Hawai'i Natural Energy Institute Research Highlights

Electrochemical Power Systems

Proton Exchange Membrane Fuel Cell Producing Hydrogen Peroxide

OBJECTIVE AND SIGNIFICANCE: Hydrogen peroxide is widely useful to many industries, as well as the military, as an environmentally friendly disinfectant and liquid oxidant for air-independent fuel cell applications. The main method for hydrogen peroxide production today, an anthraquinone-oxidation process, is energy-intensive, expensive, produces waste that negatively impacts the environment, and is not easily scalable, leading to the transport of dilute solutions at high cost to minimize safety concerns.

The objective of this project is to modify a proton exchange membrane fuel cell (PEMFC) to allow electrochemical synthesis of hydrogen peroxide. The process also produces energy, eliminates waste by producing aqueous solutions of varied hydrogen peroxide concentrations, and is scalable to address the specific needs of these various industries and communities.

BACKGROUND: Hydrogen peroxide is considered among the world's top 100 most important chemicals as it is very versatile and is mainly an eco-friendly disinfectant. Today, over 95% of hydrogen peroxide is produced from an anthraquinone-oxidation process. This process is very costly, mainly due to the fact that it can only economically work at large-scale. Further, it is a batch process that requires further separation and dilution processes, which also necessitate enormous amounts of energy to conduct. These dilution processes are vital as a safety measure to transport hydrogen peroxide over a range of distances due to its explosive nature as an oxidant. The substantial risks associated with the transportation of hydrogen peroxide alone produces a major need for scalable, onsite production of this chemical. If successful, onsite production of hydrogen peroxide would also provide the means for wastewater treatment in rural communities.

Hydrogen peroxide can be synthesized electrochemically from hydrogen and oxygen in a fuel cell utilizing the 2-electron (e^-) pathway of the oxygen reduction reaction (ORR) (Equation 1). Most polymer electrolyte (PEM) fuel cell research involves the $4e^-$ pathway of the ORR, or complete reduction of oxygen which produces water and power (Equation 2).

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2 \quad \text{(Equation 1)}$$

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \quad \text{(Equation 2)}$$

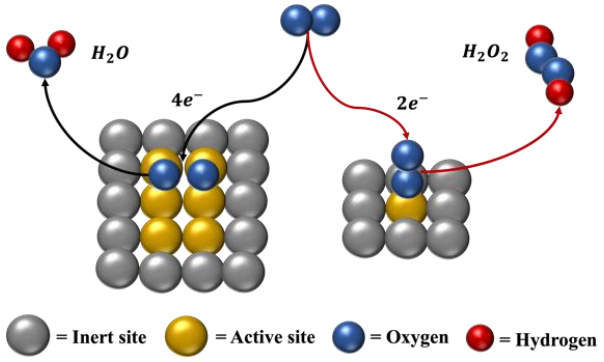

Figure 1. $2e^-$ and $4e^-$ pathways for the ORR.

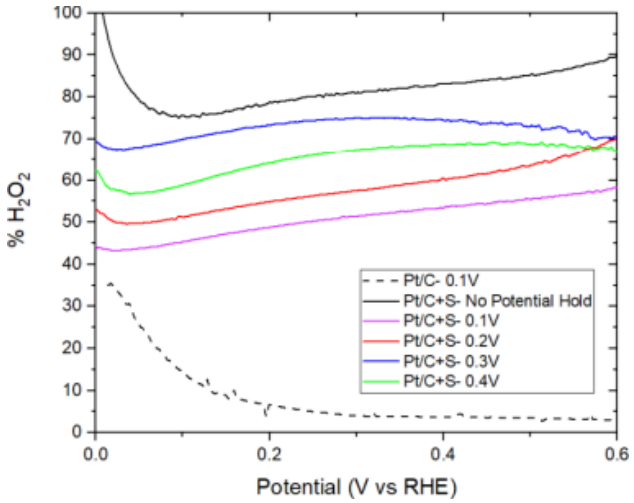

Figure 2. Hydrogen peroxide production vs potential for various deposition voltages in ex-situ test cell.

PROJECT STATUS/RESULTS: To date, HNEI has demonstrated viability of approach in ex-situ test cell producing > 50% yields of hydrogen peroxide. We also initiated test plans for in-situ experiments using 50 cm^2 single cells to determine optimal materials, system configuration, and process for producing and extracting hydrogen peroxide with a fuel cell.

This work resulted in an MS thesis titled "***Proton Exchange Membrane Fuel Cell Modification for Catalytic Cogeneration of Hydrogen Peroxide and Electricity***".

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