Degradation effects of PEMFC in the edge region of the active cell area

Peter Stahl

ElringKlinger AG, Dettingen/Erms

The components of polymer electrolyte fuel cells (PEMFC) are exposed to several degradation mechanisms which are crucial for their lifetime. Much work is done for their investigation and quantification, primarily referred to the part of the active cell area which is superimposed to the gas conducting flowfield. In this work, the cell degradation at the outer perimeter of the active area should be investigated.

Outside the edge land, which surrounds the flowfield of PEMFC at the outer perimeter, the membrane electrode assembly (MEA) is attached to sealing gaskets. They prevent gases from leaking into the opposite compartments and the environment. Manufacturing and assembling tolerances require a gap between sealing and edge land. This may result in an additional gas channel being formed, referred to as the edge channel. In bipolar plates with an uninterrupted edge land, gas movement into this compartment is only possible based on gas permeation through the gas diffusion layer (GDL). If the edge land exhibits gaps, a parasitic gas stream through the edge channel can occur [1].

Local water flooding of the GDL can hinder the reaction gases from reaching the electrode surface. Gas starvation on only one side of the membrane can cause substantial catalyst deterioration as reported in [2-4]. Flooding in the edge region is more likely due to a lower gas flow and accordingly bad water removal. Neutron imaging experiments of Owejan et al. [5] show that the edge channel can be at least partially flooded at steady state conditions. However the results cannot be assigned to the anode- or cathode-sided channel.

During the startup of a fuel cell, air can be present in the anode compartment. Even if the anode flowfield is charged with hydrogen, the air can remain in the edge channel due to limited gas transportation properties. A prolonged fuel/air boundary can be formed between flowfield and edge channel, which can cause serious electrode degradation [6-8].

Hussey et al. [9,10] conducted measurements on cells with PTFE gaskets, without a significant edge channel. They show that the membrane water content in the region under the gasket reacts really slow on variations of gas humidification. That indicates a very slow water diffusion in the in-plane direction of the membrane.

Kawaji et al. [11] refer to a higher decrease of membrane molecular weight near the electrode edge for DMFC. They see a correlation with a locally reduced cell potential.

A common way to prevent the mentioned degradation mechanisms in the edge region is to support the membrane between one or two frame elements in the outer perimeter, so called sub-gaskets [12,13]. They are adhered to the edge of the catalyst coated membrane and provide the sealing surface. Sub-gaskets mechanically stabilize the membrane and inhibit gas transport to the electrode edges. So no reaction takes place there and degradation factors are weakened. However the technique increases the manufacturing effort and requires additional parts.

The development of optimized solutions for sealing and supporting the membrane at the outer perimeter requires the knowledge of the specific degradation mechanisms in the edge area. Water distribution has a significant influence on gas transport and hence degradation through reactant starvation. Neutron imaging is a feasible method to make the water content and movement in the edge region visible without significant modifications to the cell setup.

Measurements should be conducted on a lab-scale or differential cell in a through-plane direction (beam perpendicular to the cell membrane) as well as in an in-plane direction (beam parallel to the cell membrane). Of particular interest is the water content in the edge channel in steady state at different gas humidification and load parameters.

Another objective is the mapping of the water distribution and accumulation in the anode and cathode compartment during the startup of a cell. Degradation enhancing conditions like partial cell flooding can be identified and water transport properties of the porous layer and the membrane can be concluded from the dynamic water movement.

The test setup should enable the investigation of different sealing systems such as seal-on-GDL or sub-gasket based assemblies. Also the influence of an interrupted edge land on the water content in the edge channel should be examined. Measurements are expected to require about 5 days of beam uptime.

[1] H. Kusakabe, K. Hatoh, T. Matsumoto: Patent EP1876666B1, POLYMER ELECTROLYTE FUEL CELL AND MANUFACTURING METHOD THEREOF

[2] P. Ferreira-Aparicio, A. M. Chaparro, B. Gallardo, M. A. Folgado, L. Daza: ECS Transactions 26 (1) (2010) 257-265: Anode Degradation Effects in PEMFC Stacks by Localized Fuel Starvation

[3] A. Taniguchi, T. Akita, K. Yasuda, Y. Miyazaki: Int. J. of Hydrogen Energy 33 (2008) 2323-2329: Analysis of degradation in PEMFC caused by cell reversal during air starvation

[4] A. Taniguchi, T. Akita, K. Yasuda, Y. Miyazaki: J. of Power Sources 130 (2004) 42-49: Analysis of electrocatalyst degradation in PEMFC caused by cell reversal during fuel starvation

[5] J. P. Owejan, T. A. Trabold, D. L. Jacobson, M. Arif, S. G. Kandlikar: Int. J. of Hydrogen Energy 32 (17) (2007) 4489-4502: Effects of flow field and diffusion layer properties on water accumulation in a PEM fuel cell

[6] N. Linse: Start/stop phenomena in polymer electrolyte fuel cells, PhD Thesis, ETH Zürich, 2012

[7] C. A. Reiser, L. Bregoli, T. W. Patterson, J. S. Yi, J. D. Yang, M. L. Perry, T. D. Jarvi: Electrochem. And Solid-State Letters 8 (6) (2005) A273-A276: A Reverse-Current Decay Mechanism for Fuel Cells

[8] H. Tang, Z. Qi, M. Ramani, J. F. Elter: J. of Power Sources 158 (2006) 1306-1312: PEM fuel cell cathode carbon corrosion due to the formation of air/fuel boundary at the anode

[9] D. S. Hussey, D. Spernjak, A. Z. Weber, R. Mukundan, J. Fairweather, E. L. Brosha, J. Davey, J. S. Spendelow, D. L. Jacobson, R. L. Borup: J. of Applied Physics 112 (2012) 104906: Accurate measurement of the through-plane water content of proton-exchange membranes using neutron radiography

[10] D. J. Ludlow, C. M. Calebrese, S. H. Yu, C. S. Dannehy, D. L. Jacobson, D. S. Hussey, M. Arif, M. K. Jensen, G. A. Eisman: J. of Power Sources 162 (2006) 271-278: PEM fuel cell membrane hydration measurement by neutron imaging

[11] J. Kawaji, S. Suzuki, T. Mizukami: 63rd Annual Meeting of the International Society of Electochemistry Prague, 2012: Membrane Degradation at cathode edges in MEA for direct methanol fuel cell

[12] C. Wulff, M. Keuerleber: Patent DE102011105072B3: Haltevorrichtung mit einer Membran einer Membran-Elektroden-Einheit für eine Brennstoffzelle und Verfahren zu deren Herstellung

[13] S.-m. Song, G.-y. Moon, W.-h. Lee: Patent EP1839358B1, GASKETED MEMBRANE-ELECTRODE-ASSEMBLY AND FUEL CELL SYSTEM EMPLOYING THE SAME