PEMFC Electrode Layer Modifications for Improved High-Temperature Performance

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PEMFC operation at high-temperature, 120°C to 150°C, in an under-saturated environment will accelerate PEMFC commercial viability. System efficiency increases as higher temperature enhances kinetic reaction rates and carbon monoxide tolerance, allows cogeneration using high-quality waste heat, and facilitates heat transfer. However, at constant pressure, water vapor increasingly displaces reactants as the reactant gas saturation temperature increases with the cell operating temperature, which is required to maintain full hydration of the proton exchange membrane electrode assembly (MEA). Dehydration of the state-of-the-art polymer electrolyte, Nafion, within the MEA decreases ionic conductivity, inhibits the oxygen reduction reaction, and limits carbon monoxide tolerance. The UConn MEA recipe uses solid proton conductors to decrease polymer water vapor pressure, and to provide more water-independent ionic conduction.

Several factors that limit performance of the present UConn MEA in an under-saturated environment have been identified using an empirically based theoretical model. Table 1 presents polarization losses incurred at 400mA/cm^2 by the UConn MEA operating at various conditions of pressure and temperature.

Cell Operating Pressure	**1 Atm.**	**3 Atm.**	**3 Atm.**
Cell Operating Temperature	**80 °C**	**120 °C**	**140°C**
Reactant Gas Saturation Temperature	**80 °C**	**120 °C**	**120°C**
Substrate Polarization (mV)	10	15	16
Electrode Ionic Resistance Loss (mV)	18	17	24
Electrode Diffusional Loss (mV)	32	18	60
Activation Overpotential (mV)	416	392	406

Table 1: Separation of electrochemical phenomena that cause fuel cell performance loss at high-temperature.

Activation polarization of the cathode electrode is the dominant inefficiency. Although one expects catalytic activity to increase with rising temperature, polymer electrolyte dehydration that may accompany elevated temperature decreases the overall catalyst utilization in the PEMFC. UConn data[1] demonstrate that activation polarization is not significantly increased by operation at 140°C, with reactants under-saturated at 120°C, at three atmospheres operating pressure. However, the 140°C MEA suffers increasing diffusional polarization and ionic resistance in the under-saturated environment provided by reactants saturated at 120°C. Hygroscopic solid proton conductors incorporated within the electrode polymer electrolyte support oxygen reduction kinetics and carbon monoxide tolerance in the under-saturated environment as they lower water vapor pressure, increase electrode ionic conductivity and increase electrode oxygen permeability.

The present research incorporates solid proton conductors such as phosphotungstic acid or zirconium hydrogen phosphate within the MEA electrode, as well as within the MEA proton-exchange membrane, to enhance PEMFC performance in an under-saturated operating environment. In particular, the effect of electrode composition on the oxygen reduction reaction rate and on carbon monoxide tolerance in an under-saturated environment will be reported.

[1]Y. Si, J.M. Fenton, H.R. Kunz, The 199th Meeting of the Electrochemical Society, Inc., Abstract #116 March 25-29, 2001.