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Carbon Fiber Electrode as an Electron Acceptor for a Microbial Fuel Cell Using Geobacter

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ABSTRACT

Microbial fuel cells use bacteria to produce electricity. A dual-chambered microbial fuel cell was used to harness electricity from *Geobacter*, with carbon fiber as the electrode. The peak current measured was 10.7 µA on the first day, and fell to zero within 5 days. This result is comparable to a similar experiment using the carbon fiber electrode with a different bacteria, but less than typical results from *Geobacter* when different electrodes were used.

Keywords: *microbial fuel cell, Geobacter*

INTRODUCTION

Microbial fuel cells (MFCs) are devices that use bacteria as the catalysts to oxidize organic and inorganic matter and generate current. Electrons produced by the bacteria from these substrates are transferred to the anode (negative terminal) and flow to the cathode (positive terminal) linked by a conductive material containing a resistor, or operated under a load (i.e., producing electricity that runs a device) (Logan 2006).

The proposed uses of MFCs are many. Min and Logan (Min 2004) successfully treated wastewater and produced electric current at the same time. At a modern treatment plant, the wastewater may contain 9.3× as much energy as is used to treat it (Shizas 2004); energy that can be put to use if the bacteria is harnessed by MFCs. They can also be used as self-sustaining batteries for hard to reach places. Sediment fuel cells are already being used in creek and river beds to monitor environmental sensors (Logan 2005).

There have been many studies conducted using different electrodes and different bacteria as sources

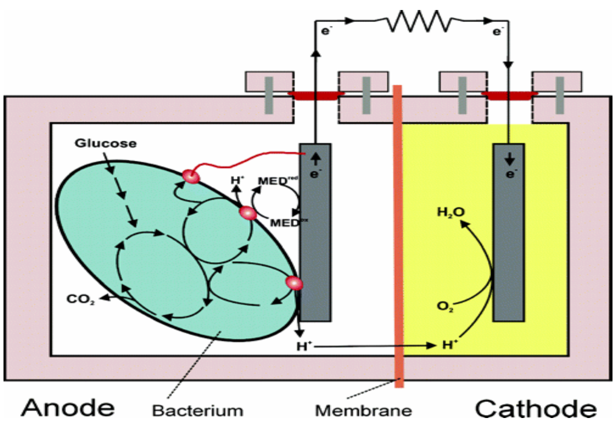

Figure 1. Operating principles of a MFC (not to scale). A bacterium in the anode compartment transfers electrons obtained from an electron donor (glucose) to the anode electrode. This occurs either through direct contact, nanowires, or mobile electron shuttles (small spheres represent the final membrane associated shuttle). During electron production protons are also produced in excess. These protons migrate through the cation exchange membrane (CEM) into the cathode chamber. The electrons flow from the anode through an external resistance (or load) to the cathode where they react with the final electron acceptor (oxygen) and protons (Rabaey, 2005).

for the microbial fuel cell. *Geobacter* species have shown the ability to transfer electrons directly to an electrode, with the electrode serving as the sole electron acceptor (Gregory, Bond, and Lovely, 2004). Scanning electron microscope images show *Geobacter* growing directly on the surface of a graphite electrode and nearly covering it. This would suggest the electrode's utility as an electron acceptor in the bacteria's metabolic cycle. Other organisms have shown the ability to transfer electrons, but *Geobacter* has thus far produced the highest current.

It has recently been discovered that Geobacter is able to perform this mediator-less transfer with the use of nanowires. These nanowire structures allow the direct reduction of a distant electron acceptor. This removes the need for soluble mediators that would be lost in a continuous-flow MFC and may allow for direct interspecies electron transfers (Logan and Regan 2006).

Studies previously performed on *Geobacter* have not used a carbon fiber electrode. In 2006, Lisa Sader performed a study with an MFC using carbon fibers as the electrode and different bacteria (Sader, 2006). The purpose of the carbon fibers was to increase surface area of the electrode, thereby increasing the amount of bacteria that can colonize and the current that can be produced. Lisa Sader's experiment was successful in producing a current, showing the effectiveness of the carbon fiber, but not surpassing any other findings.

The objective of this research is to combine the previous studies, using the most productive bacteria, *Geobacter*, and the possible benefit of the increased surface area of the carbon fiber as the electrode. It is proposed that the combination will produce the highest current recorded in a microbial fuel cell as of yet.

MATERIALS AND METHODS

A pure culture of *Geobacter*, strain DL1, was obtained from Derek Lovely and grown in a fluid thioglycollate broth.

The fuel cell used by Lisa Sader was used as a model. It consisted of two 500 mL polycarbonate narrow mouth square bottles (Nalgene). The chambers are connected by a 1/2 inch barbed bulk head fitting and a Nafion 117 proton-selective membrane. Each chamber was capped and entry allowed through two 1/4 inch barbed bulk head fittings, located on each cap.

The anaerobic chamber, where bacterial growth occurred, contained 10 cm of exposed, unsized 25K carbon fiber (Fortafil Fibers, Inc) connected to 2 inches of 12 ga braided copper wire by heat shrink tubing. Total electrode surface area is approximately 470 cm^2. Approximately 1 inch of copper wire was exposed in the aerobic chamber to transport electrons.

After construction, each chamber was filled with approximately 450 mL of Fluid Thioglycollate broth and autoclaved at 121°C for 30 minutes to sterilize. To serve as a buffer, 4 g of Tris-HCl was added to the aerobic chamber. The chamber containing the carbon fiber electrode was continually purged with a 20% CO_2 + 80% N_2 gas mixture to ensure anaerobic conditions. Room air was filtered-sterilized through a 0.02mm pore size filter and bubbled into the aerobic chamber. Both chambers were continually mixed with magnetic stir bars at approximately 200 rpm.

The anaerobic chamber was then inoculated with 1.5 mL of fluid Thioglycollate broth culture of Geobacter via a sampling port (Sader, 2006).

RESULTS

A current was produced in the µA range, peaking at 10.7 µA on the first day. The current fell on the next day, started to rise again on the third, and then continued falling to zero each day thereafter.

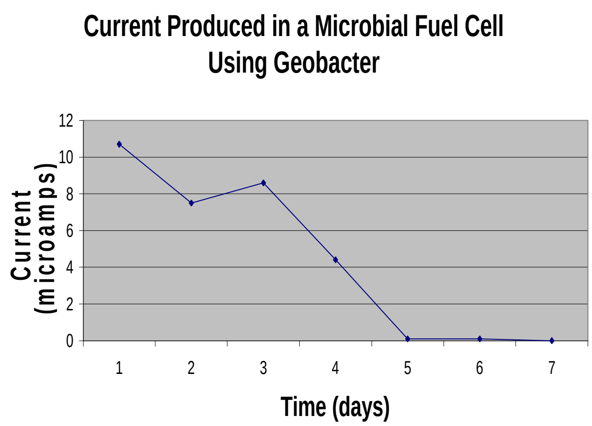

Figure 2. Current produced in a microbial fuel cell using *Geobacter*. Maximum current was produced on Day 1, 10.7 µA. The current then fell to zero within 5 days.

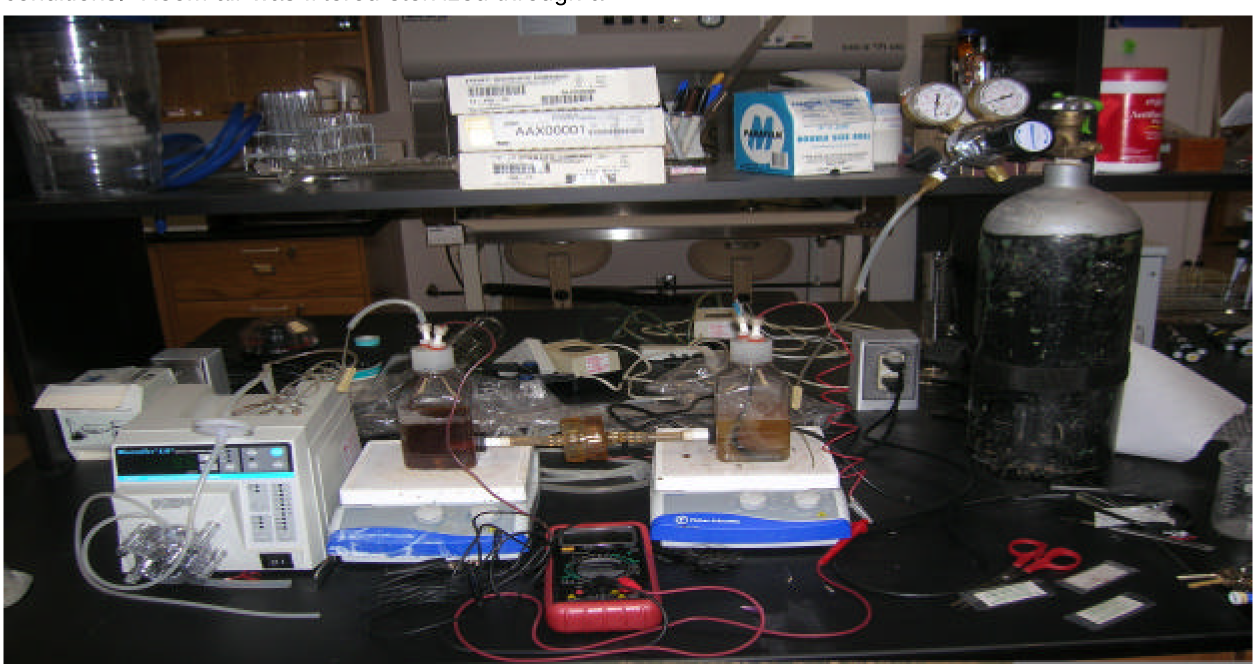

Figure 3. Microbial Fuel Cell. Two nalgene bottles are connected by a proton selective membrane. *Geobacter* is grown in anaerobic conditions on the right, while aerobic conditions are maintained on the left. An ammeter is placed in circuit to measure amperage.

DISCUSSION

The experiment showed that current at the level of µA is possible. The results compared with Sader's result of 13.68 µA. The amount of current hoped for was not produced; ways to improve the cell are discussed.

Power density, electrode potential, coulombic efficiency, and energy recovery in single-chamber microbial fuel cells (MFCs) were examined as a function of solution ionic strength, electrode spacing and composition, and temperature by Liu et al (Lui 2005). Their research showed that an MFC can be improved by increasing ionic strength, decreasing electrode spacing, and increasing temperature to above 30°C, all variables not attempted in this experiment. Research has also indicated that the highest power densities are achieved with a mixed culture broth, rather than a pure culture as was used here (Logan and Regan 2006).

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