Kettering University Fuel Cell Project

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Kettering University

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Project ID # **FCP4**

Overview

Overview

Timeline

- Start – July 2006
- Finish - June 2008
- 40% Complete

Budget

- Total project funding
  - DOE - $600K
- Funding received in FY06
  - $150K
- Funding for FY07
  - $300K
- Funding for FY08
  - $150K

Barriers

- Barriers
  - A. Materials and manufacturing costs
  - B. Membrane performance
  - C. Water and thermal management
- Targets –Improved conductivity & membrane stability

Partners

- Bei-Tech – Polymer Membranes
- Umicore Fuel Cells
  - MEA Development

Objectives

Overall	• Development of Novel Proton Exchange Membranes (PEM) for Fuel Cells • Development of CFD porous flow model for PEM fuel cells for improved water and thermal management
2006	• Low-cost, high-performance membrane - Design and Manufacturing Processes - Experimental Testing and Performance Validation
2007-2008	• Low-cost, high-performance membrane - Real-time membrane testing for single cell and stack - Real-time testing for stability and materials properties • Integrated multiphase CFD model for PEM Fuel Cell - Complete unit fuel cell performance evaluation - Performance evaluation for fuel cell stack

Approach

Plan & Approach

90% Completed

- Task 1: New Fuel Cell Membrane
  - Literature survey
  - Theoretical analysis and model development
  - Inexpensive materials search

80% Completed

- Task 2: Chemical modification
  - Modification of polymer backbone
  - Increased proton conductivity
  - Reduced resistance than peer

70% Completed

- Task 3: Thermal stability and Water management
  - Test of water uptake and thermal stability
  - Improved durability and efficiency
  - Test of stable proton conductivity

40% Completed

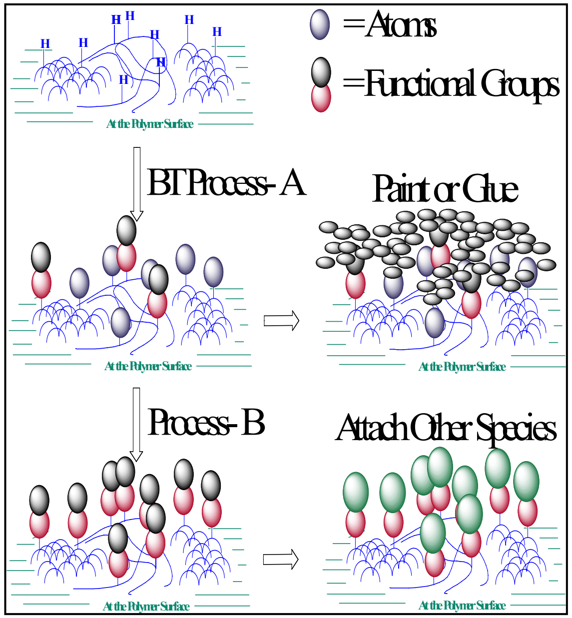
- Task 4: CFD multiphase model for PEM fuel cell
  - Literature survey
  - Developed CFD multiphase mathematical model
  - Developing graphical user interface

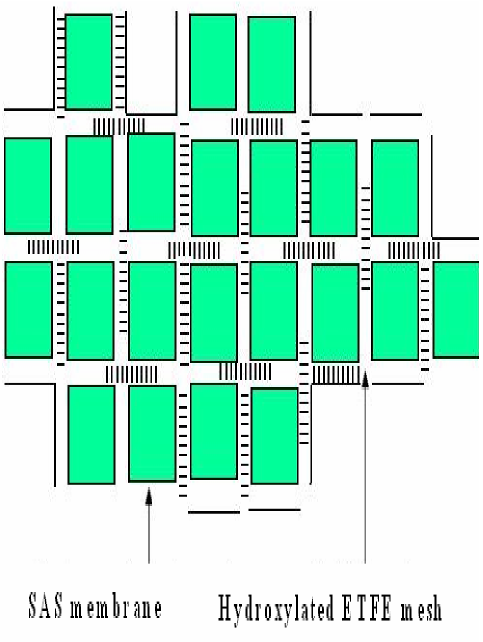
Approach

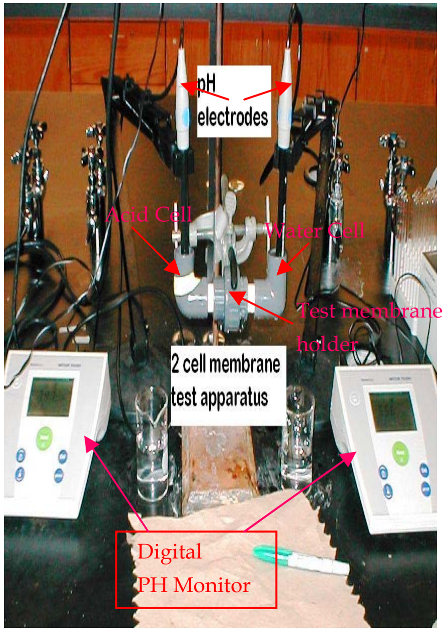
Approach Overview

- We used novel patented polymer Chain modification process through chemical treatment onto an inexpensive robust polymer backbone

- Patented Polymer backbone modification technology
- New SAS FC Membrane
- Performance Validation

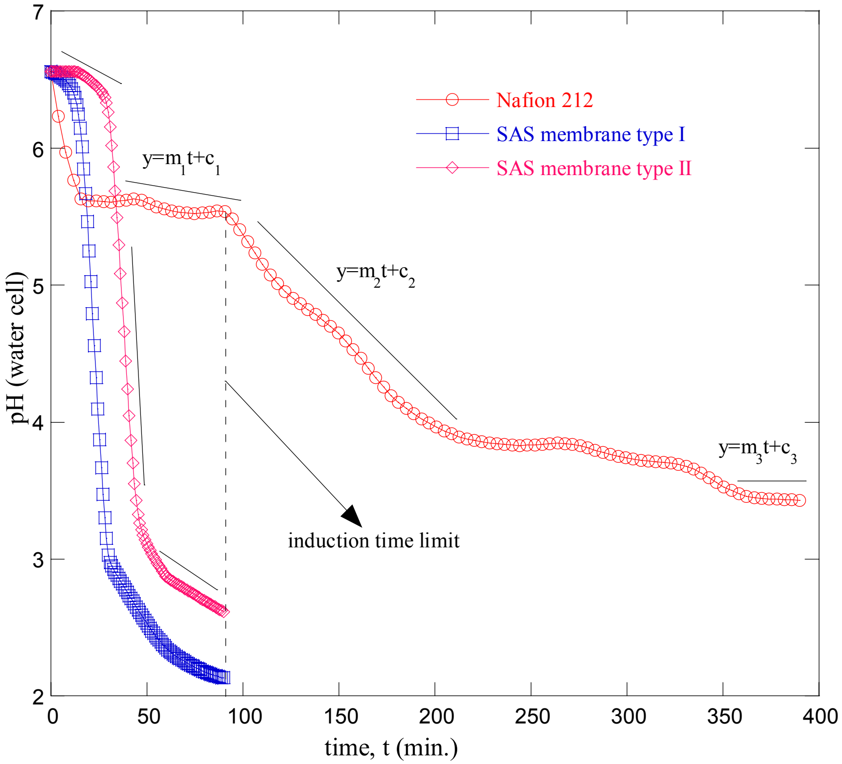


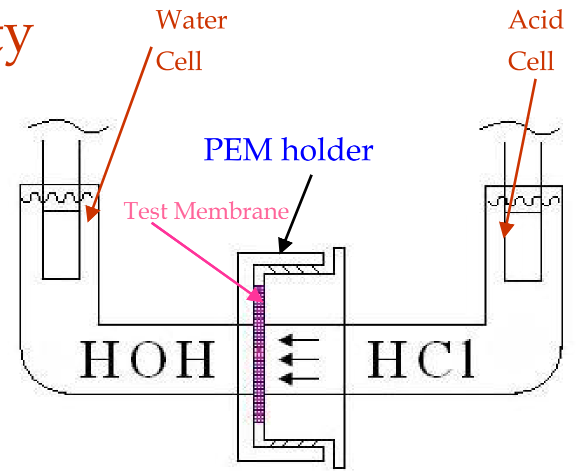




Accomplishments/Progress/Results

- Membrane's proton exchange capacity



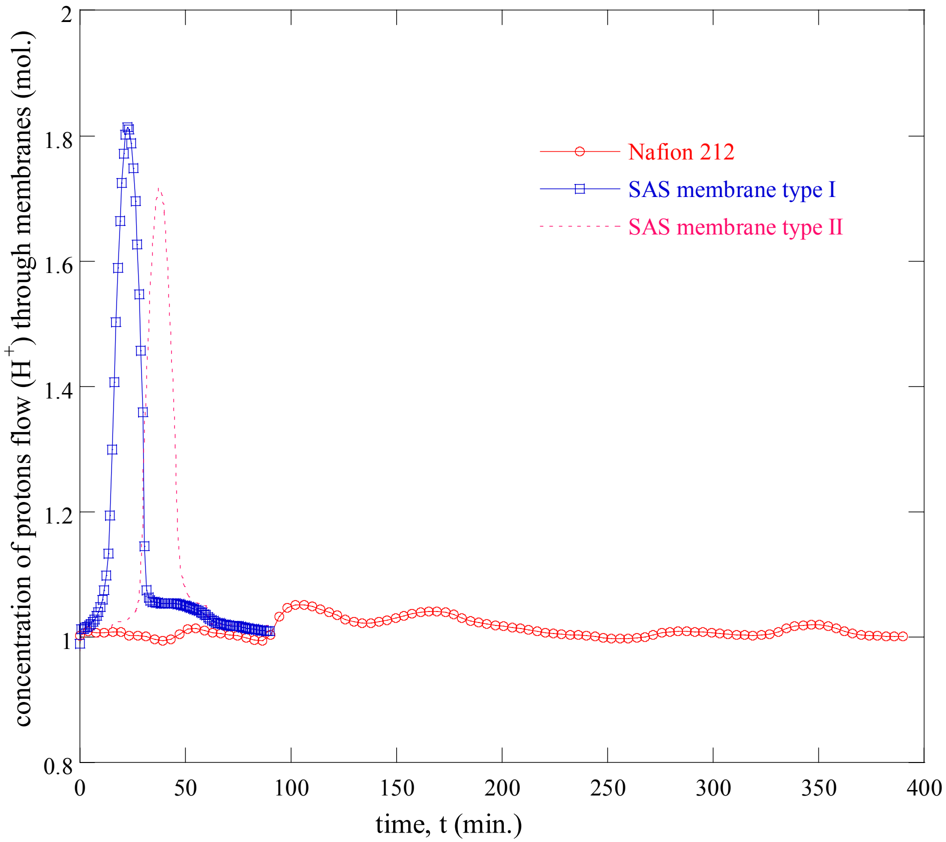


Schematic of proton exchange capacity test method

- Induction time (time required to start proton transfer) is 85% less than Nafion 212
- Higher proton transfer rate than peer membrane (Nafion 212) materials
- Steady proton transfer capacity at higher rate than Nafion 212 for extended period of time
- Very inexpensive membrane materials and easy to manufacture than Nafion 212

Accomplishments/Progress/Results

- Membrane conductivity and resistance



- 80% increased in proton conductivity than peer materials
- 85% increased in induction time
- Very low resistance in per unit area than peer (Nafion 212) materials
- Ability to quickly reach equilibrium state

Accomplishments/Progress/Results

- Comparison of membrane quantities

Membrane Type	Maximum protons transfer capacity (moles/min.)	Average protons transfer capacity (moles/min.)	Induction time (min.) (start of proton transfer)	Resistance (ohm-cm^{-2})
Nafion 212	1.0515	1.03538	99.931	0.012707
SAS type I	1.8140	1.81175	15.534	0.007261
SAS type II	1.7174	1.71080	30.042	0.007690

- 80% higher proton transfer rate than Nafion 212
- 50% less membrane resistance than Nafion 212
- Less induction time than peer

Accomplishments/Progress/Results

- Membrane Water Uptake

- Experimental test is in progress. We will present this result during poster presentation

Accomplishments/Progress/Results

- Membrane **Swelling Measurement**

- Experimental test is in progress. We will present this result during poster presentation

Accomplishments/Progress/Results

- Membrane **Thermal Stability**

- Experimental test is in progress. We will present this result during poster presentation

Future Work

- Future Work (FY07-FY08)

- Performance improvement of SAS membrane
  - Apply cross-linking agent to make membrane chemically inert towards reactant gases
  - Test thermal effect and life-cycle sensitivity
  - Map membrane water history

- Development of integrated CFD porous media multiphase model
  - FEA graphical user interface for unit PEM fuel cell and stack
  - Effect of flow, heat transfer and electrochemistry on fuel cell performance
  - Improve design of single cell and stack
  - Develop 3D surface map for effective control of fuel cell systems

Future Work

- Future Work (FY07-FY08)

- **Explore other avenues for membrane performance enhancement**
  - Replace sulfate group with phosphate group for better water management
  - Real-time test of membrane performance with single cell and stack
  - Membrane properties calculations and validation with peers

- **Improve design of unit cell and stack based on CFD modeling results**
  - Perform parametric study for design sensitivity analysis
  - Calculation of optimal combination of operating conditions based on CFD surface map
  - Identify water production and management precursors
  - Identify self-humidifying mechanism for effective fuel cells water management

Summary

Project Summary

Relevance: **Help to develop advanced membrane materials for fuel cell applications**

Approach: **Using patented polymer structure modification technology, develop and experimentally characterize new membrane properties and validated with peers**

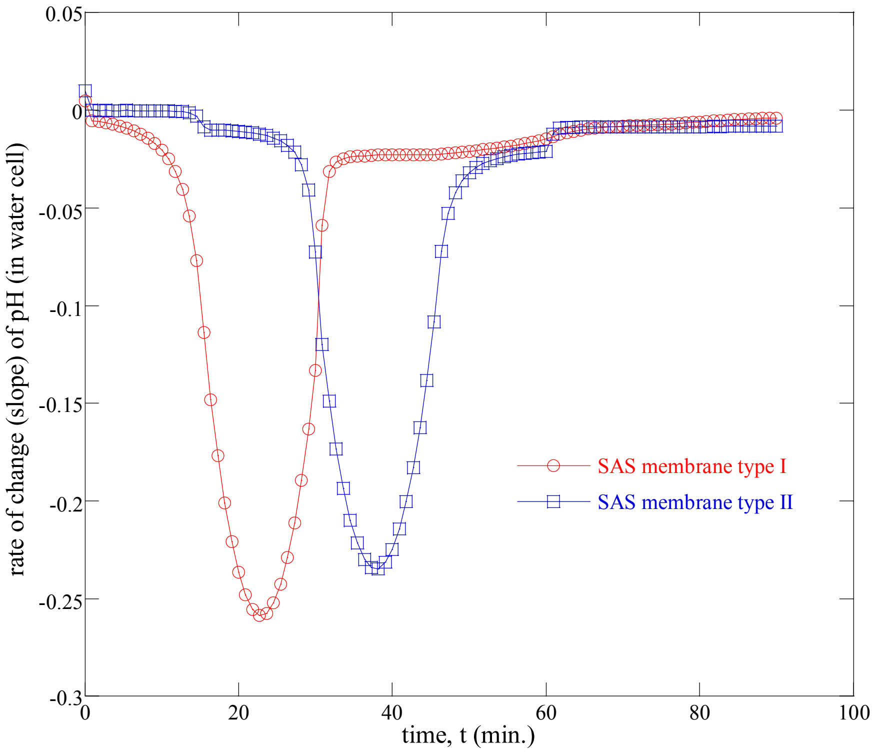
Technical Accomplishments and Progress: **Advanced fuel cell membrane manufacturing procedure has been developed. Mathematical formulation for CFD multiphase porous media flow model is completed**

Technology Transfer/Collaborations: **Active partnership with Bei-Tech, Unicore fuel cell, presentations, publication and patents**

Proposed Future Research: **Seek answers by identifying factors limiting PEM fuel cell performance**

Additional Slides 1

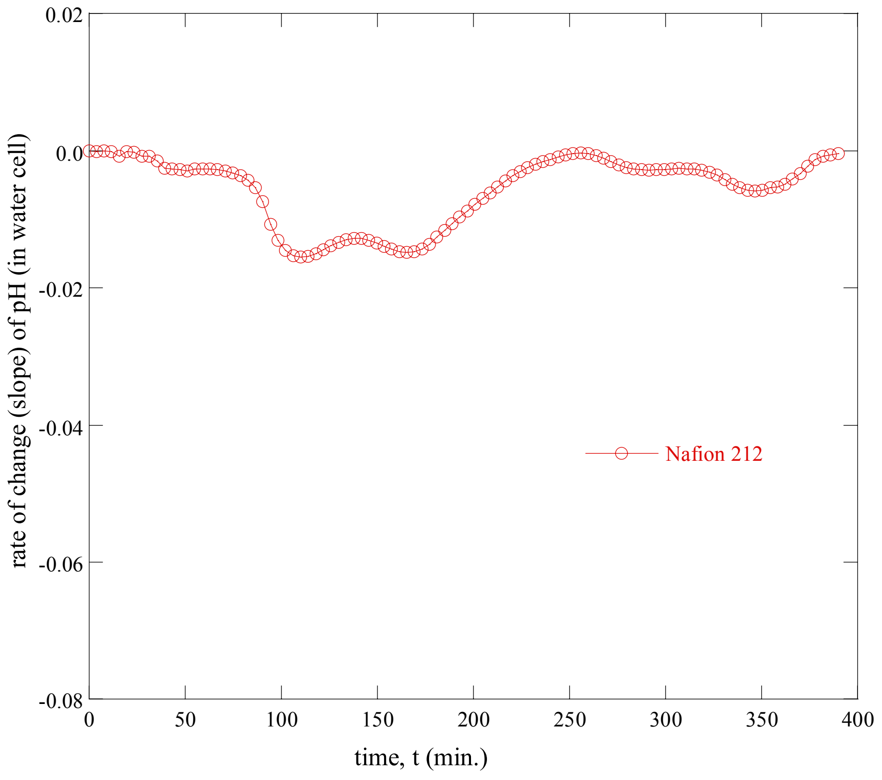
- Rate of change of pH in water cell



- Concentration of protons (H^+): 10^{-pH}

Additional Slides 2

- Rate of change of pH in water cell



- Concentration of protons (H^+): 10^{-pH}