Integrated Methanol Steam Reformer/Solid Acid Electrochemical Hydrogen Compressor

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Recently electrochemical hydrogen compressor (EHC) has been investigated for the compression of hydrogen. Compared with a mechanical compressor, there is no moving part in the EHC. The EHC has increased reliability and improved efficiency. However, these works are based on perfluorosulfonic acid polymer membranes such as Nafion, which operates at approximately 80 °C. Carbon monoxide poisoning is an issue at this temperature, and the EHC cannot purify hydrogen containing more than several tens of ppm CO.

UltraCell has developed portable reformed methanol fuel cell (RMFC) systems with electrical powers ranging from 25 to 150 W. These products have gone through extensive military specification tests and field trials. In an RMFC system, methanol is first converted into hydrogen by methanol steam reforming (MSR). The resulting reformate is then supplied to a high temperature polymer electrolyte membrane fuel cell without further purification.

Methanol steam reforming is a widely studied reaction to produce hydrogen. The typical catalyst is Cu/ZnO, and reaction temperature is 250 – 300 °C. The products of MSR include hydrogen, carbon monoxide, and carbon dioxide. The hydrogen-rich reformate needs to be further purified before it is fed into a polymer electrolyte membrane fuel cell (PEMFC).

The solid acid is a new class of proton conducting electrolyte for fuel cell applications. A solid acid comprises hydrogen bonded oxyanions and metal cations. The solid acid such as cesium dihydrogen phosphate (CsH_2PO_4) undergoes a superprotonic phase transition at elevated temperatures where the conductivity increases by several orders of magnitude to approximately 10^{-2} S/cm. The operating temperature for the solid acid electrolyte, cesium dihydrogen phosphate, is 230 – 280 °C, which is very close to the reaction temperature of the methanol steam reforming.

In the project, an electrochemical hydrogen compressor based on cesium dihydrogen phosphate electrolyte has been built and demonstrated to separate hydrogen from a reformate containing more than 2 % CO.

The high operating temperature of solid acid based EHC makes it possible to directly combine methanol steam reformer and EHC into one unit. An integrated MSR/EHC has been built and tested in the project (Figure 1 and 2). This device combines reaction, separation, and compression into one unit. The device has been demonstrated to generate, separate, and compress hydrogen from methanol. The MSR/EHC can be a fuel processing system integrated into a fuel cell system. The device can also be a stand-alone hydrogen generator. The technology has potential to be used in fuel processing systems providing pure hydrogen at high pressures.

The experimental and results of the solid acid based EHC and integrated MSR/EHC will be discussed in details in the presentation.

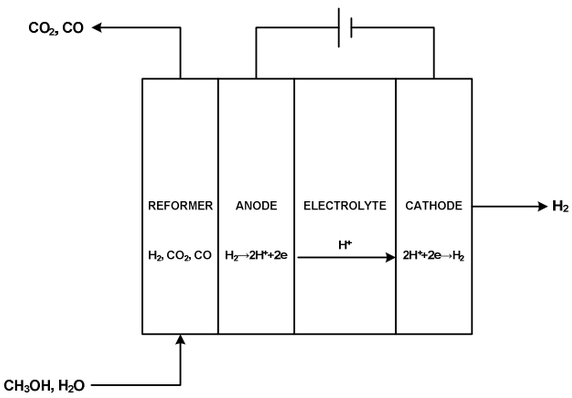

Figure 1. Schematic of integrated MSR/EHC

Figure 2. Five-cell integrated MSR/EHC device