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## Utilization of cyanobacteria in photovoltaic technology

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# Utilization of cyanobacteria in photovoltaic technology

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**Abstract.** Bio-photovoltaic is one of the energy-transfer technology that uses oxygenic photoautotrophic organisms to harvest light energy and generate electricity. The aerobic phototropic organisms such as blue-green algae primarily absorb solar energy in visible light areas (400-700 nm). The design of a bio-photovoltaic prototype cell can be constructed using electrodes and Cyanobacteria put inside a plastic container. When the cell is irradiated the photosynthetic reactions will run and produce free electrons. Based on a previous result it is possible to put the cathodes inside the chamber or outside the chamber. In this research, the anode was varied using copper, stainless steel, and zinc. For the measurement while all of the electrodes are in the chamber the efficiency value of each metal is 0.094%; 0.3475%; 4.1026% with the fill factor value of each metal is 0.5719; 0.4204; 0.5776. On the other hand, when one of the electrodes is outside the chamber efficiency value of each metal is 0.0058%; 0.4949%; 1.3013% and the fill factor value of each metal is 0.5559; 0.3519; 0.4564.

## 1. Introduction

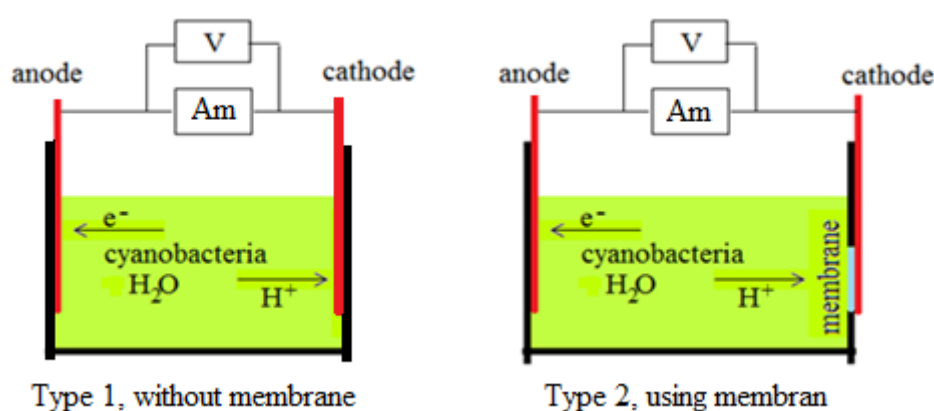
Renewable energy has been the main focus of research in energy since the last decade because of decreasing fossil fuel energy. The photovoltaic effect is one of energy conversion from the sunlight energy to be electrical energy. The most popular application of photovoltaic effect is solar cell using semiconductor materials [1]. A bio-photovoltaic cell (is also known as a microbial fuel cell) is able to be developed by utilizing oxygenic photoautotrophic organism such as cyanobacteria to harvest the sunlight energy [2,3,4]. The energy conversion in this cell involves a photochemical reaction (photosynthesis) that results in free electrons. Cyanobacteria (green-blue algae) absorb light and use it for photosynthesis reaction [5,6]. The bacteria dominantly absorbs energy from visible lights with the wavelength 400 – 700 nm [7]. The kind of bio-photovoltaic cell works anytime as long as receive enough visible lights from external sources. The electrons which are produced from the photosynthesis process in the cell may be collected on the anode to generate an electric current [8,9]. The process can be assisted by a catalyst (membrane or salt bridge) that helping the exchange of ions produced from the photosynthesis.

## 2. Materials and Methods

Algae (*Chlorella* sp), plastic container 5 x 5 x 5 cm<sup>3</sup>, graphite rod, *stainless steel*, copper, zinc, nafion membrane, silicon glue, multimeter (SANFIX BM2015C), potentiometer, aerator, spectrophotometer UV-vis (BEL Photonics UV M-51), halogen bulb. The experimental method for this research concise of preparation, observation, and analysis. Some preparations are needed in this experiment mainly in growing the algae (*chlorella* sp), checking the optimal absorption of the algae, and setting the bio-



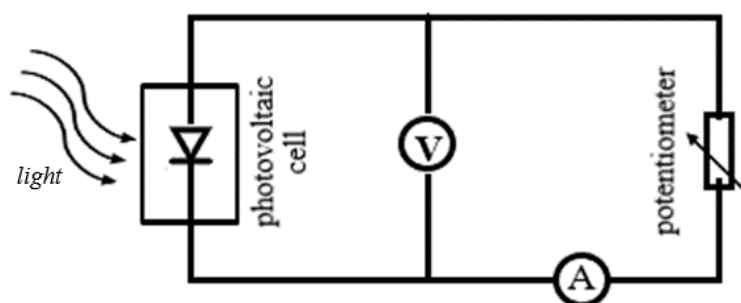
photovoltaic cell. Initially, it is taken 50 ml algae and put it in a glass bottle filled with 650 ml of aquadest and than put some Walne fertilizer. The bottle then put in a clean room, give aeration and irradiated with light from a 15 W bulb. After around 7 days the algae is ready to be used for a bio-photovoltaic cell. The optical characteristic of the chlorella sp was investigated using spectrophotometer UV-Vis to confirm that the algae absorb lots of lights with the wavelength around 400 – 700 nm. The absorption process is mainly done by the chlorophyll of the algae. The photovoltaic cell for this experiment was set up in the lab scale from a plastic container with the dimension of 5 x 5 x 5 cm<sup>3</sup>. It was set up two types of bio-photovoltaic cells, type 1 and type 2. For type 1 both of the electrodes are put in the chamber, while for the type 2 the anode is put in the chamber while the cathode is attached on the outer cell surface. The contact of the cathode with the algae inside the chamber is a connection through a hole that is shielded by a Nafion membrane (C<sub>7</sub>HF<sub>13</sub>O<sub>5</sub>S·C<sub>2</sub>F<sub>4</sub>). The chamber than filled with a solution contains cyanobacteria (Chlorella sp) and put the cell near to a light source (see Figure 1 below).



**Figure 1.** Two types of bio-photovoltaic cells; (1) without membrane, (2) using membrane.

The light source is a halogen lamp with the power of 15 W which is put at the distance around 20 cm from the cells. For both types, the cathodes of the cells are made from graphite while the anodes are variated from copper, stainless steel, and zinc.

The current flowing out of each cell was measured using ampere meter Am, while the voltage difference between anode and cathode of each cell was measured using voltmeter V as shown in Figure 1 above. The schematic diagram for the investigation of current-voltage (I-V) characteristic of the bio-photovoltaic cell is shown in Figure 2 below.

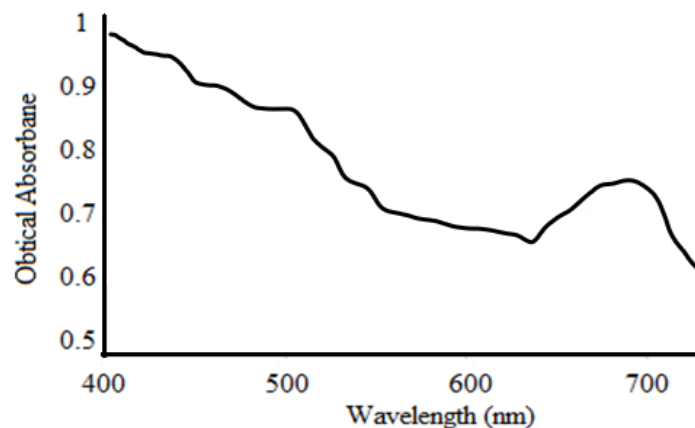


**Figure 2.** The schematic diagram for measuring I-V characteristic of the photovoltaic cell.

### 3. Results and Discussions

#### 3.1. Optical Absorbance

Investigation on optical (absorbance) characteristic of the algae results in a pattern of relative absorbance as shown in Figure 3 below.



**Figure 3.** The optical absorbance of Chlorella sp.

It is confirmed from Figure 3 that the chlorophyll of the algae indeed absorbs the visible light, dominantly at the wavelength between 400 - 500 nm. This result agrees with an investigation by the previous researcher.<sup>5</sup> It is convincing that the algae, chlorella sp, is suitable for producing electrons in the photosynthesis process. It is expected that a bio-photovoltaic cell may be developed by utilizing chlorella sp.

#### 3.2. Current-Voltage Characteristic

Applying a circuit as shown by Figure 3 results in I-V (current density-voltage) pattern of both types cell as shown by Figure 4 (a)-(f).

It is clearly seen from the Figure 4 that for the type 1 cell using copper anode the current at short circuit ( $I_{sc}$ ) is 8  $\mu$ I, and the voltage at open circuit (VOC) is 72 mV. While for the type 2 cell using copper anode the  $I_{sc}$  is 1.5  $\mu$ I, and the  $V_{oc}$  is around 19 mV. It is also can be predicted the maximum actual power ( $P_{max}$ ) by finding the maximum area under the curve from Figure 4. Moreover, the actual  $P_{max}$  may be associated with maximum voltage ( $V_{max}$ ) times the maximum current ( $I_{max}$ ). The efficiency ( $\eta$ ) of the cell in transfer energy is the ratio between  $P_{max}$  with  $P_{input}$ , where  $P_{input}$  is the input power coming from the light source. The percent of efficiency can be calculated using the formula:

$$\eta = \frac{P_{max}}{P_{input}} \times 100 \% \quad (1)$$

The quality of the solar cell is determined usually by its fill factor (FF), that is the ratio between the actual  $P_{max}$  with the theoretical  $P_{max}$ .

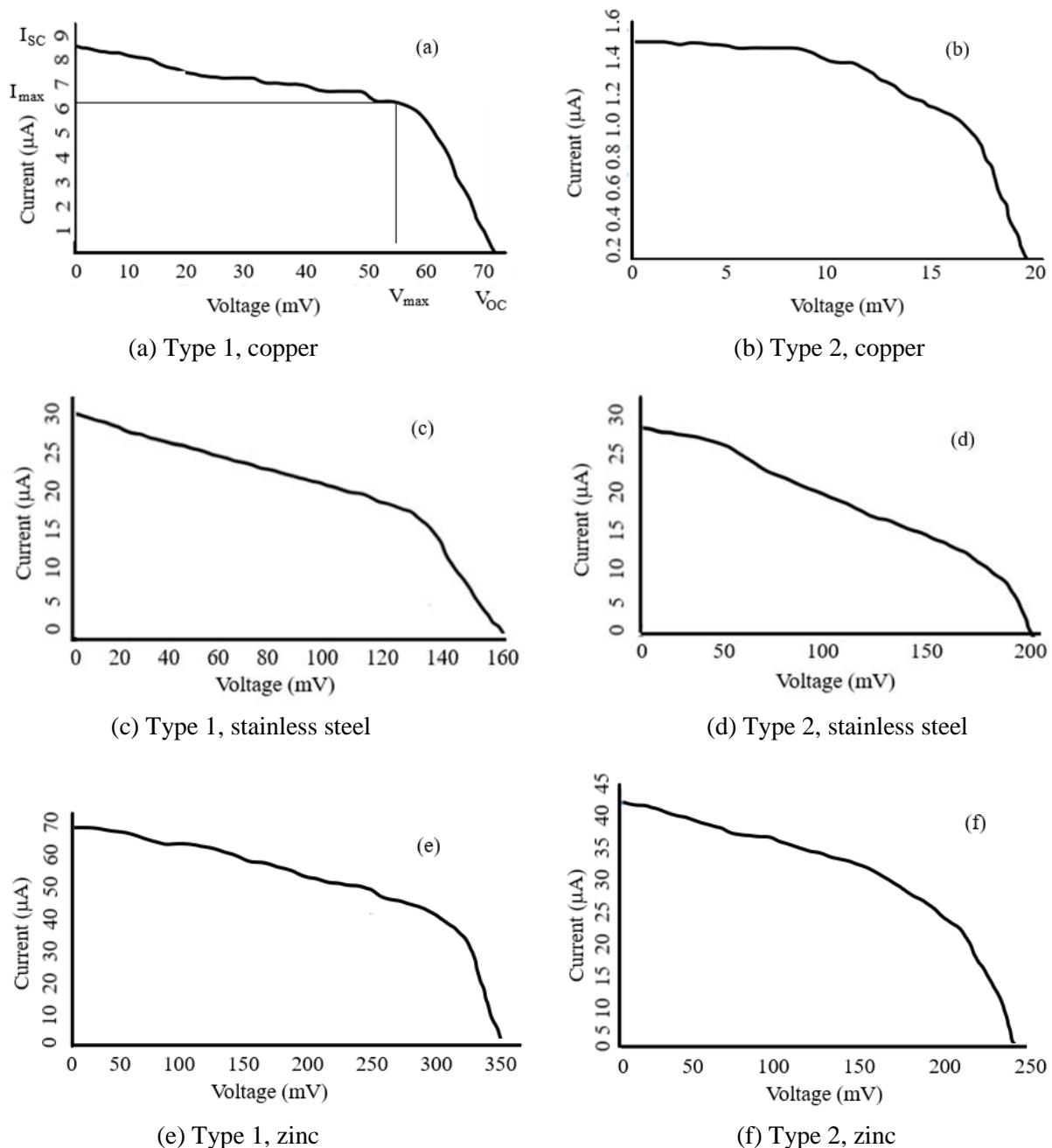
$$FF = \frac{V_{max} I_{max}}{V_{oc} I_{sc}} \quad (2)$$

The I-V characteristic of the type 1 cell, that are the values of  $I_{sc}$ ,  $I_{max}$ ,  $V_{oc}$ ,  $V_{max}$ ,  $P_{max}$ , and FF values taken from the each Figure 4 (a), (c), and (e) is shown in the Table 1, while the I-V characteristic of the

type 2 cell, that are the values of  $I_{sc}$ ,  $I_{max}$ ,  $V_{oc}$ ,  $V_{max}$ ,  $P_{max}$ , and FF values taken from each Figure 4 (b), (d), and (f) is shown in Table 2.

It is clearly seen from the Table 1 that the current production from the cell using zink anode is the highest among the three anodes, however, the current ( $I_{max}$ ) is very small, only 68  $\mu A$  at the voltage ( $V_{max}$ ) 363 mV. It is also shown by the Table 1 that the maximum efficiency is only around 4.1 %.

From the Table 2 that the current production from the cell using zink anode is also the highest among the three anodes, however, the current ( $I_{max}$ ) is only 42.7  $\mu A$  at the voltage ( $V_{max}$ ) 232 mV. It is also shown by the Table 2 that the maximum efficiency is only around 1.3 %.



**Figure 4.** The I-V pattern of the bio-photovoltaic cells type 1 and type 2 using anodes from Cooper, Stainless Steel, and Zinc.

**Table 1.** The I-V characteristic of the photovoltaic cell type 1 (without membrane).

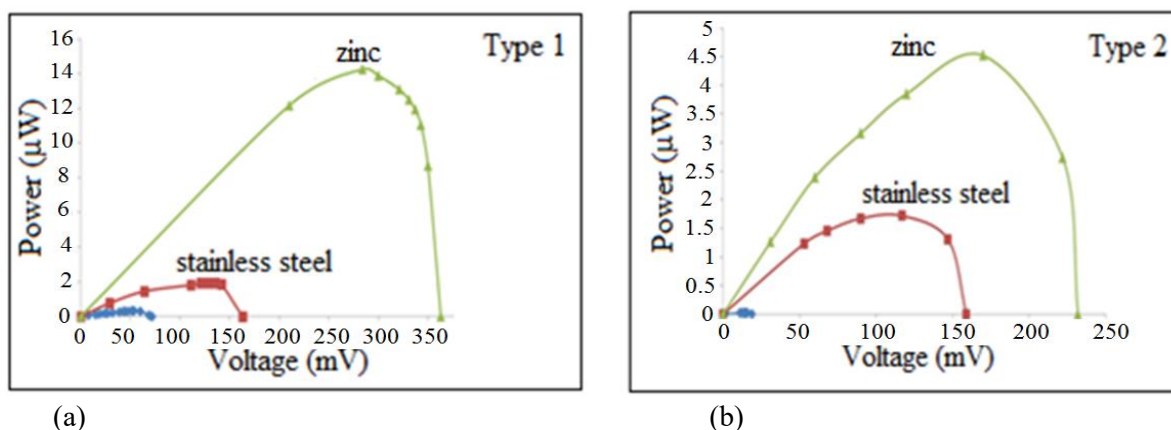
I-V Characteristic	Copper	Stainless steel	Zink
$V_{oc}$ (mV)	72	163	363
$I_{sc}$ ( $\mu$ A)	8	28.2	68
$V_{max}$ (mV)	54	128	284
$I_{max}$ (mA)	0.0061	0.0151	0.0502
$P_{max}$ ( $\mu$ W)	0.3294	1.9328	14.2568
Fill factor	0.5719	0.4204	0.5776
Efficiency (%)	0.0948	0.3475	4.1026

**Table 2.** The I-V characteristic of the bio-photovoltaic cell type 2 (using membrane).

I-V Characteristic	Copper	Stainless steel	Zink
$V_{oc}$ (mV)	19	188	232
$I_{sc}$ ( $\mu$ A)	1.5	26	42.7
$V_{max}$ (mV)	13	117	170
$I_{max}$ (mA)	0.0013	0.0147	0.0266
$P_{max}$ ( $\mu$ W)	0.0169	1.7199	4.522
Fill factor	0.5559	0.3519	0.4564
Efficiency (%)	0.0058	0.4949	1.3013

Comparing the performance of the anodes used in each type results in the conclusion that the bio-photovoltaic using zinc anode is the best while using copper anode is the worst. The maximum voltage difference between cathode and anode found from all of the cells are in order 170 – 280 mV, this means that the cell is potential to be improved for production of a higher current. Therefore the design of the cell should be improved.

Comparing the performance of two types results in the conclusion that the bio-photovoltaic cell type 1 is better than that of type 2. The comparison may also possible using information taken from Figure 5 (a) and (b) showing the pattern of power production of the two types of bio-photovoltaic cell. The maximum power produced by the type 1 cell is around 14  $\mu$ W, while that from the type 2 cell is around 4.5  $\mu$ W. The power produced by these bio-photovoltaic cells are really weak, it needs lots of cells to produce power that is suitable for our daily activities.

**Figure 5.** The Power-Voltage pattern produced by the type 1 and 2 bio-photovoltaic cells using anodes copper, stainless steel, and zinc.

#### 4. Conclusions

It is seen from the absorbance pattern that the growth of the algae, *Chlorella* sp, in this experiment was in good quality. It is confirmed that the bio-photovoltaics are able to produce electric current during their photosynthesis process. The performance of the Biophotovoltaic cell without using membrane is better than that using membrane. This might have happened due to the hole size which is too small as compared to the area of the wall, so the amount of positive ions collected by the cathode is smaller than that without a membrane. The maximum voltage difference between the electrode is within the range of 170 to 280 mV, which is quite good for the bio-photovoltaic cell. However, the current produced is very small within the range of 6 to 50  $\mu$ A. This means that the design should be improved in order to get a better result. Of those three materials used for the anode, Zinc is the best since it produced much better current as compared to stainless steel or copper.

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