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

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Project ID # FCP-1

This presentation does not contain any proprietary or confidential information

Overview

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

- **Identify novel polymer architectures**

✓ improved mechanical stability vs. Nafion® 117
✓ improved ionic conductivity
✓ > 120^0 C and < 50% RH operationally capable

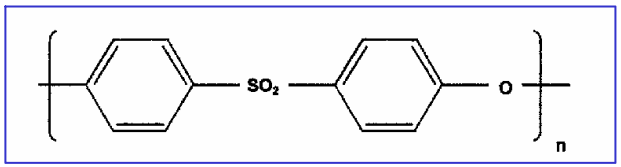
- **Identify new solution casting methodologies for thin, <u>roll-to-roll membrane formation</u>**

✓ thin, defect-free single layer membranes (± 1.0 mil)
✓ discrete, multi-layer membranes (5-20 micron individual layers)
✓ reduction in stack component cost (PEM and MEA)

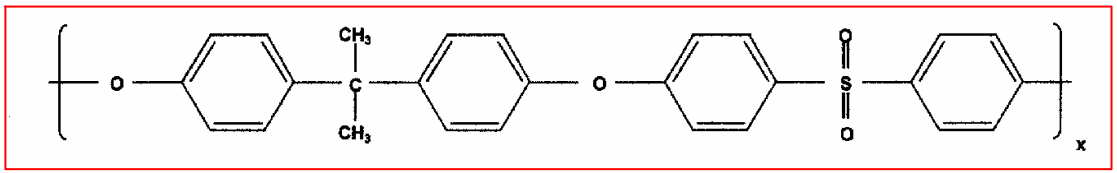
Polymer Approach

- **Evaluate base high T polymers as membrane candidates**

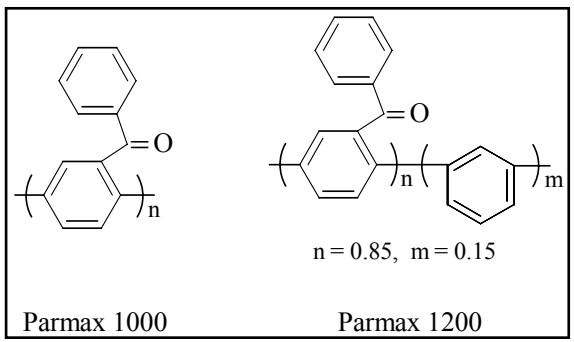
polyethersulfone:



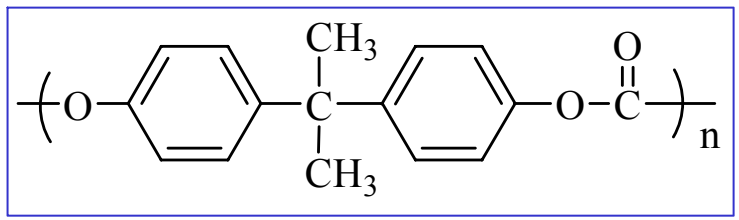
polysulfone:



Parmax poly p-phenylene:



polycarbonate:



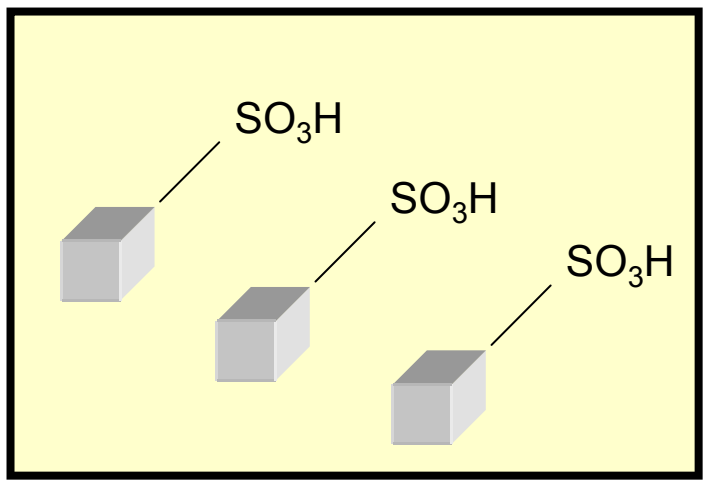
Polymer Approach

- **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

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

Polymer Casting Phase

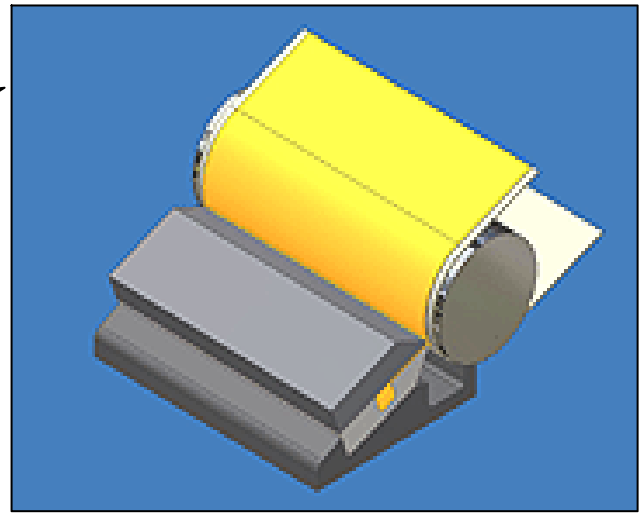
Membrane Casting Approach

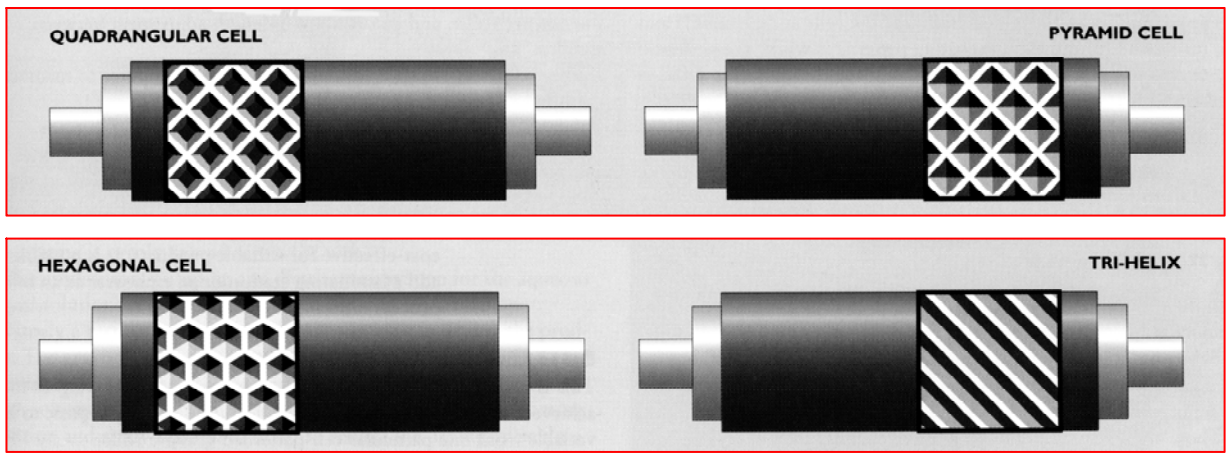
- **Evaluate potential casting sheet carriers**
  - ✓ PET, polycarbonate, others with suitable release characteristics
- **Develop rheology / solubility parameters**
  - ✓ solution casting of candidate polymers @ target calipers of
    - ~1.0 mil single layer membranes
    - 5 – 20 micron thick layers 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

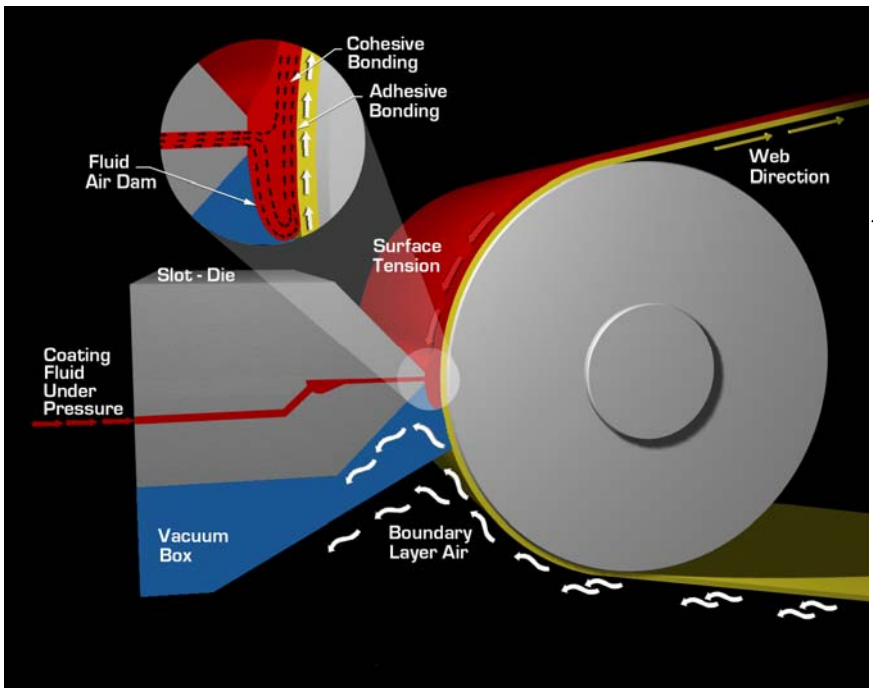


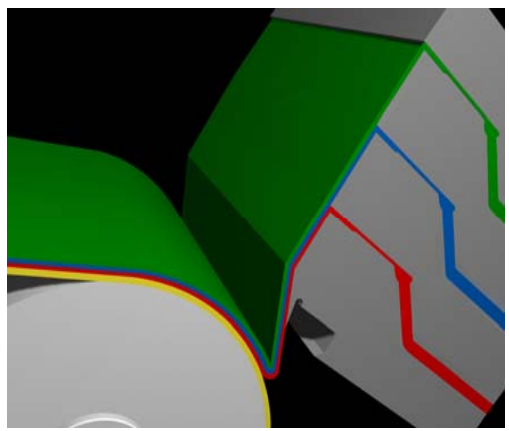


Membrane Casting Approach

Multi-Layer Membrane
(SLOT DIE)

Key Challenge: interfacial adhesion of individual layers





Technical Accomplishments

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

- **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

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

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

- Technical Targets:

✓ 1.0 mil single layer membrane structure
✓ 5-20 micron individual layers in a multi-layer membrane
✓ > 120^0 C operational capability
✓ < 50% RH operational capability