



# 2006 DOE Hydrogen Program Center for Intelligent Fuel Cell Materials Design Phase 1

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Project ID # FCP-1



# Overview

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## Timeline

- Project start: **6/1/06**
- Project end: **5/31/07**
- Percent complete: **0%**

## Budget

- Total project funding
  - **DOE: \$1,485,000**
  - **Contractor: \$624,144**
- Funding received in FY05: **\$0**
- Funding for FY06: **\$2,109,144**



# Overview

## Technical Barriers

- O. Stack Material  
Manufacturing Cost
- P. Durability
- R. Thermal and Water  
Management
- **Membrane Mechanical  
Stability**

## Partners

- **Polymer Development**  
Michigan Molecular Institute  
Dr. Claire Hartmann-Thompson
- **Membrane / Material Testing**  
Case Western Reserve Univ.  
Dr. Peter Pintauro
- **Membrane Casting Processes**  
Chemsultants International  
Dr. Pasco Santurri



# Objectives

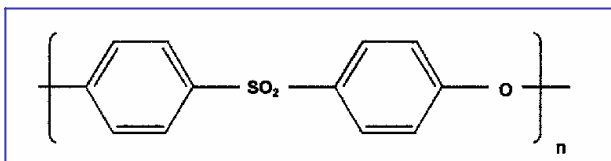
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- **Identify novel polymer architectures**
  - ✓ improved mechanical stability vs. Nafion<sup>®</sup> 117
  - ✓ improved ionic conductivity
  - ✓ > 120<sup>o</sup> C and < 50% RH operationally capable
- **Identify new solution casting methodologies for thin, roll-to-roll membrane formation**
  - ✓ thin, defect-free single layer membranes ( $\pm$  1.0 mil)
  - ✓ discrete, multi-layer membranes (5-20 micron individual layers)
  - ✓ reduction in stack component cost (PEM and MEA)

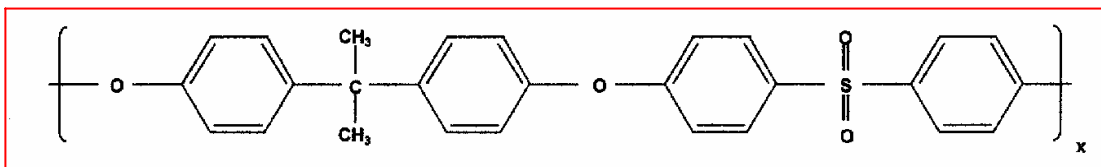
# Polymer Approach

- Evaluate base high T polymers as membrane candidates

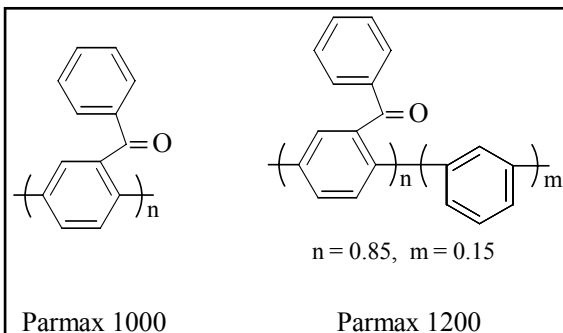
polyethersulfone:



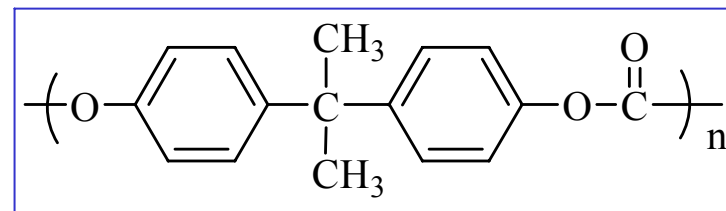
polysulfone:



Parmax poly p-phenylene:



polycarbonate:





# Polymer Approach

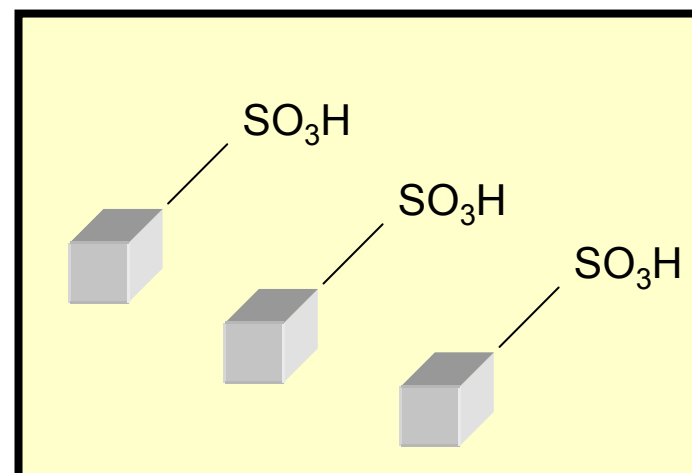
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- **Identify modifications to achieve T & RH capability**
  - ✓ polymer architecture
- **Develop nano-particle functional acid additives**
  - ✓ chemically robust nano-particles
  - ✓ phosphonic and / or sulfonic acid groups

# Polymer Approach

## PEM with Nano-Additives

- ✓ Improved proton conduction
- ✓ Improved mechanical properties  
& higher operating temperatures
- ✓ Lower gas / fuel permeability
- ✓ Improved dimensional stability





# Polymer Approach

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- **Synthesize novel additives and optimize morphology**
  - ✓ base solubility parameters
  - ✓ polymer matrix dispersibility

**Polymer Casting Phase**





# Membrane Casting Approach

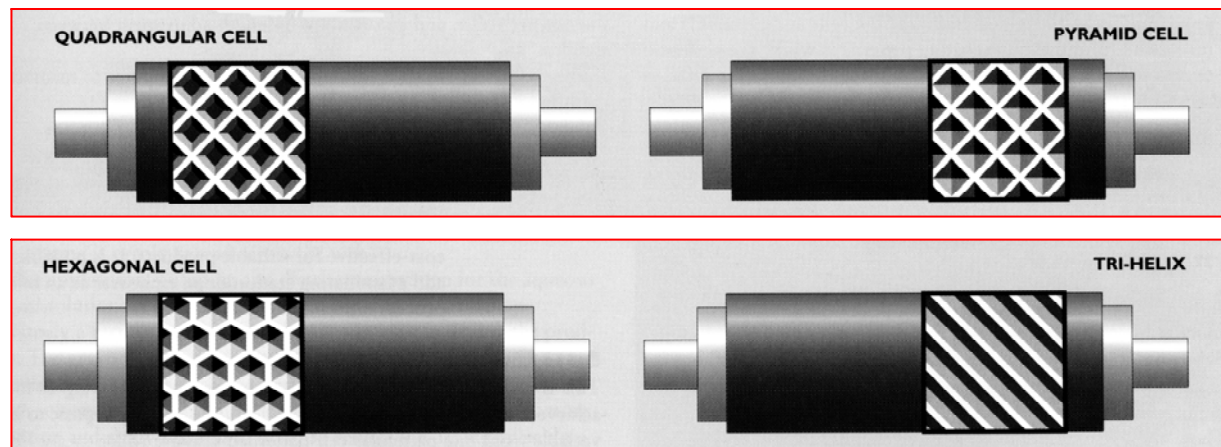
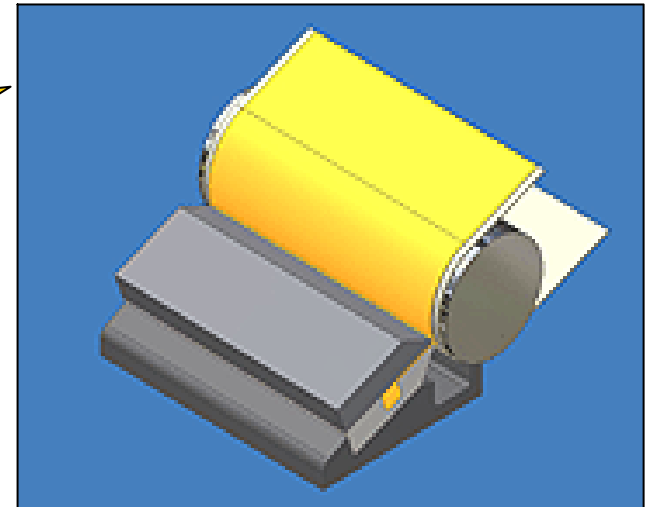
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- **Evaluate potential casting sheet carriers**
  - ✓ PET, polycarbonate, others with suitable release characteristics
- **Develop rheology / solubility parameters**
  - ✓ solution casting of candidate polymers @ target calipers of
    - ~1.0 mil single layer membranes
    - 5 – 20 micron thick layers for multi-layer membranes
- **Evaluate potential solution casting methodologies**
  - ✓ micro-gravure, slot die, other ?
- **Develop drying / curing / annealing parameters**
  - ✓ convection, convection + RF boost

# Membrane Casting Approach

## Single Layer Membrane (MICRO-GRAVURE)

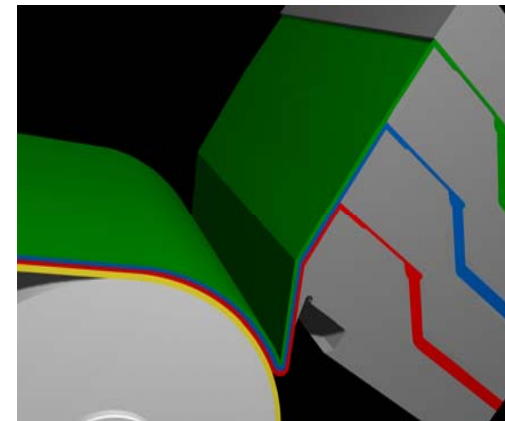
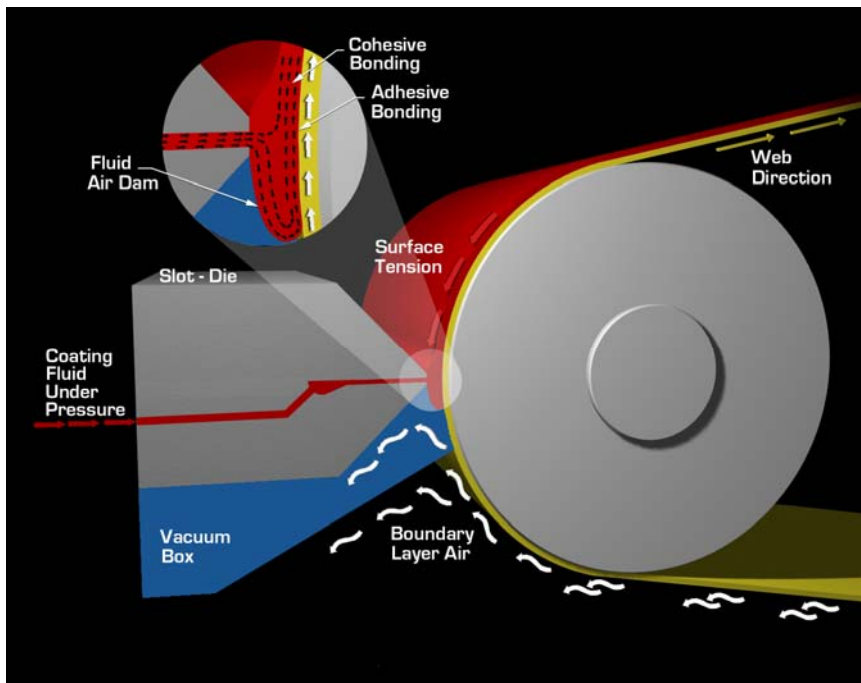
Key Challenges: BCM distribution  
rheology / solubility  
casting continuity



# Membrane Casting Approach

## Multi-Layer Membrane (SLOT DIE)

Key Challenge: interfacial adhesion  
of individual layers





# Technical Accomplishments

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This project is not scheduled to begin until  
June 1, 2006:

- Prior work on membrane casting has indicated **initial** success in 2-layer polymer solution casting of Nafion®



# Future Work

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- **FY06:**

- ✓ early stage polymer development including base high T polymers and potential modification identification
- ✓ polymer casting issues: carriers, solubility / rheology, methods

- **FY07:**

- ✓ polymer modifications ( to achieve T and RH targets ) and nano-particle additive investigation
- ✓ polymer casting issues: casting method evaluation and drying / curing / annealing development



# Milestone Targets

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## **Q-1 Milestones:**

- 1] Identification of a minimum of 2 existing & 2 new high T polymers, and modifications capable of achieving T, RH% and conductivity targets
- 2] Identification of suitable casting sheet candidates for casting polymer film membranes
- 3] Initial evaluation of solubility & rheology issues of modified polymers

## **Q-2 Milestones:**

- 1] Identification, synthesis and characterization of suitable novel ionic and mixed surface nano-particle materials as polymer additives with potential to provide target functionalities
- 2] Analysis and evaluation of rheology, solubility and process parameters (casting, drying, curing, annealing and release - from - carrier) of nano-particle modified polymers



# Milestone Targets

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## **Q3 Milestones:**

- 1] Analytical characterization of polymer / synthesized nano – particle blends & assessment of solubility, dispersion & morphology
- 2] Initial proton conductivity assessment of lab scale thin films produced
- 3] Identify suitable solution casting methods capable of producing 1.0 mil single layer and/or 5–20 micron thick (layer) composites

## **Q-4 Milestones:**

- 1] Complete profile of modified polymer blend candidates to characterize T, physical, mechanical and chemical properties.
- 2] Development of basic laboratory procedures for solution casting / drying / curing / annealing of selected modified polymer blends
- 3] Development of design of experiments plan for future pilot scale R&D of roll – to – roll membrane process parameters.



# Summary

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- Technical Targets:
  - ✓ 1.0 mil single layer membrane structure
  - ✓ 5-20 micron individual layers in a multi-layer membrane
  - ✓ > 120<sup>o</sup> C operational capability
  - ✓ < 50% RH operational capability