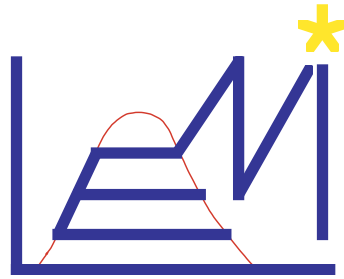




QuickTime™ and a
Graphics decompressor
are needed to see this picture.



Innovative Flexible SOFC Stacking Concept

**Stefan Diethelm, Luis Quina, Gabriele Prosperi, Nordahl Autissier,
Zacharie Wullemin, Olivier Bucheli, Jan Van herle**

*Ecole Polytechnique Fédérale de Lausanne (EPFL)
Laboratory for Industrial Energy Systems (LENI)*

OUTLINE

- SOFC stacking concept
- Stack results with baseline design
 - proof of concept
- Flexibility : new, recent stack designs

Funding acknowledgement

- Swiss Commission for Technology & Innovation, no. 6649.3 IWS-IW
 - Technology transfer, collaboration with industry



- EU Commission (SES6-CT-2003-502612) + Swiss Secretariat for Education & Research (03.0170-6)
 - FP6 « Real-SOFC » stack testing



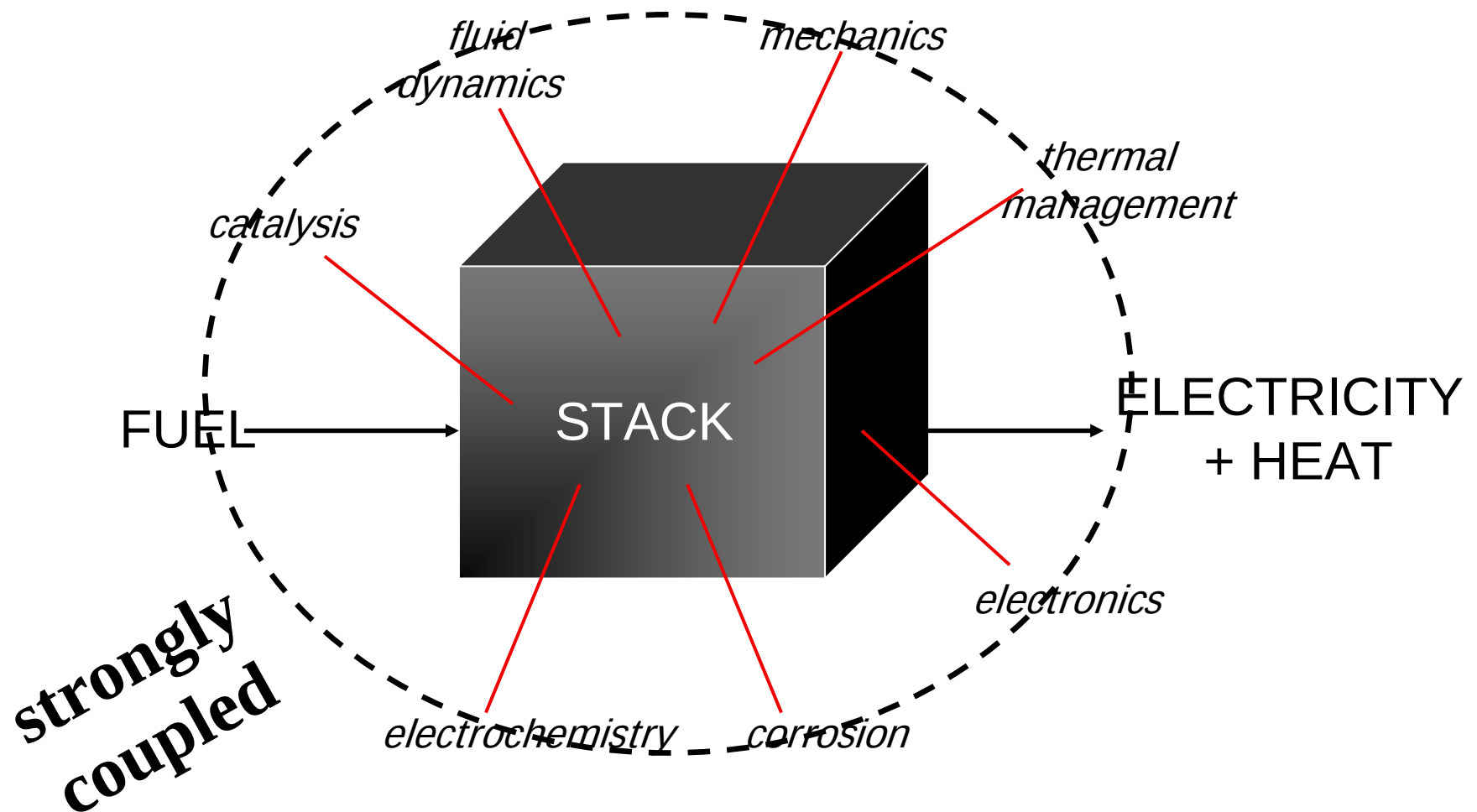
- Swiss Federal Energy Office, no. 86'895
 - Demonstration projects



- Swiss National Science Foundation, no. 200021-100721
 - Fundamental research



The challenge

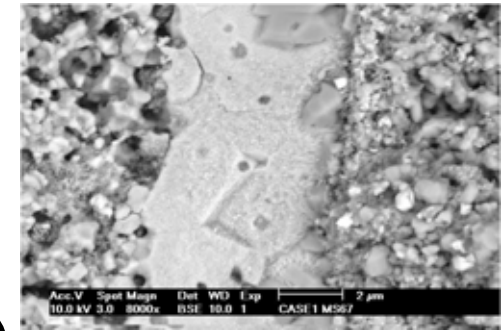


The approach

- close collaboration with stack manufacturer (HTceramix SA)
- disruptive, unique design
- stack testing laboratory (7 benches)
- development + use of modeling tools (multi-level), validated by experiment on the real components

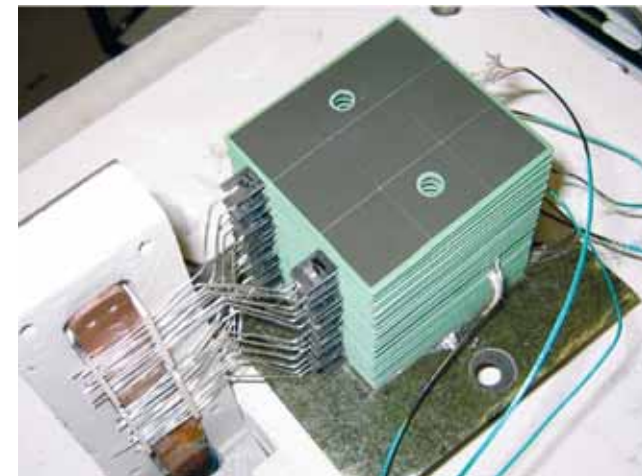
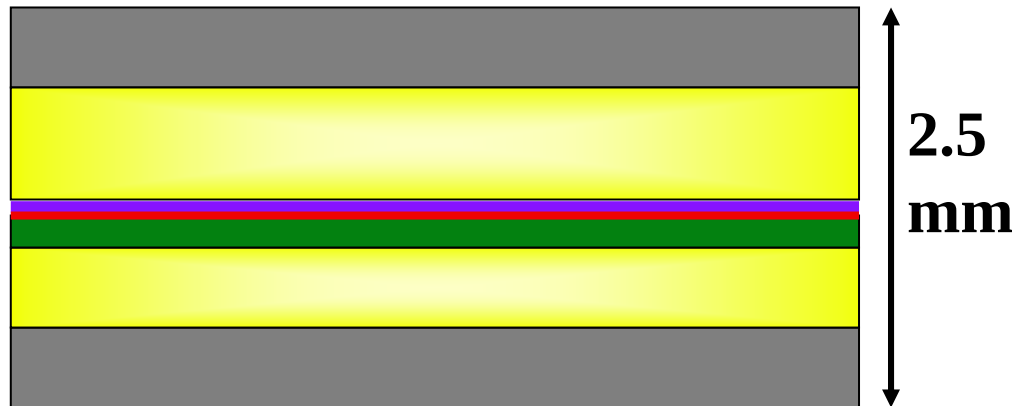
The technology

- production capability of 200 cells/week (1 m² in total)
- anode support cells (0.2 mm) + thin electrolyte (10 μm) by tape casting (aqueous)
- only wet-ceramic processing
- thin metal interconnects (0.5-1mm): unprofiled ferritic steel
- **stacking with « SOFCONNEX™ » interlayers**



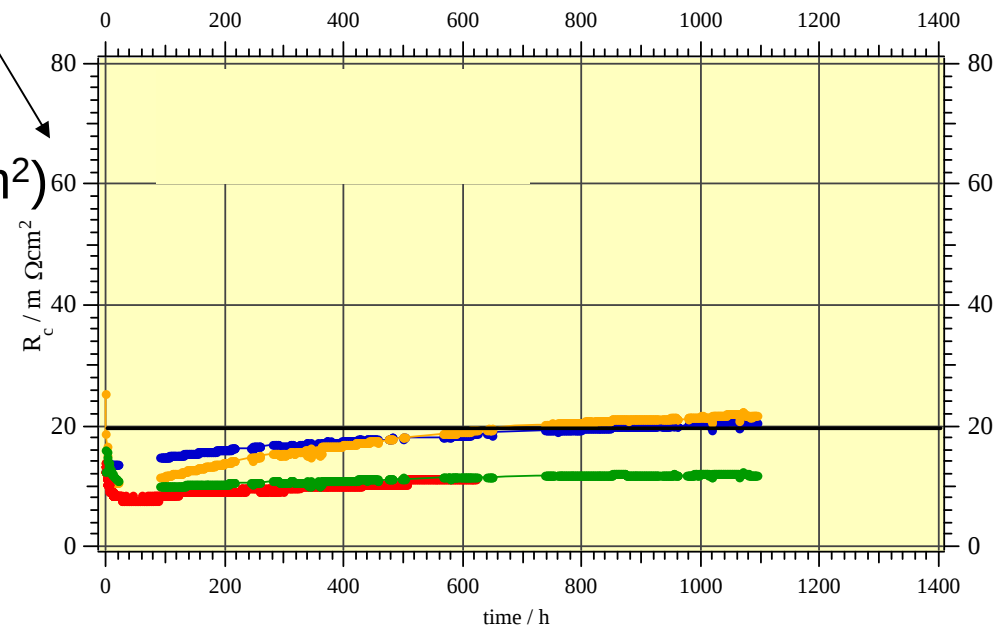
2 μm

- **compact**
- **low cost**
- **design flexible**



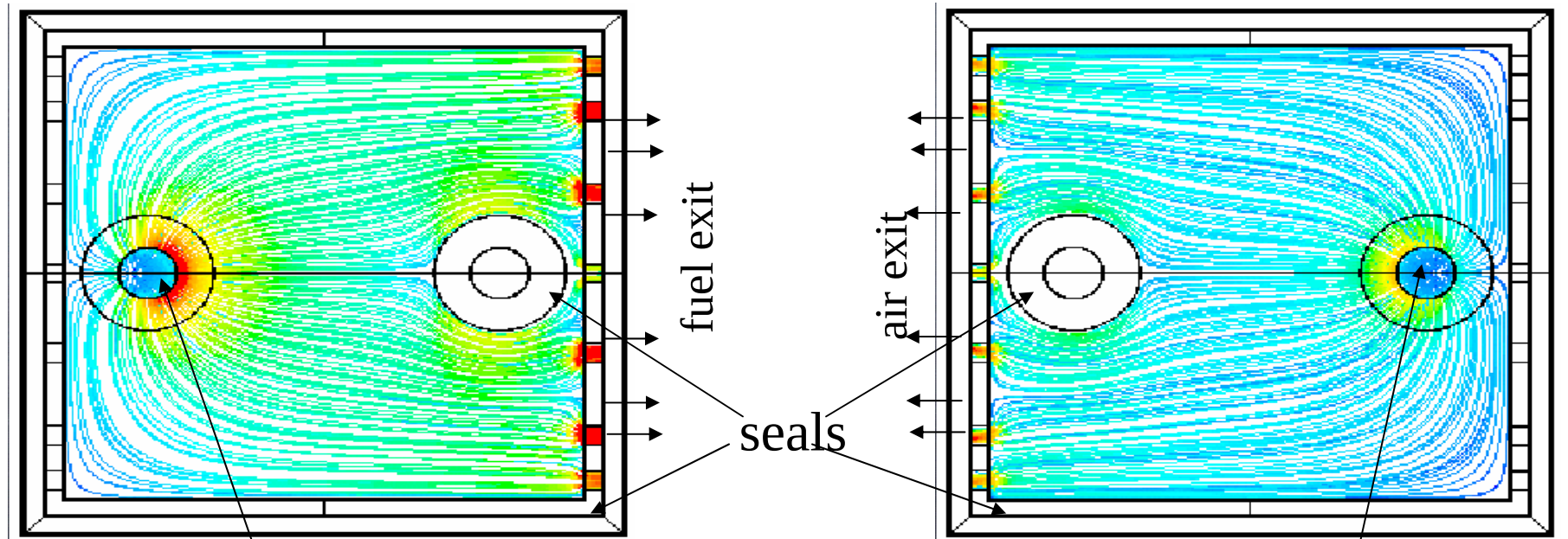
Properties of SOFConnex™ interlayers

- define flow field pattern
 - easy modification + implementation (few weeks)
 - adjustable Δp (2-100 mbar)
- high density current collection
 - low contact resistance ($10 \text{ m}\Omega\text{cm}^2$)
- compressible
 - cell-to-interconnect match
 - resists high load (20 kg/cm^2)
- compatible
 - cell, MIC
 - air, fuel
- inexpensive

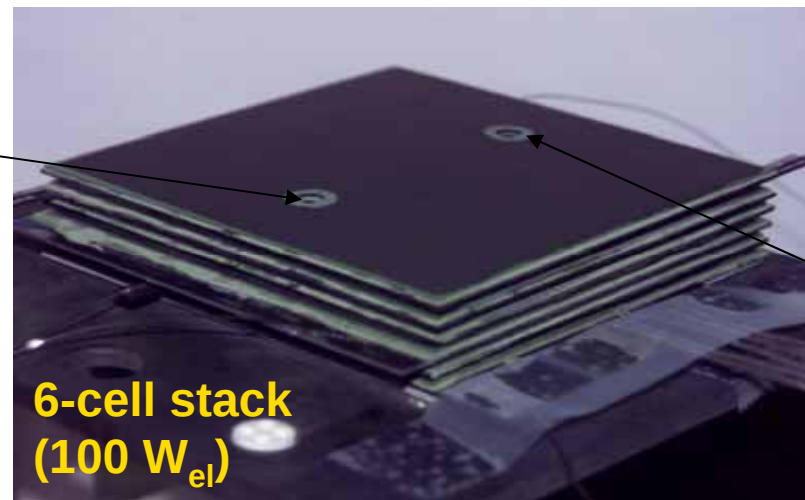


***Multifunctional SOFConnex™ allows
compact stacking and will integrate
any planar cell***

Baseline design



counterflow
internal manifolding
free postcombustion



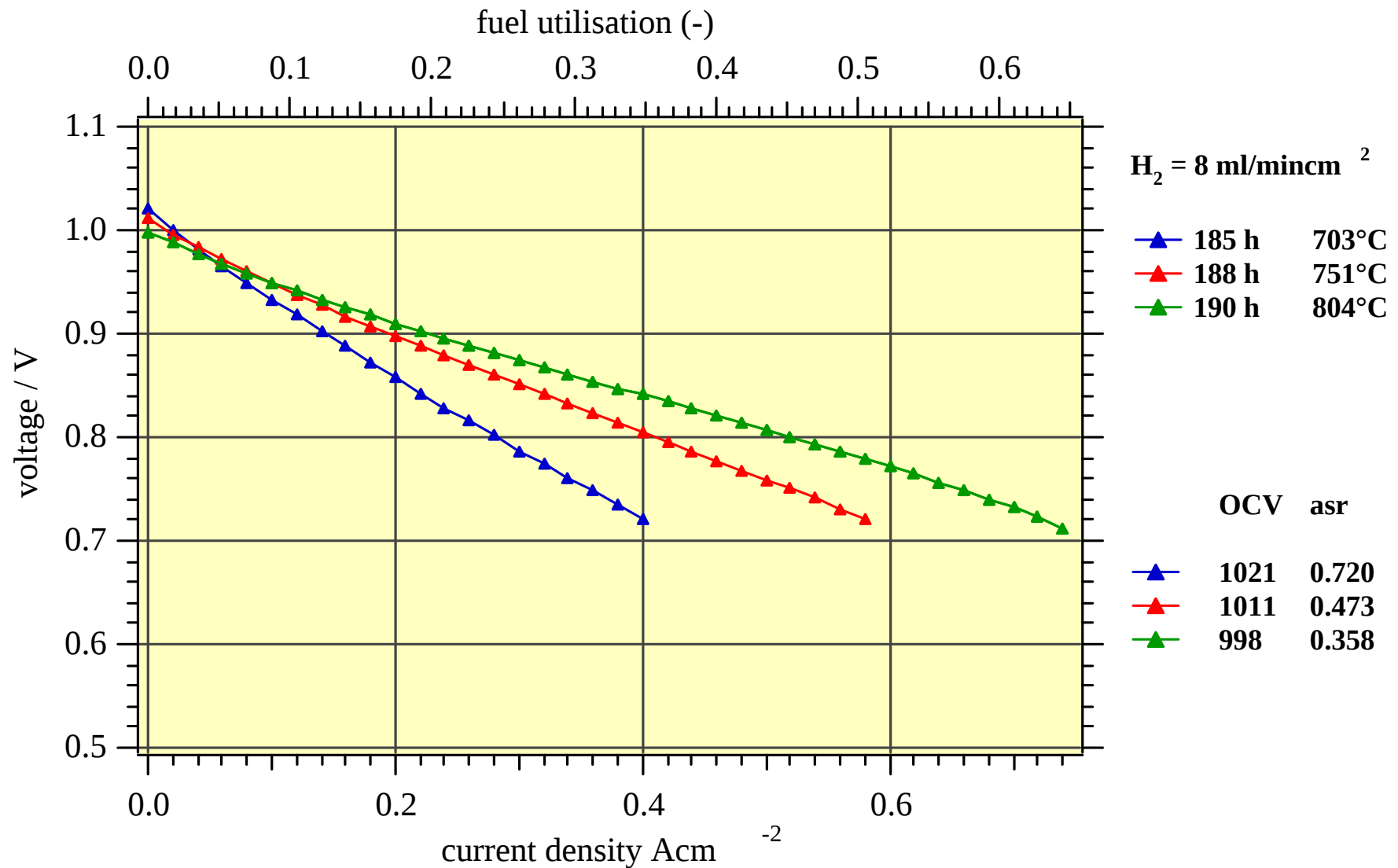
Baseline design : stack results

- power density
 - $f(T, \text{flow})$
- thermal cycling
- fuel (H_2 , CO)
- stability

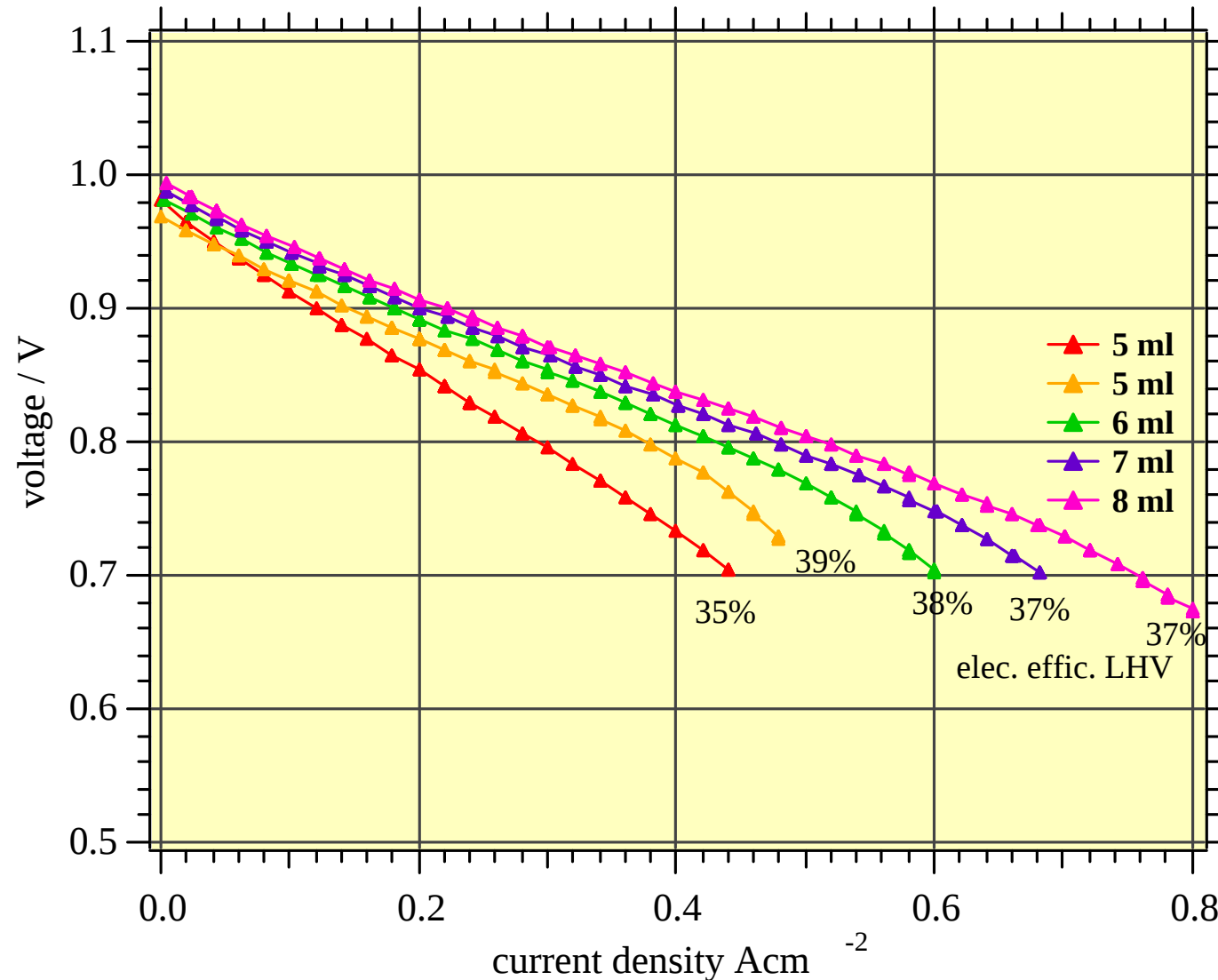


5-cell stack test set-up

Power density 700-800°C



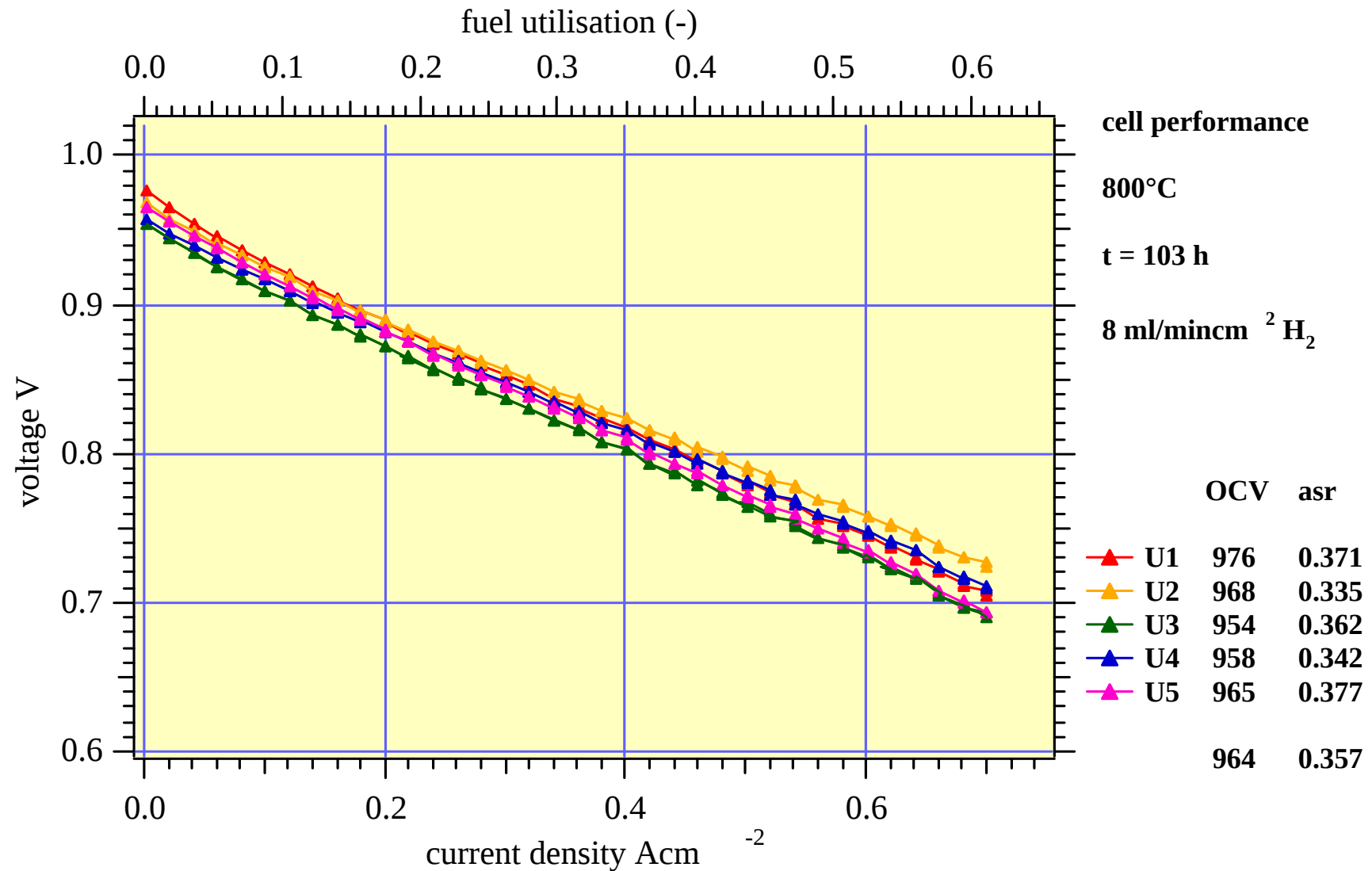
Power density as f(flow)



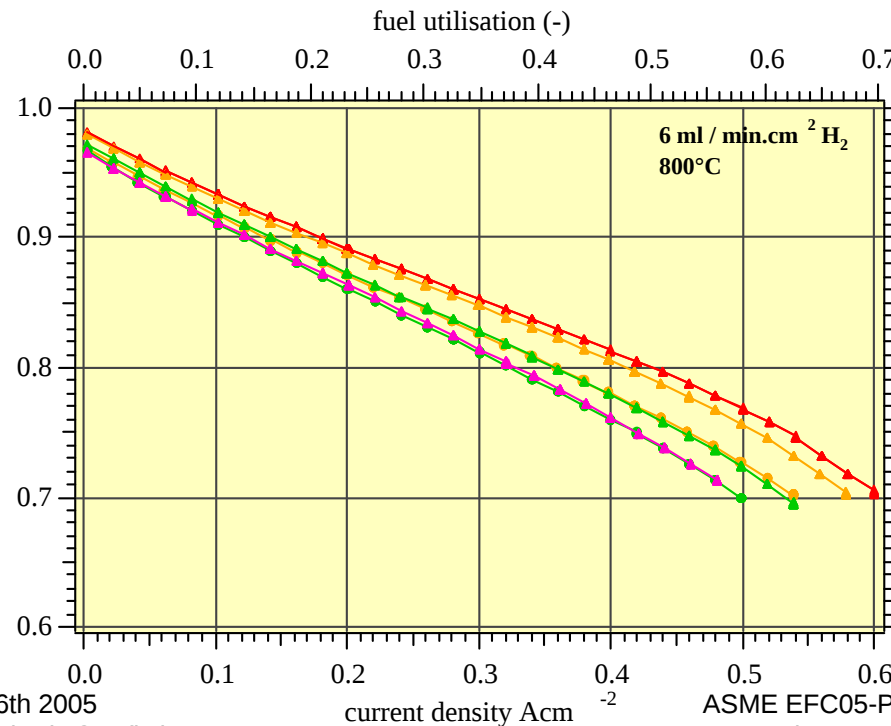
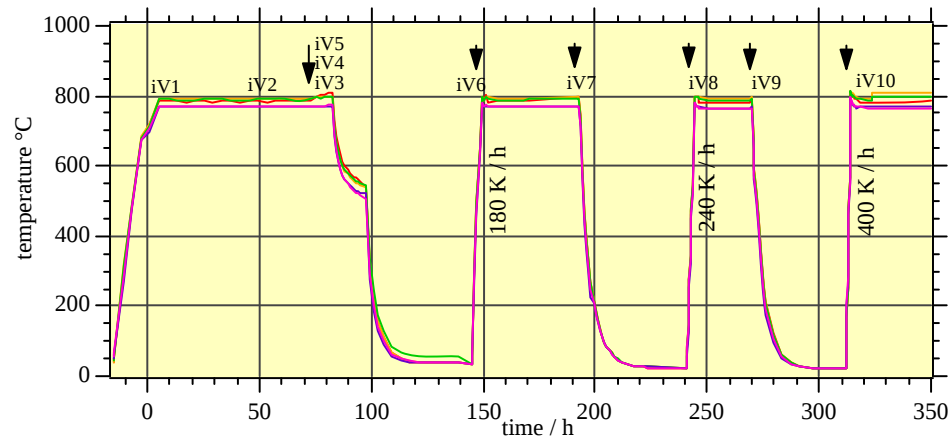
initial
performance vs. flow
(fuel H₂ in ml/mincm²)
800°C

t (h)	OCV (V)	asr (Ωcm ²)
4	0.981	0.594
75	0.969	0.436
78	0.982	0.406
80	0.989	0.379
82	0.993	0.360

Cell performance spread

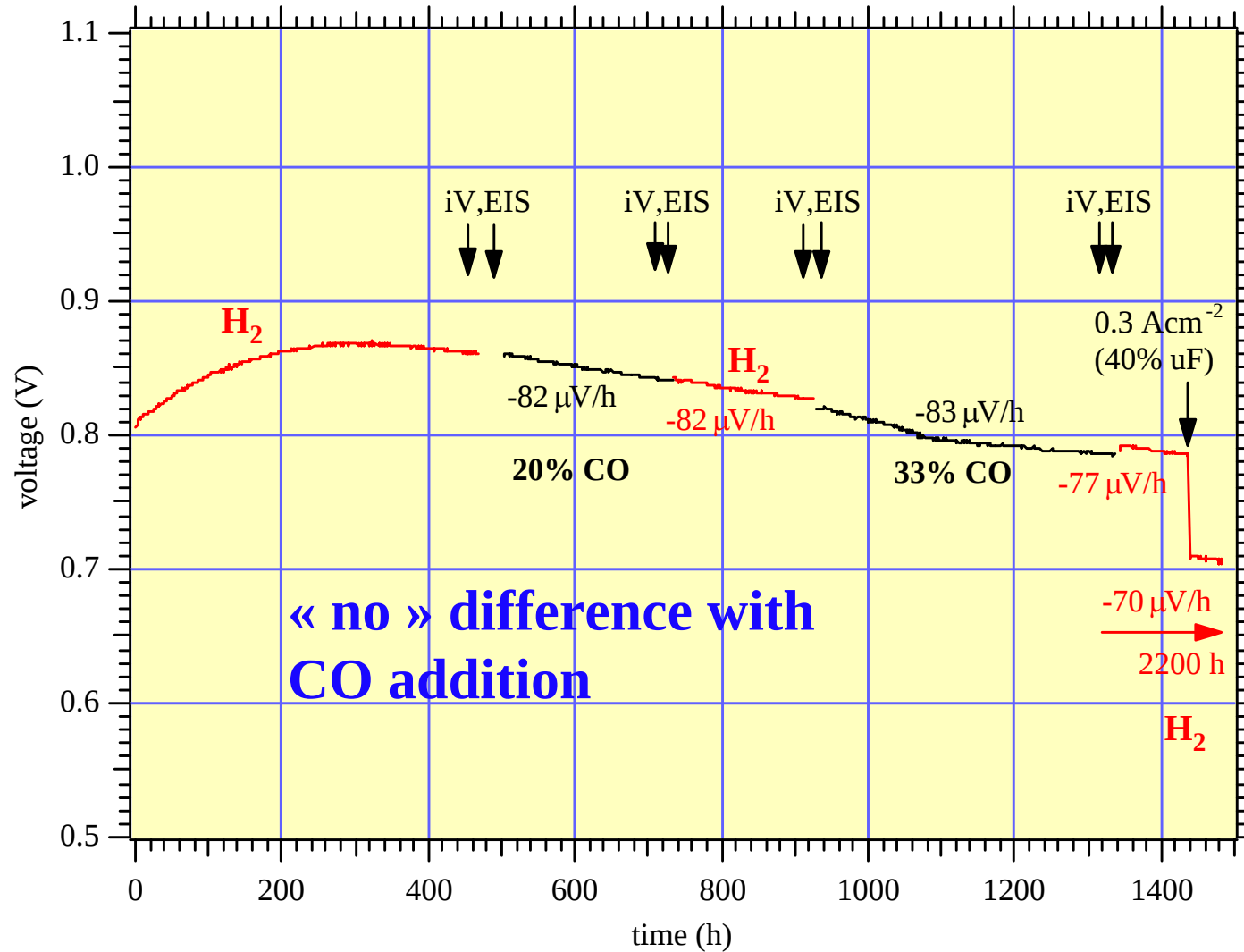


Thermal cycling



- 5 full cycles
- heating 3-7 K/min
- no OCV change
- decay in output during constant polarisation, NOT because of thermal cycling

Fuel (H₂, CO)



durability :

T = 747-757°C

j = 0.2 A/cm²

0-499 h : hum. H₂

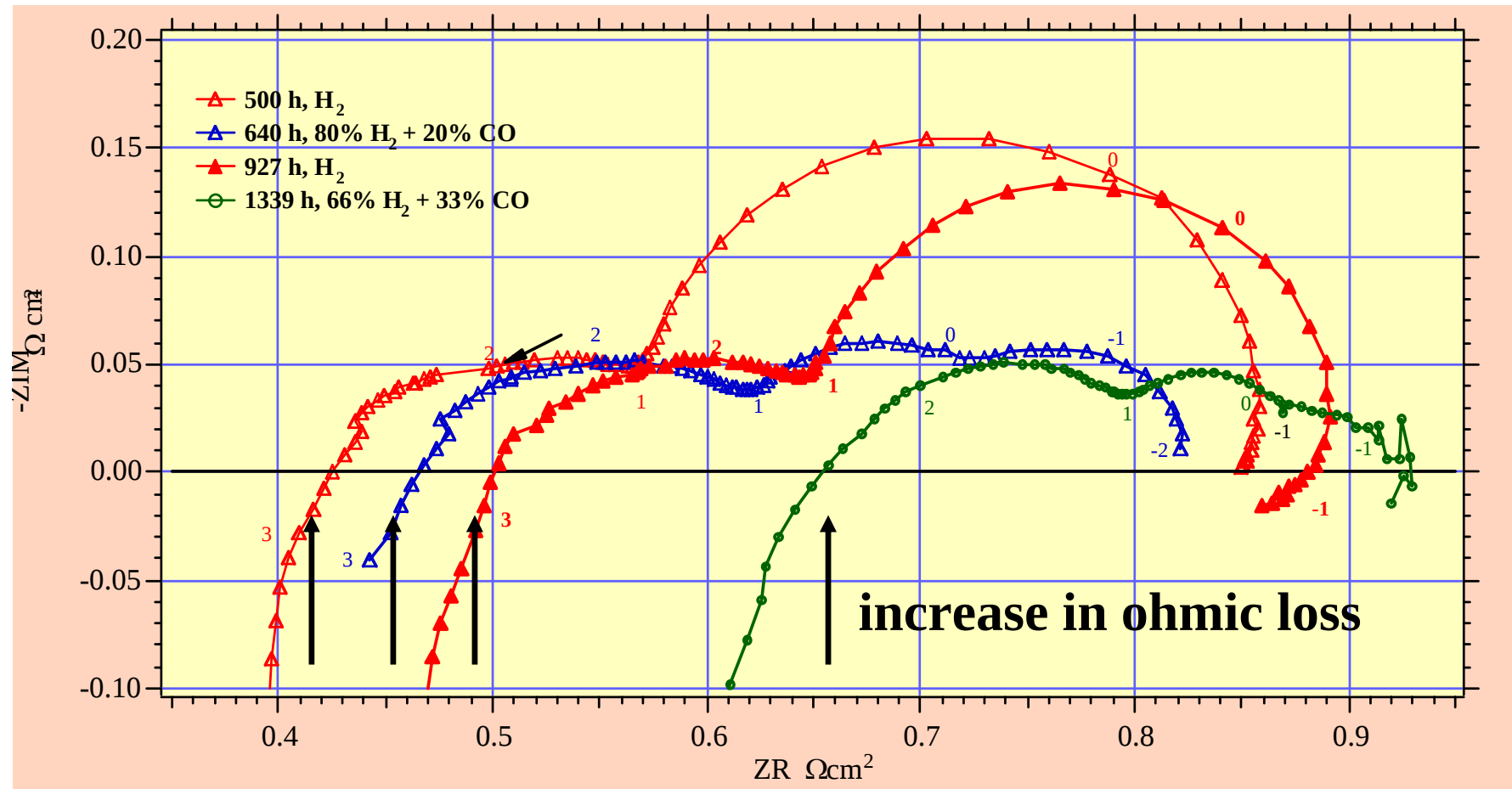
500-734 h :
80% H₂ + 20% CO

735-927 h : hum. H₂

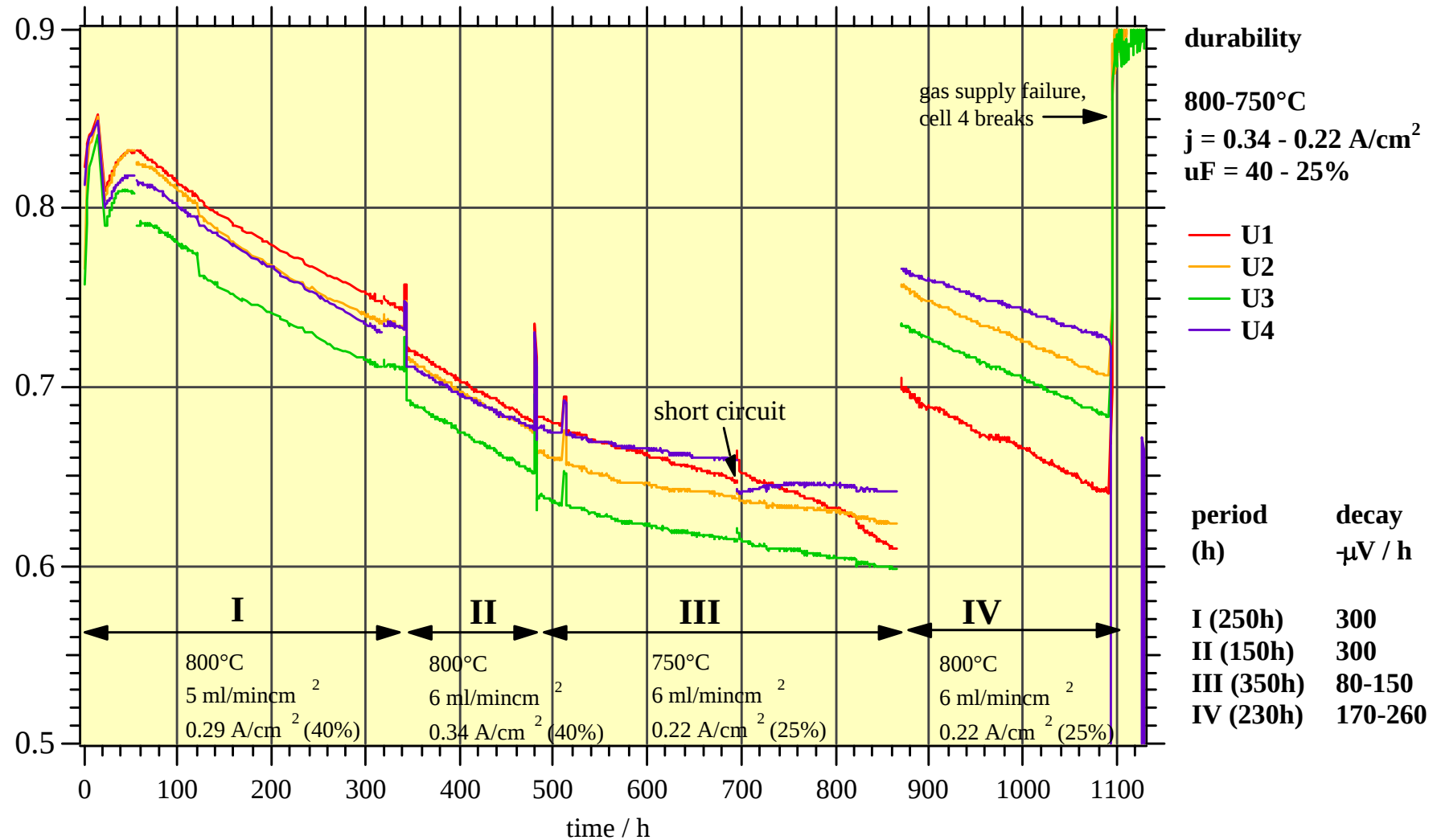
928-1340 h :
66% H₂ + 33% CO

1341 - xx h :
hum. H₂ (ongoing)

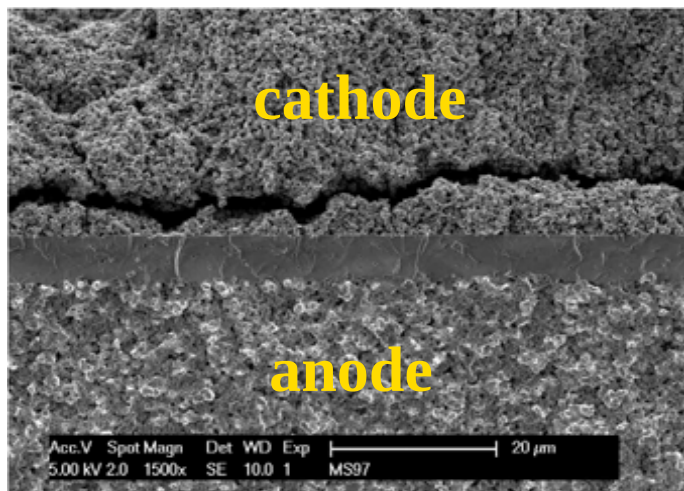
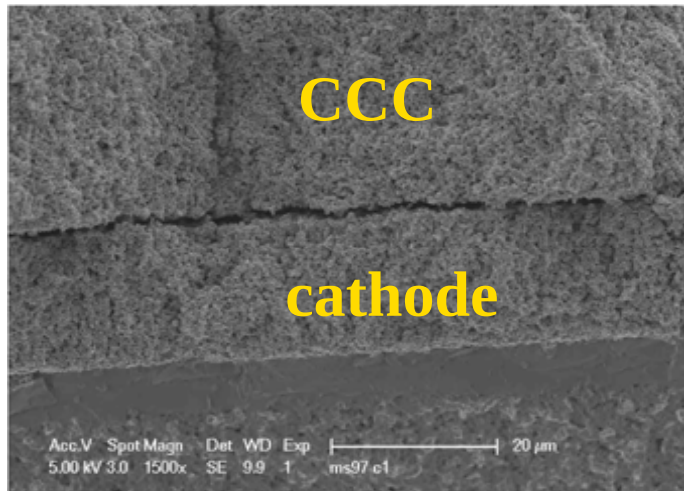
Impedance response



Durability

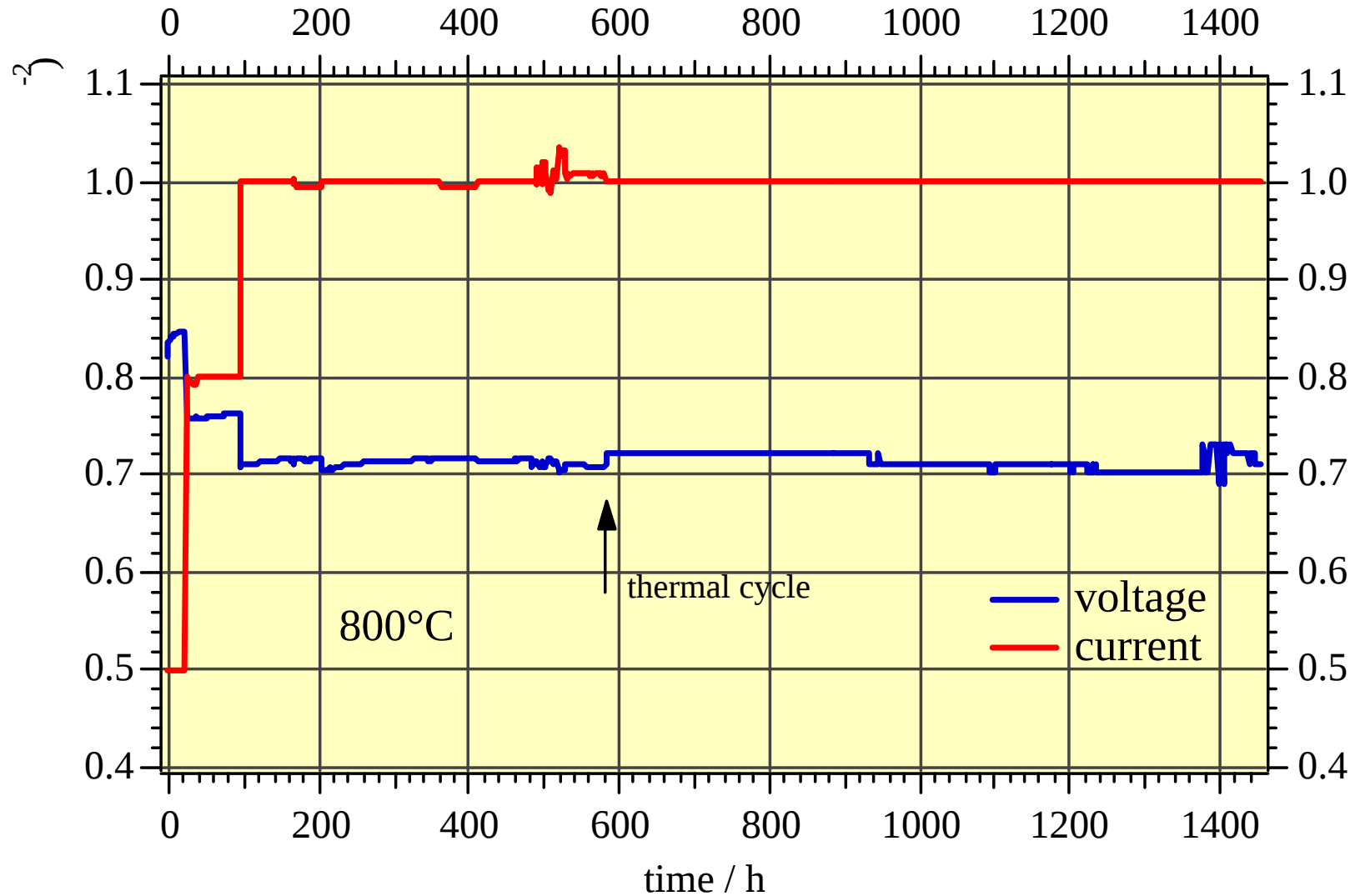


Post mortem SEM

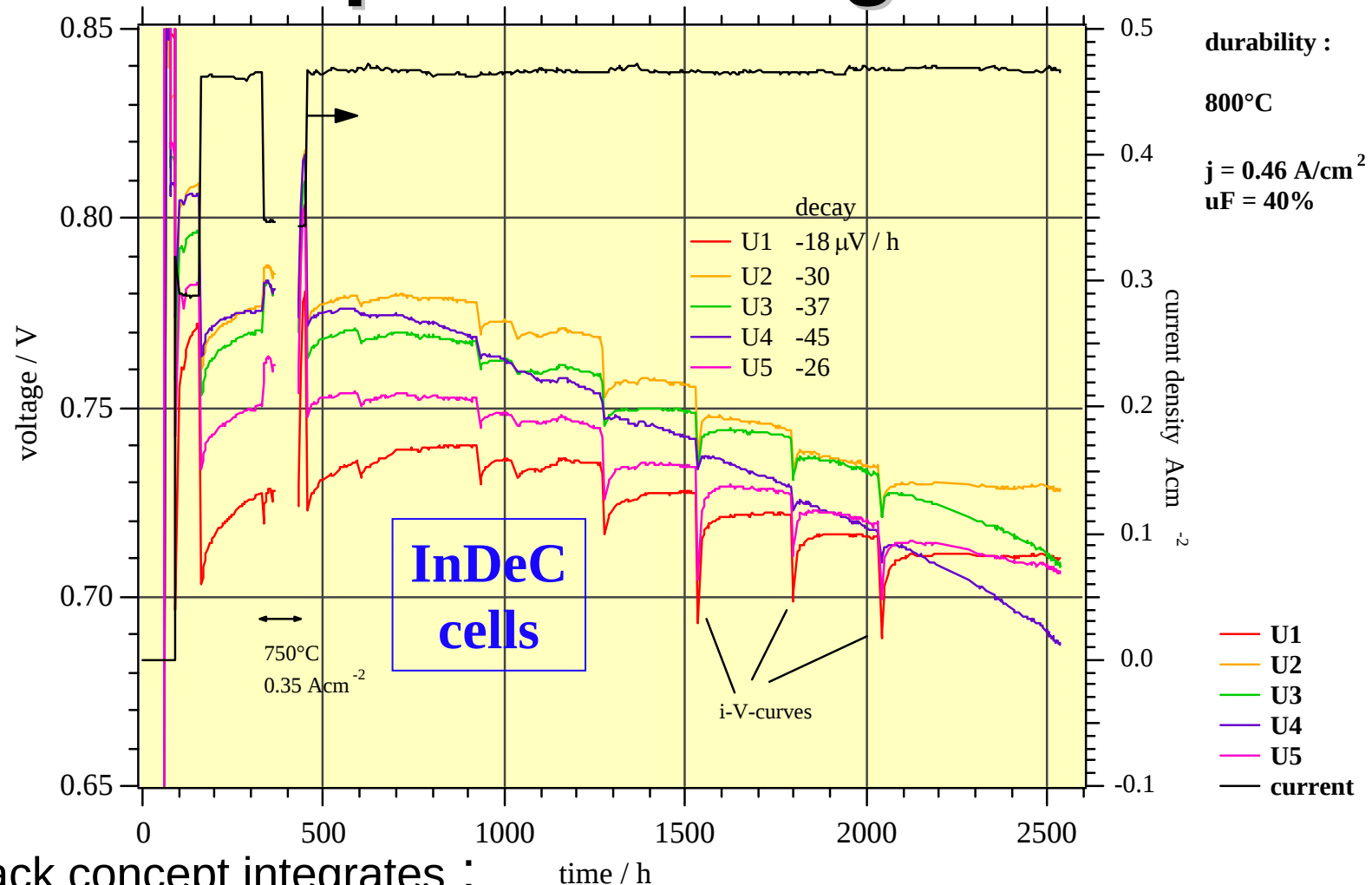


- cathode delamination appears mainly responsible
- also observed :
 - interfacial reaction (SrZrO_3)
 - Cr in CCC
 - active area loss due to sealing loss
 - marginal loss from MIC and SOFCConnex™

Recent cathode



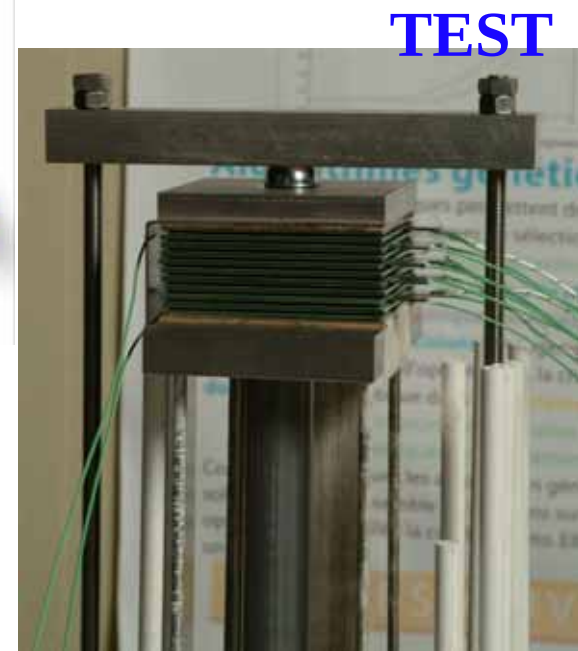
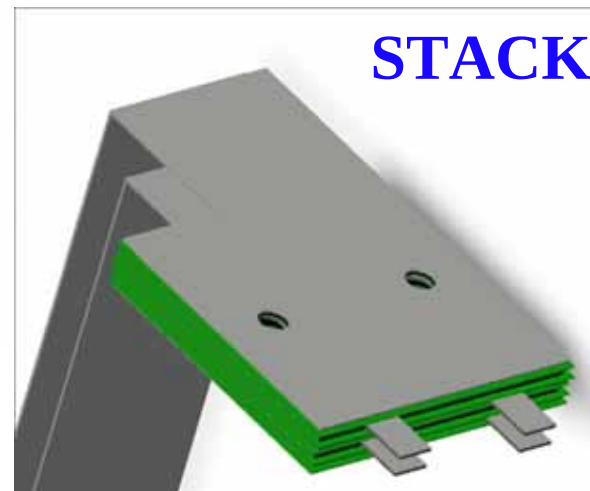
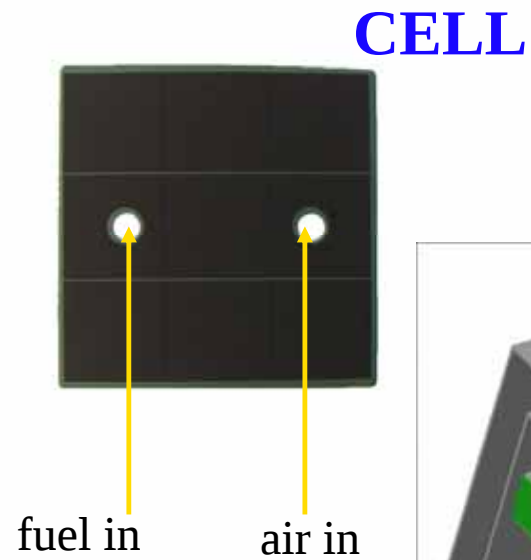
Component integration



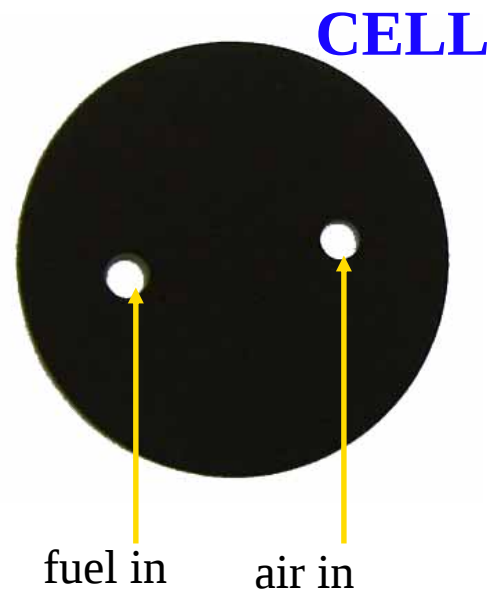
- stack concept integrates :
 - any steel sheets of any flat shape and size
 - any planar AS, ES cells ($\checkmark 800^\circ\text{C}$, $\checkmark 900^\circ\text{C}$)

Alternative, recent stack concepts using SOFConnex™ interlayers

Baseline design



Quick-start design

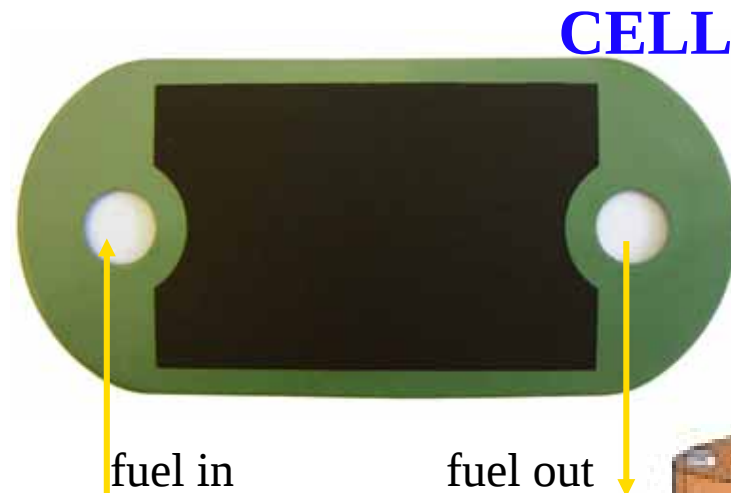


- circular, 25 cm²
- internal manifolds
- portable

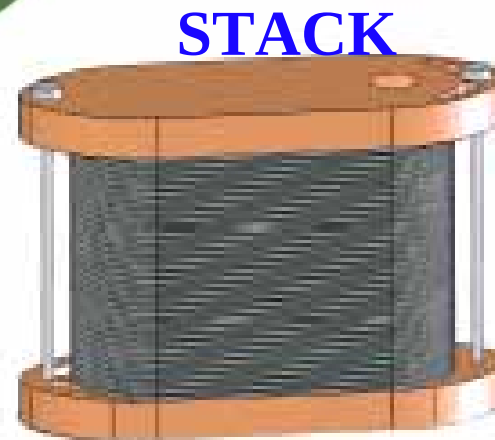
20 → 800°C in 1h
0.36 W/cm² on methanol (10-cell stack)
aim : 250-500 W on LPG



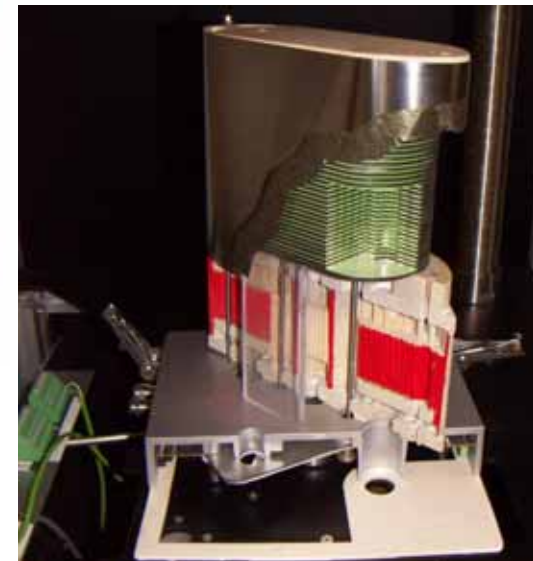
Co-flow, fuel recovery design



higher u_f and durability
50 W on 3 cell-stack
aim : 500 W (30 cells)



SYSTEM

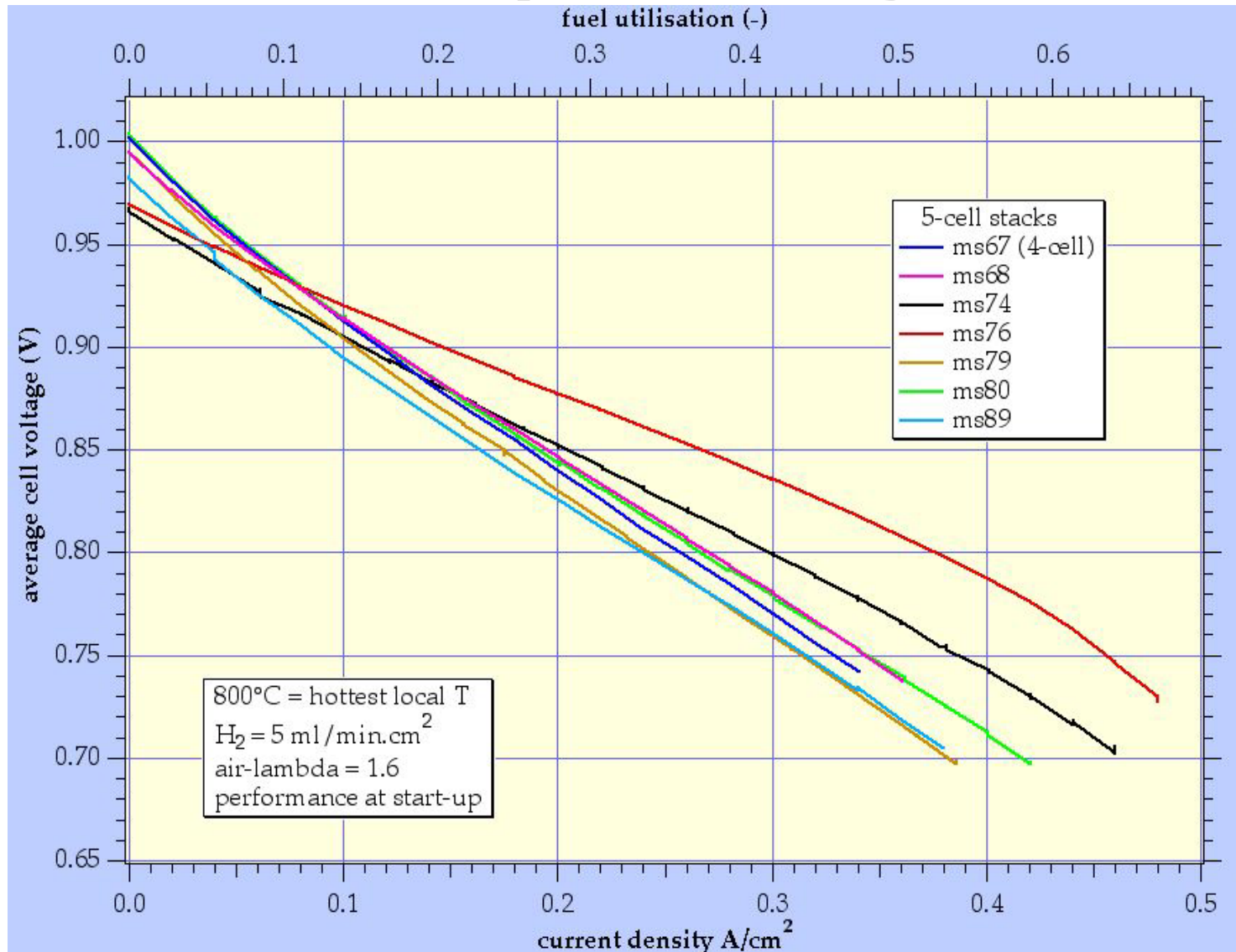


- oblong shape
- coflow
- air external manifold
- fuel recovery
- controlled postcombustion

SUMMARY

- innovative, flexible SOFC stack concept
- multifunctional SOFConnex™ interlayers integrate any planar cell & MIC shape or supplier
- with base design :
 - 0.5 W/cm² @ 0.7 V (800°C, 37% eff.)
 - repeatable, T-cyclable, C-fuel compatible
 - present (cathode) durability yet insufficient
- new designs (for systems) in test phase

Repeatability



Biogas feed (10-cell stack)

