Experimental Investigation of Spatial-Temporal Current Distribution in the Cathode of a PEM Fuel Cell using Segmented Electrodes

Dilip Natarajan and Trung Van Nguyen
Department of Chemical and Petroleum Engineering
The University of Kansas
Lawrence, Kansas 66045

Dynamics of liquid water and its effect on the transport of the reactive oxygen species has been widely acknowledged as the performance limiting phenomenon in the cathode of a PEM fuel cell. In the past, experimental efforts on fuel cells have looked only at the net average current while, mathematical models were developed to get better insight into local species and current density distribution. Lately, research has been focused on developing experimental schemes to investigate the species distribution within the fuel cell assembly and its effect on the reaction rates essential for further optimization in terms of more area usage, prevention of localized flooding and dehydration and ‘hotspots’ caused by high local current densities etc. The localized flooding is also suspected to cause spatial – temporal local current oscillations. Qualitative evidence of the effect of these local oscillations on the average measured current has been observed at high current density operation by researchers at the Electrochemical Engineering Laboratory at the University of Kansas. Other researchers have also reported unstable current profiles at high current densities, but have always dismissed them as unstable behavior. Such oscillations are not uncommon in electrochemical systems and have been reviewed in by J. L. Hudson and T. T. Tsotsis in the case of electro – dissolution and cathodic depositions of metals.

A small-scale fuel cell with segmented current collectors and electrodes has been designed and fabricated by our research group at the University of Kansas to investigate the performance of the cathode (or anode) along the length of a conventional gas distributor channel. Machined graphite strips were embedded in an acrylic block and channels were machined on the surface for gas distribution. A top and side view schematic of the segmented current collector is provided in Figure 1. Membrane electrode assemblies (MEA) with segmented electrodes on one side sharing a common electrode on the other and regular MEA’s with un-segmented electrodes on both sides were also fabricated in our research lab. The electrode on one side of the MEA was 7cm long and 0.6 cm wide. The other segmented side of the MEA had 6 electrodes 1cm long and 0.6 cm wide, separated by a distance of 0.2 cm. The segmented MEA also had a built-in reference electrode to measure the individual half cell potentials. Effort was focused on achieving a smooth finish to the segmented current collector block to avoid differential contact resistance. An MEA with un-segmented electrodes on both sides was used and a low potential was imposed sequentially to each current collector segment while the potential distribution on the other segments were monitored. Uniformity in contact between the current collector segments and the MEA was assumed when a Laplacian distribution of potential was achieved.

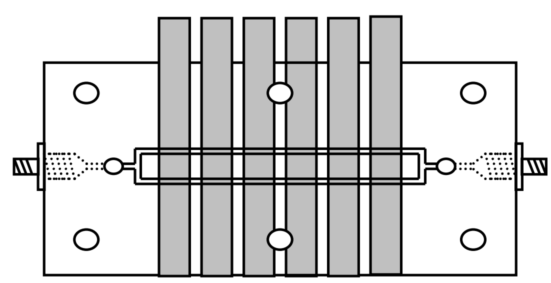
In the cathode of the fuel cell, non-uniformity in the performance along the length of the channel can be caused by localized flooding due to inherent variations in the catalyst and gas diffusion layers. Moreover, in the case of an air cathode, oxidant depletion effects can also result in non-uniform reaction rates. Experimental results obtained using the segmented MEA with pure oxygen as the cathode stream will be presented in this work. These results address the inherent differences in catalyst and backing layers and their flooding characteristics in the cathode along the length of the channel. Operating parameters like stoichiometric flow rates, step changes in the applied load and temperature were investigated. Future research efforts will be focused on extending this study to an air cathode to obtain a comprehensive idea of the oxygen and water activity distribution and its effect on the cathode performance. Previous work [2] that provided qualitative results on hydrogen starvation will also be investigated further in the future.

REFERENCES

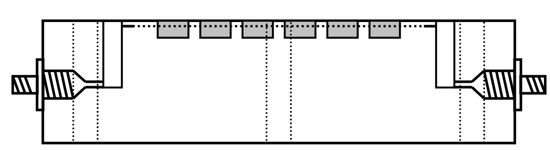
1. J. L. Hudson and T. T. Tsotsis, *Chem. Eng. Sci.,* **49**, 1493 (1994).
2. Dilip Natarajan and Trung Van Nguyen, “Experimental Investigation of Spatial-Temporal Current Distribution in a PEM Fuel Cell”, AIChE 2000 Annual Meeting, Paper – 41D, Los Angeles, California, Nov. 14, 2000

ACKNOWLEDGEMENTS

This work was supported by National Science Foundation under Grant No. CTS-9910923



a) Top view of segmented section



b) Side view of segmented section

***Figure 1**. Schematic of segmented fuel cell components designed for this work.*