Investigation of PEFC Freeze Start by X-Ray Tomographic Microscopy

J. Roth[1)], M. Zurbrügg[1)], J. Eller[1)], S. Irvine[2)], F. Marone[2)], M. Stampanoni [2)], F.N. Büchi[1)]

[1)]Electrochemistry Laboratory, [2)]Swiss Light Source,
Paul Scherrer Institut,
CH-5232 Villigen PSI, Switzerland

Starting from subfreezing temperatures presents a challenge for polymer electrolyte fuel cells. On the one hand, the product water removal is a problem since ice may form limiting the gas flow in channel, gas diffusion layer (GDL) and catalyst layer; on the other hand freezing induced degradation may limit cell durability unless special care is taken prior to freezing [1]. Under non-isothermal conditions, a start-up is successful if the cell temperature rises above freezing by self-generated heat before ice-formation leads to detrimental gas transport blockage. Model experiments under isothermal conditions below 0 °C reveal that the cell operates for a certain time, and then power drops to a low level. The runtime is a function of charge produced and temperature.

This study aims at better understanding of the water phase transition processes during operation at subfreezing temperatures by quantitative mapping of the liquid/solid water distribution during isothermal freeze starts. The experiments aim at exploring the circumstances of freezing induced termination of power production. This will finally lead to improved material/operating conditions to enable reliable, possibly non-damaging fuel cell starts under freezing conditions.

The condensed water appearing in the GDL and gas channel during freeze-starts is investigated by means of X-ray tomographic microscopy using a fuel cell set-up customized for XTM- investigation (Fig. 1). Experiments were performed at the TOMCAT beamline of the SLS [2]. The following sequence was performed:

1) Drying of the MEA to 0.25 Ω cm².
2) Cooling the cell down to -10 °C.
3) Start in potentiostatic mode.
4) Tomographic images are taken untill the current drops below 20 mA/cm².
5) A gas purge (gas velocity in cathode channel: 22 m/s) is applied to remove liquid water from the flow field channels while more scans are taken under purge conditions.

The cell was operated at ambient pressure during steps 3) and 4) with a cathode gas channel velocities of 0.8 m/s. Cell potential and temperature are kept constant for the duration of the current production.

With the given protocol, the cells operated for 6 - 8 min, before the current stagnates. Fig. 2 shows the current density and the local water film thickness in the cathode GDL for such a typical freeze start.

The saturation was observed to increase over time and at several locations the water reached the channel before shutdown (one example is shown in Fig. 3). Purging the cell after shutdown has only a minor effect on the water in the first few minutes (scans d) and e) in Fig. 2). This suggests that the shutdown is caused by a sudden solidification of super-cooled water once the gas flow in the channel interacts with the water, supporting the hypothesis on the appearance of super-cooled water (e.g. suggested by [3]). With increasing duration of the purge, water is removed primarily from the channel region of the GDL probably due to sublimation.

The propagation of the water front during the freeze start and purging will be reported and correlated with mass transport properties.

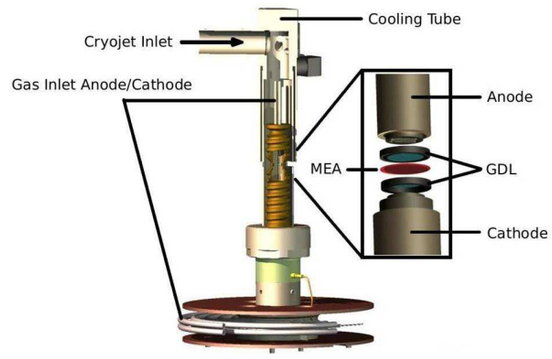

Figure 1: Schematics of the cell used for X-ray tomographic microscopy.

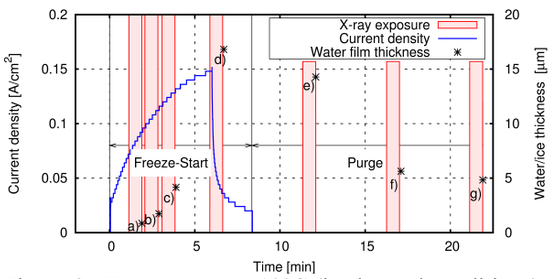

Figure 2: Freeze-start at -10°C (isothermal conditions) and 0.5 V . The labels refer to the tomographic scans.

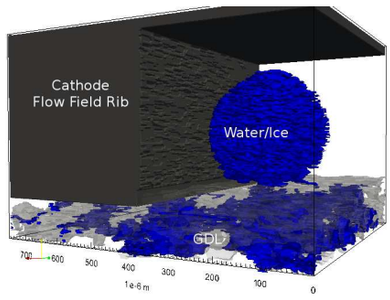

Figure 3: Local distribution of water/ice in cathode gas channel and GDL at time d) after freeze start at -10°C.

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