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ABSTRACT ABSORPTION SPECTRUM ANALYSIS OF EXTRACTED NATURAL DYES USING DIFFERENT SOLVENTS FOR PHOTOVOLTAIC APPLICATION

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ABSTRACT

The third generation of photovoltaic technology uses organic and inorganic dyes, to generate photoexcited electrons, from which energy can be harvested. In dye sensitized solar cells (DSSCs), the dyes, which act as a sensitizer, harvest the sunlight and convert the solar energy to electrical energy. The usage of organic dyes was proposed as an alternative since it is a cheaper substitute, simple preparation methods and able to produce acceptable efficiency. This paper is aimed to investigate the absorption spectrum of extracted natural dyes of DSSCs by using different types of solvent; ethanol and deionized (DI) water. From the experiment, the relationship between the type of solvent used and the efficiency of the DSSCs to absorb more sunlight is investigated. Beside, the relationship between the extraction temperatures with its corresponding absorption spectrum is crucial to examine the optimum temperature for the dye. In this study, DSSCs were assembled by using extracted natural dyes from five different plants, which are Oxalis Triangularis, Roselle, Bawang Sabrang, Ardisia, and Mango using a very simple extraction technique. The extracted dyes were characterized using a spectrophotometer in the range between 400nm to 700nm. To find the optimum temperature of extracted dye, the dye is heated at different temperatures, which is room temperature, 50°C, 75°C and 100°C. In DI water solvent, the absorption peak of Bawang Sabrang is about 400nm while for Roselle is about 500nm. As for Ardisia and Oxalis Triangularis, it found that the peak absorption is at 550nm. Plus, the absorption peak of Mango is about 450nm. The absorption peak of Bawang Sabrang in ethanol is about 400nm while for Roselle is about 530nm. For Ardisia, the absorption peak is about 540nm. Plus, the absorption peak of Mango and Oxalis Triangularis is about 450nm and 420nm respectively. Besides, the temperatures also affect the efficiency and stability of DSSCs. From the experiment that has been conducted, most of the extracted dye in DI water solvent at temperature 50°C, shows the highest peak of absorption spectrum. While in ethanol solvent, the highest peak of absorption spectrum is at 100 °C.

Keywords: dye sensitize solar cell, anthocyanin, extracted dye, absorption spectrum, varied solvents.

INTRODUCTION

Overdependence on fossil fuels leaves us vulnerable to air pollutants, and related health risks and global warming due to the increased of green-house gas concentration. Therefore, a step forward in the pursuit of alternative energy sources is the harness of energy from carbon-free sources such as wind, geothermal, and solar energy. Photovoltaic technology is divided into three generation technologies that are based on different material and properties. Generally, in the 1st generation of photovoltaic cells, the electric interface is made between doped n-type and p-type bulk silicon while the 2nd generation PV cells are based on thin film technology. These cells utilize less material and they thus drop the production cost, however, they are less efficient than the bulk cells.

However, the 3rd generation solar cells, are based on nanostructure (mesoscopic) materials and they are made of purely organic or a mixture of organic and inorganic components [1]. Natural dyes provide a practical alternative to expensive organic based DSSCs. Plant pigmentation occurs due to the electronic structure of the pigment interacting with sunlight to alter the wavelengths that are either transmitted or reflected by the plant tissue. Anthocyanins, proanthocyanidins and flavonols are three major subclasses of flavonoid compounds. Anthocyanins from various plants give different sensitizing performances.

The advantage of anthocyanin is the binding of carbonyl and hydroxyl groups to the surface of a porous TiO_2 film. This causes electron transfer from the anthocyanin molecule to the conduction band of TiO_2 [2]. The objective of this research paper is to investigate the absorption spectrum of extracted natural dyes of DSSCs by using different type of solvent and to study the relationship between the temperature of the extracted dye with the absorption spectrum.

EXPERIMENTAL PROCEDURES

Preparation of extracted dye

Ardisia, Bawang Sabrang, Roselle, Mango and Oxalis Triangularis were freshly harvested from Institute Agrotechnology UniMAP. Each of the fruits is then weigh to 1g and crushed in a mortar and pestle before dissolved in 10mL of deionized water and ethanol, respectively. The temperature is fixed at room temperature.

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Preparation of TiO_2 paste

About 3g of TiO_2 is grinded in a mortar and pestle with 9mL nitric acid solution (0.1M) in increment, and one drop of nonionic surfactant Tixton-100. Alternate grinding and a few drops of nitric acid is added until a colloidal suspension with a smooth consistency is obtained, somewhat like latex paint cake icing. A small amount of TiO_2 paste is added and the thin layer is spread quickly using a glass. The sample is then baked at temperature 450 °C at duration from 10 minutes to 20 minutes. The surface turns browns as the organic solvent and surfactant dries and burns off to produce a color sintered of TiO_2 coating. The glass is allowed to cool down slowly by dropping the temperature to 50°C to 70°C.

Characterization and measurement

Ultraviolet-visible (UV-Vis) spectrophotometer is used for measure the absorption spectrum of each dye with different solvent. The wavelength range is taking from 300nm to 700nm.

Varying the temperature

The dye is extracted at different temperature by using a hot plate. The temperature is varied at room temperature, 50°C, 75°C and 100°C. The absorption spectrum of each dye is measured in UV Vis spectrophotometer.

RESULTS AND DISCUSSION

Scanning Electron Microscope (SEM)

Scanning electron microscopy (SEM) shows that the surface morphology of the film TiO2 consist of homogeneously distributed rod shaped particles. It can be said that the TiO_2 is an anatase and SEM studies indicate that electron transport is slower in the rutile layer than in the anatase layer due to differences in the extent of inter-particle connectivity associated with the particle packing density [9]. Figure-1 shows the clearer image of porous film structure of TiO_2 with 30k magnification. The basic goal in films preparation is the high surface area of the inorganic semiconductor particles in order to achieve high amounts of dye adsorbed on it.

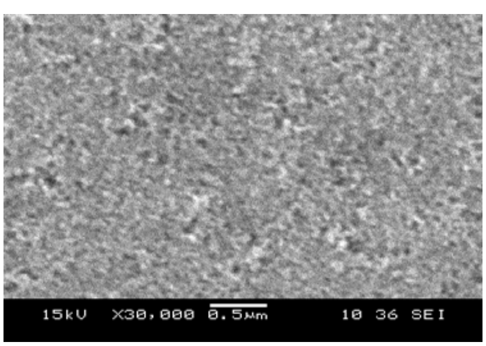

Figure-1. Scanning electron microscopy (SEM) analysis of TiO_2 film structure.

X-Ray diffraction (XRD) pattern

The structure of the synthesized material was characterized by an X-ray diffractometer. XRD measurements were performed on the Bruker D2 Phaser to determine the crystal structure. The data is extracted from the diffraction evaluation package software. From the graph, it shows that the peak of TiO_2 sample is at 4500 counts. XRD patterns of nanoparticle TiO_2 in rutile and anatase phases are shown in Figure-2. In Figure-2, XRD patterns exhibited strong diffraction peaks at 27°, 36° and 55° indicating TiO_2 in the rutile phase. On the other hand, XRD patterns exhibited strong diffraction peaks at 25°, 35° and 48° indicating TiO_2 in the anatase phase.

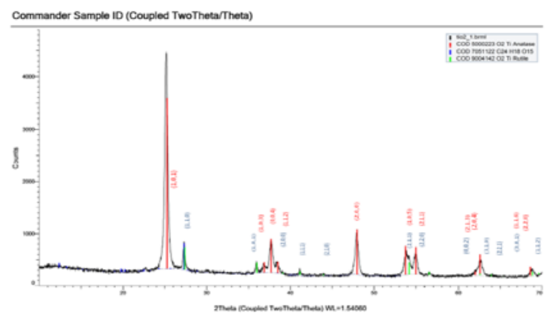

Figure-2. X-ray diffraction pattern of TiO_2 films.

Absorption spectrum

Figure-3 shows the absorption spectra of Ardisia, Bawang Sabrang, Roselle, Mango and Oxalis Triangularis in DI water. The absorption spectrum of the sample is obtained by using UV-Vis spectrophotometer. From the pattern of the graph, the absorption peak of Bawang Sabrang is about 400nm while for Roselle is about 500nm. As for Ardisia and Oxalis Triangularis, it found that the peak absorption is at 550nm. Plus, the absorption peak of Mango is about 450nm. The result for the absorption spectrum of extracted dye of Roselle is similar to the result was found for extracted rosella and blue pea that has been reported by Wongcharee *et al.* As shown in the graph, each of the dye gives different absorption characteristic. This is due to different type of anthocyanins and the color of extracted dye adverse.

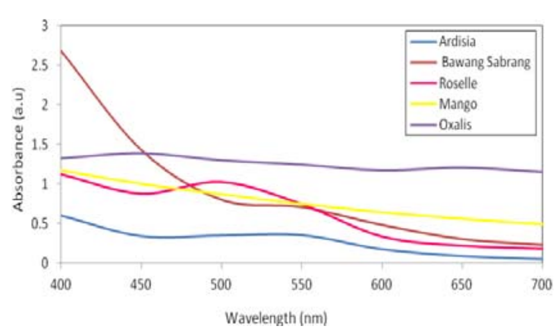

Figure-3. The absorption spectrum of extracting dye in distilled water.

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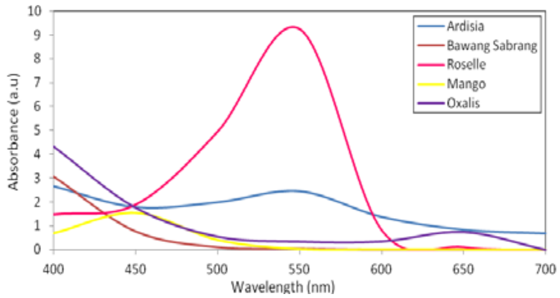

Figure-4. The absorption spectrum of extracting dye in ethanol

Figure-4 shows the absorption spectra of Ardisia, Bawang Sabrang, Roselle, Mango and Oxalis Triangularis in ethanol. From the graph, it can be said the absorption peak of Bawang Sabrang is about 400nm while for Roselle is about 530nm. While for Ardisia, the absorption peak is about 540nm. Plus, the absorption peak of Mango and Oxalis Triangularis is about 450nm and 420nm respectively. As shown in the graph, each of the dye gives different absorption characteristic. This is due to different type of anthocyanins and the color of extracted dye. Moreover, Ardisia and Roselle shows the highest absorption peak due to their dark color. Result shown in the Figure-4 prove that the presence of anthocyanin in the fruit sample which is core composition for natural dye in DSSCs.

Absorption spectrum of stained TiO_2

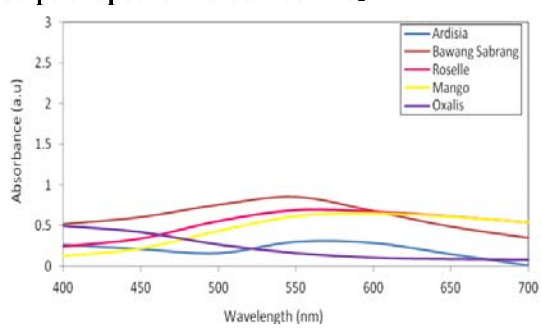

Figure-5. Absorption spectrum of stained TiO_2 in DI water

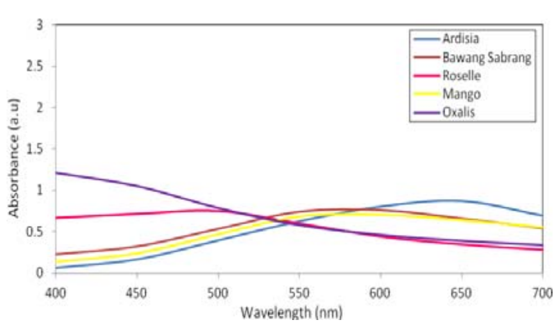

Figure-6. Absorption spectrum of stained TiO_2 in ethanol

Figure-5 and Figure-6 shows the result of absorption spectrum of TiO_2 immersed in extracted dye of different solvent. In the case of Roselle extract, the absorption peak of TiO_2 is lower compared to dye solution. Besides, the TiO_2 changed to purple color after being immersed in Roselle solution. It indicating that absorption had occurred between the film and the extracted dye. The difference in the absorption peak is due to the binding of anthocyanin the extract to the oxide surface [3].

Absorption spectrum of extracted dye at various temperature

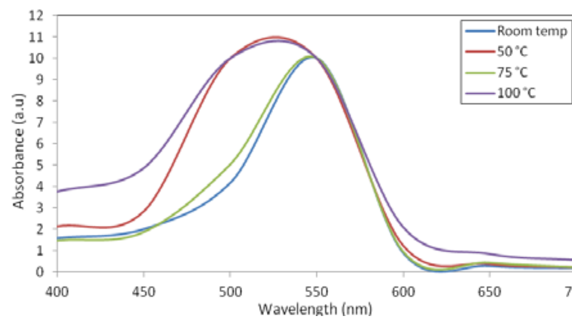

Figure-7. The absorption spectrum of Roselle in DI water at various temperature.

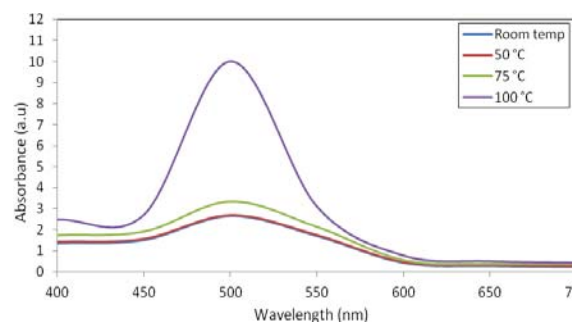

Figure-8. The absorption spectrum of Roselle in ethanol solvent at various temperature.

In Figure-7 and Figure-8, both show the absorption spectrum of Roselle in DI water and ethanol solvent at various temperatures. From Figure-7, Roselle in DI water shows the highest absorption peak at temperature 50 °C while in ethanol solvent, it shows that at temperature 100 °C the absorption peak is the highest compared to other temperature. It found that Roselle have peak absorption at 500nm. Besides, it can be said that the optimum extracting temperature of dye for DSSC's operation is from 50 °C to 100 °C.

CONCLUSIONS

As a conclusion, each of the extracted dye shows a various absorption spectra in different solvent. In extracted dye of Roselle, the absorption spectrum in DI water and ethanol solvent is 530nm. Besides, the peak of absorption spectrum in ethanol is higher compared in DI water. Plus, according to Wongcharee *et al.* the efficiency of ethanol system was found to be diminished after being exposed to the simulated sunlight for three hour while there was only a slight decrease in the efficiency for the case of using water as an extract solvent. This might be due to the photocatalytic decomposition of anthocyanin by TiO_2 in the presence of ethanol as observed by the color of the anode to become paler after exposed to the simulated sunlight. It can be said that ethanol affect the performance of DSSCs in term of stability.

Moreover, the temperatures also affect the efficiency and stability of DSSCs. From the experiment that has been conducted, most of the extracted dye in DI water solvent at temperature 50 °C, shows the highest peak of absorption spectrum. While in ethanol solvent, the highest peak of absorption spectrum is at 100 °C.

It is proven by Kelvin Alaba Aduloju et.al, which state that the optimum extracting temperature of dye for DSSC's operation is 50 °C which lies between the room temperature and the boiling point of water. Plus, it is proven that the highest efficiency of 0.51% was obtained from the device sensitized with dye solution extracted at 50 °C. One of the reasons for this could be due to the highest amount of dye absorbed onto the TiO2 film compared with other dyes obtained at different temperatures. However, the efficiency will gradually decrease as the extracting temperature of the dye increases. This fall could be due to a decrease in the stability of anthocyanin

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