Novel Materials for High Efficiency Direct Methanol Fuel Cells

2009 Fuel Cell Projects Kickoff Meeting

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Announcement Number:
DE-PS36-08GO98009

Application Number:
Arkema Inc. (1281)

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.

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

Technical Barriers and Targets

- Barriers Addressed in DOE Fuel Cell Technical Plan:
  - Durability
  - Cost
  - Performance

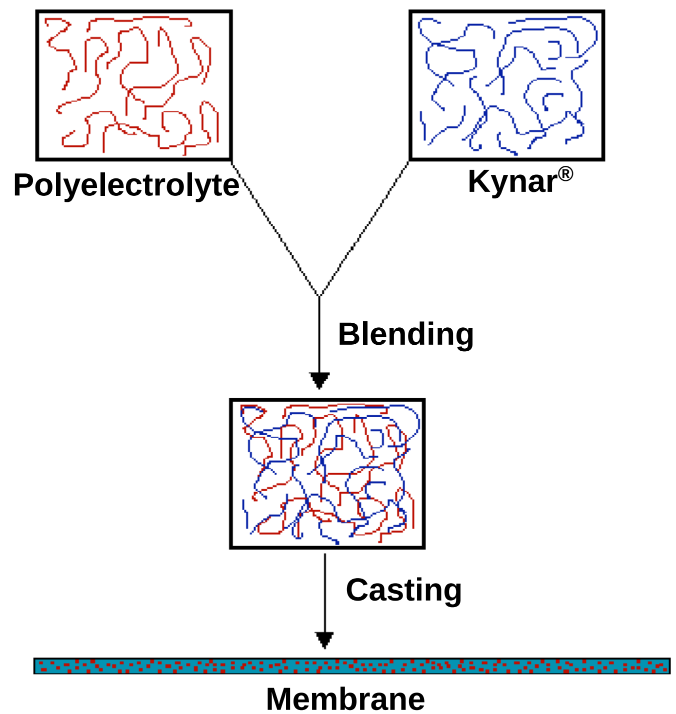
- Targets

Characteristic	Industry Benchmark	Project Target
Methanol Permeability	$1\text{-}3{\cdot}10^{-6}$ cm^2/s	$5{\cdot}10^{-8}$ cm^2/s
Areal resistance (Ωcm^2), 70 °C	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 °C

Technical 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



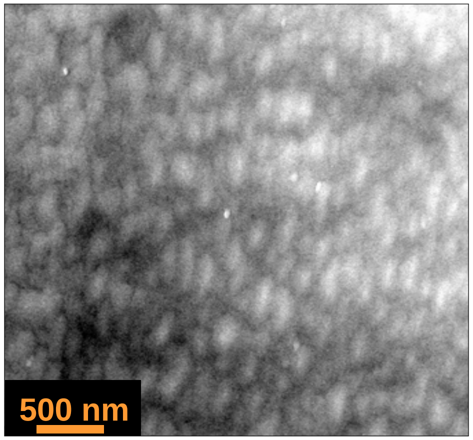
- Robust blending process
  - PVDF can be compatibilized with a large range of polyelectrolytes
  - Morphology and physical property control
  - Phase separation on a scale of 10-100s of nm
- Lower cost approach compared to PFSA
  - Kynar® PVDF - commercial product
  - Polyelectrolyte – hydrocarbon based

ARKEMA

Technical 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
- 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



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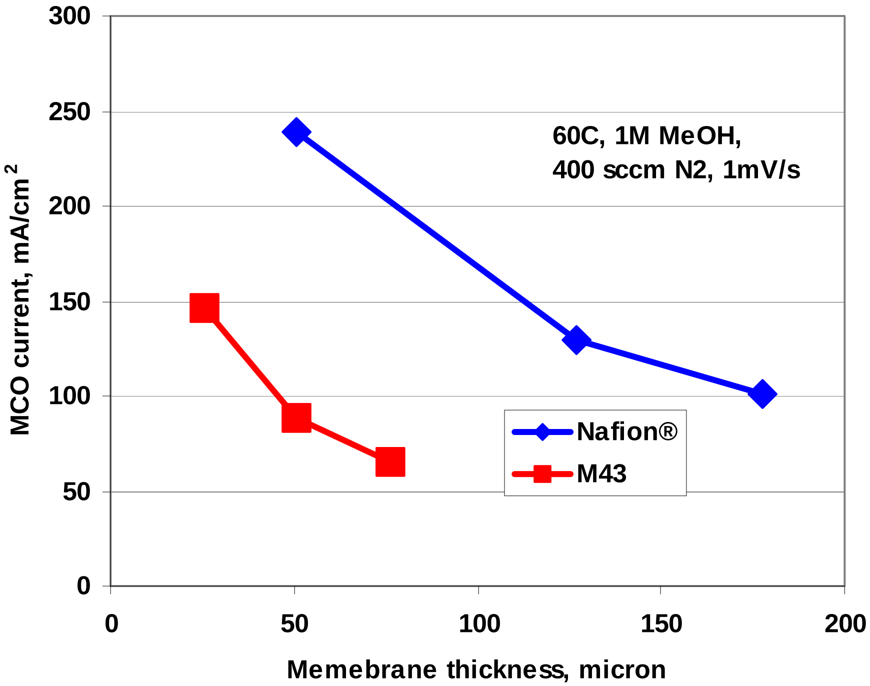
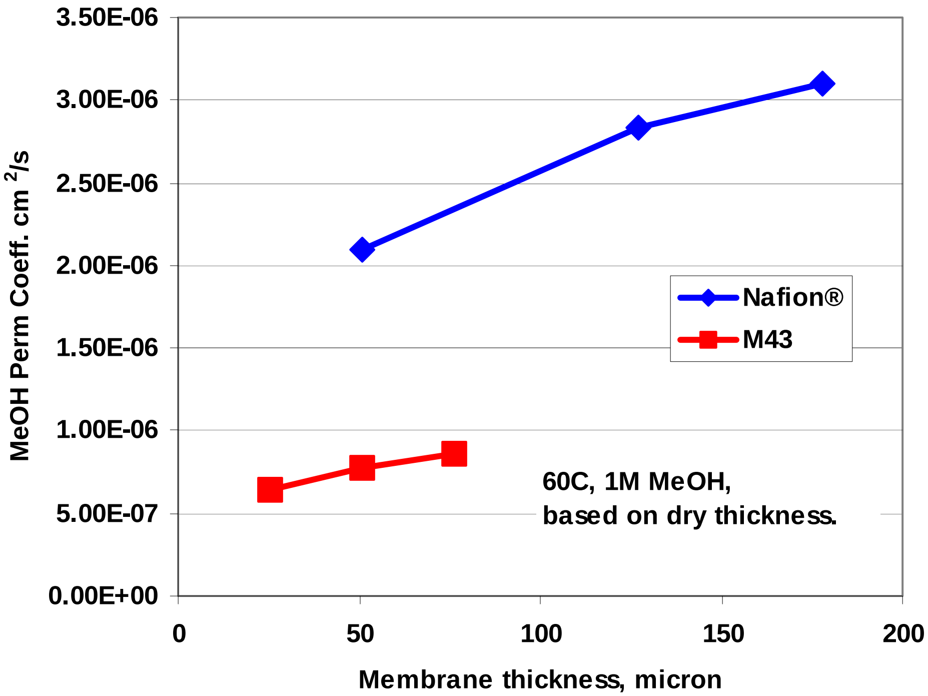
Preliminary Data: M43 Methanol Crossover

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

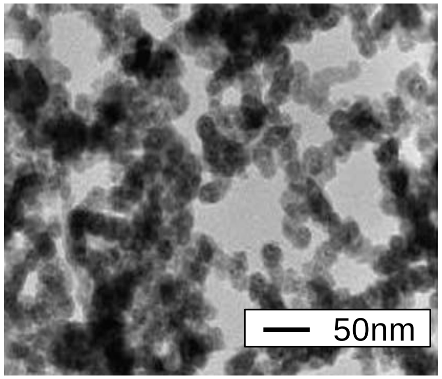


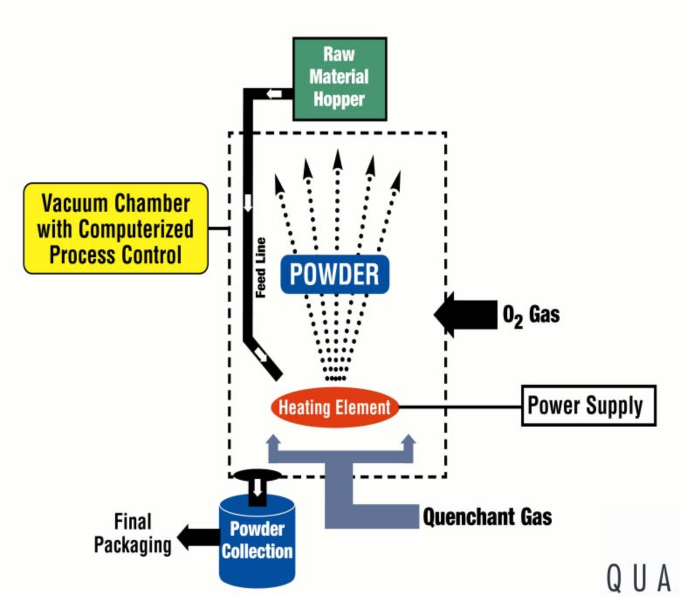


- M43 was developed for hydrogen applications
- Without any optimization, M43 is already a good methanol barrier

Technical 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



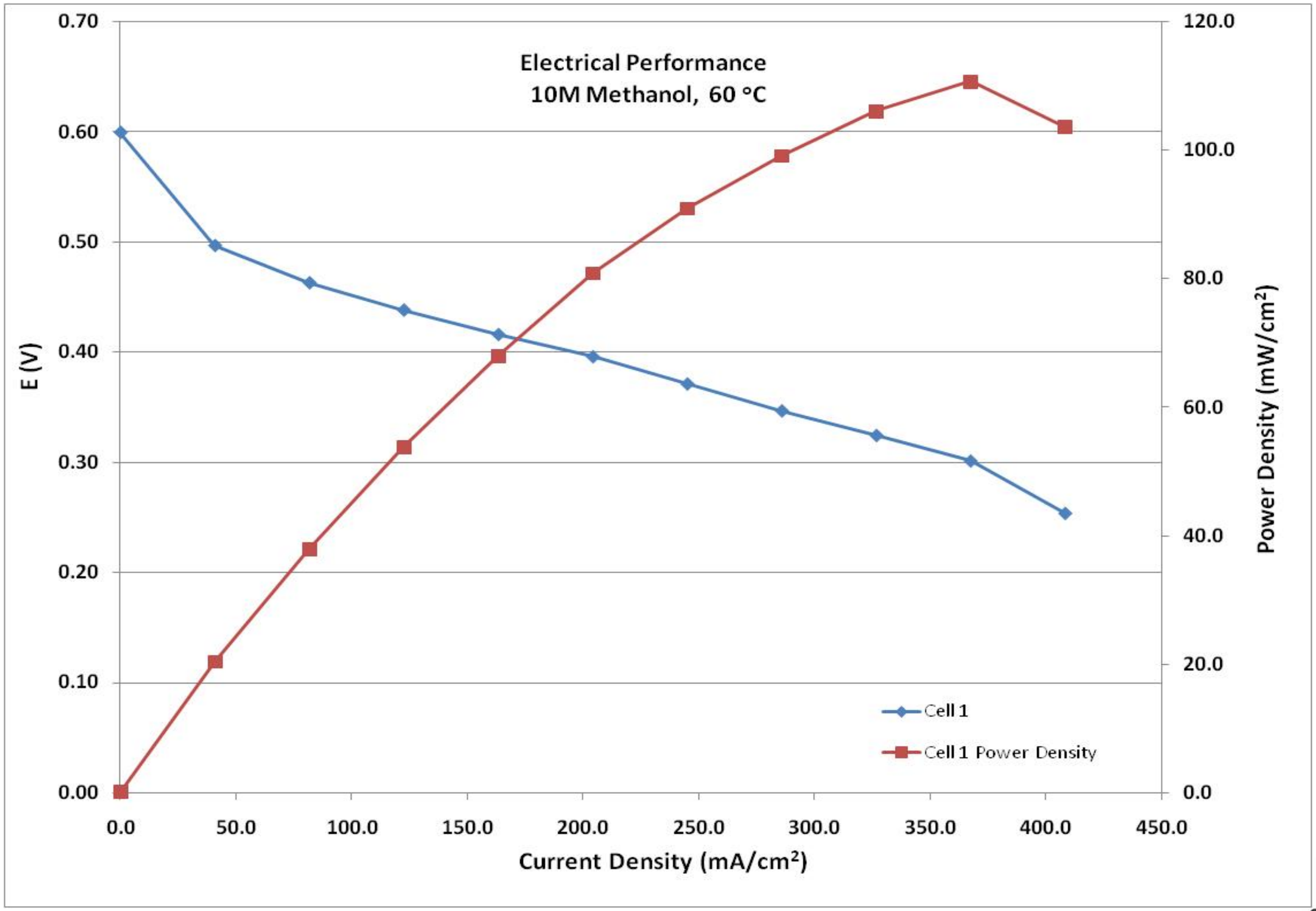


Technical Approach: MEA Testing

- 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.

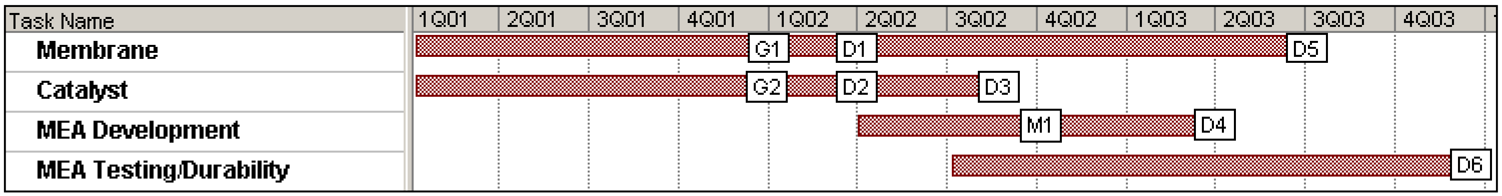
Preliminary Results: MEA Performance

Arkema M43 Low Crossover Membrane, QSI-Nano® Methanol Tolerant Cathode Catalyst (10M Methanol, 60 °C)



Proposed Project Timeline

Project start: January, 2010



G1:	Membrane w/ areal resistance $\leq$ 0.080 Ωcm^2 and a diffusion coefficient $\leq 1{\cdot}10^{-7}$ 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 $\leq$ 0.080 Ωcm^2 and a diffusion coefficient $\leq 5{\cdot}10^{-8}$ cm^2/s
D6:	MEA passes 5,000 h durability testing

Proposed Project Budget

- Assuming start-up date Jan. 2010
- Total Project Cost: $3,501,264
  - Non-federal: $867,530
  - Federal: $2,633,734

	FY2010	FY2011	FY2012	FY2013
Non-federal	$232,667	$281,129	$282,523	$71,211
Federal	$706,355	$853,478	$857,713	$216,188
Total project	$939,022	$1,134,607	$1,140,236	$287,399