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Water Management of A PEM Fuel Cell with Super-Hydrophobic Flow Channels, an Experimental and Computational Study

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Abstract

Water generated on the cathode side of a Polymer Electrolyte Membrane Fuel Cells (PEMFC) during low temperature (30 – 70°C) operations impedes the flow of oxidant reducing the rate of electrochemical reaction. Therefore, there is a need to examine water distribution throughout the entire fuel cell domain, including the anode and the cathode sides. Liquid water can cause flooding in the gas diffusion layer, and catalyst layer reducing the active surface area and, consequently, the reaction rate. Phase transfer between liquid water and water vapor influences the buildup of liquid water in these domains. To overcome this issue, it is proposed to use a novel waterborne super-hydrophobic flow fields on the flow-fields of graphite plates on the cathode side of the cell. The fuel cell was operated with different rates of humidification with different cell operating temperatures and the performance of the cell was observed in terms of polarization curve as well as water rejection. The maximum power density of the PEMFC decreased marginally due to the increase in surface resistance with the coating. However, its operating range of current density was increased and the PEMFC with super-hydrophobic flow fields could be operated without water purging. It was found that an excess 58.2% of water was removed with the use of super-hydrophobic coating compared to the usual fuel cells. This enabled a smoother operation of the fuel cell without active interventions in the form of purging of water. The performance of a PEM fuel cell has been primarily studied computationally in a single-channel domain. In addition to experimental observations, a three-dimensional, non-isothermal, two-phase numerical model incorporating both the cathode and anode domains has been developed to study water distribution. This model includes phase transition in the gas diffusion layer, catalyst layer, and channels. The mixed flow distributor is used to analyze water distribution in the domain. Additionally, the effects of liquid water accumulation in the porous layers on reactant transport and cell performance are investigated. The modeling has been further extended to include superhydrophobicity effect and compared to experimental results. The study shows how the combined experimental-numerical exercise can be used as a design tool to manage water in a PEM Fuel Cell.