

## V.A.14 Multi-Functional Catalyst Support (SBIR I)

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### Overall Objectives

- Develop a multi-functional carbon support, based on doped carbon nano-structures (i.e., CNxPy), that is engineered to perform better than conventional proton exchange membrane (PEM) fuel cell pure carbon supports.
- Improve the catalyst stability, durability and current density with lower platinum group metal (PGM) loadings.
- Demonstrate DOE 2020 targets for catalyst durability and support corrosion resistance in a membrane electrode assembly (MEA).

### Fiscal Year (FY) 2017 Objectives

- Prepare a matrix of candidate CNxPy-based supports to examine the effects of synthesis parameters on important properties.
- Demonstrate catalyst activity and durability in rotating disk electrode (RDE) testing and down-select catalyst for further MEA testing.
- Transfer RDE results to gas diffusion electrodes (GDE) for MEA testing and optimize GDE synthesis parameters to demonstrate DOE 2020 targets for catalyst durability and support corrosion resistance in an MEA.
- Demonstrate the potential of tuning the GDE hydrophobicity for improved current density.

### 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 Plan.

- (A) Durability
  - Optimize the interaction between the catalyst and the support material to improve chemical and thermal stability.
- (B) Cost
  - Enhancement of the Pt catalyst activity to reduce its loading levels.
- (C) Performance
  - Demonstrate improved performance with the multi-functional supports in an MEA.

### Technical Targets

This project aims to develop a multi-functional carbon support that will demonstrate the following 2020 DOE targets for low-PGM loading [1].

- PGM loading (both electrodes): 0.125 mg/cm<sup>2</sup>
- Catalyst durability in an MEA
  - <40% loss in initial mass activity
  - <30 mV loss at 0.8 A/cm<sup>2</sup>
  - <40% loss in initial area
- Support corrosion resistance in an MEA
  - <40% loss in initial mass activity
  - <40% loss in initial area

### FY 2017 Accomplishments

- Prepared CNxPy support samples and examined different variables on the catalytic activity (Table 1).

**TABLE 1.** Matrix of Variables Examined for the Prepared Carbon Supports Samples

Variable	Ranges
<b>Carbon Support Synthesis</b>	
Metal Precursor	None, Various Transition Metals
Hydrophobicity Treatment	None, Partial, Full
<b>Metal Deposition</b>	
Pt Loading	5–20 wt%
Metal	Pt and Pt/Ni Alloy

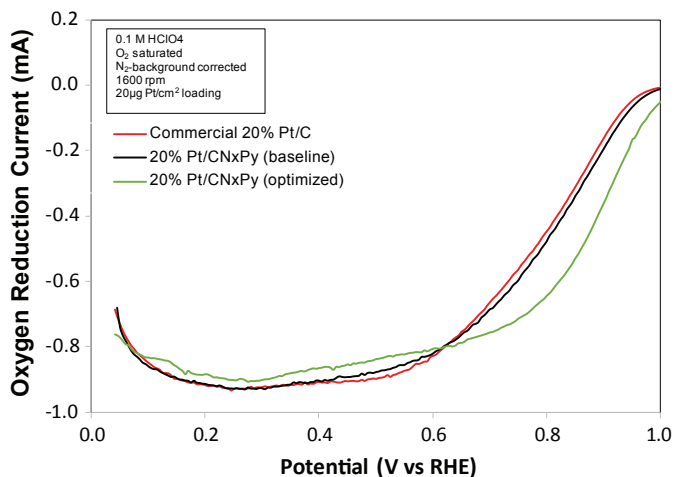
- Explored two platinum deposition procedures for each CNxPy carbon support and RDE tested. Down-selected a procedure that gave a more uniform and homogenous platinum deposition onto the carbon support (Figure 1) and higher oxygen reduction reaction (ORR) activity.
- RDE tested Pt/CNxPy samples for intrinsic activity and durability. Down-selected Pt/CNxPy samples for further MEA testing (Figure 2).
- Prepared MEAs for testing.



## INTRODUCTION

PEM fuel cells offer the capability to provide a more efficient and cleaner route for energy conversion in numerous applications, including automotive power. Unfortunately, wide-scale PEM fuel cell adoption is limited by the high cost of the fuel cell stacks. PEM fuel cells currently use Pt as the catalyst both at the cathode and at the anode. Current challenges with the electrodes are the high cost of the PGM electrode materials and the relatively fast degradation of the electrodes, specifically the cathode. To lower PEM fuel cell cathode costs, a reduction in PGM loading level with an increase in catalyst activity to maintain power output, would be needed. One way of improving low-PGM catalyst performance and durability is by optimizing the interaction between the catalyst and the support material.

pH Matter is developing a multi-functional carbon support for PEM fuel cell cathodes that is optimized to perform better than conventional PEM fuel cell pure carbon supports by enhancing the catalyst stability, durability, and electrode current density with lower PGM loadings. Nitrogen and phosphorus doped carbon nano-fibers have been reported



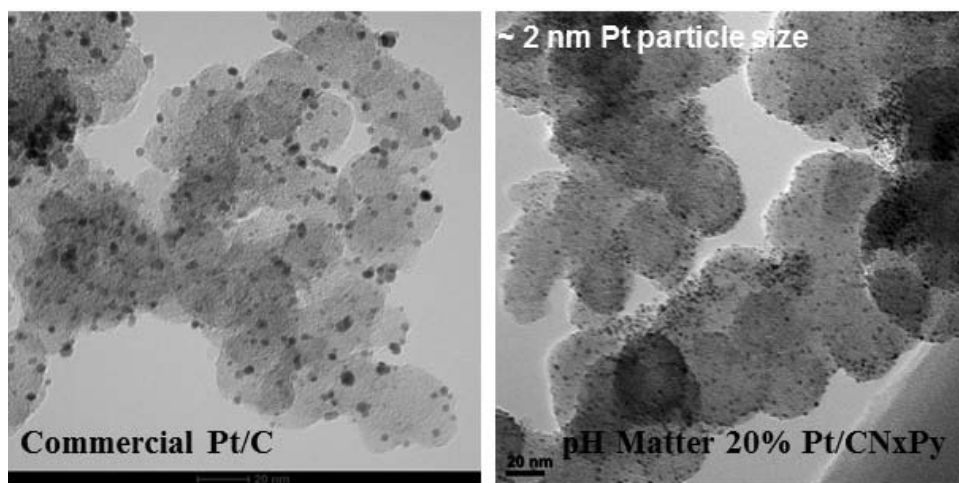
rpm – revolutions per minute; RHE – reference hydrogen electrode

**FIGURE 2.** Down-selected Pt/CNxPy catalyst samples that showed good ORR activity in RDE testing

to enhance dispersion and provide better binding of Pt nanoparticles when used as a support for PEM fuel cell catalysts and can also contribute to the ORR activity. This doped-carbon support showed improved metal-support adhesion which reduces the mobility of the platinum during long-term operation. It also showed improved resistance to oxidation, a major source of cathode degradation. The hydrophobicity of the electrodes can also be tuned to minimize cathode flooding.

## APPROACH

A matrix of doped-carbon supports are prepared wherein different variables are examined to evaluate the effects on ORR activity and porosity. Synthesis variables



**FIGURE 1.** Transmission electron microscopy imaging showed good dispersion of Pt on CNxPy carbon support using the developed deposition method

include precursors for carbon formation, including metal and non-metal options (to address the issue of ionomer and membrane poisoning), after-treatment of the carbon material and hydrophobicity treatment prior to platinization. The prepared catalysts are then screened for their intrinsic ORR performance and acceptable support oxidation resistance in RDE testing. High-performing catalyst in RDE testing are then down-selected for MEA testing to meet DOE's automotive fuel cell targets for performance and durability.

## UPCOMING ACTIVITIES

RDE and MEA testing will continue and include:

- RDE high-voltage cycling (start-stop simulation) on down-selected supports.
- Testing MEAs of down-selected supports to meet DOE targets on MEA performance.
  - Demonstrate DOE 2020 targets for catalyst durability (<40% loss in activity, <30 mV loss at 0.8 A/cm<sup>2</sup> and <40% area loss after 30,000 cycles) in an MEA with a target Pt loading in the cathode and anode of 0.125 mg/cm<sup>2</sup>.
  - Demonstrate DOE 2020 targets for support corrosion resistance (<40% loss in activity, <30 mV loss at 1.5 A/cm<sup>2</sup> and <40% area loss after 5,000 cycles) in an MEA with a target Pt loading in the cathode and anode of 0.125 mg/cm<sup>2</sup>.
  - Show potential for high current density by tuning hydrophobicity.
- Connect with MEA developers to establish partnerships for future work.
- Partner with future customers to demonstrate catalyst.

## FY 2017 PUBLICATIONS/PRESENTATIONS

1. Minette Ocampo, Paul Matter, Chris Holt, Julia Mueller, Michael Beachy, Mary Cramer, and Monica Chan, "Multi-Functional Catalyst Support," presented at the 2017 DOE Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June 2017.

## REFERENCES

1. "Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development, and Demonstration (MYRDD) Plan," Office of Efficiency and Renewable Energy, <https://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22>