Investigation of Phosphate Compounds for Use in Medium Temperature Fuel Cells and Electrolyzers

By Daniel Risskov Sørensen

The transition from a fossil fuel based energy sector, to one based on renewable energy, is a central topic in the 21st century. Renewable energy sources are mainly wind and solar energy, but the production of electricity from these sources are often in remote locations. Fluctuations in the weather cause the production output to be unreliable and fossil fuel based energy sources are required to take over at times of low production. Electrochemical cells are expected to play a major role in 'smoothing out' the renewable energy production. Surplus energy from wind mills can be used to run water electrolysis cells in which the current splits water molecules into hydrogen and oxygen molecules. Hydrogen is then stored as chemical energy and can be used to do work when needed. A fuel cell is the opposite of the electrolysis cell, where a fuel is oxidized to produce electric current. A fuel cell can thus use the hydrogen produced by electrolysis to feed electricity back into the grid at peak demand. It can also be used for mobile applications such as cars, laptops, hearing aids etc. The fuel cell and electrolyzer cells thus provide a very versatile use of renewable energy.

So far, fuel cells and electrolyzers have largely been divided into cells working at low temperature (below 200 °C) and cells working at high temperatures (650-1000°C). Cells working at low temperatures need expensive catalysts but are suitable for mobile applications. Cells working at high temperatures are only suitable for stationary applications and need expensive support materials but the efficiency is good and the catalysts are relatively inexpensive. A gap has existed between cells working at high and low temperatures, but recent research shows promise in developing cells working at medium temperatures (200-500 °C). It is hoped that cells working in this temperature range will have many of the advantages of high- and low-temperature cells and few of their disadvantages. In the electrochemical cells it is often the ion-conducting electrolyte membrane which determines the operation temperature. For medium temperature cells, the compound class known collectively as solid acids have shown promise. They are proton conductive, and exhibit large conductivities at medium temperatures. Unfortunately their mechanical properties are poor. In this project, the solid acid, CsH_2PO_4, was mixed with hard inexpensive SiC-whiskers to increase the overall strength, much like steel wires increase the overall strength in reinforced concrete. It was shown that the addition of SiC-whiskers can improve the mechanical strength of pellets made of CsH_2PO_4.

Another class of phosphates that have shown promise is the metal pyrophosphates. Especially the tin pyrophosphates have shown high conductivities. Fuel cell tests with tin pyrophosphates as the electrolyte membrane have been reported in the literature, but no reports have been made of electrolysis tests. In the project it is shown that it is possible to construct an electrolyzer working at 200 °C with tin pyrophosphates as the electrolyte membrane.