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

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NREL: Guido Bender, Bryan Pivovar

pH Matter LLC
Columbus, OH

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Project ID: FC167
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.
Objective: Develop a multi-functional carbon support (that is based on nitrogen- and phosphorus-doped carbon nano-structures (CN$_x$P$_y$) and is optimized to perform better than conventional PEMFC pure carbon supports.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>DOE 2020 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platinum group metal Loading</td>
<td>mg$_{PGM}$/cm$^2$</td>
<td>0.125</td>
</tr>
<tr>
<td>Mass activity</td>
<td>A/mg$_{PGM}$ @ 0.9V</td>
<td>0.44</td>
</tr>
<tr>
<td>Loss in initial catalytic activity</td>
<td>% Mass activity loss</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Loss in performance at 0.8 A/cm$^2$</td>
<td>mV</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Electro catalyst support stability</td>
<td>% Mass activity loss</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Loss in performance at 1.5 A/cm$^2$</td>
<td>mV</td>
<td>&lt;30</td>
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- 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
<table>
<thead>
<tr>
<th>Tasks / Key Milestone</th>
<th>Quarter after project initiation</th>
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<tr>
<td>Task 1. Catalyst Optimization (pH Matter)</td>
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<tr>
<td>Task 1.1 Support Synthesis</td>
<td>■■</td>
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<tr>
<td>Task 1.2 Platinum Deposition</td>
<td>■■■■■</td>
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<tr>
<td>Task 1.3 Catalyst Characterization</td>
<td>■■■■■■</td>
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<tr>
<td>Task 2. Catalyst Scale-up (pH Matter)</td>
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<tr>
<td>Task 2.1 Twenty-gram Batches</td>
<td>■■■ ■■■■</td>
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<td>Task 2.2 Quality Control Development</td>
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<tr>
<td>Task 2.3 Commercial-Scale Batch</td>
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<td>Task 3. MEA Synthesis (Giner)</td>
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<tr>
<td>Task 3.1 Ink Optimization</td>
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<tr>
<td>Task 3.2 High Current Optimization</td>
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<td>Task 3.3 Processing Optimization</td>
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<td>Task 3.4 MEA Synthesis for Customer Validation</td>
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<td>Task 4. MEA Testing (pH Matter)</td>
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<tr>
<td>Task 4.1 Differential 5-cm² MEA Testing</td>
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<tr>
<td>Task 4.2 Full-Scale 25-cm² MEA Testing</td>
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<tr>
<td>Demonstrate automotive targets</td>
<td></td>
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<tr>
<td>Demonstrate automotive targets with scalable processing</td>
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<td>Task 5. Validation Testing (NREL, Ballard, Others)</td>
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Approach
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/cm² was likely from the membrane.
Support Synthesis: In Phase II, pore structure of the Multi-Functional Carbon Support (MFCS) was improved:
**Accomplishments**

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

![Graph showing the comparison of Pt reduction conditions](image)

- **Pt/MFCS-1 (20% Pt)**
- **HiSpec 4000 (40% Pt/VC)**
- **pH Matter Pt/VC (40% Pt)**

The graph illustrates the relative intensity of the Pt reduction conditions for different catalysts, indicating the effectiveness of the improved reduction conditions to match commercial catalyst Pt particle size.
Catalyst performance in MEA: Improvement in performance for Pt/MFCS compared to the Phase I baseline catalyst under oxygen:

- 25-cm² active area, 80°C, 100% RH, H₂/O₂, 150 kPa
- Cathode loading of 0.1 mg_PGM/cm²
Accomplishments

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

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

### Mass Activity (mA/mg) and ΔV at 0.8 A/cm² (mV)

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Mass Activity (mA/mg)</th>
<th>ΔV at 0.8 A/cm² (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Pt/C</td>
<td>304</td>
<td>140</td>
</tr>
<tr>
<td>Phase I Baseline</td>
<td>323</td>
<td>449</td>
</tr>
<tr>
<td>Pt/MFCS-1</td>
<td>In Progress In Progress</td>
<td>In Progress</td>
</tr>
<tr>
<td>Pt/MFCS-3</td>
<td>In Progress In Progress</td>
<td>In Progress</td>
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</table>
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
- Demonstrate DOE 2020 targets for PGM loading, EOL mass activity, and durability simultaneously in 25-cm² 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
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