GDL Media Development for Improved PEM Fuel Cell Performance

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Techverse, Inc.

2018 DOE Annual Merit Review
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Project ID # **fc189**

Overview

Timeline

- **Project Start Date – 04/23/2018***
- **Project End Date – 01/22/2019***

* Expected as of 4/17/2018

Budget

- **Total Project Budget: $ 150,000**
- **Total Recipient Share: 0**
- **Total Federal Share: $ 150,000**
- **Total DOE Funds Spent*: 0**

* As of 4/17/2018

Barriers

- **C – Fuel Cell Performance**
  - Stack water management
  - System Start-Up and Shutdown Time and Energy/Transient Operation
- **A – Durability – hydrophobic GDL**
- **B – Cost of GDL**

Partners

- **Techverse, Inc.** – Project Lead
- **ElectroChem Inc.** – MEA preparation and cell testing
- **Dr. Satish Kandlikar (RIT)** – Two-phase flow visualization
- **SGL Carbon** - Industry

Relevance

Techverse, Inc.

Objectives - The overall objective of the DOE Phase I SBIR project is to develop Gas Diffusion Layer (GDL) with desired hydrophobic properties.

Need Addressed – Commercially available conventional GDL media were found to lose hydrophobic properties with exposure to electric current. For long-term effective stack water management, retention of hydrophobic properties of GDL media over PEMFC operation time is necessary.

Impact – This project will develop a novel technique for hydrophobic treatment of GDL media for lesser water retention, greater capillary breakthrough pressure, fewer transport limitations, longer durability, and greater PEMFC power output compared to conventional GDL media.

Desired GDL Properties

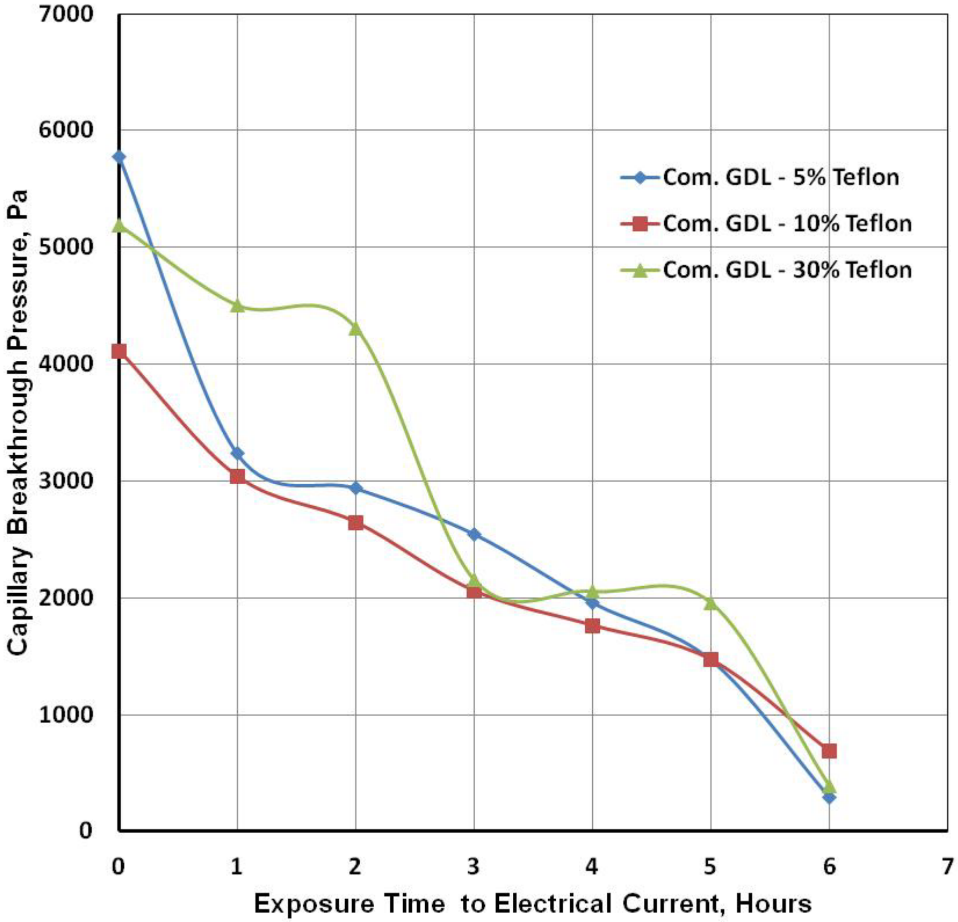
Earlier experimental and modeling investigations of water management issues by GM/RIT team (DOE Contract # DE-EE0000470) indicated desired properties of GDL for quick removal of water from GDL as well as flow channels to prevent blockage of reactant flow paths:

- NMR investigations revealed that during air purging, at shutdown, drying of conventional GDL took a long time typically indicating low internal hydrophobicity and greater water saturation.
- Studies of water breakthrough and drainage from conventional GDL revealed that it occurred only at a few preferential locations on the GDL surface indicating non-uniform internal hydrophobicity and preferential liquid water paths causing formation of water slugs in the channels.
- Two phase flow studies indicated that water film flow rather than slug flow in channels was a desirable two-phase flow pattern for reliable and consistent water removal and drainage.

Approach

- Develop an improved hydrophobic treatment of GDL media compared to conventional Teflon emulsion dip coating technique to achieve:
  - Uniform PTFE coating of carbon fibers in the Techverse GDL media instead of non-uniform deposition of Teflon particles in the conventional GDL media
  - Less residual water saturation and greater capillary breakthrough pressure at the same Teflon loading compared to conventional GDL media
  - Improved retention of hydrophobic properties with current exposure
  - Greater PEMFC power output at the same Teflon loading
- Establish hydrophobic treatment parameters for controlled and reproducible Teflon loading and scale-up to larger media size
- Develop hydrophobic treatment as a “drop-in” step in existing commercial GDL manufacturing process

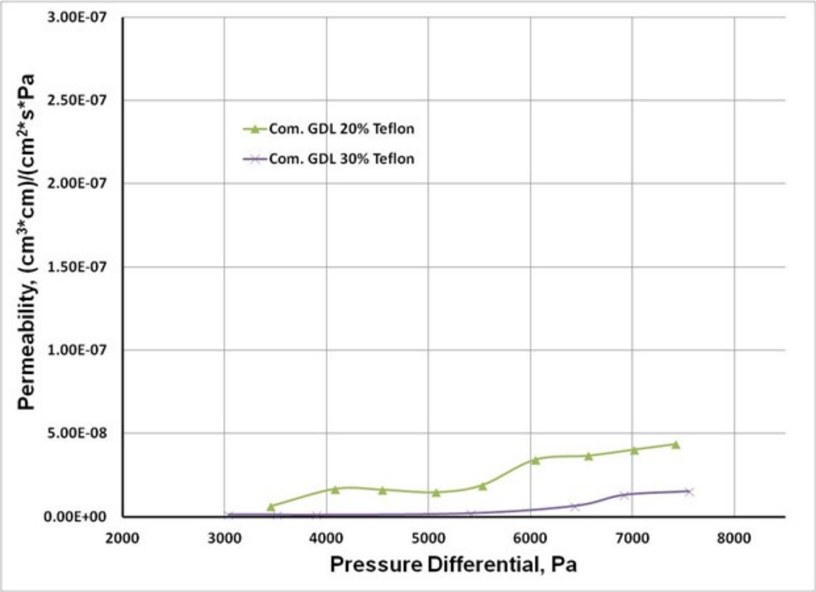
Background - Reduced capillary breakthrough pressure of commercial GDL media after exposure to electrical current

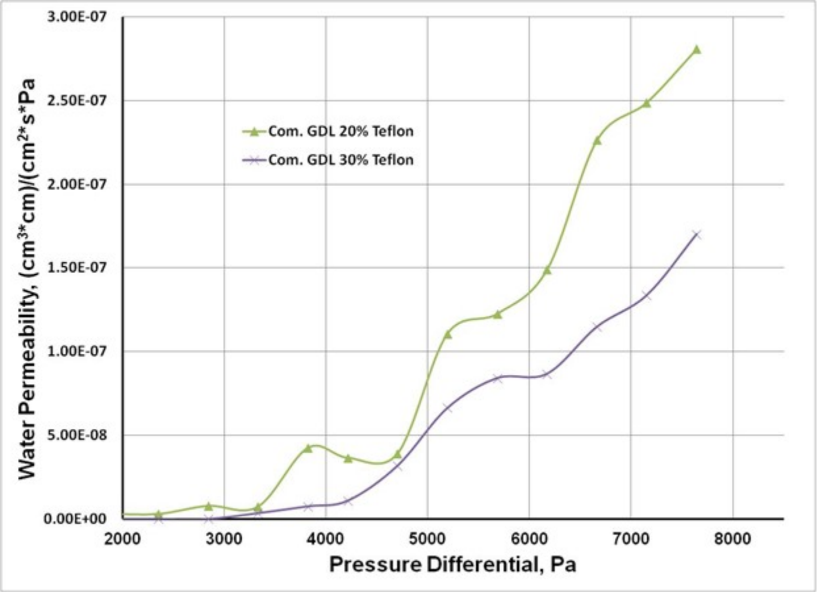


Applied voltage - 1.5 V
Current - 0.3 A

Near complete loss of hydrophobicity in commercial GDL media upon exposure to electrical current regardless of Teflon content

Background - Increased water permeability of commercial GDL media after exposure to electrical current



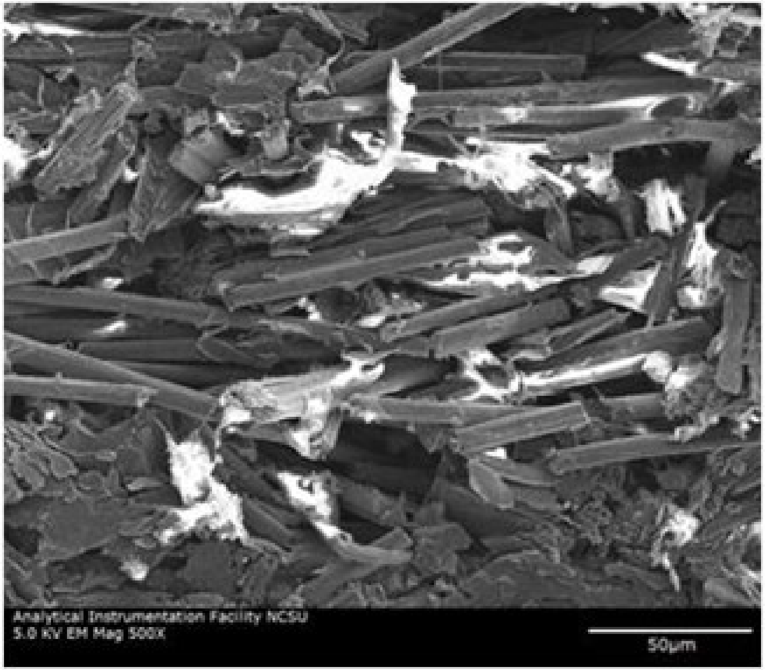


Before current exposure **After 6 hours of current exposure**

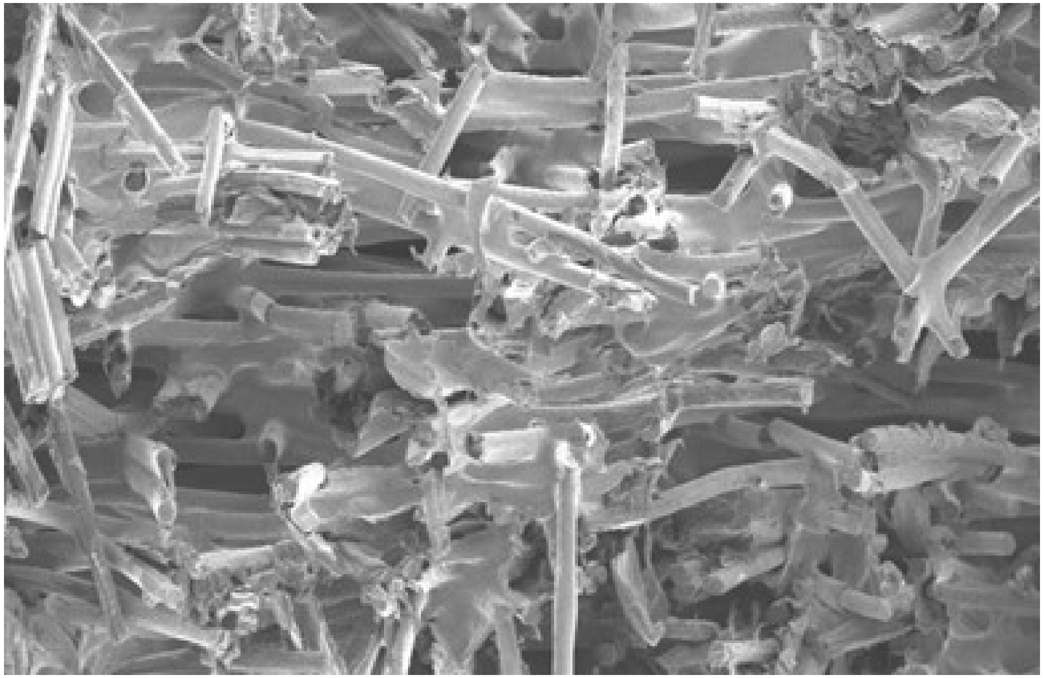
Applied Voltage - 1.5 V, Current - 0.3 A

An order of magnitude increase in water permeability of commercial GDL media upon exposure to electric current

SEM Images of Commercial GDL Media (~30% PTFE) and Techverse media (30% PTFE) with the same base carbon paper



Commercial GDL, 30% PTFE



Techverse GDL, 30% PTFE (same base carbon paper)

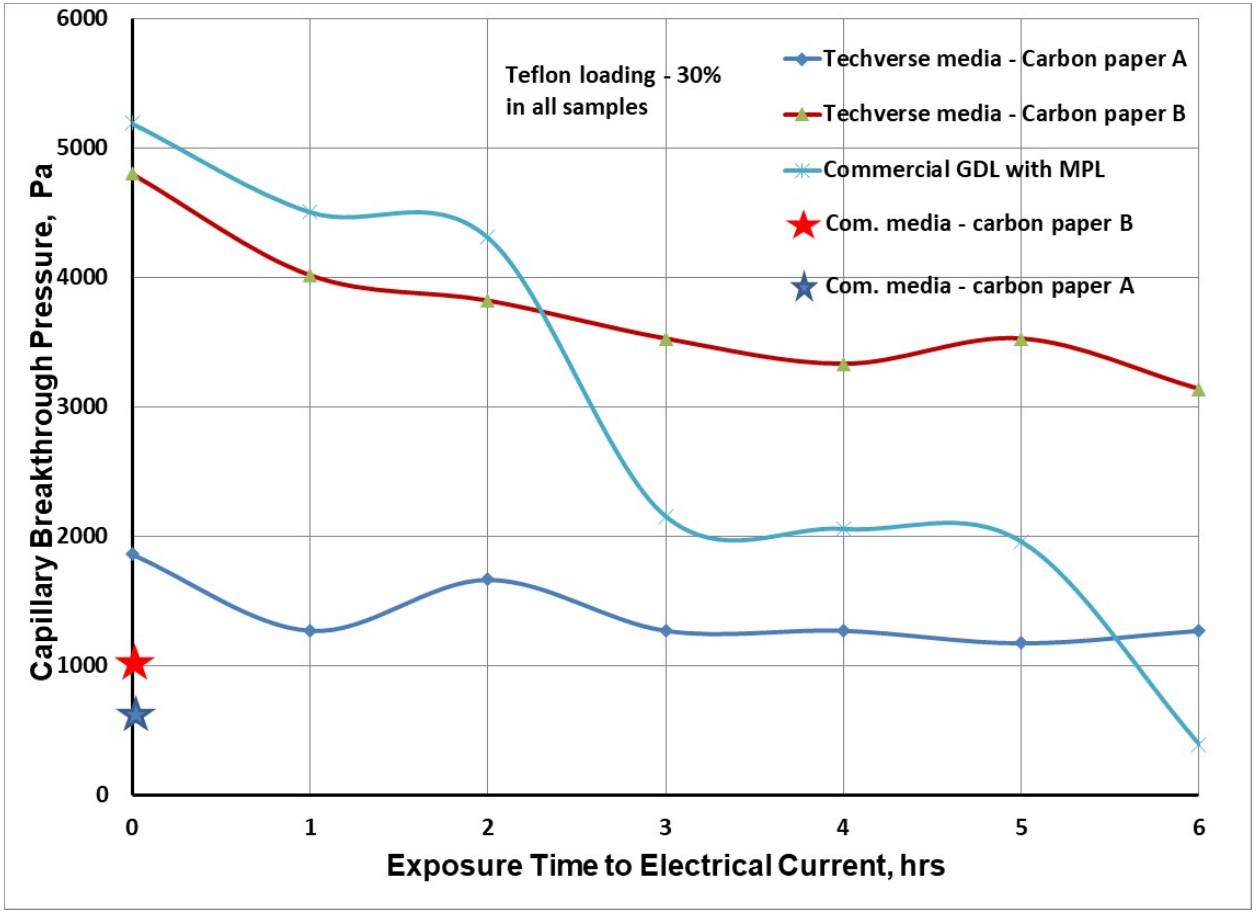
Uniform coating of carbon fibers in Techverse media compared to agglomerated PTFE particles in commercial media

Comparison of Commercial and Techverse GDL media properties (No MPL)

Sample	Residual Saturation	Breakthrough Pressure
n/a	%	Pa
Commercial GDL (Carbon Paper A) - 30% Teflon	15.52	587
Commercial GDL (Carbon Paper A) - 20% Teflon	25.54	1077
Commercial GDL (Carbon Paper A) - 10% Teflon	7.6	1175
Techverse GDL (Carbon Paper A) - 30% Teflon	2.44	1959
Techverse GDL (Carbon Paper A) - 7.5% Teflon	2.32	1763
Commercial GDL (Carbon Paper B) - 30% Teflon	2.5	1100
Commercial GDL (Carbon Paper B) - 20% Teflon	4	1000
Commercial GDL (Carbon Paper B) - 10% Teflon	3.3	780
Techverse GDL (Carbon Paper B) - 30% Teflon	0.416	4800
Techverse GDL (Carbon Paper B) - 15% Teflon	0.6	3400
Techverse GDL (Carbon Paper B) - 6% Teflon	0.8	3100

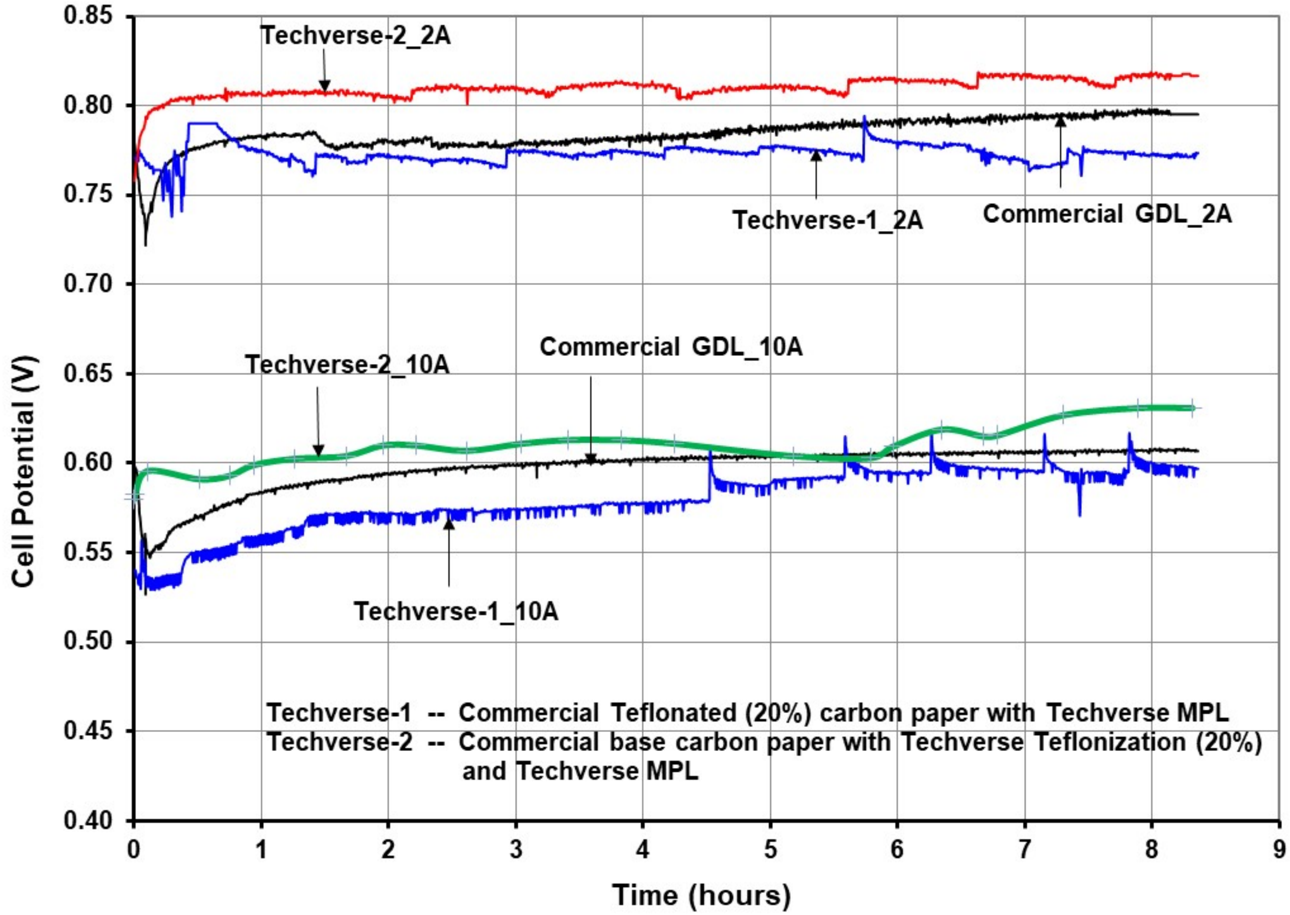
Lower residual saturation and greater breakthrough pressure for Techverse media vs commercial media

Capillary breakthrough pressure - Techverse vs. Commercial media



Higher breakthrough pressure and better retention of hydrophobicity of Techverse media

Single cell performance with Techverse and Commercial media

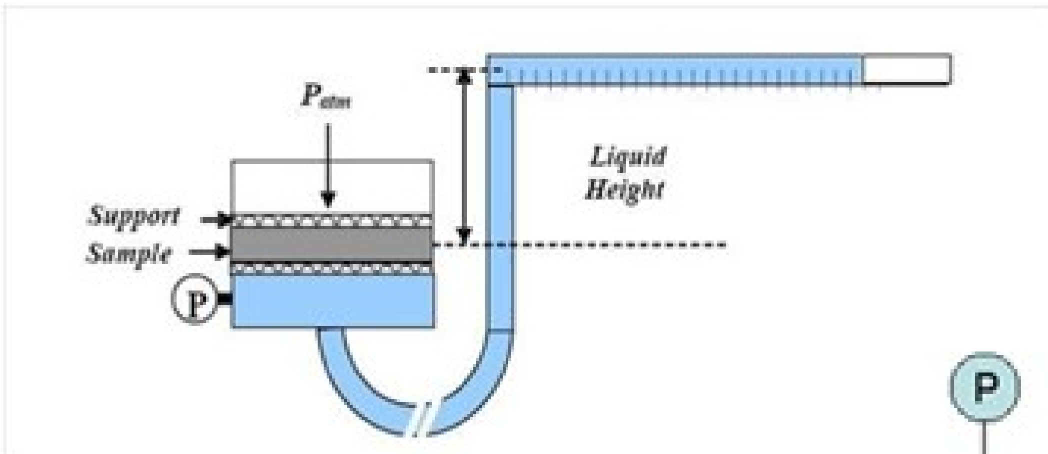


Higher cell voltage with Techverse GDL media in spite of poor Techverse MPL quality

Scope of Work – DOE Phase I SBIR Project

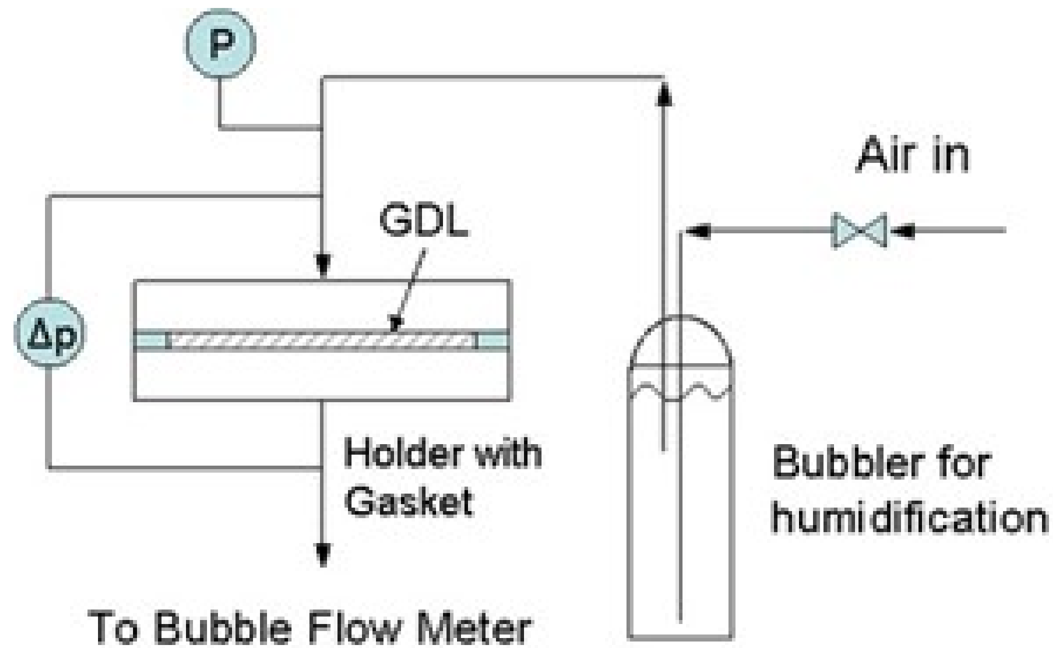
- **Task 1 – Optimization of Teflonization process parameters**
  - Establish parameters for Controlled and Reproducible PTFE loading in base carbon media
  - Various base carbon paper/cloth media
  - Initial media size 6 cm x 6 cm
- **Task 2 – Ex-situ GDL characterization at different PTFE loadings**
  - Capillary breakthrough pressure
  - Residual saturation
  - Contact angle
  - Thermal and electrical conductivity
  - Two-phase flow visualization experiments

Task 2 - GDL Characterization techniques

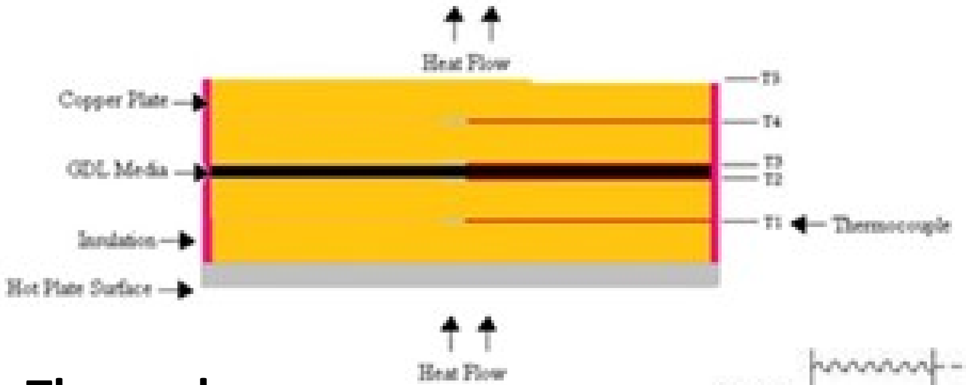


Breakthrough pressure
Residual saturation

Air/water permeability

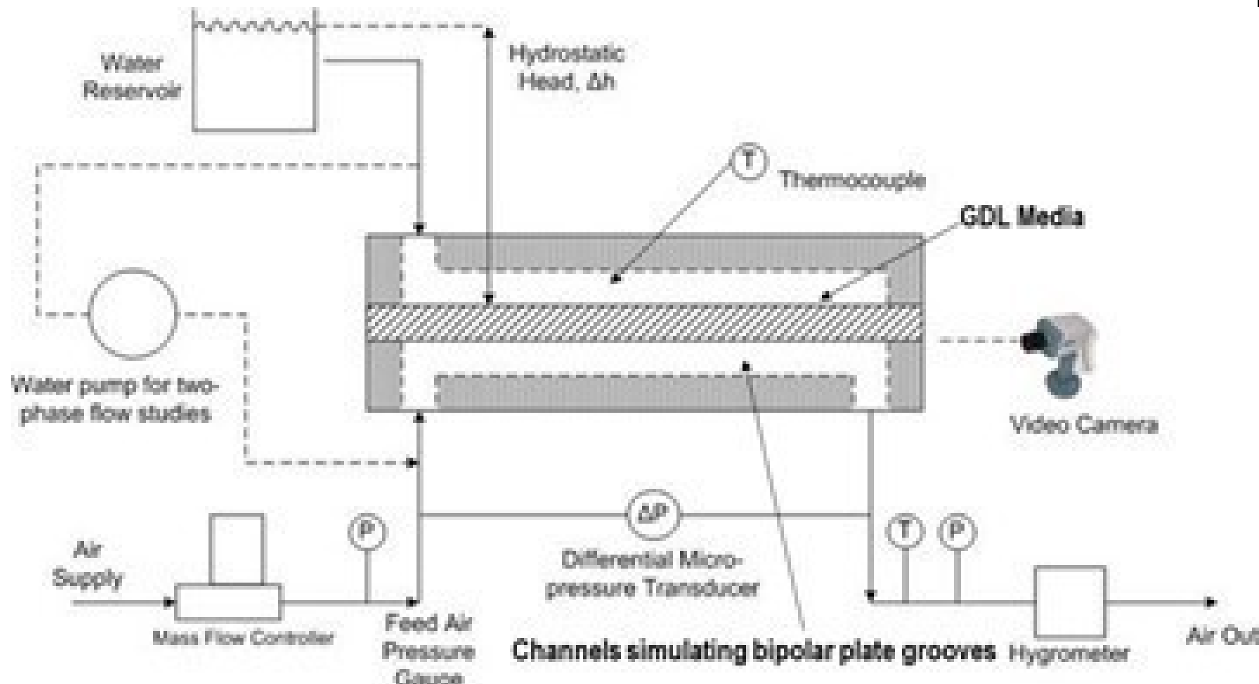


Task 2 - GDL Characterization techniques (cont.)



Thermal Conductivity

Two-phase flow visualization in flow channels



Scope of Work – Phase I SBIR Project (cont.)

Task 3 – MPL/MEA preparation and single cell PEMFC testing

- **Fabrication of MPL with ElectroChem's manufacturing process**
  - Spray coating process
  - Vulcan carbon ink solution with 10% Teflon
- **Fabrication of conventional and bifunctional GDL with GDL media**
  - conventional bulk GDL with hydrophobic paths
  - innovative bifunctional GDL integrating both hydrophobic and hydrophilic paths
  - apply micro-porous layer (MPL) coating to GDL
- **Fabrication of MEA**
  - Catalyst Coated Membrane (CCM), 0.35 mg Pt/cm^2 at cathode and 0.15 mg Pt/cm^2 at anode
  - attach the developed bulk GDL and bifunctional GDL

Scope of Work – Phase I SBIR Project (cont.)

Task 3 – MPL/MEA preparation and single cell PEMFC testing

- **Evaluation of MEA**
  - ElectroChem 25 cm^2 fuel cell hardware with special cooling plate at one separator plate to study behavior at sub-zero temperature
  - perform IV polarization OCV - 0.3V at 75^oC and 100% RH
  - performance at high current density 1.5 A/cm^2 at 75^oC and 100% RH
- **Evaluation of MEA in Sub-zero Tests**
  - evaluation of cold start-ups condition under sub-zero (-20^oC)
  - cycling tests with cell voltage OCV to 0.6V @ 50mV/sec (10 cycles)
- **Accelerated Stress Tests (ASTs) of MEA**
  - evaluation of carbon corrosion affected by hydrogen starvation
  - follow cycling potential by holding @ 1.2V and OCV in H_2/N_2
  - perform polarization curves before and after AST
  - evaluate fuel cell performance at high current density 1.5 A/cm^2 before and after AST

Scope of Work – Phase I SBIR Project (cont.)

- **Task 4 – Techno-economic analysis**
  - Cost of using hydrophobic treatment in manufacturing
  - Cost offset by reduced PTFE concentration requirement
  - Expected improvement in PEMFC performance

- **Task 5 - Commercialization feasibility and Phase II plan**
  - Scale-up the hydrophobic treatment process to larger size base carbon paper/cloth media
  - Work with an industrial partner to determine the best approach of incorporating the hydrophobic treatment in the commercial GDL manufacturing

Collaboration & Coordination

(within the DOE Hydrogen and Fuel Cells program)

Techverse, Inc. – Prime contractor - Small business

- Optimization of Teflonization parameters
- Ex-Situ GDL Characterization
- Techno-economic feasibility analysis

ElectroChem, Inc. – Subcontractor - Industry

- MPL and MEA with Techverse/commercial GDL
- Single cell testing in conditions of interest

Dr. Satish Kandlikar (RIT) – Consultant - University

- Two-phase flow visualization experiments

SGL Carbon – Industrial partner

- Feasibility of implementing Techverse Teflonization
- process in commercial GDL manufacturing

Summary

Techverse, Inc.

Objectives - To develop Gas Diffusion Layer (GDL) with desired hydrophobic properties for efficient stack water management and start-up/shutdown operations.

Relevance - For effective stack water management, retention of hydrophobic properties of GDL media over PEMFC operation time is necessary with low residual saturation and uniform internal hydrophobicity.

Approach - Develop an improved hydrophobic treatment of GDL media to achieve uniform Teflon coating of carbon fibers with lower residual water saturation and greater capillary breakthrough pressure at lower Teflon loading than commercial GDL media.

Scope of Work - Optimize teflonization parameters for controlled and reproducible Teflon loading, Conduct ex-situ GDL characterization at different Teflon loadings, Conduct MEA performance evaluation with Techverse and commercial GDL media, and conduct Techno-economic feasibility analysis.

Collaborators - ElectroChem, Inc. (MEA testing), Dr. Satish Kandlikar (GDL characterization), SGL Carbon (Industrial partner for incorporation in manufacturing.)