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Study on the Preparation Dye-Sensitized Solar Cell Based on TiO_2-*Nanotube* Sensitized Natural Dye Chlorophyll from Suji Leaf (*Pleomele angustifolia*) Optimized by Cocktail Dyes

Kezia, Jarnuzi Gunlazuardi

Departemen Kimia, Fakultas Matematika dan Ilmu Pengetahuan Alam (FMIPA)
Universitas Indonesia, Depok 16424, Indonesia
Email: kezia@ui.ac.id

Abstract

Dye-sensitized solar cell (DSSC) is a device that can convert the sunlight to electrical current by employing dyes coated semiconductor as working electrode and FTO (Fluorine Tin Oxide) glass as counter electrode. TiO_2 thin film was prepared by anodization of Ti plate in NH_4F/glycerol at potential 25 volt for 4 hours and heated at 450^oC for 2 hours. Characterization by DRS UV-Vis and FTIR showed that the TiO_2 is in anatase crystal phase. Dye that was used as *photosensitizer* were natural dyes extracted from suji leaf, carrot and green-blue algae (*Spirulina platensis*) as chlorophyll, β-carotene and phycocyanin. Optimization was done by modified the chlorophyll added by β-carotene and phycocyanin (cocktail dyes) with ratio 1:1 and 1:2. Dyes was coated into TiO_2-*nanotube* by using electrophoresis method at 20 volt for 12 minutes. The strongest visible absorption of light was shown in the electrophoresis sample using a natural 1: 1 chlorophyll-phychocyanin dye.

Keywords: dye-sensitized solar cell, TiO_2, nanotube, natural dyes, anodization, electrophoresis

Introduction

Solar energy is an alternative source of potential energy and abundant, but often overlooked. As a country located on the equator line, it causes Indonesia to receive enormous amount of sun exposure, so solar cell power is very good to be developed in Indonesia as an alternative energy source. By using solar cells, solar energy can be converted into electric currents that can replace fossil fuels.

Nowadays, new generation solar cells have been developed that are cheaper and easier to make, namely Dye Sensitized Solar Cell (DSSC). Unlike the conventional solar cell working principles, the DSSC uses a simple electrochemical principle to capture solar energy which is subsequently converted to electrical energy.

Currently, the use of organic dyes is the concern of researchers in the world. This is because the variety of pigment content contained in plants in the world, whether it comes from leaves, flowers, fruit, or roots, can be used as a dyes on the DSSC. With the diversity of pigments derived from leaves, flowers, fruits, or roots of a single plant, the variety of dyes that can be obtained for DSSC development.

Materials and Method

Preparation TiO_2-Nanotube

The Ti plate was cut to the same size then sanded with abrasive paper (500, 1000, 1500, 2000 cc). To obtain a fresh surface, the plates were placed on the ultrasonic cleaner in acetone, ethanol, and water each for 24 minutes. The plates were dried by heating in the oven, anodization process (as electrolyte was 0.4 M NH_4F solution in ethylene glycol, with a given potential of 25 V). Anodizing process was done for 4 hours. Then the plate was washed and calcined at 450^oC for 2 hours.

Dyes Extraction

5 grams of suji leaves was destroyed into small size with mortar. 30 mL of ethanol was added to the suji leaves and was placed on the ultrasonic cleaner for 16 minutes. Solution was centrifuged for 25 minutes. Filtrate was filtered using filter paper.

Carrots are washed and roughly shredded. 5 grams of carrots weighed then added 30 mL of ethanol, macerated for 24 hours. β-carotene solution was filtered using a filter paper.

Spirulina platensis powder sample weighed 10 grams. The sample was added 60 mL of water. Solution was stirrer for 1 hour without heat treatment. Solution was placed on the ultrasonic cleaner for 16 minutes and macerated for 24 hours. After 24 hours, phycocyanin was centrifuged for 25 minutes. The results of centrifugation were filtered using filter paper. The wavelengths of each dye were measured by UV-Vis. The Color substance adsorption electrophoresis process was performed on Ti/TiO_2-nanotube film.

Result and Discussion

Absorbance of extracted natural dyes shown in Figure 1.

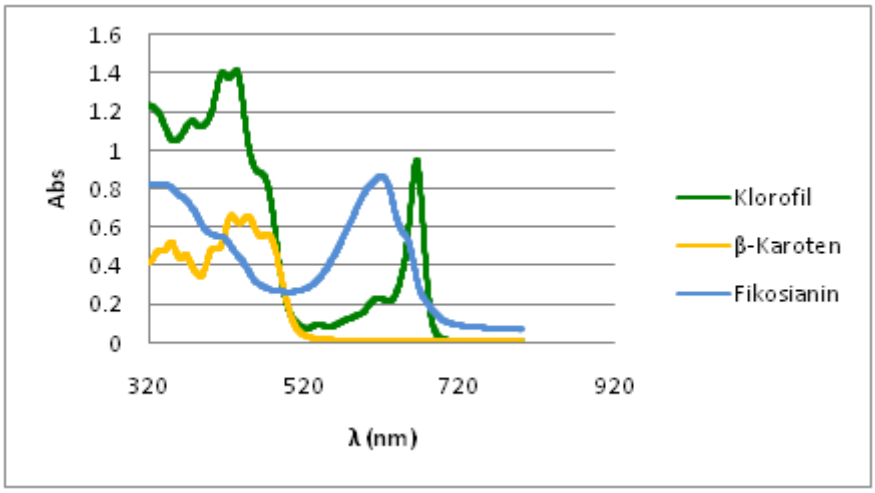

Fig. 1. Wavelength of extracted natural dyes using UV-Vis

Figure 1 shows the absorption area of the three dyes: chlorophyll, β-carotene, and phycocyanin corresponding to their respective absorbent regions in the literature. In addition, we can know that β-carotene has an absorption area in the chlorophyll area, whereas phycocyanin has an absorption region flanked by chlorophyll absorption area.

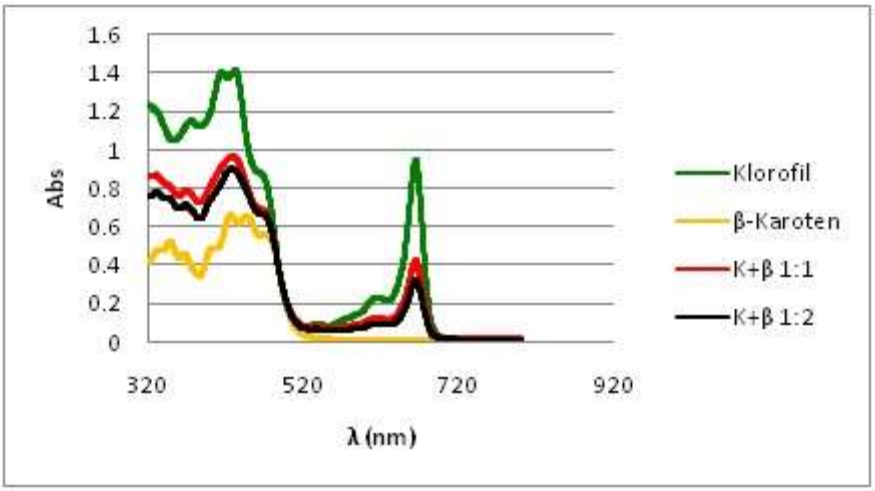

Fig. 2. Wavelength of chlorophyll-β-carotene cocktail dyes

Figure 2 shows that mixing of chlorophyll and β-carotene decreases the peak characteristic of the intermittent uptake of chlorophyll by increasing the amount of β-carotene in cocktail dyes.

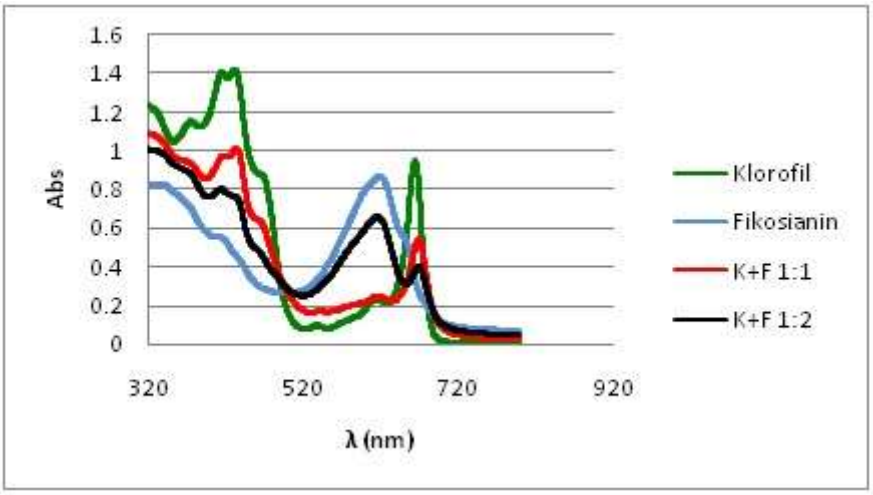

Fig. 3. Wavelength of chlorophyll-phycocyanin cocktail dyes

Figure 3 shows that cocktail dyes 1:1 chlorophyll-phycocyanin decreases the chlorophyll chart characteristic without expanding the chlorophyll absorption area in the phycocyanin absorption area. Meanwhile, in cocktail dyes 1:2 chlorophyll-phycocyanin, it is seen that there is expansion of absorption area in phycocyanin absorption area. This explains that cocktail dyes of 1:2 chlorophyll-phycocyanin has wider absorption areas as expected.

UV-DRS result of TiO_2-nanotube/dyes

In Figure 4 the results are different from each other. Each modified TiO_2-nanotube plate with natural dyes in this study showed a reflectant decrease. However, the plate modified with chlorophyll and 1:1 chlorophyll-β-carotene has not been absorbed in the visible wavelength region. Meanwhile, the plate with modification of the addition of 1: 2 chlorophyll-β-carotene, 1:1 chlorophyll-phycocyanin, and 1:2 chlorophyll-phycocyanin showed absorption in the visible wavelength region with the lowest % R given by the TiO_2-nanotube modified with the addition of 1: 2 chlorophyll-β-carotene.

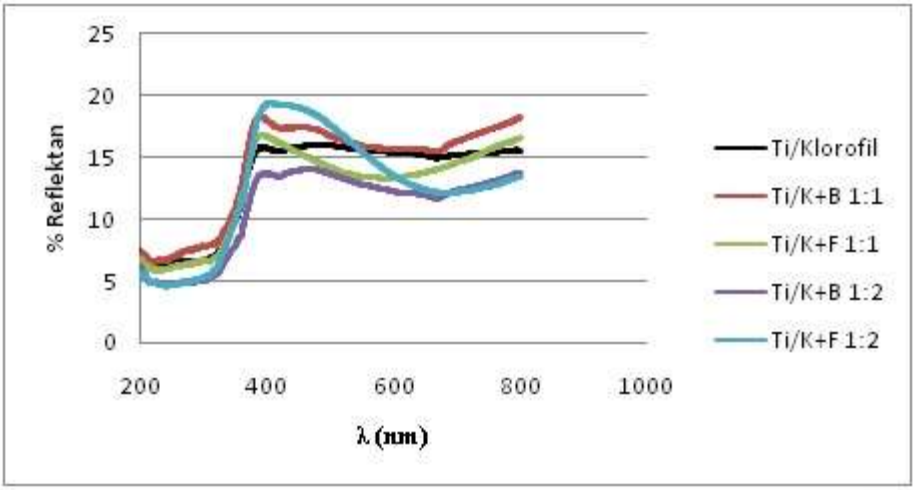

Fig. 4. UV-DRS spectrum plate TiO_2-nanotube/dyes

Table 1. UV-DRS spectrum summary of TiO_2-nanotube/dyes

Dyes	λ minimum	% R
Klorofil	669	14.931
K+B 1:1	666	15.442
K+F 1:1	586	13.307
K+B 1:2	668	11.679
K+F 1:2	689	12.125

The UV-DRS spectrum of TiO_2-nanotube/dyes samples with various dyestuffs are summarized in Table 1. Wavelength shift towards the visible (red shift) area due to the dyestuff having binds to TiO_2 and resulted in the destabilization of the HOMO and LUMO orbitals. The strongest visible absorption of light was shown in the electrophoresis sample using a natural 1: 1 chlorophyll-phychocyanin dye.

Conclusion

It has been successfully extracted natural dyes used as photosensitizers of suji leaves, carrots and blue-green algae powder (Spirulina platensis) and wavelength measurements corresponding to chlorophyll, β-carotene and phycocyanin using UV-Vis. Natural colorant is superimposed on the surface of TiO_2-nanotube by

electrophoresis method for 12 min at 20 volts potential. The strongest visible absorption of light was shown in the electrophoresis sample using a natural 1: 1 chlorophyll-phychocyanin dye.

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