Visualization of Fuel Cell Water Transport and Characterization under Freezing Conditions

Project Sponsored by:
Department of Energy

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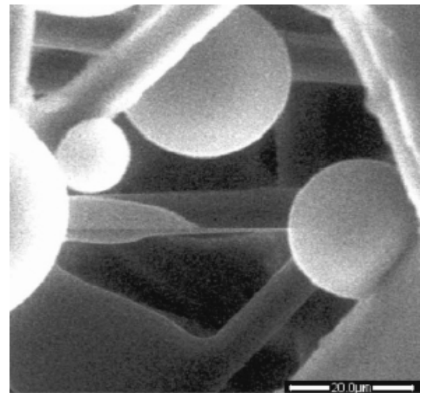
Water Management Issues, PEMFC

Excessive Water

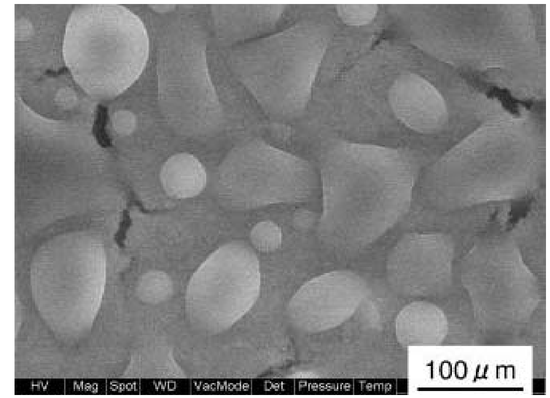
-Block reaction sites

-Saturate diffusion media

-Clog gas channels



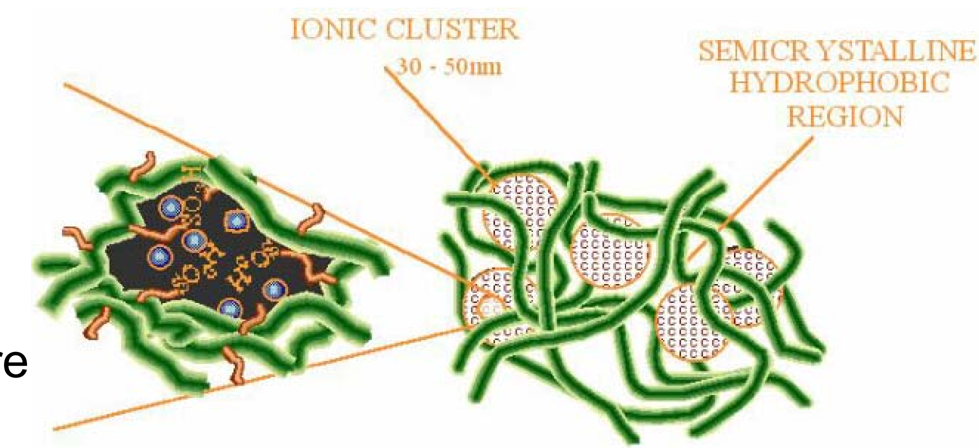
Zhang *et al.*, 2006.



Yamada *et al.*, 2006.

Insufficient Water

- Reduced Membrane proton conductivity
- Membrane fracture and failure



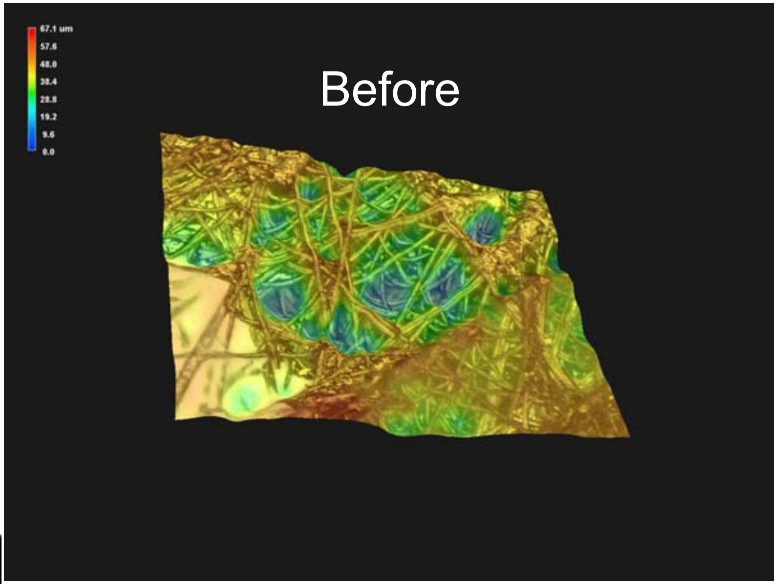
http://www.psrc.usm.edu/mauritz/images/nafion2b.jpg

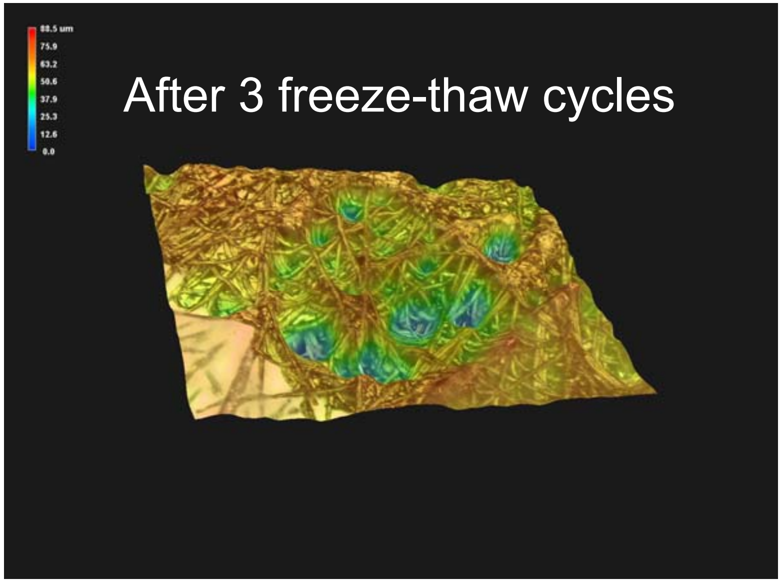
Water Management Issues, PEMFC

Repeated Freeze/Thaw Cycles

-Damage can be done to all components of PEMFC

- structural damage to GDL
- Loss of surface characteristics
- Loss of cell performance





Preliminary images of a GDL sample after several freeze-thaw cycles, RIT

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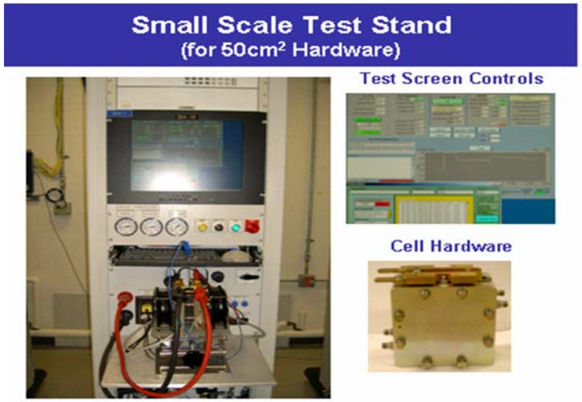
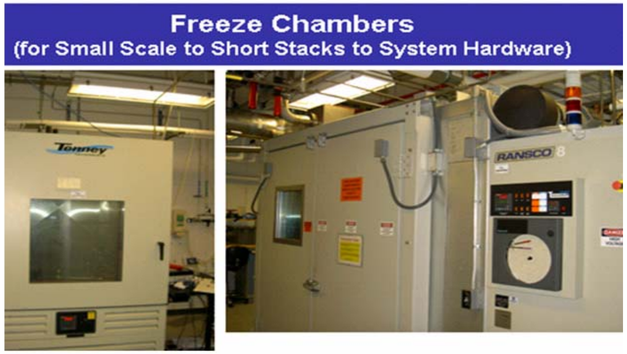
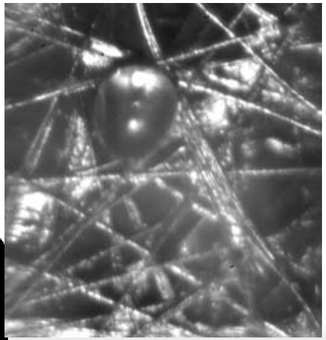
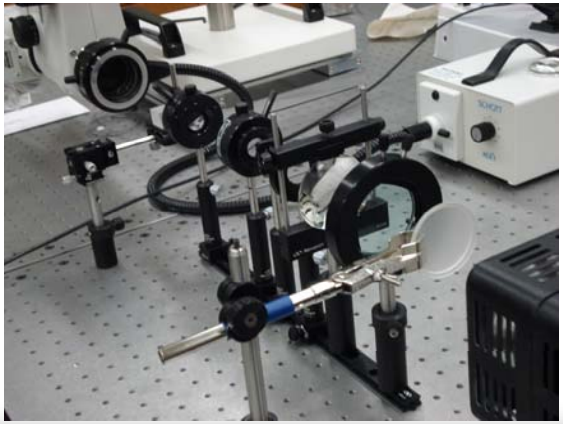
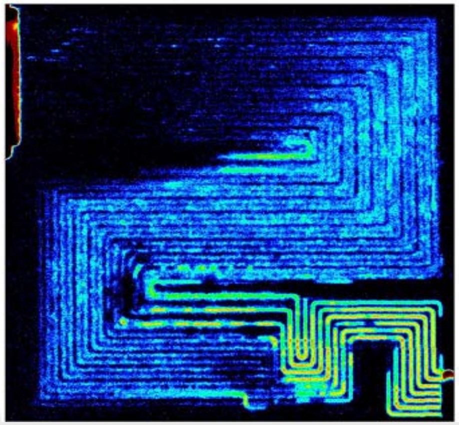
Project Focus: From Fundamentals to Component-level research











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Collaborative Research

3 year, $3.5 Million Program

Visualization of Fuel Cell Water Transport and Performance Characterization

Participants

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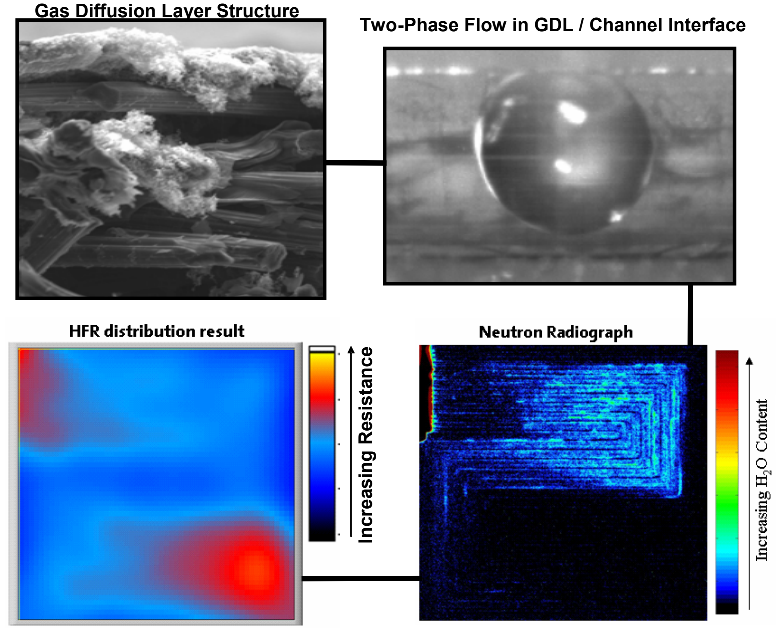


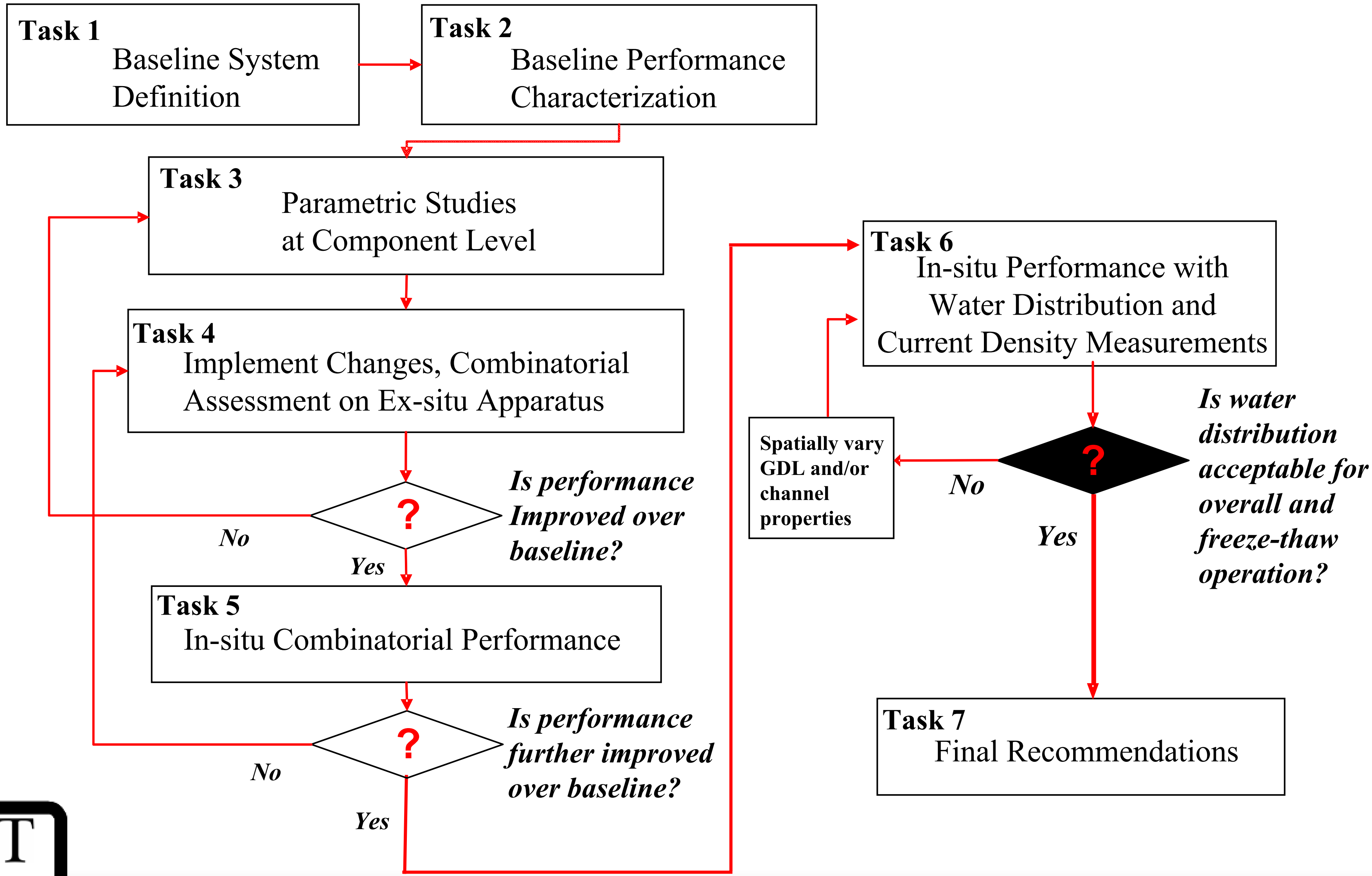
Deliverables

Optimized materials, design features and operating parameters under normal & freezing conditions

Impact

- low-cost, robust systems
- faster commercialization
- US technological leadership in fuel cell industry

Project Flow – Iterative research, learning and performance improvement



Collaborative Research Plan

Rochester Institute of Technology, P.I.

Professor Satish Kandlikar

-Significant experience in fundamentals of two-phase and microchannel flows, high speed imaging, modeling

Professor N. Rao

-Infrared imaging and digital video image processing

General Motors

Dr. Thomas Trabold, Jon Owejan

-The forefront of automotive fuel cell technology

-Extensive research & development facility

Michigan Technological University

Professor Jeffrey Allen

-Expertise in two-phase capillary-driven flows in channels and porous media

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Collaborative Research:

From fundamentals to applications

-Component level to stack

Iterative Understanding

-Studying the many fundamental processes

-Combine fundamentals into more complex experiments

-Eventually reach complete optimization of PEMFC

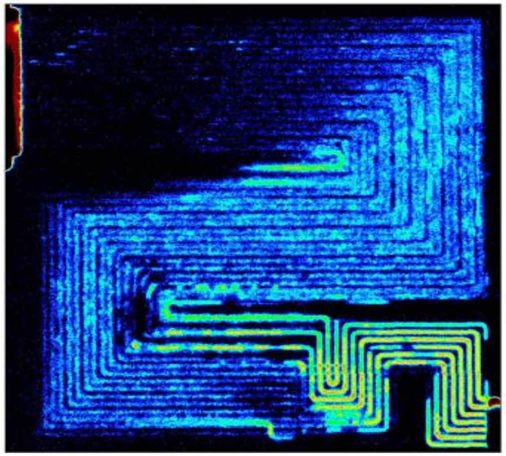
Novel Techniques

-Infrared Visualization

-High-Speed Visualization

-Neutron Radiography

-3-D Microscopy



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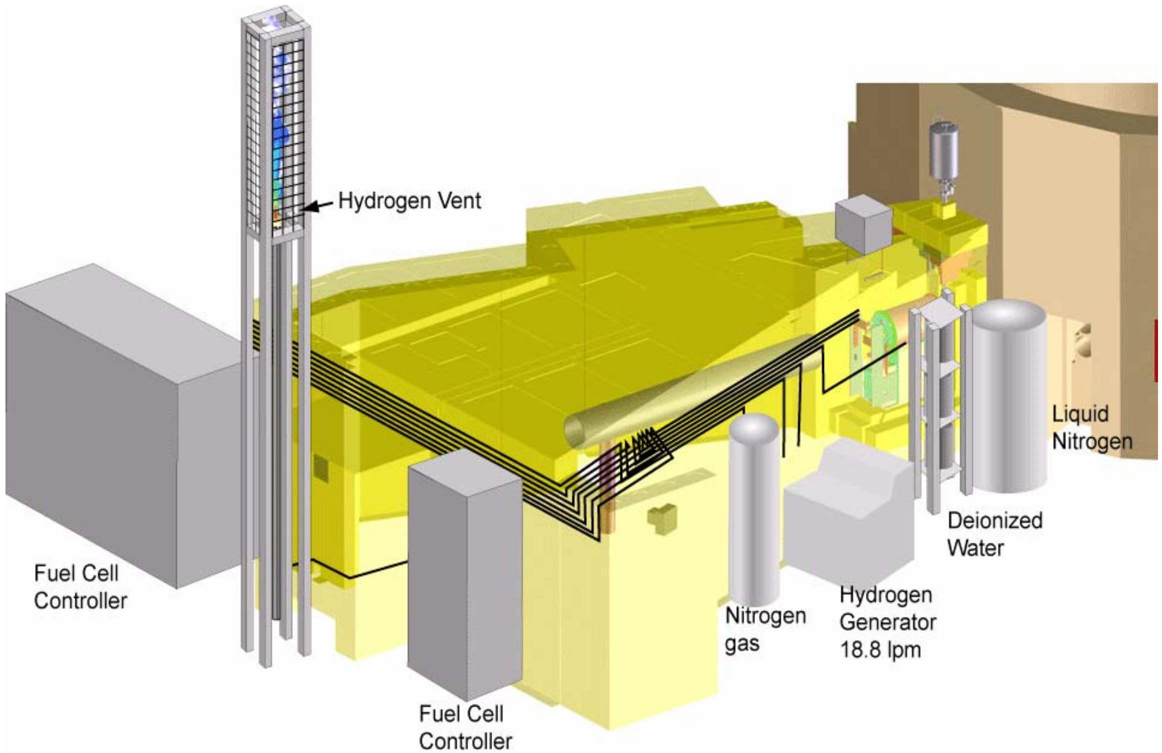
Experiments and Modeling

- **Ex-situ experiments** – water transport at GDL/channel interface, single-channel and multichannel two phase flows, header effects, freeze-thaw effects, modeling of pressure drop and instabilities.

- **In-situ experiments** – Direct visualization, local water holdup, local current distribution and freeze-thaw effects at component level using neutron radiography, verification of models.

- **Post-mortem analysis** – Microscopic analysis of GDL samples to study freeze-thaw effects as a function of cycling and shut-down protocol.

NIST-GM jointly developed fuel cell imaging facility



1. 14.6 m^2 (157 ft^2) floor space
2. Variable L/d ratio
3. Current support for fuel cell experiments
   - Hydrogen flow rates 18.8 lpm
   - micro fuel cell controller with 3 lpm H2 flow rates
   - Portable Current Distribution Board

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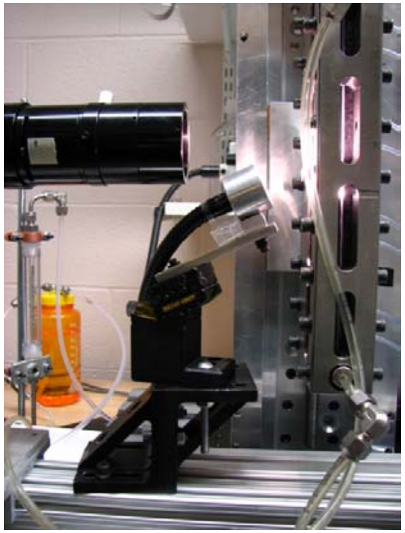
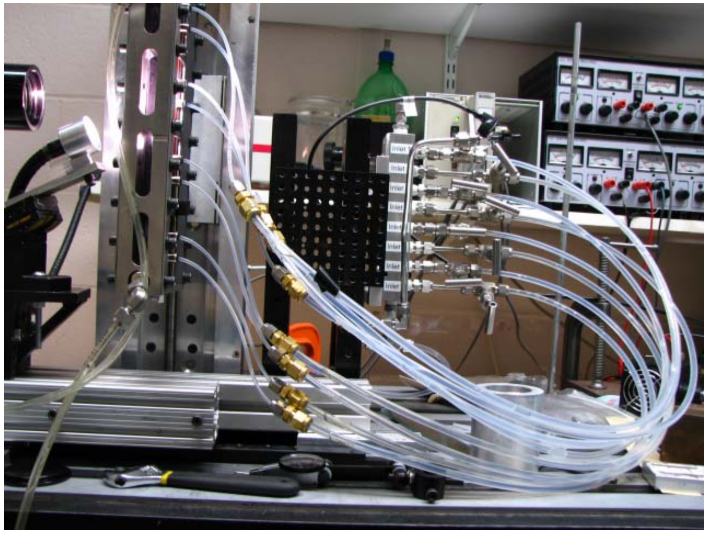
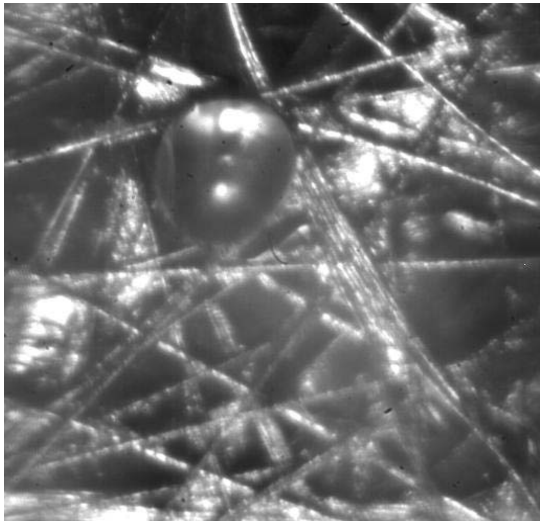
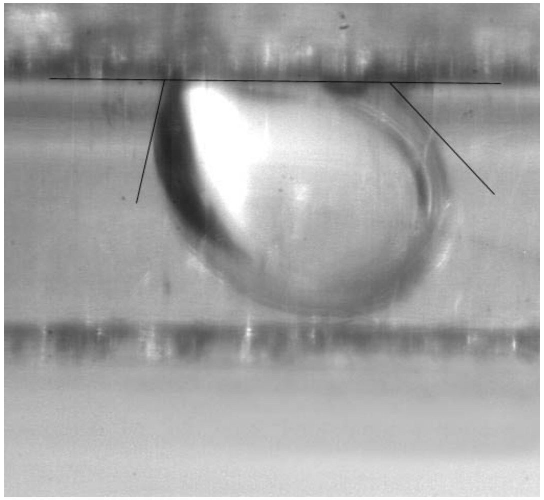
Visualization studies

- High speed imaging
- GDL/channel studies
- Single-channel, multiple channel and header flows
- Flow patterns, instabilities and pressure drop









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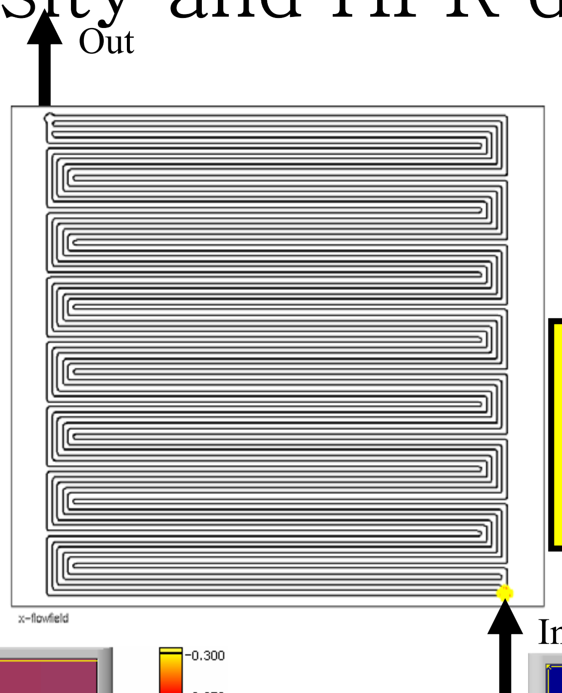
Optimized GDL/Bipolar Plate Combination

- GDL to channel transport
- Two-phase flow within channels and diffusion media
- Surface energy of diffusion media and plates
- Channel geometry & manifold design
- Optimize channel and manifold design for performance, voltage stability and freeze

Current density and HFR distributions

100 square segments
Inlet dry condition

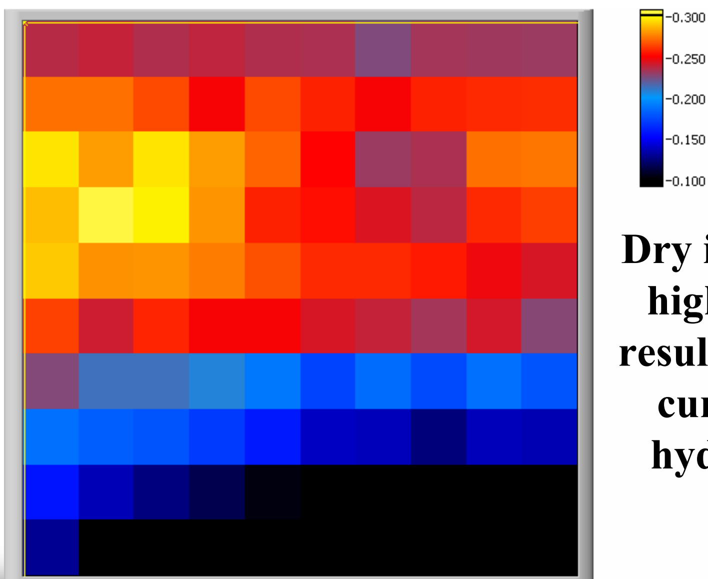
P = 200 kPa, *T* = 80 C
A/C Stoich = 2/2
A/C RH = 42/25%



3-channel,
15-pass serpentine cathode
Channel: W = 0.9 mm,
D = 0.5 mm; Land: W = 0.7 mm

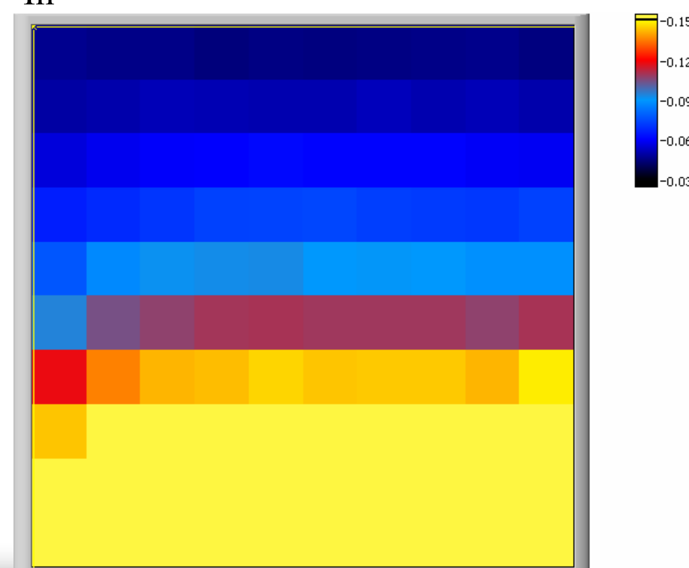
Current Density = 0.2 A/cm^2
Cell Voltage = 0.803 V
Cell HFR = 0.095 Ω cm^2

CD (A/cm^2)



Dry inlets produce high local HFR, resulting in shift of current to well hydrated outlet region.

HFR (Ω cm^2)



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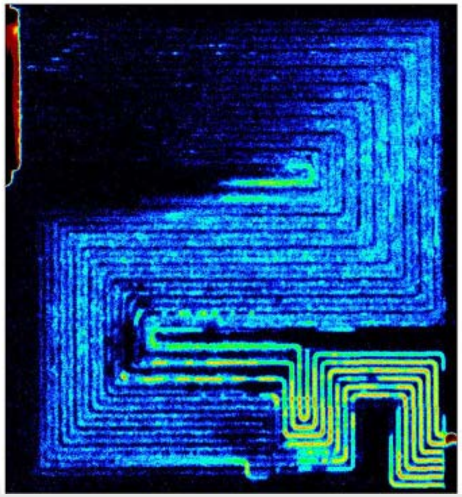
Optimized Water Distribution

Optimized Water Distribution

- Crucial to obtaining high performance and long life
- Mitigate dryout at inlets and water accumulation at outlets
- Minimize freeze start time and energy



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Thank You!