Proton Conducting Electrolytes for HT-PEMFC

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to develop a novel inorganic electrolyte with high proton conductivity under high temperature and low humidity to be used in the cathode catalyst layer of high temperature proton exchange membrane fuel cell (HT-PEMFC) to overcome the phosphoric acid (H_3PO_4) leaching issue. Operation of PEMFCs at HTs would facilitate meeting U.S. Department of Energy's (DOE) technical targets for performance, power and energy density, cost, and liability by inhibiting the poisoning effects of air pollutants and fuel impurities and simplifying the system's water and heat management.

BACKGROUND: PEMFCs are considered a promising clean energy technology for transportation and stationary applications. Contaminants in air and hydrogen fuel are a major challenge for the Pt catalysts in a typical PEMFC when it is operated in the realistic atmosphere. HT operation (150-200°C) of PEMFCs has been considered as one of the potential solutions to mitigate the poisoning effects due to the high conversion rate or weak adsorption of the contaminants. HT operation also facilitates the heat transport and the mass transfer of oxygen and hydrogen because of the large temperature difference and the absence of liquid water in membrane electrode assembly (MEA), respectively. With those advantages, HT-PEMFCs also eliminate the humidifier and simplify the air and fuel supply and the cooling system. However, the current perfluorosulfonic acid (PFSA, Nafion®) polymer electrolytes are limited in application below 90°C. The high temperature polymer PBI doped with H_3PO_4 (H_3PO_4/PBI) has been used as the PEM and the electrolyte in the catalyst layer of HT-PEMFC. However, H_3PO_4 leaching is a major issue during operation, especially from the cathode catalyst layer.

Recently, layered inorganic materials with "water in solid" have been developed as proton conducting electrolytes for the proton battery. The hydrogen bond switching among the ligand water provides a fast proton transport network in mutilayer structures (Figure 1). The proton conducting materals can also be used in the catalyst layers of the HT-PEMFC.

PROJECT STATUS/RESULTS: At HNEI, novel inorganic layered structure materils are being developed as proton conducting electrolyte. The materials will be integrated into the in the cathode catalyst layer of HT-MEAs to overcome H_3PO_4 leaching issue for the contaminant tolerant FCs in harsh environments.

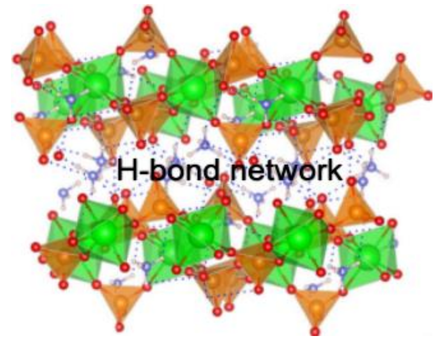

Figure 1. H-bond network in the layered structures of the inorganic proton conducting materials.

Currently, the proton conducting electrolyte powders (Figure 2) were obtained by a fluxing method. The production yield was improved from ~5% to ~50% by optimizing the conditions of synthesis, and material production is scaled up to 2 grams per batch. The electrolyte powder pellet (Figure 2B and 2C) shows a bulk proton conductivity of $\sim10^{-3}$ Scm^{-1} and a particles boundary conductivity of $\sim10^{-6}$-10^{-4} Scm^{-1} in the range of from room temperature to 150°C (Figure 3). The conductivity increases with the rise of temperature. The properties of the materials: thermal and chemical stability, composition and solubility, and the particles size impact on the proton conductivity were further analyzed and evaluated.

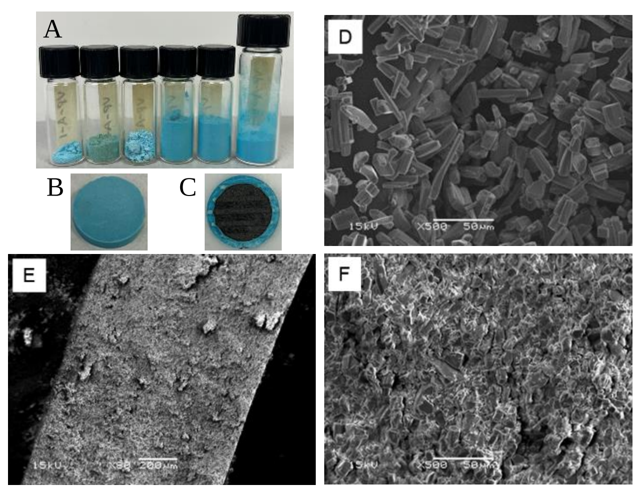

Figure 2. The pictures of the proton conductor powders (A) and the pellet (B, C). and the SEM images of the powders (D) and the cross-section of the pellet (E, F).

The material is insoluble in water, and thermal stable up to 300°C in inert or air environment, as well as electrochemically stable within the PEMFC cathode operating potential range but not below -0.1V or H_2/Pt environment. The proton conductivity in boundary/interface increases with the particle size decrease.

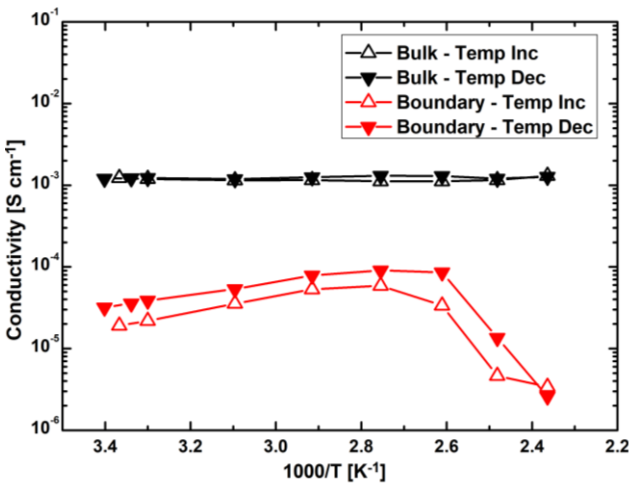

Figure 3. The bulk and boundary proton conductivity of the proton conducting particles at temperature 20-150°C.

Additionally, with collaboration of industrial and academic partners, a three-year $4M fuel cell project titled with "High Performing and Durable MEAs with Novel Electrode Structures and Hydrocarbon Proton Exchange Membranes" was awarded by U.S. DOE-EERE.

In the future, the properties and performance of the materials will be further studied and improved with the optimization the synthesis procedures. The selected materials will be integrated into the cathode catalyst layers of HT-MEAs. The performance of HT-PEMFC with new proton conductive materials will also be evaluated at 150-200°C.

Funding Source: Office of Naval Research

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Last Updated: November 2024