

UNDERSTANDING THE ELECTROCHEMICAL CHARACTERISTICS OF SOLID OXIDE FUEL CELLS WITH Ni/YSZ CERMET ANODES

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Introduction and approach

Ceramic-metal composites (*cermets*) are typical materials for solid oxide fuel cell (SOFC) anodes [1]. Nickel/yttria-stabilized zirconia (Ni/YSZ) cermets have been used since 35 years and are today standard materials for high-temperature SOFCs. Due to their technical importance, they have been studied extensively both in experiment [2,3] and theory [4]. We present the development, validation and application of a multi-scale model for the detailed description of SOFCs with Ni/YSZ cermet anodes for the identification of the physicochemical loss processes, as seen in impedance spectra and polarization curves. The model consists of an elementary kinetic description of the electrochemistry including the the electrical double layer at the electrode/electrolyte interface of the cermet anode, a homogenized description of charge and gas-phase transport in the electrodes as well as a macroscopic description of convective and diffusive mass transport in the gas phase above the electrodes. This study thus allows for a model-based interpretation of the impedance spectra and polarization behavior of SOFCs with cermet anodes.

Results – Symmetrical cells

The electrochemical impedance of Ni/YSZ cermet anodes is generally observed to consist of multiple features that can span the entire frequency range from Hz to MHz. In order assign the origin of these features, we compare simulations with impedance experiments on symmetrical cells by Sonn et al. [2] (Fig. 1). Using sensitivity analysis and model reductions, the physical model allows the assignment of the physical origin of the three observed impedance features: (1) Distributed charge transfer and electrical double layer (~5 kHz); (2) gas diffusion in the cermet and current collector mesh (~1 kHz); (3) gas diffusion in the supply channels (~6 Hz). Two-dimensional spatial and temporal evolution of electrical current, potential, gas composition, and loss processes during the impedance measurement are visualized.

Results – Segmented SOFC

Spatially inhomogeneous distributions of current density and temperature can contribute significantly to accelerated electrode degradation, thermomechanical stresses, and reduced efficiency. In order to determine local effects and to identify critical operating conditions, the model was extended to account for the description of segmented SOFCs investigated experimentally by Schiller et al. [3]. The model was validated by comparison to experiments

under a wide range of operating conditions. When the cell was operated at high fuel utilization, both measurements and simulations show a strong variation of the electrochemical performance along the flow path (Fig. 2). The simulations predict a considerable gradient of gas-phase concentrations along the fuel channel and through the thickness of the porous anode.

Conclusions

The combination of physically based models with specialized experiments has allowed a detailed understanding of the electrochemical characteristics of SOFCs with Ni/YSZ cermet anodes in terms of both impedance and polarization behavior.

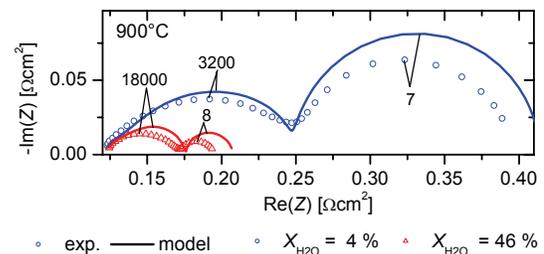


Fig. 1: Simulated and experimental [2] impedance spectra of a symmetrical SOFC with Ni/YSZ cermet anodes

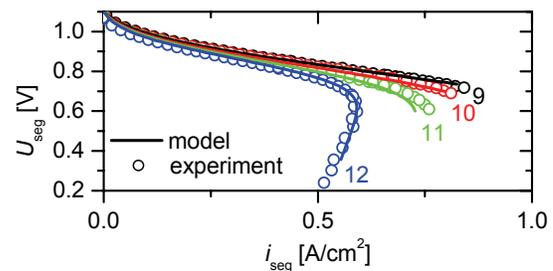


Fig. 2: Simulated and experimental [3] polarization curves of four segments of a segmented SOFC

References

- [1] S.C. Singhal and K. Kendall, High-temperature solid oxide fuel cells, Oxford (2003).
- [2] V. Sonn, A. Leonide and E. Ivers-Tiffée, J. Electrochem. Soc. 155 (2008) (7), p. B675.
- [3] G. Schiller, W.G. Bessler, K.A. Friedrich, S. Gewies and C. Willich, ECS Transactions (2009), p. submitted.
- [4] S. Gewies and W.G. Bessler, J. Electrochem. Soc. 155 (2008), p. B937.