Lattice-Boltzmann simulation of multiphase transport in porous gas diffusion media of Polymer Electrolyte Fuel Cells

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Polymer Electrolyte Fuel Cells (PEMFC) are a promising alternative to current energy conversion devices for mobile applications. Absence of harmful exhaust gases and refuelling within short periods are only two advantages that make fuel cells a clean, efficient technology and a compelling alternative to conventional combustion engine- and battery-driven cars. However there are also still problems to be solved such as performance decay due to degradation mechanisms [1].
Especially the maintenance of a stable water management in PEMFCs is a very challenging task, because the cell has to be prevented from both, drying out and flooding [2]. To achieve this balance, gas diffusion layers (GDLs) are successfully employed, but the actual two-phase transport inside the porous microstructures is complex and not yet fully understood. Experiments in this field are costly and not always accessible, however, simulations can be used to model those transport processes and to get a better understanding of multiphase flows in the porous electrodes.
Our studies focus on the simulation of liquid water transport through initially gas-filled GDLs of PEM fuel cells using the 3D colour-gradient Lattice-Boltzmann model [3]. The geometries for our simulations are derived with microstructure resolution from µCT scanning followed by image pre-processing. Liquid water transport through the porous medium is then enforced by applying different capillary pressures using the pressure boundary condition by Zou and He [4]. To account for the micro-porous layer (MPL) we assume that liquid water only enters the GDL through macro pores of the MPL. We also consider hydrophobic effects from binder material by simulating wetting phase transport for different PTFE loadings of the GDL. Based on this setup we derive wetting phase saturations for different capillary pressures and varying contents of hydrophobic PTFE. The simulations show an increase of the liquid phase saturation up to breakthrough and a decrease of the breakthrough capillary pressure for lower loads of PTFE. These findings suggest that the loss of PTFE during operation causes a higher susceptibility to flooding of the cell.

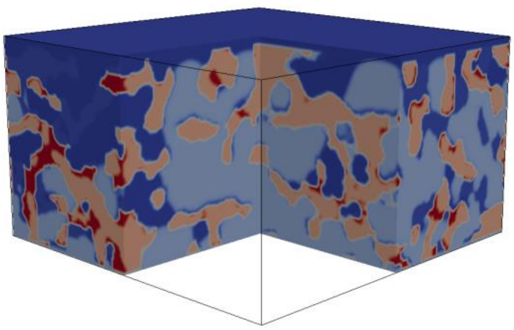

Figure 1: Liquid phase transport through porous GDL microstructure. Fluid components are depicted in blue for gas and light-blue for liquid phase, support and binder material are coloured in orange and red respectively.

References:
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4. Q. Zou and X. He, Physics of Fluids 9, 1591 (1997)