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Project Number
38415

Project Title
Self-Sustainable Microbial Fuel Cell Driven High-Efficiency Nickel-Based Water Splitting System

Abstract

Objectives/Goals
The project goal is to create a low-cost NiC(2)O(4) (nickel oxalate) catalyst for water electrolysis based on the hypothesis that porous structure leads to higher efficiency, and power this system using microbial fuel cells to generate hydrogen without releasing greenhouse gases and burdening power supply.

Methods/Materials
NiC(2)O(4) was grown on 2 pieces of nickel foam: the first piece in air (NiO) and the second one in nitrogen (N-treated) at 400°C for 40 minutes. Samples were analyzed with X-ray diffractometer and scanning electron microscope (SEM). Linear voltammetry evaluated their overpotentials, tafel slopes, and electrochemical surface areas. The electrochemical impedance (EIS) graph was obtained by applying a potential of -129 mV vs. RHE with amplitude of 5 mV from 100 kHz-1 Hz. Tryptic soy broth was made, sterilized in autoclave, and Shewanella Oneidensis MR-1 was cultivated in it. A microbial fuel cell (MFC) was constructed using anode and cathode chambers, cation exchange membrane, 2 end plates, 4 threaded rods, 4 rubber gaskets, bacteria in tryptic soy broth, and cathode electrolyte. 1 MFC was connected to multiple resistors and voltage outputs for each one were measured with multimeter. 5 MFCs were connected to water splitting device with N-treated samples.

Results
SEM shows N-treated sample more porous than air-treated one. X-ray diffraction patterns show that N-treated sample has Ni phase, and NiO one has Ni and NiO phases. For hydrogen evolution reaction (HER), overpotentials of NiO and the N-treated samples are 182 mV and 51 mV at 10 mA/cm^2 and tafel slopes are 83 mV dec(-1) and 50 mV dec(-1). For oxygen evolution reaction (OER), overpotentials of NiO and N-treated samples are 310 mV and 337 mV at 10 mA/cm^2; tafel slopes are 69 mV dec(-1), and 83 mV dec(-1). EIS Graph shows N-treated sample has lower charge transfer resistance and greater electrical conductivity than NiO sample. From electrochemical surface area graph, N-treated sample has slope of 40.16 mF/cm^2, and NiO one has a slope of 1.72 mF/cm^2. 1 MFC shows the most current at voltage of 0.15 V and has a maximum power of 1.524 mW at current of 1.73 mA.

Conclusions/Discussion
Results confirm hypothesis: porous structure leads to high water splitting efficiency. N-treated porous NiC(2)O(4) sample shows better HER and OER performance than other catalysts.

Summary Statement
We synthesized highly efficient nickel-based electrocatalysts for water electrolysis, and powered this water-splitting system using microbial fuel cells in order to generate hydrogen in a self-sustainable way.

Help Received
Research conducted at UCSC under supervision of Tianyi Kou and Prof. Yat Li.