

# New Fluorinated Ionomers for Enhanced Oxygen Transport in Fuel Cell Cathodes

Project ID: FC184



Robert D. Lousenberg, PhD  
Compact Membrane Systems, Inc.  
Newport, Delaware

2018 DOE Hydrogen and Fuel Cells Program Annual Merit  
Review and Peer Evaluation Meeting

June 13<sup>th</sup> to 15<sup>th</sup> , 2018



This presentation does not contain any proprietary, confidential, or otherwise restricted information

# Overview

- **Timeline (9 months)**

Project start: 4/9/2018

Project end: 1/8/2019

- **SBIR Phase I Budget**

\$150,000

- **Barriers**

**PEMFC cost:** facilitate lower platinum group metal (PGM)-catalyst cathode loadings – 0.125-mg PGM/cm<sup>2</sup> (2020 DOE target)

**PEMFC performance:** facilitate increased rated power – 1000-mW/cm<sup>2</sup> (2020 DOE target)

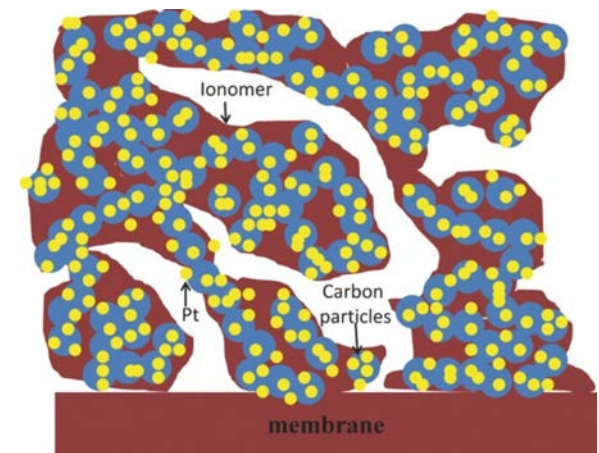
- **Partners**

None

# Relevance

## Hypothesis

New amorphous fluoropolymers (ionomers) that are highly conductive (like Nafion®) but also have higher free volume may enhance oxygen permeance to the PGM catalyst and improve overall PEMFC cathode kinetics



Cathode with ionomer layer<sup>1</sup>

## Objectives

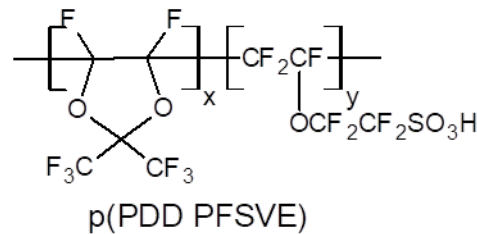
- Synthesize and characterize a series of new fluorinated amorphous ionomers with varied composition and equivalent weight (EW)
- Fabricate supported thin-film membranes from the ionomers and measure O<sub>2</sub> and air permeability at varied temperature and humidity versus similarly prepared Nafion® controls
- Go/no go decision for post Phase I MEA testing based on demonstrated superior O<sub>2</sub> permeability\*

\*Any proposed future work is subject to change based on funding levels

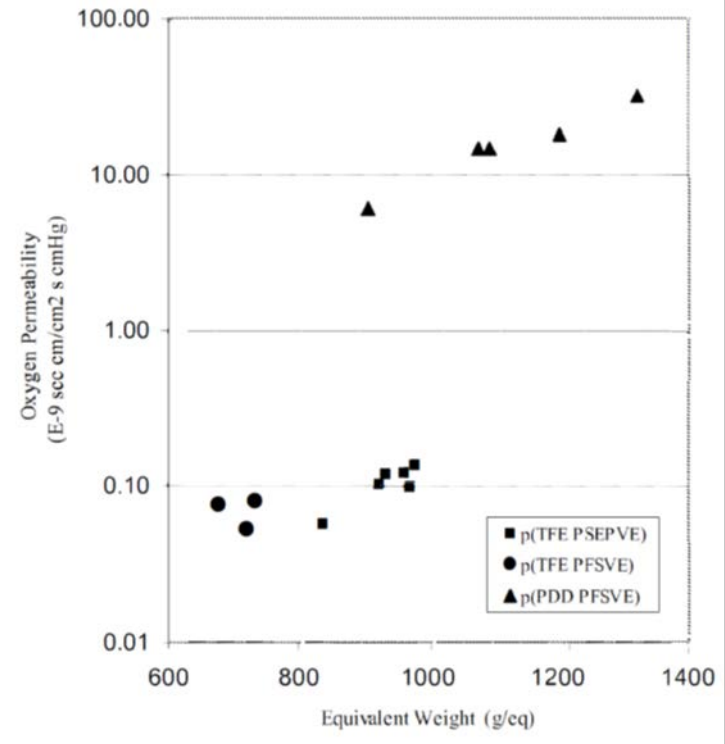
# Approach

## Background

Fluoro-ionomers comprising 4,5-difluoro-2,2-bis(trifluoromethyl)-1,3-dioxole (PDD) are known to have higher  $O_2$  permeability resulting from increased free volume



Permeability of PDD copolymers vs. p(TFE PSEPVE) "Nafion®" or p(TFE PFSVE) "Aquivion®"<sup>2</sup>



New Custom Amorphous Fluoropolymers comprising PDD may have better properties for fuel cell cathode applications

# Approach

## Thin-membrane fabrication

- Ionomer membrane thicknesses that are 5 microns or less have realistically measurable gas fluxes over manageable areas
- Dilute-solution casting on high-permeance supports to form laminar and robust composite ionomer membranes
  - Gravimetric estimation of membrane thickness
  - Support layer resistance is significantly lower than the ionomer membrane

## Permeability measurement

- Gas cell sizes from 14 to 465-cm<sup>2</sup>
- Measurements at varied temperatures with humidification

$$\text{Permeability} = \frac{\text{Volume} \times \text{Thickness}}{\text{Area} \times \text{Time} \times \Delta \text{Pressure}} = 10^{-10} \times \frac{\text{cm}^3 (\text{STP}) \times \text{cm}}{\text{cm}^2 \times \text{sec} \times \text{cm Hg}} \text{ (barrers)}$$

# Approach

## Performance Schedule

Task / Description	Month								
	1	2	3	4	5	6	7	8	9
Ionomer synthesis	█	█	█	█					
Composition and MW characterization		█	█	█					
Hydrolysis and acid exchange		█	█	█	█				
Dispersion formulation		█	█	█	█	█			
Composite membrane fabrication			█	█	█	█	█	█	
Oxygen permeability measurement				█	█	█	█	█	█
Ionomer selection for MEA testing								★	█

### ★ Milestone

Go/no go decision based on demonstrated superior O<sub>2</sub> permeability for post Phase I MEA testing

# Accomplishments and Progress

New ionomers comprising PDD and having 850, 1100, and 1450 equivalent weights have been synthesized

- Molecular weight characterization by intrinsic viscosity
- Hydrolysis, acid exchange, and dispersion formulation in lower alcohols
- Ionomer density measurements for thin-membrane thickness estimation

Thin-film composite membrane fabrication has started and initial scouting experiments to validate permeability-measurement capability and reproducibility

# Accomplishments and Progress

- Response to previous year reviewer's comments
  - Project was not reviewed last year



# Collaboration and Coordination

None during this phase I SBIR timeline

# Proposed Future Work

## Future collaboration

Johnson Matthey Fuel Cells has indicated an interest to test ionomers that demonstrate superior O<sub>2</sub> permeability in MEA's\*

\*Any proposed future work is subject to change based on funding levels

# Summary and references

## Summary

New amorphous fluoropolymers (ionomers) that are highly conductive and comprise PDD are anticipated to enhance oxygen permeance to the PGM catalysts and improve overall PEMFC cathode kinetics due to a higher free volume imparted by the PDD. Thin membranes are being tested for oxygen permeability under humidified conditions at varied and elevated temperatures for comparison to similarly prepared Nafion® control membranes.

## References and notes

1. R. Singh, A. R. Akhgar, P. C. Sui, K. J. Lange, N. Djilali, Dual-Beam FIB/SEM Characterization, Statistical Reconstruction, and Pore Scale Modeling of a PEMFC Catalyst Layer. *J. Electrochem. Soc.* **2014** 161 (4): pp 415-424
2. R. L. Perry, M. G. Roelofs, R. C. Wheland, R. M. Aten, Ionomers and Ionically Conductive Compositions. *United States Patent Application 20130245219 A1* **2013**

# Reviewer-Only Slides

# Data Management Plan

## Option 1

It is anticipated that all generated digital data will be protected as SBIR/STTR data and therefore will not be publicly shared during the applicable SBIR/STTR data protection period. If any data generated under this award are published, an effort will be made to also release any related digital data that is not protected SBIR/STTR data.