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Effect of Solvents on Natural Dyes Adsorption on the Surface of Tio_2 Film for Dye-Sensitized Solar Cell

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ABSTRACT

Recently scientific research efforts have been intensified to develop natural dyes for sensitizer's application because of its ability to convert the sunlight energy by dye-sensitized solar cells (DSSCs) devices to electricity. The extraction of chlorophyll from pandan leaves using different solvent such as ethanol, acetonitrile, ethyl-ether and n-hexane was investigated. Ethanol showed the best solvent according to the highest absorbance obtained. However, to improve the absorbance of TiO_2 as photoelectrode (TiO_2 coated with dye), chlorophyll was used with a ratio of ethanol to water 1:5. The highest absorption spectra of TiO_2 loaded by *Pandannus amaryllifolius* dyes increases with ethanol to water ratio of 2:1. This result expects good efficient of absorption of TiO_2 with dye for the future application in DSSCs devices to produce electricity under sunlight as the free source of energy.

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INTRODUCTION

The use of solar energy allows all parts of the world to exploit this energy. Solar energy is not environmentally friendly and cheap only, but also used as power that will exist for billions of years. Dye sensitized solar cell (DSSC) is one of the most promising devices for the conversion of visible light into electrical energy based on the sensitization of the wide band gap semiconductors (O'Regan, B. and M. Gratzel, 1991). In 1990, at the Ecole Polytechnique Federale de Lausanna (EPFL), Grätzel and his co-workers succeeded in developing a new type of solar cell, known as DSSC or Grätzel cell (Gratzel, M., 2003), this has attracted great interest due to their low cost, easy preparation and environmentally friendly especially that sensitized by natural dyes (Xu, S., 2011). The DSSC composed of nonporous semiconductor TiO_2 film-adsorbed dye (anode electrode), electrolyte and counter electrode (cathode electrode). When DSSC is exposed to sunlight, the dye absorbs the photons of sunlight and the electrons of dye excited from ground state to an excited state. The excited electrons injected to the conductive band of TiO_2 film. The electrons then transfer to the conductive electrode through the porous TiO_2 film (Alhamed, M., 2012; Hao, S., 2004)[2, 8]. The efficiency (η) of DSSC is determined mainly by the dye used as sensitizer (Chang, H., 2010).

Several organic, inorganic and hybrid compounds have been used as a sensitizers in DSSC (Ludin, N.A., 2014). The commercial synthetic ruthenium polypyridyl complexes are widely used as the sensitizers in DSSCs due to their highly photoelectric conversion efficiency that reached 11-12%. However, these dyes contain a heavy metal, which are expensive, limited in amount and undesirable from point of view of the environmental aspects (Noor, M.M., 2012; Shanmugan, V., 2013). Therefore, great attention in natural pigments that can replace commercial synthetic ones, which caused potential side effects (Boo, H.O., 2012).

Many natural dyes such as anthocyanin, carotenoid, flavonoid, chlorophyll, tannin and cyanin found in leaves, fruits, flowers, seeds, and bark that can be extracted by simple methods have been studied and tested as available and low cost materials (Park, K.H., 2013).The anchorage of the dye to the surface of TiO_2 film is an important parameter that determines the efficiency of DSSC (Khwanchit, W., 2006).

The dye must have carbonyl (C=O) or hydroxyl (-OH) groups capable of anchor on the nanoporous TiO_2 surface, and finally to ensure high rates of electron transfer (Li, C., 2010). Zhou, *et al*. (2011)] used different solvents such as water, ethanol, petroleum ether, chloroform, ethyl acetate and n-putanol to extract the dyes

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from the mangosteen pericarp. Their results showed different absorption spectra with solvents. As well as the photoelectrochemical performance for the extracted dyes with deferent solvents showed that the most effective component was rutin. The best effect for the solvents that using in extraction natural dyes utilized as a sensitizer in DSSC mainly attribute to the better interaction between the hydroxyl and carbonyl groups and the molecules of surface layer of nanoporous TiO_2 film (Aduloju, K.A., 2011).

MATERIALS AND METHODS

The leaves of *P. amaryllifolius* (pandan) were purchased from a local market in Bangi, Malaysia. Pandan leaves were dried for 24 hours in an oven (Thermo Electron Corporation, Heraeus) at temperature of 50°C then grind using a grinder (Mulry function disintegrator SY-04). A 10 gm of pandan leave's powder was flooded with 100 ml of different solvent (ethanol, acetonitrile, ethyl-ether and n-hexane) in 250 ml volumetric bottle at room temperature and kept in dark conditions for one week. Then the extracts were obtained using filter paper (NICE, 12.5cm, 102 Qualitative) and concentrated by rotary evaporator (Yamato RE 600) at 50 Cº for two hours.

RESULT AND DISCUSSION

The absorption spectra of extracts dye from pandan leaves using different solvents were compared as shown in Figure 1(a). The pandan leaves extract indicates that wide absorption range from 400 to 700 nm. The first absorption was broad level at 400-500 nm and the second from 575-700 nm with two main absorption peaks at the wavelength 417 and 660 nm. The highest absorption of extracts was by ethanol solvent with the strong of absorption of the visible region observed of main peaks. Absorbance peak of extracts dye shows almost closed to chlorophyll as reported earlier by previous studies (Kumara, G.R.A., 2006). The molecular structure of chlorophyll was very complicated as shown in Figure 1(b).

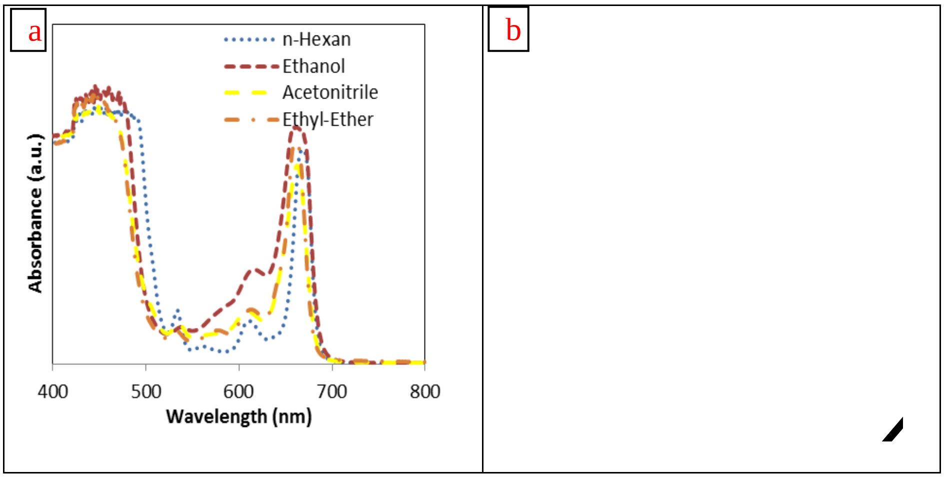

Fig. 1: The properties of chlorophyll (a) UV-Vis absorption spectra (b) chemical structure.

To study the effects of dye on the TiO_2 absorbance for the DSSC devices, the different ratio of ethanol to water with dye were used. The absorption spectra of dye with TiO_2 shows increasing with the ethanol to water up to ratio 2:1 compared to ethanol and other ratio as presented in Figure 2. This result may be attributed to a good solubility of dye and increase the polarity of the ethanol by adding the suitable amount of water as reported previously (Ba-abbad, M.M., 2012). These phenomena lead to the higher amount of dye adsorbed onto the TiO_2 surface which enhanced the absorption spectrum of dye with TiO2. Additionally, the ratio of ethanol and water was more than optimum (2:1) produces of higher polarity between the dye molecules and surface which the repulsing between them were increased (Ba-abbad, M.M., 2013). Higher absorbance of the optimum ratio sample is expected to produce good value of electricity by absorption of sunlight combined with DSSC devices.

Conclusion:

Chlorophyll dye was successfully extracted from leaves of *Pandannus amaryllifolius* using different solvents. The best solvent for extraction showed by ethanol for highest absorbance compare to be other solvent. A good improvement of TiO_2 absorbance with dye obtained by the ratio 2:1 of ethanol to water which attributed to high adoration of dye to TiO_2 surface.

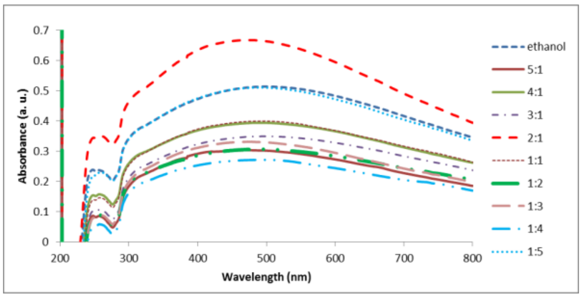

Fig. 2: Absorption spectra of *P. amaryllifolius* leave dye adsorbed on TiO_2 of different ethanol to water ratios.

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