Micro two-phase transport in polymer electrolyte fuel cells

C. Ziegler*, N. Paust , R. Zengerle
Laboratory for MEMS Applications
Department of Microsystems Engineering-IMTEK
University of Freiburg
* Email: ziegler@imtek.de Tel.: +49 761 203-7447

Micro two-phase flow plays an important role for the operation of direct methanol fuel cells (DMFC) and polymer electrolyte fuel cells operated with hydrogen (PEMFC). Through the complex coupling of the two-phase flow with the electrochemical reactions the performance and stability of DMFCs and PEMFCs are influenced by the two-phase transport on the micro-scale.
At the cathode side water is generated as a result of the oxygen reduction reaction in the DMFC and PEMFC. This leads to two-phase flow of gas and liquid water in the nano-porous catalyst layer, the micro-porous gas diffusion layer and the gas channels of the fuel cell [1,2].
We review recent approaches for improved water management at the cathode side. At the DMFC anode, carbon dioxide is generated and forms gas bubbles in the flowfield. Volume of Fluid simulations are used to develop a microfluidic anode design that allows for passive fuel supply and degassing in any orientation [3]. A bubble driven self regulating supply mechanism safely removes carbon dioxide and transports at least 3.5 times more methanol to the anode than critically needed to sustain DMFC operation. On the cathode, diffusive oxygen supply and the transport of the reaction product water along a capillary gradient out of the DMFC ensures a stable performance. In the most challenging horizontal position with the anode facing downwards, a power output of at least $p = 3.1$ mW cm^{-2} was reached. The abandonment of ancillary pumps and valves makes the system small and compact, increasing the overall energy density. Thus, the passive DMFC is a promising candidate for power supply of small portable appliances. However, a stable long-term performance in all orientations of the fuel cell poses a significant challenge [4]. Methanol supply and the removal of the reaction product carbon dioxide (CO2) on the anode, as well as oxygen supply and water removal on the cathode must be achieved in any orientation independent of gravity. Micro-scale effects such as diffusion and capillary force induced transport are applied to account for this challenge.

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