Nanostructured Carbon Based Gas Diffusion Layers for Enhanced Fuel Cell Performance

Project ID: fc192

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Overview

- **Timeline**
  - Start: April 2018
  - End: January 2019

- **Budget**
  - SBIR Phase I: $150,000

- **Partners**
  - Actively looking for collaborators from GDL and fuel cell companies

- **Barriers**
  - A. Durability
  - B. Cost
  - C. Performance

- **Targets (2020 goals)**
  - Corrosion
    - Cathode: <1μA/cm² for >24 hours
    - Anode: <1μA/cm² anode for >24 hours with no active peak
  - Conductivity
    - >100 S/cm @ 1.5 MPa
Problem

• The widespread commercialization of polymer electrolyte membrane (PEM) fuel cells is hindered by the high cost and limited lifetime of the components, including the gas diffusion layers (GDLs)

• TDA Research Inc. (TDA) proposes to lower the cost of GDLs using our specialty carbons to address the mass transport and water management issues that limit their performance
GDL Operation

- The GDLs allow the reactants (hydrogen and oxygen/air) to reach the active sites on the catalyst layers (CLs) and facilitates the removal of the liquid water to prevent flooding and the blocking of the catalyst.

- GDLs are carbon fiber substrates impregnated with Teflon to make them hydrophobic and thereby prevent the blockage of pores with water.

- A MicroPorous Layer (MPL) made of carbon black is added to the GDL surface between the CL and the GDL which enhances the water removal from the CL.
Improved MPL

• The pore sizes of the MPL are the key element to water removal

• MPLs made with carbon black give pore sizes ranging from 100-1000 nm that are too large to efficiently remove water

• TDA’s nanostructured carbons with mesopores in the 2-50 nm range allow much better diffusion of gasses to the catalytic sites and better diffusion of water out of the active catalytic layer
Comparison of TDA Nanostructured Carbon with Carbon Black

• Compared to carbon black, TDA carbons have:
  • High surface areas
  • Mesoporosity
  • Similar electrical conductivity
Relevance

- Objective: The main focus of this Phase I project is to develop nanostructured carbons with controllable pore sizes and specific surface areas to provide a much improved alternative to carbon blacks in the MPL of the GDL

- DOE 2020 Technical Targets
  - Corrosion
    - Cathode: <1μA/cm² for >24 hours
    - Anode: <1μA/cm² anode for >24 hours with no active peak
  - Conductivity
    - >100 S/cm @ 1.5 MPa
Approach

• The specific research objectives are to:
  • Prepare and characterize TDA carbons for use in the MPL
  • Prepare and characterize GDLs using TDA’s carbons for the MPL
  • Prepare membrane electrode assemblies (MEAs) using the most promising GDLs
  • Evaluate the performance and long-term durability of MEAs using TDA’s GDLs
  • Evaluate the cost of the new materials and compare their performance against today’s commercial GDLs

• The successful completion of Phase I will allow us to assess the merits of the new GDLs using TDA carbons and provide us a basis for their further design and development.
Approach: Fabrication

- Prepare carbons for the MPL
  - Equipment available at TDA
  - Low-cost precursors
- Characterize carbons
  - Surface area and pore size distribution
  - Elemental composition
  - Electrical conductivity

TDA’s Lab-Scale Rotary Furnace

TDA’s Pilot-Scale Rotary Furnace
Approach: Evaluation

- MPL layer will be applied to macroporous backing layer using TDA’s automatic drawdown machine

- Ex-situ Characterization
  - Porosity
  - Bulk Density
  - Electrical Conductivity
  - Corrosion
  - Surface Morphology

- In-situ Characterization
  - Prepare MEAs
  - Polarization Curves
  - Long-term Stability
Approach: Schedule

Task 1. MPL Carbon Preparation and Characterization
Task 2. Prepare and Characterize GDLs
Task 3. Fabrication of Membrane Electrode Assemblies (MEAs)
Task 4. Evaluation of MEAs
Task 5. Engineering Cost Analysis
Task 6. Reporting

LEGEND:
- Plan
- Revised Plan
- Actual
- Scheduled Milestone
- Completed Milestone

Months After Contract Award
1 2 3 4 5 6 7 8 9

TDA Research
Accomplishments and Progress

• Preliminary studies show that TDA GDL has 30% greater power density than commercial ELAT GDL (both with 0.5 mg-Pt/cm$^2$)
Collaboration & Coordination

• Engineered Fibers Technology, LLC
  • Relationship: Subcontractor and Commercial Partner
  • Industry: Manufacturer of Spectracarb™ GDL
  • Outside of DOE Hydrogen and Fuel Cells Program
  • Extent of Collaboration: Key partner in development and commercialization of improved GDLs
Remaining Challenges and Barriers

- Validation of enhanced performance of TDA’s GDLs
- Demonstration of durability and reliability
- Testing in existing FC platforms
- Production scale-up
- Working with commercialization partner
Proposed Future Work

• **Current activities:**
  • Preparation and characterization of TDA carbons for use in the MPL
  • Preparation and characterization of GDLs using TDA’s carbons for the MPL

• **Next activities**
  • Preparation of membrane electrode assemblies (MEAs) using the most promising GDLs
  • Evaluation of the performance and long-term durability of MEAs using TDA’s GDLs
  • Evaluation of the cost of the new materials and compare their performance against today’s commercial GDLs
  • Work with DOE funded vendor to draft a commercialization plan

• **Preparation of Phase II proposal**

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

- **Objective:** The main focus of this Phase I project is to develop nanostructured carbons with controllable pore sizes and specific surface areas to provide a much improved alternative to carbon blacks in the MPL of the GDL

- **Approach:**
  - Prepare and characterize TDA carbons for use in the MPL
  - Prepare and characterize GDLs using TDA’s carbons for the MPL
  - Prepare membrane electrode assemblies (MEAs) using the most promising GDLs
  - Evaluate the performance and long-term durability of MEAs using TDA’s GDLs
  - Evaluate the cost of the new materials and compare their performance against today’s commercial GDLs

- **Accomplishments:** Preliminary studies show that TDA GDL has 30% greater power density than commercial ELAT GDL