Assessing Performance and Degradation in PEM Fuel Cells by Electrochemical Impedance

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Proton Exchange Membrane (PEM) Fuel Cells operate under very aggressive conditions in both anode and cathode environments. Failure modes and mechanism in PEM fuel cells include those related to thermal, chemical or mechanical issues that may constrain stability, power and lifetime. Even though the number of installed units around the world continues to increase and dominate the pre-markets, the present lifetime requirements for fuel cells cannot be guarantee, creating the need for a more comprehensive knowledge of material's ageing mechanisms.

Diagnostics methods and tools used for in-situ and ex-situ analysis of PEM fuel cells are discussed in order to better categorize irreversible changes in the kinetic and/or transport properties of the cell after fuel cell ageing in extreme testing conditions with particular emphases in Electrochemical Impedance spectroscopy (EIS).

EIS is found to be instrumental in the identification of fuel cell flooding conditions and membrane dehydration associated to mass transport limitations / reactant starvation and protonic conductivity decrease, respectively. The influence different oxidant supply concentrations, fuel flow rate and pressure were studied over a wide range of current densities along the stack polarisation and power curves.

Membrane degradation in fuel cell environment is analyzed in terms of the mechanism for fluoride release which is considered an early predictor of membrane degradation. Peroxide radical attack generated from hydrogen peroxide during the oxygen reduction reaction is thought to be on the basis of extensive fluorine loss. EIS measurements are complimented by SEM and EDAX element mapping of cell cross sections.

The case of fuel starvation is also examined. The anode potential may rise to levels compatible with the oxidization of water. If water is not available, oxidation of the carbon support will accelerate catalyst sintering. Cross sections of the membrane catalyst and gas diffusion layers examined by scanning electron microscopy indicate electrode thickness reduction as a result of ageing. Catalyst particles are found to migrate outwards and located on carbon backings.

The application of diagnostic techniques such as EIS is found paramount in order to aid design and operating strategies in PEM fuel cells.

Keywords: PEM Fuel Cells, degradation mechanisms, membrane failure, fuel starvation, catalyst deactivation