Contract No:

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Disclaimer:

Title of Project
Component Development for Alkaline URFCs

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

Project Highlight
Alkaline electrochemical systems are the next generation of energy production and energy storage devices which do not require rare or precious metal catalysts when fully optimized. This project designed and demonstrated an optimized bifunctional oxygen electrode with ~50% round-trip efficiency using state-of-the-art platinum-iridium catalysts.

Project Team
Principal Investigator: Héctor Colón-Mercado
Team Members: Aaron Lando, Prabhu Ganesan
External Collaborators (all external collaborators and their respective organizations that participated in this project: William Mustain (University of South Carolina, UofSC)

Abstract
Performance, cost, and durability of the catalyst materials are the key factors that govern commercialization of H_2-based energy conversion devices such as unitized regenerative fuel cells (URFCs). Compared to existing battery systems, URFCs offer superior energy density and performance over prolonged operation. In addition, alkaline URFC systems, can utilize low-cost platinum group metal-free (PGM-free) catalysts, resulting in much lower overall system costs. This project seeks to address the major obstacles faced in URFC systems such as cost and efficiency and establish a URFC technical capability through the strategic partnership between UofSC 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.

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
- Cycle testing of electrodes

REVIEWS AND APPROVALS

1. Authors:

Hector Colon-Mercado, Prabhu Ganesan, Aaron Lando, William Mustain (UofSC)

Name and Signature Date

2. Technical Review:

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Name and Signature Date

3. PI's Manager Signature:

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Name and Signature Date

4. 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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Name and Signature

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. URFCs are also 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.

URFCs are capable of operating in both power production (fuel cell, FC) and energy storage (electrolysis cell, EC) modes. 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. Alkaline based URFCs circumvent the electrode material cost issue present in PEM systems, where PGM-free electrodes show good performance. By developing PGM-free catalysts designed for alkaline URFCs we can create higher efficiency and lower-cost systems.

Until recently, however, alkaline system performance has been negatively impacted by poor membrane and ionomer stability. These recent improvements to performance and stability seen in state-of-the-art alkaline anion exchange membranes (AEMs) has opened doors to exploring new low-cost catalyst technologies within alkaline URFCs, capable of competing with existing energy storage technologies in both system cost and performance.

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.

Accomplishments

- Optimized a membrane electrode assembly (MEA) fabrication process for direct catalyst coating using an ultrasonic sprayer to coat the electrodes with the desired catalysts at loadings ranging from 1.0 – 2.5 mg/cm^2.
- Optimized bifunctional oxygen electrode design and operated 5 cm^2 active area single cell URFC.
- Demonstrated ~50% round-trip efficiency $\left(\varepsilon_{RT} = \frac{FC\ potential\ at\ i}{EC\ potential\ at\ i} x100 = \frac{E_{FC}}{E_{EC}} x100\right)$ while operating a single URFC in fuel cell and electrolyzer mode at *i*=0.5 A/cm^2 (Figure 2).
- Demonstrated stable short-term URFC cycling studies for >5.0 hours (Figure 3)
- Used new additive to improve the URFC performance and durability.

Future Directions

- Evaluate long term performance and higher number of cycles
- Evaluate structural changes after long term operation
- Publish data in a peer-reviewed journal

Total Number of Student Researchers
Noor Ul Hassan, UofSC (off-site)

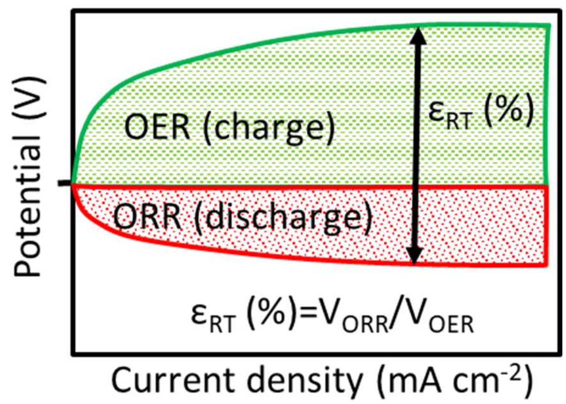

Figure 1. Representative performance curve of an URFC. Kinetic improvements are needed to minimize separation between the charge and discharge curves

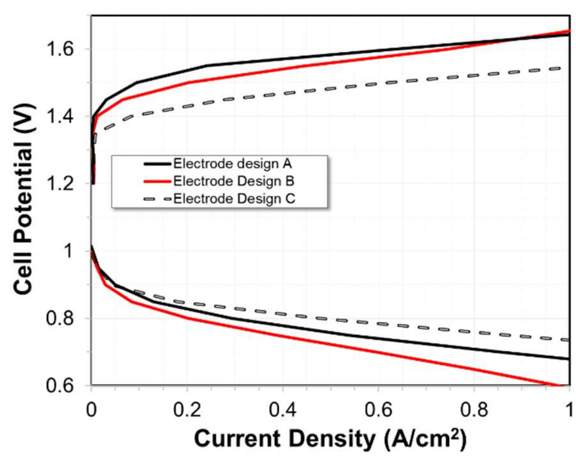

Figure 2: Performance of bifunctional oxygen electrode while operating under fuel cell and electrolyzer mode.

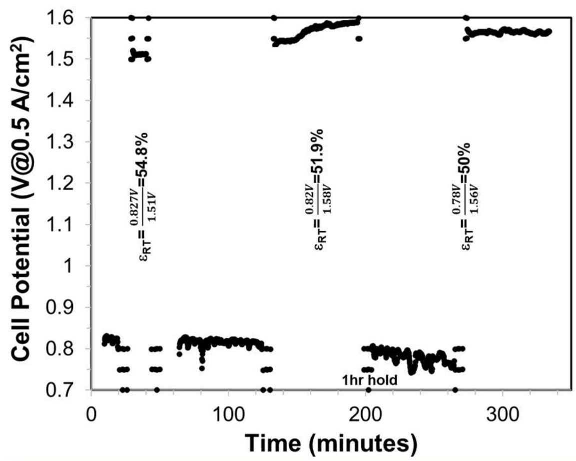

Figure 3 Short-term URFC durability test utilizing bifunctional oxygen electrode