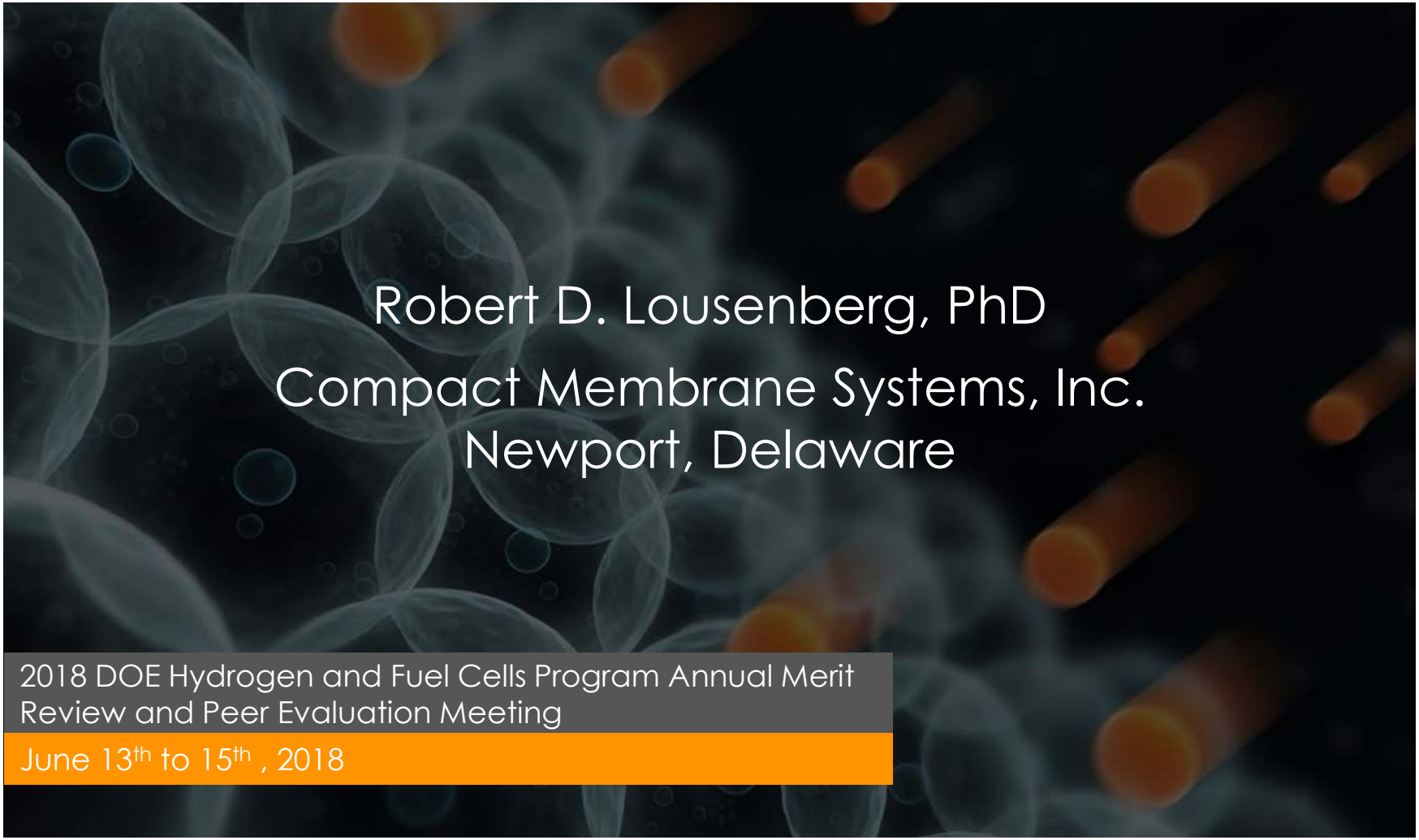
New Fluorinated Ionomers for Enhanced Oxygen Transport in Fuel Cell Cathodes

Project ID: FC184

Compact Membrane Systems



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 13th to 15th , 2018

Overview

- **Timeline (9 months)**
  Project start: 4/9/2018
  Project end: 1/8/2019

- **Barriers**
  PEMFC cost: facilitate lower platinum group metal (PGM)-catalyst cathode loadings – 0.125-mg PGM/cm^2 (2020 DOE target)
  PEMFC performance: facilitate increased rated power – 1000-mW/cm^2 (2020 DOE target)

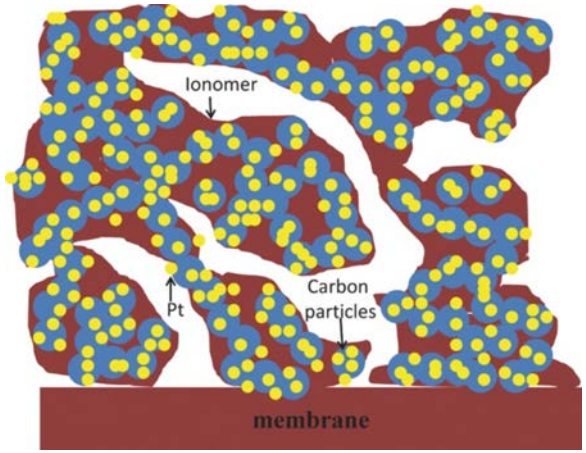
- **SBIR Phase I Budget**
  $150,000

- **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[1]

Objectives

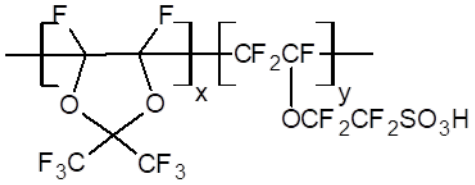
- Synthesize and characterize a series of new fluorinated amorphous ionomers with varied composition and equivalent weight (EW)
- Fabricate supported thin-film membranes from the ionomers and measure O_2 and air permeability at varied temperature and humidity versus similarly prepared Nafion® controls
- Go/no go decision for post Phase I MEA testing based on demonstrated superior O_2 permeability*

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

Approach

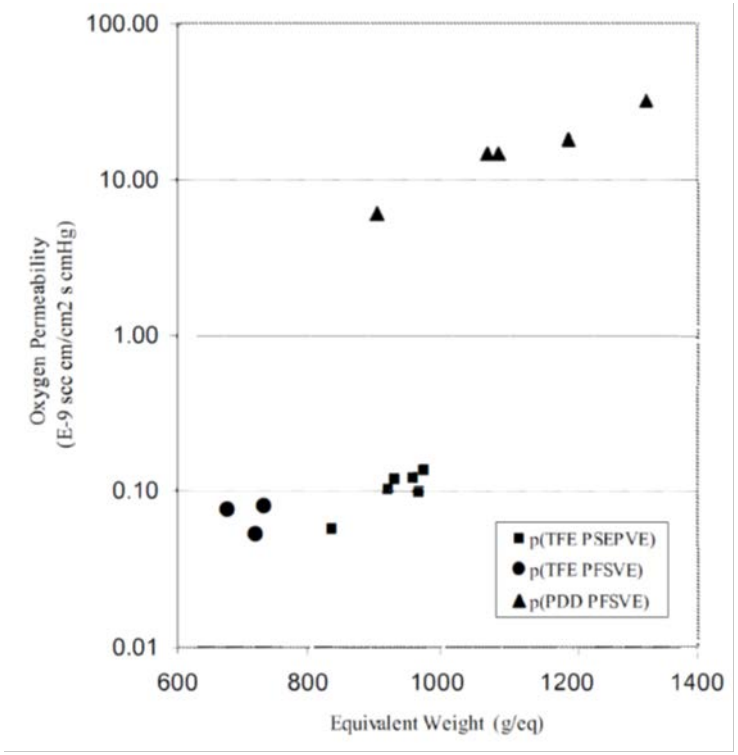
Background

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



p(PDD PFSVE)

Permeability of PDD copolymers vs. p(TFE PSEPVE) "Nafion®" or p(TFE PFSVE) "Aquivion®"[2]



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^2
- Measurements at varied temperatures with humidification

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

Approach

Performance Schedule

	Month								
Task / Description	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_2 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_2 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.