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Evaporation from gas diffusion layers of proton exchange membrane fuel cells: a pore network study

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Evaporation from porous media is of great interest to many research and engineering fields, such as recovery of volatile hydrocarbons from underground oil reservoirs, remediation of contaminant soils by vapor extraction, and water management in gas diffusion layers (GLDs) of proton exchange membrane fuel cells (PEMFCs). During runnig of PEMFCs, produced water may condense and fill open pores of the cathode GDL, which impedes the transport of reactant gas to the reaction sites and hence is adverse to the fuel cell performance. In particular, at low temperature environment, liquid in the GDL can freeze to form ice crystals, which will damage the GDL structure and deteriorate the performance and durability of PEMFCs. To this end, it is necessary to remove residual liquid in the GDL after the shutdown of PEMFCs. A common method is to purge the dry gas into the gas channel (GC) of a PEMFC to remove liquid in the GDL through the evaporation mechanism. However, the gas purge is parasitic and consequently reduces the efficiency of PEMFCs. To reduce parasitic losses and increase the system efficiency, it is important to understand the detailed evaporative liquid removal from GDL during the gas purge.
In PEMFCs, the cathode GDLs are thin (~250 μm) and treated with hydrophobic agent PTFE. However, due to non-uniform distribution of PTFE, the treated GDLs usually show mixed wet characteristics, i.e., hydrophilic and hydrophobic pores coexist. To investigate evaporation from such thin porous media with mixed wettability, a pore network model is employed in the presetn study. The GDL is conceptualized as a pore network (PN) composed of cubic pore bodies connected by cylindrical pore throats. Initially, the PN is fully saturated with liquid water. Then dry gas is flowed into the GC, during which liquid in the PN is removed by evaporation. The gas flow in the GC is considered as a fully developed laminar flow. The vapor transport in the channel is described by the convection-diffusion equation. The vapor transport in the PN is dominated by the diffusion. Both viscous and capillary effects are considered for liquid flow in the PN. The "capillary valve"effect is also taken into account to illustrate the movements of gas-liquid menisci in the pores of PN.

References

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