Water Uptake and Proton Conductivity of Polyvinyl alcohol/Siloxane Interpenetrating Polymer Networks

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Ideal proton exchange membranes (PEMs) used as electrolytes in fuel cell applications are ones that are thin, have good proton conductivity at low relative humidity's, and have efficient water management properties. PEMs that are used as electrolytes for sensor applications do not have such stringent physical requirements but more so require consistency among sensor components. Here we have studied a series of PEMs for use in breath ethanol sensor applications with the mandatory requirements being sufficient proton conductivity at a range of relative humidity's and the ability for preparation of specific thicknesses that can be incorporated into an existing sensor design. We are proposing a series of membranes that is a combination of poly-vinyl alcohol and polysiloxane polymers. The PVA component contributes flexibility and excellent film forming properties, whereas the sulfonated siloxane provides the required proton conductive properties.[1,2]

Polymer blends are often used when two virgin materials offer complementary desirable properties that are well suited for a particular application, but each on their own exhibit important undesirable characteristics that render them unsuitable for the required application. However, chemical and physical interactions between the polymers may cause the blended materials to form heterogeneous mixtures or possibly phase separate over time. One method that has been shown to effectively offset this predicament is to create interpenetrating polymer networks (IPNs), Figure 1, where two cross-linked polymers are synthesized in the presence of one another. Since the materials are physically, rather than chemically combined, they maintain many of their desirable properties but often new properties emerge as a result of the synergy between the polymers.

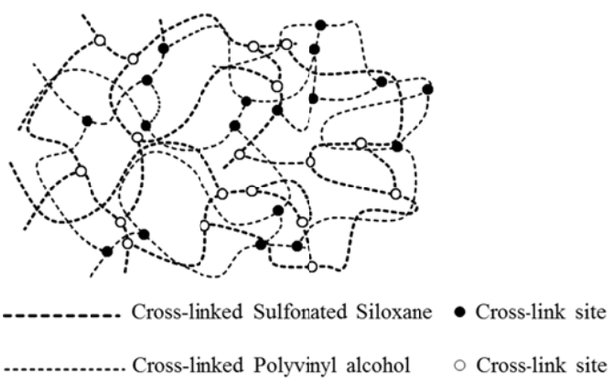

Figure 1. Schematic of an IPN

In this presentation, trends of conductivity and water uptake for two IPN materials that have been subjected to various relative humidity conditions will be discussed. The polymer networks consist of cross-linked polyvinyl alcohol (PVA), in the presence of two different sulfonated siloxane polymers, PVA-CSPMS and PVA-TPS. PVA-CSPMS was synthesized from sol-gel hydrolysis of 2-(4-chlorosulfonyphenyl)ethyltrimethoxysilane (CSPMS), Figure 2a, and PVA-TPS from sol-gel hydrolysis of 3-(trihydroxysilyl)-1-propanesulfonic acid (TPS), Figure 2b.

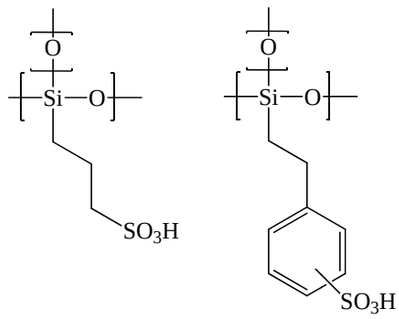

Figure 2. a) TPS b) CSPMS

Homogeneous proton conductive flexible films were obtained for both IPNs using a PVA:Silane mixture containing 50:50 wt%. Both IPN materials absorb extreme amounts of water (200%+) when fully hydrated yet remain insoluble. However, they have thus proved to be too fragile to allow measurement of proton conductivity. Both IPNs exhibit promising conductivity, and an improvement in physical properties, when subjected to conditions in the range of 80 - 95% RH, Figure 3. However, the percolation threshold is reached below 80% RH and the materials exhibit insignificant proton conductivity and become extremely brittle and crack easily.

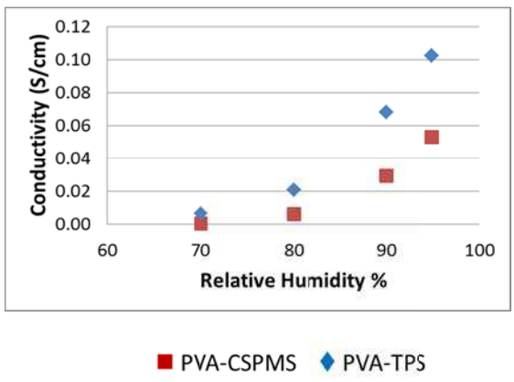

Figure 3. Conductivity of PVA-Siloxane IPNs under 80-95% relative humidity conditions.

References

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