Micro-Scale Microbial Fuel Cell: Petroleum Biosensing

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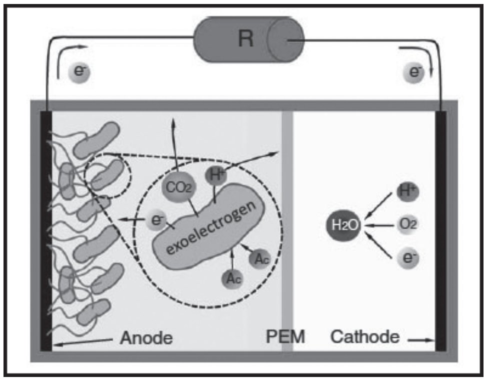

Figure 1: Simplified explanation of an MFC [4].

Introduction:

A microbial fuel cell (MFC) employs a certain type of bacteria categorized as exoelectrogenic, meaning they allow electrons to be transported from the inside to the outside of their cell membranes, via their catabolic reactions [1]. This process produces electricity as the electrons flow over an external load as shown in Figure 1. The anode and cathode chambers must be completely separate and no oxygen can enter the anode chamber, as the bacteria we explore are an anaerobic species. The final electron acceptor in the cathode is generally an inorganic catholyte [1], i.e. potassium ferrocyanide. The most common bacteria used are proteobacteria, especially those from the genus *Shewanella* and *Geobacter* [1]. An MFC has multiple applications such as water sustainability, clean energy, and biosensing. In this research, the MFC will be considered micro-scale, with a 1 cm^2 anode.

The main goal of this study was to test the effectiveness of an MFC as a biosensor in order to sense organic pollutants. The idea behind the sensor relies on a change in current generated by the MFC or series of MFCs. The bacteria in the MFC were able to oxidize organic materials such as acetate in order to produce current depending on the size of the MFC and the thickness of the biofilm [1]. When a pollutant was introduced into the anode, the bacteria were unable to break it down in the same way as the normal organic substance, causing a change in current that was detectable after knowing the previous baseline data [2].

The basis of this research project was to see if the micro-scale MFC had the ability to sense for petroleum without destroying the biofilm of bacteria. Oils spills are a major concern in any aquatic environment and it can impact the water quality for years after the initial spill. Other problems can be economic or socially problematic, such as a reduction in the tourist industry [3].

Experimental Procedure:

The micro-scale microbial fuel cells in this research were set up in a manner consistent with the micro-scale devices described by Ren [4]. The anode and cathode were glass slides with gold thin-film electrodes. Silicone gaskets prevented leakage and a proton exchange membrane (PEM) allowed protons to flow from anode to cathode. Nanoports allowed the anolyte and catholyte to reach the anode and cathode respectively at a controlled flow rate of 2 μL/min. *Geobacter sulfurreducens* enriched inoculum was used to form biofilm on the anode. The MFCs were started and allowed to reach a steady current before any testing began. The concentration of sodium acetate in the anolyte was

25 mM. In order to test the sensitivity of the MFCs to the petroleum, petroleum was diluted into the anolyte solution through a solvent bridge of toluene and ethanol. The final concentrations used were 0.5 mM and 1 mM. The anolyte used was either the 25 mM acetate with the petroleum or a buffer solution with the same ionic characteristics as the anolyte but containing no acetate. This was flowed into the MFCs at the main flow rate for several hours each and data points were taken every minute.

Results and Conclusions:

A transient curve of current density over time was taken from a working MFC in order to see the effects of the buffer solution with 0.5 mM petroleum being added, as shown in Figure 2. The results indicated in each case that the MFCs were sensitive to petroleum. If petroleum was added without other organic substrates, the MFCs could not oxidize the petroleum and the current was drastically reduced as shown in Figure 3. However, if the petroleum was added in addition to the 25 mM acetate, the MFCs were able to oxidize both the acetate and petroleum as shown in Figure 4. Previous research indicates that *Geobacter sulfurreducens* might be able to break down benzene, a large component of petroleum, via the reaction $C_6H_6 + 30Fe(III) + 12H_2O \rightarrow 30Fe(II) + 6CO_2$ [5]. More research would be required to determine if this was a consistent response.

The MFCs were able to recover from a lack of organic substrates after being starved for multiple hours. The experiments show the MFCs can be re-used after a series of spiking petroleum samples.

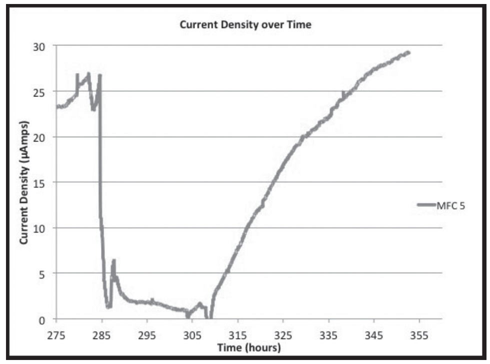

Figure 2: Current density over time with the addition of petroleum after 25 mM acetate as well as the addition of 25 mM acetate to determine recovery.

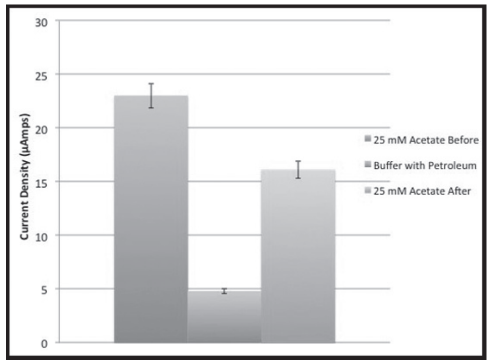

Figure 3: The average current density during each part of the curve before, during, and after the addition of buffer containing petroleum.

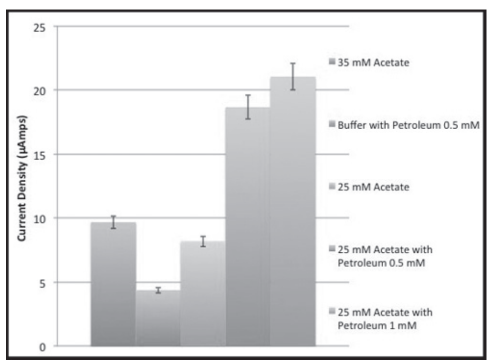

Figure 4: The addition of buffer with petroleum as well as adding different concentrations of petroleum to the 25 mM acetate to see if it could facilitate a different response from the MFC.

Acknowledgments:

I would like to thank Dr. Junseok Chae, Hao Ren, and everyone in my lab for their help with this research, Dr. Trevor Thornton for coordinating my stay at ASU, and the National Nanotechnology Infrastructure Network Research Experience for Undergraduates Program and the National Science Foundation for funding this research.

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