Facility Improvements for Fuel Cell Research and Development

A Proposal to the Maine Technology Asset Fund, No. 2056

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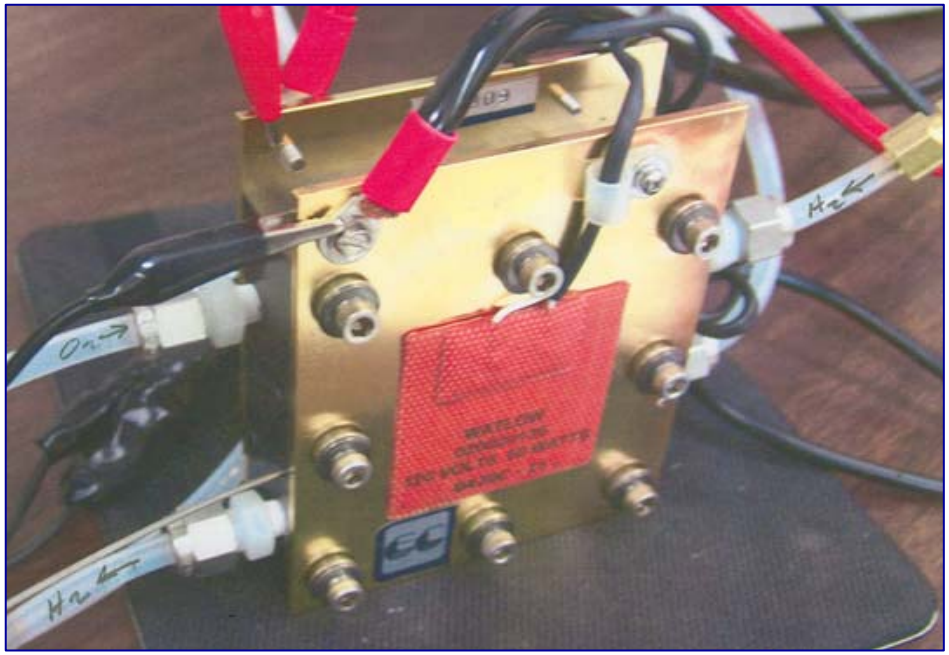
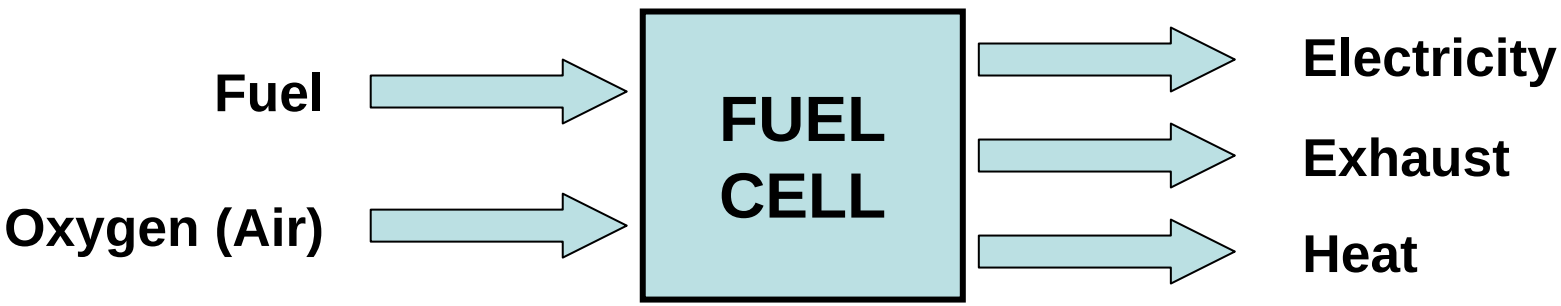
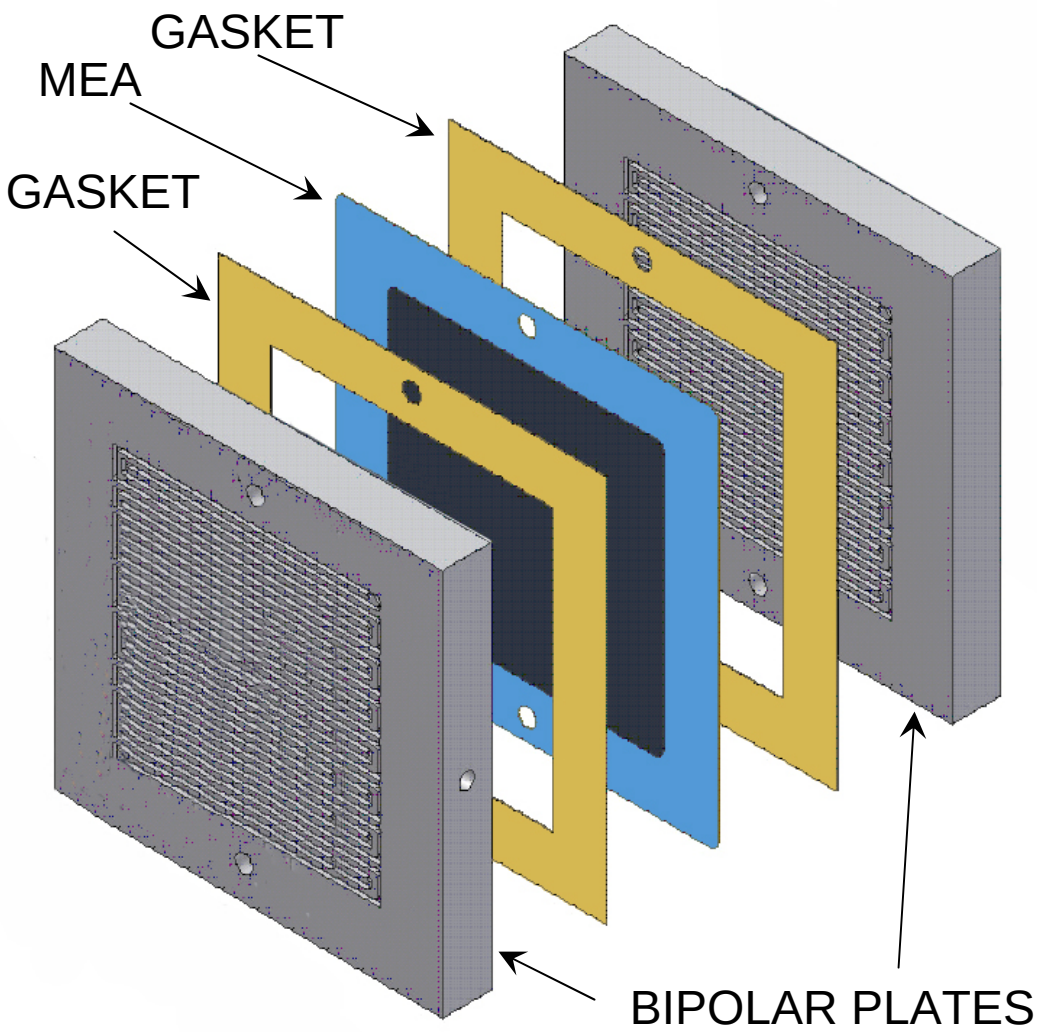
What is a Fuel Cell?



- **A device that transforms chemical energy <u>directly</u> into electrical energy:**



Fuel Cell Assembly



Project Overview:

- We have developed a novel chemical catalyzing technique which allows us to diffuse catalyst nanoparticles into the polymeric network of a typical fuel cell polyelectrolyte, and in particular perfluorinated sulfonic membranes (PSM).
- This membrane treatment method is used in the fabrication artificial muscle tissue for biomechanical applications, and is applied, for the first time, to fuel cells.
- Initial testing and evaluation shows a promising novel fuel cell manufacturing technology which may lead to commercialization and a great economic impact for the State of Maine and the US.

Project Overview:

- We have developed a novel electroless chemical catalyzing technique which allows us to diffuse catalyst nanoparticles into the polymeric network of a typical fuel cell polyelectrolyte, and in particular perfluorinated sulfonic membranes (PSM) or Nafion.
- The electroless plating method used is similar to what Shahinpoor developed for fabrication of IPMC artificial muscles used for biomechanical and industrial applications, and herein is applied, for the first time, to a novel family of fuel cells.
- Initial testing and evaluation shows a promising novel fuel cell manufacturing technology which may consequently lead to commercialization and a great economic impact for the State of Maine and the US.

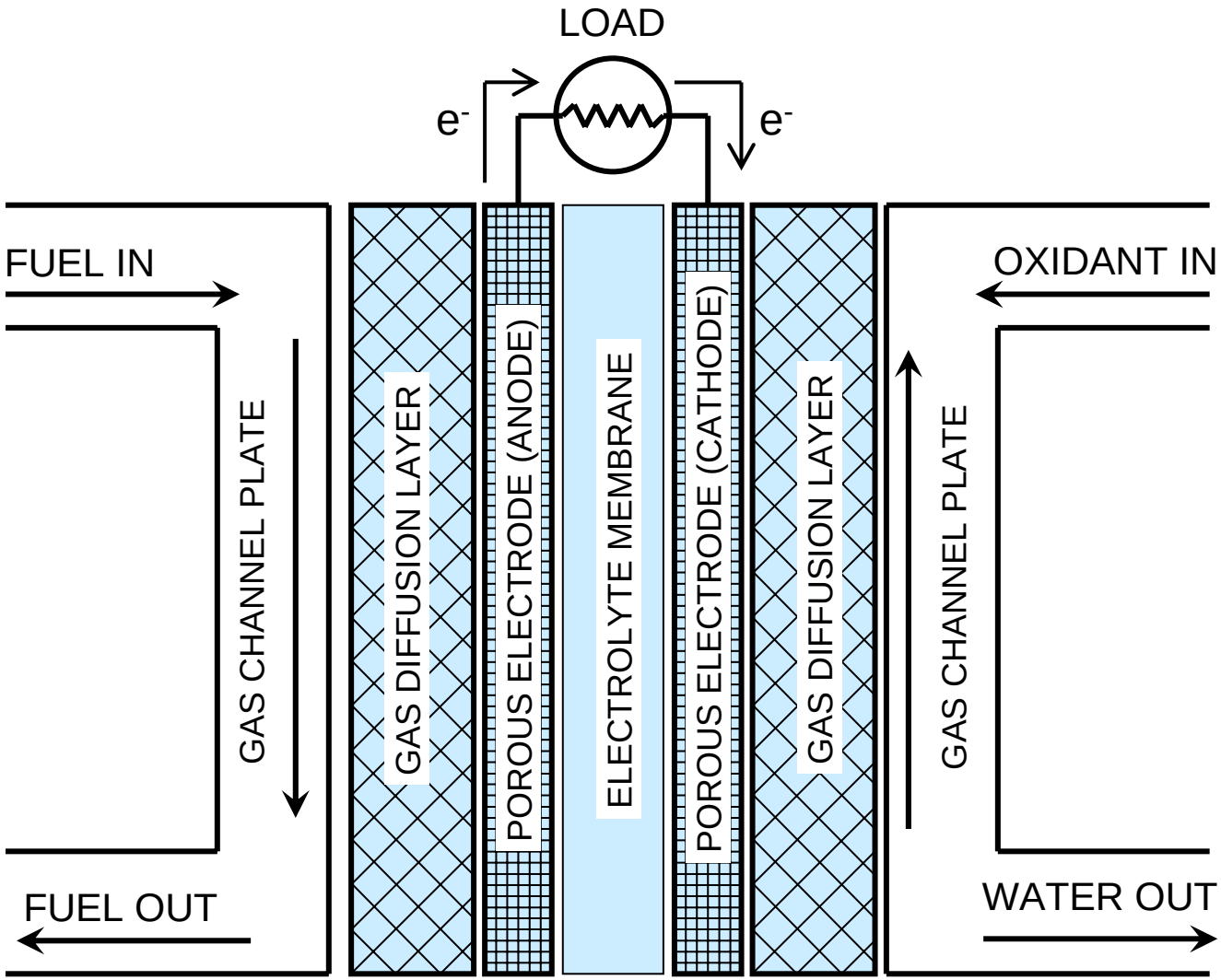
Current Barriers to Fuel Cell Commercialization:

- Material Costs
- High-Volume Manufacturing of MEA/Stack
- Reliability

Our Project Seeks to Address these issues by:

- Improving the utilization of catalysts
- Improving the manufacturing process by reducing the need from hot pressing
- Simplifying the design and manufacture of the MEA

Fuel Cell Schematic



- **GDLs + Electrodes + Electrolyte = Membrane Electrode Assembly (MEA)**

Nanochemistry of Catalization of PSN Ionic Polymers :

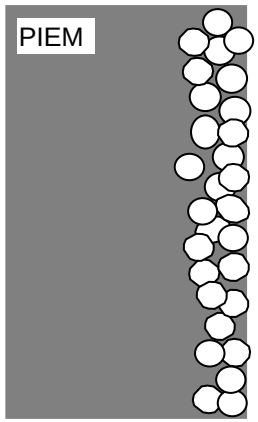
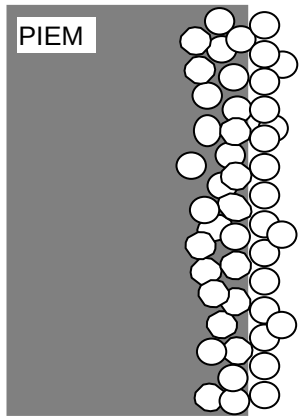
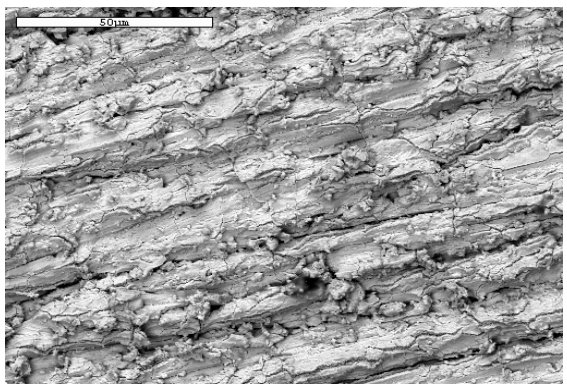
This manufacturing technique incorporates two distinct processes:

1. ***Initial process of oxidizing the PSN ionic polymer with an organometallic salt of a catalyzing metal such as $Pt(NH_3)_4HCl$ in the context of chemical reduction processes.***

2. ***Subsequent reduction to create functionally-graded conductor composite and near boundary porous electrodes.***

Novel UMaine Fuel Cell MEA Manufacturing Process

Chemical treatment causes penetration of metallic nanoparticles into the membrane, while creating surface porosity which extends into the metallized layer.

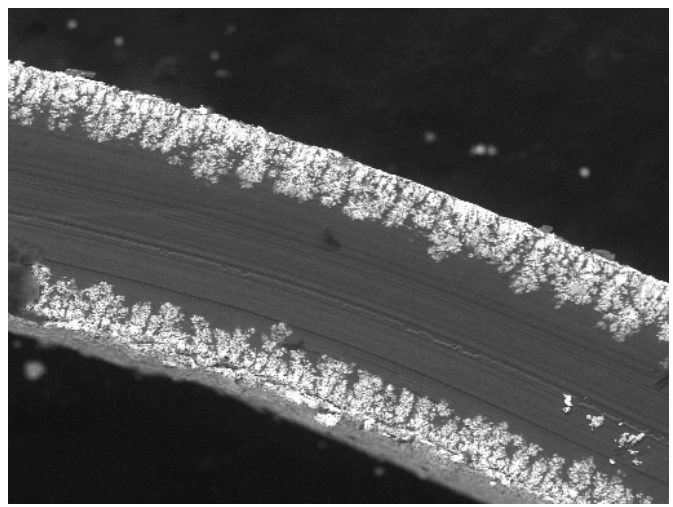
Initial Composite Process (ICP)	Surface Predominant Process (SPP)
	
	

CCM Characteristics after treatment

- **Surface features which increase effective surface area and create gas porous microchannels extending into the membrane.**
- **Imbedded metallic nanostructures which provide triple phase catalytic reaction cites and allow electron percolation out to the gas diffusion layer.**
- **The metallic composition can be varied by depth to create functionally graded layers to improve catalytic activity and electronic conduction.**

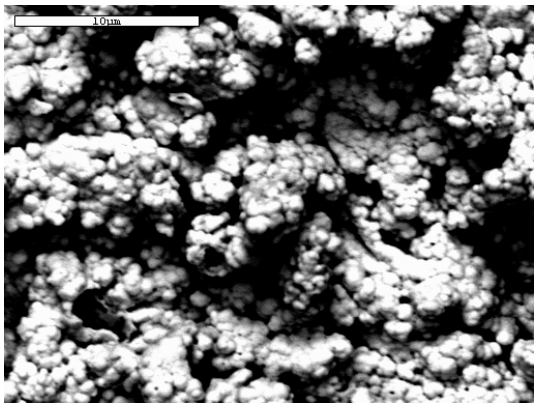
Typical Surface Texture of PSM After Chemical Plating

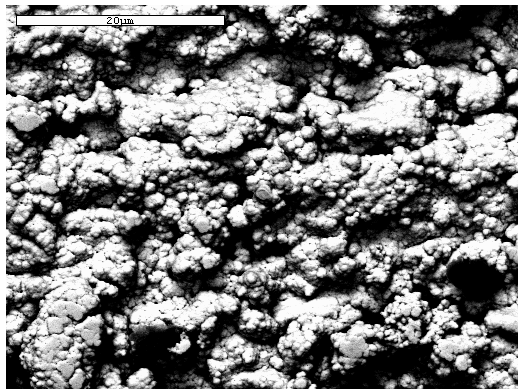
Dendritic/Fractal Penetration of Conductive Phase into PSM

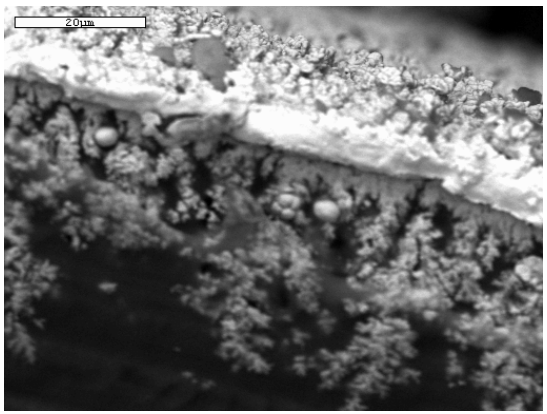


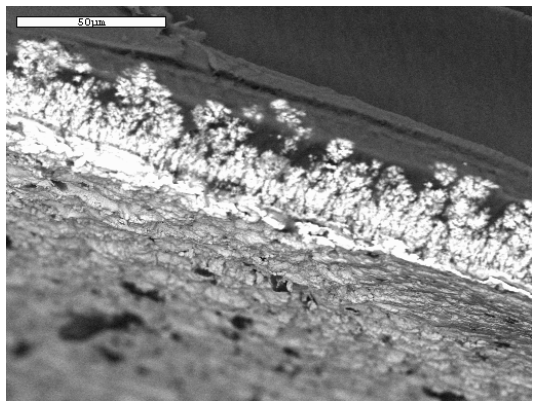
CCM Characteristics after treatment

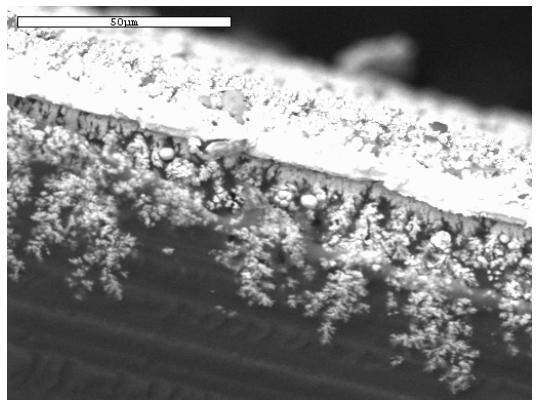
- Typical Near Boundary Porosity of PSM After Chemical Plating



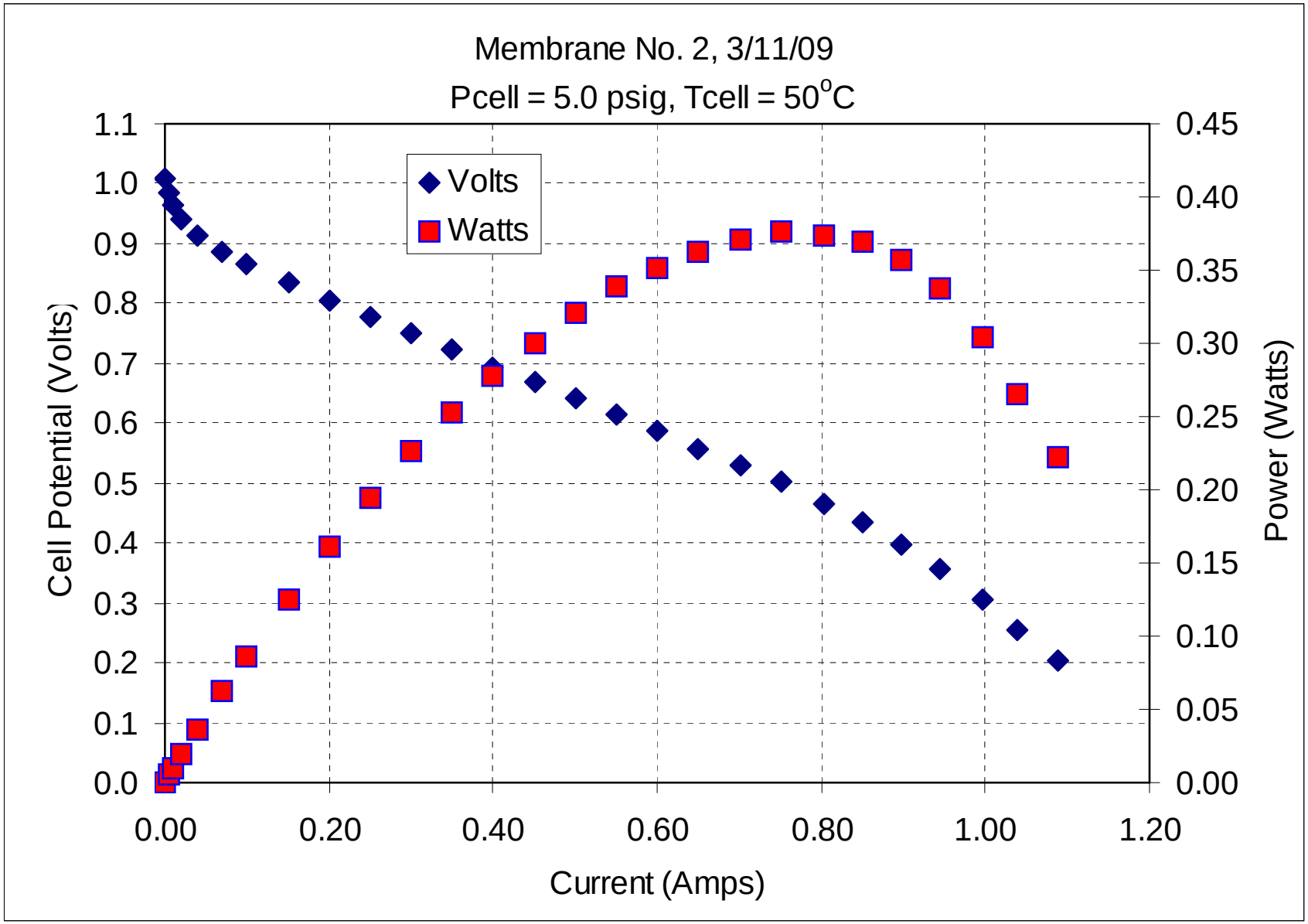


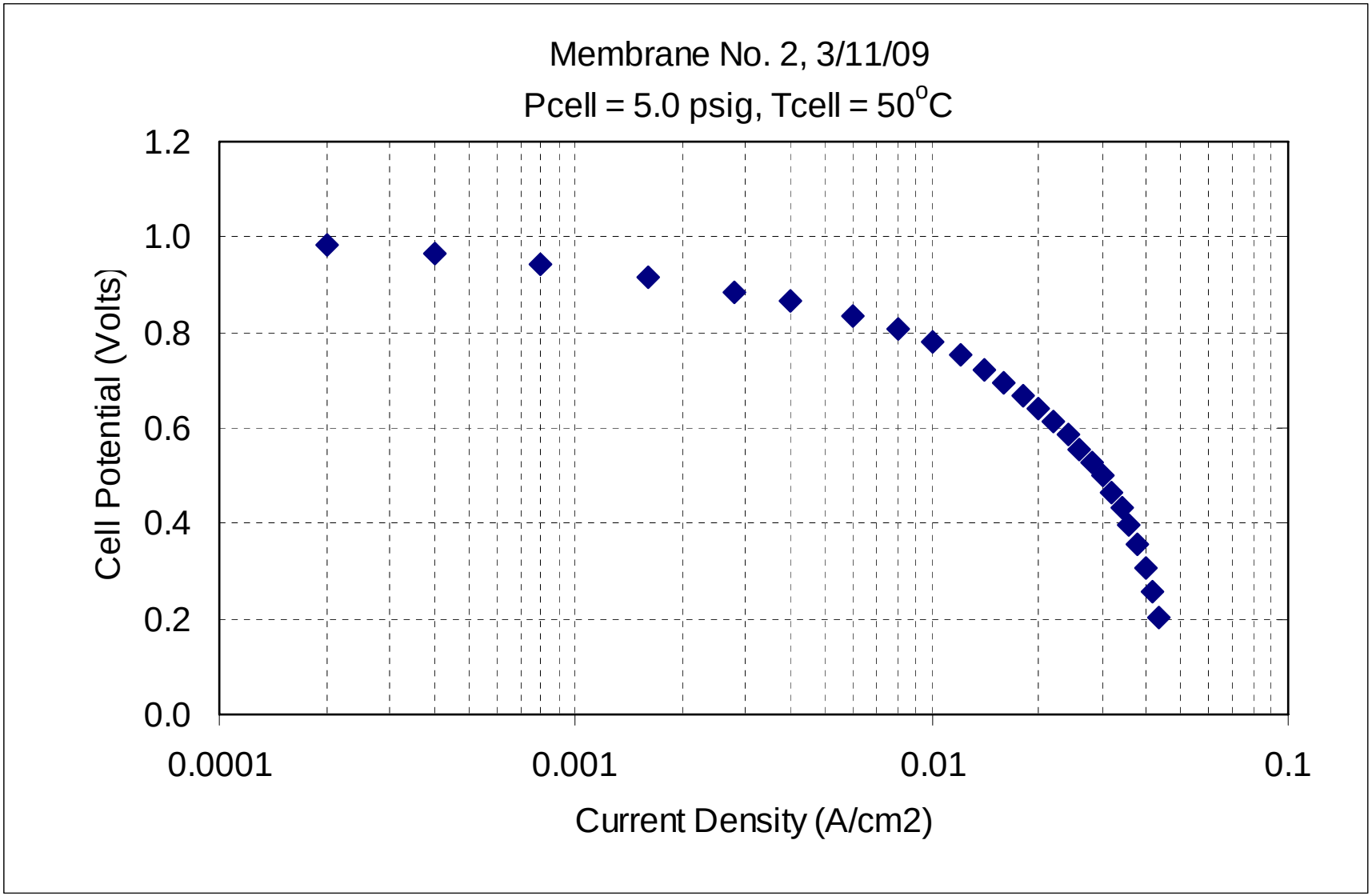


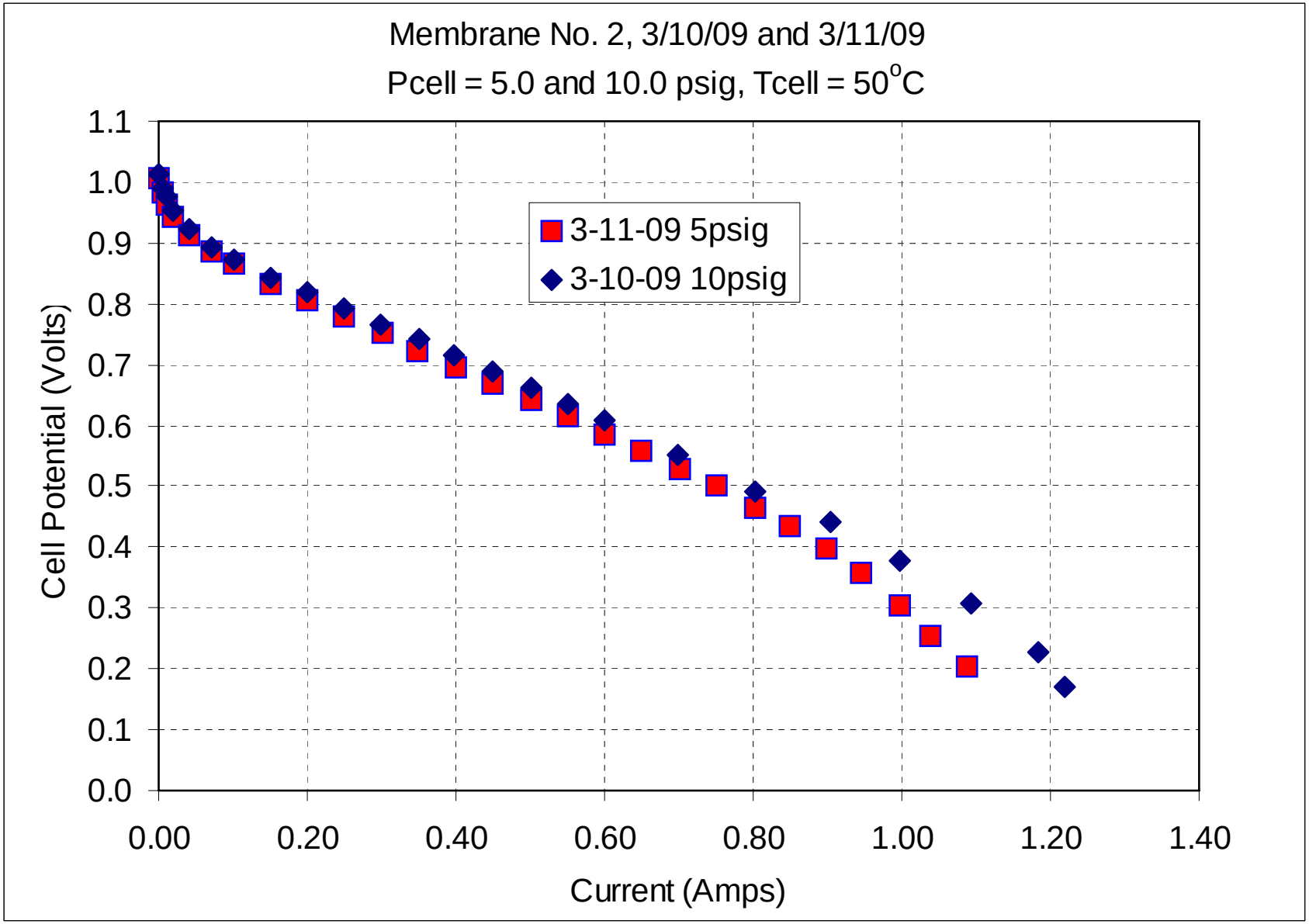


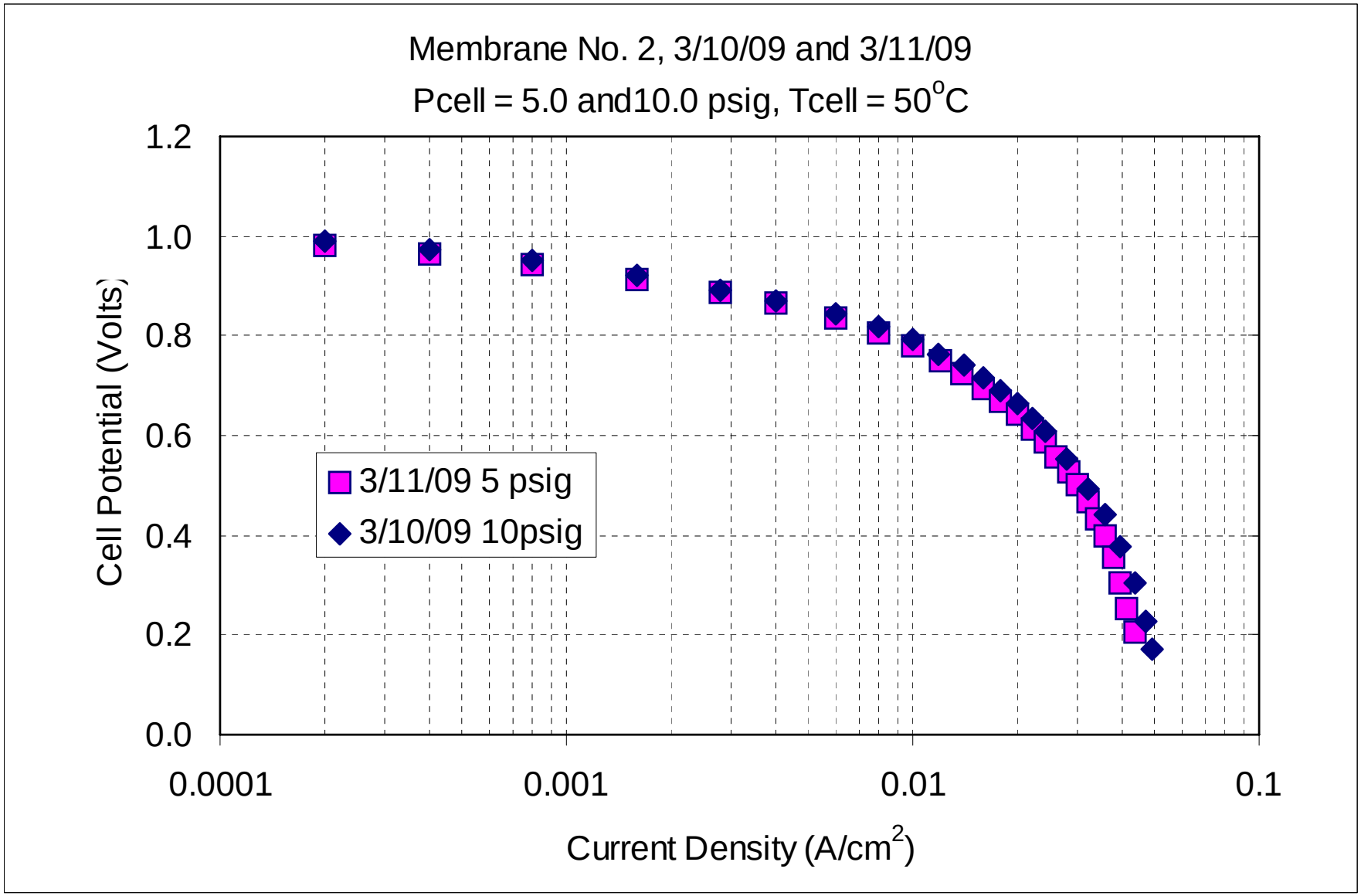


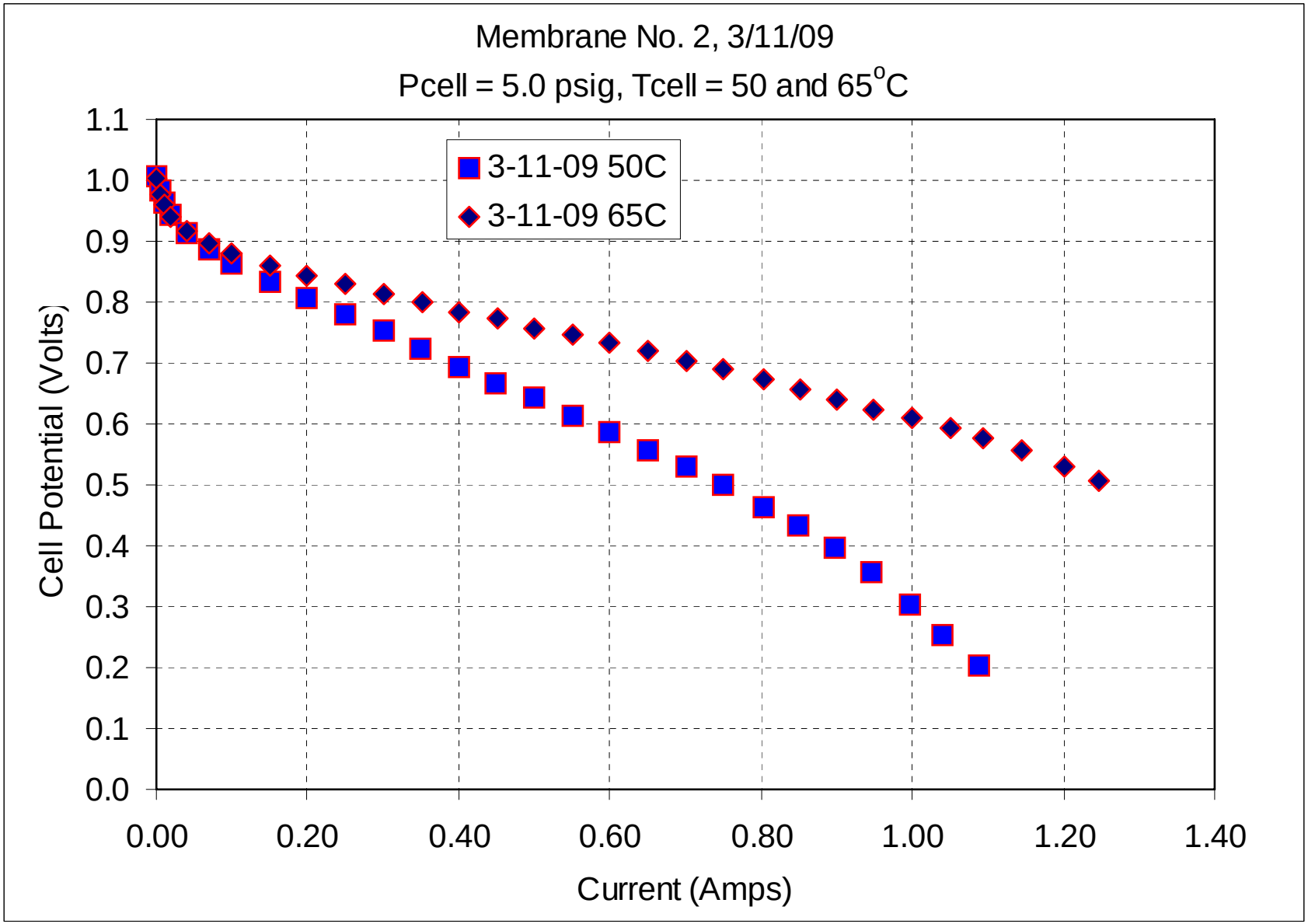
Preliminary Results: Fuel Cell Performance Using CCM

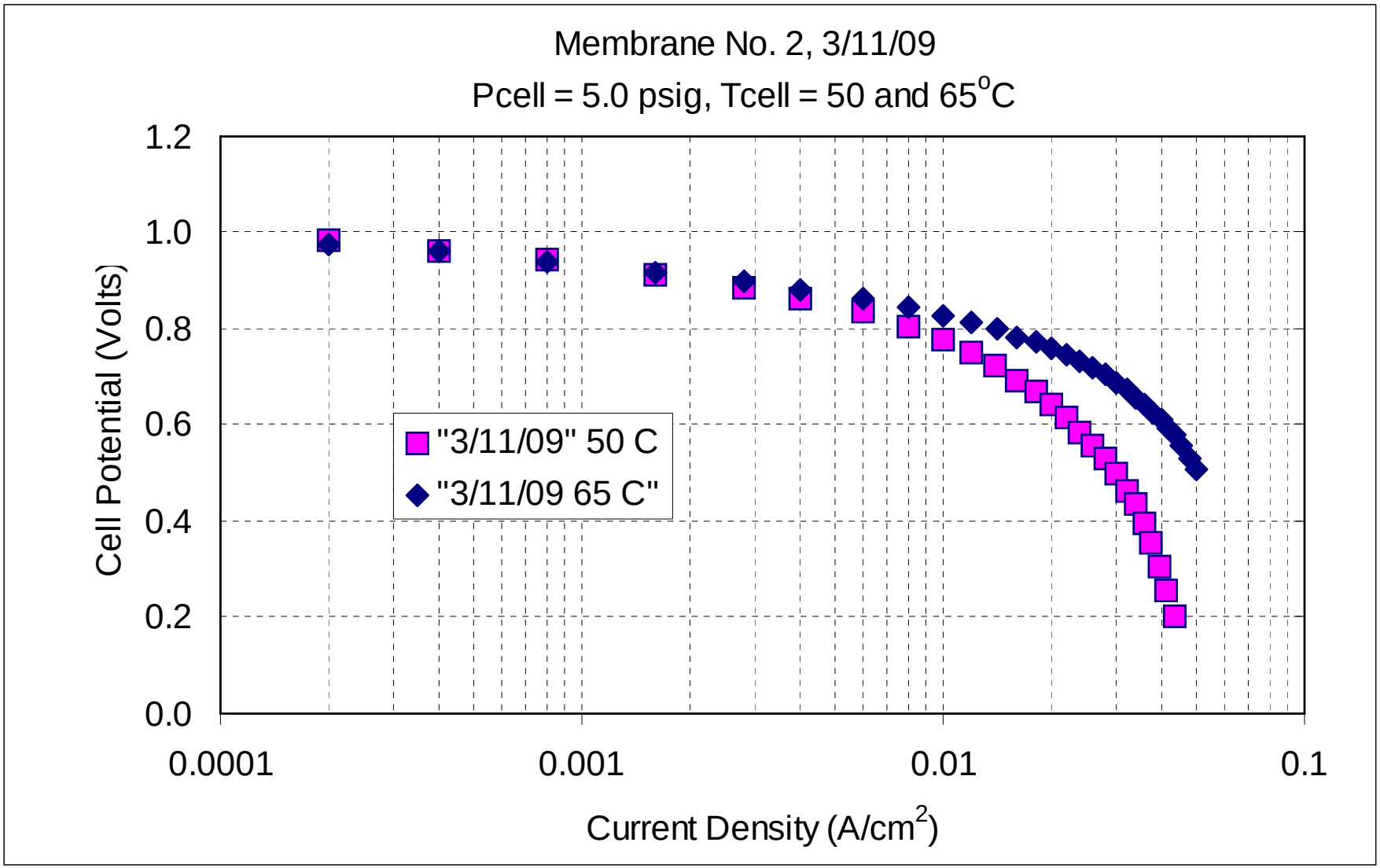



Membrane No. 2, 3/11/09
Pcell = 5.0 psig, Tcell = 50°C
Cell Potential (Volts)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0001
0.001
0.01
0.1
Current Density (A/cm2)


Membrane No. 2, 3/10/09 and 3/11/09
Pcell = 5.0 and 10.0 psig, Tcell = 50°C
Cell Potential (Volts)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Current (Amps)
3-11-09 5psig
3-10-09 10psig


Membrane No. 2, 3/10/09 and 3/11/09
Pcell = 5.0 and10.0 psig, Tcell = 50°C
Cell Potential (Volts)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0001
0.001
0.01
0.1
Current Density (A/cm2)
3/11/09 5 psig
3/10/09 10psig


Membrane No. 2, 3/11/09
Pcell = 5.0 psig, Tcell = 50 and 65°C
3-11-09 50C
3-11-09 65C
Cell Potential (Volts)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Current (Amps)


Membrane No. 2, 3/11/09
Pcell = 5.0 psig, Tcell = 50 and 65°C
Cell Potential (Volts)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0001
0.001
0.01
0.1
Current Density (A/cm2)
"3/11/09" 50 C
"3/11/09 65 C"

Summary of Results

- Current studies show promise for further development and testing
- Additional instrumentation is required to optimize the following parameters:
  - Catalyst loading and composition (anode and cathode)
  - Non-catalyst metallization (anode and cathode)
  - Membrane surface roughness/porosity
  - Membrane thickness
  - Metallization penetration
  - Hot press parameters (pressure, temperature, duration)

Progress, so far . . .

- We have demonstrated how the introduction of nano particles into a polysulphonic membrane can create porous functionally graded layers what act as transport pathways.
- We plan to optimize the properties of these layers by the adjustment of manufacturing process parameters.
- We have demonstrated fuel cell performance using these membranes.
- We have applied for a patent, provisional application is in process.
- We have partners who will work with us on future development and commercialization efforts, leading to prosperity for the people of Maine.

Thank you for your attention!

Questions?