

CsH₂PO₄-based Solid Acid Fuel Cells

Tetsuya Uda, Dane A. Boysen, Calum R.I. Chisholm,
Kenji Sasaki & Sossina M. Haile*

Materials Science, California Institute of Technology,
Pasadena, California 91125

* Corresponding Author, E-mail smhaile@caltech.edu

Solid acids are a new class of proton conducting electrolytes under consideration for fuel cell applications. Recently, the performance of fuel cells based upon the solid acid cesium dihydrogen phosphate (CsH₂PO₄) has been demonstrated [1]. These solid acid-based fuel cells (SAFCs) have numerous advantages as a result of their intermediate operational temperature (230-300 °C) over current polymer electrolyte membranes fuel cells (PEMFCs) under development, including: 1) more efficient cooling; 2) higher tolerance to catalyst poisons, such as CO; 3) reduced activation overpotentials at the electrode; 4) the possibility for alternative non-precious metal catalysts; and 5) the possibility for heat cogeneration to yield higher efficiencies. In addition, the anhydrous proton transport exhibited by solid acid electrolytes eliminate the need for complex hydrations systems ultimately leading to simpler, more efficient fuel cells.

Solid acid CsH₂PO₄ undergoes a superprotonic phase transition upon heating at 231°C, in which the conductivity increase by several orders of magnitude to a value of approximately 1.3 - 2.0 x10⁻² S/cm (at 235 °C). CsH₂PO₄ is chemically stable in hydrogen and oxygen atmospheres, but begins to dehydrate at elevated temperatures (> 230 °C) and ambient atmospheres. In Fig. 1 the dehydration pressure (p_{H₂O}) is shown as function of temperature (T). From these results, dehydration can be suppressed by a water partial pressure of ~ 0.1 atm (equal to the vapor pressure of water at 47 °C) is sufficient to suppress the dehydration of CsH₂PO₄ up to 250 °C.

Previously, we reported the results of 100 hrs of stable power generation from fuel cell using CsH₂PO₄ electrolyte in a H₂/O₂ configuration and humidified gasses [1]. Shown in Fig. 2 are typical results of cell voltage change for 35 hrs power generation(100mA/cm²) using a 260 μm thick CsH₂PO₄ membrane. There is no apparent degradation in performance.

Continued experimental efforts have been focused on optimizing the processing and structure of SAFC membrane electrode assemblies (MEAs). A new MEA structure, in which a thin solid acid electrolyte is sandwiched by two porous stainless steel disks, has been developed. Presented in Fig. 3 is a typical I-V curve of SAFC utilizing a stainless steel supported 100 μm CsH₂PO₄ electrolyte layer. The peak power and short circuit current densities were 134 mW/cm² and 528 mA/cm², although some improvement of gas diffusion efficiency and more reliable sealing or reducing micro cracks is needed still.

In this presentation, the physiochemical properties of CsH₂PO₄, the performance of new MEA SAFC structures, and improvements to the electrocatalyst composition for SAFCs will be covered.

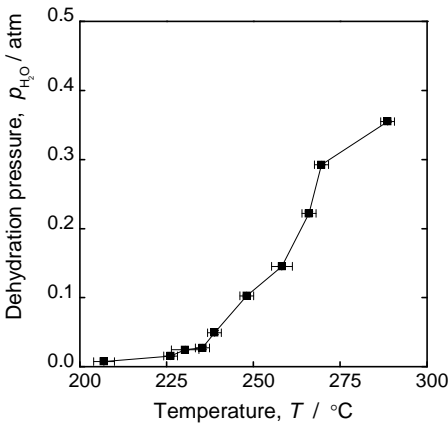


Fig.1 Dehydration pressure of CsH₂PO₄ as function of temperature.

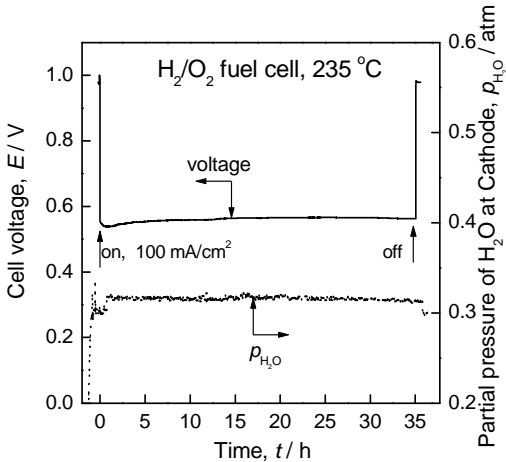


Fig.2 . Stability test of 260 μm thick membrane with drawing 100 mA/cm² continuous current for 35 hours. Cell voltage and water partial pressure as a function of time is shown. The cell was operated at 235°C under humidified H₂ and O₂ gases flowing 50 sccm. A total pressure of 1 atm was maintained at the anode and cathode, respectively.

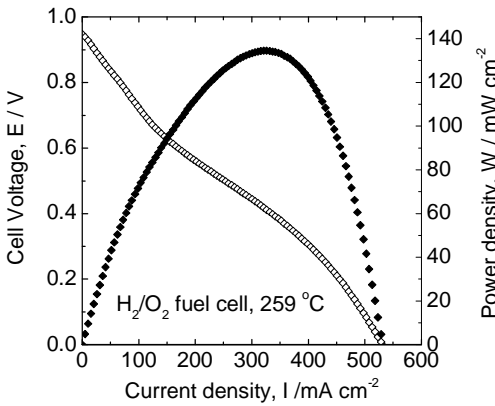


Fig.3 Cell voltage and power density curve of a 100 μm thick CsH₂PO₄ membrane supported by porous stainless steel. The cell was operated at 259 °C under humidified H₂ and O₂ gases flowing 50 sccm. A total pressure of 1 atm was maintained at the anode and cathode, respectively. Pt loadings in electrode-catalyst was 7.6 mg/cm² on each side.

[1] D.A. Boysen, T.Uda C.R.I. Chisholm & S. M. Haile : *Science*, **303**(2004), 68-70.