Multiphase water transport in polymer electrolyte fuel cells: From phase change induced flow to droplet dynamics

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ABSTRACT

Polymer electrolyte fuel cells (PEFCs) are investigated as an alternative to conventional energy conversion devices such as the internal combustion engine in transportation, remote and backup power applications. PEFCs fuelled with hydrogen produce electricity continuously without any negative emissions such as particulate matter, sulphur and carbon oxide. PEFC vehicles already meet most customer requirements including long range, quick refuelling, and start-up at sub-zero temperatures, however the cost of the PEFC remains prohibitively expensive for large scale commercialization. In order to reduce their costs, PEFCs must achieve higher current densities. High current density operation however results in an increase in water production, the only by-product in a hydrogen PEFC. Water accumulates in the porous media in the PEFC thereby blocking fuel and reactant transport and effectively shutting down the system. The analysis and design of fuel cell architectures and strategies to mitigate water accumulation at high current densities are therefore of paramount importance. To analyze such strategies, a numerical model that couples gas and liquid water transport, electronic and ionic transport, heat transfer and electrochemical reactions is needed.

In PEFCs, the physical processes above occur at multiple scales. Gases are distributed into the electrode using millimeter size channels. The gas then diffuses into a multi-layered heterogeneous porous media with pore sizes that range from micro-meters to nano-meters. Understanding gas, liquid, heat, electron and ionic transport in PEFCs therefore requires the development of numerical tools that can not only couple all these processes but that can analyze multiple scales and materials. Over the past decade, our research group has developed pore level imaging, analysis and simulation tools to study gas and liquid transport and electrochemical reactions at the micro-scale in porous electrodes [1]; multi-physics volume-average numerical simulation models to study a complete PEFC [2], and gas-droplet dynamics simulations for the gas channels [3]. The aim of this presentation is to provide an overview of these numerical tools. The numerical tools are validated with experimental results from fuel cell testing and ex-situ experiments.

REFERENCES

[1] Sabharwal M., Pant L.M., Putz A., Susac D., Jankovic J., Secanell M. Analysis of Catalyst Layer Microstructures: From Imaging to Performance, *Fuel Cells* (2016) 16 (6), 734-753.

[2] Zhou J., Putz A., Secanell M. A mixed wettability pore size distribution based mathematical model for analyzing two-phase flow in porous electrodes I: Mathematical model, *Journal of the Electrochemical Society* (2017) Accepted.

[3] Jarauta A., Ryzhakov P., Secanell M., Waghmare P.R., Pons-Prats J., Numerical study of droplet dynamics in a polymer electrolyte fuel cell gas channel using an embedded Eulerian-Lagrangian approach *Journal of Power Sources* (2016) 323, 201-212.