T/J Technologies Inc.

# Low Cost, High Performance PPSA-based PEM Fuel Cell Membranes

## DOE SBIR Phase I

Junqing Ma
T/J Technologies, Inc.
May 23, 2005

CASE WESTERN RESERVE UNIVERSITY



Project ID #: FCP6

# SBIR Phase I Project Overview

T/J Technologies Inc.

## Timeline

- Started: 07/13/2004
- Ended: 04/13/2005
- Percent complete 100%

## Budget

- Total project funding
  - DOE 100K
  - Contractor 31K
- Funding received in FY04: 60K
- Funding for FY05: 40K

## Barriers

- Barriers addressed:
  - High cost of Current PFSA membranes;
  - Low proton conductivity of PFSA membranes at low R.H.
- Targets:
  - Develop new, lower-cost, longer-life materials
  - Develop MEAs that tolerate excursions to 120 °C and/or operate at RH 25-50%.

## Partners

- Case Western Reserve University

CASE
CASE WESTERN RESERVE UNIVERSITY

# Project Objectives

T/J Technologies Inc.

***To develop a low-cost, high performance $H_2/O_2$ fuel cell polymer electrolyte membrane to replace state-of-the-art Nafion Perfluorinated membranes;***

- To develop a low cost, thermally, chemically and electrochemically stable membrane material for applications in PEM fuel cell;
- To demonstrate a higher proton conductivity than PFSA membranes at any R.H.;
- To develop a molecular model for the new membrane material;
- Successful testing of the material in a $H_2/O_2$ fuel cell performance equal or better than PFSA membranes at similar operating conditions;

# Project Approaches

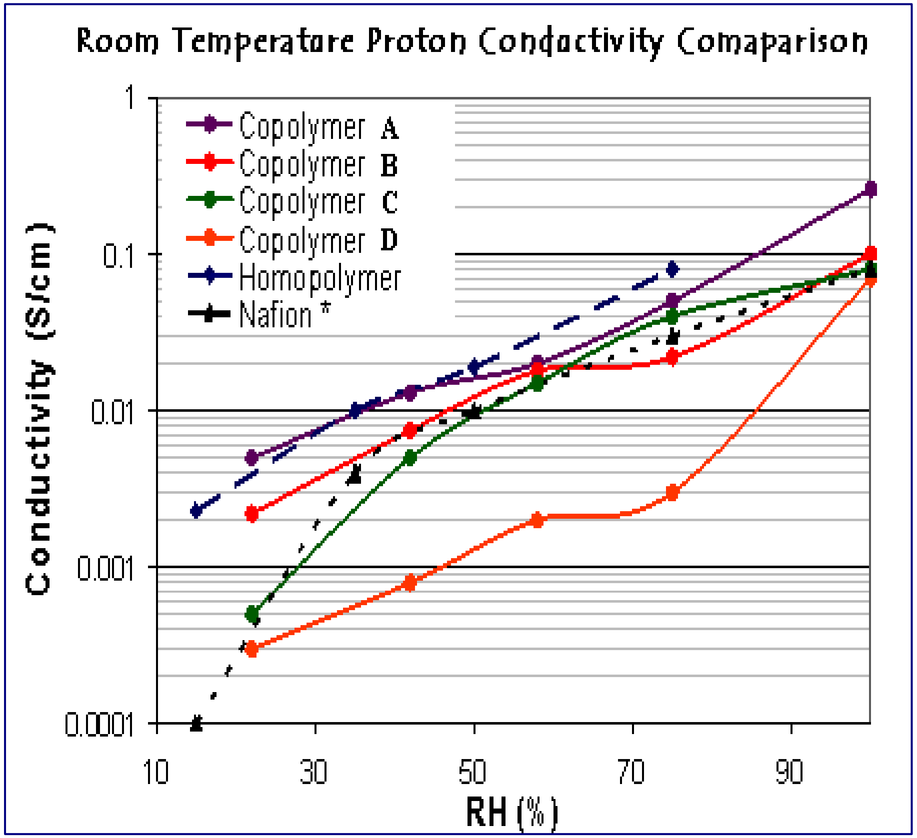
T/J Technologies Inc.

1. Development of a low cost, thermally and chemically stable, and mechanically robust membrane material:
   - Utilizing low cost precursors and easy fabrication;
   - Use highly stable Liquid Crystalline Polymers (LCPs) as base materials;
2. High proton conductivity at room Temperature and low R.H. (20-50%):
   - High degree of sulfonation;
   - Develop a unique LCP based rigid molecular channel structure that is capable of conducting Proton without larger amount of water.
3. Develop a working procedure for the fabrication membrane-electrode-assemblies and fuel cell demonstration:
   - Study the difference between the molecular structures and proton conduction mechanism between Nafion and PPSA;
   - Selection and development of a new catalyst binder system and fabrication procedure;

# PPSA Membrane Proton Conductivity @ Room Temperature

T/J Technologies Inc.

- Homopolymer is extremely soluble in water; Copolymers are insoluble in water;
- Copolymer A exhibited higher proton conductivity than Nafion at ~100R.H.
- The proton conductivity of copolymers A to D is one magnitude higher than Nafion at relative humidity of 20%;

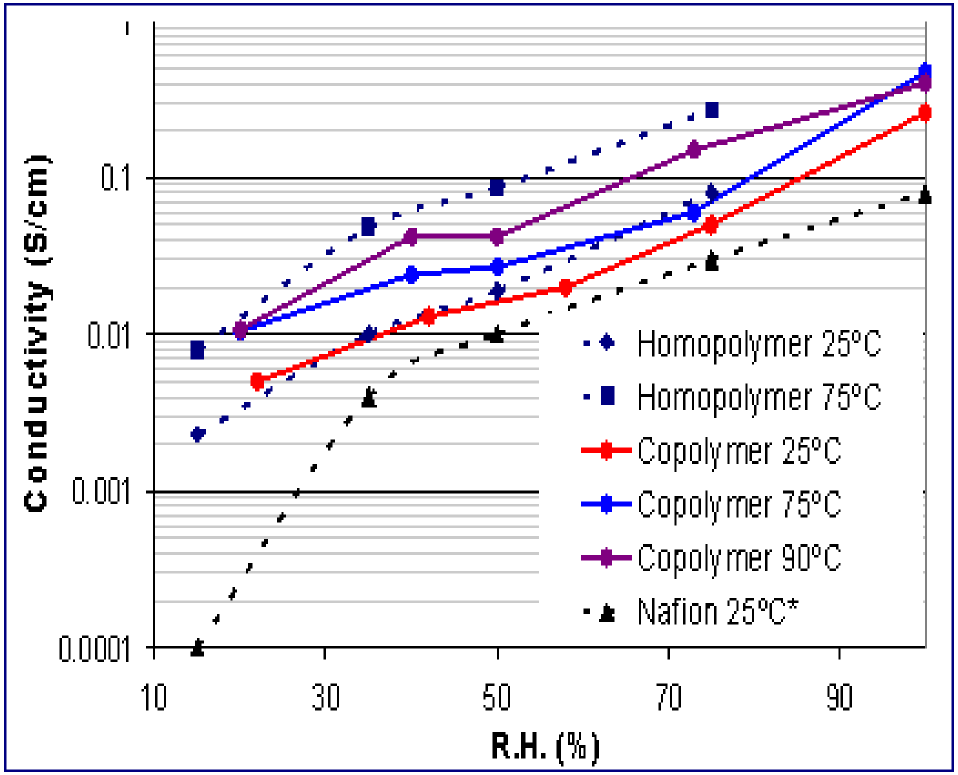


# PPSA Membrane Proton Conductivity @ elevated Temperature



- Copolymer A exhibited the best proton conductivity of all;
- The proton conductivity of copolymer A at 98% R.H. is ~0.15 S/cm.
- The proton conductivity of copolymers A is about two-magnitude higher than Nafion at relative humidity <20% ;

Proton Conductivity of Copolymer A at different Temperature and Relative Humidity

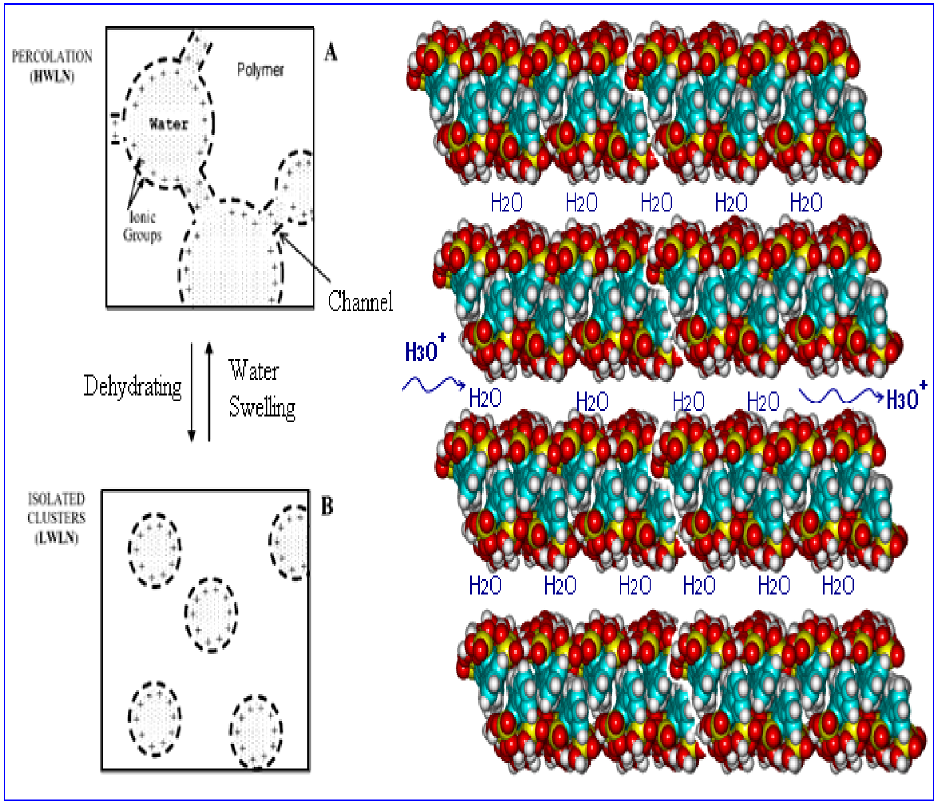


# Molecular Model and H⁺ conduction Mechanism of PPSA

T/J Technologies Inc.

- Unlike PFSA, channels in PPSA are rigid and non-collapsible;
- High sulfonation degree of PPSA realizes the interconnection of sulfonation domains;
- Most of the water in PPSA is tightly bonded to sulfonic groups which can be removed only at high temperature;
- The PPSA channel gap is below 20Å;
- The permeability of PPSA is outstanding due to these rigid channels;

A Comparison of proton conductuion mechanism between PPSA and PFSA

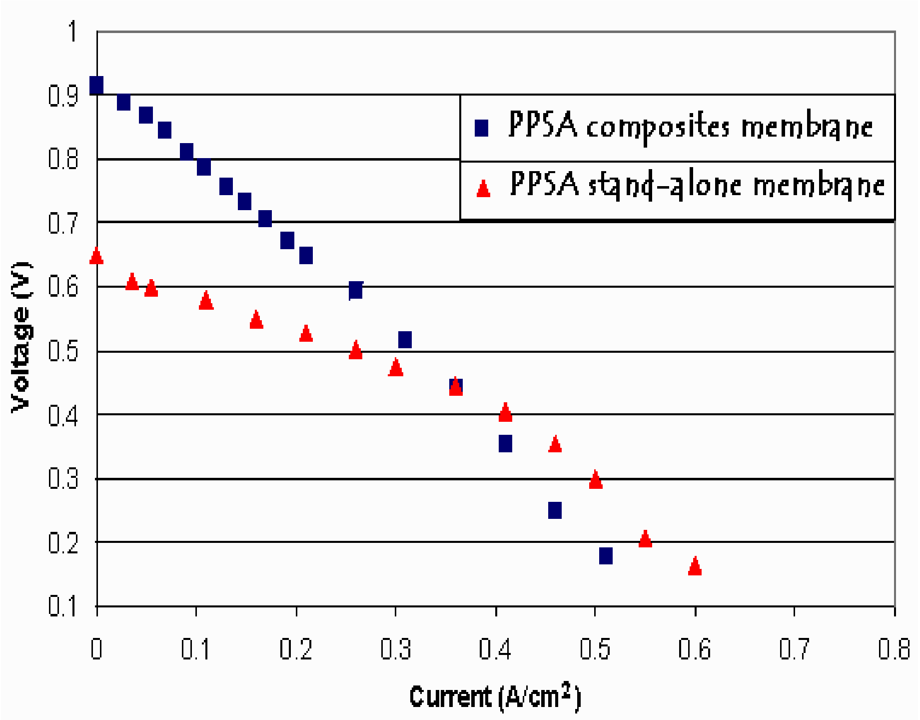



PFSA's flexible water channels; PPSA's rigid non-colapsible channels

# PPSA Membrane Fuel Cell Performance

T/J Technologies Inc.

- PPSA membrane-electrode-assemblies were fabricated under non-optimized conditions;
- Fuel cell performance was under totally non-optimized conditions;
- Significant IR loss due to high resistance at electrode and membrane interface;
- Due to the completely different structure of Nafion and PPSA – Nafion is not a good binder for PPSA MEAs;




Polarization curves of porous substrate supported PPSA and PPSA stand-alone membranes operating under totally non-optimized conditions in a 5 $cm^2$ $H_2$ / $O_2$ fuel cell; cell temperature 80°C; gas flow rate was 80 ml/min; Zero back pressure.

# T/J's PPSA-PFSA Composite Membranes

T/J Technologies Inc.

- PPSA homo- and co- polymers stay in PFSA's channels and physically impossible to **leach out** !
- Permanently enlarge the water conduction channel of PFSA membranes therefore significantly increasing PFSA's **proton conductivity at low R.H.**;
- 10% PPSA in Nafion can increase its proton conductivity at 100 % R.H. by >30%;
- Enhance the **mechanical properties** and durability of PFSA therefore lengthen **performance life**;
- Rendering improved **dimensional stability** upon hydration and dehydration;
- Lower the **cost** of Nafion: if 10% PPSA is added into Nafion, 10% membrane cost will be saved, since PPSA can be made very cheap!

Demonstrate high proton conductivity at low R.H. for crosslinked PPSA materials:

- Instead of chemical crosslinking of PPSA, we found another way to make PPSA insoluble in water;
- High proton conductivity has been demonstrated for insoluble PPSA at low R.H.; > 0.01S/cm at 20% RH.

Electrochemical stability of PPSA copolymer or composites in a fuel cell working environment:

- The PPSA copolymers has demonstrated to be extremely electrochemical stable;
- Performance life will be demonstrated in 2005;

Adequate Gas separation:

- Gas permeability data will be provided in 2005;

# Future Work

T/J Technologies Inc.

- Processing PPSA materials using optimized solution casting procedure or other new methods;
- New PPSA copolymer synthesis;
- Optimizing MEA with a completely new polymer – especially the catalyst and polymer interface;
- Demonstration of a $H_2$/air Fuel cell stack using PPSA as PEM;