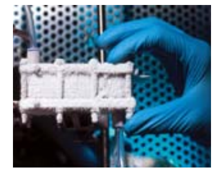
Freezing effects in polymer electrolyte membrane fuel cell stacks



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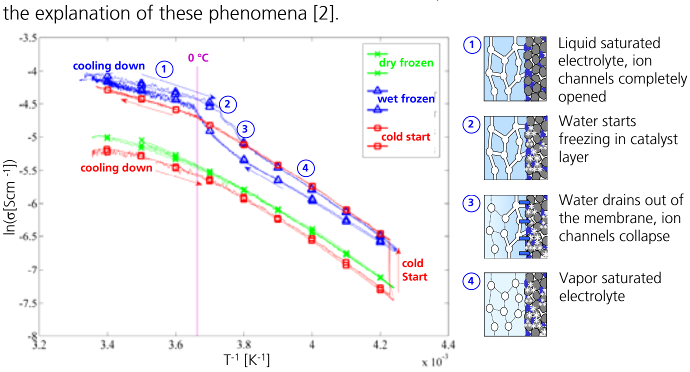
Introduction

The degradation of fuel cells caused by temperatures below 0 °C is a very important issue for the commercialisation of fuel cells.
In this work [1], the effect of freezing temperatures on two 6-cell fuel cell stacks is investigated in-situ and ex-situ. Stack one was only frozen in a dry status and stack two was frozen in a wet status with subsequently cold starts.

Water allocation and transport during freezing and cold start

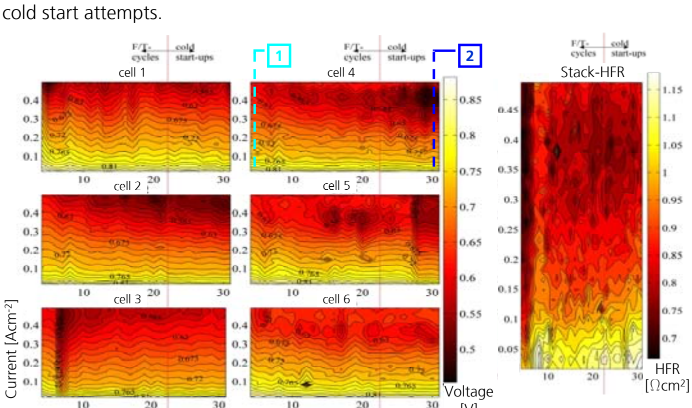
Arrhenius plots of temperature dependent conductivity show different slopes above and below 0 °C when freezing in a wet status, freezing in a dry status and before/after a cold start attempt at -40 °C. A significant hysteresis between cooling and heating as well as a sudden change in conductivity at 0 °C is only observed for the wet frozen stack. Recent models provide a theoretical basis for the explanation of these phenomena [2].

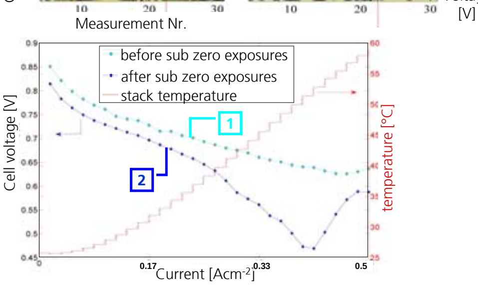


- Water is drained out of the membrane at sub zero conditions up to -40 °C and is mainly freezing in the catalyst layer, not in the membrane
- Lower conductivity after cold start than before freezing in a wet status (electrodes not fully saturated after cold start)

Freezing induced changes in cell performance

31 Polarisation curves of the wet frozen stack during 62 freeze/thaw cycles and 9 cold start attempts.

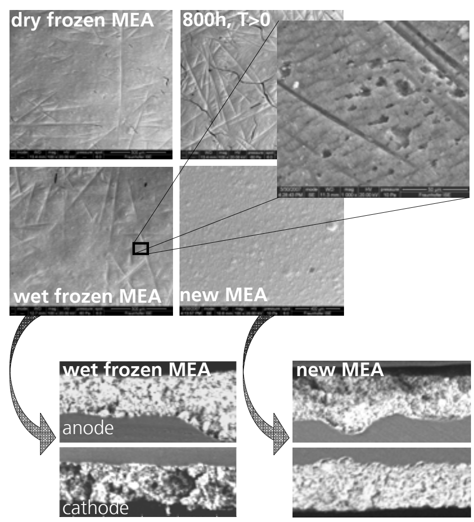




- Higher degradation at high current
- Decrease in HFR at high currents due to changed water transport properties
- No apparent correlation between position of cell in stack and degradation

Ex-situ examination after disassembling

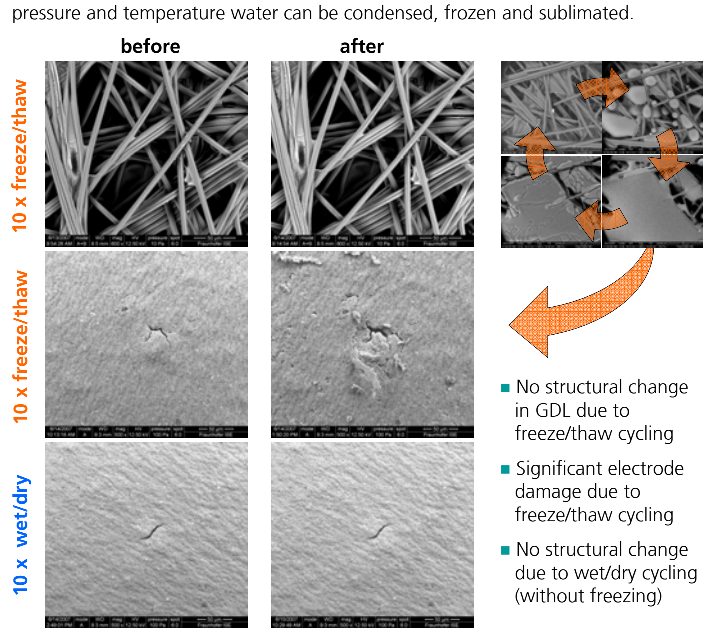
Top- view and cross section examination of CCM in SEM.



- Pinholes with ∅ of ~ 10 µm found in CCM surface of the wet frozen stack
- Cracks in surface only for a stack with long operating time but no freezing
- Significant electrode damage visible in MEA cross sections of the wet frozen stack
- Reduced electrode cross section surface in the wet frozen stack mostly on the cathode side: -13.0% anode -35.9% cathode

Ex-situ examination within an ESEM

10 freeze/thaw cycles of MEA and GDL samples were conducted within an environmental scanning electron microscope (ESEM). By means of variation of pressure and temperature water can be condensed, frozen and sublimated.



- No structural change in GDL due to freeze/thaw cycling
- Significant electrode damage due to freeze/thaw cycling
- No structural change due to wet/dry cycling (without freezing)

Conclusions

- Cathode catalyst layers are mostly affected by freezing of water
- Structural changes of the catalyst layer lead to increasing water accumulation in the electrodes and increasing mass transport losses as a consequence
- Changes are most severe in dynamic performance of the cells [1]
- Degradation due to freezing can be prevented by a preceding drying step [1]

[1] R. Alink, D. Gerteisen, M. Oszcipok, J. Power Sources 182 (2008) 175-187.
[2] A.Z. Weber, J. Newman, J. Electrochem. Soc. 150 (2003) A 1008-A1015.