Affect of Feature Dimensions on PEM Fuel Cell Performance under Flow Fields Capable of Switching between Parallel and Interdigitated Configurations

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Novel water management and reactant distribution strategies are important to the development of next generation polymer electrolyte membrane fuel cell systems (PEMFCs). Poor water management and distribution can lead to saturation of the gas diffusion layer (GDL) which blocks active area of the membrane, or may cause under saturation the membrane, reducing efficacy. By improving these strategies in PEMFCs, the required stack size in a vehicle may be shrunk, which in turn reduces weight and improved the price competitiveness of fuel cell vehicles compared internal combustion engines.

Parallel and interdigitated flow fields, Figure 1, are two common types of PEMFC designs that have benefits and drawbacks depending upon operating conditions. Parallel flow fields suffer from longer diffusion lengths which inhibits delivery of reactants and removal of byproduct water. Interdigitated flow fields induce convective transport, known as cross flow, through the porous GDL between adjacent channels and therefore are superior at water removal beneath land areas which can lead to higher cell performance. Unfortunately, forcing flow through the GDL results in higher pumping losses as the inlet pressure for interdigitated flow fields can be up to an order of magnitude greater than that for a parallel flow field.

This research seeks to examine the affect varying feature size has on the performance of a fuel cell under

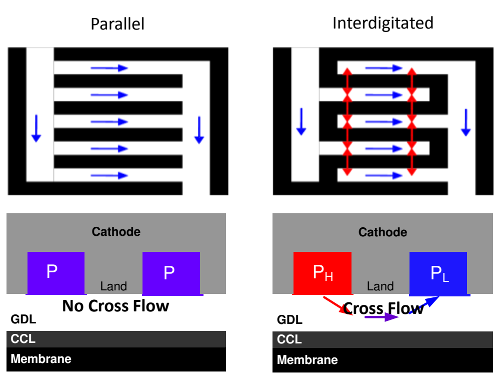

Figure 1: Interdigitated and parallel diagrams.

parallel and interdigitated conditions and to compare the change in performance between these two flow regimes. Changing feature size affects the distribution of water generation, as well as the distribution of gaseous reactant in the cell. The features of interest are channel width, and channel depth. The width of lands for the bipolar plates mirrors the width of channels on that plate.

The affect of width and depth of channels are currently being examined. Channel dimensions of interest are (width x depth, in millimeters) 1x1, 0.5x0.5, 0.25x0.25, 0.5x1, and 0.25x1. The effect of these features is being explored through the use of interchangeable bipolar plates. The bipolar plates are 20 cm long and 1.5 cm wide, for a total active area of 30 cm^2. The bipolar plates are machined out of aluminum and have a nonreactive gold coating on the active areas to prevent corrosion and eliminate unaccounted for reactions on the surface of the plate. The use of gold further reduces the interfacial contact resistance with the GDL, decreasing the voltage loss due to ohmic resistance.

These bipolar plates can fit into a cell superstructure that has the ability to change from parallel configuration to interdigitated configuration through the use of valves and a novel manifold – channel connection design. The valves close the inflow of gas to every other channel, and close the outflow of gas to the remaining channels. This can be done without taking apart the cell, allowing for direct in situ comparison of parallel and interdigitated flow fields.

The work of this study has already been started, with preliminary testing of a nickel plated version of the 1 x 1 mm plates already completed. These results can be found in Figure 2. These results can serve as a baseline for comparison of the new set of plates. This preliminary testing has further given a better understanding of how the system behaves during operation and improvements which may be made in the new plates. Additionally the ability to enhance performance through cross flow control is demonstrated by showing an optimized power curve produced by running the cell at optimal levels of cross flow taking into account pumping losses.

This experimental work is complemented by a simulation of the reactant flow through the GDL at these lengths. The multiphysics package COMSOL was used to simulate the interdigitated flow field with varying feature dimensions and conditions in three dimensions. The model focuses on the cathode flow field and GDL layer and does not take into account the electrochemical reaction. As this study is interested in how feature dimensions affect pressure and cross flow distribution, modeling the entire electrochemical process is not necessary because the electrochemical reaction has little effect on bulk cross flow; additionally, the experimental portion of this work characterizes cell performance. Reaction by-product water is a factor; however, no models can currently account for this completely.

When complete, this study will have developed the relationship between bipolar plate feature size and cross flow through the GDL in interdigitated fuel cell designs. It will further have developed the relationship between the cell power and the reactant flow conditions inside the cell. This will provide for better designs which can reduce stack size and increase the viability of fuel cells in automotive applications. Additionally, the ability to control cross flow for increased performance will be probed at these dimensions to see whether or not advanced cell designs may benefit from flow switching methods of operation.

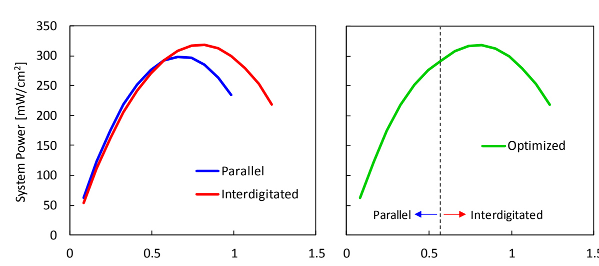

Figure 2: Results for the 1x1x1 mm set up.