The impact of holding time variation on the effectiveness of DSSC TiO₂ transparent with dye Ipomoea aquatica Forsk

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ABSTRACT
In dye-sensitized solar cells, the working electrode is frequently made of the semiconductor TiO₂ (DSSC). TiO₂ is utilized in two different forms: transparent paste and nano powder. In this study, TiO₂ and a transparent sort of paste were used to fabricate DSSCs with success. To fabricate the DSSC, transparent TiO₂ paste 18 NR-T was placed in the furnace Carbonite 1100 heating process with three different holding times. 10 minutes, 20 minutes, and 30 minutes at 500 °C were the different holding times employed. Ipomoea aquatica Forsk is the source of natural colouring. Keithley 2620A and UV-Vis Spectrophotometer Lambda 2S were used for the I-V test and the absorbance test, respectively, for DSSC characterization. According to the characterization results, the efficiency was 5.5 x 10⁻² per cent. At the same time, the absorbance test found absorption peaks in the wavelength ranges of 400–440 nm and 640–680 nm for each watercolour dye.

KEYWORDS
Molecular light absorbers for DSSCs, dye, TiO₂, Efficiency; DSSCs; Dye, TiO₂

Introduction
Due to their lower production costs than traditional semiconductor solar cells and excellent electrical conversion efficiency, dye-sensitized solar cells (DSSC) are potential solar energy harvesting technologies (Meng et al., 2015). DSSCs have received a lot of research attention in comparison to amorphous silicon cells because of their promise of low cost, ease of assembly, and high efficiency. A solar cell device’s power conversion efficiency (I) is primarily influenced by four elements: the dye sensitizer structure, photoanode, opposing electrode, and electrolyte. The most crucial factor in getting high power conversion efficiency is photo morphology. Therefore, creating novel structures from photoanodes for DSSCs is still crucial and vital (Lu et al., 2015).

The research on DSSC 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 significant band gaps of nanocrystalline TiO₂ semiconductor films on the conduction of transparent glass substrates (photodiodes) during light illumination (Saji & Pyo, 2010). DSSC, as a type of cheap and renewable energy device has been considered a prospective alternative for silicon solar cells due to its high energy conversion efficiency and ease of manufacture. O’Regan and Grätzel first showed efficient conversion > 7% to facilitate titanium mesoporous nanoparticle dioxide (TiO₂). Since then, much interest has been developed in 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 electrodes Pt. The four simple components and their interfaces have been widely surveyed to minimize photoelectron loss, which leads to high power conversion efficiency (Kim et al., 2013).

Because of its flexible and exotic nature, TiO₂ nanoparticles have been used as photocatalysts, photovoltaic materials, gas sensors, etc. The efficiency of DSSC based on TiO₂ nanoporous and perovskite photodelektro was 20.1%. It was reported that the structure of TiO₂ nanoparticles, which showed the best efficiency in DSSCs, had trapped sites in the contact area between TiO₂ nanoparticles. This disrupted electron transport in thin films of TiO₂. One-dimensional (1D) TiO₂ 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 TiO2 allows shorter and less disturbed electrical path directions for photogenerated operators. It increases load separation and transportation cost properties in many photoelectrochemical devices such as DSSC (Pawar et al., 2016).

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.
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 (Isah Kimpa et al., 2012). 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 (Nygren, 2010). 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.

Methods

Experimental

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.

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.

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.

The deposition of platinum (counter electrode)

The platinum solution is made from a mixture of Hexachloroplatinic (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.

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.

Results and discussion

Discussion

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$^2$ (J, 2011). From the measurement results obtained the efficiency shown in Table 1.

<table>
<thead>
<tr>
<th>Variation</th>
<th>$I_c$ (mA)</th>
<th>$V_{oc}$ (mV)</th>
<th>$I_{sc}$ (mA)</th>
<th>$V_{max}$ (mV)</th>
<th>$\eta$ (%$) \times 10^{-2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 minutes</td>
<td>0.00019</td>
<td>0.50020</td>
<td>0.00012</td>
<td>0.30313</td>
<td>3.5</td>
</tr>
<tr>
<td>30 minutes</td>
<td>0.00023</td>
<td>0.59113</td>
<td>0.00013</td>
<td>0.31832</td>
<td>5.0</td>
</tr>
<tr>
<td>60 minutes</td>
<td>0.00018</td>
<td>0.54534</td>
<td>0.000015</td>
<td>0.33333</td>
<td>5.1</td>
</tr>
</tbody>
</table>
From Table 1, it can be seen that during the process of holding time for 10 minutes produces a DSSC efficiency of $3.5 \times 10^{-2} \%$. When the holding time process is raised to 30 minutes DSSC efficiency also increases to $5.1 \times 10^{-2} \%$. 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](image1)

**The Absorbance of Dye Ipomoea aquatica Forsk**

The characterization of wavelength absorption was done by using UV-Vis Spectrophotometer Lambda. The test result is shown in Figure 2.

![Figure 2. The Dye Ipomoea aquatica Forsk Curve Absorbance](image2)

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 (Syafinar et al., 2015).

**Conclusion**

The DSSC fabrication with paste TiO2 18 NR-T transparent and dye Ipomoea aquatica Forsk has been successfully 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.

References


