pH Matter llc
Materials for Energy

FY18 SBIR Phase II Release 1: Multi-Functional Catalyst Support

pH Matter: Minette Ocampo, Paul Matter, Chris Holt

Giner: Hui Xu, Magali Spinetta

NREL: Guido Bender, Calita Quesada, Bryan Pivovar

pH Matter LLC
Columbus, OH

Project ID: FC167

pH Matter llc
Materials for Energy

Company Background

- Founded in 2010, located in Columbus, OH
- Mission: to develop and commercialize material-based products for alternative energy applications.
- Expertise in:
  - Catalyst synthesis, development, and scale-up
  - Fuel Cell development
- Commercialization experience with catalysts, advanced materials, and electrochemical devices

Overview

Timeline and Budget

- Project Start Date: 05-21-2018
- Project End Date: 05-20-2020
- Total Project Budget: $ 1,000,000

Partners

- Giner Labs
- NREL
- Dr. Shyam Kocha

Barriers Addressed

- Cost:
  - Enhancement of the Pt catalyst activity (and durability) to reduce its loading levels.
- Durability:
  - Optimize the interaction between the catalyst and the support material to improve chemical and thermal stability.
- Performance:
  - Demonstrate improved performance in MEAs.

Relevance

Objective: Develop a multi-functional carbon support (that is based on nitrogen- and phosphorus-doped carbon nano-structures (CN_xP_y) and is optimized to perform better than conventional PEMFC pure carbon supports.

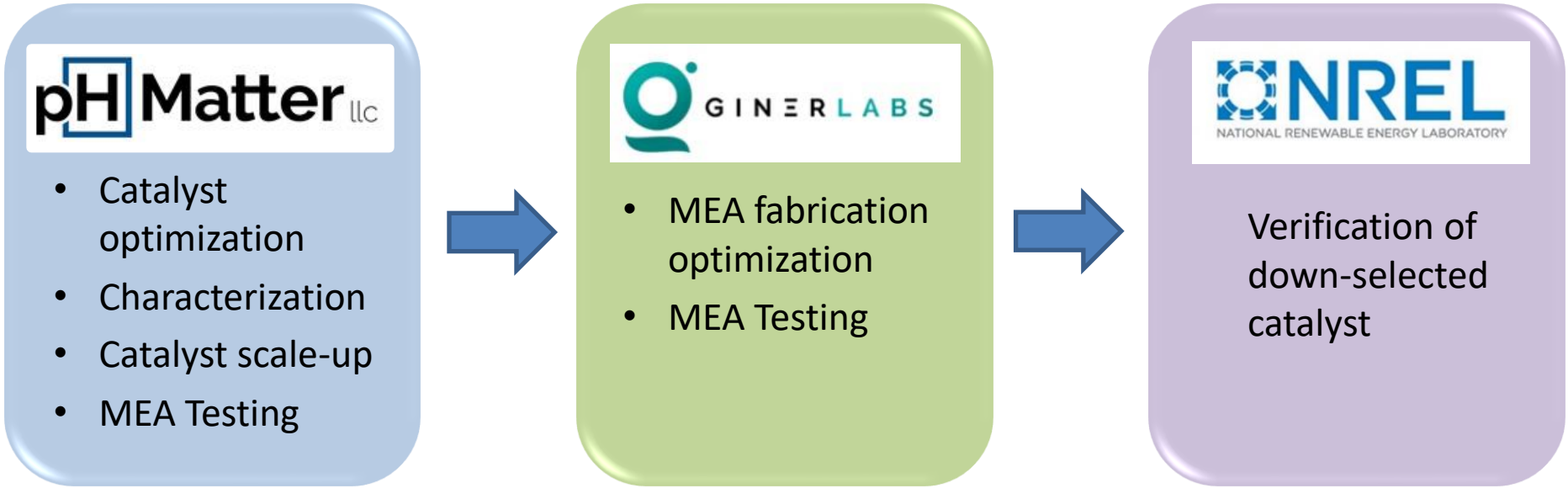
Characteristic	Unit	DOE 2020 Target
Platinum group metal Loading	mg_{PGM}/cm^2	0.125
Mass activity	A/mg_{PGM} @ 0.9V	0.44
Loss in initial catalytic activity	% Mass activity loss	<40
Loss in performance at 0.8 A/cm^2	mV	<30
Electrocatalyst support stability	% Mass activity loss	<40
Loss in performance at 1.5 A/cm^2	mV	<30

- **Demonstrate DOE 2020 targets for catalyst durability with low PGM loadings**
- Improved current density at low PGM loadings
- Show potential for high current density by tuning hydrophobicity

Approach

Phase 1: Demonstrated that Pt/MFCS-A catalysts can achieve target mass activity and durability

Phase II: Achieve high current density with durability at low PGM loading

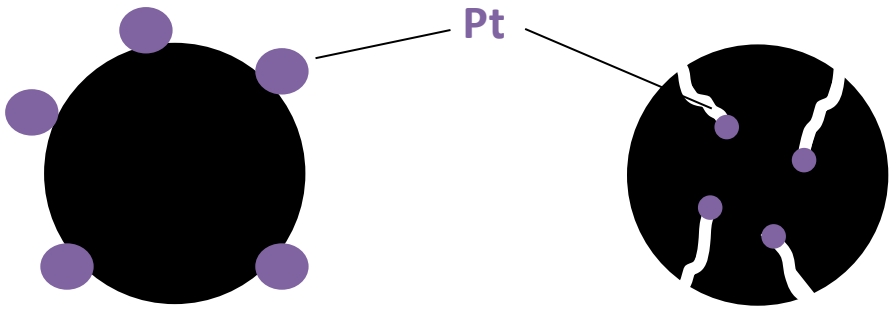


Accomplishments

Support Synthesis: Down-selected in-house made supports with the following naming convention:

- MFCS-A: denotes Phase I baseline support, microporous throughout
- MFCS-B: denotes "accessible pore" support
- MFCS-C: denotes intermediate microporous support

Conventional Catalysts

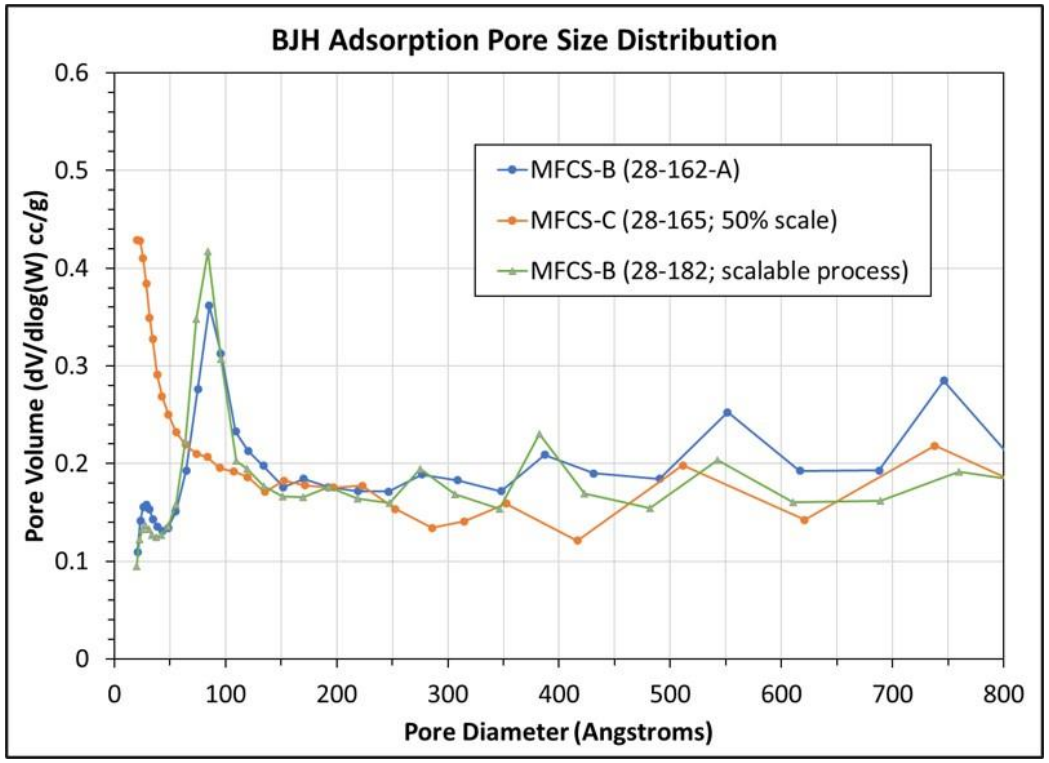


Pt / Vulcan Carbon
- Solid carbon
- High gas transport
- Poor durability

Pt / Ketjenblack
- Micro-porous HSC
- Good durability
- Poor gas transport

Accomplishments

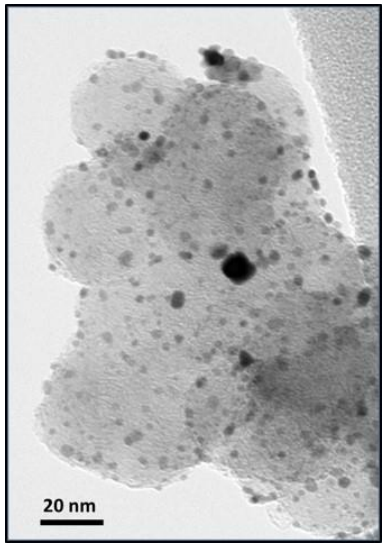
Tuned porosity of supports



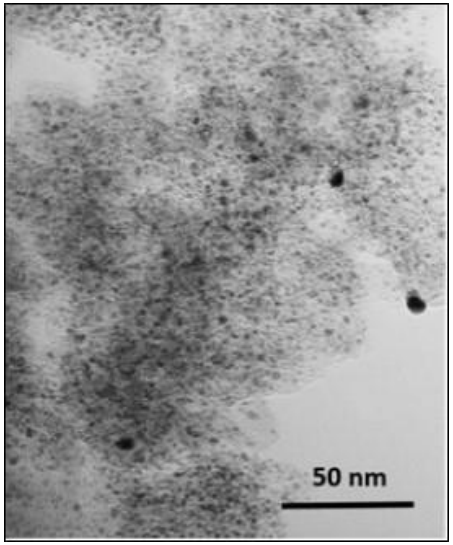
- MFCS-B:
  - 100-250 m^2/g
  - Tap density: ~0.36 g/cc
- MFCS-C:
  - 650-750 m^2/g
  - Tap density: ~0.18 g/cc
- Demonstrated 1 kg/hr process for both supports

Accomplishments

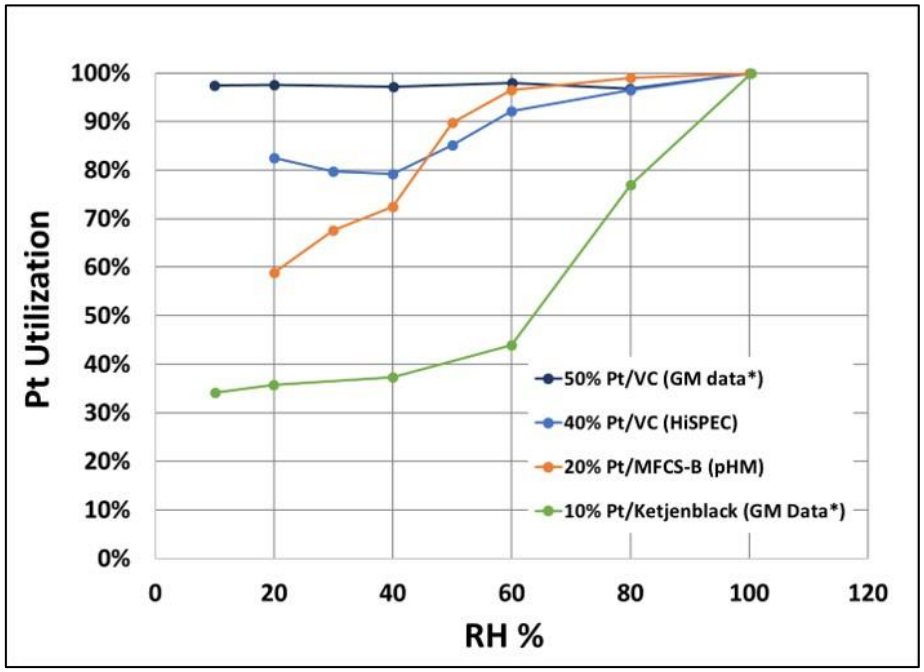
Catalyst Characterization



58-20B 20% Pt/MFCS-B (non-alloy)



Phase I Baseline (20% Pt)

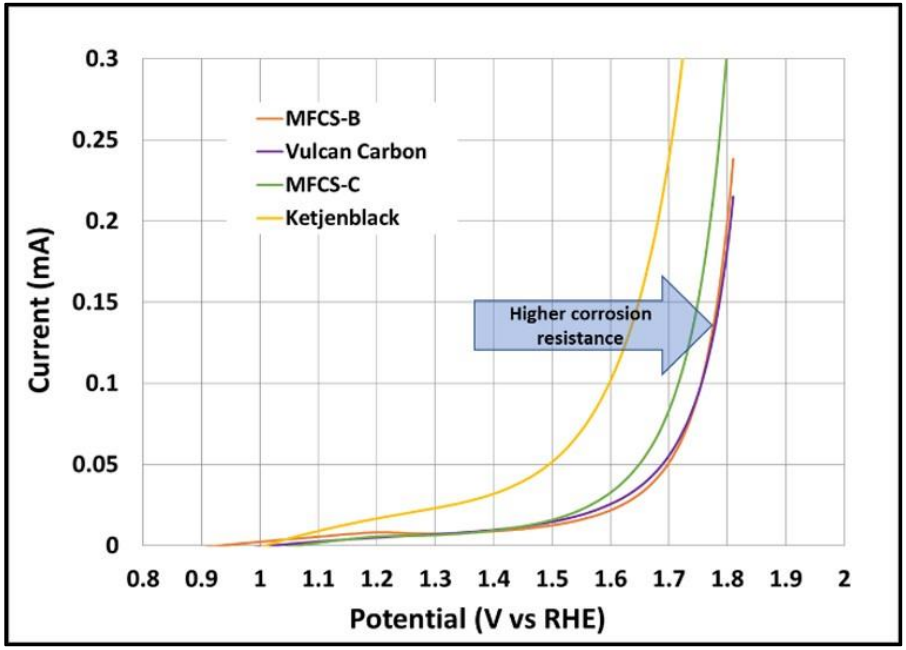


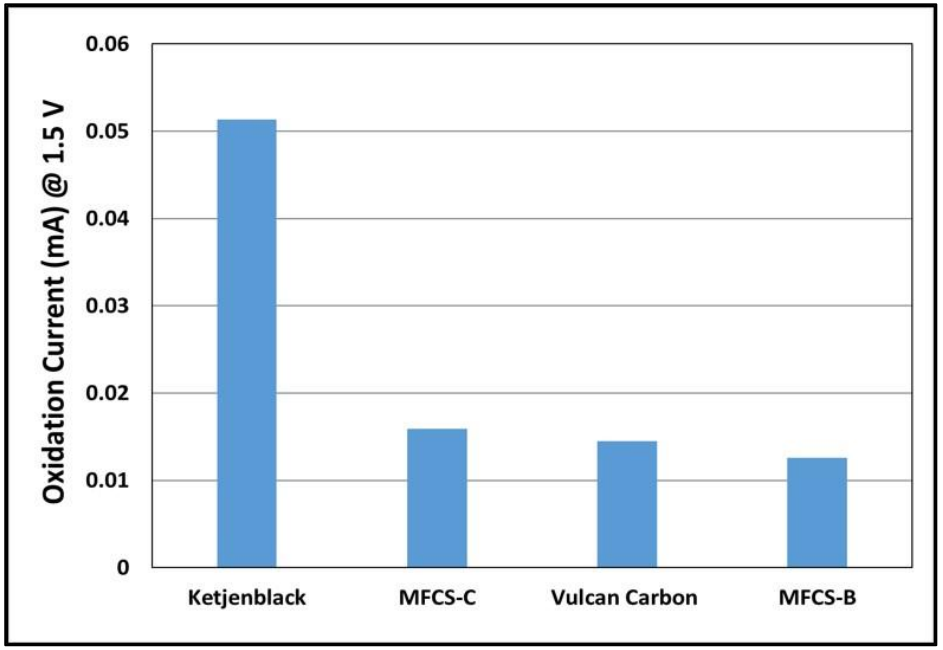
- CO adsorption experiments performed in varying RH to quantify Pt location
- Platinum is more accessible for MFCS-B catalyst
- Higher mass transfer resistances for MFCS-A (Phase I baseline catalyst)

*Padgett, E., et al., Journal of the Electrochemical Society, 165,3, F173-F180, 2018

Accomplishments

Screening RDE corrosion test



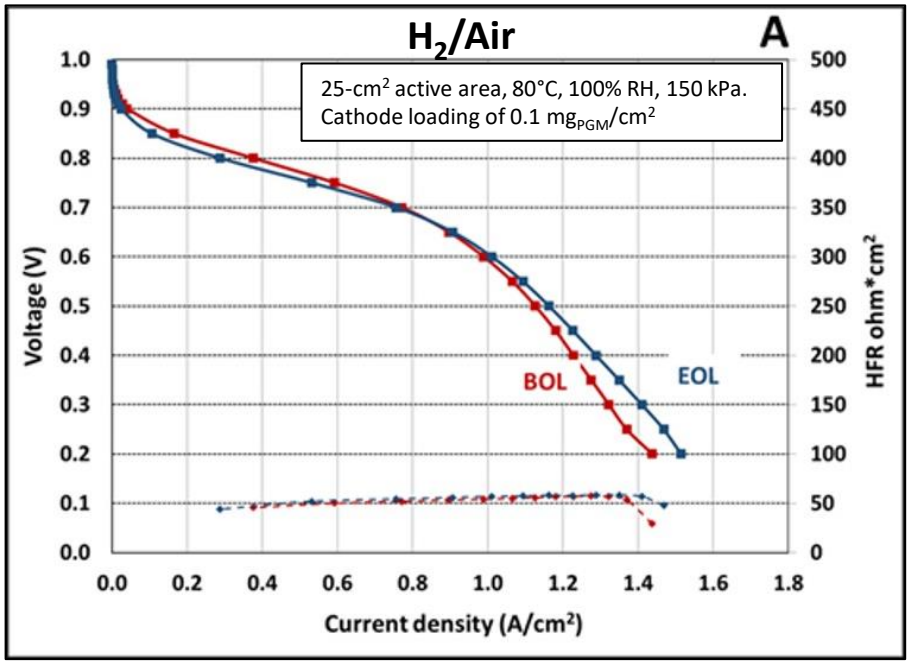


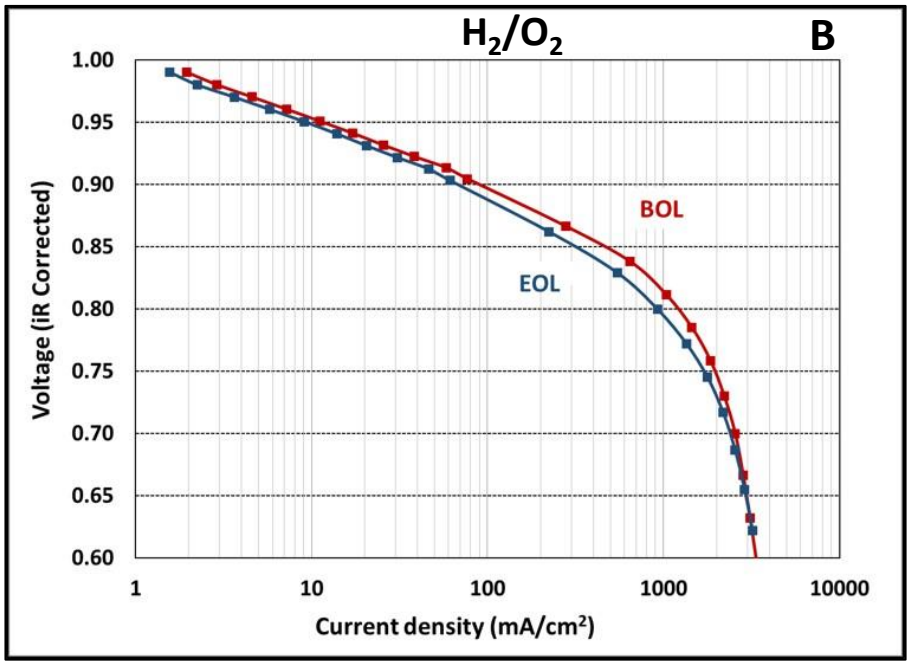
- Low surface area supports: MFCS B has better corrosion resistance than Vulcan Carbon
- High surface area supports: MFCS-C has better corrosion resistance than Ketjenblack

Accomplishments

Achieved DOE Targets with 30% Pt-Co/MFCS-C

Performed 3 different tests with repeatable results

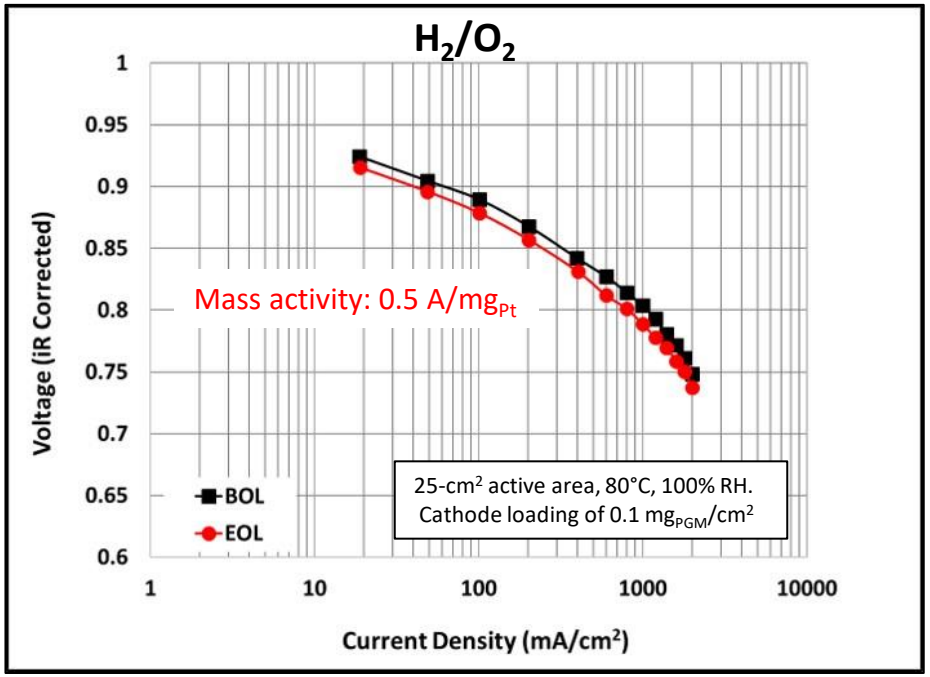


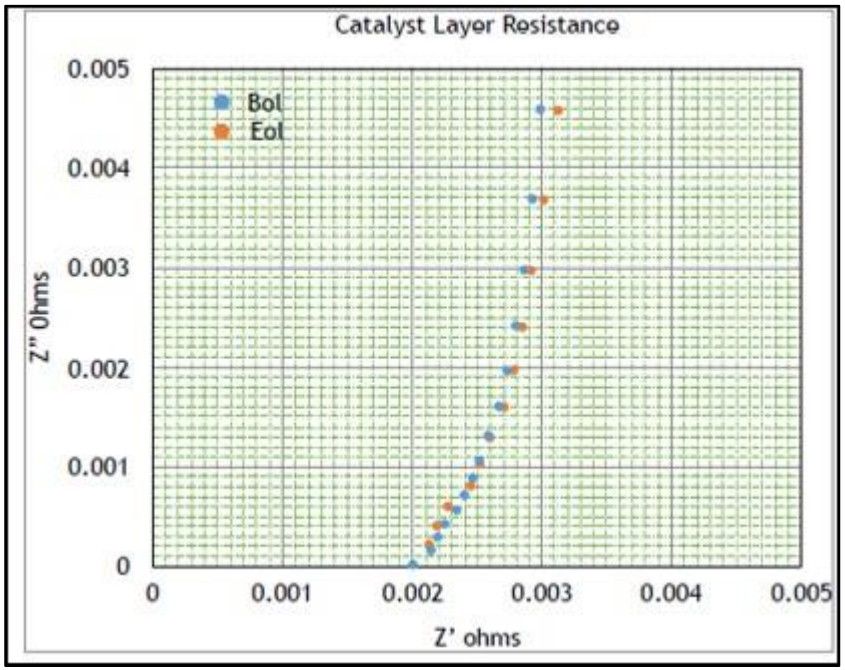


	Loading (mg/cm^2)	BOL Mass activity (A/mg_{Pt})	BOL Current @ 0.8V (A/cm2)	% Mass Activity Loss	ECSA Loss	ΔV @ 0.8 A/cm^2
DOE Targets	0.125	> 0.44	> 0.3	< 40%	< 40%	< 30 mV
30% Pt-Co/ MFCS-C	**0.1**	**0.77**	**0.38**	**27%**	**17%**	**0**

Accomplishments

30% Pt-Co/MFCS-C Third-Party Validation

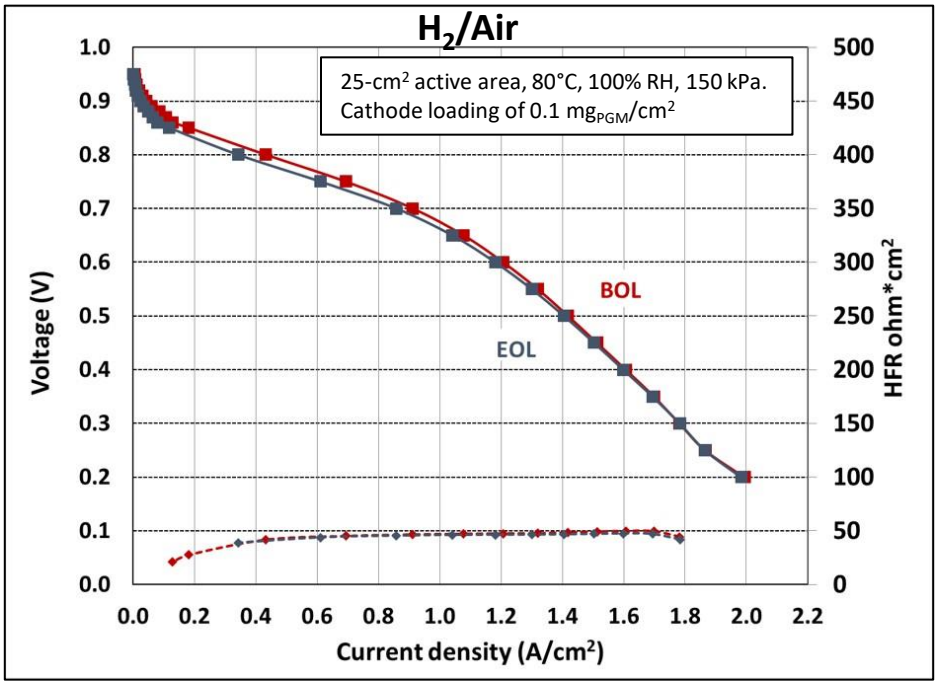


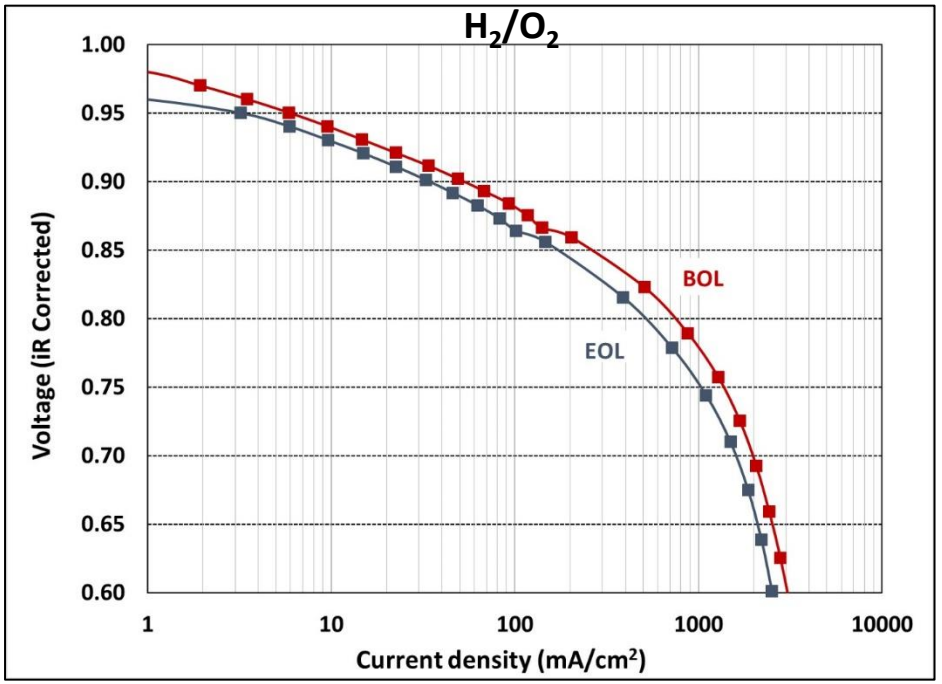


- Above target mass activity with no apparent degradation
- Difference in high current density observed due to MEA testing set-up, conditioning, or compression (catalyst kinetics and catalyst layer conductivity proved to be very durable)

Accomplishments

Achieved DOE Targets with 14% Pt-Co/MFCS-B

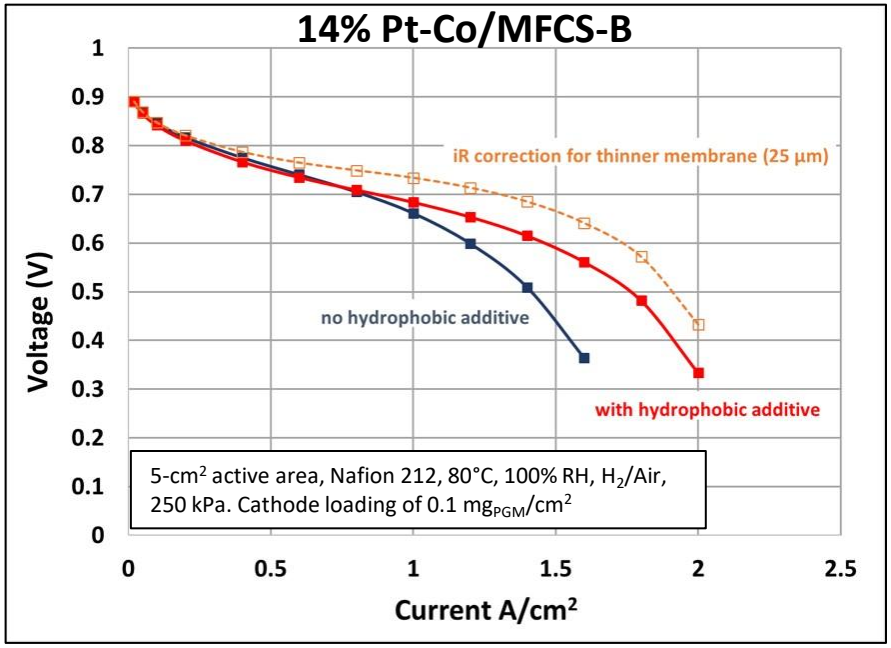




	Loading (mg/cm^2)	BOL Mass activity (A/mg_{Pt})	% Mass Activity Loss	ECSA Loss	ΔV @ 0.8 A/cm^2
DOE Targets	0.125	> 0.44	< 40%	< 40%	< 30 mV
14% Pt-Co/ MFCS-B	**0.1**	**0.53**	**34%**	**0%**	**< 10**

Accomplishments

Improved high-current density performance by tuning hydrophobicity



- Patent-pending process for modifying catalyst layer hydrophobicity
- Optimized hydrophobicity for high-current density performance and acceptable durability

	Loading (mg/cm^2)	BOL Mass Activity (A/mg_{Pt})	% Mass Activity Loss	ECSA Loss	ΔV @ 0.8 A/cm^2
DOE 2020 Targets	0.125	>0.44	<40%	<40%	<30 mV
14% Pt-Co/MFCS-B	0.1	0.53	34%	-4%	<10 mV
14% Pt-Co/MFCS-B + 10% HP	**0.1**	**0.53**	**26%**	**7%**	**23 mV**
14% Pt-Co/MFCS-B + 20% HP	0.1	0.55	54%	43%	50 mV

pH Matter llc
Materials for Energy

Reviewers' Comments

This project was not reviewed last year

Collaborations

- **Giner Labs**
  - Industry Partner
  - Subcontract
    - Ink development
    - MEA fabrication
    - MEA testing

- **NREL**
  - Federal Lab Partner
  - Independent validation of MEAs under industry standard procedures

- **Ballard**
  - No-cost partner
  - Provide testing and feedback on MEA performance

- **Dr. Shyam Kocha**
  - Consultant

Remaining Challenges and Barriers

- Further improve high-current density performance at low PGM loading
- Demonstrate improved corrosion resistance of engineered supports versus commercial catalysts (in MEA)
- Perform third-party tests to confirm catalyst performance

Future Work

- Optimize for higher MEA performance
  - Hydrophobicity of electrode
  - I:C ratio
  - Testing at 250 kPa at lower RH
- Characterization experiments
  - 3D imaging
  - MEA TEM imaging
- Third-party validation to demonstrate DOE targets
- Partnerships with MEA manufacturers
- Demonstrate heavy duty application targets as well

Any proposed future work is subject to change based on funding levels

pH Matter llc
Materials for Energy

Technology Transfer

- Licensed carbon composition from the Ohio State University
- Pending patents on the multi-functional carbon support
- Giner is providing expertise and know-how with state-of-the-art MEA synthesis and ionomers

pH Matter llc
Materials for Energy

Summary Slide

- Demonstrated improved performance from the Phase I baseline catalyst
- Demonstrated scalable synthesis for both MFCS-B and MFCS-C supports
- Optimized catalyst synthesis process and confirmed repeatability and scalability of down-selected process
- Demonstrated DOE targets for BOL and EOL performance for both MFCS-B and MFCS-C catalysts
- Demonstrated DOE targets for BOL and EOL performance with the addition of the hydrophobic additive to improve high-current density performance