Dynamic Water Management Studies by means of Perforated GDLs and In-situ ESEM Observations

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Freiburg, Germany

Diagnostic Tools for Fuel Cell Technologies
24.06.2009, Trondheim

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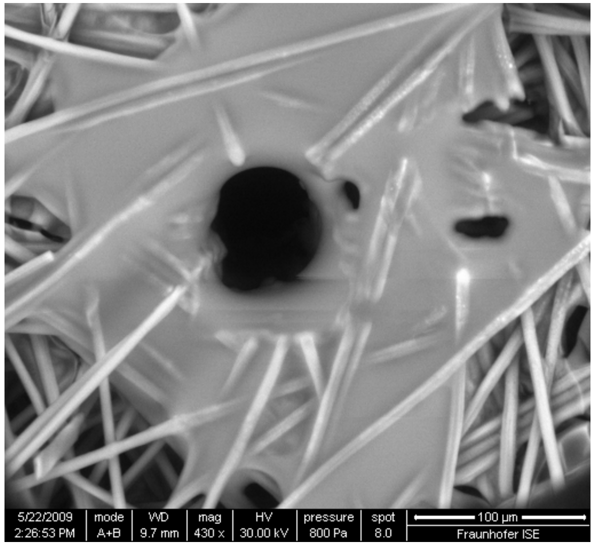
Overview



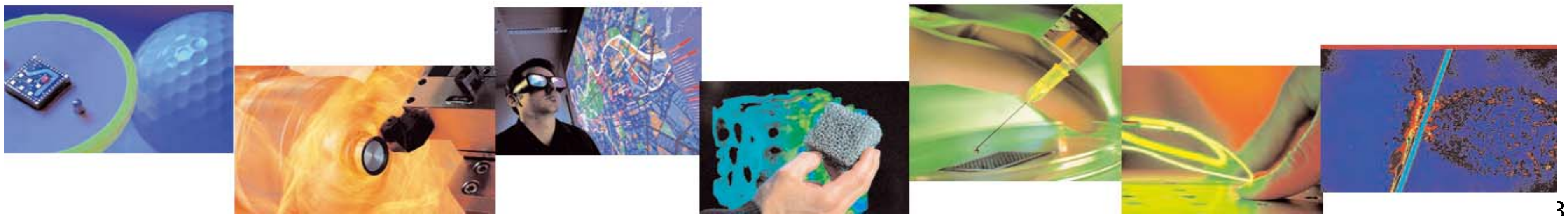
- Test scope: Examination of the water transport properties of laser perforated of gas diffusion layers
- In-situ single cell experiments and stack experiments
- Ex-situ visualizing of water transport in untreated and perforated GDLs in ESEM

The Fraunhofer Society

58 Institutes - 12 600 Employees – 1.2 Bio € Budget

7 Alliances

- Mikroelectronics
- Production Technology
- Information and Communication Technology
- Materials, Devices
- Life Sciences
- Surface Technology and Photonics
- Defense and Security Research



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Research & Development, Services

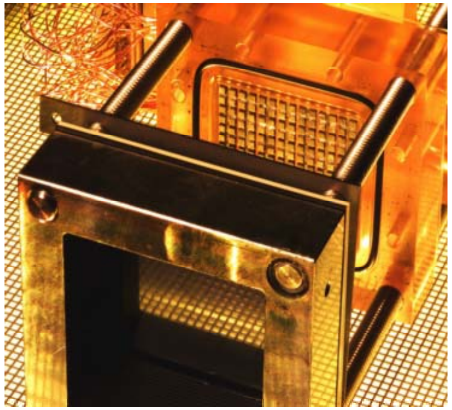
Research
Materials
Modelling
Methods

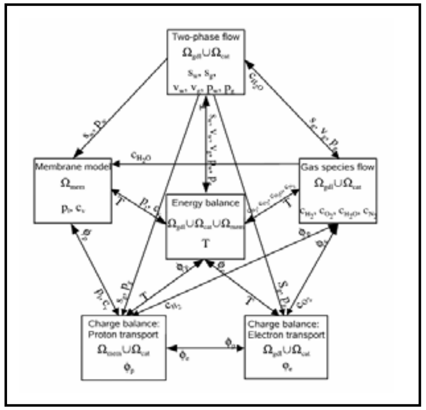
Development
Components
Products, Prototypes
Systems, Processes

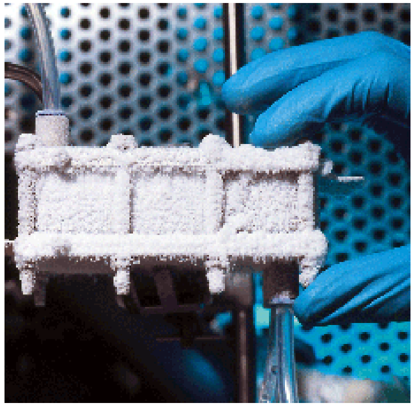
Services
Consulting, Tests
Monitoring
Quality Assurance

Fuel Cell Systems

- Development of fuel cell systems, stacks and autonomously controlled systems
- Characterizing and modelling single cells, stacks and systems
- Control and safety technology







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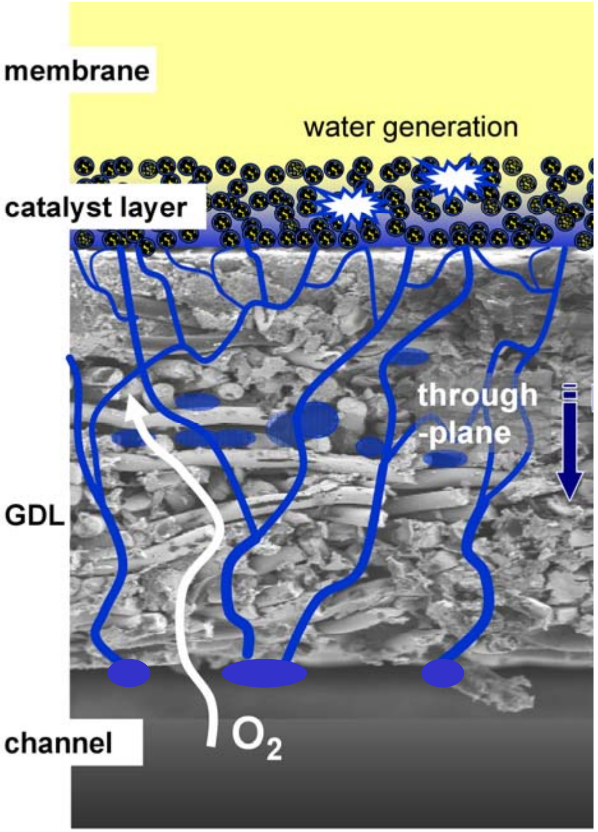
How can perforation of GDLs help to enhance the performance?

- Water is generated in the catalyst layer
- Water flows through small cavities
- Small filled cavities merge to larger cavities
- Void space gets filled by liquid water

<u>As consequence:</u>
➢ water hinders oxygen diffusion



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How can perforation of GDLs help to enhance the performance?

- Pressure needed for through-plane transport of liquid water is higher than that for in-plane transport
- Water transport channels (WTCs) support the through-plane transport

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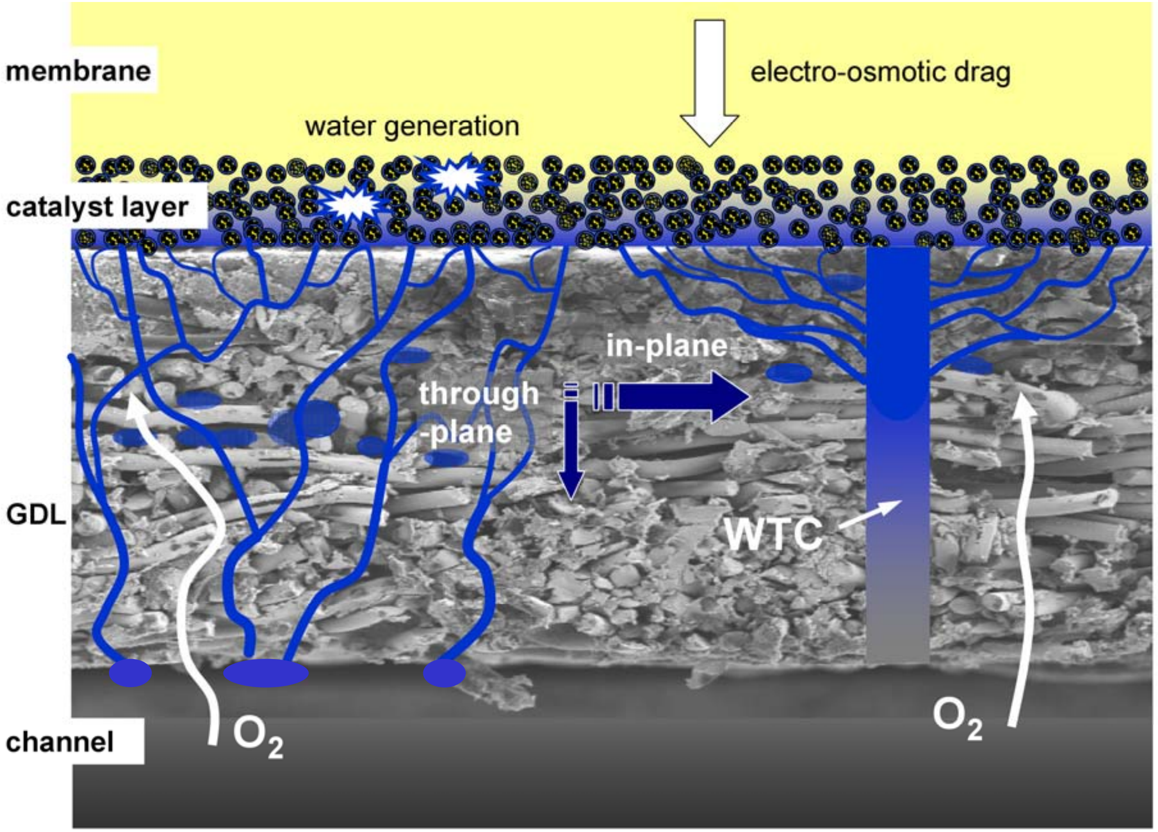
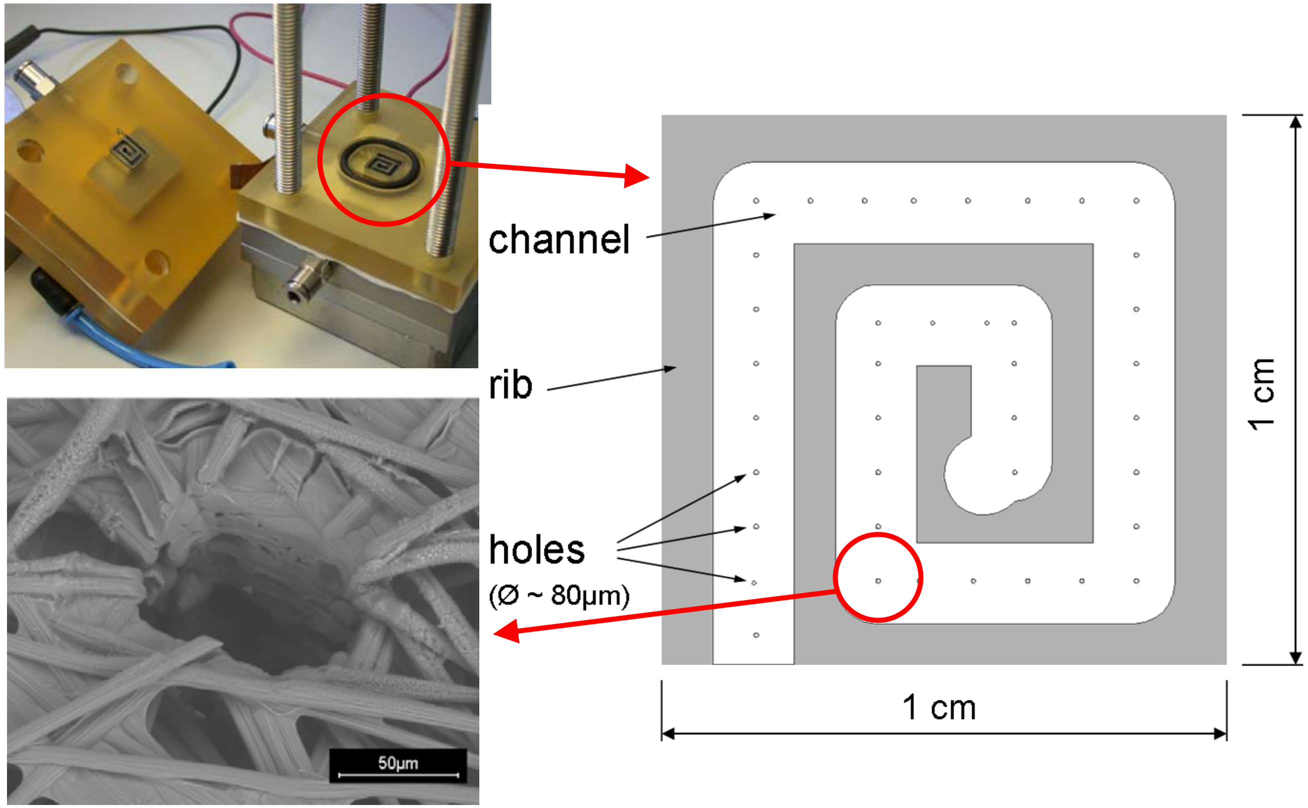
<u>Decrased saturation and increased oxygen diffusivity</u>



Investigation of single cell

- Investigation of single cell with an active area of 1 cm^2
- Cathode GDL „under the channel“ was perforated by laser treatment
- Holes have a diameter of 80 $\mu\mu$ and a gap distance of 1 mm



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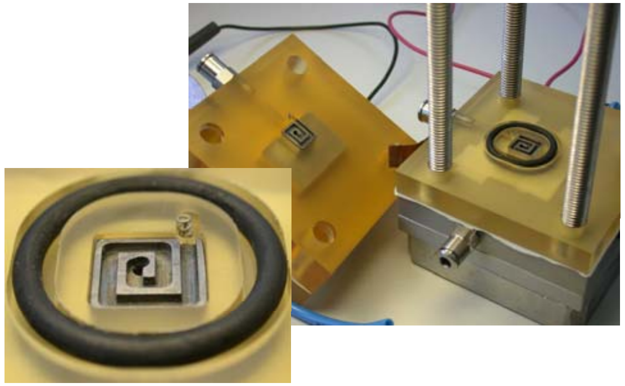
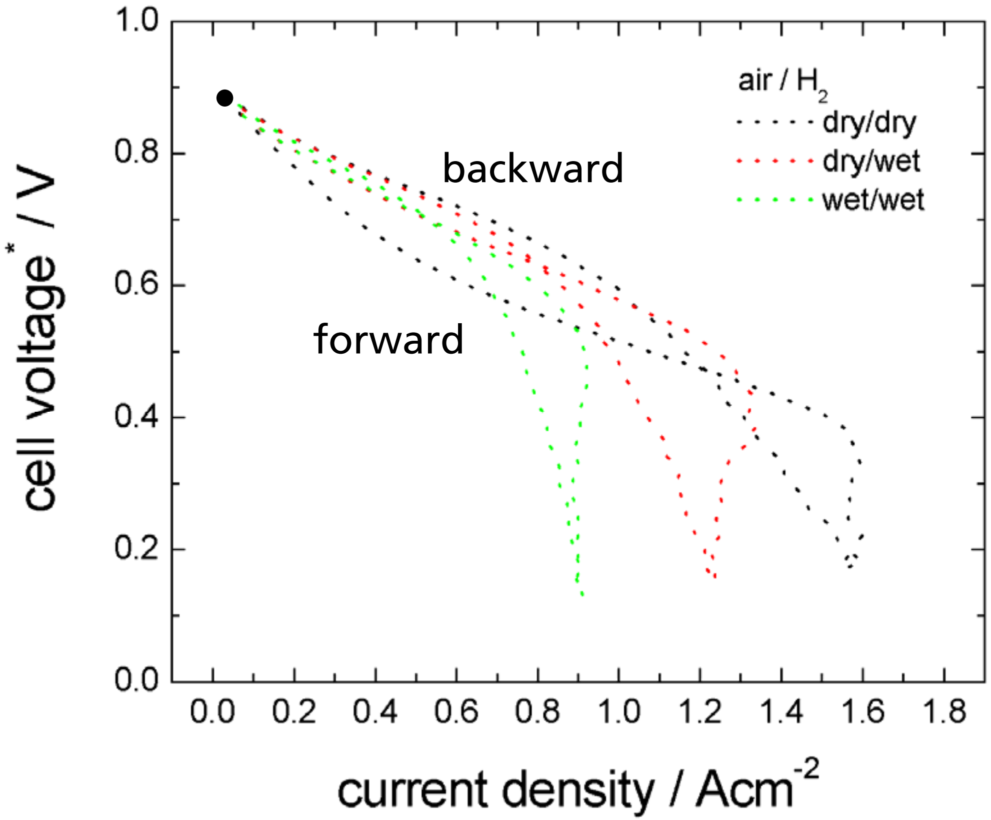
In-situ characterising of GDL water transport properties

Dynamic polarisation curves @

- different operating conditions
- sweep rate 10 mV/s

show hysteresis effect





* without anode polarization

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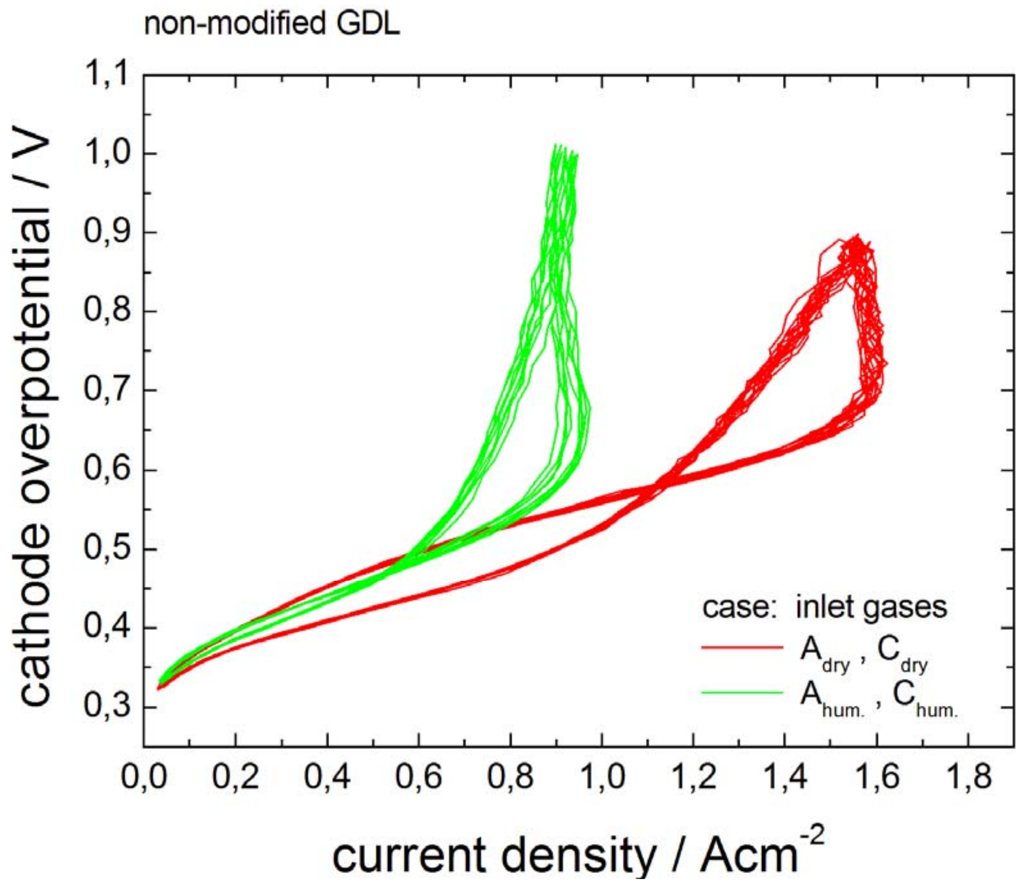
Enhancing liquid water transport by laser perforation of a GDL in a PEM fuel cell
Journal of Power Sources, Vol 177, Issue 2, 1 March 2008, P 348-354
D. Gerteisen, T. Heilmann, C. Ziegler

Improving the liquid water transport in the GDL

- Potential sweep measured with non-modified GDL



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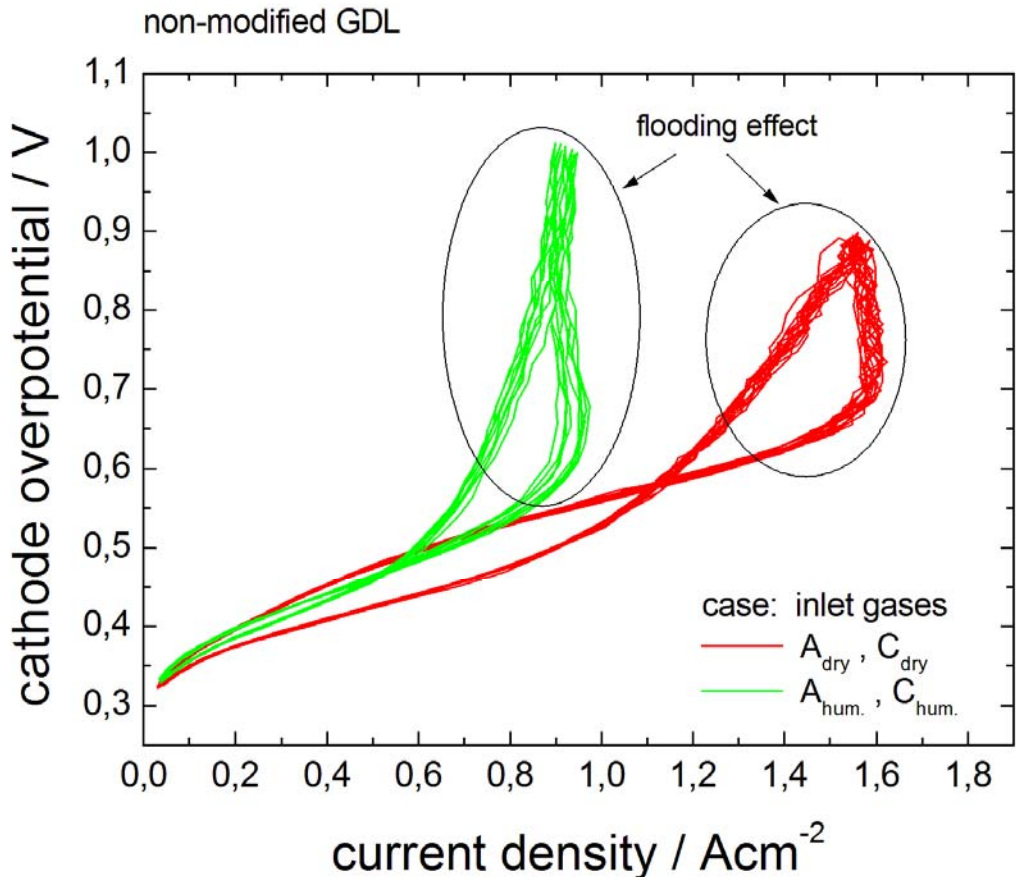
Improving the liquid water transport in the GDL

- Potential sweep measured with non-modified GDL
- Hysteresis knee due to flooding effects



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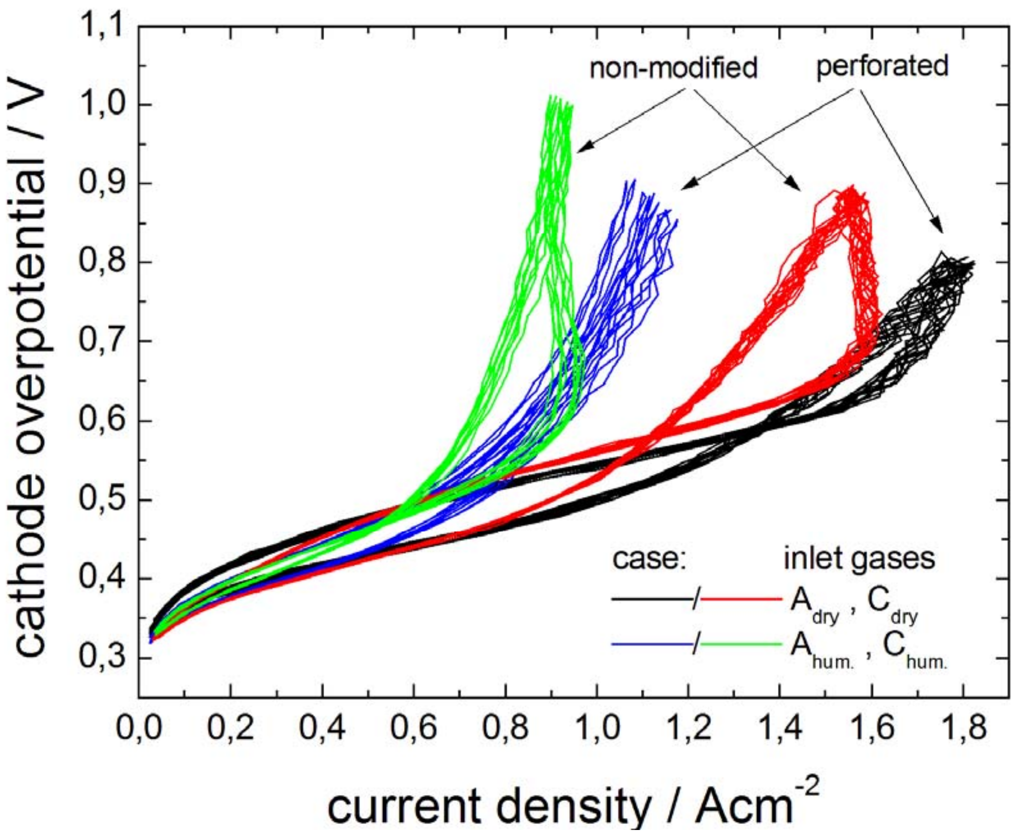
Improving the liquid water transport in the GDL

- Potential sweep measured with non-modified GDL
- Hysteresis knee due to flooding effects
- Perforated GDL shows lowered pore flooding



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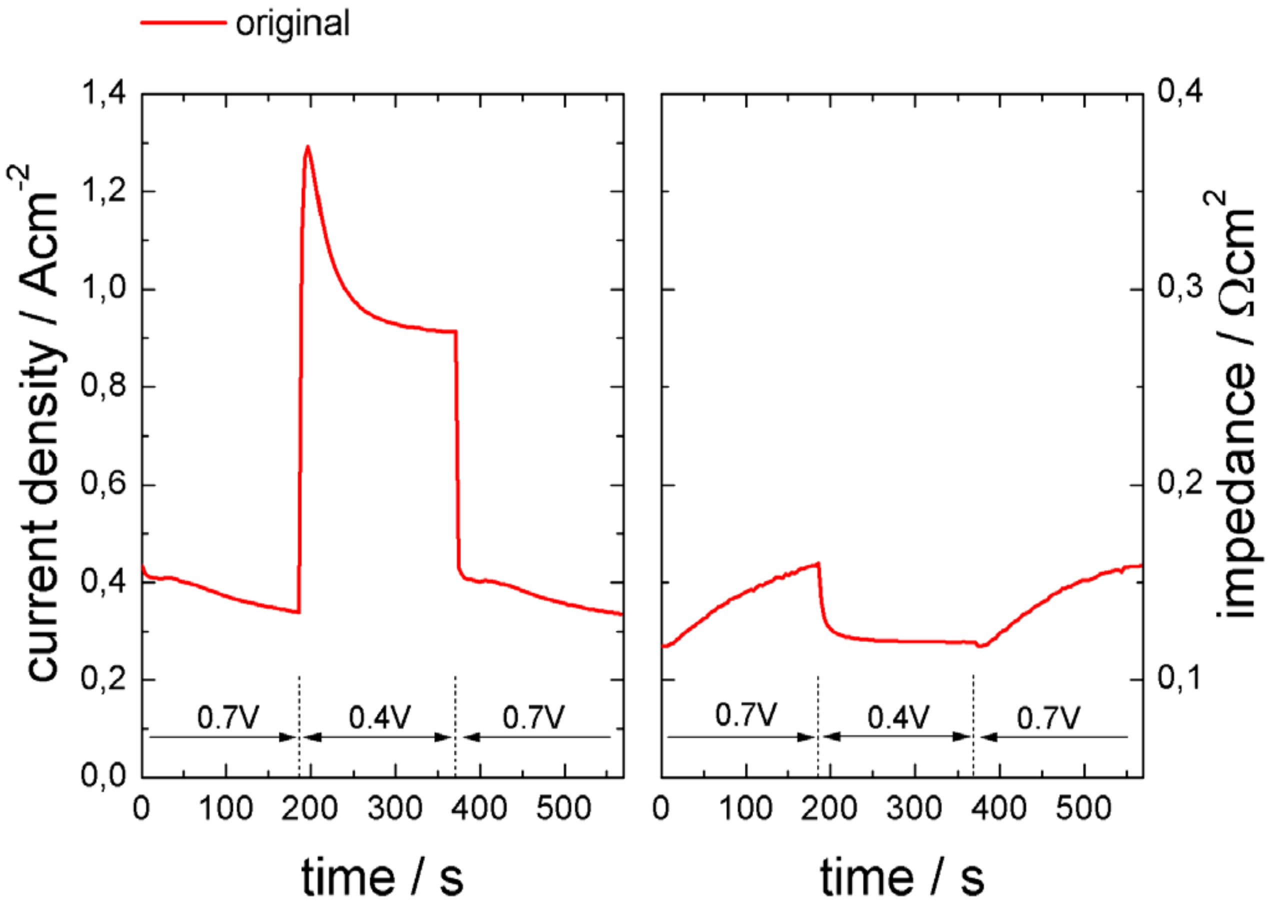
Improving the liquid water transport in the GDL

- Chronoamperometriy

  700 ⇔ 400 mV



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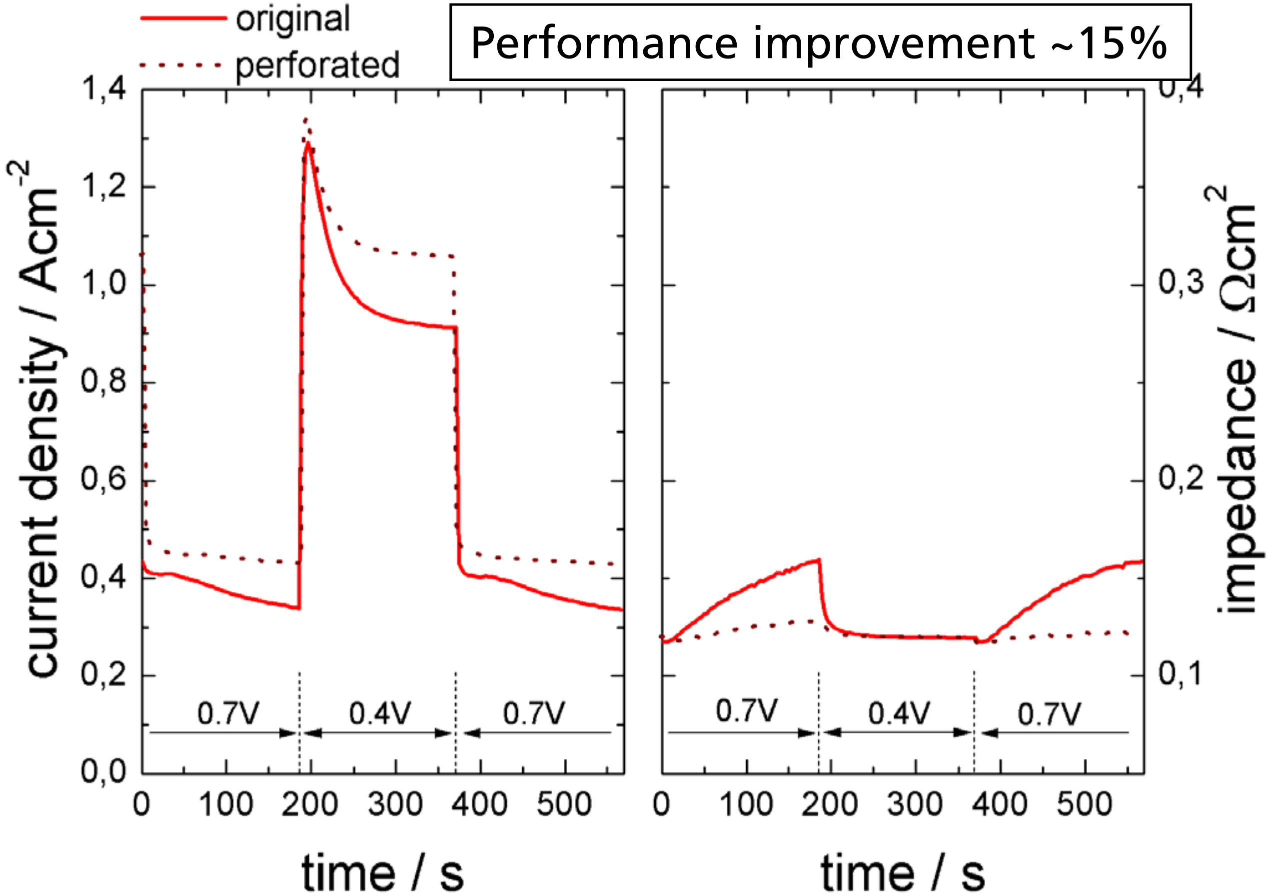
Performance improvement ~15%



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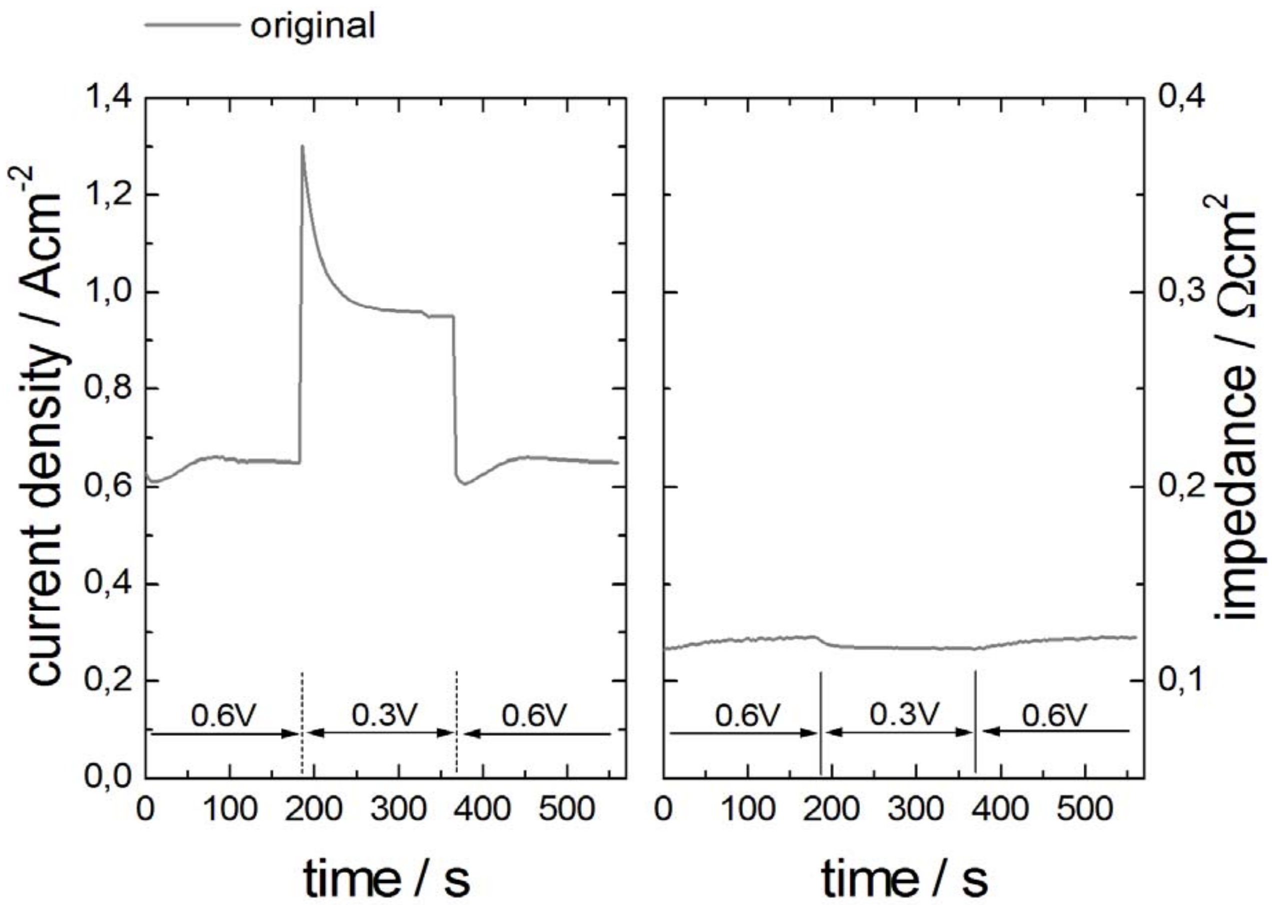
- Chronoamperometriy

  600 ⇔ 300 mV



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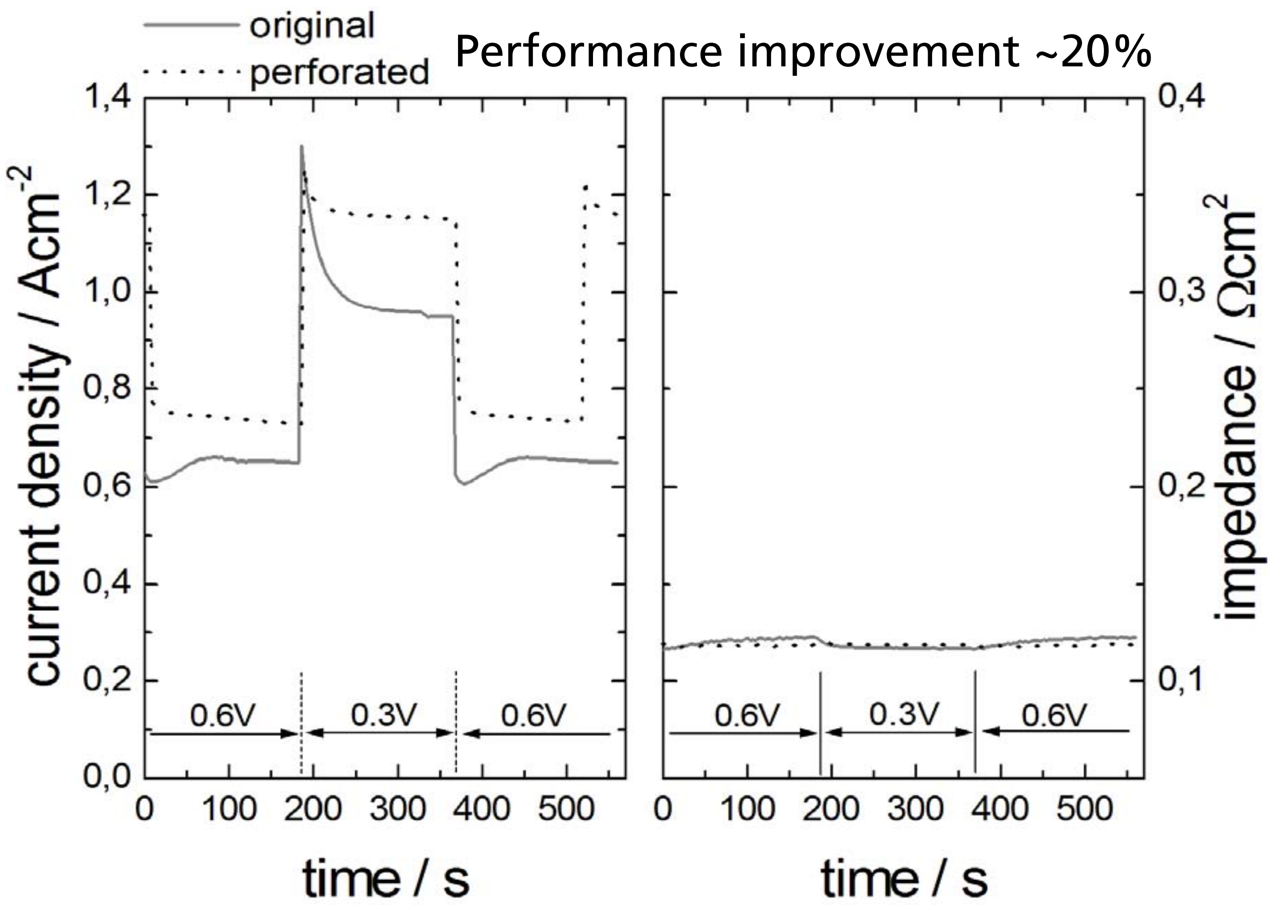
- Chronoamperometriy

  600 ⇔ 300 mV

Performance improvement ~20%



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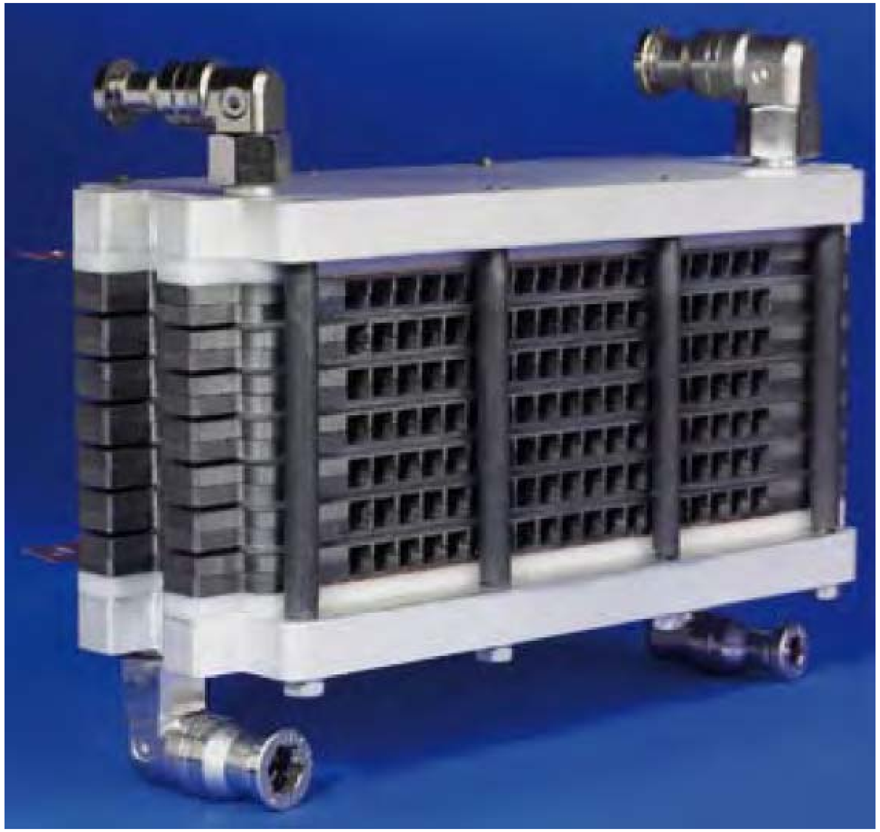
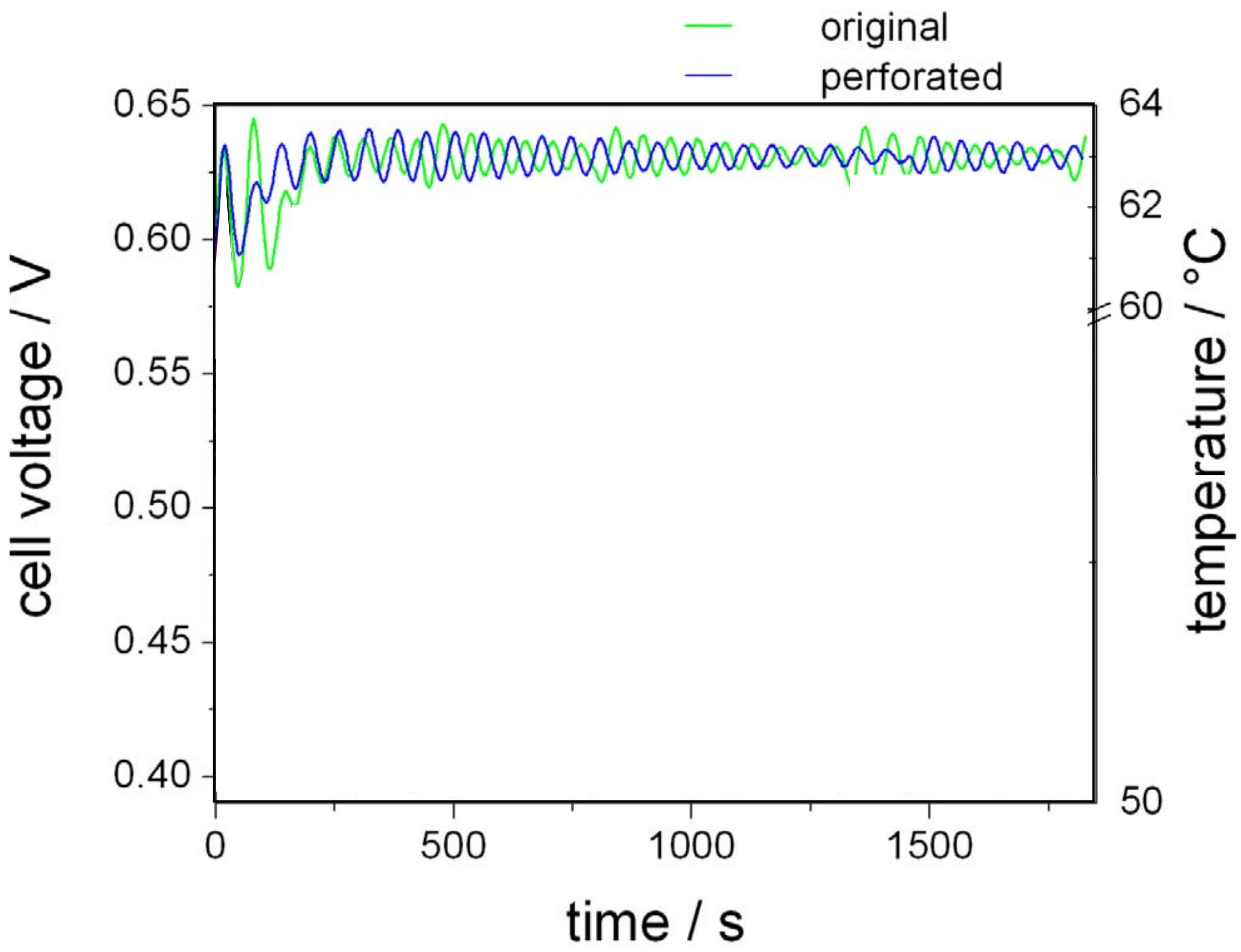
Investigation of fuel cell stack

- Air cooled stack
- 6 cells
- Active area of 6 x 31 cm^2



Cell stability at 0.71 A/cm²

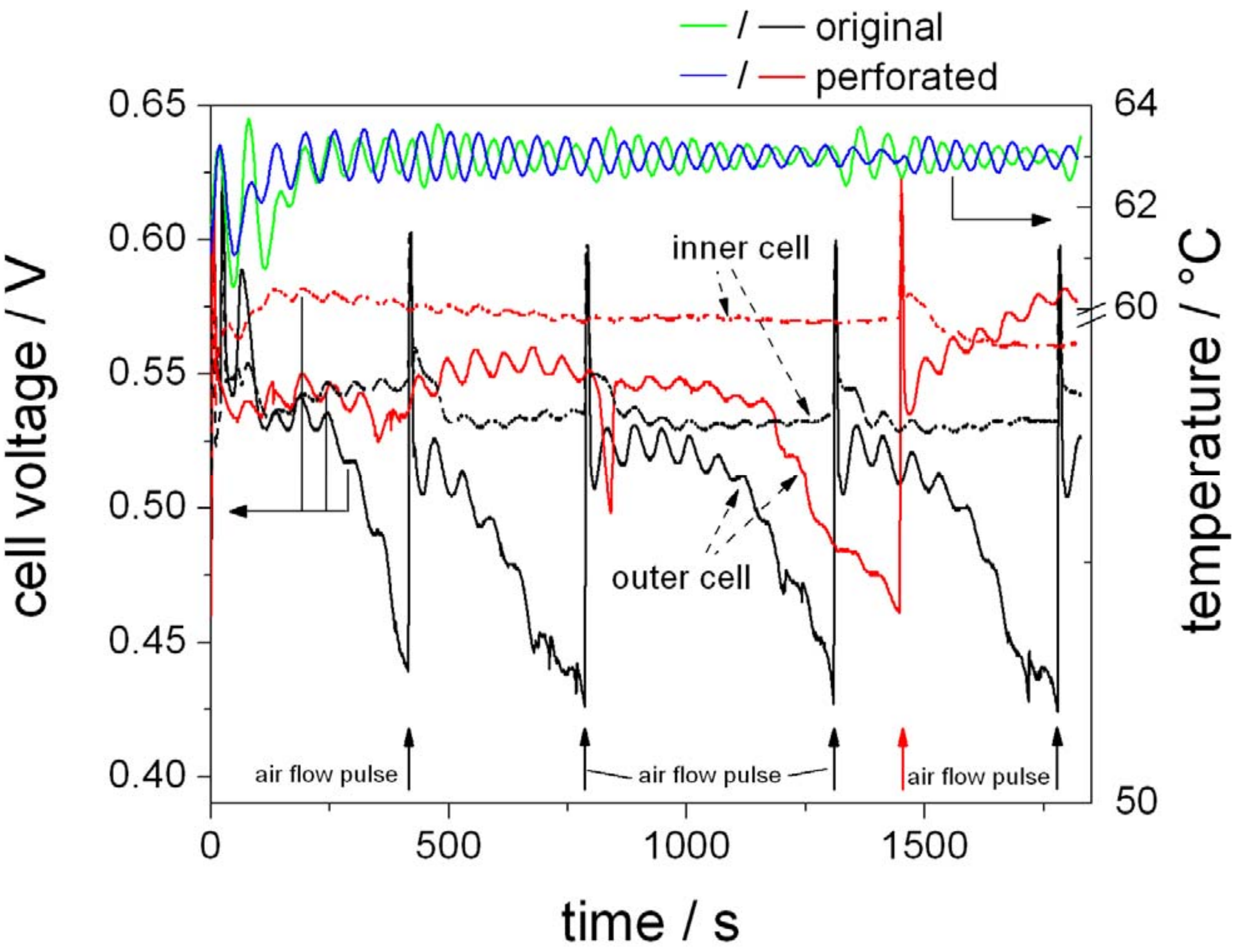
- Stability test at 0.71 A/cm² and 63 °C



Cell stability at 0.71 A/cm²

- Stability test at 0.71 A/cm² and 63 °C
- Voltages of outer cells tend to collaps due to flooding
- Higher overall performance
- 3 times less purging steps

Increased stability and performance



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Polarisation curve

- Higher Voltage at constant current
- Less variation of single cell-voltage

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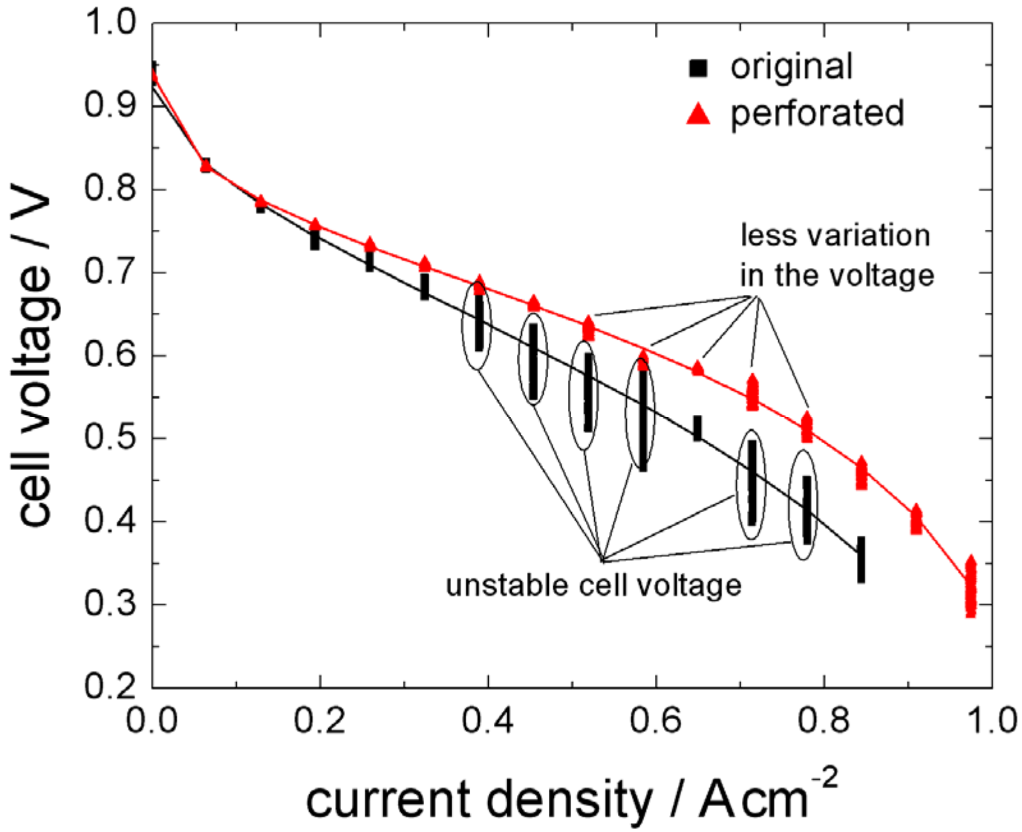
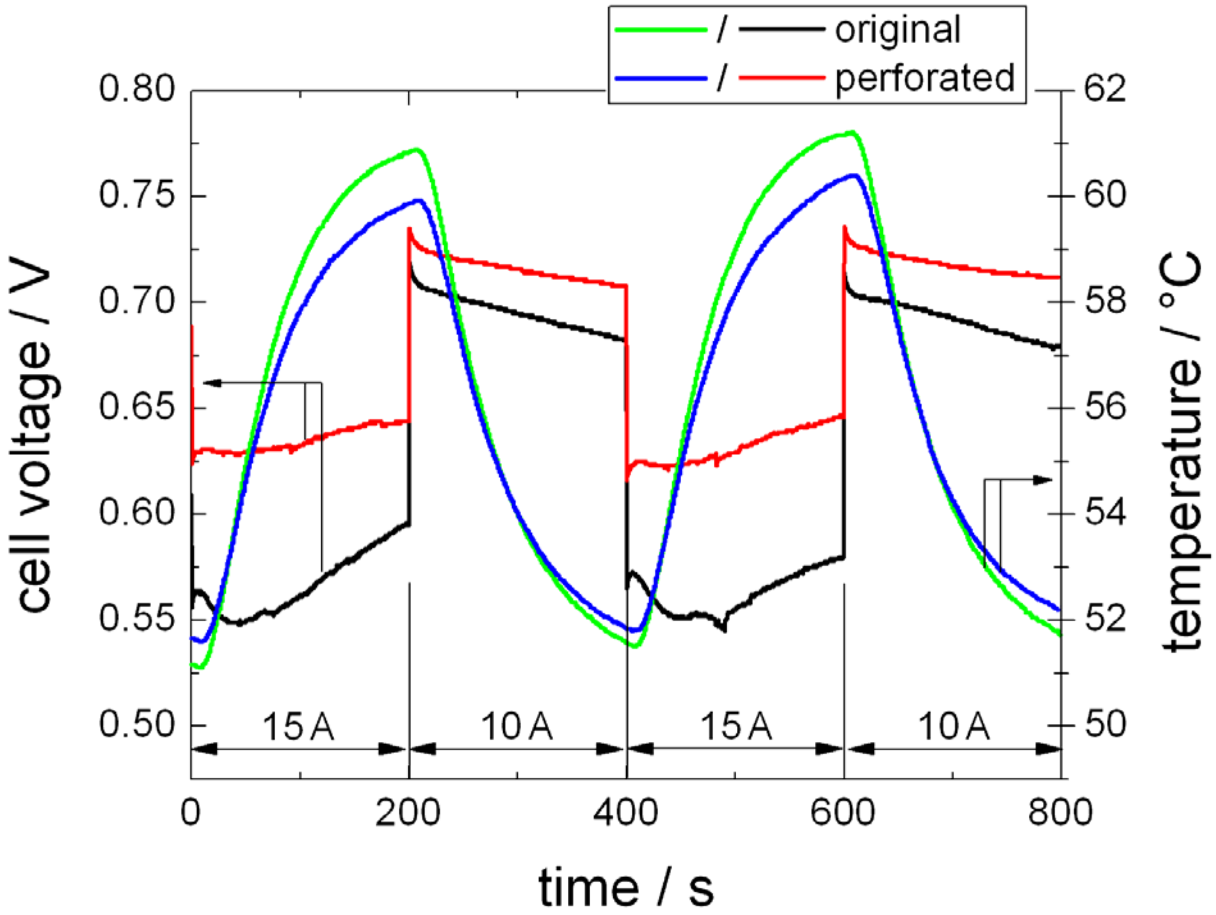
Increased stability and performance



Chronovoltametry

- Higher Voltage after switching to higher current
- Lower temperature due to lower mass transport losses



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Increased stability and performance

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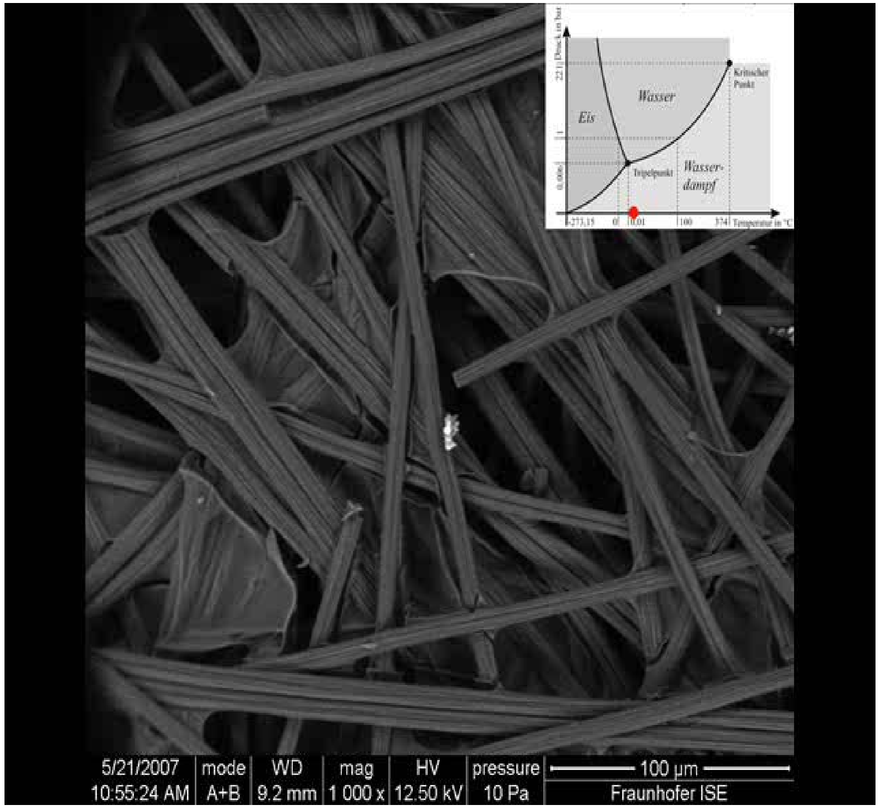
Examination of degradation by freezing water in ESEM

- ESEM working in water vapor athomsphere
- All 3 phases of water possible by adjusting temperature and pressure



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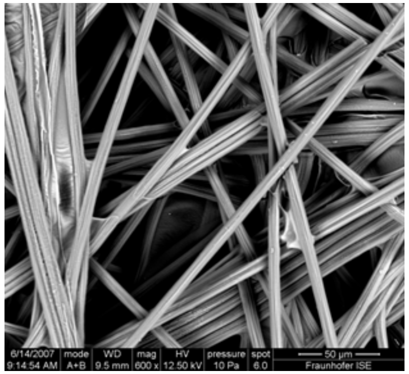
Examination of degradation by freezing water in ESEM

- Freeze / thaw cycling of GDLs

before



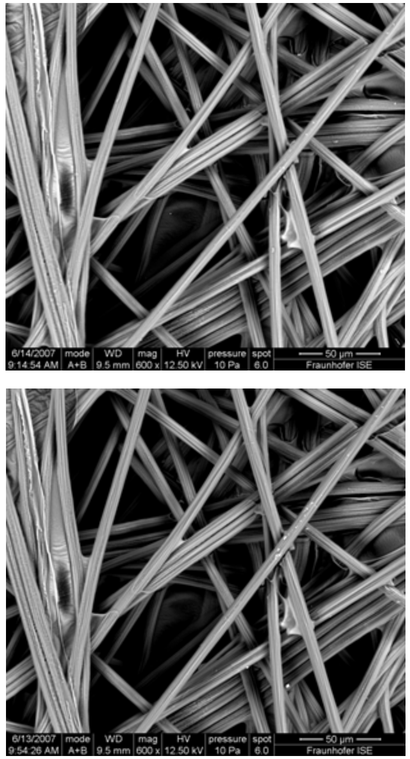
Examination of degradation by freezing water in ESEM

- Freeze / thaw cycling of GDLs

10 x freeze / thaw

before

after



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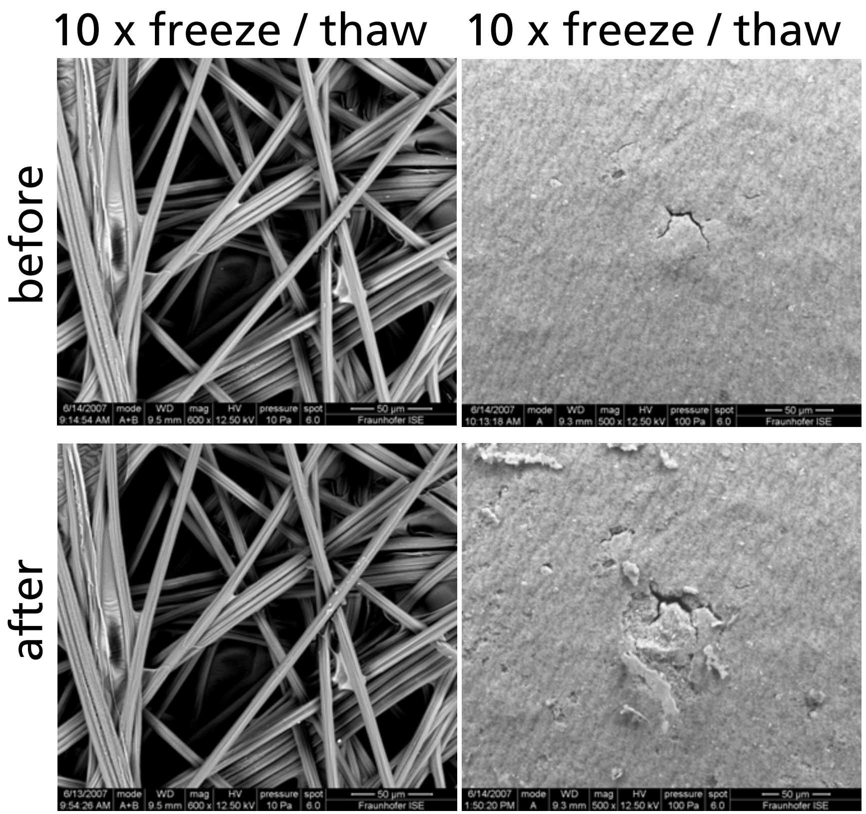
Examination of degradation by freezing water in ESEM

- Freeze / thaw cycling of GDLs
- Freeze / thaw cycling of MEAs



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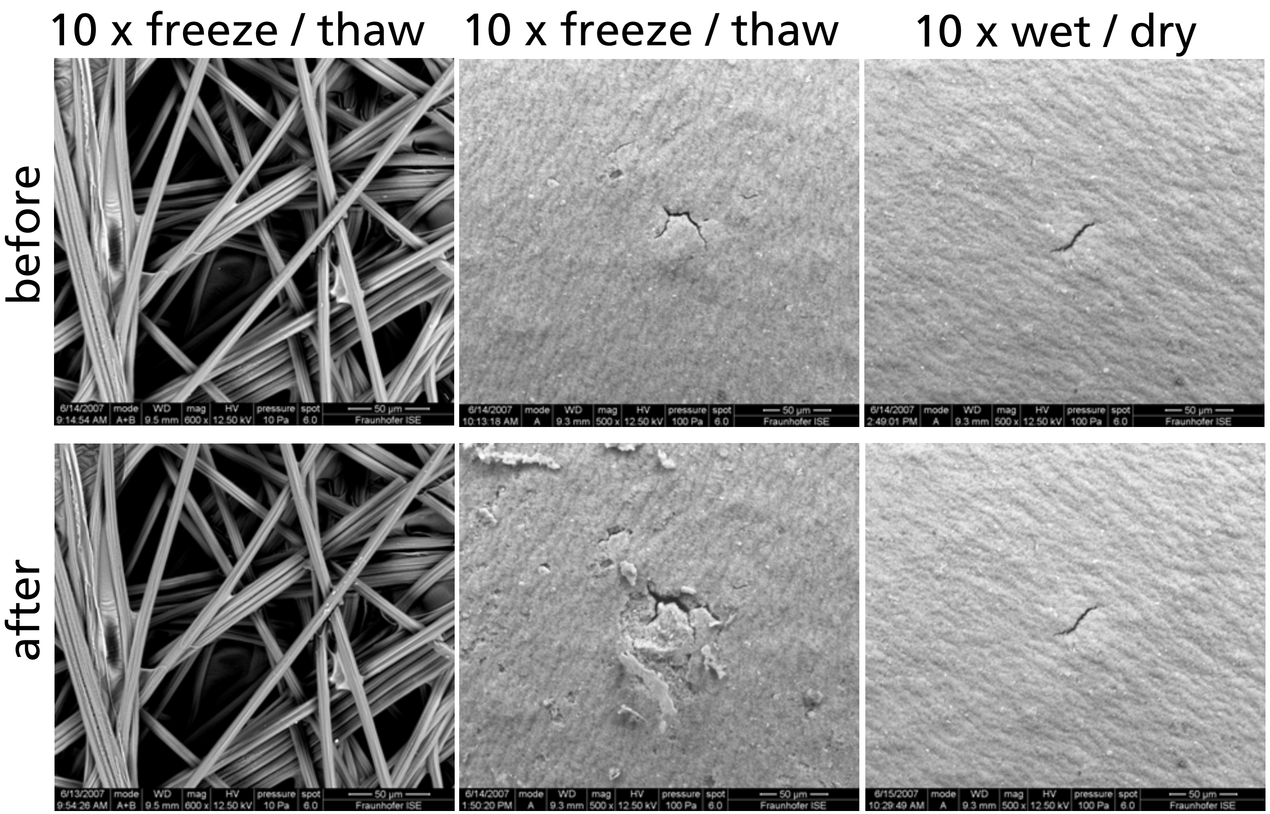
Examination of degradation by freezing water in ESEM

- Freeze / thaw cycling of GDLs
- Freeze / thaw cycling of MEAs
- Wet / dry cycling of MEAs as reference



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Liquid water examination in ESEM

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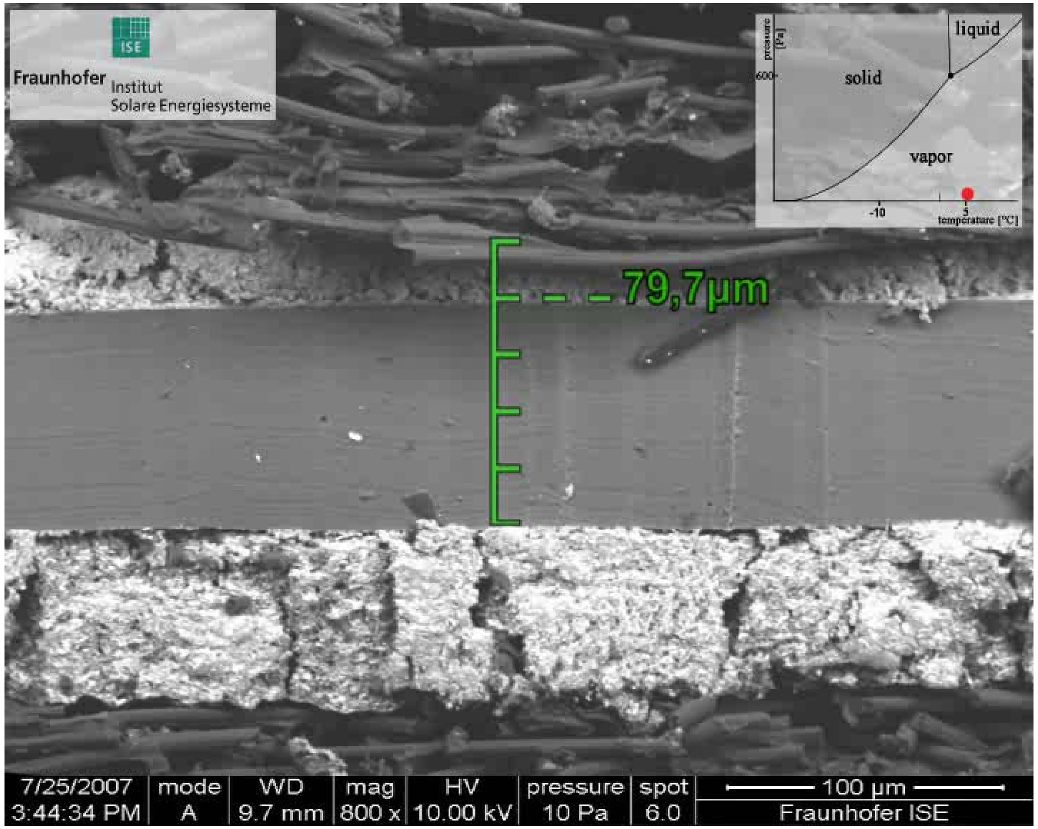

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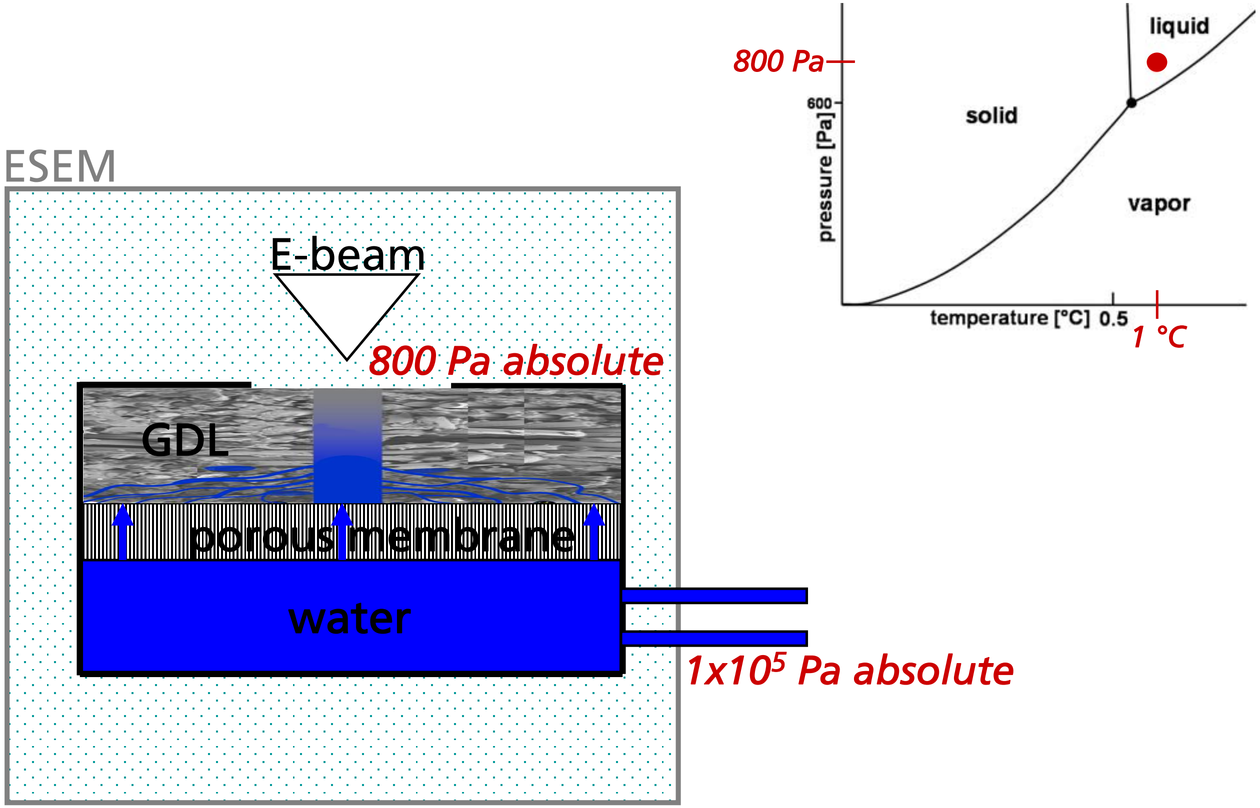
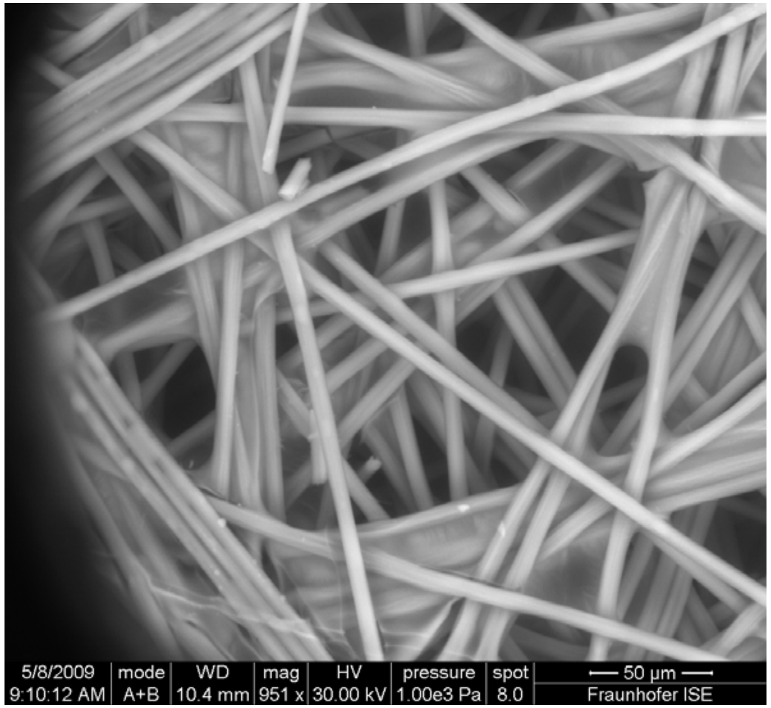
Ex-situ visualization of liquid water breakthrough in ESEM

- Water is „sucked“ through a porous membrane and the GDL
- Visulization of water breakthrough near the GDL surface



Transportation of water within an untreated GDL



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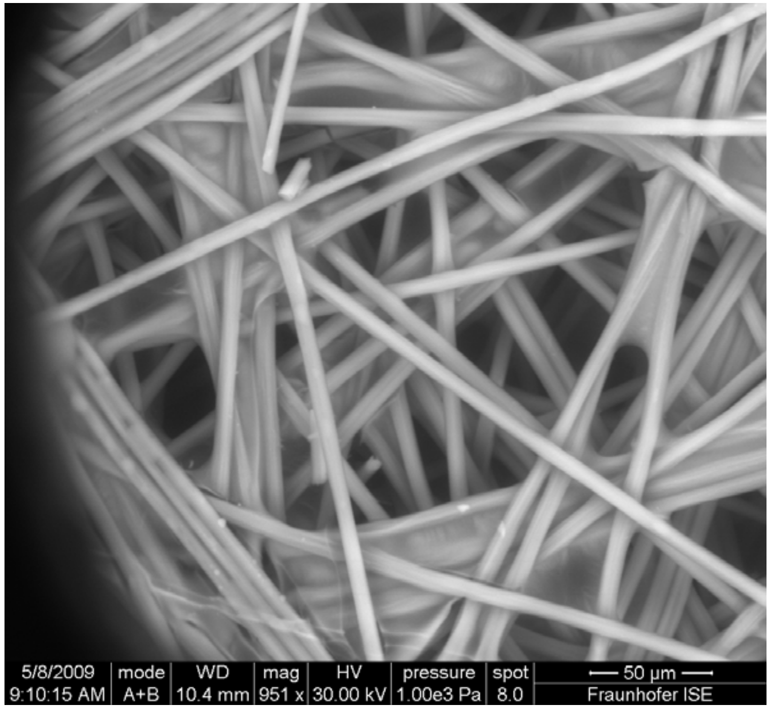

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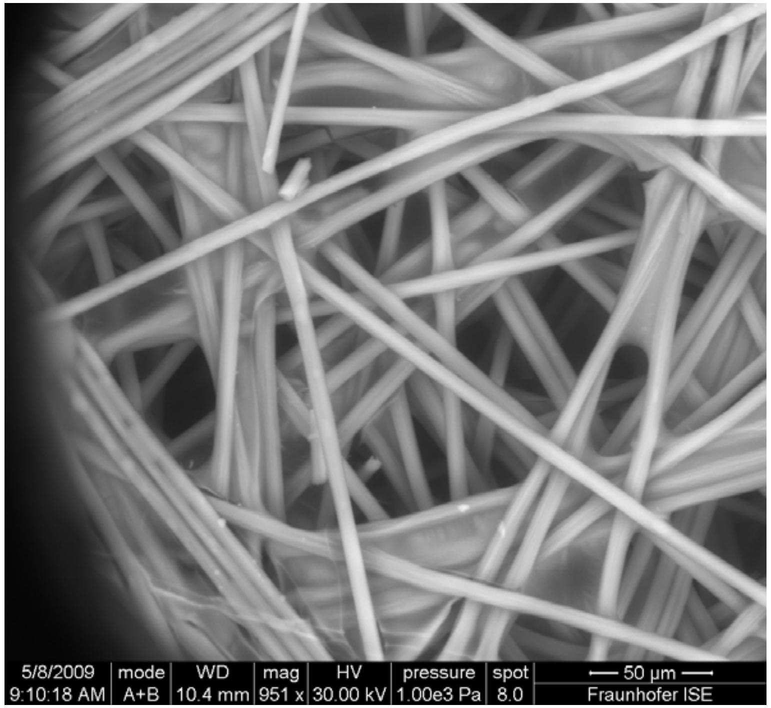

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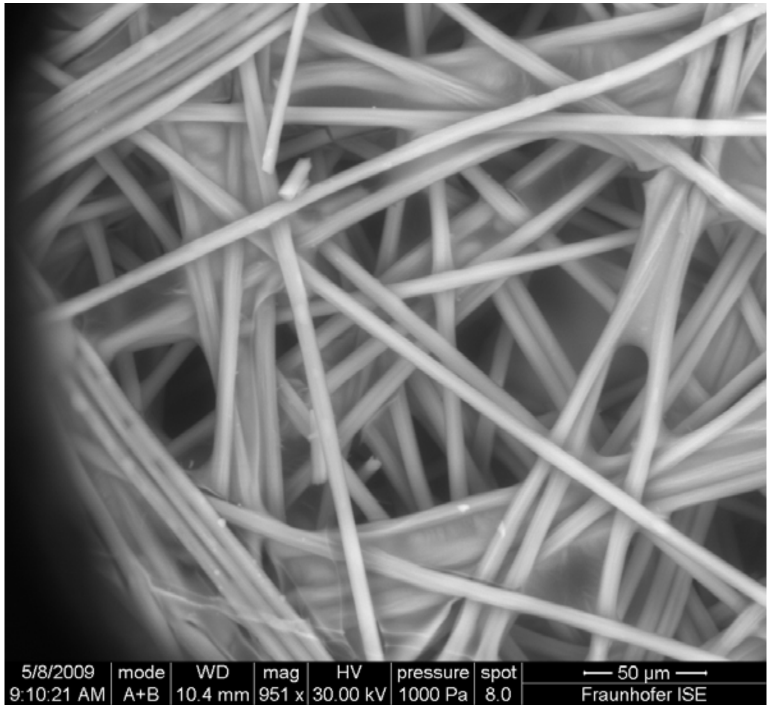

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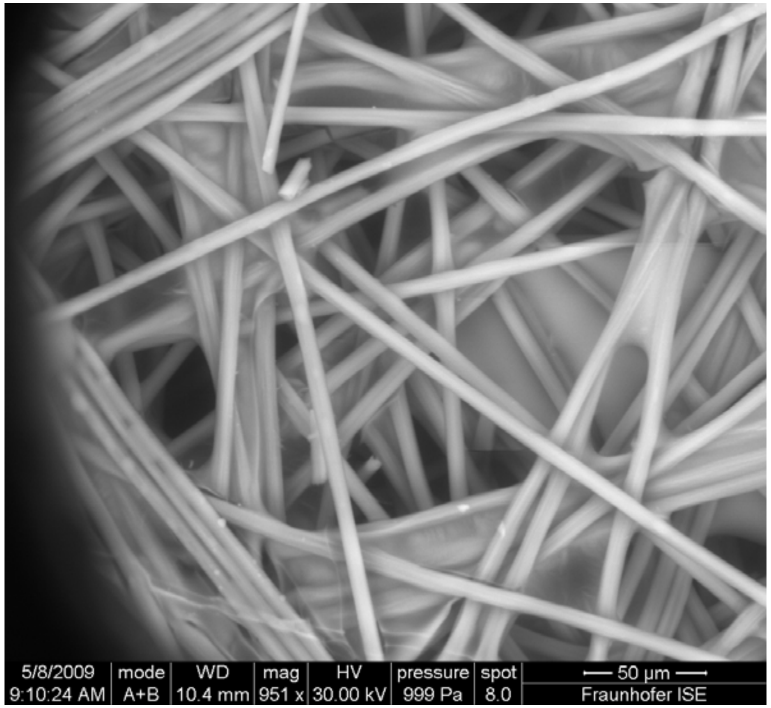

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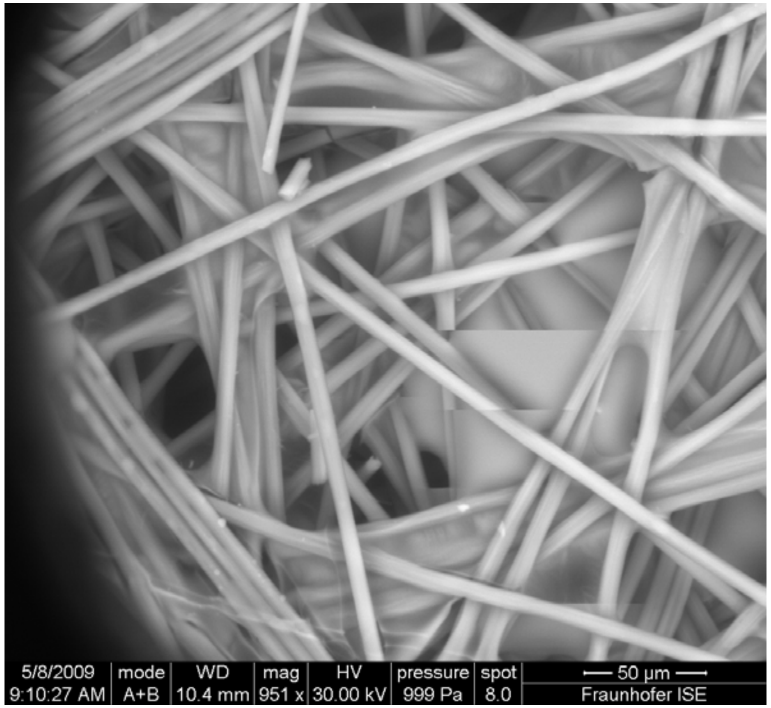

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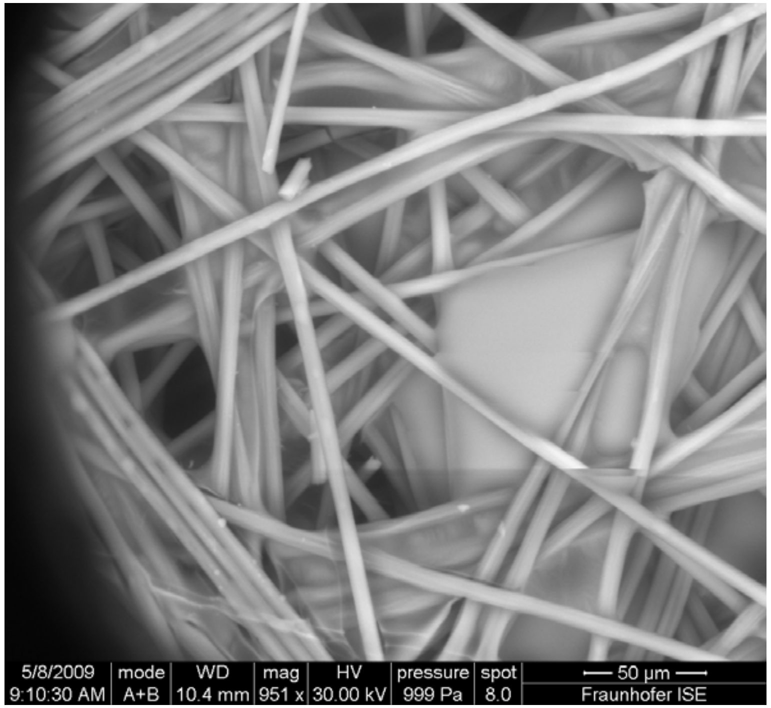

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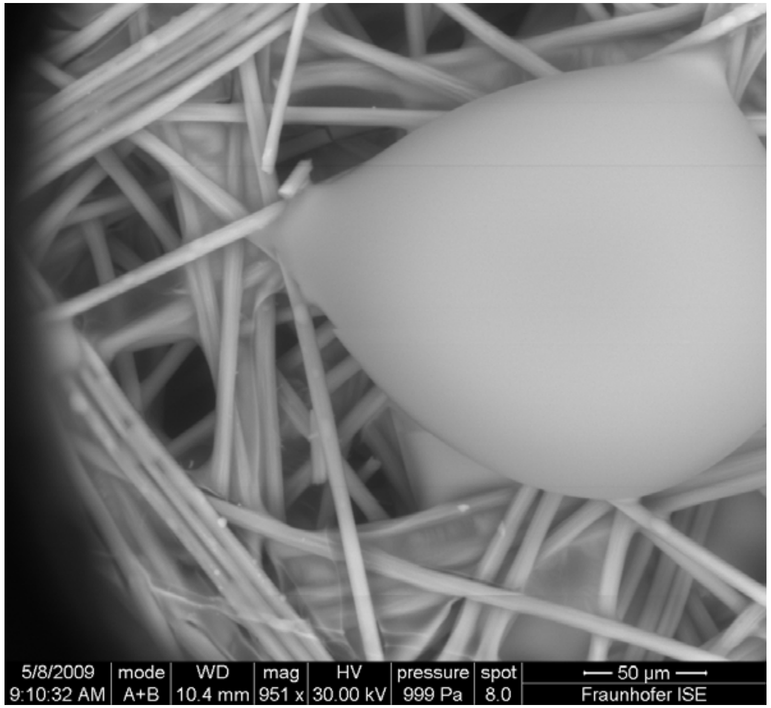

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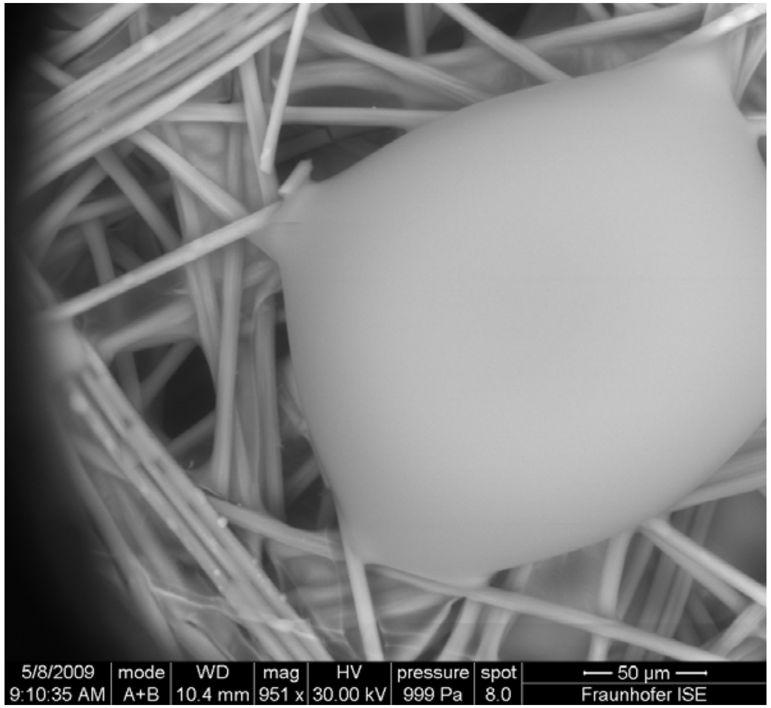

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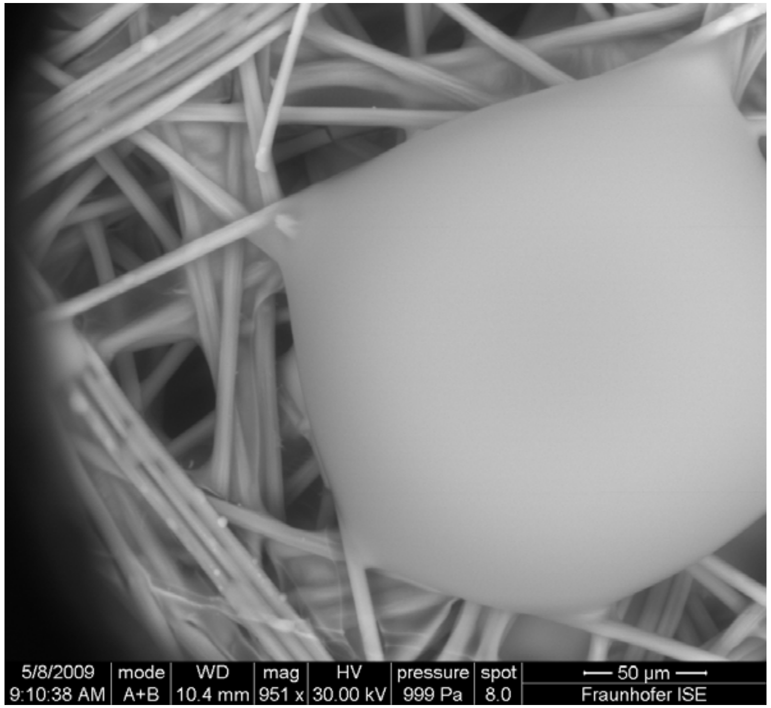
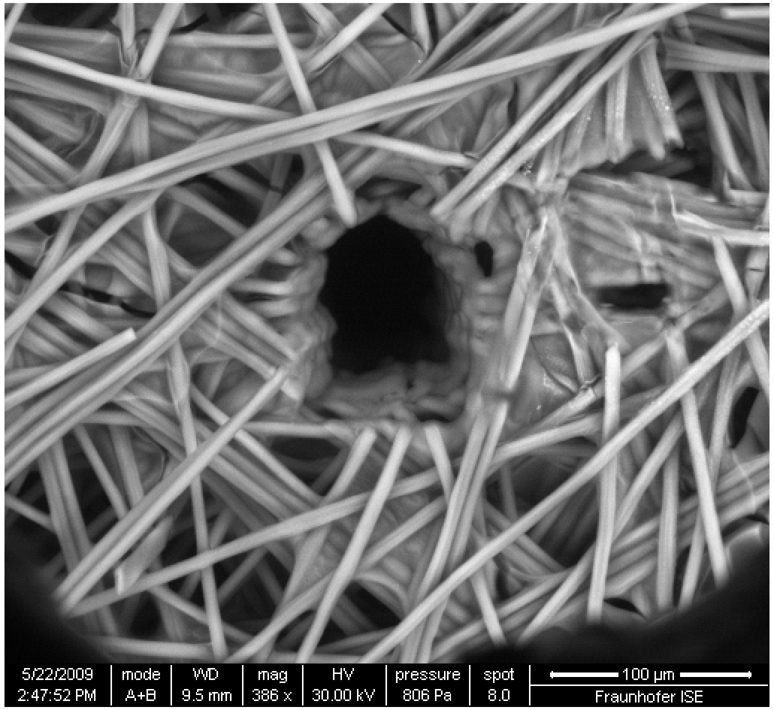


Transportation of water within a perforated GDL



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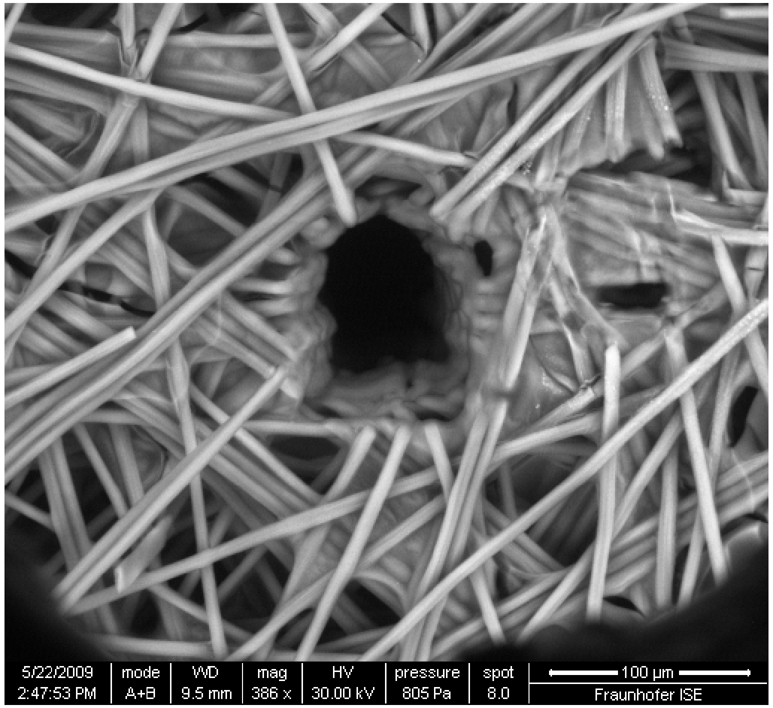

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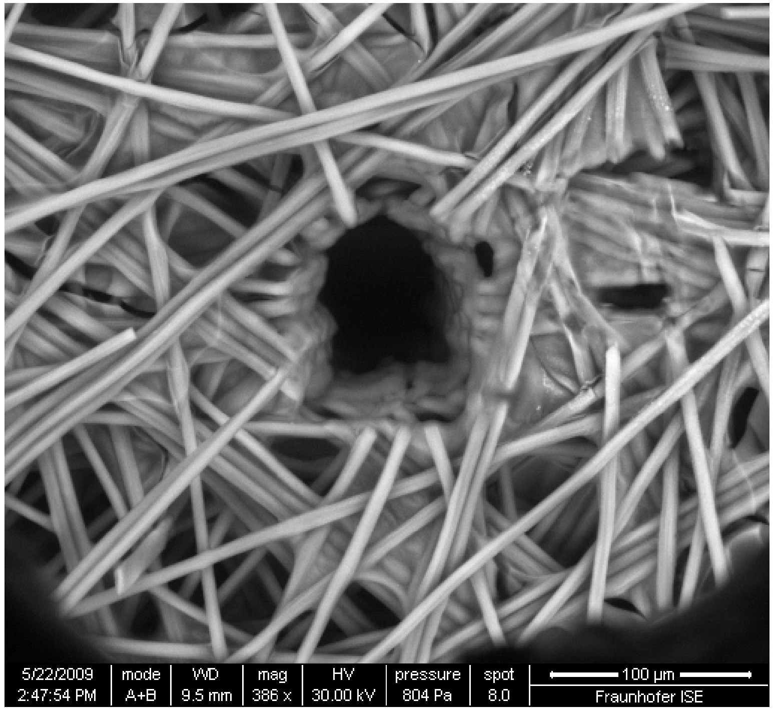

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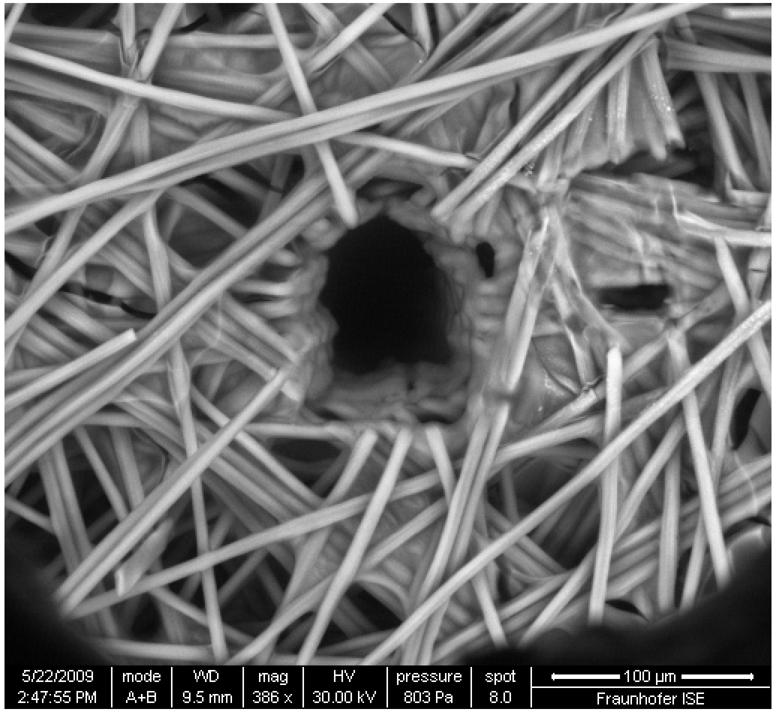

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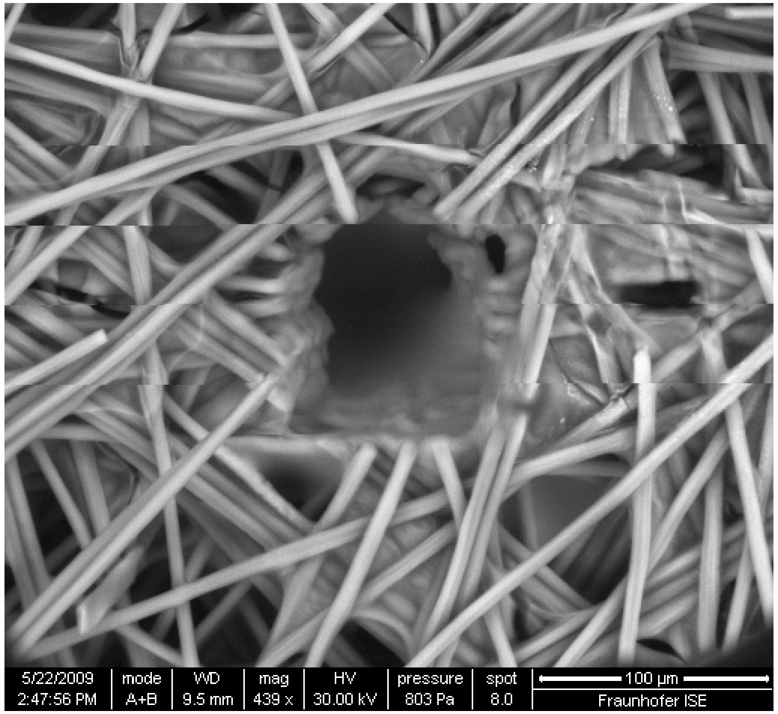

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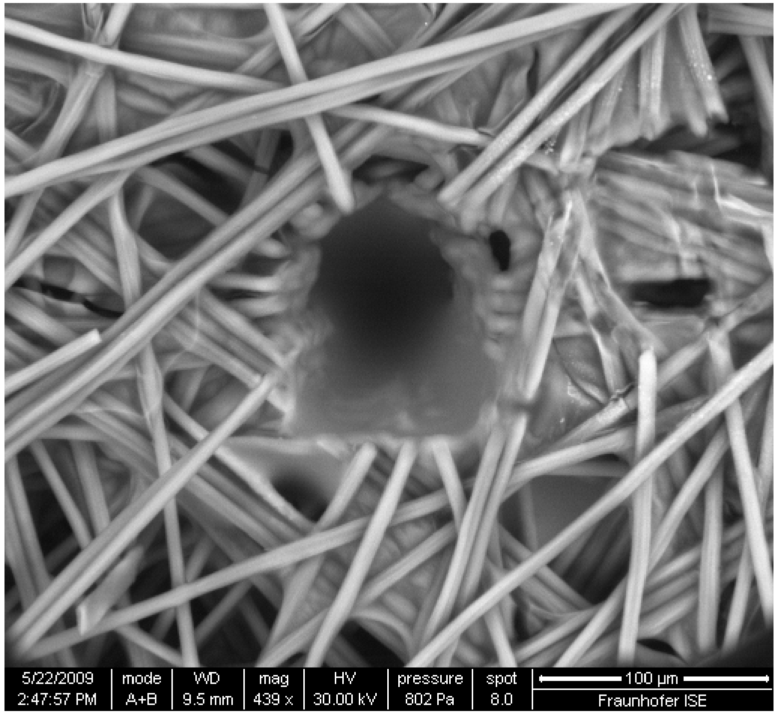

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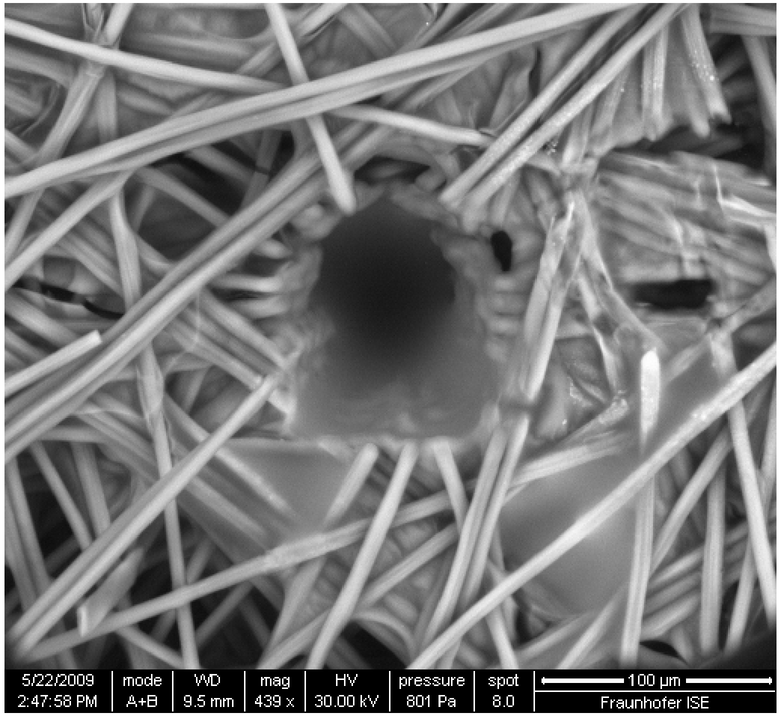

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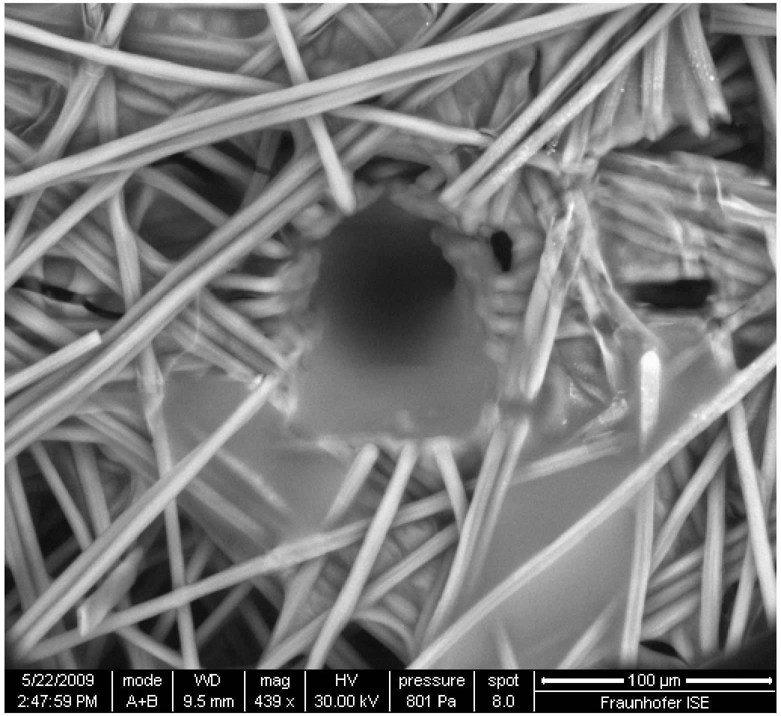

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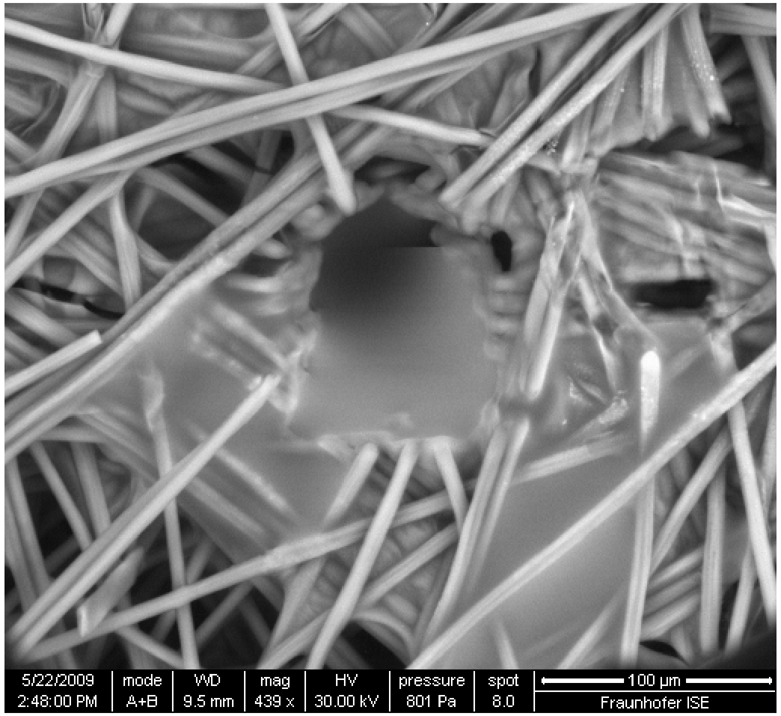

Transportation of water within a perforated GDL

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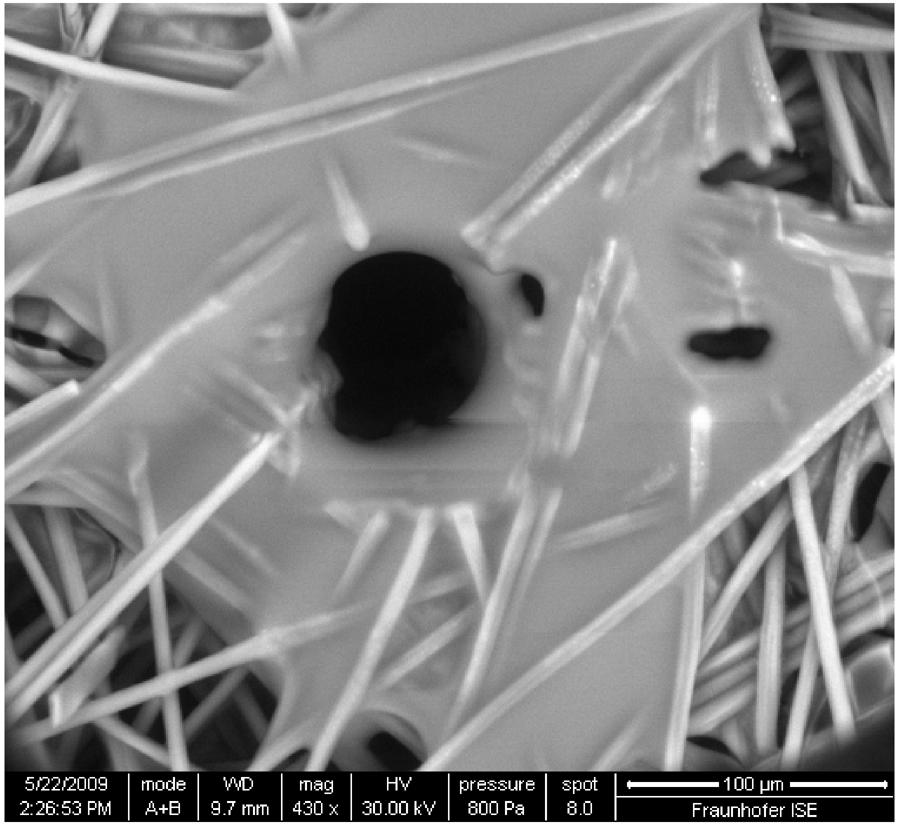
Summary

- Single cell experiments consistant with stack experiments
- Significant increase in cell performance and stability achieved
- New method found to visualize water transport in GDLs in ESEM



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