



Hawai'i Natural Energy Institute Research Highlights

Electrochemical Power Systems

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 HT 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 ($150\text{-}200^\circ\text{C}$) 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 the large temperature difference and the absence of liquid water in the cell, respectively. With those advantages, HT-PEMFCs would 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 application below 90°C . The high temperature polymer PBI doped with H_3PO_4 ($\text{H}_3\text{PO}_4/\text{PBI}$) 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 multilayer structures (Figure 1). The proton conducting materials can also be used in the catalyst layers of the HT-PEMFC.

PROJECT STATUS/RESULTS: At HNEI, novel inorganic layered structure materials are being developed as proton conducting electrolyte. The candidate will be integrated into the in the cathode of

HT membrane electrode assemblies (MEAs) of the contaminant tolerant FCs for harsh environments.

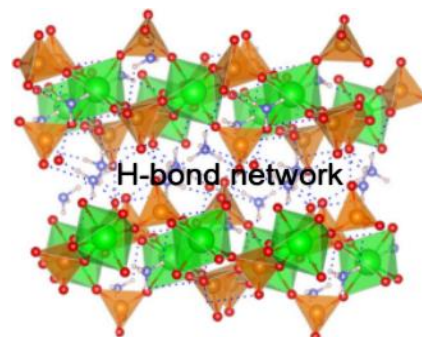


Figure 1. H-bond network in the layered structures of the inorganic proton conducting materials.

Currently, the proton conducting electrolyte powders (Figure 2a) were obtained by a fluxing method. The production yield was improved from $\sim 5\%$ to $\sim 50\%$ by optimizing the conditions of synthesis. With the preliminary tests, the electrolyte powder pellet (Figure 2b and 2c) shows a bulk proton conductivity of $\sim 10^{-3} \text{ Scm}^{-1}$ and a particles boundary conductivity of $\sim 10^{-5} \text{ Scm}^{-1}$ in the range of from room temperature to 150°C (Figure 3). The conductivity increases with the rise of temperature.

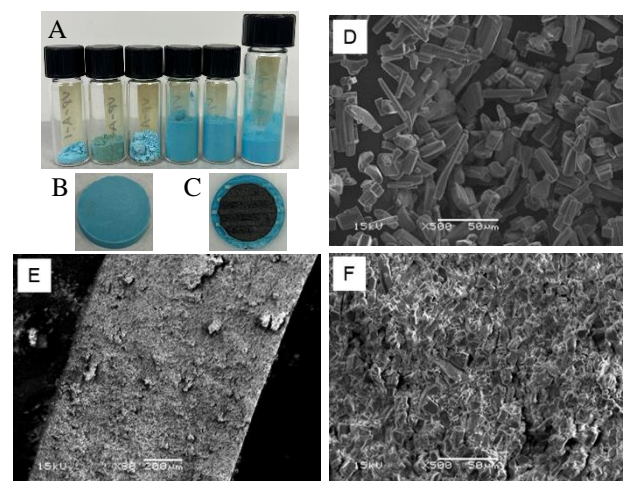


Figure 2. The pictures of the proton conductor powders (A) and the pellet (B, C), and the SEM images of the powders (D) and the cross-section of the pellet (E, F).

Additionally, with collaboration of industrial and academic partners, a proposal titled with “High Performing and Durable MEAs with Novel Electrode Structures and Hydrocarbon Proton Exchange Membranes” was submitted to the U.S. DOE for addressing: Hydrogen and Fuel Cell Technologies

Office FOA in Support of Hydrogen Shot (DE-FOA-0002920), Topic Area 4: High Performing and Durable Membrane Electrode Assemblies for Medium- and Heavy-Duty Applications. The proposed research was selected for a \$4M award in three years.

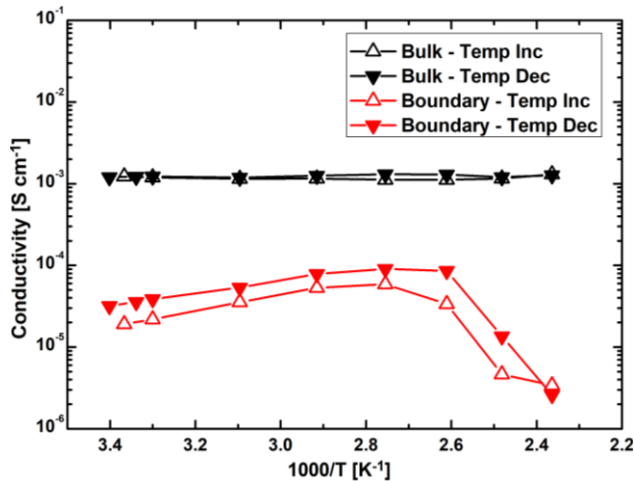


Figure 3. The bulk and boundary proton conductivity of the proton conducting particles at temperature 20-150°C.

In the future, HNEI plans to characterize the materials structures, composition and stability. 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.

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