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Electrochemically Coupled Multi-Physics Transfer in PEM Fuel Cell Development

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Abstract:
The commercialization of proton exchange membrane (PEM) fuel cell requires major breakthroughs in cost, performance and durability. In addition to the new material development, optimal catalyst layer (CL) microstructure and fuel cell structure also play an important role. However, the latter is largely hindered by current poor understanding of the complex 'gas-liquid-heat-electron-proton' transfers in conjunction with the electrochemical reactions, which is also greatly influenced by the temporal CL microstructure evolution during long-term operation. Herein, on one hand, we present several important research & development (R&D) directions after critically examining the multi-physics transfer in fresh CLs and the microstructure evolution of degraded CLs. This knowledge is essential to design and fabricate ultralow-Pt CLs for cost-effective, high-performance and durable PEM fuel cells, and to meet the urgent need for development of new research tools, including pore- and cell-scale models, experimental methods, machine learning algorithms and their rational combinations; on the other hand, using a 3D fuel cell model that was comprehensively validated against experimental data regarding the polarization curves, electrochemical losses, spatial current density distributions, temperature distributions, etc., we also comprehensively evaluated the relationship between the cell structure and fuel cell performance, including several presentative BP and flow field structures (e.g. straight channel, wave-like channel, fine channel, channel inserting baffle, partially narrow channel, pin-type, 3D fine mesh and foam flow field), and the novel integrated BP-MEA and double-cell structures. The results indicate the importance of cell structure design and optimization in boosting the power density of PEM fuel cells.

Keywords: Proton exchange membrane fuel cell; multi-physics transfer; CL microstructure; cell structure

Dr. Guobin Zhang received his Ph.D. in 2021 under the supervision of Prof. Kui Jiao at Tianjin University, China, and he studied in the University of California, Irvine as a visiting scholar under the supervision of Prof. Yun Wang during 2018-2019. He joined the Xi'an Jiaotong University in 2021 and now is an assistant professor in the group of Prof. Zhiguo Qu. Dr. Zhang's main research interests are water and thermal management of fuel cells and electrolyzers, multiphase flow, heat and mass transfer in porous media, etc. As the first or corresponding author, he has published 24 international peer-review SCI journal papers in *Joule*, *Chemical Reviews*, *Small Methods*, *Applied Energy*, *International Journal of Heat and Mass Transfer*, etc.