Contract No:

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Disclaimer:

Component Development for Alkaline URFCs

Project highlight. Through the development of efficient and low-cost catalysts and electrodes for URFCs, the Energy Materials directorate is working on the development of bifunctional oxygen electrodes to enable the use of electrochemical energy storage devices based on O_2 chemistries.

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

SRNL Legal Signature

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Signature **Date**

Component Development for Alkaline URFCs

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Subcontractor: University of South Carolina

Project Type: Standard

Project Start Date: October 1, 2019
Project End Date: September 30, 2021

Performance, cost, and durability of the catalyst materials are the key factors that govern the commercialization of H_2-based energy devices such as unitized regenerative fuel cells (URFCs). URFCs offer the advantage of high energy density vs. existing battery systems. In addition, with the use of an alkaline URFC system, lower system costs can be achieved through the use of platinum group metal-free (PGM-free) materials. This project seeks to address the major obstacles faced in URFC systems and establish a URFC technical capability through the strategic partnership between USC and SRNL. The research focuses on the development of low-PGM and PGM-free based bifunctional oxygen catalysts and electrodes, as well as the development of a URFC testing capability at SRNL.

FY2020 Objectives

- Establish *ex-situ* baseline performance of state-of-the-art bifunctional catalysts
- Establish in-situ discrete baseline performance of state-of-the-art bifunctional catalysts
- Low-PGM bifunctional catalyst development and *ex-situ* evaluation
- Design of URFC testing facility
- Facility construction/evaluation

Introduction

The development of high-performance and low-cost bifunctional electrodes for oxygen evolution reaction (OER) and oxygen reduction reaction (ORR) is critical for enabling the use of electrochemical energy storage devices based on O_2 chemistries such as metal–air batteries and URFCs. URFCs are superior to existing battery systems with respect to energy density and performance over prolonged operation, making them the preferred choice for applications such as stationary renewable energy storage for utility power, other large power applications (e.g. rail), and surveillance systems. By developing low PGM or PGM-free catalysts we are able to move towards more efficient and lower-cost URFC operation.

URFCs are capable of operating in both power production (fuel cell, FC) and energy storage (electrolysis cell, EC) modes. URFCs are seen as a key enabler of intermittent renewable energy technologies, as they are able to store and convert chemical energy to electrical energy depending on supply and demand. The attractiveness of URFCs is that the theoretical energy density is approximately an order of magnitude higher than commercial lithium ion batteries. However, as is typical with low TRL technologies, URFCs are currently too expensive to compete with existing energy storage technologies. A major contributor to URFCs high cost is their incorporation of platinum group metal (PGM) catalysts in the electrodes. This reliance on PGMs is because they are currently the only catalysts that show both high activity and stability in the acidic environment of proton exchange membrane (PEM) based URFCs. To circumvent the electrode material cost in PEM systems, alkaline systems enable the use of PGM-free electrodes.

However, until recently, alkaline system performance has been negatively impacted by poor membrane and ionomer stability. Recent improvements to performance and stability in state-of-the-art alkaline anion exchange membranes (AEMs), has opened the doors to new technology development within low cost URFCs, capable of competing with existing energy storage technologies.

Approach

Highly active and stable catalysts are needed to achieve high round trip thermodynamic efficiency (ε_{RT}>50%, Figure 1) and long system life for URFC systems. To meet these objectives, this project will focus on three main areas:

(i) increasing ε_{RT} through the development of stable catalysts with improved overall ORR and OER kinetics

(ii) Electrode development capable of efficient operation at the conditions required in energy production and energy delivery modes, and

(iii) Establish a functional test facility capable of analyzing various operating energy cycles.

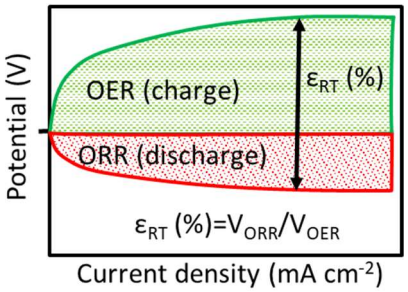

Figure 1. Representative performance curve of an URFC. Kinetic improvements are needed to minimize separation between the charge and discharge curves.

Results/Discussion

Due to the slow kinetics for both oxygen reactions (OER and ORR), the primary barrier to achieving high εRT is the oxygen electrode performance. To compensate for this inefficiency, typical URFCs combine the best electrocatalysts for the ORR (namely Pt based catalysts) and OER catalyst (namely Ir, Ru and their oxides) to prepare a bifunctional oxygen electrode. However, most of these catalysts are non-supported and the cell suffer from high precious metal loadings. To lower the cost of the bifunctional electrode, SRNL is producing supported PGM. Figure 2 shows the *ex-situ* testing of commercial electrocatalyst and SRNL synthesized bifunctional catalysts. Figure 3 shows the short-term *ex-situ* cycle stability for various of the catalysts. As observed in the figures the prepared catalyst not only has comparable activity to commercial catalysts, but also has comparable stability.

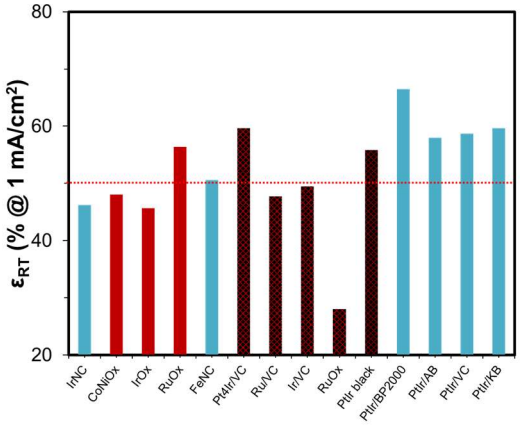

Figure 2. Round trip efficiency comparison of commercial and synthesized catalysts

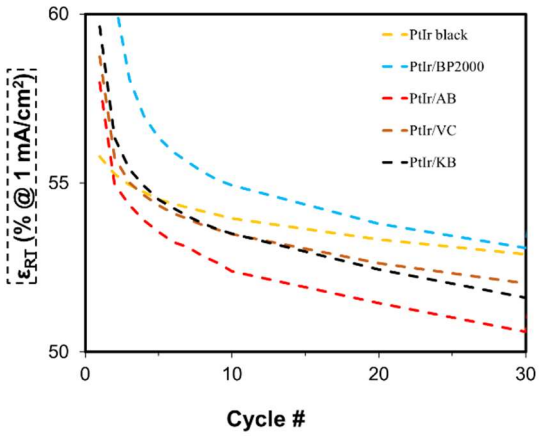

Figure 3. Short-term cycle stability of PtIr on various carbon supports.

In-situ cell electrode optimization was performed at USC in an electrolysis cell using commercial electrocatlaysts. Figure 4 shows the performance test of the electrolysis cell using standard electrode fabrication. Finally, figure 5 shows the modified test station at SRNL to initiate in-house URFC testing.

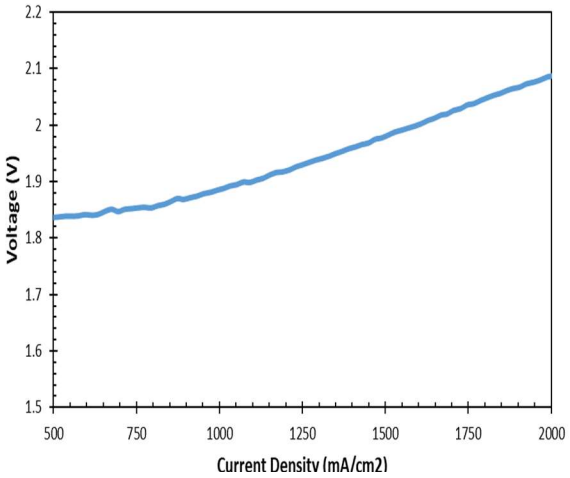

Figure 4. Electrolysis cell test using commercial electrocatalysts.

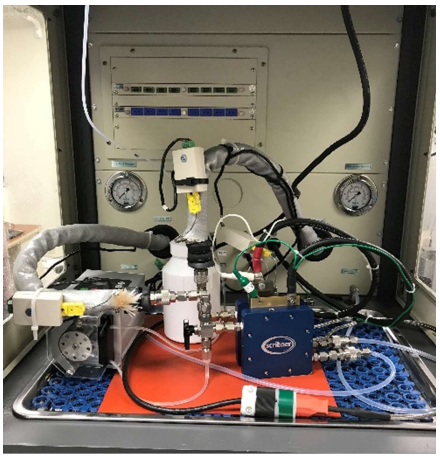

Figure 5. In-situ testing set up completed and SRNL inspected

FY2020 Accomplishments

- Optimized and decreased synthesis time by moving to a polyol microwave synthesis technique
- Found PtIr on BP2000 to have the highest OER and ORR activity
- Initiated electrode optimization at USC
- Built and SRNL approved URFC Station

Future Directions

- Create an operational base-line for the URFC Station
- Development of PGM-free bifunctional catalysts as electrodes
    - PGM-free catalysts based on metal oxides and pyrolyzed organic frameworks will be prepared and characterized.
    - Catalysts prepared will be down selected for electrode optimization via ORR and OER cyclying measurements and compared to PtIr on BP2000.
    - Systematically optimizing the anionomer:carbon:catalyst ratio, catalyst loading, hydrophilicity/hydrophobicity, cell temperature, and reactant flowrates for the optimization of water flow and overall FC performance.

Acronyms

EC - electrolysis cell
FC - fuel cell
PGM - platinum group metals
ε_{RT} - round trip efficiency
URFC - unitized regenerative fuel cell

Total Number of Student Researchers

Noor Ul Hassan, USC (off-site)

External Collaborators

William Mustain (University of South Carolina)