

II.B.6 Economical Production of Hydrogen Through Development of Novel, High Efficiency Electrocatalysts for Alkaline Membrane Electrolysis

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Subcontractors:

- Washington University, St. Louis, MO
- Georgia Technology Institute, Atlanta, GA
- Pajarito Powder, Albuquerque, NM

Project Start Date: April 11, 2016

Project End Date: April 10, 2018

Overall Objectives

- Refine the pyrochlore synthesis technique for electrocatalysis of oxygen evolution.
- Replicate catalyst synthesis in the manufacturing environment and scale up.
- Compare commercial and optimized ionomers and refine formulations based on results.
- Scale up downselected ionomers for demonstration in electrolyzers.
- Integrate optimized catalyst, membrane and ionomer materials into the cell stack and verify performance through durability testing.
- Develop and implement accelerated stress tests for the anionic chemistry.
- Verify a 12–14-cell stack configuration for laboratory scale hydrogen generation.
- Complete the design and build of a 12–14-cell prototype system.

Fiscal Year (FY) 2016 Objectives

- Select oxygen evolution catalysts from synthesis optimization.
- Complete cell testing for selected catalysts.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(F) Capital Cost

Technical Targets

The only metrics for hydrogen production are \$/kW and \$/kg at the system level. Because of the infancy of the manufacturing processes for electrolyzer technology, these high level metrics cause difficulties in highlighting even major changes at the component level. However, the end cost will be largely dependent on raw material costs. Reducing platinum group metal content and eliminating valve metals such as titanium is therefore critical to meeting the end targets. Developing and scaling stable alkaline membrane technology is also important in establishing feasibility of the technology. The current program aims at meeting the following targets:

- Scale up of catalyst synthesis to 50 g batches and show pathway to kilogram scale
- Verify cell stack scale up to 12–14 cells
- Durability: 500 h of stable operation

FY 2016 Accomplishments

- Synthesized higher surface area pyrochlor catalysts and downselected candidates for cell testing. (milestone)
- Initiated product requirements document for laboratory scale hydrogen generator product.



INTRODUCTION

As the need for renewable energy capture grows, the balance between electricity feedstock cost and capital cost shifts, due to the ability to obtain low cost electrons but at

lower capacity factors. Since the electrolyzer is on for a lower percentage of the time, the capital cost has a larger impact on the overall lifecycle cost. Anion exchange membrane (AEM)-based electrolyzers offer a pathway to significantly reduce the cost of the cell stack, by enabling low cost oxygen flow fields such as nickel or stainless steel, as well as reduction or elimination of platinum group metals in the catalyst layer. The team has demonstrated the exceptional activity and stability of lead ruthenate pyrochlore electrocatalysts for the oxygen evolution reaction. While these catalysts still contain some noble metal, eliminating the titanium from the cell has a greater impact on cost and provides an initial stepping stone for product cost reduction.

In theory, AEM-based electrodes should represent a drop in replacement to Proton's existing cell stack designs. However, the supply chain for AEMs is still developing, and membrane formats are smaller than the typical Nafion[®] rolls produced for fuel cell and electrolyzer applications. Introduction of new materials into the cell stack that are unproven in the field also represents a large capital risk at megawatt scale. Proton's laboratory product provides an opportunity to introduce these materials to market at a lower risk entry point and gain field experience on the pathway to eventually applying AEM technology for larger energy related applications.

APPROACH

Proton will continue to work with the Ramani group at Washington University to scale up catalyst synthesis and transition to a commercial company such as Pajarito Powder. Proton will also continue to incorporate the most promising membrane and ionomer combinations in order to optimize performance and stability. While the baseline Tokuyama materials are available commercially and may provide acceptable performance with buffered electrolyte and lower temperature operation, there are better options which may be selected if a commercial pathway to the polymer fabrication is determined to be feasible. As one option, Proton will compare the Tokuyama materials with ionomers developed in Paul Kohl's group at Georgia Tech, which have been used in systems at Acta.

In parallel, Proton will work to scale the stack to an appropriate capacity for the laboratory product portfolio. The planned capacity will supplement existing options rather than supplanting an existing product, to provide more value for the same investment. This work also leverages work done for the U.S. Air Force on a higher capacity hydrogen generator with similar footprint to our lab line (Figure 1). Approaches for electrolyte management (pure water or supporting electrolyte) will be finalized and the resulting system design completed.

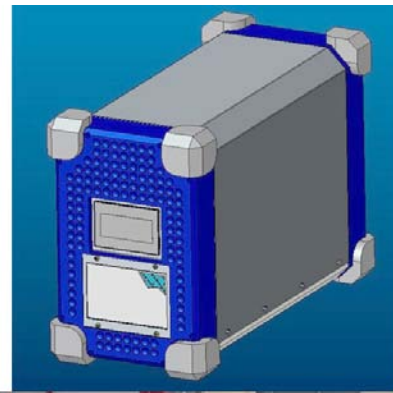


FIGURE 1. System schematic and prototype from Air Force program

FUTURE DIRECTIONS

Next steps include evaluation of advanced materials, and work to define the eventual system design, as follows:

- Characterize potential degradation mechanisms for Georgia Tech ionomers based on post-operational analysis.
- Reproduce pyrochlore synthesis at commercial supplier and perform manufacturing study for volume manufacturing.
- Define system parameters including thermal management and dryer sizing.
- Integrate and test multi-cell stack with integrated AEMs and catalysts.