CISTEM

Construction of Improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units

HT-PEM Degradation Aspects

Maren Rastedt, F. Javier Pinar, Nadine Pilinski, Peter Wagner

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Agenda

- Introduction NEXT ENERGY
- Project CISTEM
- Fuel Switching
- Oxygen-Enriched Air
- Start-Stop-Cycling
- Summary

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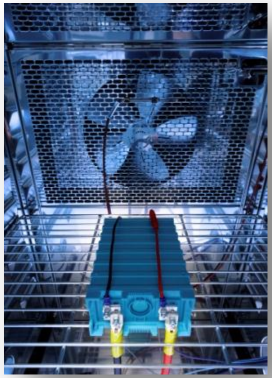

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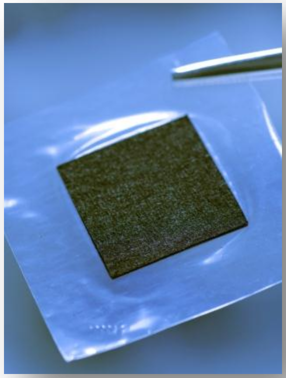

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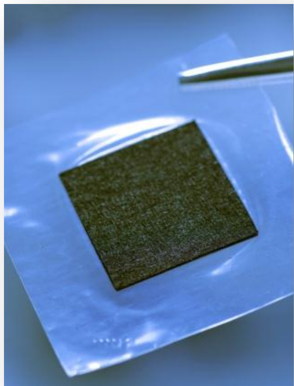

Fuel Cells
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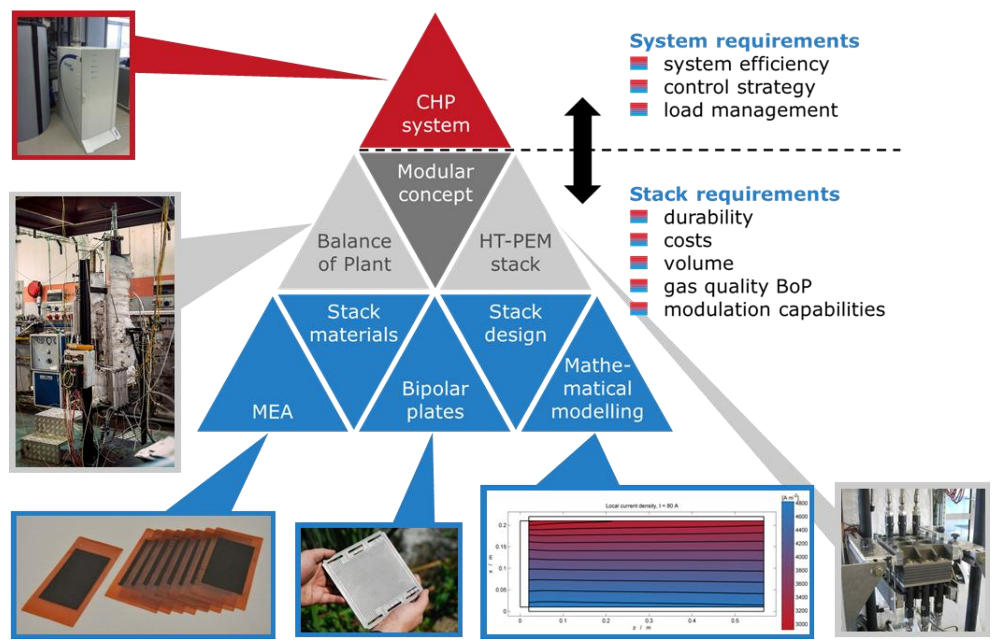
CISTEM

- **CISTEM**: **C**onstruction of **I**mproved HT-PEM MEAs and **S**tacks for Long **Te**rm Stable **M**odular CHP Units
- **Vision**: Development of a new FC based CHP technology with high efficiency and long lifetime
- Fuel flexible operation
- Degradation investigations on all levels (MEAs, single components, stacks, CHP units)



↑Development Overview

- GA No: 325262
- www.project-cistem.eu

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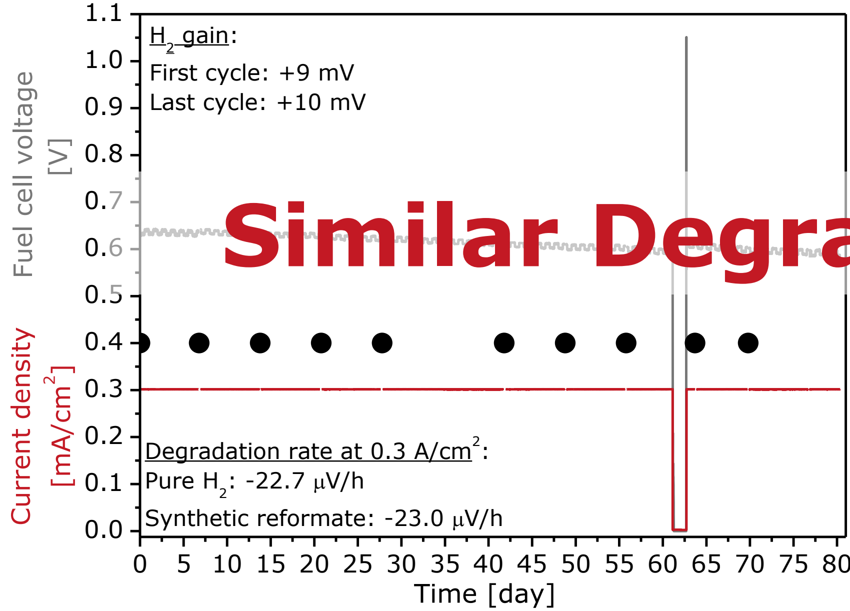
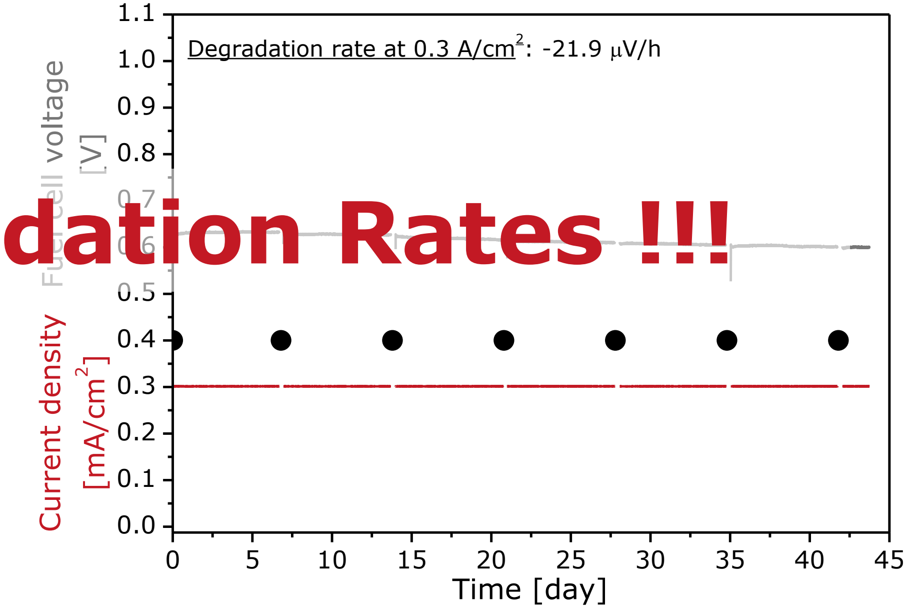
Fuel Switching

Fuel Switching



Long Term



Similar Degradation Rates !!!

- Fuel switching at const. load: 0.3 A/cm²
- *Fuel*: 12h 78% H_2 + 22% CO_2 operation/12h H_2 operation (λ>1.5)
- *Oxidant*: O_2 enriched Air (30% O_2) (λ>2.85)

Still in operation

- Serpentine flow fields

- 1100h at const. load: 0.3 A/cm²
- *Fuel*: H_2 (λ>1.5)
- *Oxidant*: O_2 enriched Air (30% O_2) (λ>2.85)
- Serpentine flow fields

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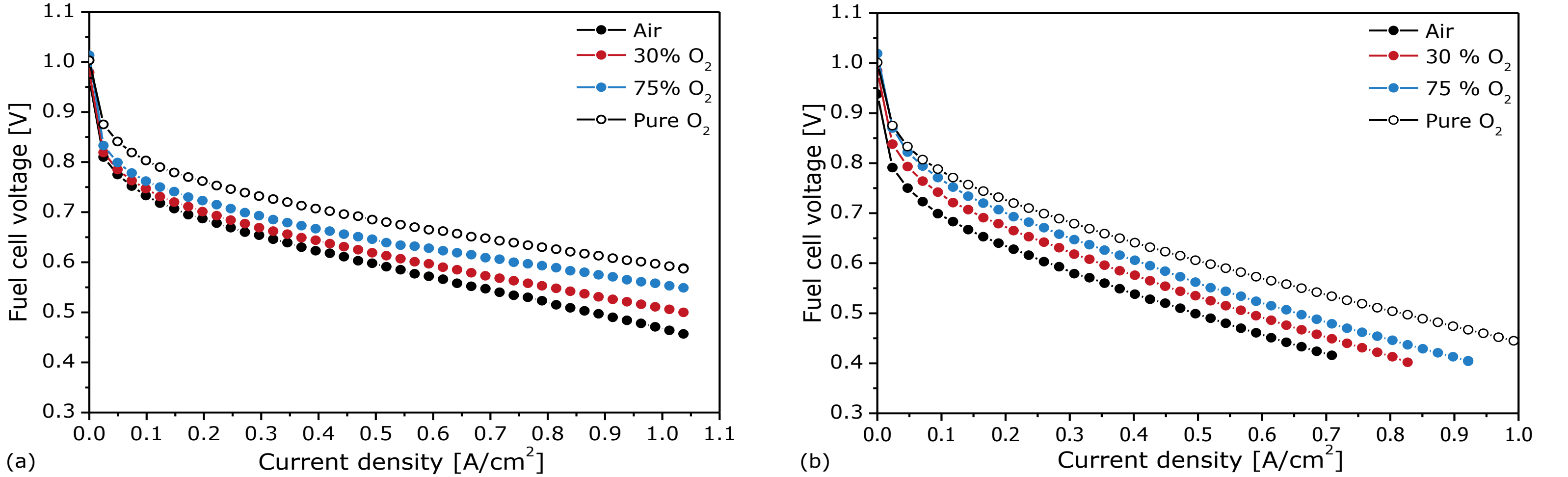
Fuel and Air/O_2 Optimisation - 1

Effect of O_2-Enrichment on Fuel Cell Performance:



Polarisation curves for the fuel cell operating with H_2/Air* as function of oxygen enriched air. MEA: (a) BASF, (b) DPS. 5-fold serpentine flow field, P_c=0.75 MPa, T=160 °C, P=1 atm. * λ_{H2}=1.2; λ_{Air}=2, $\lambda_{Air\text{-}30\%\ O2}$=2.85, $\lambda_{Air\text{-}75\%\ O2}$=7.1, λ_{O2}=9.5

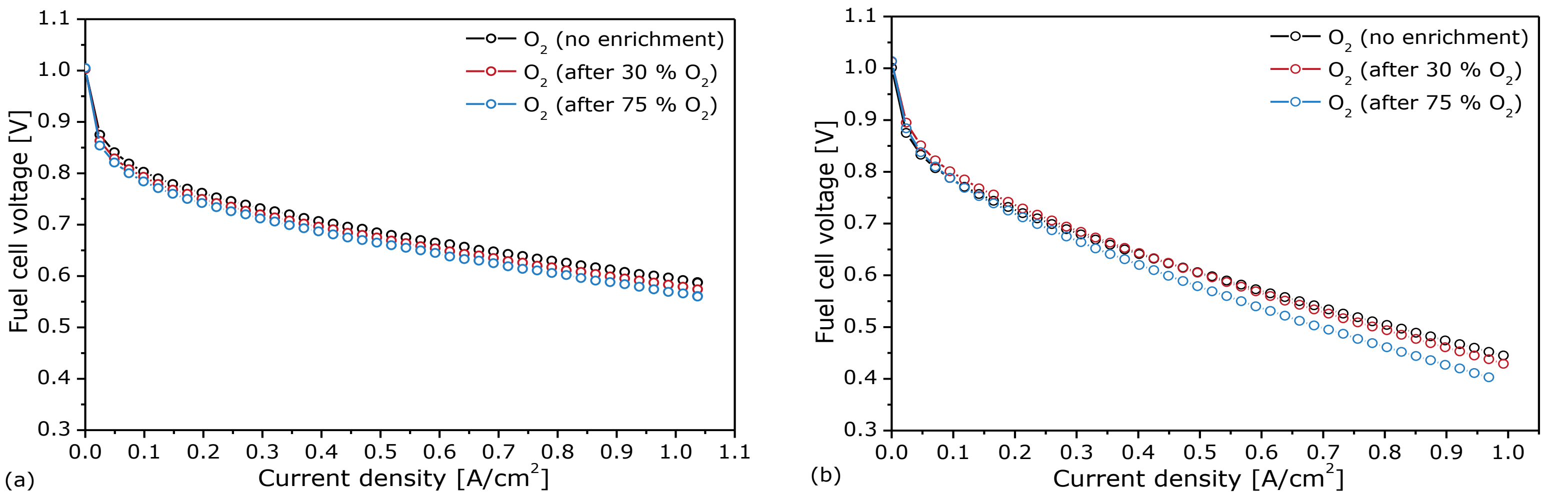
- The higher the oxygen concentration, the better the performance of the fuel cell is.
- Mass transport improvement from the gas flow channels to the cathode CL

O_2 [%]	Celtec® η_{el} [%]*	Dapozol® η_{el} [%]*
21 (Air)	43.4	38.5
30	44.4	41.1
75	46.0	43

*At 0.3 A/cm²

Fuel and Air/O_2 Optimisation - 2

Effect of O_2-Enrichment on Fuel Cell Performance:



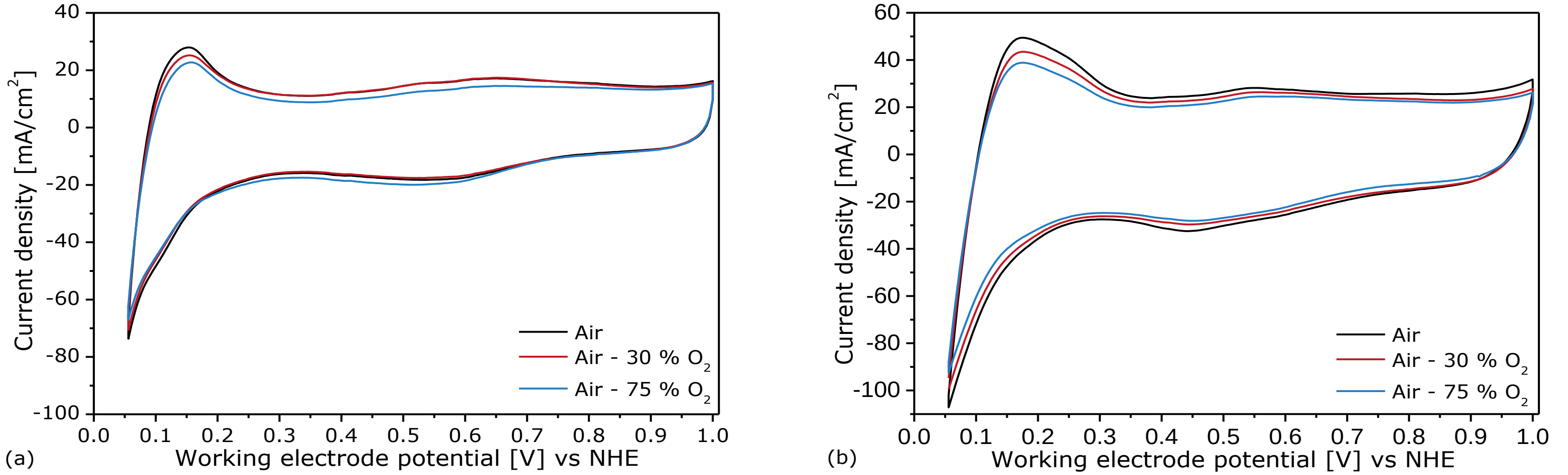
Polarization curves for the fuel cell operating with H_2/ O_2 after oxygen enriched operation. MEA: (a) BASF, (b) DPS. 5-fold serpentine flow field, P_c=0.75 MPa, T=160 °C, p=1 atm. λ_{H2}=1.2; λ_{O2}=9.5

Operation with pure O_2:

- Celtec®: FC performance cannot reach the initial performance anymore after operating with the oxygen-enriched air → slight degradation.
- Dapozol®: FC performance has been reduced after operation with the oxygen-enriched air but not after operation with 30% oxygen.

Fuel and Air/O_2 Optimisation - 3

Effect of O_2-Enrichment on CV:

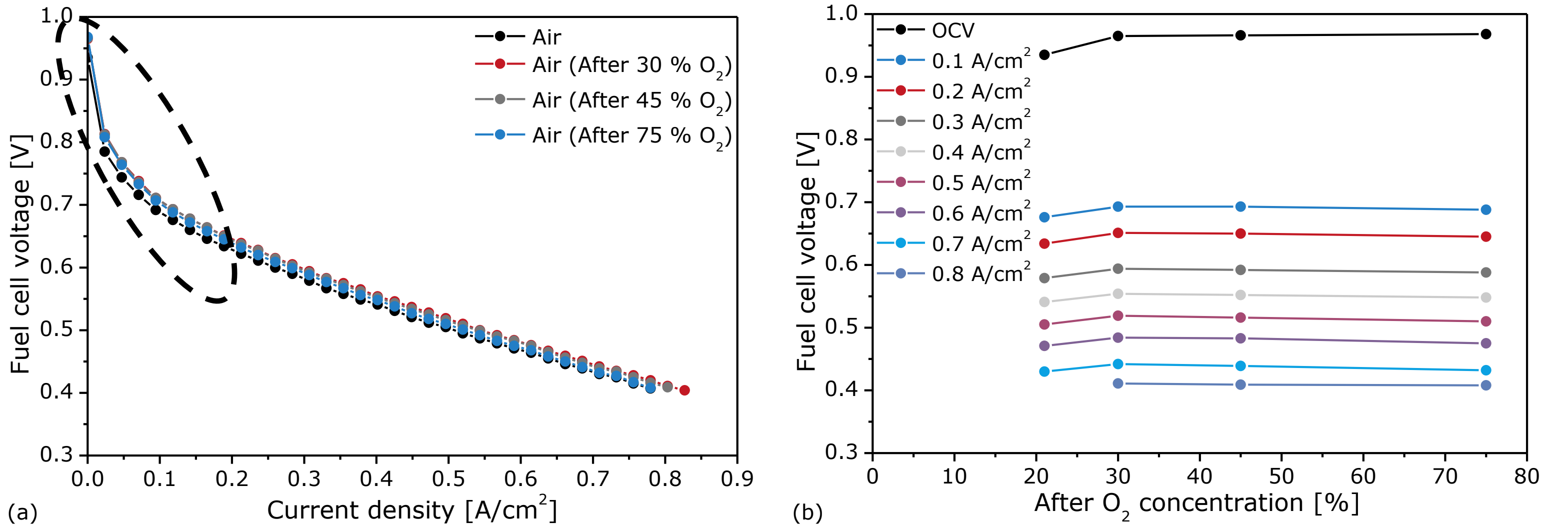


Cyclic voltammograms with electrical short correction after fuel cell operation with oxygen enriched air. MEA: (a) BASF, (b) DPS. 5-fold serpentine flow field, P_c=0.75 MPa, T=160 °C, p=1 atm. H_2/N_2=100/100 ml/min, sweep rate=100 mV/s

- Reduction of H_2 desorption area after O_2-enrichment
  - Higher O_2 availability during FC operation → C corrosion (reduction CL support):
    - Pt detachment, Pt agglomeration, Pt ripening …

Effect of O_2-Enrichment (Fuel: synthetic reformate):

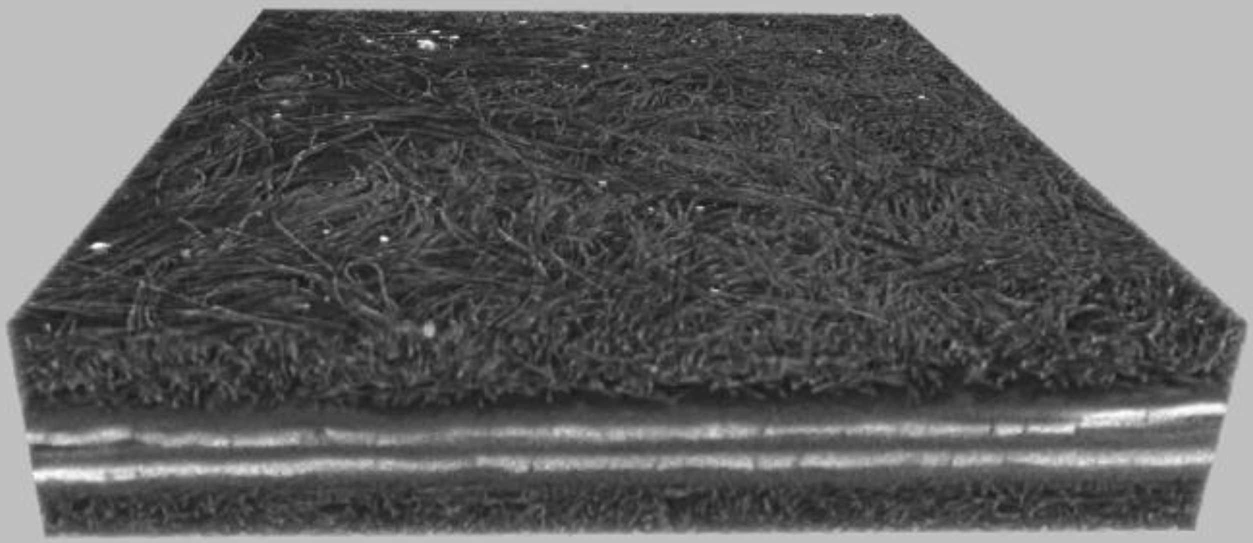
- MEA Characterisation: O_2 enrichment → Air



(a) Polarisation curves and (b) selected points of polarisation curves for the fuel cell operating with 78% H_2+ 22% CO_2/Air ($\lambda_{H_2}/\lambda_{Air}$=1.5/2) after oxygen enrichment. T=160 °C, p=1 atm, serpentine flow fields, P_c=0.75 MPa

- Polarisation curves: ↑ performance after [O_2] = 30 %
- Selected points: [O_2] = 45 - 75 % → ↓ performance at j>0.5 A/cm^2 ≈ Air
- After O_2-enrichment "activation region" is improved.

Fuel and Air/O_2 Optimisation - 5



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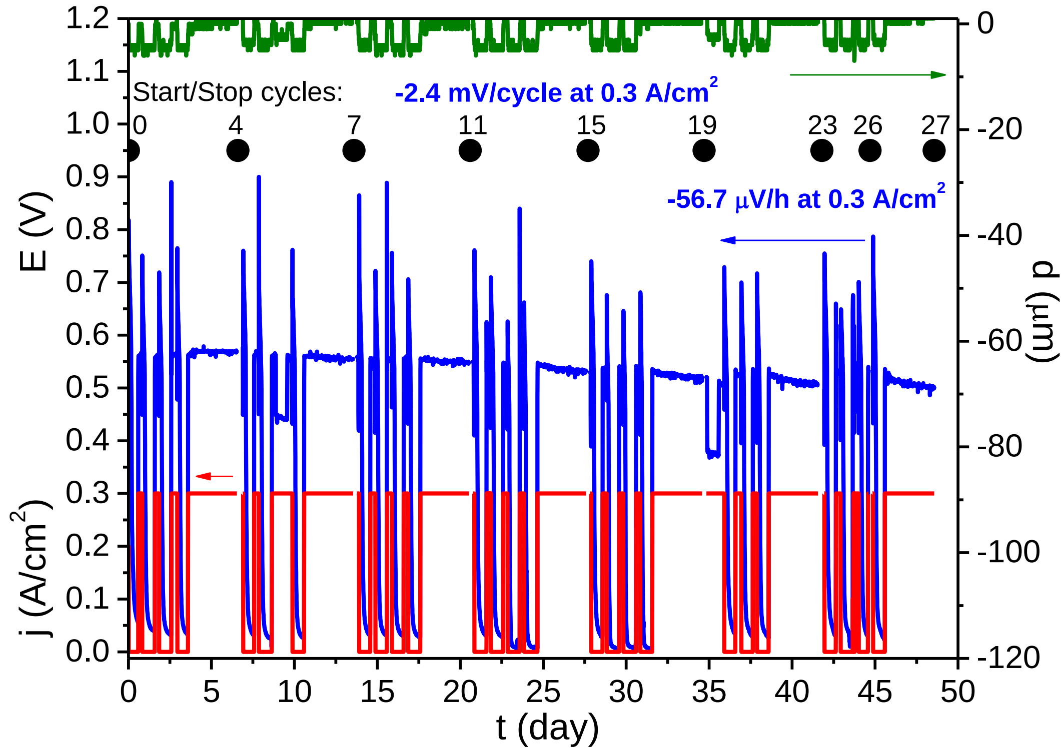
Start-Stop-Cycling - 1

Test Procedure

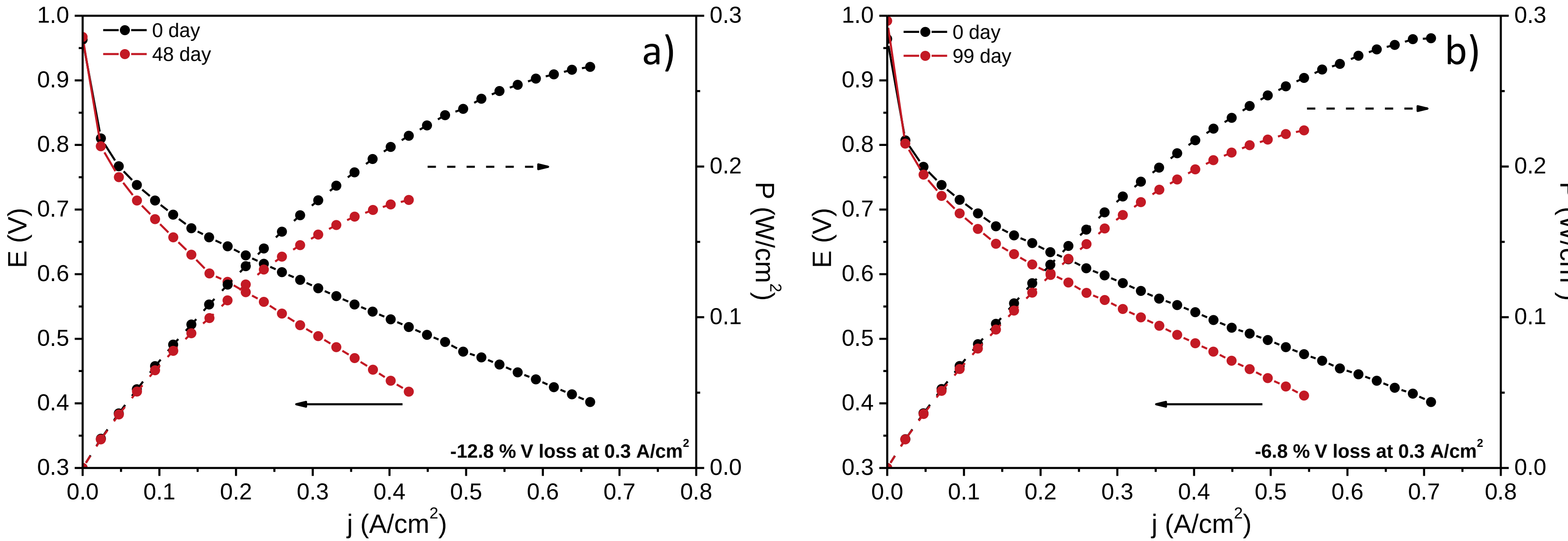
- Duration of start/stop cycle: 1 day
- Standard break-in
- 0.3 A/cm² for 6h between cycles
- Shut-down with N_2 and OCV to T_{idle} and equilibration overnight
- T_{idle}: 100°C
- Weekly: IV and EIS with air/O_2
- Monthly: full characterisation
- Weekend: 0.3 A/cm²/ 160°C/H_2/air
- 4 cycles per week



Current density, **voltage** and **thickness** changes as function of time, start-stop-cycling,T=160 °C, p=1 atm, serpentine flow fields, P_c=0.75 MPa

Start-Stop-Cycling - 2

- T_{idle}=100°C
- T_{idle}=25°C



Polarisation and power density curves for the fuel cell operating with H_2+Air ($\lambda_{H_2}/\lambda_{Air}$=1.5/2), start-stop-cycling-procedure, a) T_{idle}=100°C and b) T_{idle}=25°C, T=160 °C, p=1 atm, serpentine flow fields, P_c=0.75 MPa

- 27 cycles until EoL (at day 48)
- >1100h

- 50 cycles until now; >2300h
- Test is still running.

→ Lower degradation rates for lower T_{idling}

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Summary

- Similar degradation rates for long term tests at constant current densities and for **fuel switching**
- Improvement of fuel cell performance after operating with **oxygen-enriched air** (O_2=30%)
- Lower degradation rates for **start-stop-cycling** with lower idling temperature (T_{idle}=25°C)

Thank you
for your attention!

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