Novel Materials for High Efficiency Direct Methanol Fuel Cells

2010 U.S. DOE HYDROGEN PROGRAM AND VEHICLE TECHNOLOGIES PROGAM ANNUAL MERIT REVIEW AND PEER EVALUATION MEETING

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Project ID# FC063

Overview

Timeline
- Proposed Start: May 1, 2010
- Proposed End: April 30, 2012
- Percent Complete: 0%

Barriers
- Durability
- Cost
- Performance

Funding
- Total Project Funding: $3,501k
  - DOE: $2,634k
  - Contractor: $867k
- Funding Received FY09: $0
- Proposed Funding FY2010: $780k

Organization
- Project Lead
  - Arkema Inc.
- Partners
  - QuantumSphere Inc. (QSI)
  - Illinois Institute of Technology (IIT)

Organization

Project Lead

PEM Development and testing

MEA diagnostics and durability

Catalyst development

MEA production and testing

Dr. Vijay Ramani's Research Group

Cutting-edge characterization of MEAs and development of composite membranes

Relevance

- Project Objectives
  - Develop ultra-thin membranes having extremely low methanol crossover, high conductivity, durability, and low cost
  - Develop cathode catalysts that can operate with considerably reduced platinum loading and improved methanol tolerance
  - Produce an MEA combining these two innovations and having a performance of at least 150 mW/cm^2 at 0.4 V and a cost of less than $0.80/W for the membrane and cathode catalyst
- Targets

Characteristic	Industry Benchmark	Project Target
Methanol Permeability	1-3·10^{-6} cm^2/s	5·10^{-8} cm^2/s
Areal resistance (Ωcm^2), 70 ºC	0.120 (Nafion® 117)	0.080 (2 mil thick film)
Catalyst Mass Activity (RDE) †	22.5 mW/mg Pt	> 100 mW/mg Pt
MEA Cathode Catalyst Loading	4 mg/cm^2	1.5 mg/cm^2
MEA I-V Cell Characteristic	90 mW/cm^2 @ 0.4 V	150 mW/cm^2 @ 0.4 V
MEA Lifetime	> 3,000 h	5,000 h

† conditions at 0.45 V & 70 ºC.

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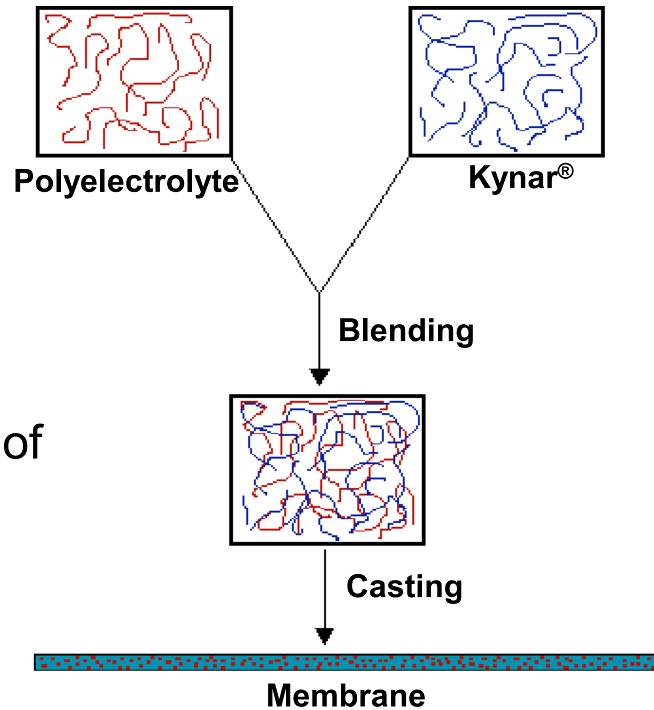
Approach: Membrane Development

- Polymer blend
  - Decouples conductivity from other requirements
  - Kynar® PVDF
    - Chemical and electrochemical stability
    - Mechanical strength
    - **Excellent barrier against methanol**
  - Polyelectrolyte
    - H^+ conduction and water uptake



- Robust blending process
  - PVDF can be compatibilized with a large range of polyelectrolytes
    - Latest generation taken to a pilot scale is M43, which is a baseline for this project
  - Morphology and physical property control
    - Phase separation on a scale of 10-100s of nm
- Potential lower cost approach compared to PFSAs
  - Kynar® PVDF - commercial product
  - Polyelectrolyte – hydrocarbon based

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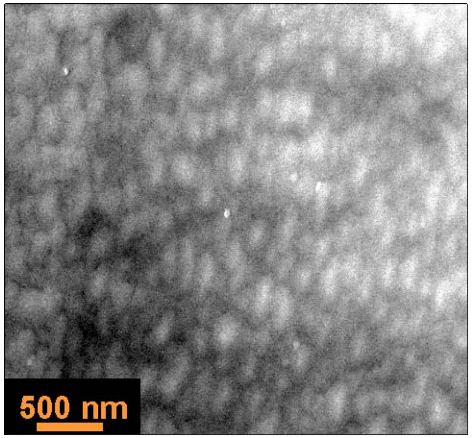
Approach: Membrane Development

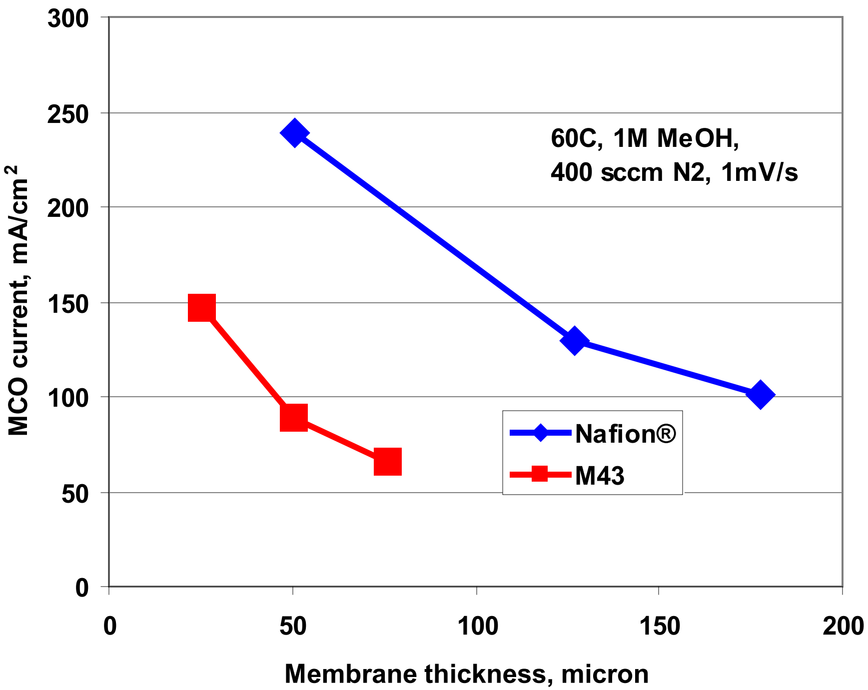
The key to the desired properties resides in careful control of composition, architecture, and morphology of the membrane components.

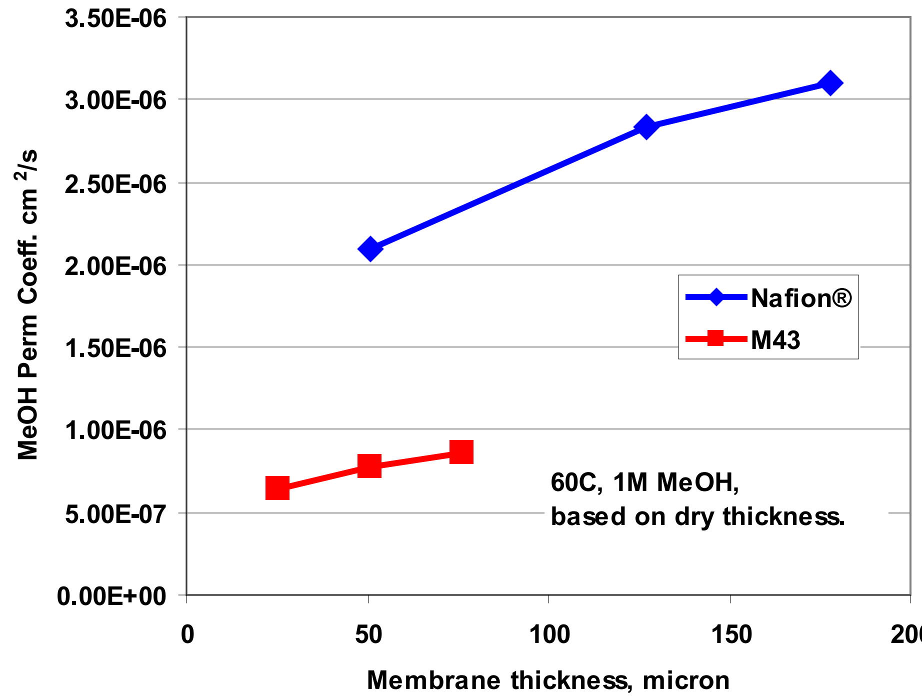
- Phase separation on the order of 10s of nm
  - Polymer architecture, composition, and type of compatibilizer
- PVDF matrix optimization
  - Degree of crystallinity (barrier against methanol permeation)
- Tailor the polyelectrolyte composition to minimize methanol permeation in this phase
  - Different acid and ion-containing groups
- Acidic inorganic additives
  - Reduce swelling in the membrane while maintaining conductivity



Preliminary Data: M43 Methanol Crossover

Conductivity: 140 mS/cm (1 mil) @ 70 °C (in DI Water)





- M43 was developed for hydrogen applications
- Without any development, M43 is already a good methanol barrier

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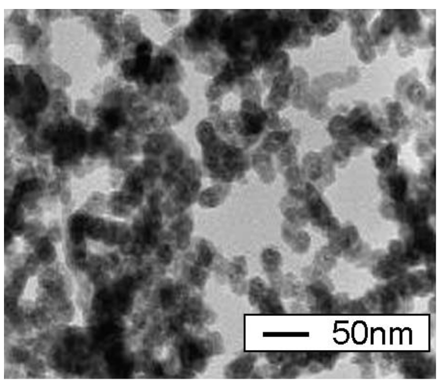
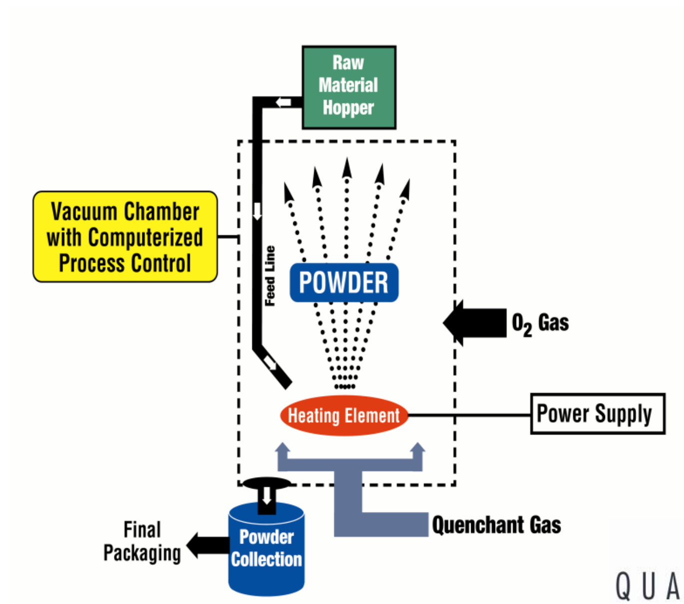
Approach: Methanol Tolerant Cathode Catalyst

- Pd based alloy nanocatalyst mixed with Pt/C
  - Improved mass activity by suppressing methanol oxidation
  - Significant cost reduction by lower Pt content
  - Particle size = 3-10nm
- Pd-based nanocatalysts prepared using gas phase condensation
  - Control of particle size, alloy ratio, and core-shell structure
- Catalysts screening by rotating disk voltammetry, in presence and absence of methanol





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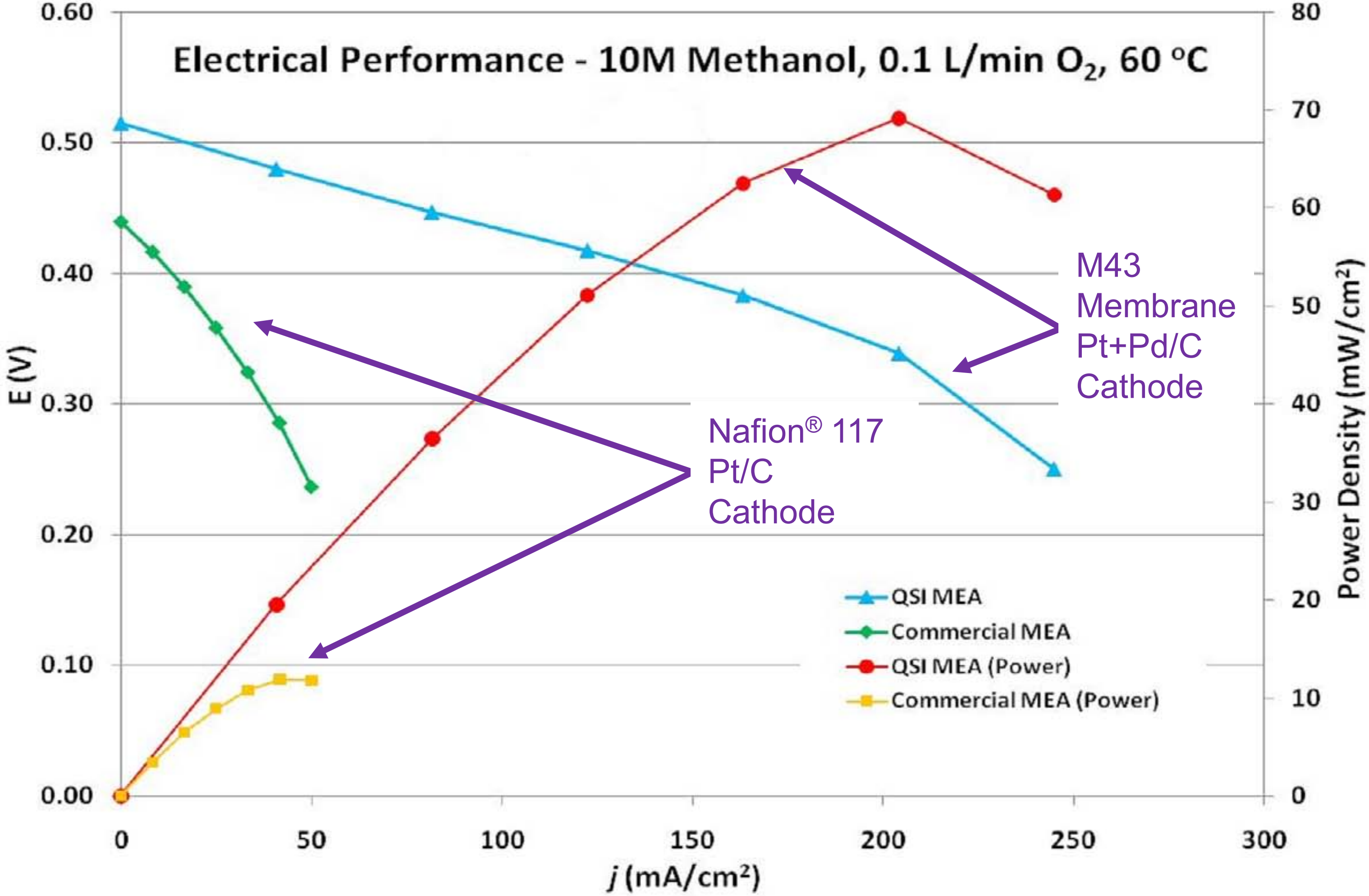
Approach: MEA Testing

- MEA development and characterization (QSI)
  - Optimize catalyst layer composition/construction
    - Ionomer content
    - GDE vs CCM
- MEA diagnostics (IIT, Arkema, QSI)
  - Single cell polarization with 1-10M methanol/air
  - Anode and cathode half-cell polarization measurement using reference electrode
  - Linear sweep voltammetry and CO_2 sensor to monitor methanol crossover
  - Cyclic voltammetry for catalyst active area
  - In-situ AC impedance for MEA resistance and transport resistances.
- MEA durability testing (Arkema, IIT, QSI)
  - Constant current mode, monitoring voltage loss over time.

Preliminary Results: MEA Performance

Arkema M43 Low Crossover Membrane, QSI-Nano® Methanol Tolerant Cathode



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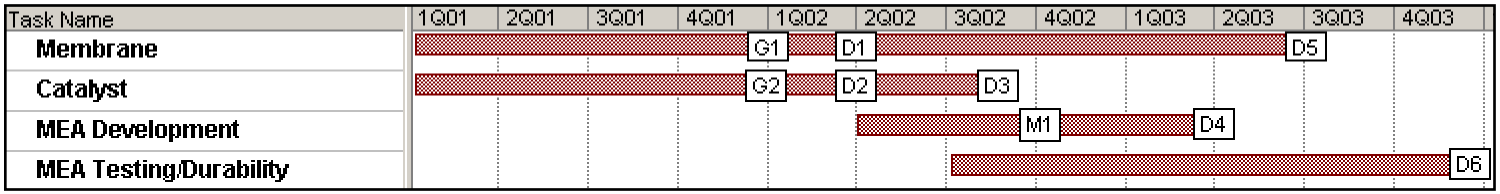
Approach/Milestones

Project start: May 2010



G1:	Membrane w/ areal resistance ≤ 0.080 Ωcm^2 and a permeation coefficient ≤ $1 \cdot 10^{-7}$ cm^2/s
G2:	Catalyst w/mass activity > 70 mW/mg
D1:	Membrane scale-up for MEA development
D2:	Catalyst scale-up for MEA development
D3:	MEA w/ 50% Pt reduction and mass activity > 100 mW/mg
M1:	MEA w/ ohmic resistance < 0.12 Ωcm^2 (determined from impedance)
D4:	MEA performance of 150 mW/cm^2 @ 0.4 V (60 C, 1 M methanol)
D5:	Membrane w/ areal resistance ≤ 0.080 Ωcm^2 and a permeation coefficient ≤ $5 \cdot 10^{-8}$ cm^2/s
D6:	MEA passes 5,000 h durability testing

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Summary

- The primary project objective is to develop new materials for DMFC that be the basis for a device to meet the DOE's technical targets for consumer electronics.
  - A multi-pronged approach will be taken to address the reduction of methanol cross-over through the membrane (morphology, membrane composition, polyelectrolyte chemistry, and additives).
  - Pd based nanocatalysts for the cathode will be developed that can operate with considerably reduced platinum loading and improved methanol tolerance.
- Preliminary data on a MEA containing Arkema's M43 membrane and QSI's methanol tolerant cathode catalyst shows good performance in 10M methanol at 60°C.
- Proposed project start in May 2010.