



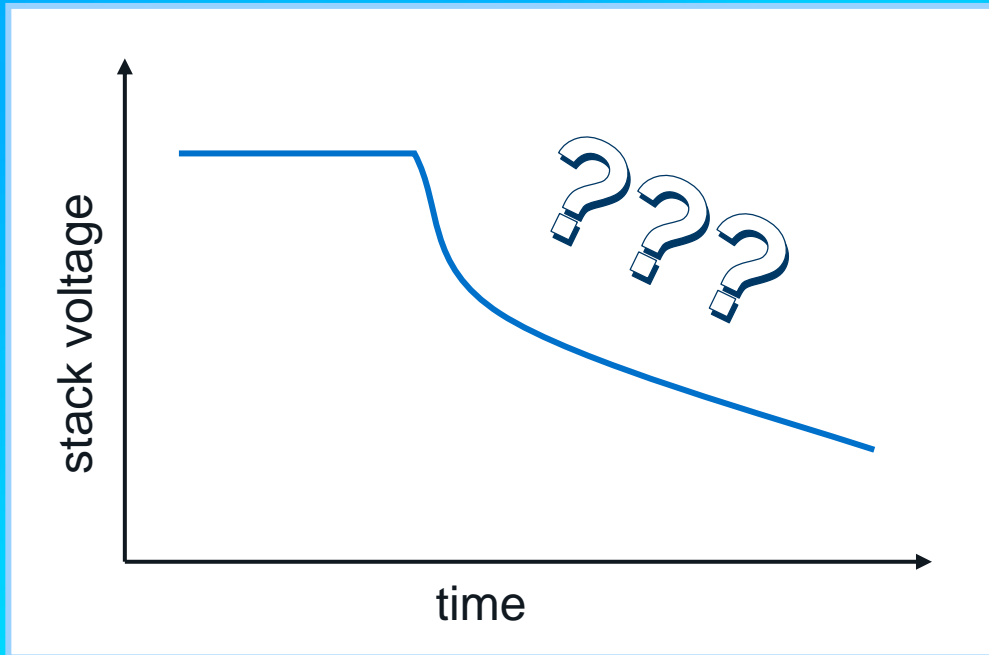
Classifying Error States of PEMFCs by Current Mapping and Cell Voltage Monitoring

FDFC Conference | 25th -27th Sep 2023 | Ulm Germany



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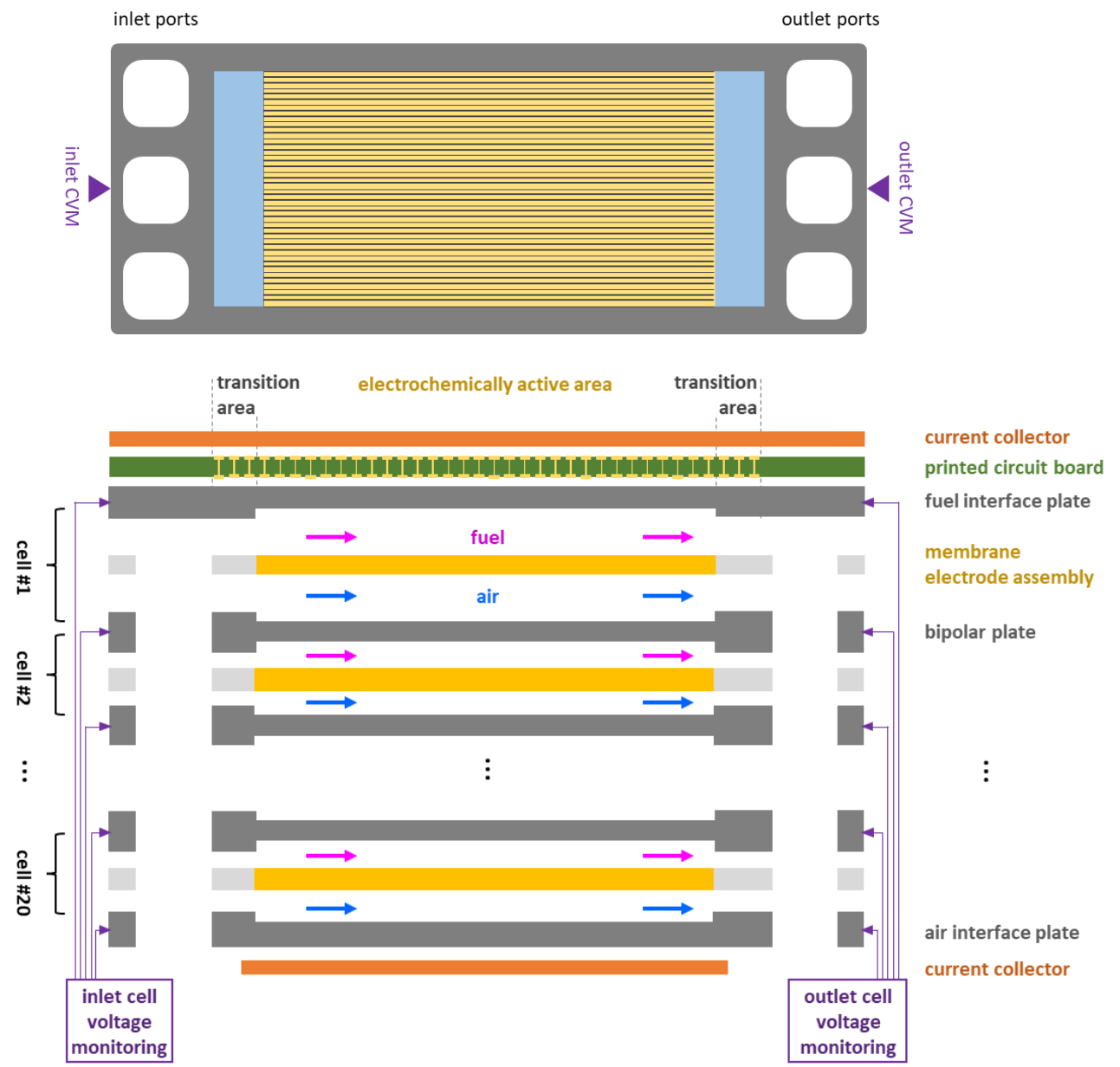


Experimental Setup

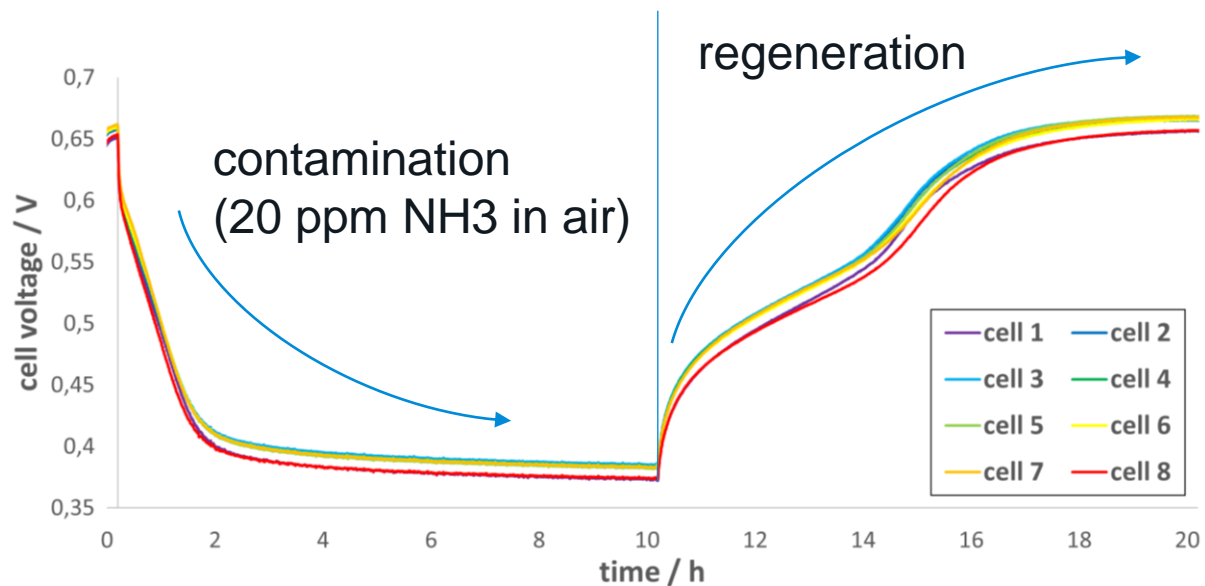
- Automotive LT-PEMFC short stack (20 or 8 cells)
- Straight-channel carbon composite flow field plates
- Current Density Distribution (CDD) of cell #1 measured by Printed Circuit Board (by S++)
- Cell Voltage Monitoring at inlet and outlet position

Advice for expressive CDD measurements

- Artifacts in CDD can be caused by bends of flow field (meander) or inhomogeneous MEA compression
 - High in-plane resistance of flow field plates decreases crosstalk, esp. thin carbon plates.
 - Media co-flow simplifies simulations
- Otherwise, cell segmentation or data post processing may be required for interpretation



Media Contamination



Experiment:

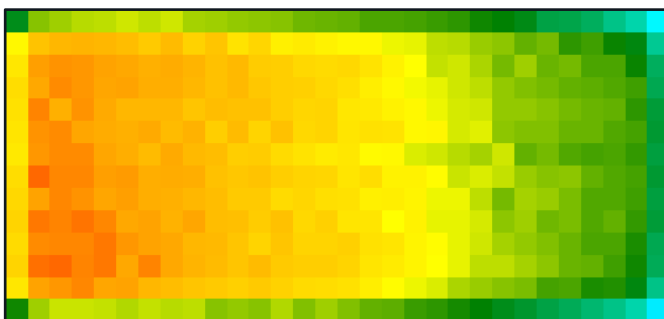
- Galvanostatic steady-state operation
- Contamination: 20 ppm NH₃ in air for 10h
Regeneration: fresh air for 10h

Results:

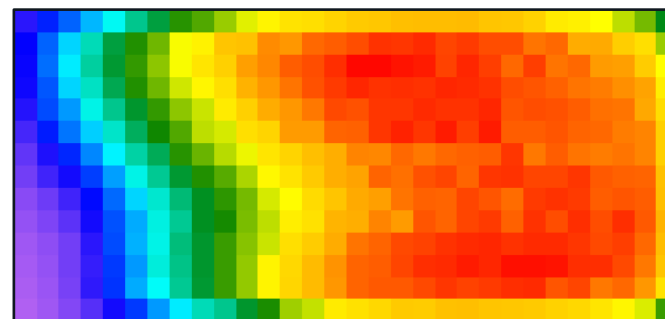
- Voltage of all cells sharply decreases over 2h, then attain a plateau
- All cell voltages affected almost identically
- **Current density redistribution** from inlet to outlet shows how catalyst layer is poisoned over time

Favorite Paper: Reshetenko 2014
doi: 10.1016/j.jpowsour.2014.06.146

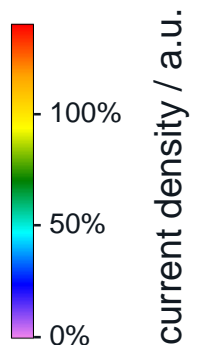
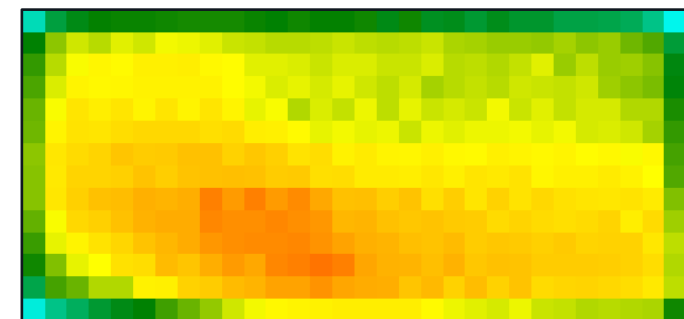
before contamination (t = 0 h)



in progress (t = 0.72 h)



fully contaminated (t = 10 h)



Fuel Gross Starvation

Experiment:

- H₂ stoic of cell #1 = 0.74 (by intentional defect)
- Presented data: after 2 minutes of “steady state”

Results:

- CDD shows spatial separation of hydrogen oxidation (inlet) and subsidiary reactions (outlet)
- CVM shows strong differences of cell voltages
- Voltage of identical cells varies between inlet and outlet

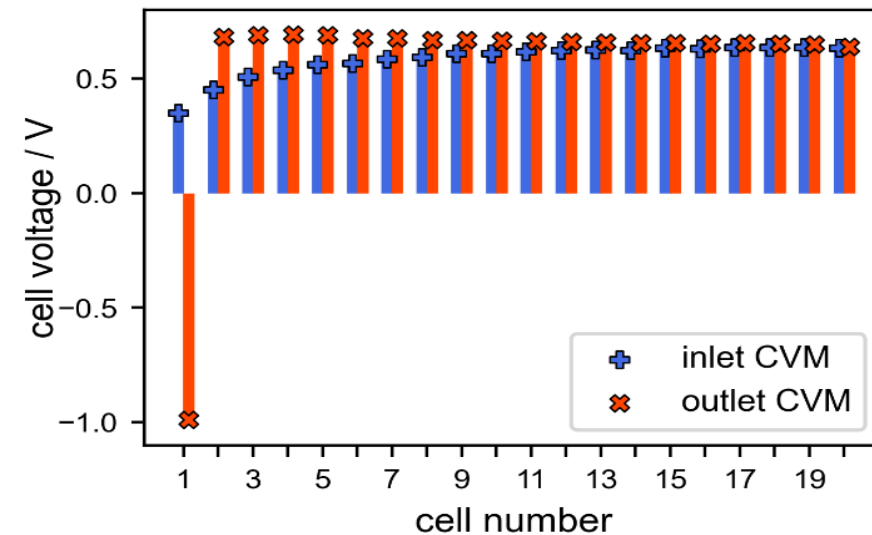
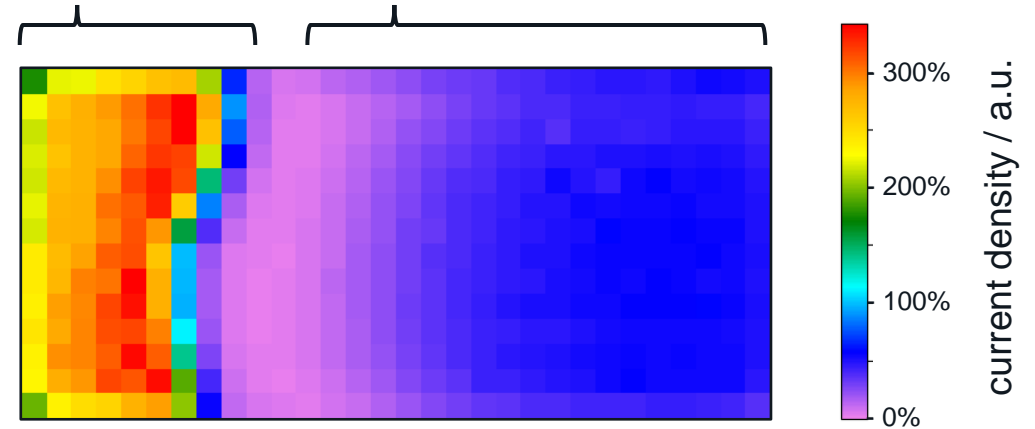
Deductions:

- Variation of local cell voltages indicates error states
- Characteristic CVM patterns may aid error state analysis

Favorite Paper: Lin 2021,
doi: 10.1016/j.enconman.2021.114037

Inlet: High current,
positive voltage
→ H₂ oxidation reaction

Outlet: Low current density, negative
voltage → Oxygen evolution and
carbon oxidation reaction





Pinhole

Experiment:

- Recording polcurve
- Pinhole in MEA of cell #1

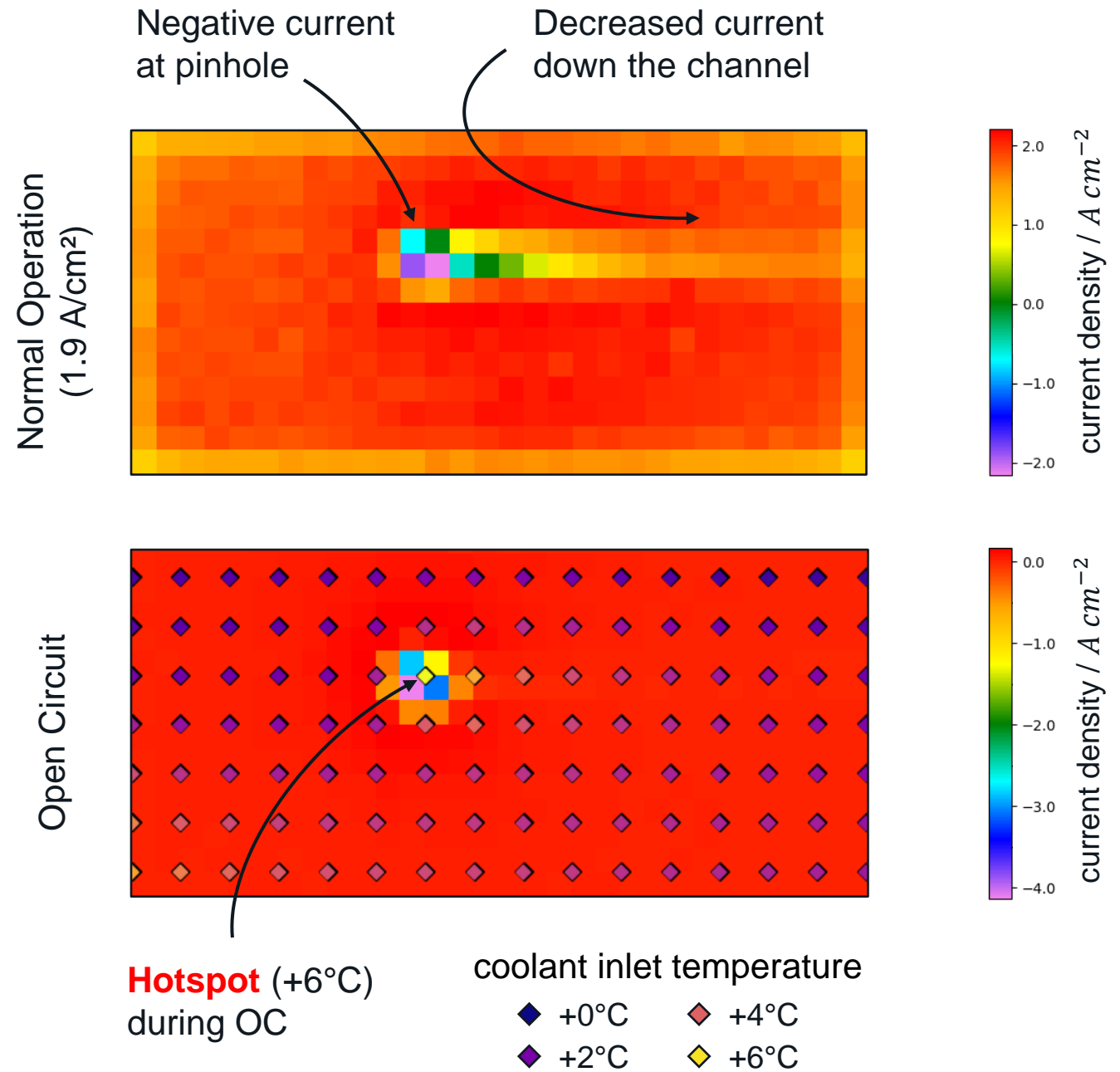
Results:

- Negative current around pinhole
- No changes over experiment duration (4.3 h)
- Open Circuit Voltage of defect cell 78mV lower than other cells (residual polcurve identical)
- Hotspot of +6°C during OCV (low coolant flow)

Deductions:

- Polcurve not suitable to identify pinhole. Better technique: Voltage Relaxometry [1]
- Sensors of PCB very large, compared to pinhole

Favorite Paper: [1] De Moor 2011
doi: 10.1002/fuce.201100161





Air-Air start up

Experiment:

- Fuel cell startup with air in anode and cathode
- Open Circuit → Net current is zero

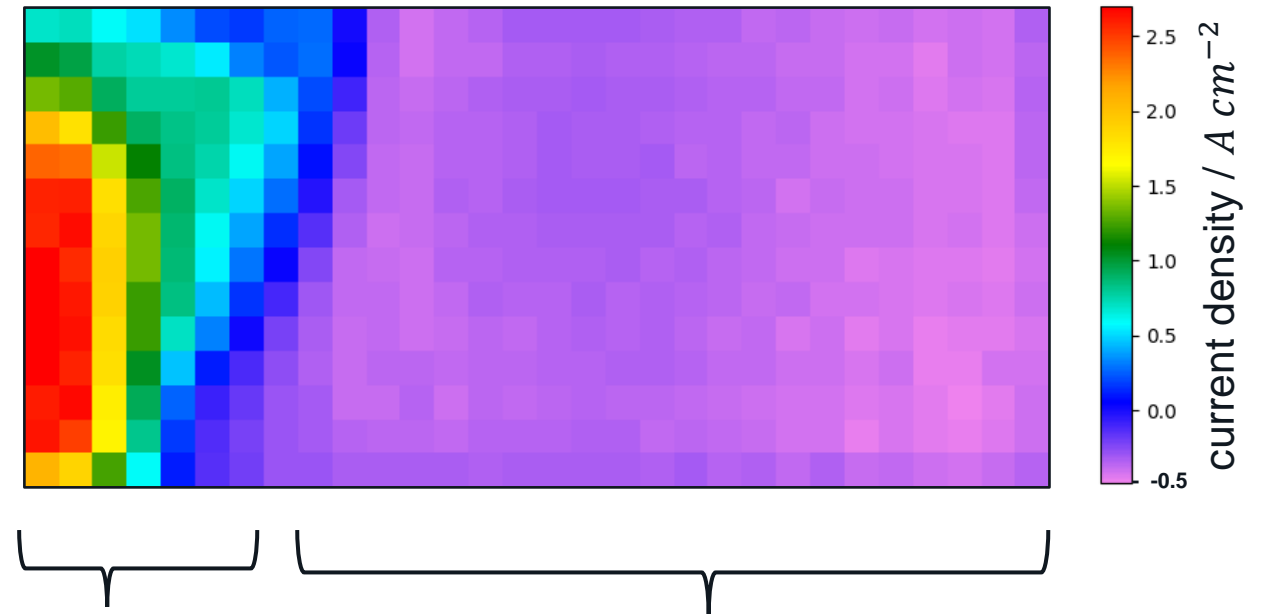
Results:

- Air-Hydrogen front is pushed through anode
- For short duration (~100 ms)
 - very high current at inlet
 - Negative current over residual MEA

Deductions:

- Investigating fuel cell start up requires extremely high temporal resolution (max. temporal resolution of used PCB is 70 ms)

Favorite Paper: Lamibrac 2011
doi: 10.1016/j.jpowsour.2011.07.013



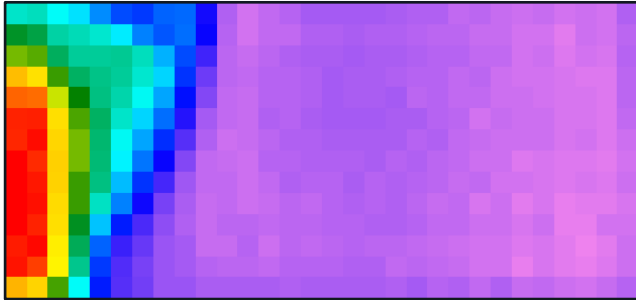
- Inlet:
- Hydrogen on anode
 - High positive current (hydrogen oxidation)
 - Applies voltage to outlet-region

- Outlet:
- Air on anode
 - negative current, including **carbon oxidation reaction** of the cathode

PEMFC error states
with current or voltage redistribution

extremely fast processes
→ temporal resolution important

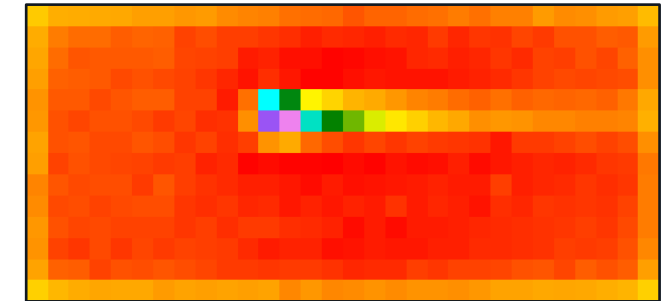
Air-Air start up



Slow processes
(almost steady-state)

Small affected MEA area
→ Local resolution insufficient

Pinhole



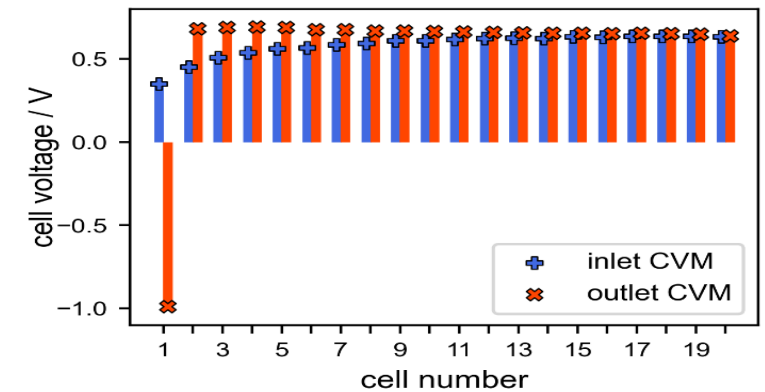
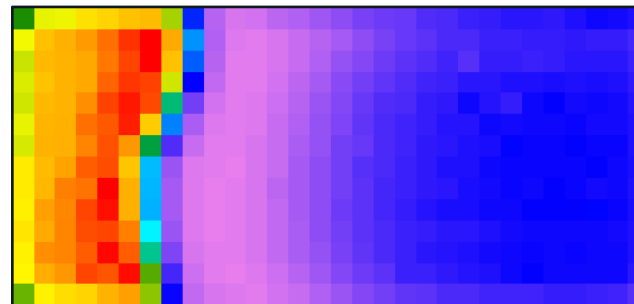
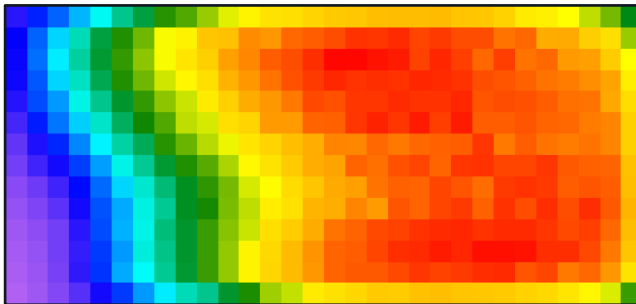
Large affected MEA area

Different CDD of adjacent cells

Fuel gross starvation

Similar CDD of all cells

Media Contamination





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cellcentric

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