Determining Degradation in Solid Oxide Fuel Cells Electrode Materials Using COMSOL Multiphyics® Software

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Abstract

Solid Oxide Fuel Cells (SOFCs) are one of the most attractive technologies for meeting our future energy demands. They promise the efficient conversion of chemical to electrical energy and are a growing area of both academic and industrial interests. Typical electrode-supported SOFCs consist of three key components, two porous functional electrode layers (anode and cathode) and one dense electrolyte layer. In particular, the microstructures of the electrodes and their interfaces with electrolytes are of crucial importance for the performance of the cell. They not only affect the overall electrode kinetics and thus the electrochemical reaction efficiency, but also the mechanical properties, which greatly influence the durability of SOFCs.

However to date, the direct link between the detailed microstructures and the mechanical properties of SOFC functional electrodes remain poorly understood. Through using experimentation, high resolution 3D tomographic techniques and 3D modeling it is possible to evaluate structure-performance relationships. In the present work, nanoindentation is performed on each component to examine the mechanical properties (elastic modulus and fracture) and their interfacial adhesion to the dense electrolyte.

Real microstructure of the electrodes obtained through advanced imaging techniques can be imported into COMSOL Multiphysics®. The elastic properties of the 3D microstructures are then computed by finite element modeling (FEM) using COMSOL. Then the computed elastic moduli are compared with the measured values and the results interpreted in terms of mechanical models of porous electrode materials. The work shows computational modelling is an effective tool to compute values and distributions of stress/strains allowing direct understanding of how electrode microstructure affects performance and evaluating sources of degradation and cell failure.