Hawaiʻi Natural Energy Institute Research Highlights

Electrochemical Power Systems

Proton Exchange Membrane Fuel Cell Producing Hydrogen Peroxide

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to modify a proton exchange membrane fuel cell (PEMFC) to optimizer hydrogen peroxide synthesis. Hydrogen peroxide is widely useful by many industries, as well as the military, as an environmentally friendly disinfectant. The main method for hydrogen peroxide production today, an anthraquinone-oxidation process, is energy-intensive, expensive, produces waste negatively impacting 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 develop an alternative, electrochemical method for synthesizing hydrogen peroxide that also produces energy, eliminates waste by producing aqueous solutions of varied hydrogen concentrations, and is scalable to address the 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, because the economics are such that the process can only 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).

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2 \quad \text{(Equation1)}$$

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

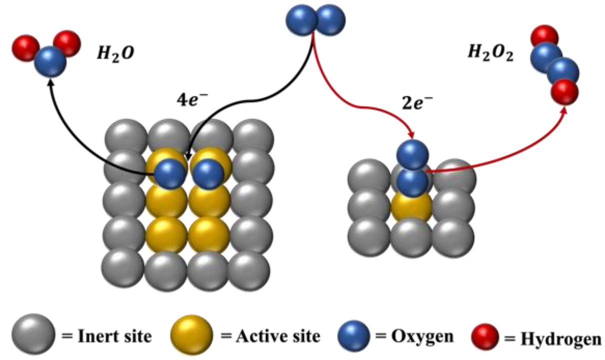

Figure 1. $2e^-$ & $4e^-$ pathways for the ORR.

PROJECT STATUS/RESULTS: HNEI has reviewed the concept, invention disclosure, and relevant literature. As a result of the review and prior results, an experimental plan and detailed procedures for a selective catalyst for the $2e^-$ pathway has been developed and will be tested in further experimentation. This innovative approach to the synthesis of hydrogen peroxide will enable onsite production of this chemical, and power.

Experiments will begin by verifying the co-generation of hydrogen peroxide and power ex-situ in a Rotating Ring Disk Electrode (RRDE). Experiments will then be performed in-situ in a PEMFC for further verification and identification of modifications to design of fuel cell to increase removal rate of hydrogen peroxide and limit decomposition to maximize performance, productivity, and yield. HNEI will also begin verification experiments ex-situ in the RRDE. PEMFC assembly, modification, and operation training will ensue thereafter.

The project is ongoing and will continue through at least Fall 2023.

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