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PEM FUEL CELLS: MATERIALS AGEING MECHANISMS AND PERFORMANCE IMPACT

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Abstract

Polymer exchange membrane (PEM) fuel cells are considered promising power sources, with a vast application domain that includes consumer electronics, automotive and residential applications. As the technology matures, durability, reliability and cost are amongst the most critical issues, so creating the need for a more comprehensive knowledge of material's ageing mechanism.

In this work, the Membrane-Electrode Assembly, MEA, is considered a key component subject to material's ageing with considerable impact on fuel cell performance. As it contains the polymer electrolyte membrane, the active catalysts and the gas diffusion layers (GDL), the mechanisms of degradation are complex. Furthermore, performance is also link to components such as gas distributor plates, since the used design and flow channels dimensions (channel width, channel depth, rib width) allow minimization of the diffusion pathway for gases. Effective oxidant supply and water management is greatly affected by cell geometry and materials.
In-situ and ex-situ evaluation of MEA degradation were conducted after fuel cell ageing in extreme testing conditions. Humidified and dry gas feeds were also examined and the effect on cell performance and membrane conductivity examined. Variations of membrane conductivity with temperature and water content were considered critical: drying during operation as a result of dragging of water by protons or over saturated conditions cause condensation at the electrodes causing flooding with the consequent voltage degradation. Electrochemical Impedance Spectroscopy was found instrumental in the identification of flooding conditions using an equivalent circuit to model the interfaces at critical current densities, according to the location of identified irreversibility's in the voltage-current domain of the fuel cell.
Electrocatalyst surface area loss due to growth of catalyst particle size and particle agglomeration with the number of load cycles is suggested when using cyclic voltammetry of electrodes, this is thought to be due to a mechanism involving catalyst dissolution/precipitation.
Cross sections of the membrane catalyst layers and GDL´s were examined under a FEG-SEM indicating that cathode thickness is considerably reduced as a result of ageing. Catalyst particles were found to migrate outwards and located on carbon backings. Fluoride release was considered as an early predictor of membrane degradation, quantified using an ion selective at gases outlet.

MEA degradation mechanisms are discussed together with contributions that might aid design and operating strategies in PEM fuel Cells.

References

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