Docket #: S12-308

Microbial Batteries Produce Energy from Wastewater and Other Organic Matter

An interdisciplinary team of Stanford engineers have developed a low-cost, patented, in situ method to efficiently produce electricity from organic matter such as wastewater. This microbial battery (MB) employs an anode coated with exoelectrogenic microbes that can ingest organic waste to produce excess electrons. The electrons travel to a solid state cathode which can be removed from the MB to release the electrons and recharge. The simple, membrane-free design lowers the cost and avoids oxygen diffusion.

Overall, the MB has high energy recovery efficiency, high power output and low capital costs. In addition, it avoids the odor, safety and environmental risks inherent in bioreactors that produce methane. This technology could be particularly useful for in situ removal of hydrocarbon deposits in sediment or for decentralized treatment of wastewater. The system could effectively offset the electricity now used to treat wastewater – currently estimated at 3% of the total electrical load in developed nations.

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Schematic of the microbial battery (MB) equipped with a Prussian Blue (PB) cathode. *The microbial anode produces electrons from organic matter. The electrons flow to the PB electrode that functions as a cathode and is reduced. When exposed to oxygen in air, the reduced PB is re-oxidized.*

Stage of Development

The inventors have built prototype microbial batteries and demonstrated their efficiency. Initial tests were performed with a silver cathode which achieved efficiency of electrical energy conversion of 44-49% glucose and 22-38% for real domestic wastewater. In subsequent testing with a lower cost Prussian Blue cathode, they demonstrated 85% charge transfer, with net energy recovery efficiency ~30% (exceeds MFC) with no loss of capacity over 20 cycles of operation.

Applications

- **Biofuel/alternative energy** - in situ energy extraction from a range of organic sources, such as:
    - wastewater
    - hydrocarbon and decaying biomass in sediments or landfills
    - organic pollutants in dead zones of lakes and coastal waters
    - methane deposits in the subsurface and deep ocean

Advantages

- **High efficiency energy recovery:**
    - ~20-40% with MB compared to ~4% for conventional bioreactor and microbial fuel cell technology
    - direct conversion of chemical energy into electricity
- **No hazardous biogas** - avoids safety, odor and environmental impact concerns of bioreactors that produce methane
- **In situ operation:**
    - can convert organic matter in low concentrations and in hard to access locations
    - positioning MB within wells to access subsurface deposits enables carbon dioxide to be released, neutralized and sequestered at depth
- **Simple, membrane-free design** - compared to microbial fuel cells which rely on a membrane, MB's have:
    - higher power output
    - lower cost
    - reduced oxygen diffusion

Publications

- Xie, X., Ye, M., Liu, C., Hsu, P. C., Criddle, C. S., & Cui, Y. (2015). Use of low cost and easily regenerated Prussian Blue cathodes for efficient electrical energy recovery in a microbial battery. *Energy & Environmental Science*, 8(2), 546-551.
- Xie, X., Ye, M., Hsu, P. C., Liu, N., Criddle, C. S., & Cui, Y. (2013). Microbial battery for efficient energy recovery. *Proceedings of the National Academy of Sciences*, 110(40), 15925-15930.

Patents

- Published Application: WO2014055671
- Issued: 9,509,028 (USA)

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