From model-type thin film electrodes to 3D porous cermets

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To fight global warming, a highly efficient utilisation of fuels and storage of renewably produced energy is of utmost importance. Solid oxide fuel and electrolysis cells (SOFCs and SOECs) are a promising technology that can make an important contribution to the energy transition, since they allow conversion of chemically stored energy into electricity as well as electrolysis of H_2O or CO_2 to store electricity in a persistent form – both with highest efficiencies. For these cells, gadolinia-doped ceria (GDC) based materials such as Ni/GDC are the currently most promising fuel electrodes. For a targeted optimisation of real porous Ni/GDC cermet electrodes, a detailed insight into the role of the material properties for the electrochemical polarisation resistance is crucial.

Here, model-type GDC thin film electrodes grown by pulsed laser deposition were used for basic characterization of the material's electrochemical elementary parameters such as surface reaction resistance and chemical capacitance. These parameters and their physically correct relationship on Ni/GDC cermet structures were used to interpret of the impedance of real 3D porous electrodes. Accordingly, an analytical transmission line circuit is derived. Fitting the electrode impedance to this circuit, allows separation and quantification of the individual contributions to the electrode polarisation resistance, such as oxygen ion transport across the electrolyte/GDC interface, ionic conductivity of the ceramic phase, and electrochemical reaction at the GDC surface. Comparison with our model studies yields very good quantitative agreement. With these detailed insights, we can quantitatively explain the polarisation resistance of real porous Ni/GDC fuel electrodes. Moreover, we can demonstrate that fuel electrode functional layers consisting entirely of GDC (i.e. without any metallic phase) can even surpass the performance of cermet electrodes, if the functional layer is sufficiently thin and good contact to a current collecting layer is established.

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