Investigation and Modelling of the Flow Field in SOFC

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Abstract:
The solid oxide fuel cells developed by BMW Group & Partners for the APU application in vehicle, have been investigated in this work in terms of mass transport such as the flow field in the gas channels and permeability and diffusion in porous function layers.

As reported in an earlier article [1], the DLR SOFC is based on the planar concept with metallic interconnectors and vacuum plasma sprayed electrodes and electrolyte (Thin film concept developed at DLR, Stuttgart [2]).

The relevant transport processes have been experimentally investigated, these processes are the flow in gas channels, the gas permeability through and the diffusion in the function layers, respectively. The experiments have been performed under operating conditions as possible. The flow measurements provide pressure drops dependent on volume flux, so that the permeability can be calculated. The effective diffusion coefficients in ceramic layers such as electrodes have been determined using the Wicke-Kallenbach-method, the porosity of the electrodes has been specified using mercury porosimetry, and for validation polished specimen have been prepared and microscopically analysed, and the porosity is then examined by graphical software.

A mathematical 3-D model has been developed to simulate the flow field distributions. In the gas channels the mass transport can be described by the well known Navier-Stokes equations using a detailed transport model including thermal diffusion. However, the modelling of processes like diffusion and permeability of gas species in various function layers is most challenging, since most transport and reaction limiting steps take place in these layers, but the experimental characterisation in these regions is still very difficult due to the complex porous microstructure, furthermore, there is hardly any research work relating to the modelling at present. At the start of investigations the porous structure is assumed to be homogeneous in this paper, so that a global quantity can be used for the considered porous region. A diffusion model consisting gas phase and Knudsen diffusion has been used, the gas permeability is described by Darcy law. A more detailed model will be developed in future.

In order to simplify the numerical treatment a single planar solid oxide fuel cell has been investigated. To solve the problem the method of Finite-Volume has been applied, the numerical calculations have been implemented using the CFD program StarCD, and the grid system has been generated by ICEM CFD.

One of the numerical studies focus on the 3-dimensional flow distribution, with the goal to ensure a uniform supply of reactants over the whole electrode surface. Numerous simulations have been carried out both for laminar and turbulent flow, using parameters like varied composition of inlet fuel gas and different boundary conditions. Thus, an optimised feeding strategy can be deduced.

Additionally, the experimentally detected diffusion coefficients and permeability are set into the porous model, so that the influence of the porous structure on the distribution of flow and the concentration of gas species can be showed.

References:
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