Hawaiʻi Natural Energy Institute Research Highlights

Electrochemical Power Systems

Catalyst-Modified PEMFCs for Hydrogen Peroxide and Power Co-Generation

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to modify a proton exchange membrane fuel cell (PEMFC) to allow electrochemical synthesis of hydrogen peroxide. The process simultaneously produces energy and aqueous solutions of varied hydrogen peroxide concentrations while being scalable.

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. Over 95% of hydrogen peroxide is produced from an anthraquinone-oxidation process, which is very costly—mainly since it can only economically work at large scale. Moreover, 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 would also provide the means for wastewater treatment in rural communities.

PROJECT STATUS/RESULTS: A rotating ring-disc electrode (RRDE) measurement system, was used to conduct ex-situ experiments to identify a stable catalyst which could perform effectively and maintain integrity under the challenging conditions within a fuel cell. After achieving a stable catalyst, further experiments were conducted to optimize the operational parameters for the co-generation of hydrogen peroxide and electricity. It was observed that the catalyst, when used without applying potential holds, produced the highest yield of hydrogen peroxide. However, introducing potential holds led to a significant increase in current suggesting enhanced efficiency for electricity generation. Despite a slight reduction in hydrogen peroxide production with the potential holds, the trade-off was a marked improvement in overall current performance.

These results elucidate possible preferred conditions to maximize the production of hydrogen peroxide and electricity at an applied potential near 0.3 V with an indirect measurement of hydrogen peroxide yield up to 89%.

With the ex-situ work having demonstrated a set of operational parameters sufficient for inducing significant peroxide formation while simultaneously producing electricity, work began by scaling up to a working single cell PEMFC. An industry standard 50 cm^2 fuel cell test hardware was selected as a starting point, as this hardware has been well-characterized over the years. We established a test protocol to systematically evaluate and optimize the production, removal, and capture of aqueous hydrogen peroxide from the system. Several parameters were explored to evaluate the impact on the hydrogen peroxide yields and the resultant power production from the cell.

Generally, we found it difficult to distinguish whether low reaction efficiency is occurring or high reaction efficiency with decomposition of peroxide occurring prior to measurement. Ex-situ RRDE-based experiments were able to achieve upwards of 60-80% production efficiencies while the best achieved in-situ prior to end of the grant was 1-3%, which may be sufficient for water purification applications. However, ultimately the goal is to achieve >50% faradaic efficiencies.

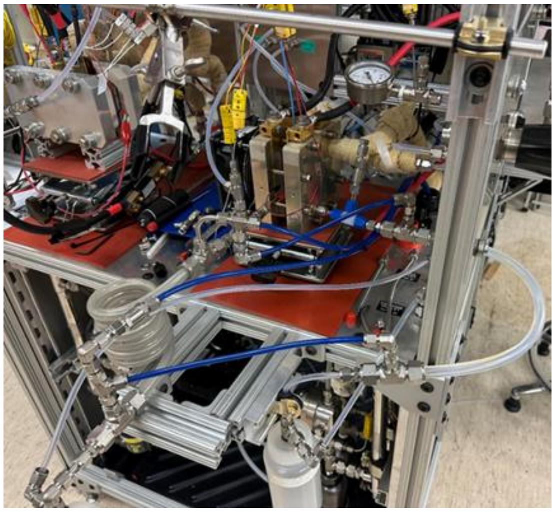

Figure 1. In-situ test hardware and hydrogen peroxide effluent collection equipment.

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