V.C.11 Novel Nanocomposite Polymer Electrolyte Membranes for Fuel Cells

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Subcontractor:
ElectroChem, Inc., Woburn, MA

Project Start Date: February 22, 2016
Project End Date: November 21, 2016

Overall Objectives

- Develop a composite polymer electrolyte membrane (PEM) with high proton conductivity, low gas permeability and lower cost than perfluorinated sulphonic acid (PFSA)-based membrane.
- Demonstrate feasibility of a novel concept for PEM that has not been explored before.

Fiscal Year (FY) 2016 Objectives

- Construct 4 in x 4 in composite PEM
- Optimize membrane architecture
- Measure proton conductivity and gas permeability
- Demonstrate advantages over state of the art

Technical Barriers

This project addresses the following technical barriers from Fuel Cells section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(B) Cost

(C) Performance (cell issues)

Technical Targets

This project is developing a novel composite PEM and demonstrating its benefits. We have demonstrated higher proton conductivity than state-of-the-art PFSA based membrane measured at 65°C and 76% and 23% relative humidity (RH) conditions. Further developments will bring us closer to the following DOE membranes for transportation applications targets for 2020.

- Maximum oxygen crossover: 2 mA/cm^2
- Maximum hydrogen crossover: 2 mA/cm^2
- Area specific proton resistance at maximum operating temperature and water partial pressures from 40–80 kPa: 0.02 ohm cm^2
- Maximum operating temperature: 120°C
- Cost: \$20/m^2

FY 2016 Accomplishments

- Designed a composite membrane which can be used to incorporate highly proton conducting heteropolyacid (HPA) in a 3-D network.
- Composite design optimization has resulted in higher proton conductivity than PFSA based membrane measured at 65°C and different humidity conditions.

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INTRODUCTION

The state-of-the-art PEM for fuel cells is based on PFSA ionomers. Besides the high cost, PFSA materials face challenges such as decreased proton conductivity at higher temperatures, water management issues and CO poisoning. Although efforts have been made to find low cost alternatives, to date non-PFSA membranes have not stood up against PFSA membranes in terms of performance and durability.

The proposed Phase I program aims to develop a novel non-PFSA polymer electrolyte membrane, utilizing highly proton conducting 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.

APPROACH

In this demonstration project, we develop a polymer–HPA composite membrane in ways that have not been explored before. The uniqueness of our approach is that HPA is stored in microvascular channels, which provide continuous proton pathway for improved conductivity. HPA is a water soluble proton conductor which suffers from the problem of leaching out in conventionally mixed polymer–HPA composite. In our composite membrane, HPA is shielded to prevent from leaching. The polymer matrix provides mechanical strength and gas barrier property to the composite membrane. Finally, all our processes use standard industrial practices which can greatly help commercialization of this technology.

RESULTS

Figure 1 illustrates a polymer–HPA composite membrane that is fabricated. The center area, which is greater than 4 in x 4 in, is the area where HPA are stored in microvascular channels. The composite membrane is fabricated using standard industrial processes.

Table 1 lists the proton conductivity of our initial membrane measured at room temperature after the membrane has been stored in a container with saturated water vapor. The conductivity of the initial sample approaches that of Nafion® membrane.

FIGURE 1. Composite polymer–HPA membrane

TABLE 1. In-Plane Proton Conductivity Measured at Room Temperature

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

With improved processing and optimization, the newer membranes demonstrated higher proton conductivity. Table 2 lists the proton conductivity measured at 65°C at different humidity conditions.

TABLE 2. In-Plane Proton Conductivity Measured at 65°C at Different Relative Humidity Conditions

Sample\Conductivity	Conductivity (S/cm) (RH = 76%)	Conductivity (S/cm) (RH = 23%)
NEI-29	0.25	0.22
Nafion®115	0.19	0.17

CONCLUSIONS AND FUTURE DIRECTIONS

Although the project is still in its early stages of development, some conclusions can be drawn:

- Novel polymer–HPA membrane has been designed to maximize the benefits of highly proton conducting HPA while locking them in microvascular channels.
- Polymer–HPA membrane samples have demonstrated higher proton conductivity than PFSA based membrane.

Future work includes:

- Conduct further architecture optimization to improve proton conductivity and gas barrier properties.
- Measure gas permeability in a quantitative manner.
- Assemble membrane in a membrane electrode assembly and evaluate performance.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. "Novel Nanocomposite Polymer Electrolyte Membranes for Fuel Cells," presentation made at 2016 Hydrogen and Fuel Cells Program Annual Merit Review meeting.