Mixed Conducting Porous SOFC Cathodes:
Current Distributions and Polarization Resistances

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Mixed ionic and electronic conducting cathodes are considered to be very attractive for solid oxide fuel cells since they allow oxygen reduction and incorporation into the electrolyte not only via the surface of the cathode (three phase boundary mechanism) but also through the electrode bulk. However, porous fuel cell cathodes exhibit a complex geometry/morphology and even if all relevant transport and reaction parameters of the elementary electrochemical reaction steps are known it is frequently not trivial to predict how the interplay of material properties and geometry (porosity, particle size, electrode thickness, etc.) affects the polarization resistance.

Numerical calculations of the multi-dimensional potential distributions in porous mixed conducting cathodes are therefore presented for model electrodes of different geometry and varying material parameters. It is shown that such calculations can be used i) to identify optimal cathode geometries for given material parameters, ii) to elaborate those material properties that should primarily be optimized in order to lower the polarization resistance and iii) to define target values for material parameters that should be achieved in the search for new materials.

In particular, it is demonstrated that, depending on the ratio k^q/D^q (surface incorporation factor / oxide ion diffusion coefficient) different regimes can be distinguished: For large k^q/D^q-values only small regions close to the three phase boundaries are relevant with respect to the oxygen reduction; a decreasing k^q/D^q ratio, however, “activates” an increasingly larger portion of the cathode, i.e. the area of the surface that is involved in the oxygen reduction reaction, monotonically increases [1,2]. The impact of geometrical parameters (grain size, three phase boundary length, surface area) and thus suggested optimized geometries depend on k^q/D^q. The numerical results are applied to different perovskite-type cathode materials such as doped $LaMnO_3$ or $LaFe_yCo_{1-y}O_3$.

[1] J. Fleig, *J. Power Sources* 105 (2002) 128
[2] J. Fleig and J. Maier, *J. Europ. Ceram. Soc.* in press

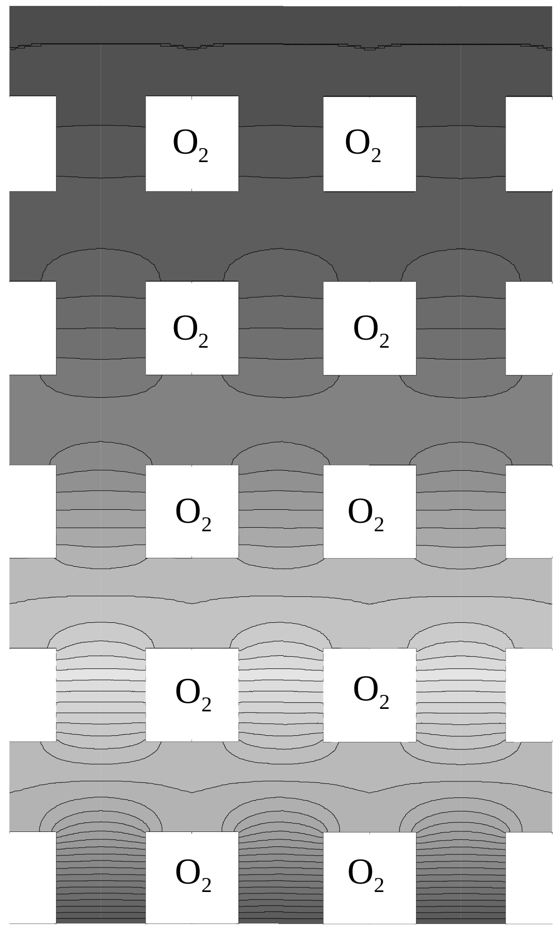

Fig. 1: Calculated potential distribution in a mixed conducting porous cathode for k^q/D^q = 62.5cm^{-1} and a grain size of 1.6 μm.

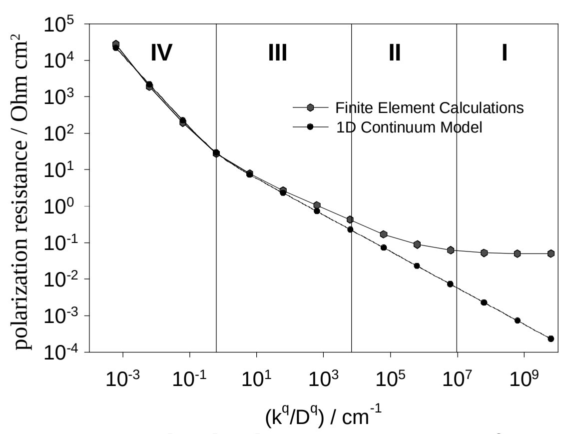

Fig. 2: Area-related polarization resistance of a mixed conducting cathode for different k^q / D^q ratios; grain size = 1.6 μm, ion conductivity = 10^{-3} S/cm. Four different regimes (I-IV) can be distinguished.