AvCarb Material Solutions
Two Industrial Avenue
Lowell, MA 01851-5199 USA
www.AvCarb.com

Moving Energy
with Carbon Fiber

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

PI: Jason Morgan

AvCarb Material Solutions
2 Industrial Avenue, Lowell, MA

Wednesday, June 13th, 2018

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

AvCarb®

Project Relevance (1)

- **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

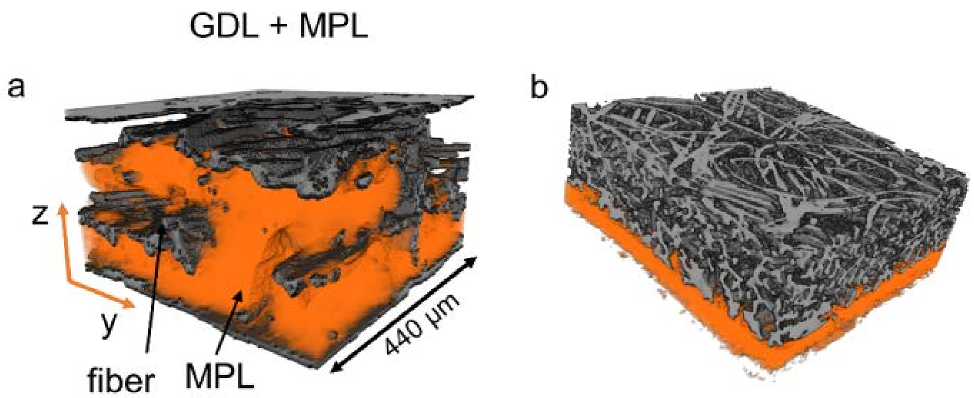
AvCarb®

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

AvCarb®

- **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.



GDL with:

a) Poor MPL penetration into the GDL

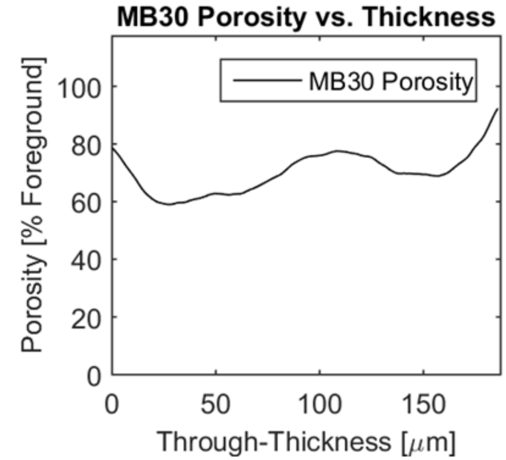
b) GDL with free- standing MPL

AvCarb®

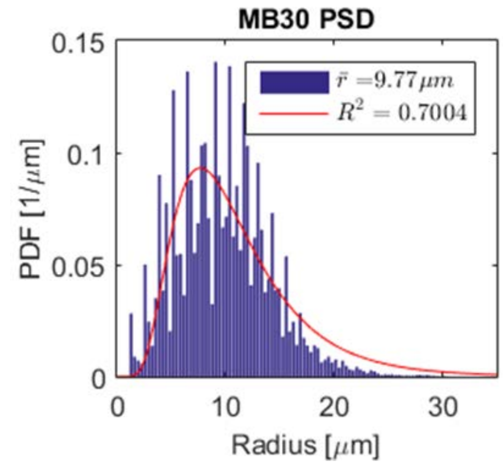
- **Performance:**
  - **Modification of In-plane/Through-plane morphological properties**
    - Saturation Ink:
      - Modify amount of binder and types of particles in the substrate in the saturation ink
    - Heat Treatment Profile:
      - Altering the ramp rate and soak time to influence the cross-linking 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



Pore size distribution of AvCarb MB-30 GDS



AvCarb®

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

AvCarb®

Accomplishments & Progress (1)

- **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®

Collaboration & Coordination (1)

- **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

AvCarb®

Proposed Future Work (1)

- **This program has just begun, please find a projected timeline for the efforts highlighted in this program below**

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

*If necessary Milestone ◆

AvCarb®

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

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?

AvCarb®

Summary (1)

- **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

AvCarb®