Development of Innovative Gas Diffusion Layers for Polymer Electrolyte Membrane Fuel Cells

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Project ID #: fc187
Project Overview

**Timeline**
- Start Date: April 9, 2018
- End Date: January 8, 2019
- 0% complete

**Budget**
- Total project funding:
  - DOE share: $149,997
- Funding received in FY18: $149,997
- Funding for FY19: $0
- This is an SBIR Phase I project

**Barriers**
- Performance – improved water management properties
- Durability – improved corrosion resistance
- Cost – high-volume manufacturing methods

**Partners**
- Tufts University – Dr. Iryna Zenyuk
- University of Miami – Dr. Hongtan Liu
- Gaia Energy Research Institute – Dr. Whitney Colella
- AvCarb Material Solutions - Prime
This project addresses three DOE technical barriers:

- **Performance:**
  - Improved water management properties through:
    - Controlled hydrophobic/hydrophilic gradient within the GDL
    - Improved MPL properties (penetration and micro-cracking)
    - Modification of in-plane/through-plane morphological properties

- **Durability:**
  - Improved corrosion resistance through:
    - Heat treatment process – improved uniformity, influence of temperature
    - Particulate types in the MPL (graphite vs. carbon black)

- **Cost:**
  - Utilization of high-volume manufacturing methods
  - Development of a techno-economic analysis for high-volume manufacturing of improved GDL design at automotive production levels
Project Approach (1)

- Performance:
  - Controlling the hydrophobic/hydrophilic gradient within the GDL
    - A three-pronged approach is proposed by the team including:
      - Controlled penetration of PTFE within the GDL
        - Control the solids content of the PTFE solution and alter the coating style to limit the penetration of PTFE within the GDL
      - Utilize different PTFE loadings in multiple MPLs applied on the surface of the GDL
        - Create multiple MPLs of similar construction (same particle type/size), but with various PTFE loadings and apply them in sequence to create a gradient.
      - Utilize a hydrophilic agent on one side of the GDL to create a gradient
### Performance:

#### Improved MPL

- **Ink penetration:**
  - Adjustments to MPL composition (e.g., particle size, viscosity) can be made to control the amount of penetration of the MPL into the substrate.

- **Controlled micro-cracking:**
  - Altering the drying profile (quick heat applied to the surface) will allow for the rapid formation of a smooth solid layer. Additional heating will drive the liquid through the surface, creating micro-cracking within the GDL.

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**GDL with:**

- a) Poor MPL penetration into the GDL
- b) GDL with free-standing MPL
**Performance:**

- **Modification of In-plane/Through-plane morphological properties**
  - **Saturation Ink:**
    - Modify amount of binder and types of particles in the substrate in the saturation ink
  - **Heat Treatment Profile:**
    - Altering the ramp rate and soak time to influence the cross-linking of the binder and alter the pore size and structure
  - **Measurement:**
    - Utilize X-ray CT scans to evaluate changes to the structure

[Through-plane image of AvCarb MB-30 GDS]

[Porosity as a function of through-plane thickness]

[MB30 Porosity vs. Thickness]

[MB30 PSD]

Pore size distribution of AvCarb MB-30 GDS

PDF [1/μm]

Radius [μm]
**Project Approach (4)**

- **Durability:**
  - Improved conductivity and corrosion resistance
    - Heat treatment
      - Examine the impact of the temperature and soak time for the graphitization process on the GDL and determine its effect on thermal and electrical properties of the substrate
  - Particle Type
    - Investigate potential improvements in corrosion resistance by utilizing graphite particles in place of carbon black particles within the substrate

- **Cost**
  - Development of a processing plant model
    - Estimate of the costs associated with producing GDLs with the improvements from this project at a commercialization volume consistent with a FCEV fleet to ensure any modifications can meet the DOE cost targets
This program is in its initial phase, so far the focus has been on:

- Preparing sample designs
- Obtaining necessary materials
- Coordinating the production schedule
- Setting up contracts and charge numbers
- Organization of the team (kick-off meeting)
- Sending standard production materials for baseline testing
AvCarb Material Solutions – Prime

Tufts University – Partner

- Dr. Iryna Zenyuk will lead the effort to:
  - Conduct ex-situ corrosion testing on provided novel GDLs from AvCarb
  - Measure key morphological properties, such as porosity, pore size distribution, and tortuosity with X-ray CT

University of Miami – Partner

- Dr. Hongtan Liu will lead the effort to:
  - Fabricate MEAs with commercially available catalyst/membranes and novel GDLs
  - Provide in-situ performance data of various improved GDL designs

Gaia Energy Research Institute – Dr. Whitney Colella

- Dr. Whitney Colella will lead the effort to:
  - Build a preliminary plant model for manufacturing the novel GDL designs
  - Estimate the cost of the GDL at volumes adequate to support a FCEV fleet
This program has just begun, please find a projected timeline for the efforts highlighted in this program below.

<table>
<thead>
<tr>
<th>Work Stream</th>
<th>WBS</th>
<th>Task</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Producing a Hydrophobic/Hydrophilic Gradient</td>
<td>1.1</td>
<td>Modify penetration level of PTFE solution</td>
<td>M1 M2 M3 M4 M5 M6 M7 M8 M9</td>
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<td></td>
<td>1.2</td>
<td>Produce samples with modified MPLs applied</td>
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<td></td>
<td>1.3</td>
<td>Evaluate performance of initial samples</td>
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<td></td>
<td>1.4</td>
<td>Utilize hydrophilic coating on GDL*</td>
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<tr>
<td>2 Controlling MPL Penetration and MPL Micro-cracking</td>
<td>2.1</td>
<td>Modifying the MPL solution for optimal penetration</td>
<td></td>
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<tr>
<td></td>
<td>2.2</td>
<td>Modification of drying conditions to create micro-cracking</td>
<td></td>
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<tr>
<td></td>
<td>2.3</td>
<td>GDL Characterization &amp; Testing</td>
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<td></td>
<td>2.4</td>
<td>Adjustments to processing conditions*</td>
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<tr>
<td>3 Modification of the In-Plane/Through-Plane Permeability Ratio</td>
<td>3.1</td>
<td>Investigate various compositions of saturation inks</td>
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<td></td>
<td>3.2</td>
<td>Determine influence of heat treatment process</td>
<td></td>
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<tr>
<td></td>
<td>3.3</td>
<td>Optimize In-plane/Through-plane permeability ratio</td>
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<tr>
<td>4 Improvement of GDL Thermal and Electrical Conductivity</td>
<td>4.1</td>
<td>Modification of heat treatment process</td>
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<tr>
<td></td>
<td>4.2</td>
<td>Prepare samples with different MPL constituents</td>
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<tr>
<td></td>
<td>4.3</td>
<td>Testing of materials</td>
<td></td>
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</tbody>
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*If necessary Milestone
Remaining Challenges & Barriers (1)

- Receiving necessary materials to produce samples
- Scheduling time to create sample materials
- Test station validation
- Scheduling time for ex-situ measurement techniques
- Coordinating efforts for maximum efficiency
- Technical barriers for development
  - Can we adequately produce hydrophilic/hydrophobic gradient?
  - Can we accurately measure the MPL penetration within the substrate?
  - Will we be able to discern the uniformity of micro-cracking in the MPL?
  - Will alterations to the heat treatment process be adequate to change the corrosion resistance?
Objective

- Develop advanced GDL designs for improved fuel cell performance

Relevance

- GDLs play a key role in the performance of fuel cells and technical barriers remain in performance, durability, and cost

Approach

- Generate novel GDL designs focused on improving:
  - Performance – Improve water management by creating a hydrophobic/hydrophilic distribution in the GDL, control MPL penetration and micro-cracking, and improve the in-plane/through-plane morphological properties
  - Durability – Utilize improved heat treat processes and different particle types to enhance corrosion resistance
  - Cost – Develop a techno-economic model to estimate GDL costs at commercialization volumes consistent with a fleet of FCEV

Accomplishments

- Program has just begun, initial efforts are underway

Collaborations

- This is a strong, experienced group comprised of both industry partners and academia