

Lab Call FY19: Accessible Platinum-Group-Metal-Free Catalysts and Electrodes: ElectroCat

Jacob S. Spendelow (Primary Contact),
Rangachary Mukundan, Md. Aman Uddin, Md.
Tanvir Alam Arman, Siddharth Komini Babu,
Xiaoxiao Qiao, and Michael Workman
Los Alamos National Laboratory
PO Box 1663
Los Alamos, NM 87545
Phone: (505) 667-9434
Email: spendelow@lanl.gov

DOE Manager: Dimitrios Papageorgopoulos
Phone: 202-586-5463
Email: Dimitrios.Papageorgopoulos@ee.doe.gov

Project Start Date: January 1, 2018
Project End Date: December 31, 2019

Overall Objectives

- Enhance transport of O₂, H⁺, and H₂O in platinum group metal (PGM)-free membrane electrode assemblies (MEAs) through design of novel electrode structures.
- Increase local accessibility of PGM-free active sites through design of nanoscale catalytic interfaces.

Fiscal Year (FY) 2019 Objectives

- Fabricate PGM-free MEAs that have ionomer channels for enhanced H⁺ transport.

- Perform initial templated catalyst synthesis to provide improved active site accessibility.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan¹:

- (A) Durability
- (B) Cost
- (C) Performance.

Technical Targets

This project focuses on development of materials solutions that can provide enhanced transport and improved performance in PGM-free MEAs, resulting in progress toward the technical targets shown in Table 1.

FY 2019 Accomplishments

- Performed initial fabrication of PGM-free electrodes containing ionomer channels for enhanced H⁺ conduction.
- Performed initial synthesis of PGM-free catalysts using templating approach to produce enhanced active site accessibility.

Table 1. Progress toward Meeting Technical Targets for Electrocatalysts and MEAs for Transportation Applications

| Characteristic | Units | DOE 2020 Electrocatalyst and MEA Targets | Project Status (5 cm ² cell, differential conditions) |
|----------------------------|---|--|--|
| PGM-free catalyst activity | A/cm ² @ 0.9 mV _{iR-free} | ≥0.044 | 0.016 |
| MEA performance | mA/cm ² @ 800 mV | ≥300 | 73 |
| MEA performance | mW/cm ² @ rated power (670 mV) | ≥1,000 | 280 |

INTRODUCTION

Substantial cost reduction is needed to enable widespread deployment of fuel cells for transportation and other applications. Because PGM catalysts are projected to account for nearly half the cost of a fuel cell stack [1], replacement of PGMs with PGM-free catalysts is an attractive route to cost reduction and accelerated

¹ <https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22>

commercialization. Despite a major research effort that has resulted in significant kinetic improvements in recent years, performance of PGM-free oxygen reduction reaction (ORR) electrodes remains far below that of state-of-the-art PGM-based electrodes, with high-current performance being particularly problematic. To achieve target power densities, improvements in electrode transport and in catalysis are needed.

APPROACH

This project comprises two thrust areas: (1) accessible electrode structures and (2) accessible catalysts. The first thrust focuses on developing innovative electrode structures for enhanced O_2 and H^+ transport at the micron scale that will enable PGM-free electrodes with improved high-current performance. The second thrust focuses on developing new catalysts that are synthesized from the bottom up to provide high active site density and high active site accessibility to O_2 and H^+ . Ultimately, accessible catalysts developed in Thrust 2 will be incorporated into the accessible electrode structures developed in Thrust 1 to provide synergistic improvements in PGM-free performance.

RESULTS

Several types of accessible PGM-free electrode structures that incorporate non-tortuous transport channels are under development in this project, as depicted in Figure 1. Initial testing of MEAs containing proton channel electrodes, in which non-tortuous ionomer channels provide enhanced proton conductivity while simultaneously reducing the amount of ionomer that must be directly mixed with catalyst, are shown in Figure 2.

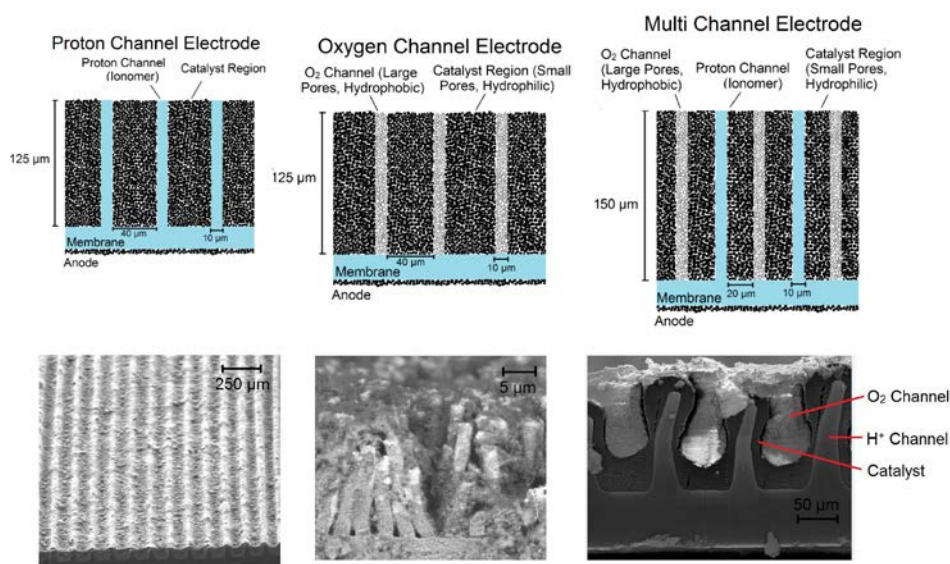


Figure 1. Accessible electrodes being designed in this project, with schematics (top) and corresponding scanning electron micrographs of electrodes (bottom)

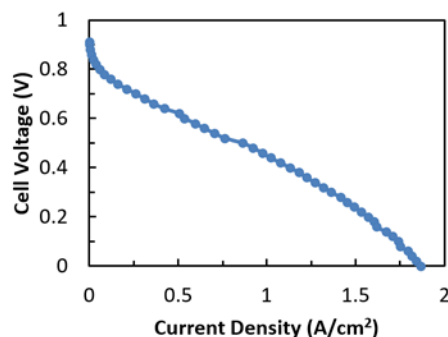


Figure 2. Polarization performance of an MEA with a PGM-free cathode at 80 °C, 150 kPaabs, 100% RH, H_2 /air

Along with the initial fabrication of accessible PGM-free electrodes, work began on design and synthesis of accessible PGM-free catalysts in FY 2019. An early prototype of such a catalyst, based on polyaniline in a nanowire configuration, is depicted in Figure 3.

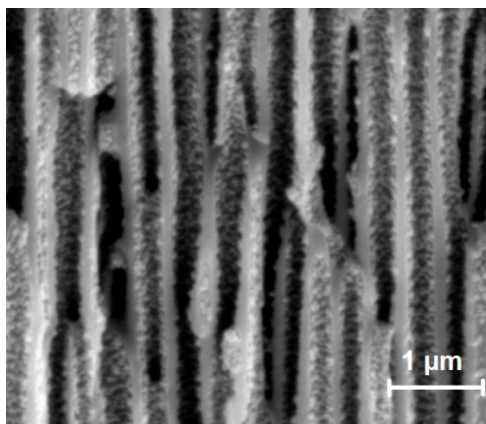


Figure 3. Initial synthesis of accessible PGM-free catalysts based on PANI nanowires

CONCLUSIONS AND UPCOMING ACTIVITIES

Initial fabrication of PGM-free electrodes containing ionomer channels for enhanced H⁺ conduction, along with initial synthesis of accessible PGM-free catalysts, was performed in FY 2019. Upcoming activities will build on this initial work to design and demonstrate improved accessible PGM-free electrode structures and improved catalysts, with experimental work performed in conjunction with numerical modeling. Upcoming activities will also include characterization of PGM-free catalysts and electrodes, along with in situ and in operando diagnostics.

FY 2019 PUBLICATIONS/PRESENTATIONS

1. J.S. Spendelow, “New Catalysts and Electrode Structures for Polymer Electrolyte Fuel Cells,” Seminar at Case Western Reserve University, February 21, 2019.

REFERENCES

1. A. Wilson, et al., DOE Hydrogen and Fuel Cells Program Record #17007, “Fuel Cell System Cost—2017,” https://www.hydrogen.energy.gov/pdfs/17007_fuel_cell_system_cost_2017.pdf.