V.I.3 New High Performance Water Vapor Membranes to Improve Fuel Cell Balance of Plant Efficiency and Lower Costs (SBIR Phase I)

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Fiscal Year (FY) 2012 Objectives

- Demonstrate water vapor transport membrane with >18,000 gas permeation units (GPU)
- Water vapor membrane with less than 20% loss in performance after stress tests
- Crossover leak rate: <150 GPU
- Temperature Durability of 90°C with excursions to 100°C
- Cost of <$10/m^2 at volumes of 2,500 kg/yr

Technical Barriers

- Ionomer membrane performance optimization through improvements in molecular architecture
- Durability improvement
- Scale up of high performance materials to lower cost

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

(A) Durability
(B) Cost
(C) Performance

Technical Targets

The design and development of high performance low cost water vapor membranes for cathode humidification through unique polymer structures was explored. The commercially available 25-µm (N111) and 50-µm (N112) Nafion® membranes do not meet the 18,000 GPU performance target herein, and neither does a Perma Pure™ device made with Nafion® hollow tube membranes. The water transfer permeance target of 18,000 GPU (1 GPU=1x10^{-6} cm^3(standard temperature and pressure)/(cm^2·s·cmHg) is a 50% increase over the 25 µm Nafion® N111. Once the performance is met, the need for minimal crossover, loss in performance, highest durability temperatures and lowest cost will be addressed as outlined in our Phase II proposal. The current status for water permeance is highlighted in Figure 1, in which the 18,000 GPU target was achieved.

TABLE 1. Technical Targets for Water Vapor Transport Membranes

Characteristic	Units	2012 SBIR Targets	Status
Water Permeance	GPU	>18,000	18,319
Crossover leak rate	GPU	<150	<50
Loss in performance	% after stress test	<20	11 after 500 hours
Durability	°C for 20,000 cycles	90	85
Cost	$/m^2	<10	~20

SBIR – Small Business Innovation Research

Approach

Tetramer's basic ionomer technology has been developed for hydrogen ion transport in polymer electrolyte membrane (PEM) fuel cells. Currently Tetramer's semifluorinated ionomer, whose identity will be released after intellectual property is established, has equaled or exceeded the incumbent perfluorosulfonic acid with significant (>50%) cost and processing advantages.

These ionomers have come surprisingly close to meeting the initial target of 18,000 GPU for water vapor permeance in water vapor transport application, but have mechanical deficiencies, which will inhibit making thinner membranes. Higher permeance is always desirable and considering that initially the materials were not at all optimized for water vapor transport, we are optimistic the newly tailored

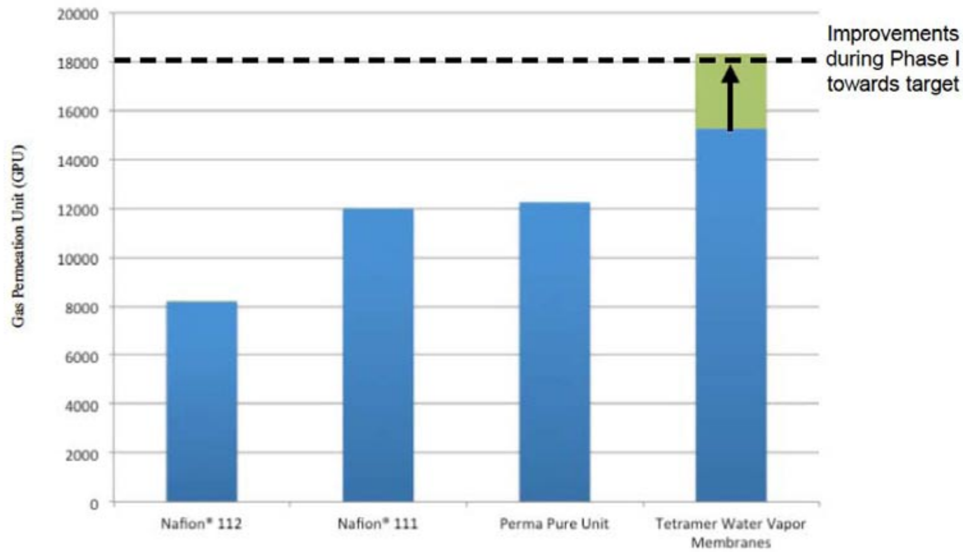

FIGURE 1. Performance of Water Vapor Membranes

versions of ionomers described below will produce improved permeance and durability.

Accomplishments

- Demonstrated that from the 20 new proprietary structures, we were able to exceed the original goal of >18,000 GPU.
- Determined that current polymer structures would not reach the target water vapor permeation or mechanical stability goals.
- Demonstrated the ability to improve structures towards long-term stability through various means.
- Consistently met the target goal of 150 GPU crossover leak rate.
- Passed the 20,000-cycle hours durability test.
- Scaled up the down-selected polymer to the 100 g scale to verify cost projections.

Future Directions

- Increase water vapor transport from 18,000 GPU to 30,000 GPU.
- Utilize initial results to optimize membrane durability to less than 20% loss in performance after 20,000 cycle hours in humidity cycle testing from 0 to 100% relative humidity with 2-minute hold times.
- Use these new molecular architectures to increase Temperature durability from 80°C to 90°C with excursions of 100°C.
- Automotive prototype membrane performance testing in FY 2013.
- Down-selected membranes will be then tested for non-automotive prototype membrane performance using module prototype production.