Research Notes

Brush Anode, Tubular Cathode Scale Up Microbial Fuel Cells

Generating electricity from renewable sources will soon become as easy as putting a brush and a tube in a tub of wastewater, according to a Pennsylvania State University (Penn State; Collegeville) news release. 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 news release states.

“The carbon fiber brushes are electrically conducting, are very inexpensive to produce, and supply large surface area for the bacterial biofilm attachment,” said Bruce E. Logan, Kappe Professor of Environmental Engineering at Penn State. “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, Penn State notes.

Using brush anodes, which have 300 to 1500 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 2 years ago. A fuel cell using a small brush about 25.4 mm (1 in.) in diameter and 25.4 mm (1 in.) long produced the equivalent of 2.4 watts for every 984 L (260 gal) of water using the carbon paper cathode, the researchers reported in the March issue of Environmental Science and Technology.

“The anode is no longer a limiting factor in power production for these cells,” Logan reports.

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 1.8 to 2.4 m (6 to 8 ft) tall, these membrane tubes are not electrically conductive.

“We painted the tubes with conducting graphite paint and added a cobalt-based catalyst,” Logan said. The painted tubes did work to produce power, but not as much as the carbon paper doped with platinum, the press release notes.

“We showed a proof of concept with these tubes, but now we have to improve the efficiency and reduce costs,” Logan said.

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 15.2 mm (0.6 in.) in diameter doped with a cobalt catalyst on the inside, and the fuel cell produced 18 watts per 984 L (260 gal) of water and achieved a charge efficiency of more than 70%.

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,” Logan said.

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.

Contact Logan at biogan@psu.edu for additional information.

**Cornstarch Yields Eco-Friendly Laundry Ingredient**

U.S. Agricultural Research Service (ARS) scientists, collaborating with Folia Inc. (Birmingham, Ala.), a developer and marketer of biodegradable polymers, have come up with an environmentally friendly laundry detergent. The new detergent ingredient may be a bit easier on our water supply, according to an ARS news release.

ARS scientists Randy Shogren and J.L. Willett have worked with Folia scientists and others to develop a detergent additive — called a cobuilder — that prevents the formation of crusty deposits known as scale. The new cobuilder ingredient, derived from cornstarch, is biodegradable.

In hard-water regions, scale can cause harm ranging from discolored clothing and cloudy dishes to diminished cooling and washer damage, the news release says. Currently, the petroleum derivative polyacrylic acid is used. It improves cleaning power by softening water and keeping calcium carbonate from crystallizing. But polyacrylic acid isn’t biodegradable, which raises the likelihood for this additive to accumulate in the environment, noted Shogren, a chemist.

“It goes down the drain and into the water supply, where its accumulation could be a problem,” Shogren explained. Shogren and Willett, a chemical engineer, work at the ARS National Center for Agricultural Utilization Research in Peoria, Ill.

In studies there, Shogren and Willett researched ways to make a scale-fighting cobuilder that would be degradable by microbes in soil and water. That led to the use of two food-grade additives — citric acid and sorbitol — and a heat-based method of fusing them so that they would form polyester-based cobuilders.

In tests, solutions of calcium carbonate formed crystals within 1 minute, the ARS news release notes. But adding the polyester-based cobuilder staved off crystal formation for 10 minutes. Although less polyacrylic acid was needed to do the same, it lacked the biodegradability of the polyester-based cobuilder.

The team’s method of making the polyester cobuilders from citric acid and sorbitol avoids the use of costly solvents, which has restricted the sales of similar biodegradable detergent additives to niche markets, according to ARS. The team’s focus now is scaling up production of the cornstarch-based polyester cobuilders. Folia is also sending product samples out for independent testing.

For more information, see the April 2007 issue of Agricultural Research magazine at www.ars.usda.gov/is/AR/archive.

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