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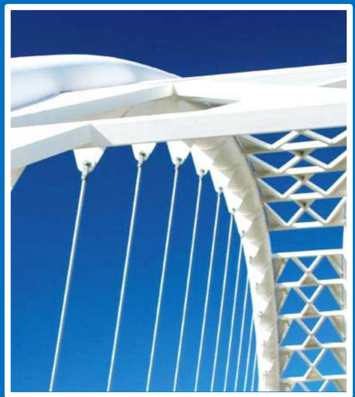


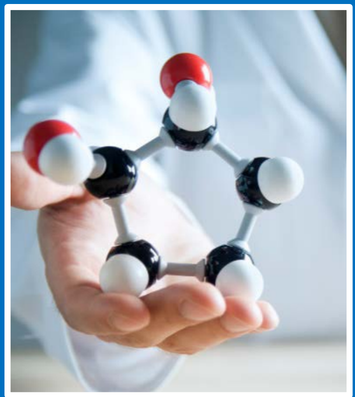

Novel Nanocomposite Polymer Electrolyte Membranes for Fuel Cells

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Project ID#: FC153

Overview

Timeline

Project start date: 02/22/2016

Project end date: 11/21/2016

Barriers

- High cost of ionomer based polymer electrolyte membranes
- Decreased proton conductivity at high temperature
- Water management

Budget

Total project budget: $150,000

Partners

Electrochem., Inc.

Relevance

Objectives: The focus of the current program is to demonstrate feasibility of a novel concept for PEM that has not been explored before.

DoE technical targets for fuel cell membranes for transportation applications

Characteristic	Units	Target 2020
Maximum operating temperature	°C	120
Area specific proton resistance at		
Maximum operating temp and water partial pressures from 40-80 kPa	Ohm•cm²	≤ 0.02
80°C and water partial pressures from 25-45 kPa	Ohm•cm²	≤ 0.02
30°C and water partial pressures up to 4 kPa	Ohm•cm²	≤ 0.03
-20°C	Ohm•cm²	≤ 0.2
Maximum oxygen cross-over	mA/cm²	2
Maximum hydrogen cross-over	mA/cm²	2
Minimum electrical resistance	Ohm•cm²	1000
Cost	$/m²	≤ 20
Durability		
Mechanical	Cycles	≥ 20,000
Chemical	Hours	> 500

Abstract

The proposed Phase I program aims to develop a novel non-PFSA polymer electrolyte membrane, utilizing highly proton conducting heteropolyacids (HPAs) in an organic matrix in a way that has not been explored before. The novel HPA/polymer membrane has a unique structure that ensures that the active proton conducting species (HPA) are contained in a continuous interconnected channel. The overall objective of the Phase I program is to demonstrate the feasibility of a robust PEM that has high proton conductivity, low H_2 and O_2 cross-over and is highly durable for extended use in a fuel cell.

Polymer Electrolyte Membrane (PEM) for Fuel Cells

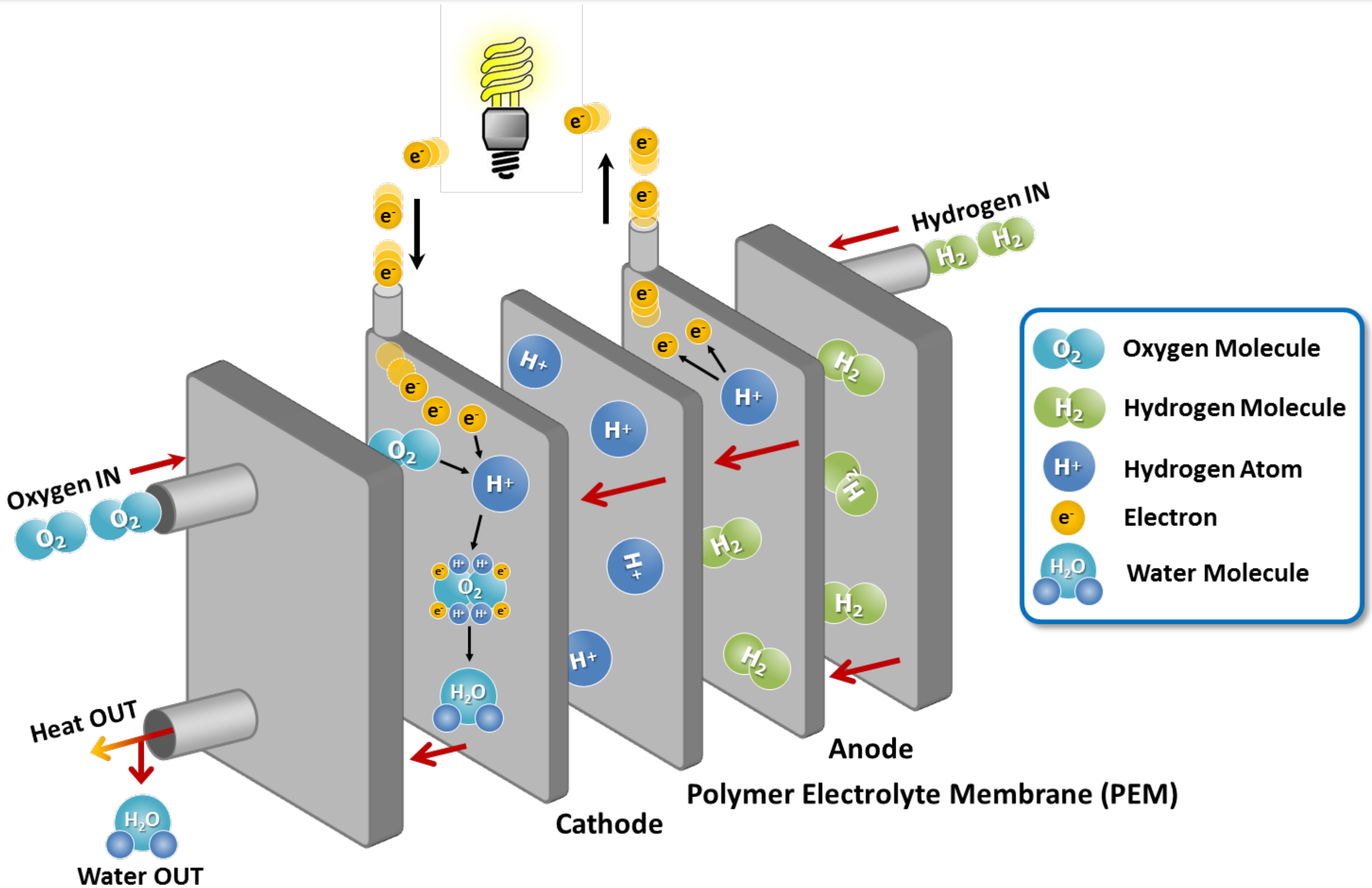

Illustration of polymer electrolyte membrane fuel cell operating on hydrogen fuel and oxygen from air

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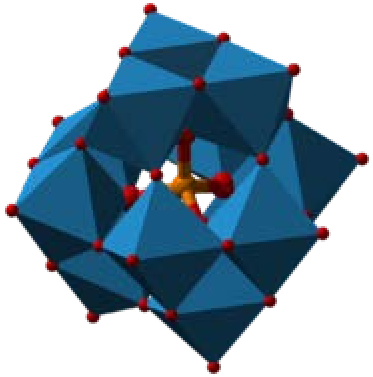
State-of-the-art PEM for Fuel Cells

- Perfluorosulfonic acid (PFSA) ionomers
- High cost
- Decreased proton conductivity at higher temperatures
- Water management
- CO poisoning

Non-Ionomer Approaches

- Heteropolyacid (HPA)
- High proton conductivity at room temperature
  - 2×10^{-2} S/cm to 2×10^{-1} S/cm
- Issues
  - HPA alone cannot be processed into flexible membrane
  - Decreased conductivity as additives in a polymer composite
  - Leaching out because of water solubility



Keggin structure, $XM_{12}O_{40}^{n-}$

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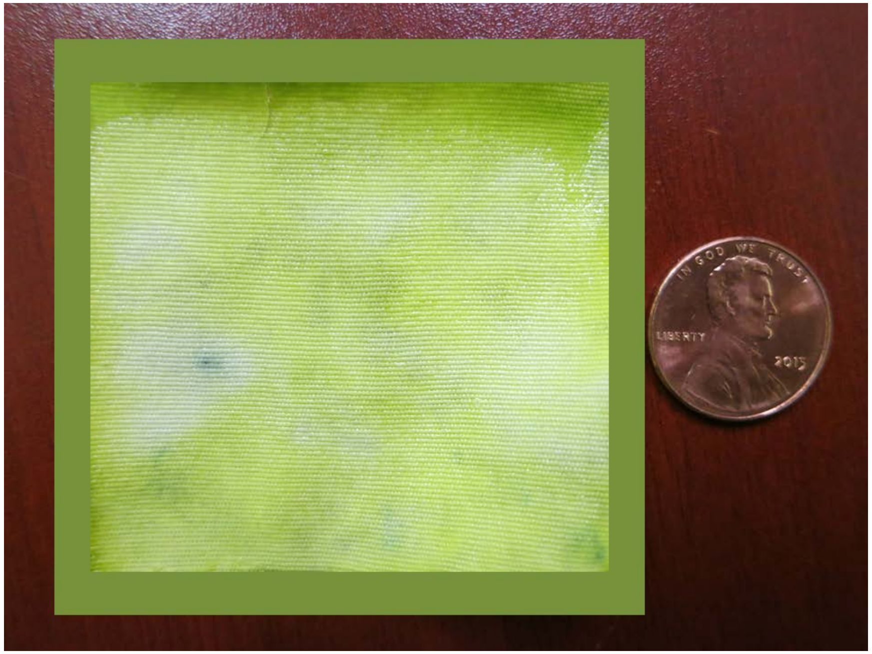
Technical Approach

- Polymer/HPA composite membrane
- HPA stored in microvascular networks
- Continuous proton pathway for improved conductivity
- HPA shielded to prevent leaching
- Polymer matrix to provide mechanical strength and gas barrier property
- Standard industrial processes

Preliminary Results

- Composite membrane fabricated
- Proton conductivity measured

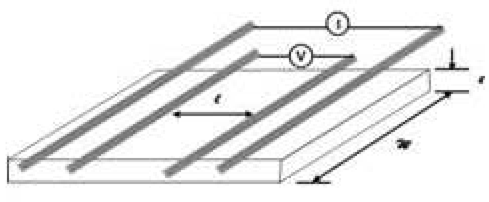


Polymer/HPA composite membrane

Proton Conductivity

In plane	Length, cm	Width, cm	Thickness, cm	Resistance, ohm	Conductivity, S/cm
NEI-4	0.457	0.318	0.025	976.5	0.06
Nafion® 115	0.457	0.318	0.013	143.5	0.79
Through plane	Length, cm	Width, cm	Thickness, cm	Resistance, ohm	Conductivity, S/cm
NEI-4	2.240	2.240	0.025	4.63	0.001
Nafion® 115	2.240	2.240	0.013	4.40	0.001

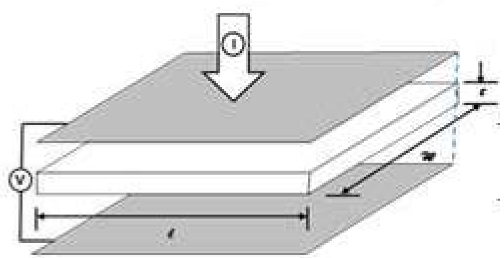
* Membrane was stored in a container with saturated water vapor at room temperature (24°C). Membrane resistance was measured at room temperature (24°C).



In plane

$R = \rho * L/A$

$\rho = R * A/L$
$= R*(w*t)/l$



Through plane

$R = \rho * L/A$

$\rho = R * A/L$
$= R*(w*l)/t$

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Collaboration

Partner

- ElectroChem. Inc.

Project role

- Perform membrane tests
  - Proton conductivity
  - Hydrogen cross-over
- Compare with state-of-the-art PEM

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Proposed Future Work

- Fabricate high quality polymer/HPA composite membrane
- Characterize composite PEM
- Test membrane performance
- Compare with state-of-the-art PEM
- Improve processes

Summary

Objectives: demonstrate feasibility of a novel concept for PEM that has not been explored before

Relevance: novel composite PEM can significantly increase proton conductivity

Approach: build a microvascular network of highly proton conductive HPA in a polymer matrix

Accomplishments: initial samples fabricated with proton conductivity approaching that of Nafion® membrane

Contact

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