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Performance Of Pandan Leaf Pigment For Dye Sensitized Solar Cell (Dssc): Effect Of Dye Extraction Temperature

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***Abstract*—In Dye Sensitized Solar Cell (DSSC), the dye sensitizer plays the key role. Dye-sensitizer embedded in TiO_2 will be able to absorb visible light up to approximately 800 nm and the energy conversion efficiency increase. In this study provides performance of pandan leaf pigment for Dye Sensitized Solar Cell (DSSC). The dye from pandan leaf pigment was extracted using distilled water solvent with various temperature, then investigated the absorption spectrum using UV-Vis spectroscopy. The extracted dye was adsorbed onto the surface of TiO_2 based on Fourier Transform Infrared Spectroscopy (FTIR) analysis. The inhibition of crystallinity of TiO_2 was investigated by X-ray analysis.**

Keywords — Dye Sensitized Solar Cell; Dye Extraction Temperature

I. INTRODUCTION

Among possible sources of clean energy in the future is solar cell. It is device that directly converts the light into electrical energy. Previously, solar cell based on silicon has high efficiency but the fabrication more complicated and expensive. In the year 1991, Gratzel proposed the concept of Dye Sensitized Solar cell (DSSC) [1]. The DSSC has attracted considerable attention because it has a lot of advantages compare silicon based. This covers simple preparation procedure, environmental compatibility, low cost production, and good performance under diffuse light condition. DSSC consists of a transparent conducting glass electrode with a porous layer of wide band gap semiconductor, such as TiO_2 coated with a dye that serves as light sensitizer, an electrolyte layer, and a counter electrode, typically coated with graphite or platinum [2][3][4].

Important aspects for DSSC reside in increasing the photon collection efficiency over a broad spectrum of wavelengths in the visible regime and in retarding the charge recombination process [5][6]. The photon collection is first step in procces of solar energy harvesting, and a dye sensitizer plays the key role [7]. The absorption of light in the DSSC is achieved through dye-sensitizer embedded in semiconductor such as TiO_2. The dye converts photons into excited electrons, which facilitate current flow. The higher capture of photons, will increase efficiency of solar energy conversion. The dye molecules that are adsorbed on the surface of mesoporous semiconductor layer absorb the incident photons and gets excited. These excited dye molecules injects an electron into the conduction band of the mesoporous photoanode network and the dye molecules that loose an electron gets oxidized [8]. These injected electrons travel through the semiconductor layer to the external load to reach the counter electrode. The dye should possess these following requirements such as having a strong absorption in the visible light spectrum, carry a suitable attachment of the chemical group to be bound with semiconductor and can inject the electrons into a semiconductor surface [9].

The dye sensitizer contains synthetic dye and organic dye. Organic dye available fruits, flowers, leaves, bacteria etc exhibit various colors and contain several pigments that can be easily extracted and employed in DSSC [10]. Advantages of employing these organic dyes as photosensitizers in DSSC are due to their large absorption coefficients invisible region, relative abundance, ease of preparation and environmental friendliness [11][12]. Pigments from organic dyes include chlorophyll, carotenoid, flavonoid and anthocyanin that are relatively easy to extract from plants when compared to synthetic dyes [13][14]. Chlorophyll extracted from spinach with distilled water has region of the visible light spectrum in the range of 400 to 720 nm, and the photo electrochemical parameter for DSSC showed the open circuit voltage (Voc) of 440 mV, current short circuit (Isc) of 0.35 mA and a fill factor (FF) of 0.49 [15]. The absorbance of chlorophyll from Cordyline fruticosa and Pandannus amaryllifolius pigments show a broad range of wavelength frequency between 410 nm and 700 nm, which is located within the visible range, and with three main peaks located at 530, 605, and 660 nm [16].

The extraction yields of chlorophyll were significantly influenced by type of leaf, extraction time, extraction pressure, extraction temperature and concentration of cosolvent [17]. In this study provides performance of pandan leaf pigment extraction with various temperature for produce extraction yields optimally. The extraction yields as organic dye was investigated the absorption spectrum using UV-Vis spectroscopy. The dye was adsorbed onto the surface of TiO_2 based on Fourier Transform Infrared Spectroscopy (FTIR) analysis. The inhibition of crystallinity of TiO_2 was likewise investigated by X-ray analysis. The parameters are seen to ensure that the pandan leaf pigment has good potential a requirement standard as DSSC material.

II. Materials And Methods

A. *Dye and Its Properties*

Pandan is a genus of monocots with some 750 accepted species. They are palm-like, dioecious trees and shrubs native to the old world tropics and subtropics. Common names include pandan, screw palm, and screw pine. They are classified in the order Pandanales, family Pandanaceae.

The dye identified in the present work is natural extract from leaves of Pandan plant (Pandan amaryllifolius) found abundantly in East Java, Indonesia. The dye obtained from the leaves of this plant is deep green. Fig. 1 shows the plant with green leaves, used in this present work. This green leaves contains chlorophyll that responsible for photosynthesis proses.

Fig. 1. The Plant of Pandan

B. *Preparation of Natural Dye*

50 gr of pandan leaves are washed with distilled water then crushed using mortar into fine powder. Subsequently, the samples of the powdered leaves were devided 5, each 10 gr of pandan leaf powders were placed into 150 ml of distilled water solvent and mixed using stirrer with speed 300 rpm for 2 hour at various temperature (25^0 C, 35^0 C, 50^0 C, 70^0 C, 95^0 C). The all samples of solutions were kept for 5 hours at room temperature under dark condition. Solid residues were filtrated with a filter paper to produce natural dye.

C. *Preparation of Dye-TiO$_2$ Mixed*

The each samples were mixed with TiO$_2$ powder (supplied from MERCK). The solutions were kept for 5 hours at room temperature under dark condition. The TiO$_2$ particles that adsorbed dye were filtrated with a filter paper and were dried by desiccator.

D. *Characterization*

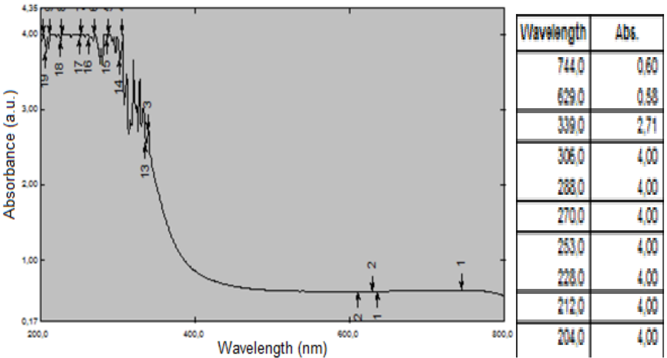
The light absorption spectrum of dye was investigated using UV-Vis spectroscopy. The adsorbtion of dye onto the TiO$_2$ particles was investigated using FTIR. The crystal phase composition of the TiO$_2$ nanoparticles was determined by XRD.

III. Results And Discussion

A. *UV-Vis Analysis*

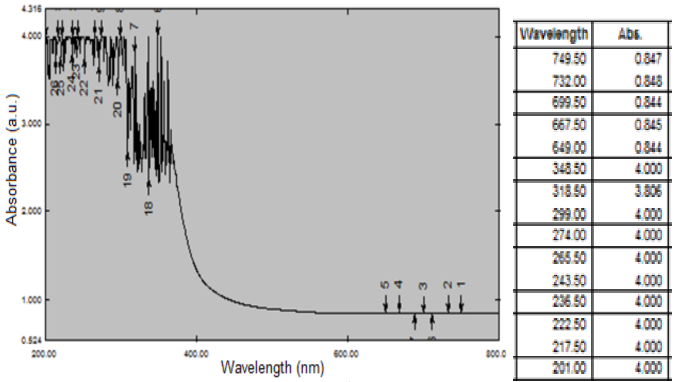
Fig. 2 shows the absorbtion spectra of Pandan leaves extracted by various extraction temperature. The extraction condition that produce the highest absorbance were 35^0 C. The absorbance decreased with extraction temperature less than or over than 35^0 C.

The optimal extraction was done at temperature of 35^0 C. Extraction of natural dye needs heat energy, similar results were observed during the extraction of chlorophyll from green tea leaves[17]. But if the extraction temperature more than 35^0 C showed the spectrum absorbance decrease. It shows the degradation of chlorophylls happened. It similar result were observed the degradation of chlorophylls in green peas [18].



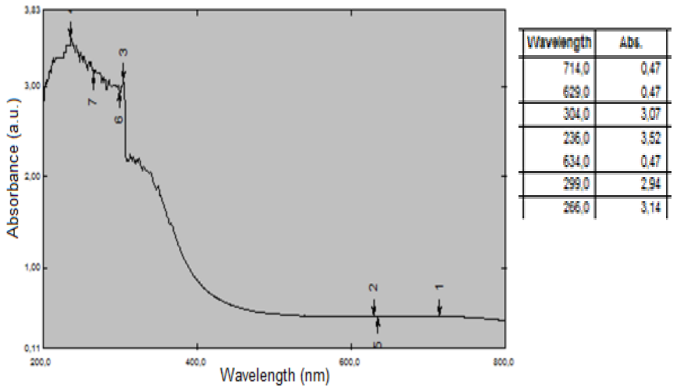
Wavelength	Abs.
744,0	0,60
629,0	0,58
339,0	2,71
306,0	4,00
288,0	4,00
270,0	4,00
253,0	4,00
228,0	4,00
212,0	4,00
204,0	4,00

Fig 2a. UV-Vis Spectra of 25^0 C Dye Extraction temperature



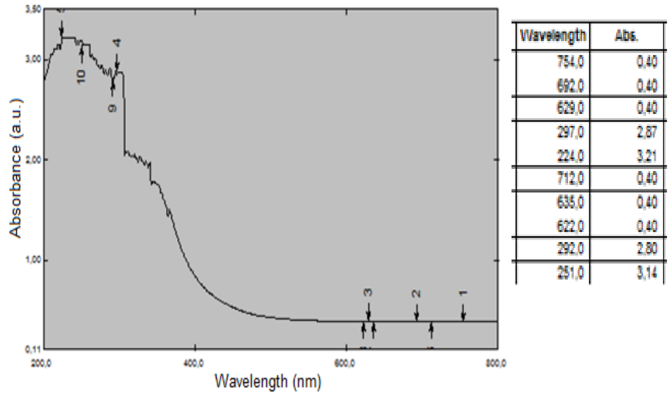
Wavelength	Abs.
749.50	0.847
732.00	0.848
699.50	0.844
667.50	0.845
649.00	0.844
348.50	4.000
318.50	3.806
299.00	4.000
274.00	4.000
265.50	4.000
243.50	4.000
236.50	4.000
222.50	4.000
217.50	4.000
201.00	4.000

Fig 2b. UV-Vis Spectra of 35^0 C Dye Extraction Temperature



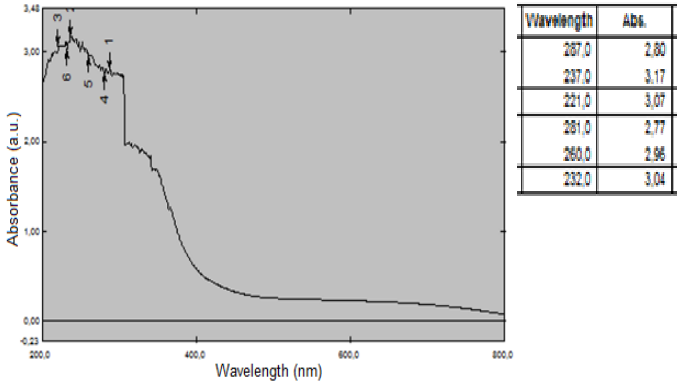
Wavelength	Abs.
714,0	0,47
629,0	0,47
304,0	3,07
236,0	3,52
634,0	0,47
299,0	2,94
266,0	3,14

Fig 2c. UV-Vis Spectra of 50^0 C Dye Extraction Temperature



Wavelength	Abs.
754,0	0,40
692,0	0,40
629,0	0,40
297,0	2,87
224,0	3,21
712,0	0,40
635,0	0,40
622,0	0,40
292,0	2,80
251,0	3,14

Fig 2d. UV-Vis Spectra of 70^0 C Dye Extraction Temperature

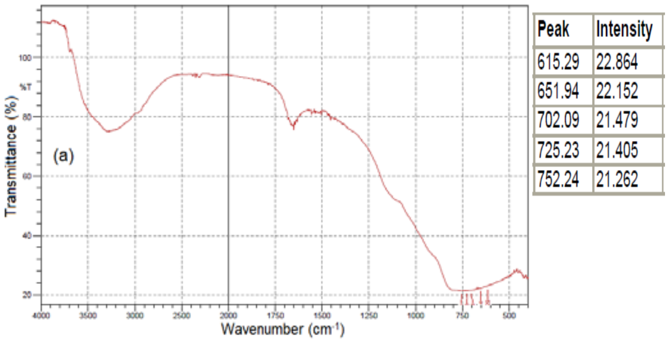


Wavelength	Abs.
287,0	2,80
237,0	3,17
221,0	3,07
281,0	2,77
260,0	2,96
232,0	3,04

Fig 2e. UV-Vis Spectra of 95^0 C Dye Extraction Temperature

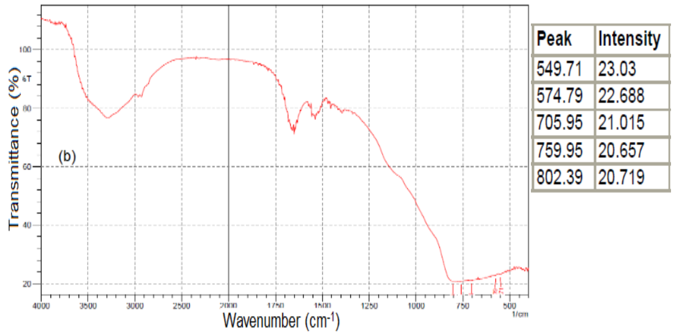
B. *FTIR analysis*

Fig. 3. shows the structure of dye-TiO_2 mixed is confirmed by its FTIR spectra. Various temperature were used for finding an optimal extraction. All shows almost similar structures of functional group position. Wave number between 500 – 750 cm^{-1} show similar structure due to wavelength absorbance of the Ti-O-Ti group. The optimal adsorption of dye onto TiO_2 observed in extraction temperature of 35^0 C as indicated by more and shaper peaks of functional group position at wavenumber between 1400 - 1750 cm^{-1} due to wavelength absorbance of the OH, C=C and C=O group of organic dye.



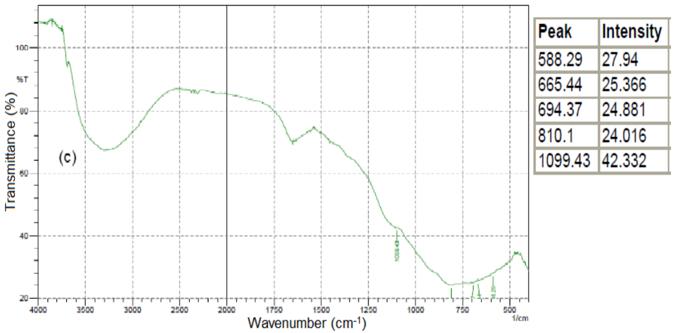
Peak	Intensity
615.29	22.864
651.94	22.152
702.09	21.479
725.23	21.405
752.24	21.262

Fig 3a. FTIR Spectra of 25^0 C Dye Extraction Temperature



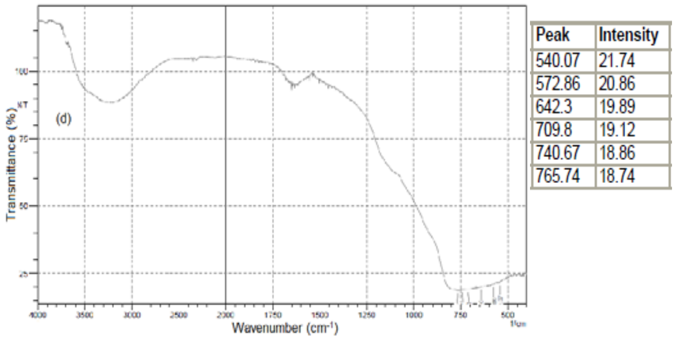
Peak	Intensity
549.71	23.03
574.79	22.688
705.95	21.015
759.95	20.657
802.39	20.719

Fig 3b. FTIR Spectra of 35^0 C Dye Extraction Temperature



Peak	Intensity
588.29	27.94
665.44	25.366
694.37	24.881
810.1	24.016
1099.43	42.332

Fig 3c. FTIR Spectra of 70^0 C Dye Extraction Temperature

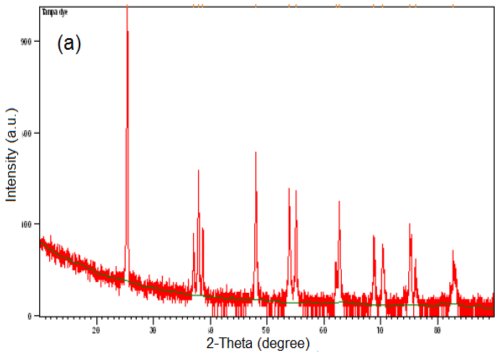


Peak	Intensity
540.07	21.74
572.86	20.86
642.3	19.89
709.8	19.12
740.67	18.86
765.74	18.74

Fig 3d. FTIR Spectra of TiO_2 without Dye

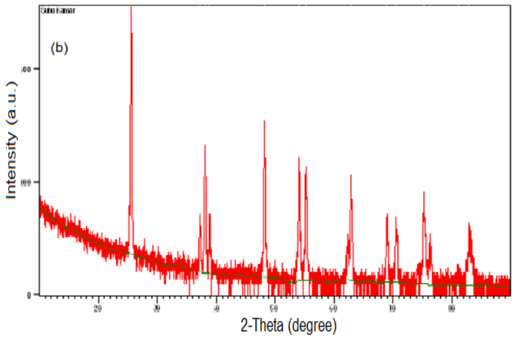
C. XRD analysis

The inhibition of crystallinity of TiO_2 was investigated via X-ray analysis. Fig. 4. shows the pure TiO_2 before and after the adsorption of Pandan leaf dyes. The higher intensity of the main peak (at $2\theta = 25^0$) was observed before the dyes were adsorbed onto the surface of TiO_2. After adsorption of dyes on TiO_2, the intensity decreased approximately to half compared with those in pure dyes. Thus, the dye suitable to the application with enhanced absorbance. This phenomenon indicates the good functional chains between the dyes and the TiO_2 surface.



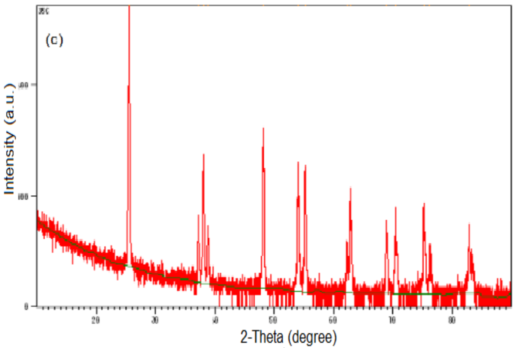
Pos.[°2Th.]	Height[cts]
25.3661	1088.80
37.0374	63.44
37.8646	249.96
38.6380	78.42
48.1033	313.99
53.9544	188.52
55.1232	186.22
62.1630	30.69
62.7472	154.45
68.8132	59.81
70.3409	54.16
75.0994	91.64
76.0893	32.23
82.7130	45.35

Fig 4a. XRD of TiO_2 without Dye



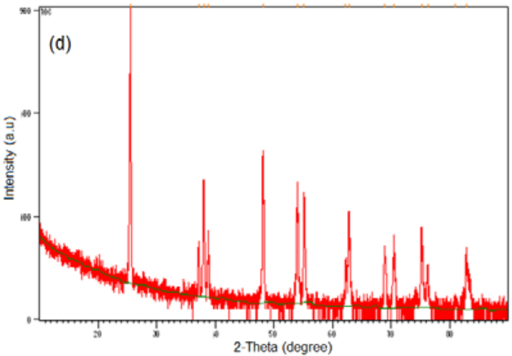
Pos.[°2Th.]	Height[cts]
25.5508	643.98
37.1898	41.07
38.0361	160.66
38.8032	45.16
48.2601	229.99
54.1241	129.28
55.2879	125.53
62.8976	110.40
68.9675	37.43
70.4838	46.29
75.2486	71.30
76.2921	13.65
81.0427	2.88
82.8665	37.63

Fig 4b. XRD of 25^0 C Dye Extraction Temperature



Pos.[°2Th.]	Height[cts]
25.5114	695.31
37.1627	53.26
38.0187	163.23
38.7705	45.76
48.2239	259.97
54.0837	168.90
55.2531	159.54
62.2756	28.71
62.8642	116.23
68.9367	55.59
70.4481	57.88
75.2145	85.63
76.2065	27.32
82.8354	49.07

Fig 4c. XRD of 35^0 C Dye Extraction Temperature



Pos.[°2Th.]	Height[cts]
25.4775	911.48
37.1323	43.21
37.9867	179.11
38.7480	59.04
48.2063	267.17
54.0560	175.49
55.2168	151.43
62.2625	29.38
62.8335	105.47
68.9166	42.58
70.4336	60.66
75.1936	70.49
76.2306	14.71
80.9421	2.42
82.8009	36.63

Fig 4d. XRD of 70^0 C Dye Extraction Temperature

IV. CONCLUSIONS

This research was done for determine the spectrum absorbance of natural pigment, namely, chlorophyll was extracted from Pandan leaves with extraction temperature variation. The optimal spectrum absorbance was reached at the extraction temperature of 35^0 C. The dyes of chlorophyll were successfully extracted from leaves using different temperatures. Furthermore the dyes were mixed with TiO_2. The adsorption of Pandan dyes onto the surface of TiO_2 were confirmed with an FTIR analysis, was used before and after adobe of dyes on the surface. Using FTIR, the functional groups were confirmed. These dyes showed a similar structure of functional groups but the 35^0 C of extraction temperature showed more and shaper peaks of functional group position at wavenumber between 1400 - 1750 cm^{-1}. Inhibition of crystallinity of TiO_2 was investigated by X-ray analysis to confirm adsorption of dyes onto TiO_2 surface. After adsorption of dyes onto TiO_2, the intensity decreased approximately to half compared with those in pure dyes.

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