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Article

Performance of Sediment Microbial Fuel Cell (SMFC) System using Carbon Fiber Electrodes

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Abstract. A microbial fuel cell (MFC) is a type of biological fuel cell that converts chemical energy stored in an organic mixture into electrical energy that further penetrates the catalytic reaction of microorganisms. The Sediment Microbial Fuel Cell (SMFC) is a microbial fuel cell that can convert complex organic matter in the sediment to generate electrons. This research was conducted by designing a single chamber SMFC power generation system using graphite and carbon fiber electrodes. As a result, the single-chamber SMFC system with carbon fiber electrode performed better with an average electric power output of 561.11 mW for 21 days.

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1. Introduction

A microbial fuel cell (MFC) is a device that can generate electricity from organic components by breaking down microbes [1-3]. MFC is still a hot topic in the world of alternative energy technologies. MFC itself is a technology that combines bio-electrochemical systems using indirectly interacting bacteria commonly found in nature [4-11]. Marine sediments are part of essential marine resources that store various treasures such as oil, natural gas and mineral mining materials. Marine sediments are also a source of organic matter for various important plants such as mangroves, algae and seagrass beds[12-15]. In addition, marine sediments contain certain microorganisms that have the potential to be used in microbial fuel cell (MFC) based technology. A sediment microbial fuel cell (SMFC) is one of the MFC models [16].

SMFC uses microorganisms found in sediments to break down organic matter. The main part of the SMFC circuit generally consists of an anode, cathode and electronic devices. SMFC generally uses carbon as the anode material because it is suitable for bacterial growth, easy to connect with wires, and the price is relatively cheap [17-22]. The position anode is usually planted in the sediment and then utilizes the microorganisms contained therein [23-25]. The use of marine sediments in SMFC technology is said to be a solution to the energy crisis. In addition, their relatively simple mechanism allows SMFC to be an alternative to new technologies that minimize pollution so as not to harm the environment, such as fossil fuels that cause global warming. Great potential for organic matter content in marine sediments in Indonesia, which has a tropical climate, this makes the development of tropical marine SMFCs a promising alternative technology.

Various studies have been conducted to investigate the potential of microbial fuel cells to generate electrical energy with different specifications ranging from bioreactor design, use of electrodes, types of electrolyte solutions and aerobic and anaerobic conditions [26-27]. The variation of various parameters in the MFC system is done with the aim of achieving maximum power results. Therefore, this research was conducted by designing a single-chamber microbial sediment fuel cell system for electric power generation using graphite and carbon fiber electrode. As a variation to increase the amount of energy produced, this is done by varying the surface area of the electrode and the type of electrode.

2. Experimental Section

The subject of this research focuses on a series of sediment microbial fuel cells with two different circuits, namely single-chamber circuit (SC) sediment microbial fuel cells with graphite and carbon fiber electrodes. The method used in this study is an experiment with the research workflow presented in the Figure 1. Sediment samples were taken from marine sediment material in Cirebon harbor using a grab. Sediment samples of up to 3 kg are taken and placed in a jar, then stored in a cool box fitted with ice cubes, and seawater is also taken from the same location.

The fabrication of the SMFC circuit involves three stages consisting of electrode preparation, fabrication of a single-chamber circuit, and current-voltage measurement setup. The electrodes used for the manufacture of SMFC are graphite and carbon fiber with dimensions of 8 x 1 cm^2. Each ready-to-use electrode is connected to a cable. The connection between the cable and the electrode is sealed watertight with silicone rubber. Contaminated sediment samples are placed in the vessel to a depth of 5 cm, and then a graphite/carbon fiber electrode (anode) is covered with sediment to a depth of 2 cm. Then add 400 ml of sea water and leave to steep for 24 hours. Then a graphite/fiber electrode (cathode) is placed 1 cm above the surface. The wires from the anode and cathode are connected to a 820 ohm resistor, forming a closed circuit. SMFC is operated in the dark (without lighting) and at room temperature (27 ºC) with ventilation. Water lost through evaporation during the electric current measurement period is replaced with demineralized distilled water. Current measurements were taken after 0, 4, 8, 16, 24, 48, 72 hours up to 480 or 20 days. The electrical parameters observed are current (mA) and voltage (mV) using a digital multimeter. The current and voltage values obtained are then converted into power (watts) and energy (joules).

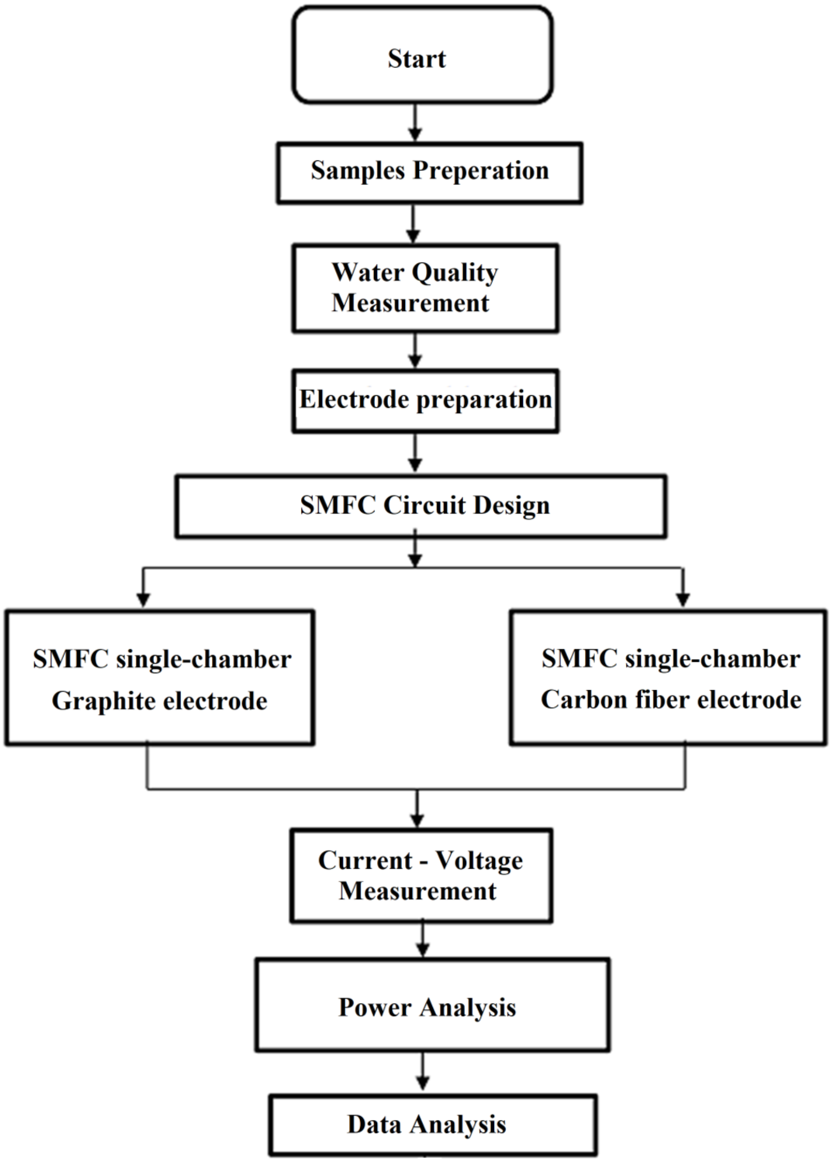

Figure 1. Flowchart of the SMFC circuit design

3. Results and Discussion

3.1. Variation of Electrode

From Figure 2 below, it can be seen that the longer the time, the lower the current generated. The high amount of electric current at the start of the study was due to the accumulation of electrons already present in the sediment and the activity of microorganisms in the sediment, while the decrease in current from 0 to 108 hours was due to reduced organic matter around the anode, due to the lack of suction.

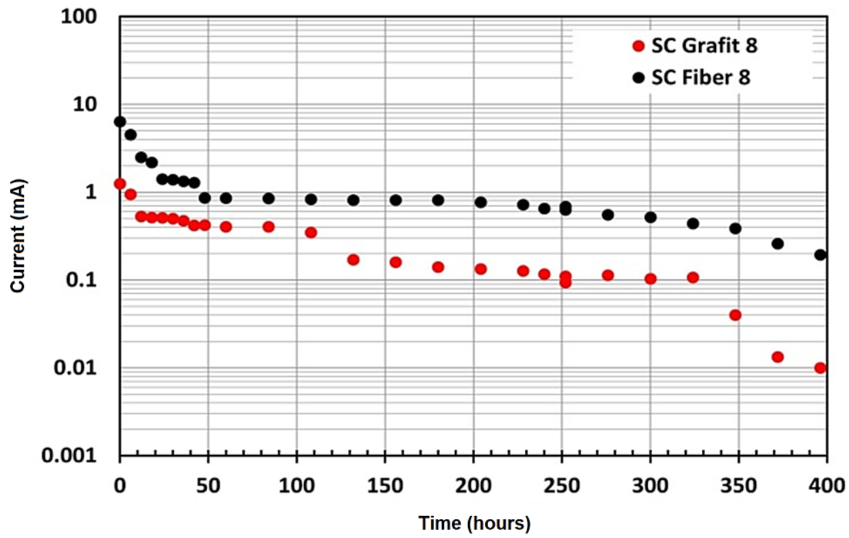

Figure 2. Influence of electrode type on current changes in the SMFC single-chamber (SC) system.

Microorganisms receive food, while it can be seen from Figure 3 that the voltage value increases and then decreases due to the metabolic activity of bacteria as complex compounds are broken down into simple compounds. The increase and decrease in electrical voltage are related to the number of free electrons generated from the results of bacterial metabolism. The difference in the use of the type of electrodes affects the performance of the SMFC in generating an electric current. It can be seen from the two figures below that using fiber type electrodes produces greater current and voltage generation than graphite electrodes. This is because the structure of carbon fiber is fibrous to increase the contact area compared to graphite as it is rigid, so that more microorganisms adhere to the fiber than to graphite.

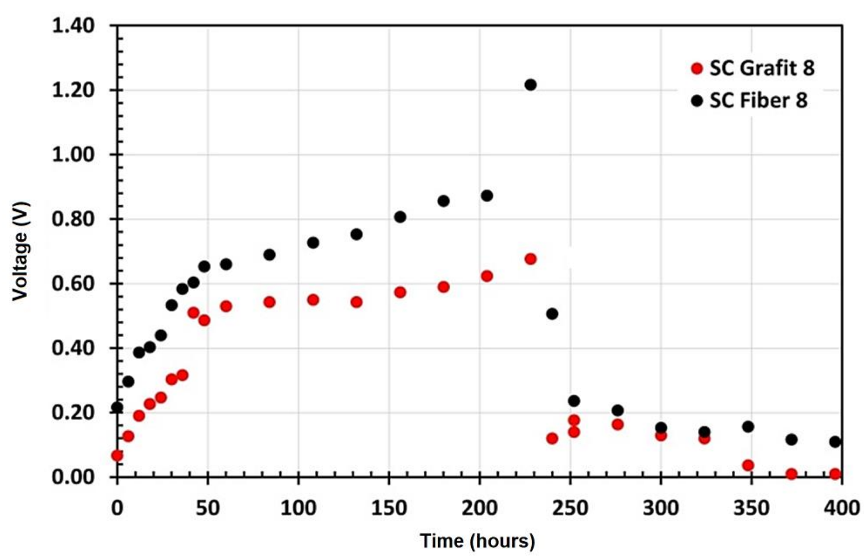

Figure 3. Influence of electrode type on voltage changes in the SMFC single-chamber (SC) system.

3.2. Reactor System Variations

It can be seen from Figure 4 that the generation of larger flows occurs with a single-chamber system compared to a dual-chamber system because the single-chamber system has only one chamber, so the sediment and the substrate mix without a membrane, since the membrane is in the double chamber prevents the transfer of electrons from the anode chamber to the cathode. The SMFC single-chamber systems with carbon fiber have a rated power of 561.11 and 122.40 mW.

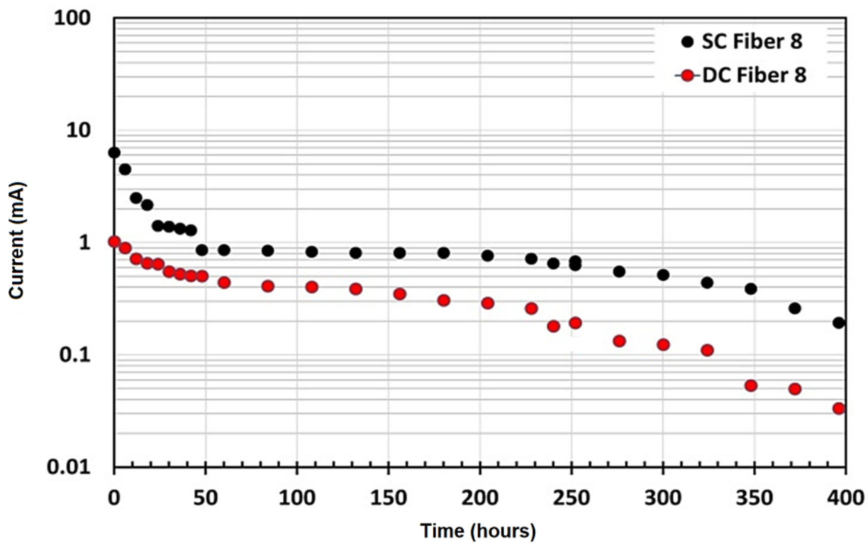

Figure 4. Current change with time in single-chamber (SC) and dual-chamber (DC) SMFC systems

4. Conclusion

Based on the conducted research and discussion, it can be concluded that the sediment microbial fuel cell can be used as an alternative energy source, generating electrical energy using single-chamber circuit. The increase in electric current at the beginning of the study was due to the accumulation of electrons already present in the sediment and the activity of microorganisms in the sediment, while the decrease in current from the start to the 108^{th} hour was due to a reduction in organic material around the anode, due to the lack of receptive food for microorganisms. Mass transfer in sediment formation is a limiting factor in generating these flows. The highest power output achieved was achieved in the microbial single-chamber fuel cell system with 8 cm^2 carbon fiber electrodes, which corresponds to 561.11 mW for 21 days.

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