Polyphosphazene-Based H_2/O_2 Fuel Cells

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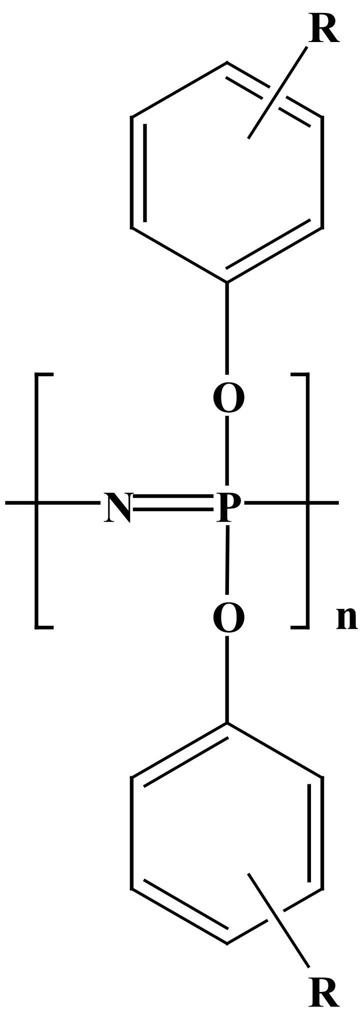
Objective

- The ultimate goal of the project is to develop a high temperature polymer electrolyte fuel cell using a new class of proton exchange membranes based on polyphosphazenes.
- We are exploring polyphosphazenes because of the thermo-oxidative and reductive stability of the phosphorus-nitrogen backbone, and because of the ability of this system to permit large or subtle changes to be made in the side group structure in order to optimize membrane properties.

Poly[(aryloxy)phosphazenes]

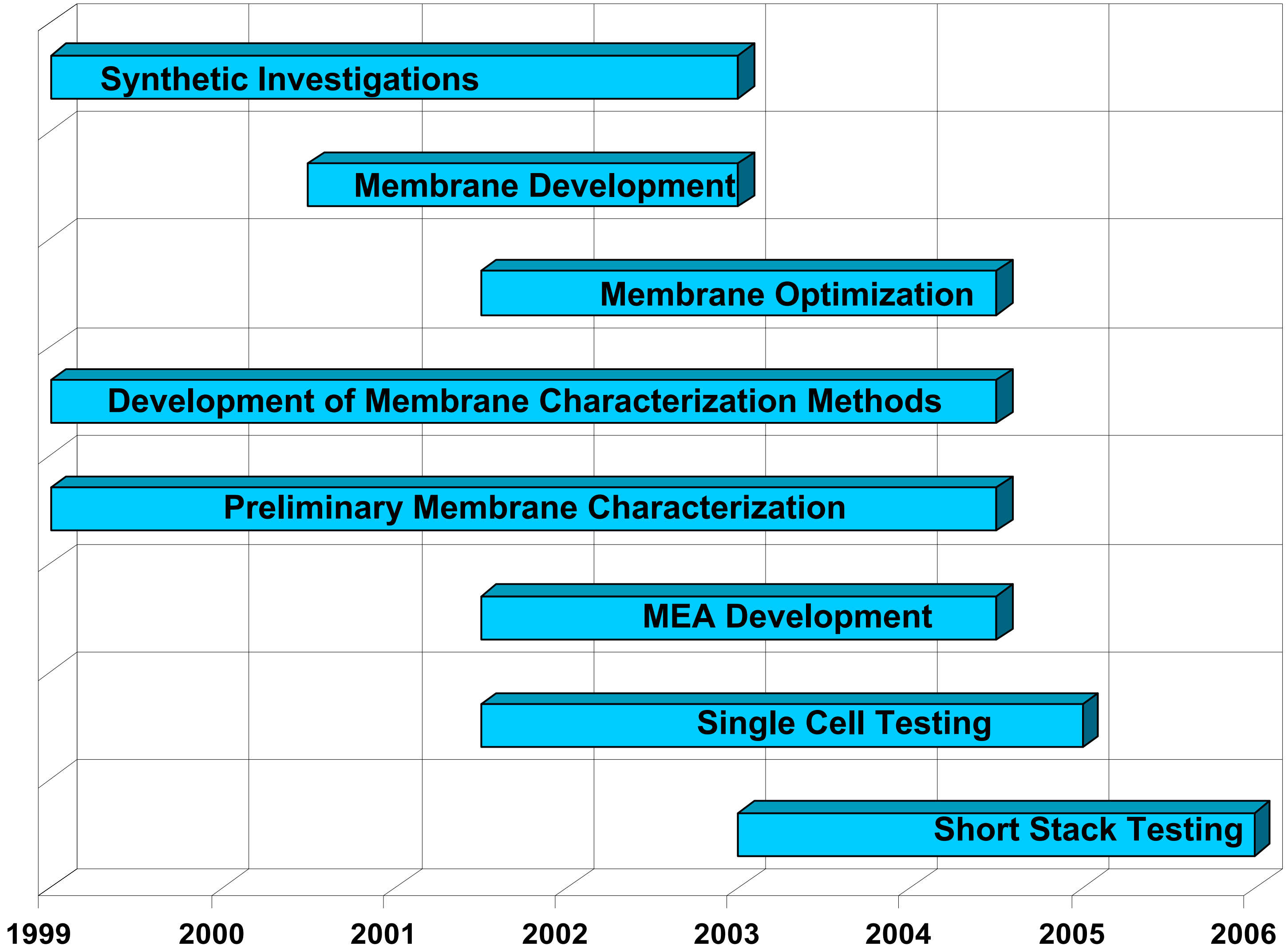


- Mechanically stable
- Easily fabricated
- Good film forming characteristics
- High chemical and thermo-oxidative stability
- Resistant to free radical skeletal cleavage

Approach

- Polymer design, synthesis, molecular characterization, and membrane property optimization
- Preparation of Membrane Electrode Assemblies (MEAs) using different techniques
- Electrochemical characterization and evaluation of the membranes and MEAs over a wide range of temperature
- Construction of a bench-scale prototype fuel cell and determination of MEA performance over a wide range of temperature

Program Timeline



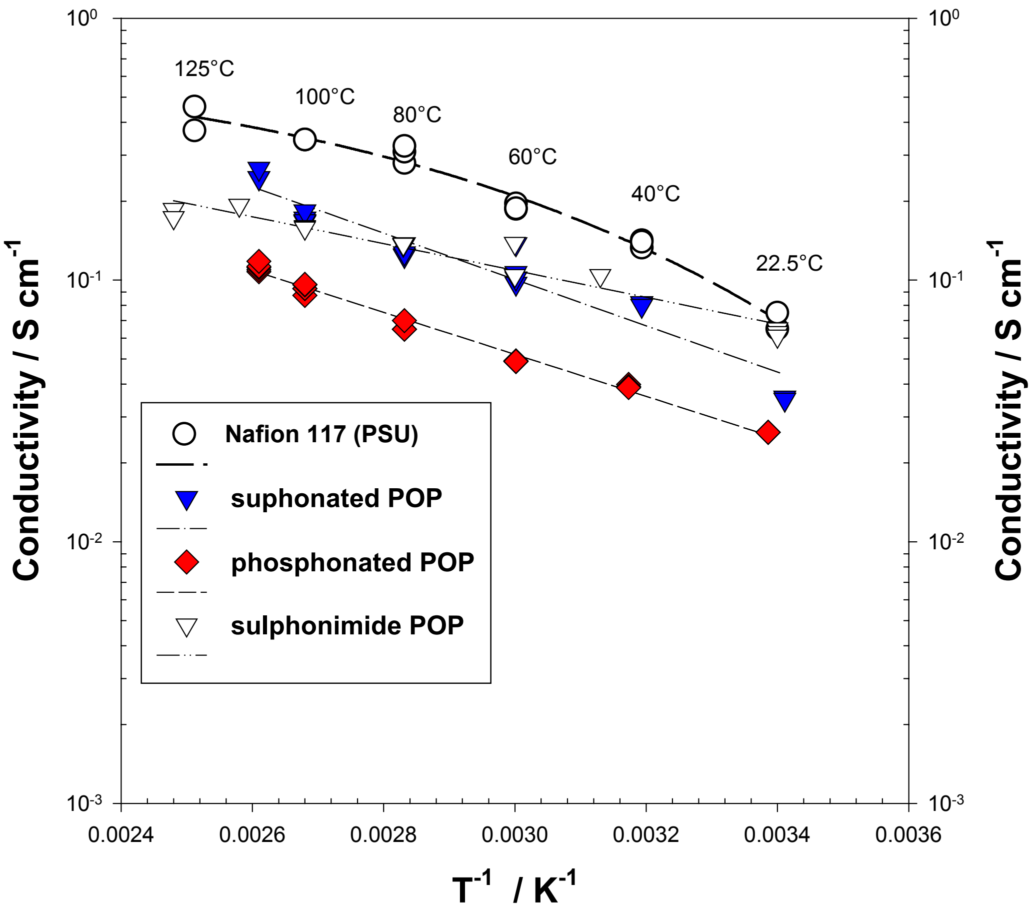
Accomplishments - Synthesis

- A method for the synthesis of the sulfonimide containing side group, $HOC_6H_4SO_2NNaSO_2CF_3$, for incorporation into phosphazene polymers has been developed.
- This side group was used to prepare a sulfonimide-functionalized phosphazene polymer with an ion-exchange capacity of ~1.0 meq/g, conductivity of ~0.06 S cm^{-1}, and swelling of ~40%.
- The membrane properties may be improved through a number of optimization methods, including cross-linking and blending techniques.

Accomplishments – Membrane Properties at Ambient Conditions

Polymer membrane/ method	Cross-linking Radiation (Mrad)	IEC (meq g^{-1})	Swelling (%)	Conductivity (S cm^{-1})
Nafion 117	N/A	0.91	30	0.100
Sulfonated Phosphazene Polymer	20	1.07	38	0.035
Phosphonated Phosphazene Polymer	40	1.35	14	0.053
Sulfonimide Phosphazene Polymer	40	0.99	42	0.058

Accomplishments – Conductivity of Membranes at High Temperatures

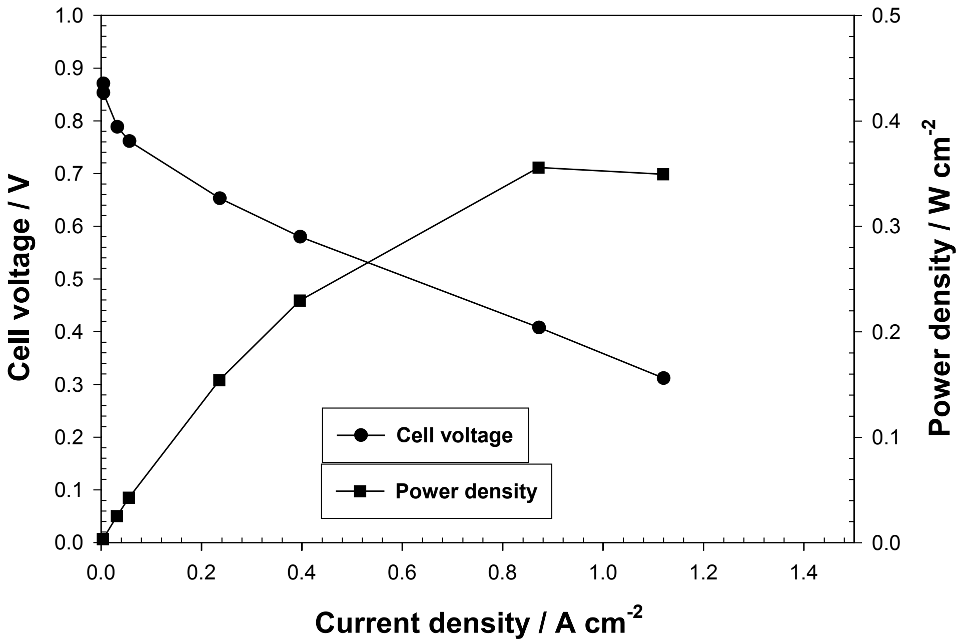


Accomplishments – Fuel Cell Test

- A proton conductive sulfonimide polyphosphazene-based MEA was developed and tested in a H_2/O_2 fuel cell. The catalyst loading was 0.33 mg cm^{-2} for both the anode and the cathode.

- At 22°C the limiting current density of the sulfonimide polyphosphazene-based H_2/O_2 fuel cell was 1.12 A cm^{-2} and the peak power densities was 0.36 W cm^{-2}.

Accomplishments – Fuel Cell Test



Polarization and power density curves for the sulfonimide polyphosphazene based H_2/O_2 fuel cell at 22°C. Conditions: H_2 and O_2 pressures are 2 and 3 bar, respectively; there was no humidification of either the anode and cathode.

Conclusions

- Sulfonimide polyphosphazene proton conducting membranes have been synthesized and tested at ambient conditions
- A Sulfonimide polyphosphazene-based MEA has been prepared and evaluated in a H_2/O_2 fuel cell
- The limiting current density of the sulfonimide polyphosphazene-based H_2/O_2 fuel cell was 1.12 A cm^{-2} at 22^oC and the peak power densities was 0.36 W cm^{-2} at 22^oC.
- The performance results are comparable to those obtained for a home made Nafion 117 MEA.

Future Studies

- Improvement of the polyphosphazene membranes by side group modifications
- Further improvement of the membrane characteristics through blend formation with a variety of polymers, including PVDF
- Optimization of polyphosphazene MEA preparation techniques
- Membrane characterization tests at elevated temperature
- Fuel cell tests at elevated temperatures

Acknowledgements

This work was funded by the United States Department of Energy under contracts:

- DE-PS02-98EE504493
- DE-FC36-01GO11085