Microbial Fuel Cells Offer Innovative Technology for Oil, Gas Industry and Biorefineries

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Technology Summary

Researchers at ORNL have developed several concepts of importance to the oil, gas, and biorefinery industries, using microbial fuel cells (MFCs) to treat wastewater generated in oil and gas production, to neutralize harmful petroleum by-products, and finally, to increase ethanol yields at biorefineries—in each instance adapting the MFCs to use the organic waste to generate electricity.

The first concept addresses a longstanding problem in the oil and gas industry, where organics and salt contaminate water in significant amounts during fossil fuels production. Currently, no practical technologies exist for purging contaminants from water in the field. In the first step, salts are removed. In an MFC, protons are transferred from the anode to the cathode. Industrial water contains positively charged cations other than protons, such as K^+, Na^+, Ca^{2+}, Mg^{2+}, NH^{4+}, and since the concentration of the cations is about 5–6 orders of magnitude higher than protons, their rate of transfer from the water to the cathode is high. This removes the cations from the water. The negatively charged anions can be removed by adding lime. In the second step, the organic acids in the wastewater, such as benzene, toluene, xylene (BTX), and polyaromatic hydrocarbons, are removed when the MFC's anode biocatalyst synthesizes the organics and converts them to generate electricity.

The second concept being developed at ORNL is a method for removing a hazardous by-product of petroleum processing, hydrogen sulfide. MFCs use reduced organic or inorganic sources to extract electrons and protons and generate electricity. The MFC can be modified to produce hydrogen instead of electricity, by applying additional 0.3 V across the anode and cathode. Hydrogen sulfide can be split into protons and electrons in the presence of an aqueous catalyst as follows: $H_2S + 4H_2O \rightarrow 10H^+ + SO4^{2-} + 8e$-. Microbial catalysts carry out complete oxidation of hydrogen sulfide to sulfate, using the molecule as an energy source. Using these organisms in a fuel cell anode can result in production of electricity or hydrogen. Such a device can operate as a hydrogen sulfide removal unit while simultaneously producing electricity or hydrogen.

Advantages

In biorefineries, the conversion of biomass to ethanol for energy is hindered by inhibitors produced during pretreatment. The ORNL researchers propose using MFCs that can consume such inhibitors as a fuel to recycle the water stream, improving ethanol yields while producing electricity at the same time. The MFCs can also consume as fuel residual sugars and fermentation metabolites in the recycle stream, giving additional electrical power. The resulting biorefinery effluent streams are amenable to treatment by MFCs so that the streams can be recycled.

Potential Applications

All the methods are a significant advance on current technologies in that the MFCs make use of organic waste in each case to generate electricity for related industrial processes. The technology to increase ethanol production at biorefineries is expected to be commercialized by 2012. The MFC method described here can produce up to 3.5 MW of power from acetate alone, in a biorefinery producing 70 million gallons of ethanol per year.

Patent

Abhijeet P. Borole and Constantino Tsouris, *Microbial Fuel Cell Treatment of Fuel Process Wastewater,* U.S. Patent Application 12/366,709, filed February 6, 2009.

Abhijeet P. Borole, *Bioelectrochemical Treatment of Gaseous Byproducts,* U.S. Patent Application 12/628, 282, filed April 7, 2009.

Abhijeet P. Borole, *Microbial Fuel Cell Treatment of Ethanol Fermentation Process Water,* U.S. Patent Application 12/366, 713, filed Feburary 6, 2009.

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