BRUSH ANODE AND TUBULAR CATHODE SCALE UP MICROBIAL FUEL CELLS

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PENNSTATE 1855

Generating electricity from renewable sources will soon become as easy as putting a brush and a tube in a tub of wastewater.

A carbon fiber, bottle-brush anode developed by Penn State researchers will provide more than enough surface for bacteria to colonize, for the first time making it possible to use microbial fuel cells for large scale electricity production. In addition, a membrane-tube air cathode, adapted from existing wastewater treatment equipment, will complete the circuit.

"The carbon fiber brushes are electrically conducting, very inexpensive to produce and supply large surface area for the bacterial biofilm attachment," says Bruce E. Logan, the Kappe Professor of Environmental Engineering. "These anodes can be made by any existing brush manufacturer in any size or shape desired."

Microbial fuel cells work through the action of bacteria, which can pass electrons to an anode of a fuel cell. The electrons flow from the anode through a wire to the cathode, producing an electric current. In the process, the bacteria consume organic matter in the wastewater and clean the water. The Penn State approach uses the bacteria that naturally occur in wastewater, requiring no special bacterial strains or unusual environmental demands.

Previously, Logan and his team showed that small, rectangular fuel cells that used a carbon fiber paper as anode and a carbon fiber paper with platinum catalyst as cathode could produce electricity and clean water from wastewater. However, commercial scale-up for carbon fiber paper cells was not practical.

Using brush anodes, which have 300 to 1,500 times more surface area than the previously used carbon paper anode, the fuel cells created more than twice the power produced by the fuel cells two years ago. A fuel cell using a small brush about 1 inch in diameter and 1 inch long produced the equivalent of 2.4 watts for every 260 gallons of water using the carbon paper cathode, the researchers reported in today's (Mar. 21) online edition of Environmental Science and Technology.

"The anode is no longer a limiting factor in power production for these cells," says Logan. Other carbon anodes were problematic because the pores or spaces became clogged with the biofilm and lost efficiency, but because the brush contains very fine fibers with plenty of circulation room around them, dead bacteria do not clog the brush.

With the anode no longer limiting scale up or bacterial growth, the researchers turned to the cathode. "We needed a new type of cathode that could produce much more surface area," says Logan. "Many systems use platinum catalysts, but platinum is too expensive.

While the brush anode can be submerged in the wastewater, the cathode must have one side exposed to the oxygen in the air to work. The researchers looked at membrane tubes currently used in wastewater treatment applications for an answer. Commercially available in a variety of sizes ranging up to 6 to 8 foot tall, these membrane tubes are not electrically conductive.

"We painted the tubes with conducting graphite paint and added a cobalt-based catalyst," says Logan.

The painted tubes did work to produce power, but not as much as the carbon paper doped with platinum. "We showed a proof of concept with these tubes, but now we have to improve the efficiency and reduce costs," he adds.

The researchers tested two cathode configurations, one with the catalyst on the outside of the tubes and one with the catalyst on the inside of the tube.

In the best test case, the researchers used a carbon fiber brush anode and two tubular cathodes of about .6 inches in diameter doped with a cobalt catalyst on the inside, the fuel cell produced 18 watts per 260 gallons of water and achieved a charge efficiency of more than 70 percent.

The newly configured anodes and cathodes also allow for a variety of configurations of the fuel cell. "With these new anodes and cathodes the design of a wastewater treatment reactor could be as simple as a large tank with the brushes and tubular cathodes inserted into the same tank," says Logan.

An additional benefit to the microbial fuel cell is that while it generates electricity, it cleans up the wastewater, something that usually requires the consumption of energy.

Working on the anode research were Logan, Shaoan Cheng, research associate and Valerie Watson, graduate student, civil and environmental engineering, and Garett Estadt, recent graduate, chemical engineering. Working on the cathode research were Logan; Cheng; and Yi Zuo and Doug Call, graduate students, civil and environmental engineering. The National Science Foundation and the U.S. Department of Agriculture supported this work.