PEM FUEL CELLS: IMPACT OF MATERIALS AGEING ON PERFORMANCE AND LIFETIME

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ABSTRACT:

Due to their high power density, low operating temperature and high power-to-weight ratio, PEM fuel cells are considered promising power sources. As the technology matures and the timescale for commercialization continues to decrease, durability, reliability and cost are amongst the most critical issues to be tackled.

The mechanisms of fuel cell degradation are not well understood. Even though the numbers of installed units around the world continue 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 mechanism.

In this work, failure modes and mechanism in PEM fuel cells are reviewed including those related to thermal, chemical or mechanical issues that may constrain stability, power and lifetime.

PEM fuel cell operates under very aggressive conditions in both anode and cathode. Increase in cell voltage leading to higher efficiencies may lead to surface oxidation of the catalyst, decreasing reaction activity and accelerating catalyst degradation. In the case of fuel starvation, 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.
Water management has a major impact on PEM fuel cell performance. Inappropriate relative humidity conditions lower performance and efficiency and may lead to irreversible degradation of catalyst and membrane.

Diagnostics methods and tools used for in-situ and ex-situ analysis of PEM fuel cells will be discussed in order to better categorize irreversible changes in the kinetic and/or transport properties of the cell.

Data regarding membrane electrode assembly (MEA) degradation obtained during and after fuel cell ageing in extreme testing conditions will be discussed. Electrochemical Impedance Spectroscopy (EIS) is found instrumental in the identification of fuel cell flooding conditions and membrane dehydration associated to mass transport limitations / reactant starvation and protonic conductivity decrease, respectively. 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.

Nafion degradation in fuel cell environment is analysed 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. In this context gas crossover issues will be also examined.

Apart from the need to apply a full range of diagnostic techniques the contribution of mathematical modeling in PEM fuel cells will be emphasized, since they play an important role in the prediction of conditions for a better thermal and water management and in aiding design and operating strategies in PEM fuel cells.

Keywords: *PEM fuel cells, durability, reliability, ageing mechanism.*