Hawai'i Natural Energy Institute Research Highlights

Electrochemical Power Systems

Mass Transfer Analysis for High Power Fuel Cells

OBJECTIVE AND SIGNIFICANCE: At high power production, the performance of electrochemical conversion systems, like proton exchange membrane fuel cells (PEMFCs), direct liquid fuel cells, and metal/air batteries, are constrained by mass transport processes. The purpose of the project is to develop a novel diagnostic method for the determination of mass transfer parameters which will provide guidance for improvements in electrode structure design.

BACKGROUND: PEMFCs should operate at high current to maximize power density. Under these conditions, performance is controlled by the finite transport of reactants and products. For PEMFCs, reagents transfer from a gas channel to the catalyst occurs through molecular diffusion, Knudsen diffusion in fine pores and diffusion through water and ionomer films within a gas diffusion electrode (GDE), consisting of a gas diffusion layer and a catalyst layer (Figure 1). In order to determine and separate each of these contributions we developed the novel method.

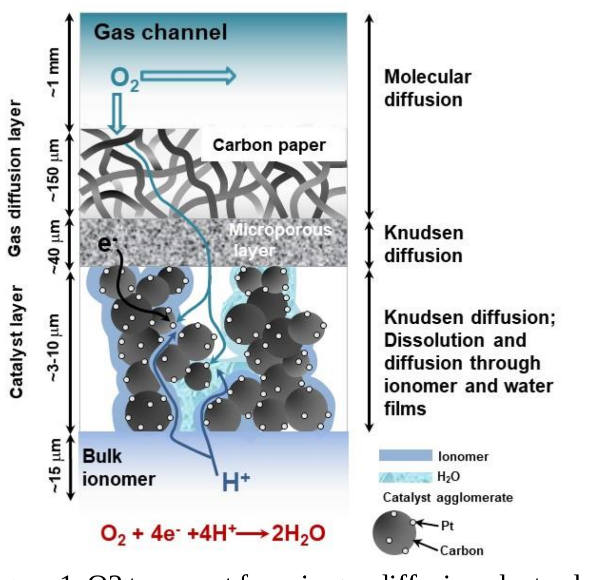

Figure 1. O2 transport from in gas diffusion electrode.

The method is based on measurements of the limiting current distribution over an electrode area. In order to determine the current distribution, we are using a segmented cell system developed at HNEI (Figure 2). A limiting current condition can be achieved by applying highly diluted reagent mixtures (~3-10 vol.% of H_2 or O_2). Variations in diluent molecular weights (from He to C_3H_8) and operating conditions allow us to separate the gas phase molecular diffusion coefficient, a Knudsen diffusion and diffusion through ionomer/water films.

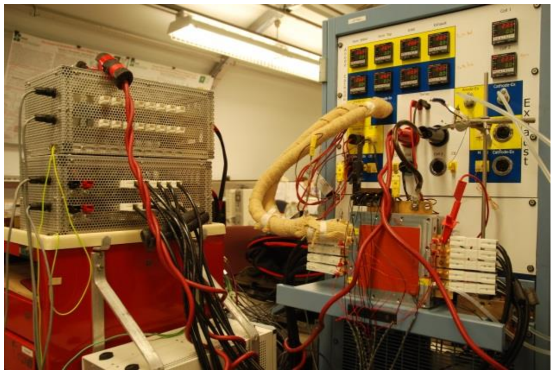

Figure 2. Segmented cell system and test station.

PROJECT STATUS/RESULTS:

- The method was validated for oxidant and fuel (O_2 and H_2) using commercial fuel cell components from Nuvera Fuel Cell, Gore, and 3M.
- The obtained results were supported and complemented by independent measurements and modeling of electrochemical impedance spectroscopy data.
- Effects of catalyst loading and gas diffusion layer properties on hydrogen and oxygen mass transfer coefficient were studied. The results provided an approach on quantitative determination of different electrode components contribution to mass transfer.
- Oxygen and hydrogen mass transfer coefficients were determined for wide range of operating conditions (temperature, gas humidification, and back pressure). These data showed an interplay between performance, operating parameters and mass transport processes in working fuel cell.

The results were reported to the funding agency, presented at scientific conferences, and will be published.

Funding Source: Army Research Office; Office of Naval Research

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Additional Project Related Links

Papers and Proceedings:

1. 2019, T. Reshetenko, A. Kulikovsky, **On the Origin of High Frequency Impedance Feature in a PEM Fuel Cell**, Journal of the Electrochemical Society, Vol. 166, Issue 15, pp. F1253-F1257. (Open Access: **PDF**)
2. 2019, T. Reshetenko, A. Kulikovsky, **Nafion film transport properties in a low-Pt PEM fuel cell: impedance spectroscopy study**, RSC Advances, Vol. 9, Issue 66, pp. 38797-38806. (Open Access: **PDF**)
3. 2019, T. Reshetenko, A. Kulikovsky, **On the distribution of local current density along a PEM fuel cell cathode channel**, Electrochemisty Communications, Vol. 101, pp. 35-38. (Open Access: **PDF**)
4. 2019, T. Reshetenko, A. Kulikovsky, **A Model for Local Impedance: Validation of the Model for Local Parameters Recovery from a Single Spectrum of PEM Fuel Cell**, Journal of the Electrochemical Society, Vol. 166, Issue 6, pp. F431-F439. (Open Access: **PDF**)
5. 2018, T. Reshetenko, A. Kulikovsky, **A Model for Extraction of Spatially Resolved Data from Impedance Spectrum of a PEM Fuel Cell**, Journal of the Electrochemical Society, Vol. 165, Issue 5, pp. F291-F296. (Open Access: **PDF**)
6. 2017, T. Reshetenko, A. Kulikovsky, **Impedance Spectroscopy Characterization of Oxygen Transport in Low- and High-Pt Loaded PEM Fuel Cells**, Journal of the Electrochemical Society, Vol. 164, Issue 14, pp. F1633-F1640. (Open Access: **PDF**)
7. 2017, T. Reshetenko, A. Kulikovsky, **Impedance Spectroscopy Study of the PEM Fuel Cell Cathode with Nonuniform Nafion Loading**, Journal of the Electrochemical Society, Vol. 164, Issue 11, pp. E3016-E3021. (Open Access: **PDF**)
8. 2016, T. Reshetenko, A. Kulikovsky, **Variation of PEM Fuel Cell Physical Parameters with Current: Impedance Spectroscopy Study**, Journal of the Electrochemical Society, Vol. 163, Issue 9, pp. F1100-1106. (Open Access: **PDF**)
9. 2016, T. Reshenko, A. Kulikovsky, **Comparison of Two Physical Models for Fitting PEM Fuel Cell Impedance Spectra Measured at a Low Air Flow Stoichiometry**, Journal of the Electrochemical Society, Vol. 163, Issue 3, pp. F238-F246. (Open Access: **PDF**)
10. 2016, J. St-Pierre, T.V. Reshetenko, **PEMFC Reactant Mass Transfer Coefficient Measurement and Separation – Method Extension to the Mixed Kinetic and Mass Transfer Control Regime**, Proceeding of the ECS MA2016-02 Meeting, ECS Transactions, Vol. 75, Issue 14, pp. 63-76.

Presentations:

1. 2019, T.V. Reshetenko, B.L. Ben, **Analysis of Mass Transport Phenomena in PEMFC Cathode Electrode: Effects of Operating Conditions**, Presented at the ECS MA2019-02 Meeting, Atlanta, Georgia, October 13-17, Abstract 1449.
2. 2016, J. St-Pierre, T.V. Reshetenko, **PEMFC Reactant Mass Transfer Coefficient Measurement and Separation – Method Extension to the Mixed Kinetic and Mass Transfer Control Regime**, Presented at the ECS 2016-02 Meeting, Honolulu, Hawaiʻi, October 2-7, Abstract 2356.