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# The effect of holding time variation on the efficiency of DSSC $TiO_2$ transparent with dye *Ipomoea aquatica* Forsk

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**Abstract.** $TiO_2$ semiconductor material is commonly used as a working electrode in dye-sensitized solar cell (DSSC). There are two types of $TiO_2$ used, namely the form of nanopowder and transparent paste. In this study, the fabrication of DSSC has been successfully carried out using $TiO_2$ with a transparent type of paste. DSSC fabrication was carried out by placing transparent $TiO_2$ paste 18 NR-T using three variations of holding time in the heating process using furnace Carbolite 1100. Variations of holding time used were 10 minutes, 20 minutes and 30 minutes at 500 °C. Natural dye that is used comes from *Ipomoea aquatica* Forsk. For DSSC characterization, I-V test was done using Keithley 2620A and absorbance test using UV-Vis Spectrophotometer Lambda 25. The results of the characterization obtained the highest efficiency 5.5 x $10^{-2}$%. While the absorbance test obtained absorption peaks in the wavelength range for each watercolor dye 400-440 nm and 640-680 nm.

## 1. Introduction

Dye-sensitized solar cells (DSSC) are promising devices for using solar energy because of low production costs compared to conventional semiconductor solar cells, and also in high light for electrical conversion efficiency [1]. Compared to amorphous silicon cells, DSSCs have been widely researched for their low-cost potential, assembling simple technology and good efficiency. There are four main factors that influence the power conversion efficiency ($\eta$) of a solar cell device: dye sensitizer structure, photoanode, opposing electrode and electrolyte. Most importantly, photo morphology that plays an important role in achieving high power conversion efficiency. Therefore, it is still important and critical to developing new structures from photoanodes for DSSCs [2].

The research on DSSC carried out has attracted much attention as a substitute for potential alternative energy for Si-based photoelectric cells mainly due to the relatively high conversion efficiency and cost effectiveness. DSSC uses fast electron injection from molecular light absorbers for large band gap of nanocrystalline $TiO_2$ semiconductor films on the conduction of transparent glass substrates (photodiodes) during light illumination [3]. DSSC as a type of cheap and renewable energy device has been considered a prospective alternative for silicon solar cells due to high energy conversion efficiency and ease of manufacture because O'Regan and Grätzel first showed efficient conversion > 7% to facilitate titanium mesoporous nanoparticle dioxide ($TiO_2$) . Since then, much interest has been developed for the fundamental aspects and application of technology, and the efficiency of photovoltaic conversion, now exceeding 12%. The DSSC is usually assembled with an electron transport layer made of 10-15 µm nanoparticulate films as thick as photo-codes, organic dye molecules as photosensitizers, redox electrolytes consisting of redox pair iodine, and opposite

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electrodes Pt. The four simple components and their interfaces have been widely surveyed to minimize photoelectron loss, which leads to high power conversion efficiency [4].

Because of its flexible and exotic nature, $TiO_2$ nanomaterials have been used as photocatalysts, photovoltaic materials, gas sensors, etc. The efficiency of DSSC based on $TiO_2$ nanoporous and perovskite photoelectrode, was 20.1%. It was reported that the structure of $TiO_2$ nanoparticles, which showed the best efficiency in DSSCs, had trapped sites in the contact area between $TiO_2$ nanoparticles and this disrupted electron transport in thin films of $TiO_2$. One-dimensional (1D) $TiO_2$ nanomaterials such as nanotubes (NTs), nanorods (NRs), and nanowires (NWs) have shown a reduction in recombination rates for electron-hole pair excitation and display optical and electrical uniqueness.. In particular, vertical growth NRS $TiO_2$ allows shorter and less undisturbed electrical path directions for photogenerated operators and increases load separation and transportation cost properties in many photoelectrochemical devices such as DSSC [5].

In nature a lot of organic materials have coloring molecules that are very promising to be used as ingredients for solar cells. Terms dye can be used as an active material (sensitizer), the material must be able to become a medium of transfer of an electric charge when absorbing photon energy. Plant pigmentation occurs because the structure of the pigment interacts with sunlight and changes the wavelength to be transmitted or reflected by plant tissue [6]. The weakness of DSSC with dye type ruthenium is small in nature and not environmentally friendly because it is toxic, so it is a consideration to be applied to large-scale DSSC. Dye is environmentally friendly and abundant in nature, the dye from the leaves, seeds, fruit, stems, and roots of plants becomes an alternative choice as a sensitizer in DSSC [7]. Substances such as chlorophyll, β-carotene, anthocyanin, tannin, curcumin, etc. in plants can be applied as a sensitizer.

Chlorophyll is widely found in green plants that function as givers of green pigments in plants. This compound plays a role in the process of photosynthesis of plants by absorbing and converting light energy into chemical energy. Chlorophyll is the main pigment in photosynthesis, absorbs more blue and red light, where supplementary pigments such as carotenoids and phycobilin can increase the absorption of green-blue and yellow spectra. The attractive properties of photosynthetic pigments are applied such as sensitizers in solar cells [8]. Sensitizers function to absorb light energy and use them to excite electrons, so that the more light energy absorbed, the more electrons are expected to be generated to increase the solar cells efficiency.

## 2. Experimental

### *2.1. The $TiO_2$ 18 NR-T Preparation*
The transparent $TiO_2$ paste made from a mixture of $TiO_2$ 18NR-T paste with ethanol stirred with a magnetic stirrer for an hour at 350 rpm.

### *2.2. The.Preparation of Natural Dye Ipomoea aquatica Forsk*
The Chlorophyll natural dye is prepared by dissolving 20 grams of *Ipomoea aquatica* Forsk and 60 ml of ethanol then stirring with 450 rpm speed for an hour. Dye is kept for 24 hours at room temperature and then filtered.

### *2.3. The Deposition of $TiO_2$ (Working Electrode)*
The process of $TiO_2$ deposition on *Flouro Tin Oxide* (FTO) glass was carried out by pouring transparent $TiO_2$ paste using the spin coating method with active areas of 1 x 1 cm. After the $TiO_2$ paste is dripped then rotated at a speed of 1000 rpm for 15 seconds. Then the deposition results are heated using the Furnace (Carbolite 1100) at a temperature of 500 °C. At this stage, three variations of the process of holding time are made which are 10 minutes, 30 minutes, and 60 minutes. Then immersed into the dye solution for 24 hours.

*2.4. The Deposition of Platinum (Counter Electrode)*

The platinum solution is made from a mixture of *Hexaclhoroplatinic* (IV) Acid 10% with Isopropanol. The platinum deposition process is carried out by heating the FTO glass using a hot plate with a temperature of 250 °C for 15 minutes. Then the platinum solution is dripped appropriately until a platinum layer forms on the FTO glass.

*2.5. The Fabrication of DSSC*

The DSSC fabrication is made by assembling work electrode + Dye, electrolyte, and the opposing electrode. The arrangement of the circuit resembles a sandwich.

## 3. Results and Discussion

*3.1. Performance of DSSC*

The characterization of DSSC performance was tested by using I-V meter Keithley 2620A with a light source of 1000 watt illumination lamp. This is done because the energy given is almost the same as the solar photon radiation energy which is equal to 1360 W/m$^2$ [9]. From the measurement results obtained the efficiency shown in Table 1.

**Table 1.** Performance of DSSC

| Variation | $I_{sc}$ (mA) | $V_{oc}$ (mV) | $I_{max}$ (mA) | $V_{max}$ (mV) | $\eta$ (%) x $10^{-2}$ |
|---|---|---|---|---|---|
| 10 minutes | 0.00019 | 0.50020 | 0.00012 | 0.30313 | 3.5 |
| 30 minutes | 0.00023 | 0.59113 | 0.00013 | 0.31832 | 5.0 |
| 60 minutes | 0.00018 | 0.54554 | 0.00015 | 0.33333 | 5.1 |

From Table 1. It can be seen that during the process of holding time for 10 minutes produces a DSSC efficiency of 3.5 x $10^{-2}$%. When the holding time process is raised to 30 minutes DSSC efficiency also increases to 5.1 x $10^{-2}$%. In the 60 minutes of holding time process, the efficiency of DSSC the increase is small.

The curve of DSSC performance efficiency will be shown in Figure 1.

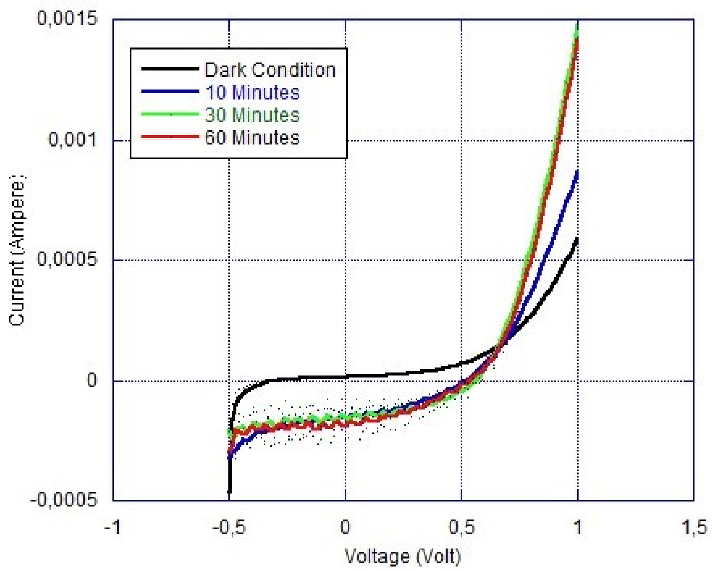


**Figure 1.** The DSSC Performance Curve

### *3.2. The Absorbance of Dye Ipomoea aquatica Forsk*
The characterization of wavelength absorption was done by using UV-Vis Spectrophotometer Lambda 25. The test result is shown in Figure 2.

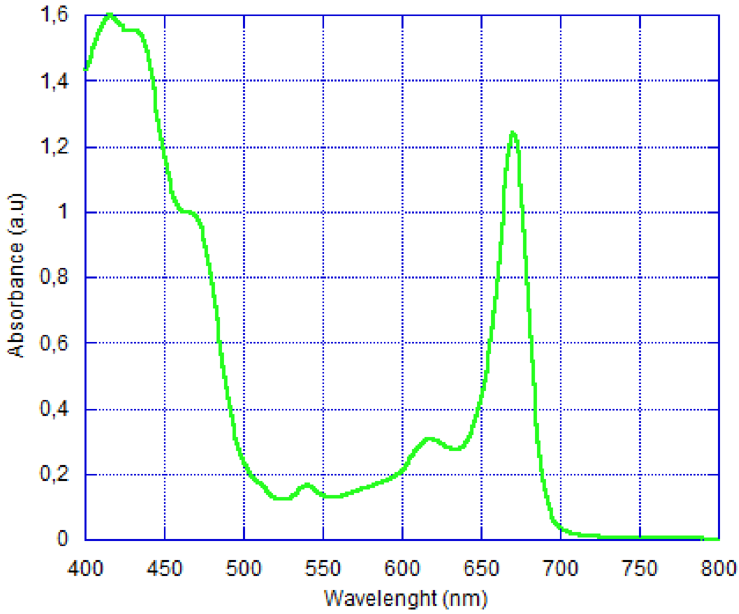


**Figure 2.** The Dye *Ipomoea aquatica* Forsk Curve Absorbance

From Figure 2. It can be seen that the peak of the absorbance at *Ipomoea aquatica* Forsk dye is 416 nm and 670 nm. The graph shows that the Ipomoea aquatica Forsk dye is a chlorophyll-a. The result of preparation of natural dye shows that absorbance spectrum of dye *Ipomoea aquatica* Forsk according to the references [10].

## 4. Conclusion
The DSSC fabrication with paste $TiO_2$ 18 NR-T transparent and dye *Ipomoea aquatica* Forsk has been succesfully performed. The test results showed an increase in the efficiency of DSSC in the process of holding time 10 minutes, 30 minutes, and 60 minutes. The biggest efficiency increase is the increase from the holding time of 10 minutes, 30 minutes, and 60 minutes. The highest efficiency obtained at 60 minutes holding time is $5.1 \times 10^{-2}$ %. The peak absorbance of *Ipomoea aquatica* Forsk dye is at a wavelength of 416 nm and 670 nm. From the results of the research on *Ipomoea aquatica* Forsk dye according to chlorophyll-a.

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