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

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pH Matter LLC
Columbus, OH

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Project ID: FC167

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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 with the engineered supports in an MEA.

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

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Approach

Tasks / Key Milestone	Quarter after project initiation							
	1	2	3	4	5	6	7	8
Task 1. Catalyst Optimization (pH Matter)								
Task 1.1 Support Synthesis	■ ■							
Task 1.2 Platinum Deposition	■ ■	■ ■	■					
Task 1.3 Catalyst Characterization	■ ■	■ ■	■ ■					
Task 2. Catalyst Scale-up (pH Matter)								
Task 2.1 Twenty-gram Batches		■ ■	■ ■	■ ■				
Task 2.2. Quality Control Development			■ ■	■ ■	■ ■			
Task 2.3 Commercial-Scale Batch					■ ■	■ ■		
Task 3. MEA Synthesis (Giner)								
Task 3.1. Ink Optimization	■ ■	■ ■						
Task 3.2. High Current Optimization		■ ■	■ ■	■				
Task 3.3. Processing Optimization					■ ■			
Task 3.4 MEA Synthesis for Customer Validation						■ ■	■ ■	
Task 4. MEA Testing (pH Matter)								
Task 4.1. Differential 5-cm^2 MEA Testing	■ ■	■ ■						
Task 4.2. Full-Scale 25-cm^2 MEA Testing			■ ■	■ ■	■ ■	■ ■	■ ■	
Demonstrate automotive targets				●				
Demonstrate automotive targets with scalable processing							●	
Task 5. Validation Testing (NREL, Ballard, Others)				■ ■				■ ■

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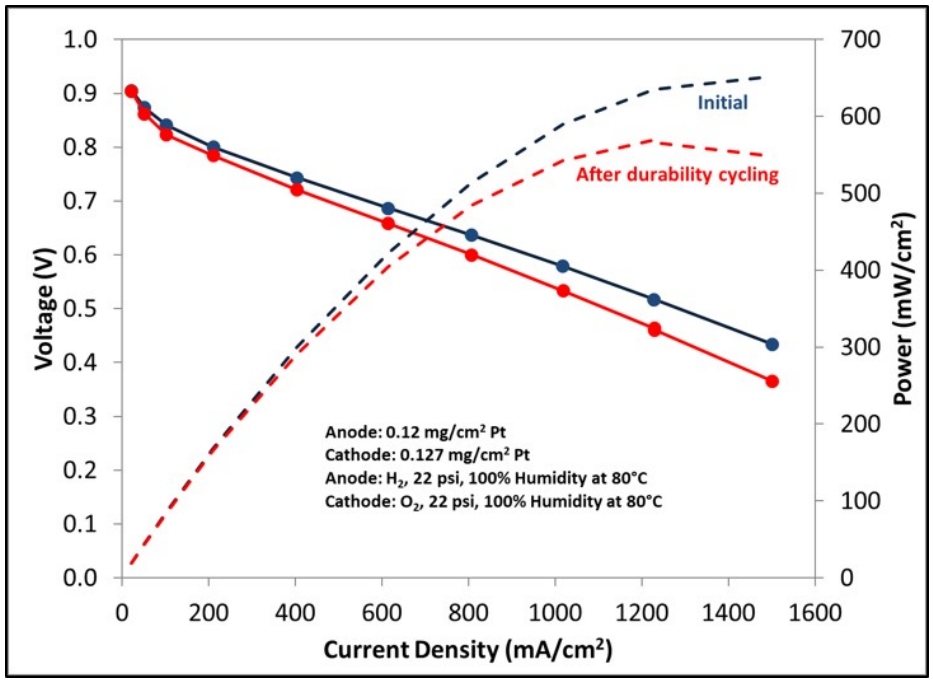
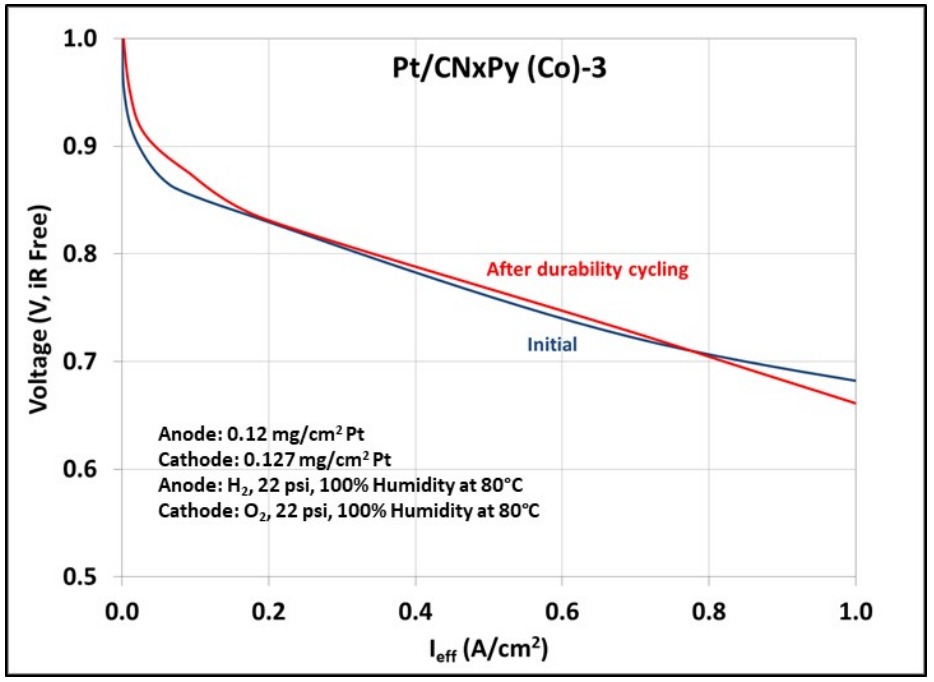
Accomplishments (Phase I)

Developed a catalyst with pH Matter engineered CNxPy support that demonstrated DOE targets for Pt loading, mass activity and durability in Phase I

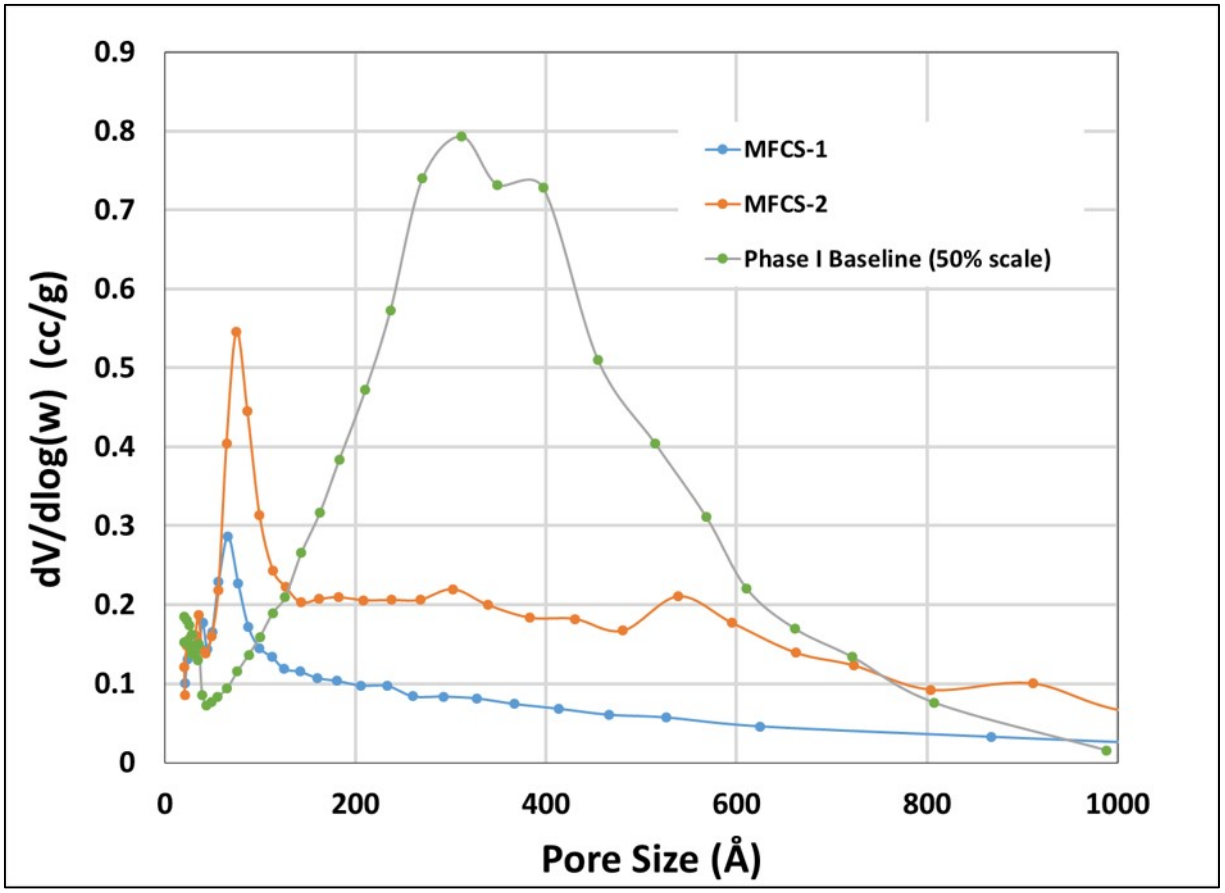


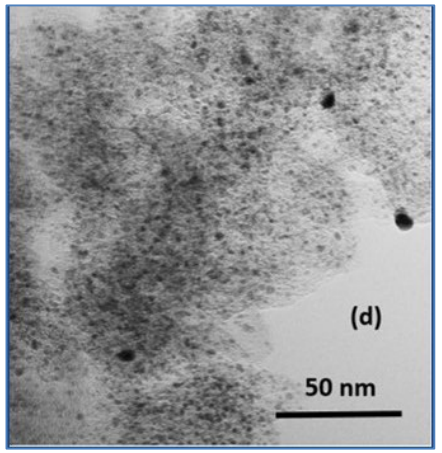


Based on IR-correction, the degradation at 0.8 A/cm^2 was likely from the membrane

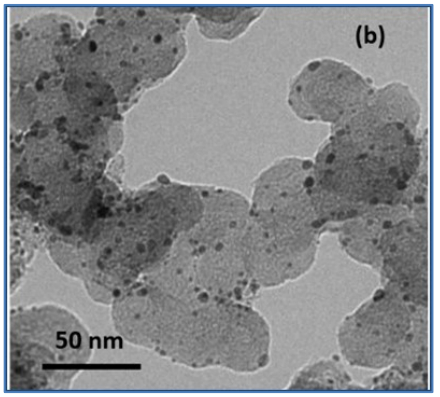
Accomplishments

Support Synthesis: In Phase II, pore structure of the Multi-Functional Carbon Support (MFCS) was improved:





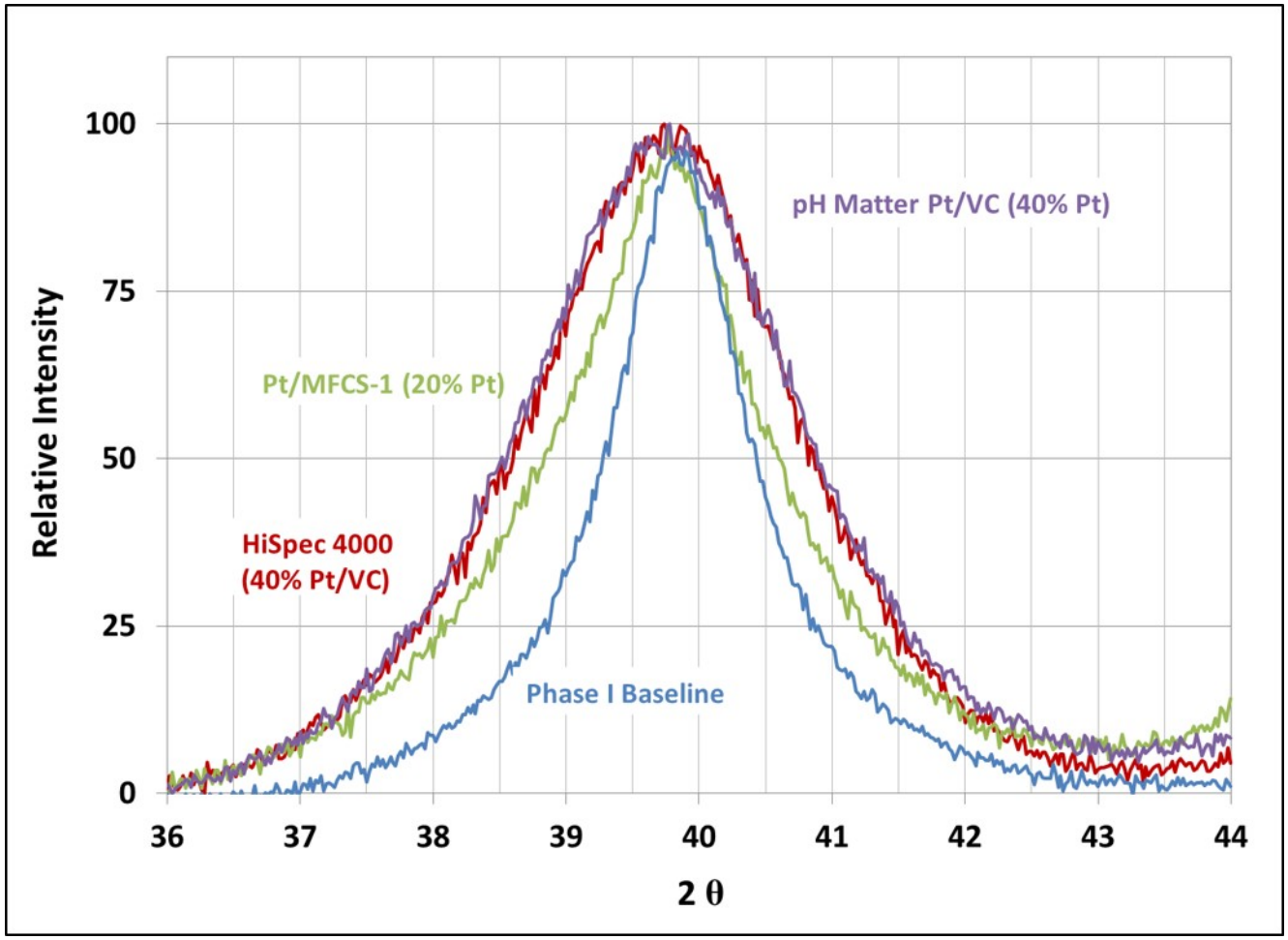
Phase I Baseline (20% Pt)



20% Pt/MFCS-1

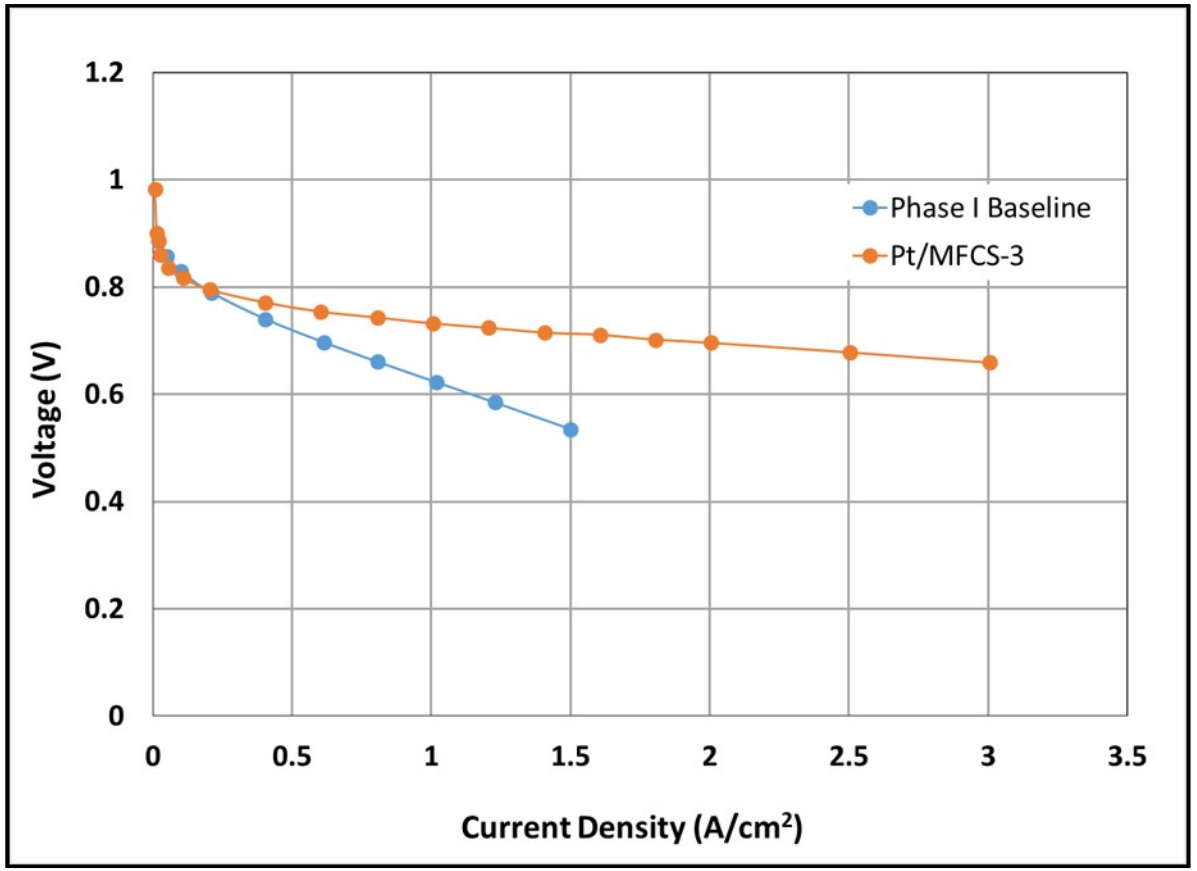
Accomplishments

Pt Reduction: improved reduction conditions to match commercial catalyst Pt particle size:



Accomplishments

Catalyst performance in MEA: Improvement in performance for Pt/MFCS compared to the Phase I baseline catalyst under oxygen:



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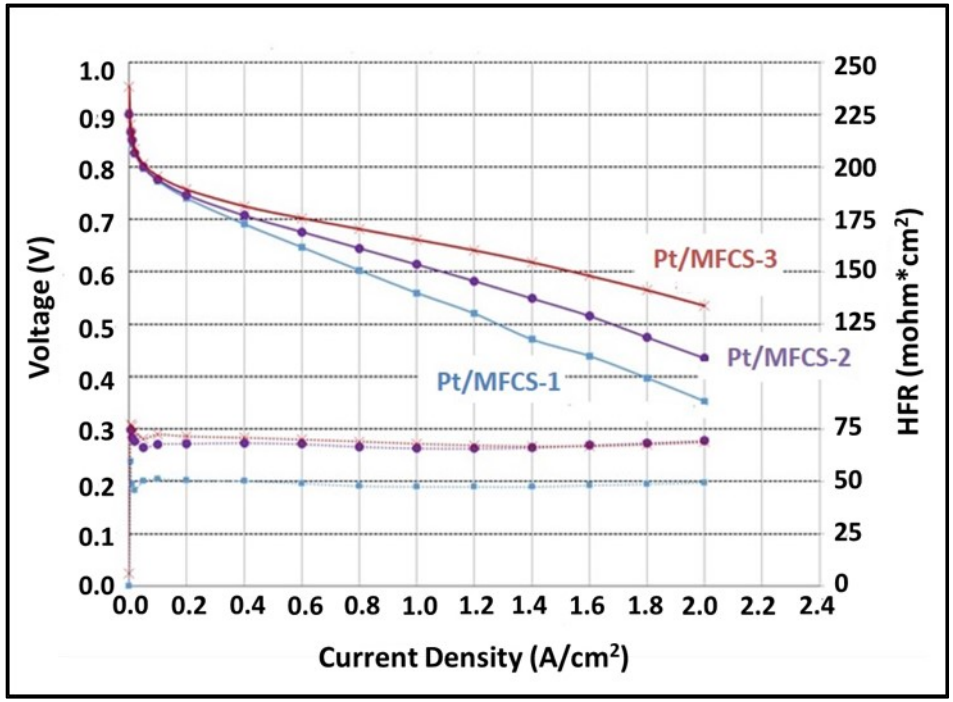
25-cm² active area, 80°C, 100% RH, H_2/O_2, 150 kPa
Cathode loading of 0.1 mg_{PGM}/cm^2

Accomplishments

MEA Performance and durability: Steady improvement in air performance both BOL and EOL:



Catalyst	Mass Activity (mA/mg)		ΔV at 0.8 A /cm² (mV)
	BOL	EOL	
Commercial Pt/C	304	140	148
Phase I Baseline	323	449	36
Pt/MFCS-1	In Progress	In Progress	In Progress
Pt/MFCS-3	In Progress	In Progress	In Progress

Cathode loading of 0.1 mg/cm², 80°C, 100%RH, 150 kPa

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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

- Demonstrate DOE 2020 targets for PGM loading, EOL mass activity, and durability simultaneously in 25-cm^2 MEA testing
- Demonstrate improved corrosion resistance of engineered supports versus commercial catalysts
- Platinum deposition scale-up on the MFCS

Future Work

- Further improve catalyst performance by alloying the platinum with other metals
- Further MEA optimization to address mass transport and cathode flooding issues by tuning hydrophobicity
- Electrode characterization before and after cycling to better understand degradation mechanisms
- Third-party validation to demonstrate DOE targets
- Partner with MEA manufacturers

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

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

Summary Slide

- Synthesized Multi-Functional Carbon Supports (MFCS) that are optimized for high power and durability
- Optimized catalyst synthesis to obtain optimal platinum particle size and performance
- Demonstrated high power performance over Phase I baseline catalyst with no significant alloying
- Demonstrated improvement of performance with further catalyst synthesis optimization
- Further improvement of catalyst activity will be performed with alloying and electrode structure optimization