Two-Dimensional Lattice Boltzmann Simulation for Liquid Water Transport in Hydrophobic Porous Layers of Polymer Electrolyte Membrane Fuel Cells

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The polymer electrolyte membrane fuel cell (PEMFC) is a promising energy conversion device for clean and efficient generation of electricity using hydrogen. During the operation of the PEMFC, water is continuously produced as the reaction by-product, which should be properly exhausted through the catalyst layer (CL) and the gas diffusion layer (GDL). The problem of electrode flooding occurs when water condenses into liquid phase because of low operating temperature and excessive water production in the PEMFC. This condensed water residing in the porous electrode hinders the gas diffusion towards the active reaction sites, significantly limiting the performance of the PEMFC. Many studies demonstrated that the electrode flooding can be reduced by employing hydrophobic coating for the GDL and inserting microporous layer (MPL) between the CL and the GDL.

This study numerically investigated two-phase liquid water transport in hydrophobic porous transport layers (PTLs) of the PEMFC, aiming at better understanding of the process and improved control of the electrode flooding. The lattice Boltzmann method (LBM) was adopted since it is generally accepted as an ideal model for simulating microscale capillary flow in the PTLs. Using the two-dimensional multi-phase LBM, the authors studied the effects of the uniform and non-uniform wettabilities of the GDL on the liquid water transport dynamics as well as the water saturation level therein. In addition, the effects of the MPL insertion were also investigated by varying the thickness of the MPL.

The results showed that higher hydrophobicity generally reduces the water saturation level in the GDL of uniform wettability. However, for the GDL of non-uniform wettability, the saturation level was found to be less influenced by the composition of hydrophilic/hydrophobic surfaces. The results also demonstrated the advantage of the MPL insertion in reducing the electrode flooding. These results were discussed in relation with the liquid water transport dynamics predicted by the LBM.

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