Sulfonated Diels-Alder Polyphenylenes: Physical Properties and Performance Characteristics in a Hydrogen Fuel Cell

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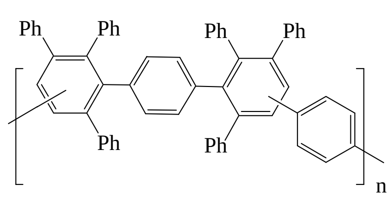
Introduction:

The physical property limitations of perfluoronated polymer electrolyte membranes (PEM) such as Nafion are represented by its poor mechanical properties at temperatures above 80^oC, high methanol flux in direct methanol fuel cells, loss in proton conductivity at elevated temperatures, and high material cost has resulted in a considerable amount of research seeking to solve these material property deficiencies with an alternative polymer electrolyte.[1,2,3] While Nafion is currently the state-of-the-art polymer electrolytes for fuel cells, several alternative polymer electrolyte materials have demonstrated potential as being a viable alternative to Nafion.

Polyphenylenes represent a promising class of thermoplastics, which demonstrate the potential of being used as a PEM within a fuel cell. Furthermore, polyphenylenes synthesized though Diels Alder (DA) polymerizations have the advantages of thermal stability, while maintaining organic solubility making it possible to form mechanically robust films.[4,5,6] The chemistry afforded by the parent DA polyphenylene represents a system that has tunable chemical structure and the potential of adding six sulfonic acid moieties per repeat unit.



Scheme 1. Polyphenylene.

We report here some of the physical properties and preliminary hydrogen and methanol fuel cell performance data of this sulfonated Diels-Alder polyphenylene (SDAPP).

Experimental:

Ion-Exchange Capacity: 0.2 g of acidified polymer was dried and weighed. The sample was then treated with 10 mL of 0.1 M NaOH and stirred for 24 hrs. The sample was then filtered and titrated against 0.01 M HCl.

Water Uptake: The acidified films were immersed in DI water for 24 hrs. at 25 ^oC. They were then blotted dry and weighed (W_s). The films were then dried and weighted until a constant weight was achieved (W_d). Water uptake was calculated by:

$$\textit{Water uptake} = [\, W_s - W_d / W_d] \times 100\%$$

Proton Conductivity: The conductivities were determined in fully hydrated films by AC impedance spectroscopy over a frequency range of $1x10^3$ Hz to $1x10^6$ Hz using a Solartron 1260 gain phase analyzer and Solartron 1287 potentiostat at 25^oC in deionized water.

Fuel Cell Testing: Polarization curves of the membranes were taken on a Fuel Cell Technologies instrument using ulta-pure hydrogen, oxygen, and air as reactant gases.

Results and Discussion:

Sulfonated DA polymers were readily cast into films from NMP. These films were mechanically robust and were creasable after drying in a vacuum oven.

The films displayed proton conductives ranging from 8-115 mS/cm while still maintaining mechanical stability.

IEC (meq/g)	Water uptake (weight %)	λ (H_2O/SO_3H)	Conductivity (mS/cm)
0.98	21	12	8
1.4	36	14	52
1.6	75	19	78
2.2	137	30	115

Fuel cell performance data indicted that the sulfonated DA polymers could obtain high power levels and current densities of 1000 mW/cm^2 at 2000 mA/cm^2 at 80^oC with pure oxygen.

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