Abstract
This study aims to utilize various natural dye extracts from Indonesian plants to be applied as sensitizers to DSSC. The dye extract is derived from the turmeric plant (Curcuma longa L.), henna tree (Lawsonia inermis L.) and pandan (Pandanus amaryllifolius). TiO2 nanoparticles was used as semiconductor material for DSSC as they have a good crystallization structure and a wide surface area. The results showed that the DSSC using turmeric extraction produced a maximum power of $2.53 \times 10^{-3}$ mWcm$^{-2}$ with an efficiency level of 0.04%. While the henna tree extract produced a power of $1.27 \times 10^{-2}$ mWcm$^{-2}$ with an efficiency level of 0.25% and pandan extract produced a power of $4.01 \times 10^{-2}$ mWcm$^{-2}$ with an efficiency of 0.8%. Thus the dye extract from pandan is the best sensitizer that can be applied to the DSSC.

INTRODUCTION
Energy is one of the greatest challenges faced by every country in the world. It is predicted that in 2055 the energy problem will be a big problem that will befall mankind (Smalley, 2005). The depletion of reserves of fossil energy sources makes humans look for new and renewable energy sources. Of the many candidates for the newest energy source, Dye Sensitized Solar Cell (DSSC) is now a very potential alternative to be used as renewable energy source of solar cells. One of the most promising factors of this DSSC is the relatively cheap manufacturing cost, considering that cost is the biggest barrier factor for commercialization of conventional Silicon based solar cells (Ramakrishnan et al., 2020). In contrast to silicon solar cells, in dye-concentrated solar cells, the photons are absorbed by the dye which adheres to the surface of the TiO2 particles. In this case dye acts as an electron donor that is generated when it absorbs light, similar to the function of chlorophyll in the photosynthetic process (Omar et al., 2020, Umale et al., 2019, Kumara and Prajitno, 2012).

DSSC using ruthenium dye has achieved an efficiency of up to 14% (Kakiage et al., 2015). However DSSC with this type of ruthenium dye is not commonly found in nature and is not friendly to environment, so it is consideration for the application on a large area DSSC (Dahlan et al., 2016). Dyes from the leaves, fruit, seeds, roots and stems of plants are very potential to be used as sensitizers in DSSC because they are abundant in nature and are environmentally friendly. Substances such as chlorophyll, beta-carotene, anthocyanins, tannins, curcumin, etc. in plants can be used in application as a sensitizer (Iqbal et al., 2019). This paper describes the analysis of the utilization of nature dye such as Turmeric (Curcuma longa Linn), Henna Tree (Lawsonia inermis L.), and Pandan (Pandanus amaryllifolius). This is useful information for selecting the right type of dye to be applied to the DSSC.
MATERIALS AND METHODS

TiO2 Paste Formation

The first step was dissolving 1 gram of powdered TiO$_2$ into 10M NaOH solvents to form TiO$_2$ nanoparticles powder and then ultrasonic process for 2 hours at a temperature of 80°C. The nanoparticle then washed repeatedly with 2% of HCl and distilled water to leave TiO$_2$ nanoparticles precipitate. This precipitated material was then dried and grounded to form TiO$_2$ powder. Next, the TiO2 powder was heated in a furnace for 2 hours at 400°C to form nano TiO$_2$ powder with anatase phase. TiO$_2$ Paste was prepared by grinding 0.1 grams of TiO$_2$ powder using a mortar produces TiO$_2$ paste then drop cast 2 drops of 10% wt PVA and subsequently crushed to form a homogeneous TiO$_2$ paste.

Dye Solution Preparation

Each 10 g of turmeric, henna tree leaves and Pandan leaves was crushed separately using a mortar then soaked them in 6 mL of ethanol and then stirred for 1 hour. The solution was then filtered after leaving it for 1 day. While the electrolyte solution was prepared by mixing 12 mL of KI solution (0.1 M) and 12 mL of I$_2$ (0.01 M) solution and subsequently added with 1 gram of polyethylene oxide and stirred until homogeneous.

Constructing the DSSC

TiO$_2$ paste was deposited on the on the 3x3 cm$^2$ glass conductor using doctor blade method then the layer was dried for 15 minutes. It was immediately heated in a furnace at a temperature of 450°C for 30 minutes and immersed in the dye solution for approximately 30 minutes. Prior to the deposition, the TCO counter-electrode was then placed on top of the TiO$_2$ layer with a sandwich structure. The electrolyte solution was then dropped into the space between the two electrodes. And the solar cells were ready to be tested for IV characterization.

RESULT AND DISCUSSION

XRD results (figure 1) show that the TiO$_2$ has an anatase structure, which is compatible with the International Centre for Diffraction Data (JCPDS) no: 21-1272. The anatase structures were identified by a strong intensity in the region $2\theta = 25.28^\circ; 37.80^\circ; 48.05^\circ; 53.89^\circ$ and 55.06$. In addition, the intensity of the sample diffraction pattern is quite high, indicating that the TiO$_2$ has a good crystallinity degree which accelerates the process of electron diffusion in the TiO2 layer, which means that the electron transfer process of the devices will be faster and will improve the performance of solar cells (Tamarani et al., 2019).

![Fig 2. The morphological structure of the TiO2 sample](image)

The morphological structure of the TiO$_2$ sample was tested using a Scanning Electron Microscopy (SEM) instrument (Figure 2). The SEM result shows that the TiO$_2$ particle size was less than 200 nm. The sample also contains a number of particle networks that form the nanopore structures of the TiO$_2$ material; the sample has good interconnection between particles. This particle interconnection is needed so that the electron diffusion path is shorter (Dong and Fei, 2020).

![Fig 3. The absorption rate of Turmeric, Henna Tree & Pandan](image)
The ultraviolet-visible spectroscopy (UV-Vis) spectra showing the absorption of the samples. The absorption peak of henna tree, pandan and turmeric of 238 nm, 319 nm and 426 nm, respectively. These results indicate expected absorption spectra for turmeric, henna tree and pandan (Masek et al., 2013, Sathyajothi et al., 2017, Al-awani et al., 2017).

Fig 4. DSSC Prototype (a) Henna tree dye (b) Chlorophyll Pandan dye (c) Turmeric dye

Fig 5. The circuit of I-V characteristic measurement

Solar cells are assembled in a sandwich arrangement with a TiO$_2$ / Dye / Electrolyte / TCO coating. The results of the solar cell prototype that have been assembled can be seen in Figure 4.

Table 1. Solar cells parameters

<table>
<thead>
<tr>
<th>Sel</th>
<th>$V_{oc}$ (mV)</th>
<th>$I_{sc}$ (mA)</th>
<th>$V_{max}$ (mV)</th>
<th>$I_{max}$ (mA)</th>
<th>$P_{max}$ (mW/cm$^2$)</th>
<th>FF</th>
<th>η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandan</td>
<td>235.5</td>
<td>6.0x10$^{-4}$</td>
<td>128</td>
<td>3.13x10$^{-4}$</td>
<td>4.01x10$^{-2}$</td>
<td>0.28</td>
<td>0.8</td>
</tr>
<tr>
<td>Henna tree</td>
<td>98.2</td>
<td>4.4x10$^{-4}$</td>
<td>53.2</td>
<td>2.4x10$^{-4}$</td>
<td>1.27x10$^{-2}$</td>
<td>0.31</td>
<td>0.25</td>
</tr>
<tr>
<td>Turmeric</td>
<td>77.4</td>
<td>1.0x10$^{-4}$</td>
<td>34.6</td>
<td>7.33x10$^{-5}$</td>
<td>2.53x10$^{-3}$</td>
<td>0.30</td>
<td>0.04</td>
</tr>
</tbody>
</table>

CONCLUSION

Dye Sensitized Solar Cell which uses turmeric extraction produces a maximum power of 2.53x10$^{-3}$ mW/cm$^2$ with an efficiency level of 0.04%. While the nail henna extract produced a power of 1.27x10$^{-2}$ mW/cm$^2$ with an efficiency level of 0.25% and pandan extract produced a power of 4.01x10$^{-2}$ mW/cm$^2$ with an efficiency of 0.8%. Thus the dye extract from fragrant pandanus is the best sensitizer that can be applied to DSSC.

The solar cell prototypes are then characterized to determine Voltage-Current curves produced. This characterization test circuit is shown in Figure 5. The measurements were conducted directly under sunlight source with the measured intensity of 50.401 W/cm$^2$. The I-V characteristics can be seen in Figure 6 and the device parameters are presented in table 1.

Fig 6. I-V characteristics of TiO$_2$ solar cells with various dyes (A) Pandan (B) Henna Tree and (C) Turmeric

Of the three dyes used, pandan extraction is the best material that can be utilized for DSSC which produces a maximum a a power of 4.01x10$^{-2}$ mW/cm$^2$ with an efficiency level of 0.8%. The difference in the maximum voltage value ($V_{max}$) is probably due to a decrease in the amount of free charge (excitons) that is generated when the dye interacts with the photons continuously. Good dye will produce a large free charge, which is then converted into current when it reaches the electrodes (Li et al., 2019, Low et al., 2020).

REFERENCES


