



Hawai'i Natural Energy Institute Research Highlights

Electrochemical Power Systems

Proton Conducting Electrolytes for HT-PEMFCs

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 cells (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, inorganic materials with “water in solid” or “electron hole defects” have been developed as proton conducting electrolytes for the proton batteries or the electrochemical sensors. The hydrogen bond switching among the ligand water or defect sites provide a fast proton transport network in multilayer structures or on the particle surface. These proton conducting materials can also be used in the catalyst layers of the HT-PEMFC.

PROJECT STATUS/RESULTS: At HNEI, novel inorganic materials have been developed as a proton conducting electrolyte for HT-PEMFCs. These include a multilayer structure material, referred to as “VP”; and another based on ceramic nanoparticles, referred to as “SP.” Some of the candidates electrolytes show a good proton conductivity at 20-200°C and low relative humidity. The selected candidates will be integrated in the cathode catalyst layer of HT-MEAs to overcome H_3PO_4 leaching and contaminants poisoning issues for the contaminant tolerant PEMFCs.

The yields of the proton conducting electrolyte powders have been improved from ~5% in the initial work to ~50% by optimizing the conditions of synthesis and scale up of the materials production to 10 grams per batch. The proton conductivity of the materials was preliminarily evaluated with single cell hardware and then a special conductivity test platform. The properties of the materials (thermal and chemical stability, composition and solubility, and the particles size impact on the proton conductivity) were initially analyzed and evaluated. Microscope images of the proton conducting powder/particles are shown in Figures 1 and 2.

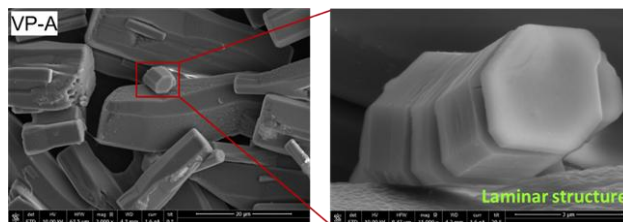


Figure 1. The scanning electron microscopy (SEM) images of VP powders.

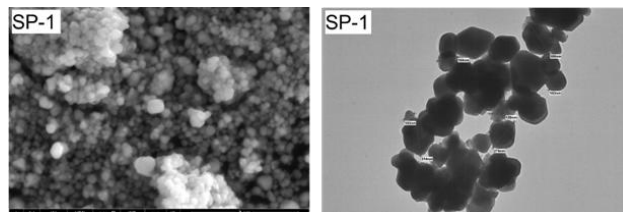


Figure 2. The SEM and transmission electron microscopy (TEM) images of SP particles.

The electrolyte powder pellets demonstrate a proton conductivity of $\sim 10^{-3} \sim 10^{-5} \text{ Scm}^{-1}$ in the range of from room temperature to 200°C and low relative humidity. Figure 3 shows the representative results of the two materials without humidification. It can be

seen that the conductivity of both pellets increases with the rise of temperature, and SP material has better performance than the VP-A material within the overall testing temperature range.

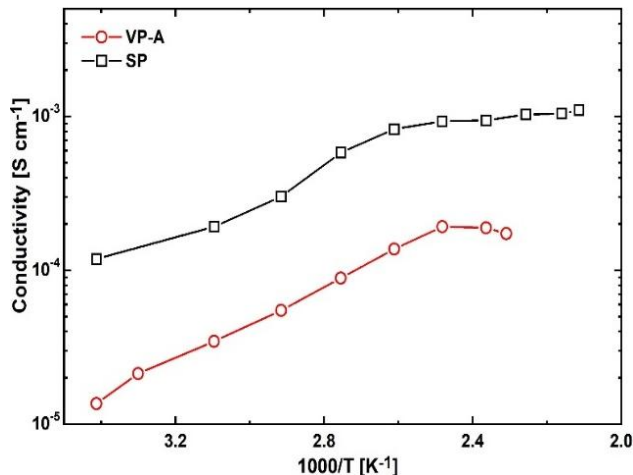


Figure 3. The proton conductivity of the proton conducting material pellets at temperature 20-200°C without humidification.

Both of the materials are insoluble in water or low concentration acids, and thermal stable up to 300°C in inert or air environment. VP-A is electrochemically stable within the PEMFC cathode operating potential range but not below -0.1V or H₂/Pt environment. The proton conductivity in boundary/interface increases with the particle size decrease.

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In the future, the properties and performance of the materials will be further studied and improved with the optimization of the synthesis procedures. The powder/particle will be reduced in size to meet the MEA catalyst layer requirements and then integrated into the cathode catalyst layers of HT-MEAs. The performance of HT-PEMFC with the selected proton conductive materials will also be evaluated at 150-200°C.

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