# High Temperature Membrane With Humidification-Independent Cluster Structure

For
DOE Hydrogen Program Review Meeting

By
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FuelCell Energy, Inc.

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ultra-clean power delivered to customers around the world

Project ID #
FCP10



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# Overview

## Timeline

- Project start date: May 2006
- Project end date: May 2011
- Percent complete: 0%

## Budget

- Total project funding
  - DOE share: $1500k
  - Contractor share: $600k

## Barriers

- Low Proton Conductivity at 25-50% Relative Humidity and 120$^{o}$C

## Targets

- Membrane Conductivity:
  - At 120$^{o}$C: 0.1 S/cm
  - At Room Temp.: 0.07 S/cm
  - At –20$^{o}$C: 0.01 S/cm
- Cell Area Specific Resistance: 0.02 $\Omega cm^2$



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# Objectives

- Develop humidity-independent, thermally stable, low-EW composite membranes with controlled ion-cluster morphology, to provide **high proton-conductivity** at 120°C (Overall Goal: Meet DOE 2010 targets)
- Improve mechanical properties to significantly increase the **durability** and reduce the gas cross-over
- Expand the operating range to **sub-freezing** temperatures



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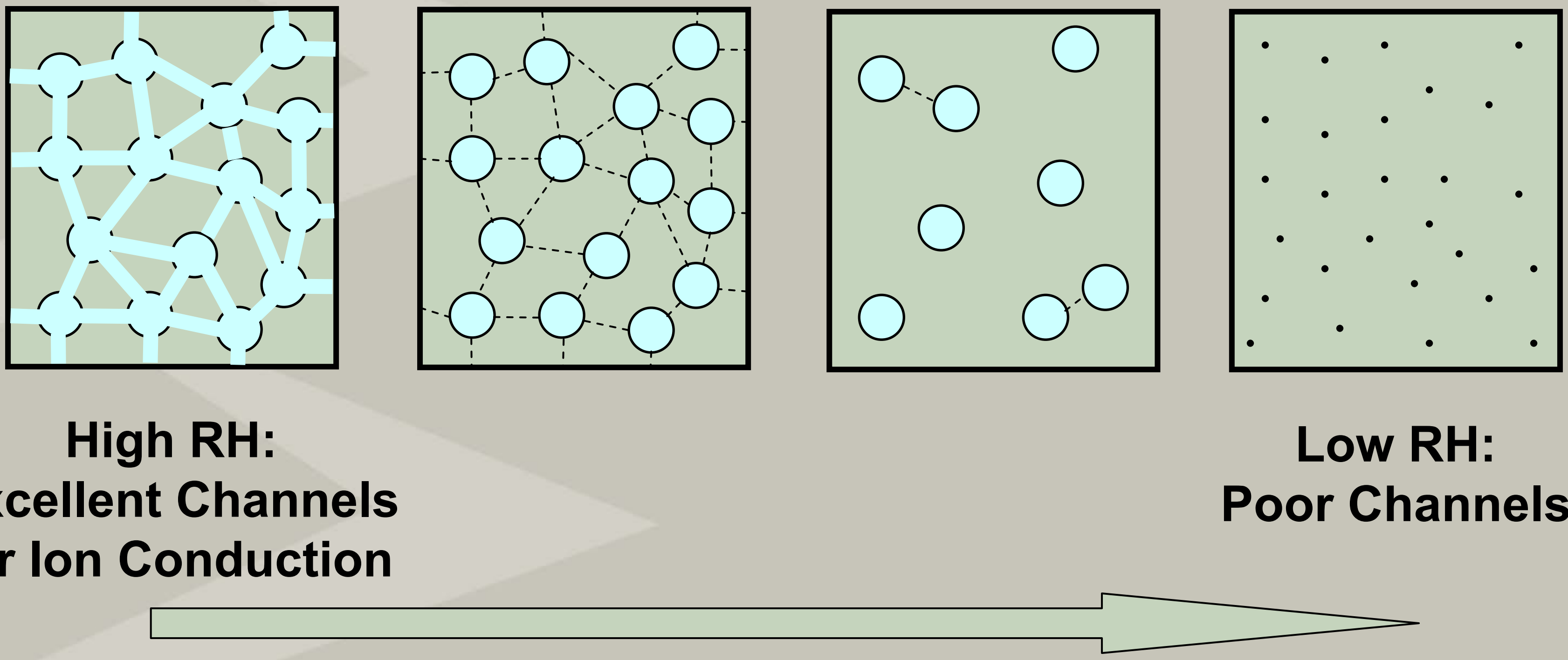
# Challenge: Low RH Operation



**High RH:**
**Excellent Channels for Ion Conduction**

**Low RH:**
**Poor Channels**

Ensure ion conducting path through the membrane even at low Relative Humidity (RH) conditions

MO3135
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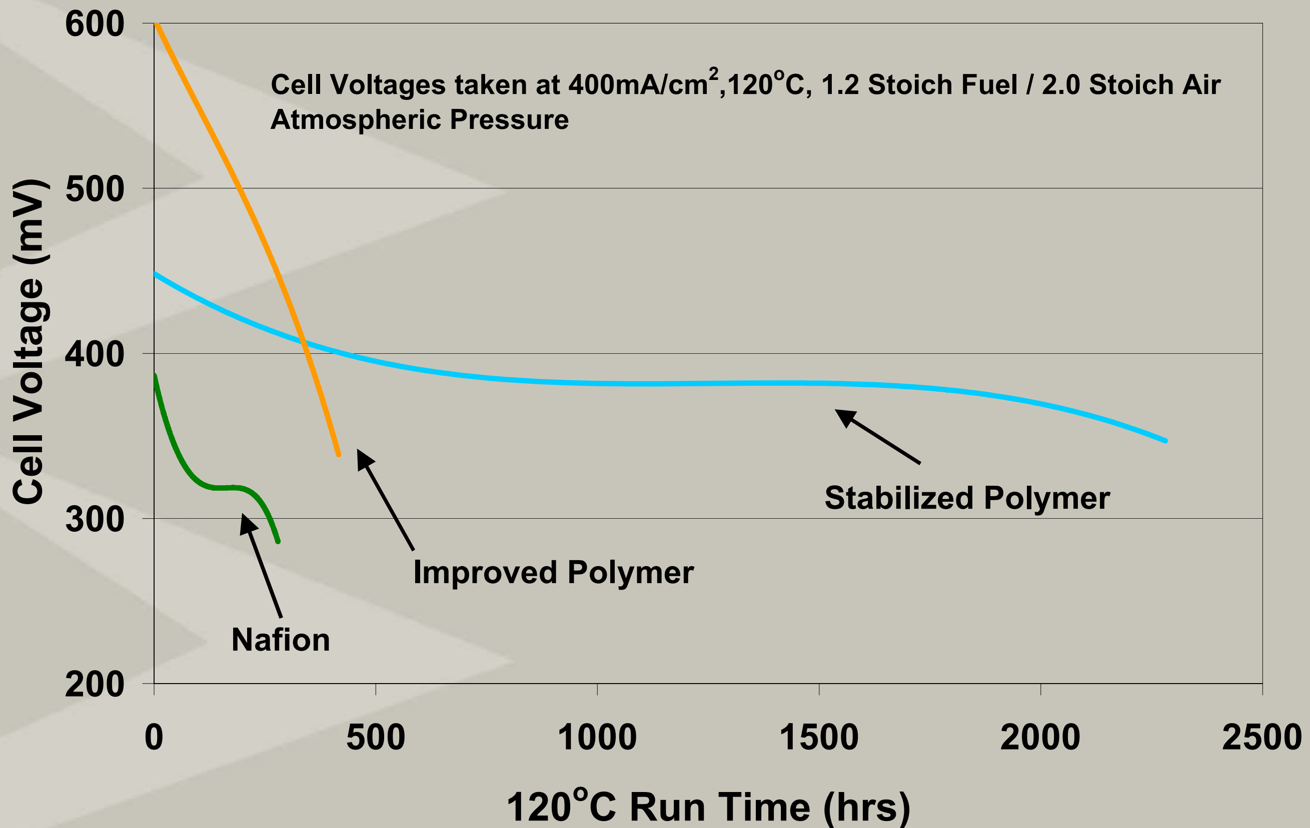
# FCE's Development Status




The improved/stabilized polymers show significant increase in cell life at 120°C, ~35% RH

# Approach for the Composite Membrane

| Target Parameter | DOE Target (2010) | Approach |
| --- | --- | --- |
| Conductivity at : 120°C | 0.1 S/cm | Lower EW |
| : Room temp. | 0.07 S/cm | Higher number of functional groups |
| : -20°C | 0.01 S/cm | Stabilized nano-additives |
| Inlet water vapor partial pressure | 1.5 kPa | Immobilized cluster structure |
| Hydrogen and oxygen cross-over at 1 atm | 2 $mA/cm^2$ | Stronger membrane structure; functionalized additives |
| Area specific resistance | 0.02 $\Omega cm^2$ | Improve bonding capability for MEA |
| Cost | <40 $\$/m^2$ | Simplify polymer processing |
| Durability:<br>- with cycling at >80°C<br>- with cycling at ≤80°C | <br>>2000 hours<br>>5000 hours | Thermo-mechanically compliant bonds, higher glass transition temperature |
| Survivability | -40°C | Stabilized cluster structure design |

# Future Work: Composite Membrane Dev.

- Conduct project Kick-off Meeting
- Develop Baseline and Advanced polymer systems
  - Polymer composition
  - Polymer processing options
- Develop proton-conducting additives:
  - Catalog promising additives and their properties (structure, composition, proton conductivity, water adsorption isotherm, particle size, ease of production and cost)
  - Evaluate concentration ratios (additive to polymer)
  - Evaluate compatibility with ionomer and solvents used for membrane preparation
  - Collect experimental data to develop computer model for conductivity estimates in a composite structure

# Future Work: Membrane Characterization

- Measure EW, swelling and water uptake at various temperatures and relative humidities
- Evaluate membrane mechanical properties as a function of temperature and relative humidity: tensile modulus, tensile strength, elongation at break, creep, crack formation, crack-spacing-concentration, coefficient of thermal expansion, etc.
- Perform membrane stability tests: Fenton's test for accelerated membrane degradation, stability tests in membrane conductivity cell

# Key Milestones for 2006-2007

- Select Baseline membrane material and processing technique (6 months)
- Update list of promising additives for high temperature and low relative humidity (HT-LRH) membrane (12 months)
- Complete characterization of promising membrane options (18 months)

# Summary

- A composite membrane incorporating proton conducting additives in an advanced co-polymer system has a potential to meet the DOE requirements
- Candidate materials and processing options for high mechanical strength, durability and low cost have been identified for initial evaluation
- Synergistic exploitation of FCE's experience in PAFC, MCFC and SOFC is planned