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Investigation of a Microliter Microbial Fuel Cell inoculated with Shewanella oneidensis MR-1

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Introduction

Micron-scale microbial fuel cell has recently drawn lots of attention as a portable power generation device due to its high power density and environmentlly-friendly process. We designed and fabricated a microbial fuel cell which has a sub-5 µL PDMS chamber and two carbon cloth electrodes. Shewanella oneidensis MR-1 was chosen to be the electrogenic bacterial strain and inoculated into the anode chamber. Ferricyanide was used as the catholyte and pumped into the cathode chamber continuously during the experiment. The microbial fuel cell generates a power density of greater than 50 W m-3 and has a considerably short restart time after pumped in fresh medium again. Also, we have shown that for smaller chambers, the power density could be higher.

Materials

- PDMS
  - Benefits of PDMS
    - PDMS acts as a viscous liquid at high temperatures, which makes it possible to form any desired patterns using this materia. Solid PDMS has a hydrophobic surface, and can be used for polar solvents (water) without material deformation.
  - Typical use of PDMS
    - Silicone based lubricant, microfluidic chips
- Carbon Cloth
  - Reasons for using Carbon Cloth
    - Carbon materials are most commonly used electron material in microfluidic fabricatcn, due to its excellent electrical conductivity and chemical stability. Carbon cloth is used in MFCs as a flat-plate electron, which has the benefit of reducing the distance between the two electrodes.
  - Alternatives
    - Other carbon materials include graphite rod, graphite fiber brush and carbon fiber. Stainless steel and gold also have been used by some research groups, but the power density is lower than MFCs using carbon electrons for stainless steel, and gold is very expensive and has limited applications.
- Nafion PEM
  - What is Nafion?
    - Nafion is a sulfonated tetrafluoroethylene based fluoropolymer-copolymer.

Bacteria

- Bacterial strain
  - Shewanella oneidensis MR-1, indicating "metal reducing", is a bacterium which can reduce heavy metal and capable of surviving in bcth aerobic and anaerobic conditions.
  - Shewanella oneidensis MR-1 is widely used as a electrogenic bacteria in MFC applications.
  - MR-1 strain was cultured aerobically in trypticase soy broth (TSB) plate at 30°C for 24 hours, then put into refrigerator for future use. The strain can be kept and good to use for 1 week before next subculture.

Fig. 1 Image of Shewanella oneidensis MR-1

Fabrication

- Creating the molds
  - Molds were created by printing the silhouette of the chamber onto a thermoplastic sheet multiple times.
  - The sheet was then heated to 150 °C for 8 minutes.
  - Duringthe heating the sheet shrunk to 60% of the original size and the ink rose 150%
- Creating the chambers
  - PDMS was poured onto the molds and solidified by heating to 110°C for 15 minutes
  - This process created a chamber that was 4 mm by 10 mm and 100 µm deep
- Assembling the MFC
  - Plates were made to hold everything together and all the tubing was connected to them
  - The PDMS chambers were aligned with the tubes.
  - The carbon cloth and wires were placed onto the chambers
  - The PEM was placed between the chambers and the plates screwed together

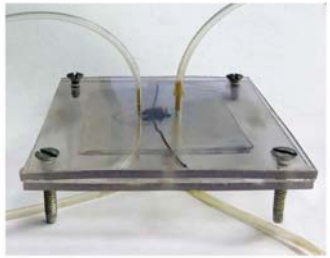

Fig. 2 MFC assembly used in the experiments

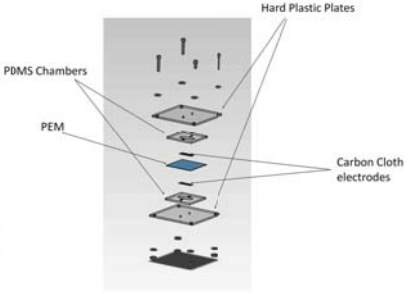

Fig. 3 Exploded view of MFC assembly

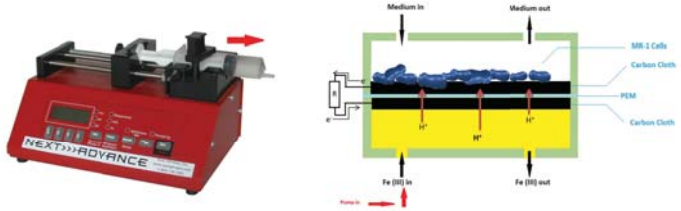

Fig. 4 Cross-sectional view of MFC

Experimental Setup

The MFC was connected to a 10 kohm resistor and the voltage drop over the resistor was measured by a Digital Multimeter that was connected to a computer running LabView. LabView calculated the current that was generated by Ohm's Law (I = V/R). The current was recorded every ten minutes and plotted on a graph to show the general trend.

Results

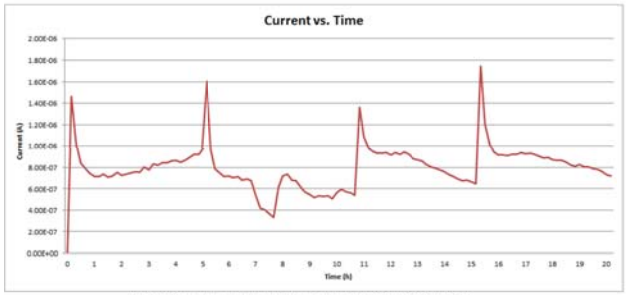

Fig. 5:Graph of current generated over time by the Microbial Fuel Cell

Current across the MFC was recorded and plotted in Figure 5. Electric current was observed immediately after inoculation and reached its peak value of 1.8 µA in 30 min. TSB medium was refilled every 5 hours, and maximum current values were restored in a relative short time period, range from 0.5-1 h.

Conclusions

A 4 µL PDMS-based microbial fuel cell has been designed and tested in our experiment. According to the data we got, the conclusion can be made that electricity could be generated with this microscaled fuel cell using shewanella MR-1 as the electrogenetic microbes. A highest current value of 1.8 µA can be reached with our design. Leakage of the setup has limited the capability of the fuel cell so far. If leakage is improved, then we expected the current be higher and last longer.

Future Work

In the future we will be developing new ideas for solving the leakage problems as well as experimenting with different elecrodes, proton exchange membranes, chamber material and microbes, in an effort to improvethe power density of the fuel cell and to ultimately make it into a viable way to produce electricity.

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