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Mechanical and Aerospace Engineering Department
University of Texas at Arlington

The Effect of Controlled Nanomaterial Wettability on Electrodes
For Microbial Fuel Cells and Electrolysis Cells

By

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Abstract

Microbial fuel cells (MFCs) and microbial electrolysis cells (MECs) are relatively new energy harvesting technologies that utilize the bacteria in wastewater or other organic-rich aqueous media to produce either electricity or hydrogen gas, respectively. Given that MFCs and MECs are newer technologies, there has been many works over the past two decades that have provided understanding into how modifying electrode surface chemistry can improve these cells. It has been widely known that increasing the surface functional groups of MFC anodes, either chemically or thermally, causes the cell power density to increase dramatically. Since MFCs and MECs use the same anodes, a corresponding increase in power density for a MFC will cause an increase in hydrogen generation if the anode is used in a MEC. Previous studies have also demonstrated that increasing the hydrophobicity of anode electrodes causes a corresponding decrease in output voltage and increases the necessary start-up time for MFCs. However, these studies do not correlate whether increasing hydrophilicity of anodes is of any benefit and there has been little study of how hydrophilicity can affect the MEC cathode where hydrogen generation takes place.

In this work, a one-step electrophoretic deposition (EPD) process is undertaken to deposit carbon nanotubes (CNTs) with variable wettability for MFC/MEC anodes and MEC cathodes. The EPD process allowed for the controlled wettability of the CNT depositions by changing the composition of the organic solvent used to disperse the nanomaterials, from hydrophilic to
hydrophobic, without changing the applied voltage or nanomaterial concentration. Scanning electron microscopy images and Fourier-transform infrared spectroscopy were used to characterize these depositions and understand how changing the deposition solvent causes the corresponding change in surface wettability. The CNT depositions allowed previously poor performing bare metals, such as stainless steel, to express significantly increased volumetric power density and Coulombic efficiencies. A novel radial EPD technique was developed to deposit nanomaterials uniformly on stainless steel brushes to create a cost-effective, hierarchical three-dimensional anode for MFCs/MECs. All anodes were extensively studied electrochemically at each step of the cell wastewater inoculation process, when the bacteria colony is developed on the anode, as well as during the steady-state operation using either a conventional phosphate buffered solution or an amended wastewater.