

Modeling the effect of chemical membrane degradation on PEFC performance

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An isothermal, two-dimensional (2D) model for the chemical degradation of a polymer membrane in a polymer electrolyte fuel cell (PEFC) is developed. The model is based on the conservation of charged and neutral species, including radicals. At this stage of development the model is applicable to cases where localized mechanical-stress and/or thermal effects are negligible. Simulation of the degradation rate (defined as the loss of cell voltage with time at a fixed cell operating condition and at a point of time with a known degradation history) under varying operating conditions encompassing a range of relative humidity, pressure, species concentration, material characteristics and cell current match qualitatively with the degradation rates reported in the literature.

In the past increased rates of crossover H_2 and O_2 in the membrane due to membrane degradation have been neglected¹. This would lead to underestimation of the performance losses due to undervalued measure of the concentration gradient, as is observed in our results. This can also have important implications for the overall degradation rate of the membrane. Moreover, the reaction involving crossover species in the catalyst layers can potentially lead to hydrogen peroxide and/or direct radical formation and subsequently polymer degradation within the volume of the membrane. The exact nature and selectivity of the reactions, chemical and/or electrochemical, depends on local species concentration, potential distribution and operating conditions².

Preliminary analysis of the various irreversible voltage losses identified some of the main contributors to the voltage loss as: crossover of gaseous species and reduction in ionic conductivity due to loss of charged sites. Other contributors to the overall voltage loss, likely minor, are deterioration in catalyst active surface area, increase in contact resistance and increased overpotential to concentration dependent kinetics due to the loss in transport properties of the porous media.

Ongoing work aimed at achieving quantitative linkages between membrane degradation and performance is also discussed and includes 1) incorporating the effect of mechanical stressors on degradation and, 2) accounting for non-isothermal effects and their coupling with chemical degradation.

References:

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