The concentration of natural dye were fixed by ratio of weight of natural dye powder: solvent volume (1 g:10 ml). Characteristic color and light absorption of natural dye were analyzed by digital camera and UV-vis spectroscopy (wavelength of 290 – 1100 nm). The complete cell was fabricated from the molecule of dye insert in porous TiO_2 working electrode (P25), electrolyte (iodide/tri-iodie liquid) and platinum (Pt) counter electrode, respectively. The photon light conversion to photocurrent was measured by solar simulator (under light intensity of 100 mW/cm^2, AM 1.5). Results, the characteristic color of natural dye show yellow, brown, green, light green and opaque white for the turmeric, saman bark, Bai-ya-nang, butterfly pea and black rice, respectively. Light absorption of Bai-ya-nang and the turmeric sensitizer can be seen higher than the saman bark, the Butterfly pea and Black rice, respectively for wavelengths of 500 – 700 nm. However, the maximum cell efficiency of 0.2% was achieved from the turmeric dye due to adhesion of turmeric dye with porous TiO_2 occurred several more than other natural dye. Although, absorption spectra of Bai-ya-nang dye obtains the highest but molecule cannot adhered with porous TiO_2. Our results show that this simple preparation of the natural dye local cab be applied as a dye sensitizer for DSSC.

Keywords: DSSC: Dye-sensitizer: Natural dye: Efficiency of DSSC

Introduction

The Dye-sensitized solar cell (DSSC) is a new generation of photovoltaic device. Remarkable feature of DSSC are simple fabrication, low cost materials and photo-current produce under less intensity light. Recent, the efficiency of DSSC research can be increased as high as 10 - 11% [1, 2].

The operating system of DSSC shows directly conversion of solar radiation into electric current. The working principle of DSSC is illustrated in Figure 1. The structural component of DSSC cell consists of the

porous TiO_2 working electrode, dye molecule adhered in TiO_2 layer, the counter electrode and liquid electrolyte, respectively. The operating principle of the DSSC is shown in Figure 1

In the operation, photon light energy is absorbed by electrons of molecule dye-sensitizer at lowest unoccupied molecular orbital (LUMO) state or ground state (process (1)). Electrons excited to the highest occupied molecular orbital (HOMO) state or excited state (process (2)). Electrons are injected to external circuit by electric filed as show in the Figure 1. On the other side, Re-oxidation reaction occurred between surface of the counter electrode and ion electrolyte liquid. DSSC can be produced a photo-current under less light intensity.

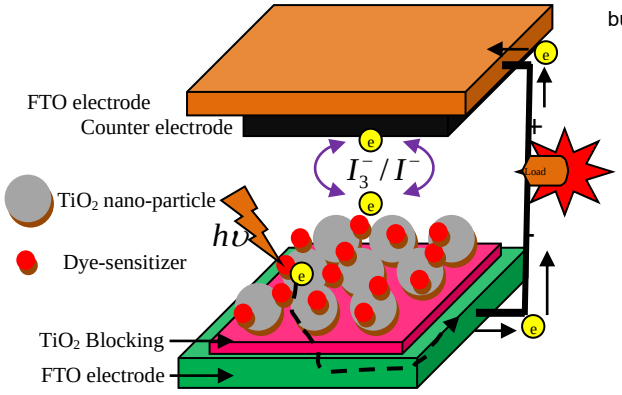


Figure 1 Structure and operation of DSSC

Advantage of the DSSCs used with dyes having heavy transition metal complexes such as ruthenium complex (N719) are the most efficient and operate with power efficiency as high as 11–12% using nanoporous TiO_2 electrodes [3, 4].

However, the major problem of DSSC research is high cost materials for dye-sensitizer synthesis. Research of natural dye sensitizer has been the attractive for new generation of DSSC [5-10]. This work, synthesis of natural dye was prepared from the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively.

Materials and Methods

A) Synthesis of natural dye-sensitizers

The natural dye-sensitizers were synthesized from the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively. These natural dyes were prepared from finely grind powder of the Turmeric, the Saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively dissolved in ethanol (purity 99.99%) solution and compared with butanal mixed acetone nitride solution. The condition of preparation of natural dye was fixed by the concentration ratio of dye-sensitizer of 1 g: 10 ml. The varies conditions were types of natural dye (the Turmeric, the Saman bark, Bai-ya-nang, the Butterfly pea and Black rice), fresh and dry of natural dye and the comparisons solvent between the ethanol and butanal mixed acetone nitride solutions, respectively.

Figure 2 Photography of natural dye-sensitizer which are (a) the Turmeric (b) the saman bark, (c) Bai-ya-nang, (d) the Butterfly pea and (e) Black rice, respectively.

B) Preparation of the TiO_2 working electrode and Cells assembly

The DSSC device was fabricated from the TiO_2 working electrode which consists of the porous titanium dioxide (TiO_2) layer coated with screen method on the dense TiO_2/FTO substrate. Then, the TiO_2 working electrode was sintered by furnace at 450°C. The TiO_2 working electrode was immersed in natural dye-sensitizer (the Turmeric, the Saman bark,

Bai-ya-nang, the Butterfly pea and Black rice) for 24 hours. The structural property of the TiO_2+dye/FTO electrode was analyzed by X-ray diffraction (XRD). Finally, the TiO_2 working electrode complete sandwich the Pt counter electrode and injected iodide electrolyte solution.

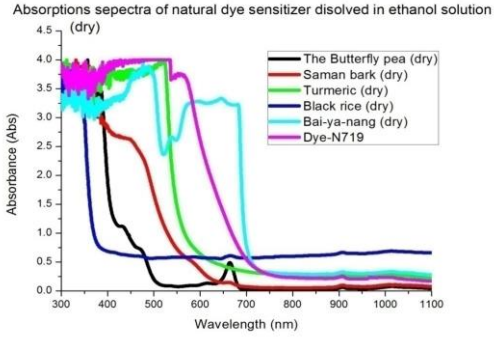
Two sides of the cell were glued together using Para films. Then, the electrolyte was injected into the cell. Finally, the photo-to-current conversion under standard AM 1.5 radiation (100 mW/cm^2) was measured.

C) Characterization tools

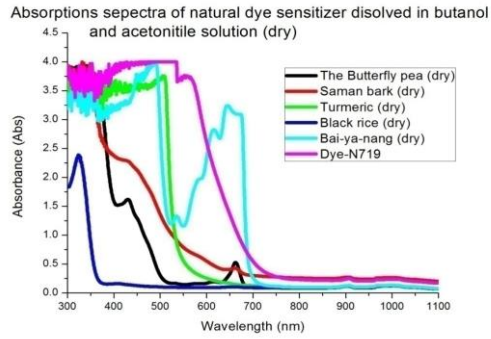
The light absorption spectra of natural dye were analyzed by UV-vis spectroscopy (wavelength of 290 – 1100 nm). The structural property was measured by XRD. The photo-to-current conversion was measured by solar simulator.

Results and Discussion

The natural dye solutions were measured by UV-vis spectroscopy (wavelength of 290 – 1100 nm). Light absorption spectra of Bai-ya-nang and the turmeric sensitizer can be seen higher than the saman bark, the Butterfly pea and Black rice, respectively for wavelengths of 500 – 700 nm as shown in the Figure 3.



(a)



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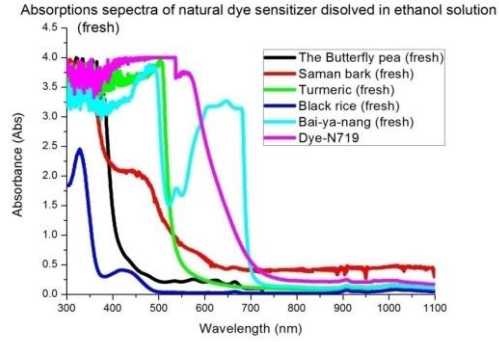
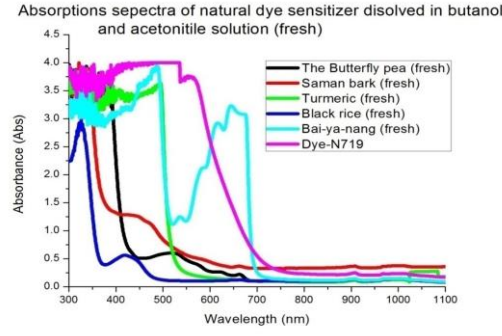


(c)



(d)

Figure 3 Absorption spectra of natural dye sensitizer solutions can be seen in the Figure (a), (b), (c) and (d) for dry material dissolve in ethanol, fresh material dissolve in ethanol, dry material dissolve in butanol and acetonitile, fresh material dissolve in butanol and acetonitile, respectively.

The XRD patterns showed that the as-deposited the TiO_2+dye/FTO electrode are crystalline as shown in the Figure 4. It can be seen from the XRD pattern that the film has crystalline quality. The plane (*hkl*) of FTO exhibits at (110), (200) and (211) respectively. A well-defined peak of FTO (110) at 2theta = 26.52º is observed. The planes explicitly of TiO_2/FTO substrate are (101), (200) and (211) which theses confirm the anatase TiO_2 phase. The XRD patterns of the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice on TiO_2/FTO substrate dissolve in ethanal shows characteristics as well as dissolve in butanal and acetonitile solution.

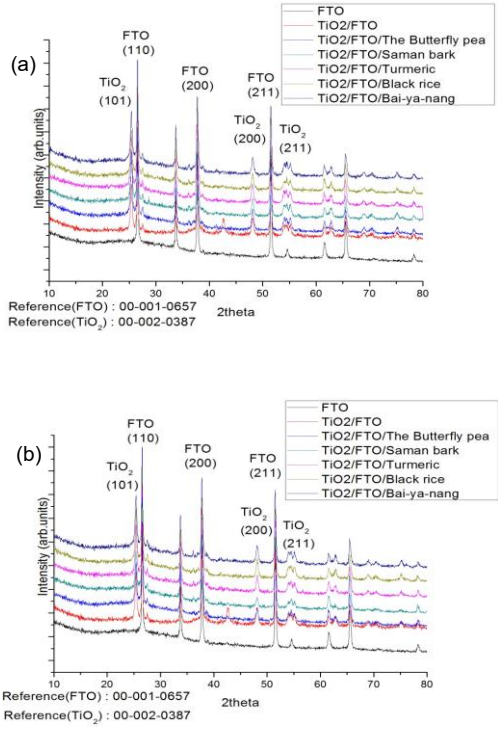


Figure 4 The XRD patterns of the TiO_2+dye/FTO substrate dissolve in (a) ethanol and (b) butanol mixed acetonitile solution.

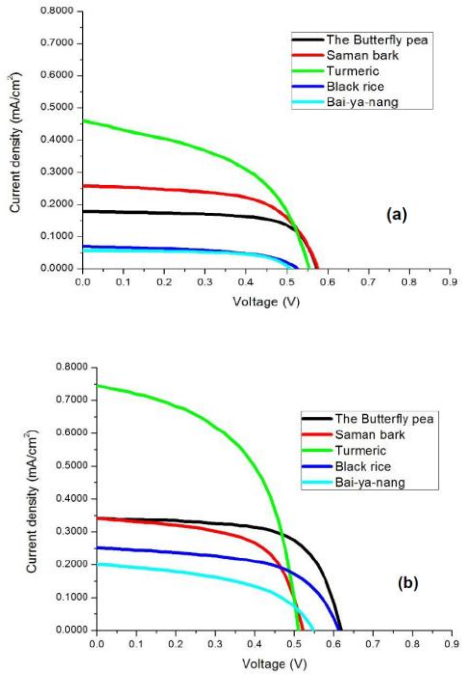


Figure 5 Photovoltaic curves (J–V) of the DSSC based on natural dye which is the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively.

The photovoltaic curves (J–V) of the DSSC based on natural dye which is the Turmeric, the saman bark, Bai-ya-nang, the Butterfly pea and Black rice, respectively is as shown in the Figure 5. It was found that, the current density of the Turmeric dissolve in ethanol has the highest as well as the Turmeric dissolve in butanol and acetonitile solutions as shown in the Figure 5 (a) and (b), respectively.

The photo-current parameters are the current density (Jsc), the open-circuit voltage (Voc), fill factor (FF) and efficiency (η). Table 1 indicates the current density (Jsc), the open-circuit voltage (Voc), fill factor (FF) and efficiency (η) for dry materials condition. The Butterfly pea obtains the current density (Jsc) of 0.1775 mA/ cm^2, the open-circuit voltage (Voc) of 0.602 V, fill factor (FF) of 0.67 and efficiency (η) of 0.0715%, respectively. . The Saman bark obtains the current density (Jsc) of 0.2576 mA/ cm^2, the open-

circuit voltage (Voc) of 0.578 V, fill factor (FF) of 0.61 and efficiency (η) of 0.0908%, respectively. The Turmeric has the current density (Jsc) of 0.4604 mA/cm^2, the open-circuit voltage (Voc) of 0.555 V, fill factor (FF) of 0.48 and efficiency (η) of 0.192%, respectively. It was found that, the Turmeric natural dye has highest the efficiency for dry materials condition.

Table 1 Photoelectrochemical parameters of natural dyes based DSSC for dry materials and dissolve in ethanol solution.

Natural dye	A (cm^2)	J_{sc} (mA/cm^2)	V_{oc}(V)	FF	η (%)
Butterfly pea	0.25	0.1775	0.602	0.67	0.0715
Saman bark	0.25	0.2576	0.578	0.61	0.0908
Turmeric	0.25	0.4604	0.555	0.48	0.1239
Black rice	0.25	0.0692	0.527	0.53	0.0192
Bai-ya-nang	0.25	0.0567	0.522	0.62	0.0184

Table 2 Photoelectrochemical parameters of natural dyes based DSSC for dry materials and dissolve in butanol mixed acetonitile solution.

Natural dye	A (cm^2)	Jsc (mA/cm^2)	Voc(V)	FF	η (%)
Butterfly pea	0.25	0.3404	0.622	0.65	0.1379
Saman bark	0.25	0.3405	0.522	0.59	0.1067
Turmeric	0.25	0.7449	0.516	0.53	0.2022
Black rice	0.25	0.2521	0.617	0.57	0.0889
Bai-ya-nang	0.25	0.2009	0.551	0.49	0.0537

The photo-current parameters are the current density (Jsc), the open-circuit voltage (Voc), fill factor (FF) and efficiency (η). Table 2 indicates the current density (Jsc), the open-circuit voltage (Voc), fill factor (FF) and efficiency (η) for fresh materials condition. The Butterfly pea obtains the current density (Jsc) of 0.3404 mA/ cm^2, the open-circuit voltage (Voc) of 0.622 V, fill factor (FF) of 0.65 and efficiency (η) of 0.13%, respectively. . The Saman bark obtains the current density (Jsc) of 0.3405 mA/ cm^2, the open-circuit voltage (Voc) of 0.522 V, fill factor (FF) of 0.61 and efficiency (η) of 0.11%, respectively. The Turmeric has the current density (Jsc) of 0.7449 mA/cm^2, the open-circuit voltage (Voc) of 0.516 V, fill factor (FF) of 0.59 and efficiency (η) of 0.20%, respectively. It was found that, the Turmeric natural dye has highest the efficiency for fresh materials condition.

Conclusions

The maximum cell efficiency of 0.2% was achieved from the turmeric dye due to adhesion of turmeric dye with porous TiO_2 occurred several more than other natural dye. Although, absorption spectra of Bai-ya-nang dye obtains the highest but molecule cannot adhered with porous TiO_2. Our results show that this simple preparation of the natural dye local cab be applied as a dye sensitizer for DSSC.

Acknowledgments

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