Accelerated Tests, early prediction and modeling tools

Parametrical coordinates and microsamples simulating a real SOFC stack

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The investigation of a real SOFC stack under operation is usually made checking or imposing a few parameters strictly related to each other: Temperature, Voltage, Current Load, fuel composition. To keep under control the performance and the natural degradation process the voltage is considered the most direct measure that could be done keeping the load and all other parameters constant. The introduction of segmented cells in an experimental stack is one of the most up to date strategies to have an overview of the phenomena occurring during operation because it is known that while the polarization might be considered evenly distributed over the cell, temperature and fuel composition are changing across the cell from the inlet to the outlet manifolds with consequent changes in the related local voltage. The post operational characterization of the cell is then mandatory in order to understand which parts of the cell itself or of the stack were degrading during the working period. Knowing the local set of parameters of a specific samples allows the combination of such information with the alteration of materials opening the possibility to increase the awareness on the degradation processes and thus to contribute to the set up of materials improvements or of the introduction of tailored counteractions.

The issue of such a wise strategy is that the sampling process is extremely difficult and the test might result complex for unexpected collateral phenomena (e.g. gas shortage, black out) abruptly interrupting the experimental session. Learning from modelling and practical experience how the parametrical coordinates (i.e. T, I, Fuel, Mechanical load) may have an effect on performances and degradation rates a cost effective and simple approach is suggested and demonstrated in the present paper: the usage of micro-samples, 25 to 30 mm of diameter, made of the cell (complete with all current collecting layers), the sealants and the metallic interconnects. Such cell is the mounted in a specific test bench known as Real Life Tester rel. 2.0 (RLT2) where the operating conditions can be easily replicated and modified in order to virtually move the cell in various areas of the stack and to check how the materials are responding according to the parametrical coordinates in use. The samples can then be easily monitored and then studied post-experiment having all at once information about the cell, the sealing and the metal or, in other words, of the whole stack components.

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WORKSHOP PROCEEDINGS

DEGRADATION MECHANISMS
IN SOLID OXIDE CELLS
AND SYSTEMS

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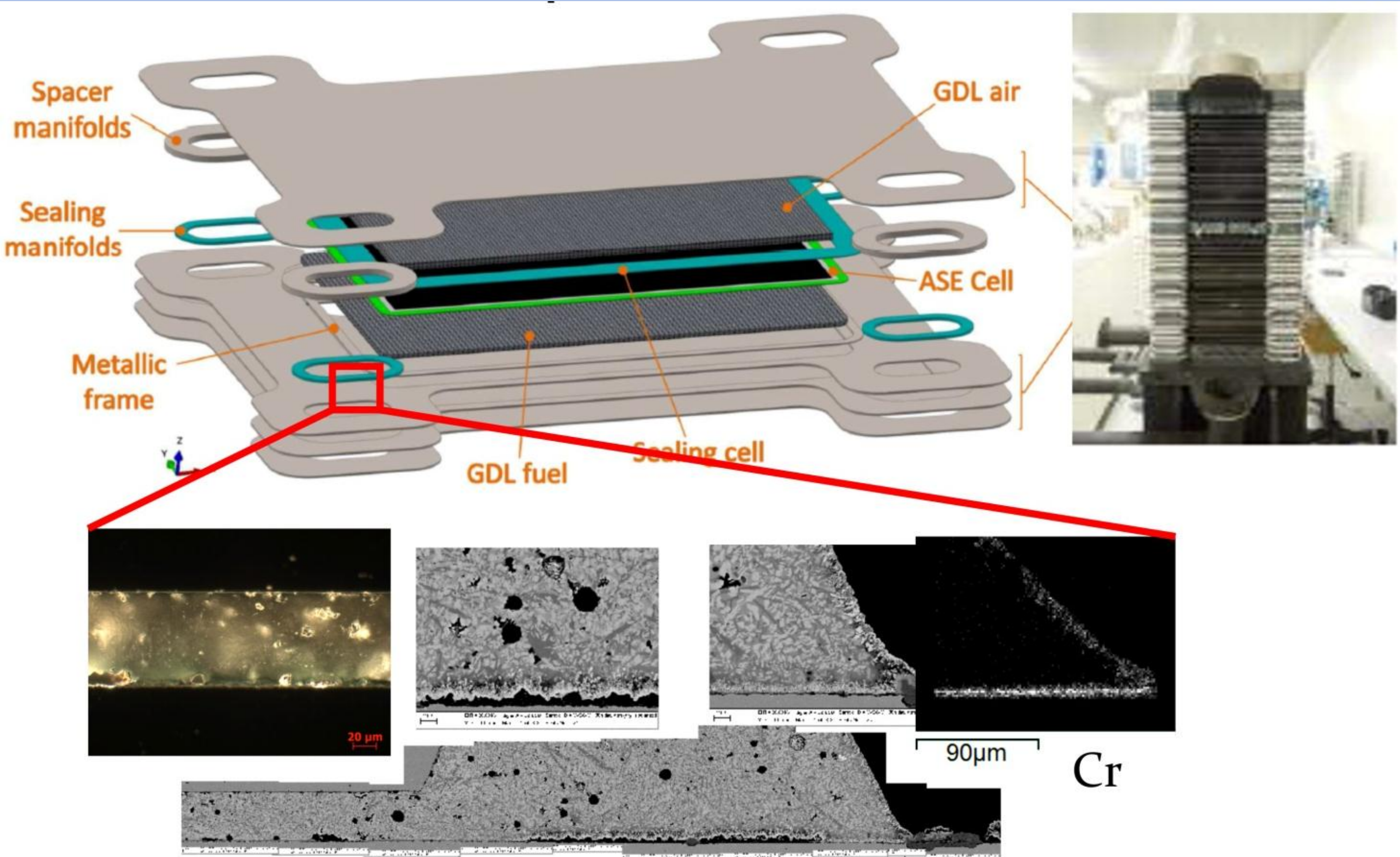
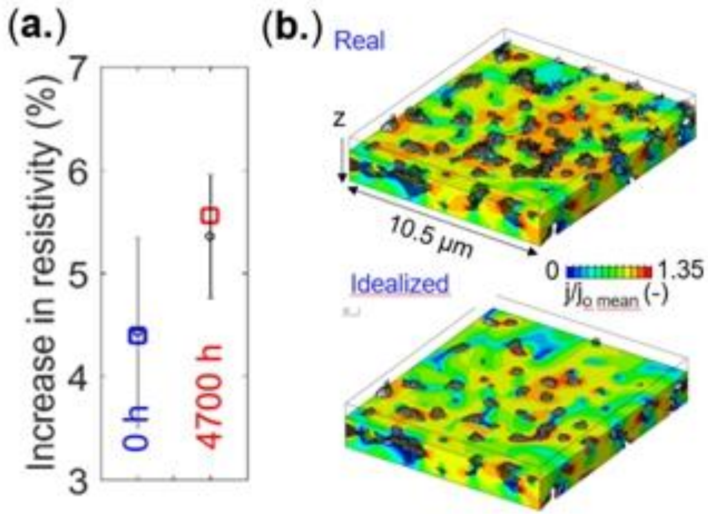
Università degli Studi di Genova

ENDURANCE project

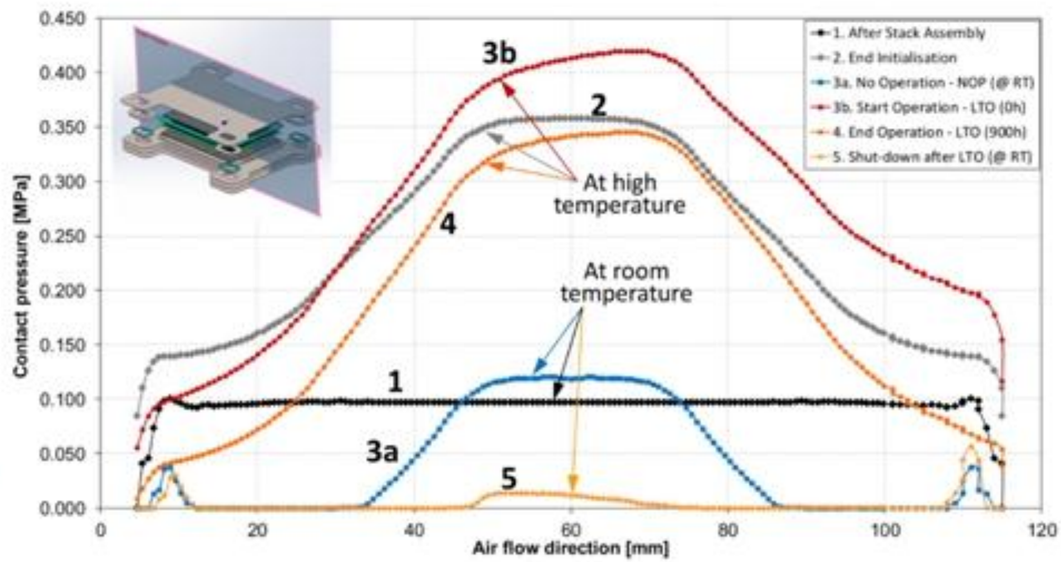
Introduction to the parametrical coordinates



Thermal, mechanical&electrical gradient



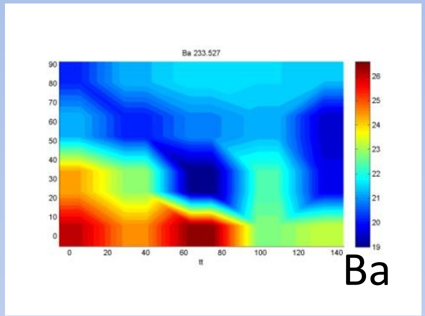
(a) Increase in effective resistivity caused by the Sr-containing phases, in the pristine and aged sample. (b) Current density computed in the pristine sample with (upper) and without (lower) the Sr-containing phase.

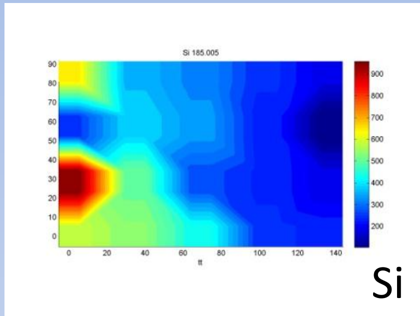


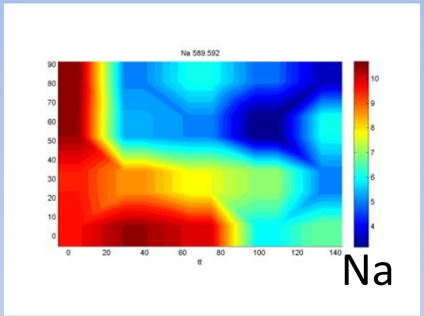
Evolution of the contact pressure at the interface anode/GDL fuel along the symmetry line of the SRU, depending upon the stack operation history

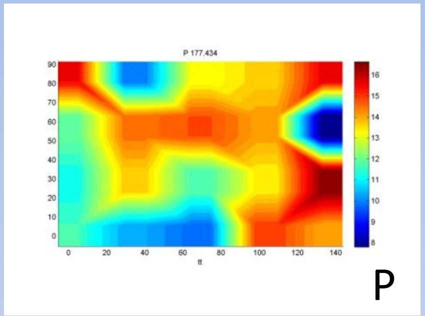
ENDURANCE

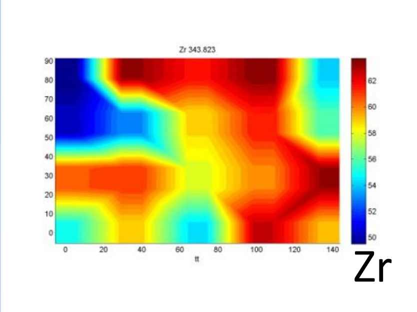
Thermal & Chemical gradient

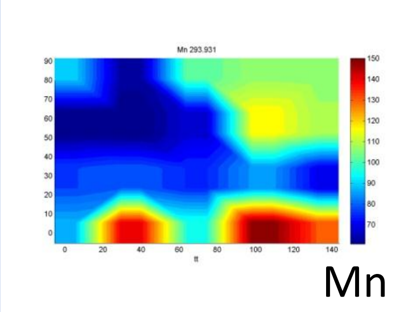


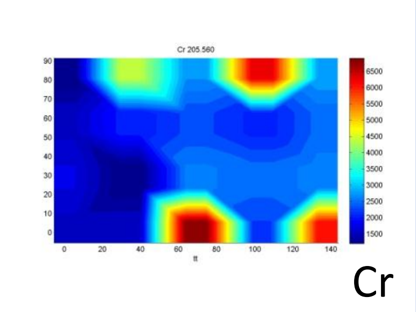


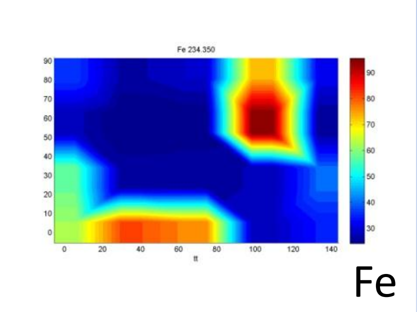


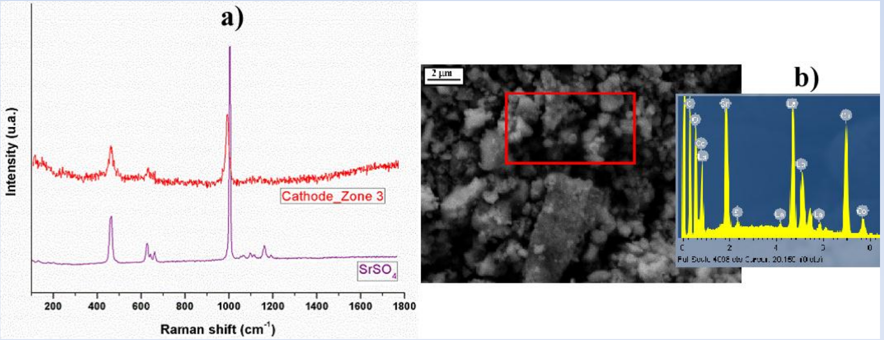




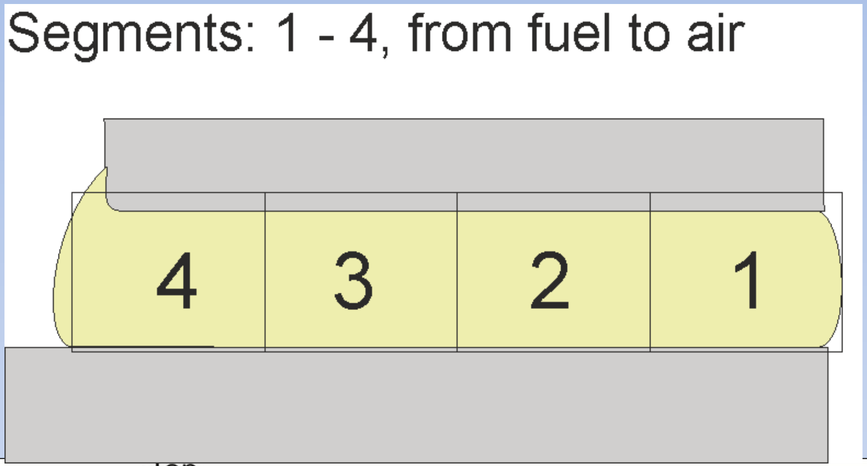


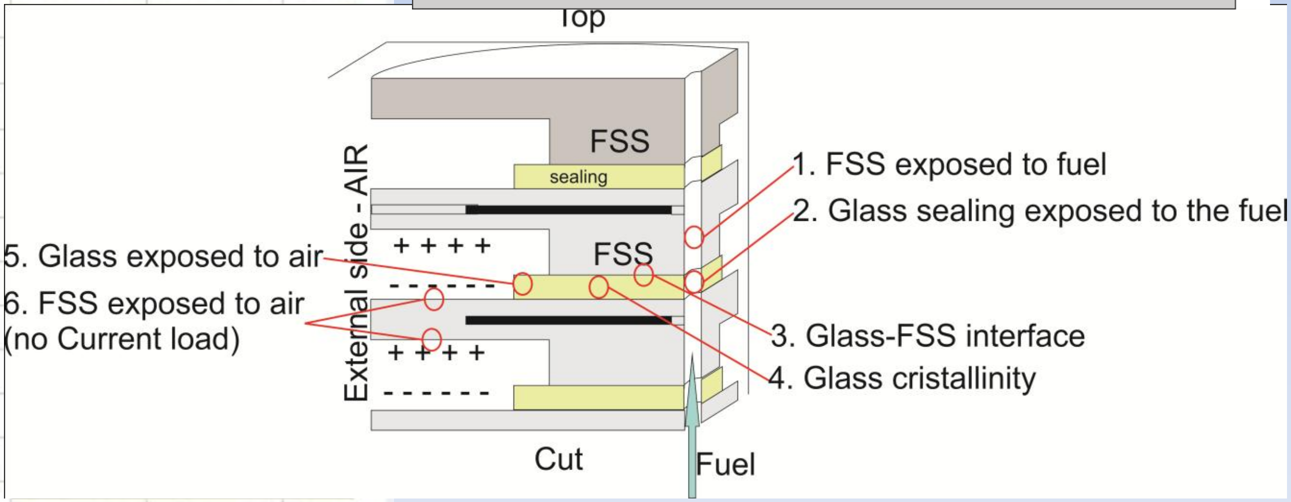






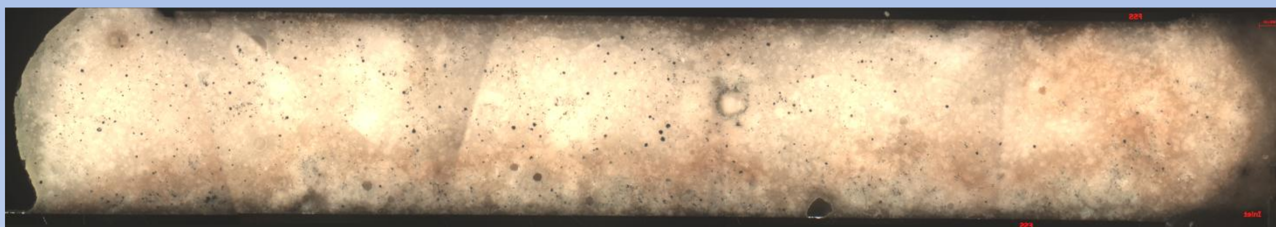
Thermal, chemical & gases composition gradients





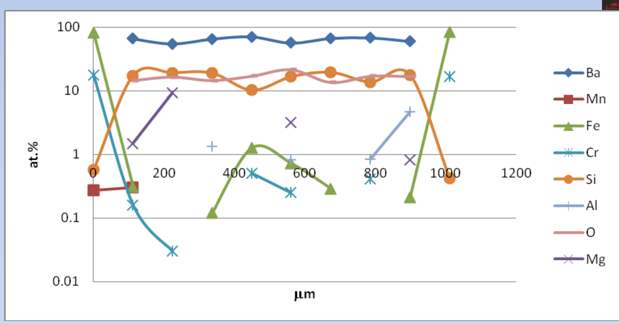
ENDURANCE

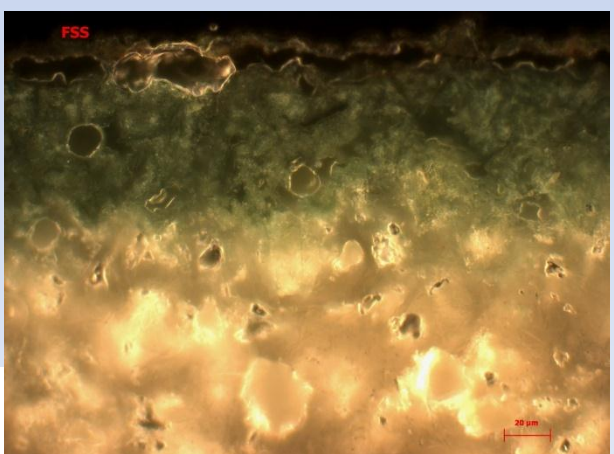
Polarization

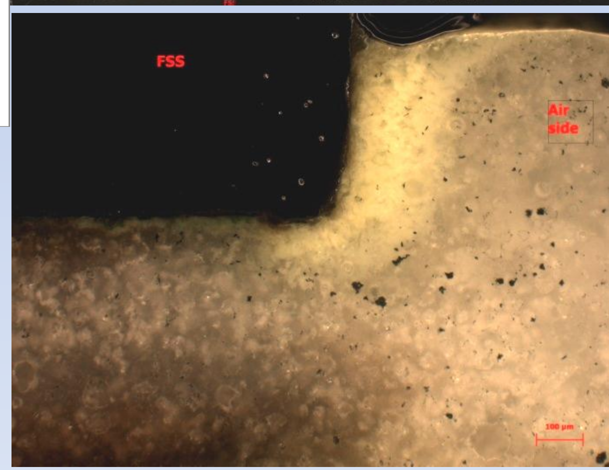


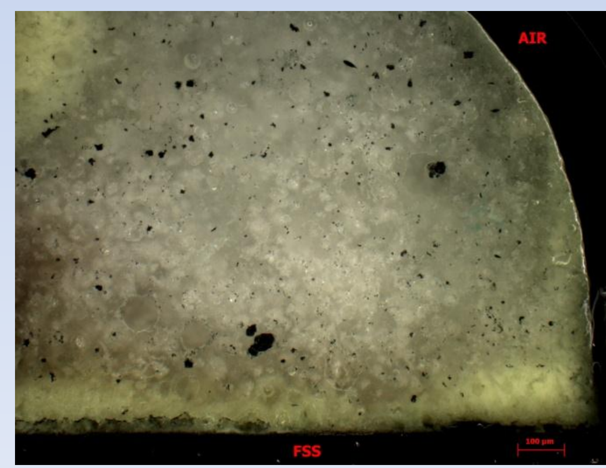
INLET

OUTLET

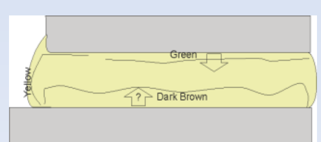








AIR



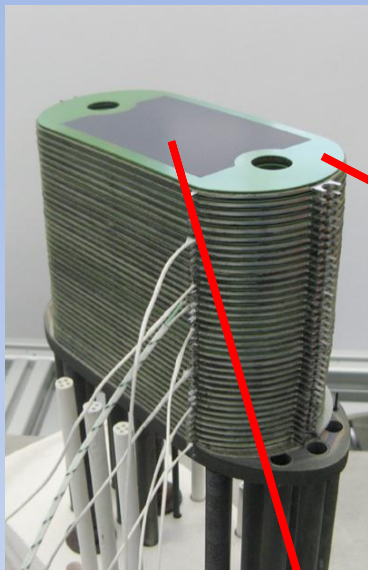
FUEL

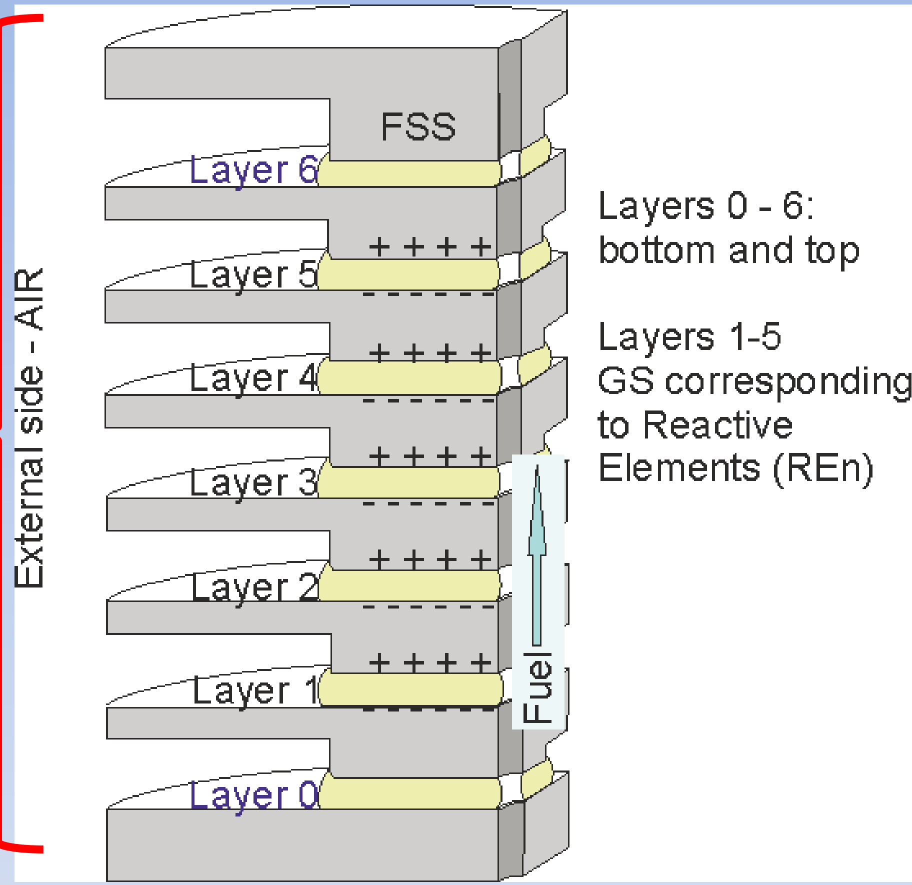
Which parameters, which coordinates

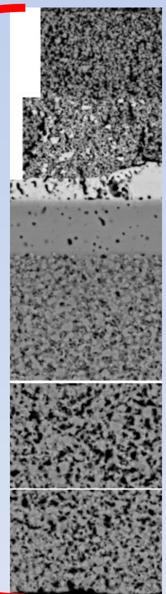
- Fuel and oxidant chemical composition
- Polarization
- Materials interaction
- Mechanical gradient
- Electrochemical properties
- TEMPERATURE

ƎNDURANCE

Observing a stack







GS and MIC degradation

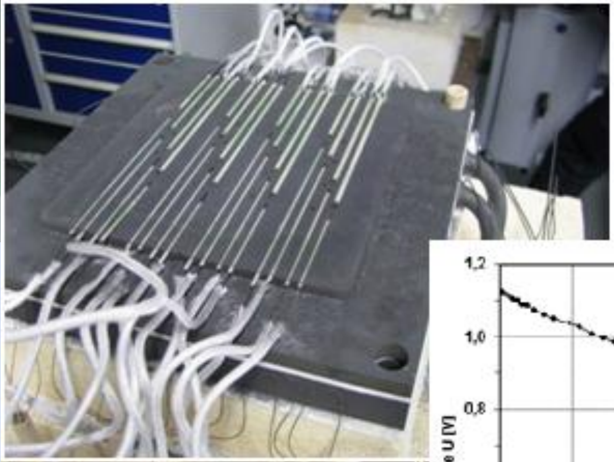
Interdiffusion phenomena

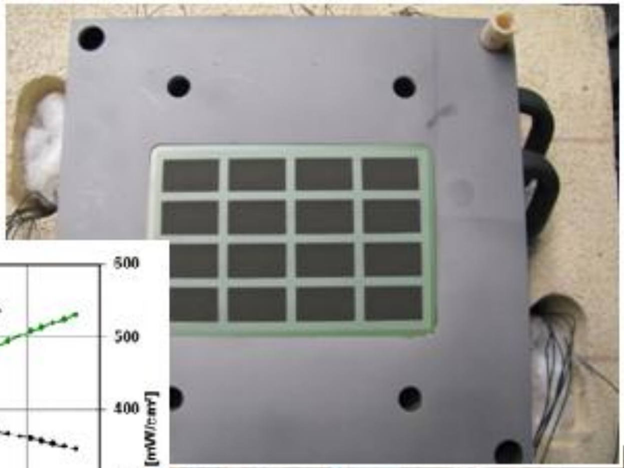
High risk of failure

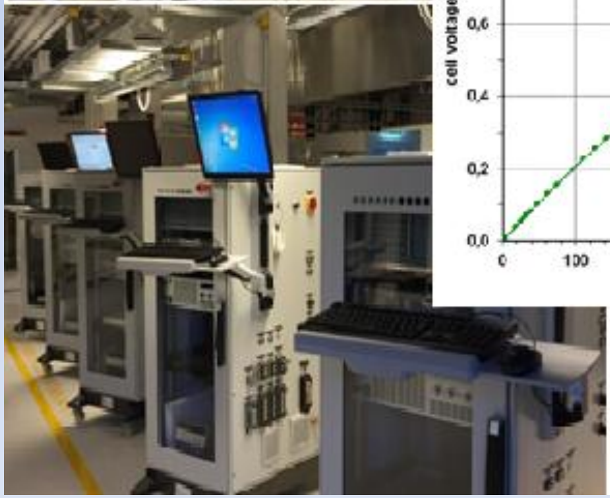
High risk of degradation

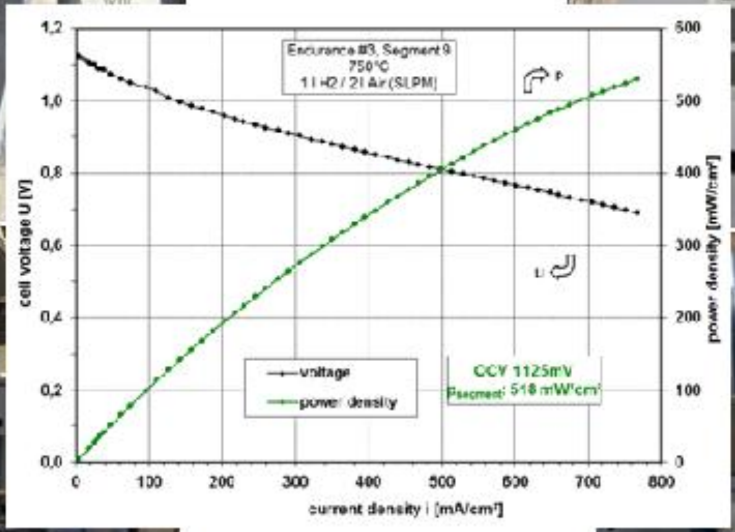
ƎNDURANCE

Macro solution: Segmented stack

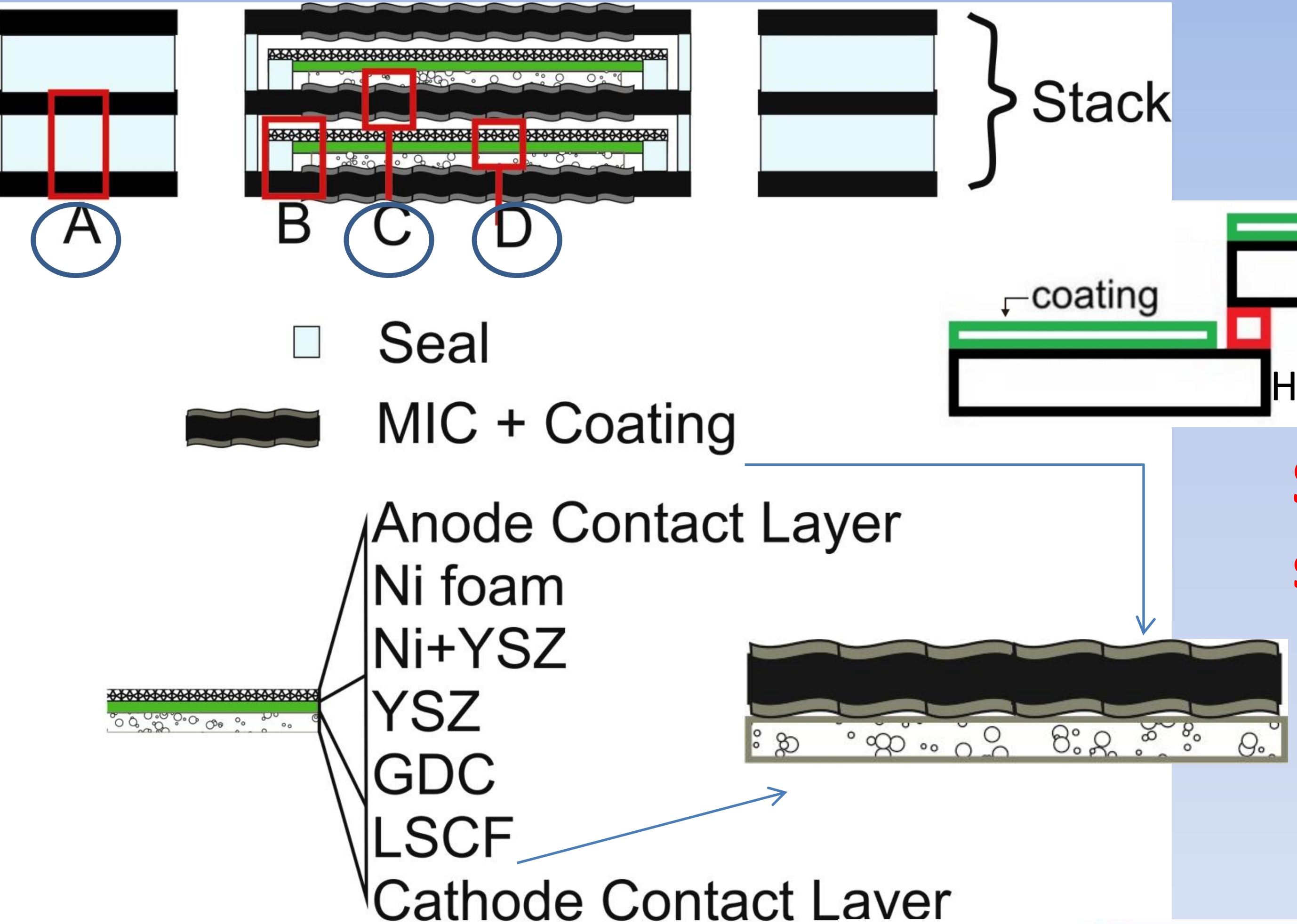


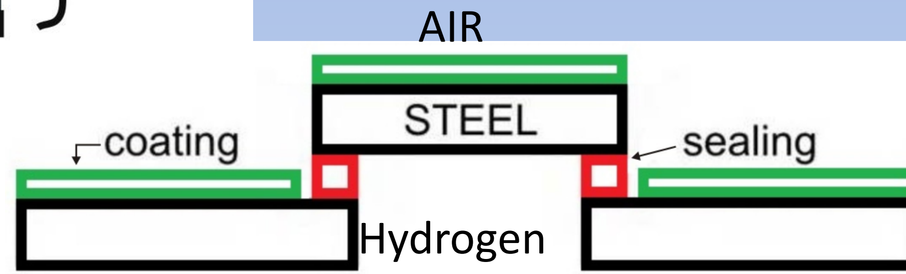






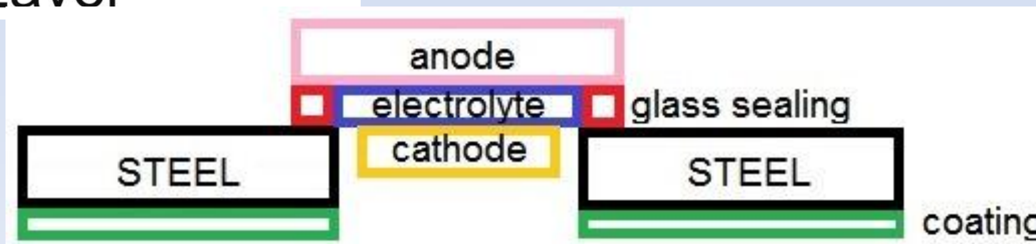
Micro solution: ENDURANCE cell





Sealing-scaffolding steel

ENDURANCE cell



Why going back to microsamples

Advantages

- All materials at once
- Cost effective
- Fast&safe for mounting and unmounting samples
- No gradients
- Rapid switch
- Easy post experiment investigation
- Limited issues in case of failure

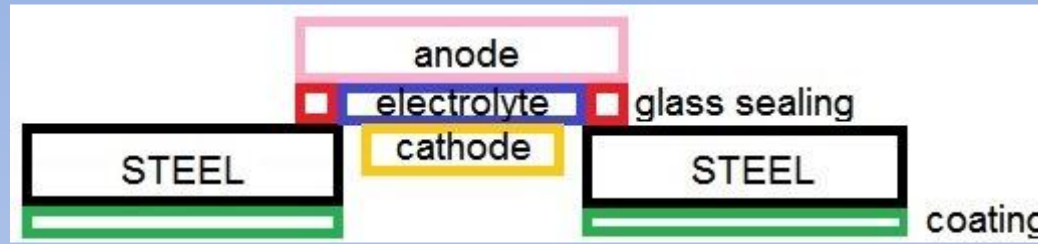
Disadvantages

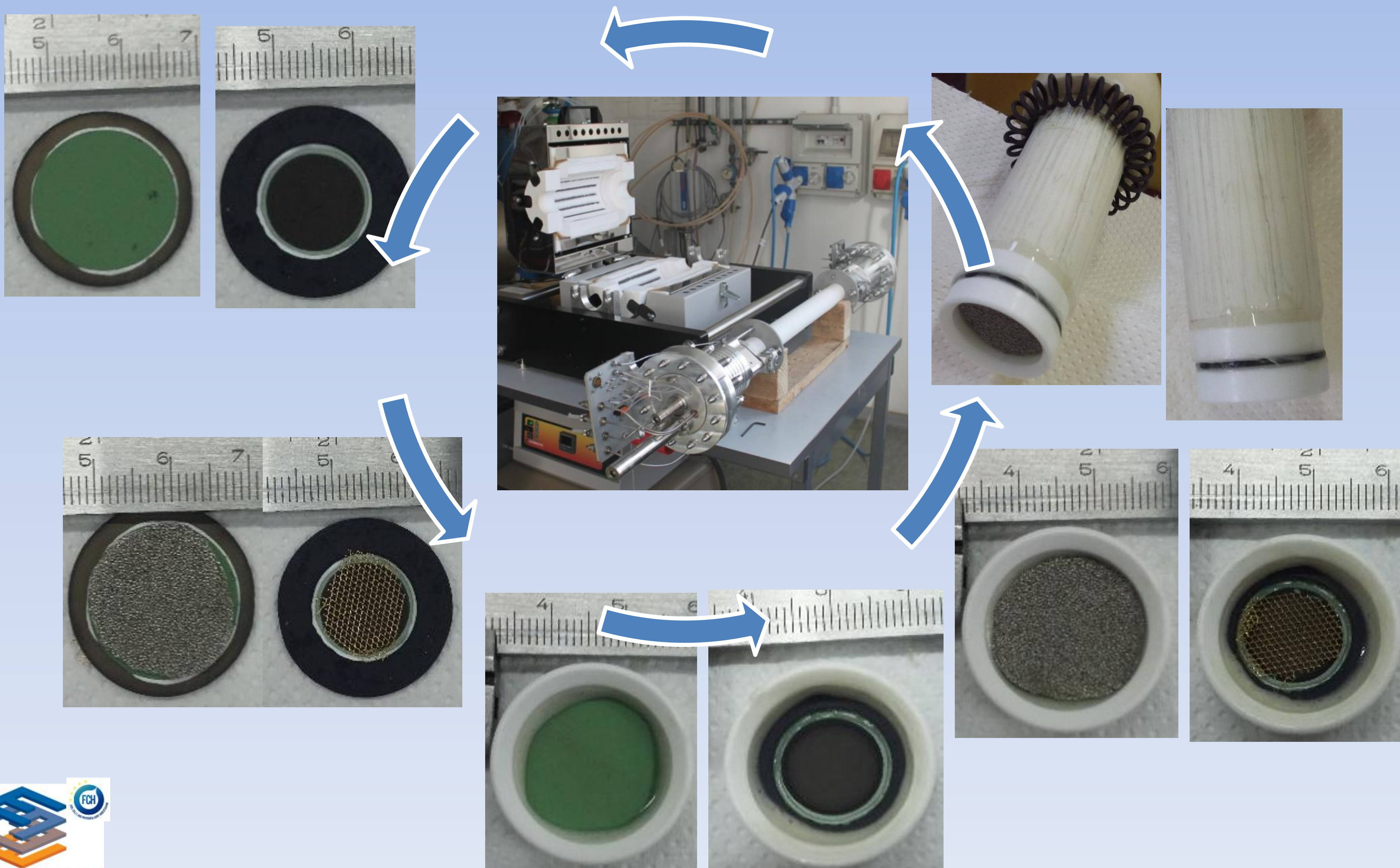
- Need for Design of Experiment
- Low efficiency
- Specific cells

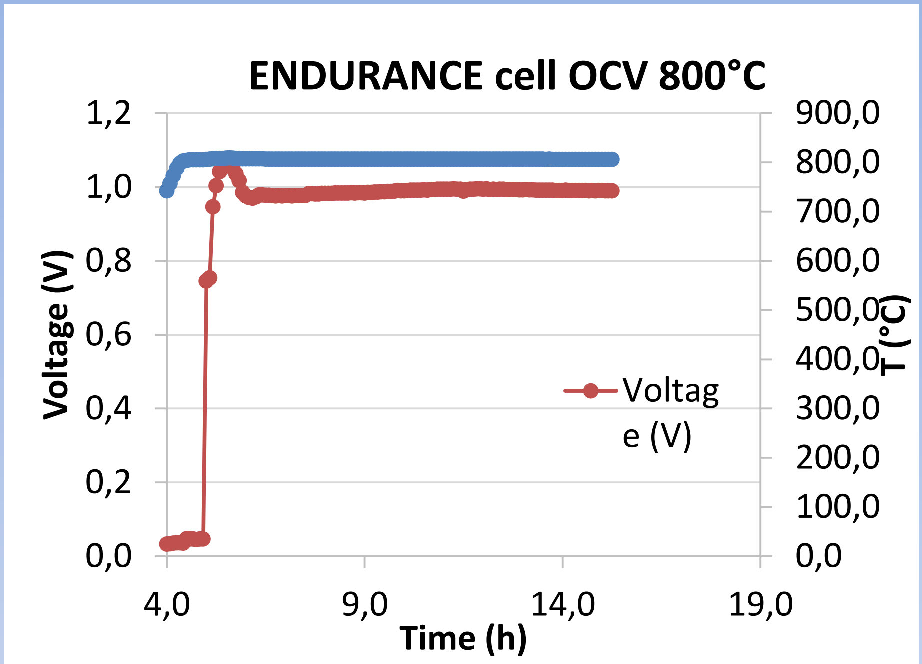
Parameters of the first experiment: ENDURANCE cell 1

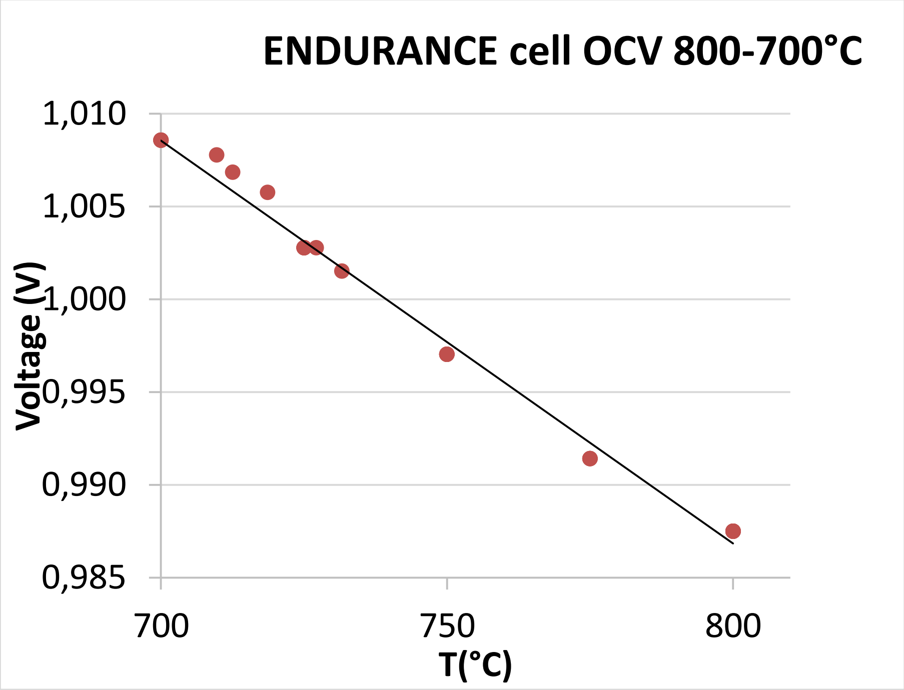
- Fuel: Hydrogen / Nitrogen (60 / 40)
- Oxidant: air
- All gases are controlled by flowmeter
- Current load based on the I-V curve: 150 mA/cm^2
- **Temperature range: 700°C – 800°C**
- OCV each 25°C, EIS before and after operation at 775°C, performance for 25h at fixed T

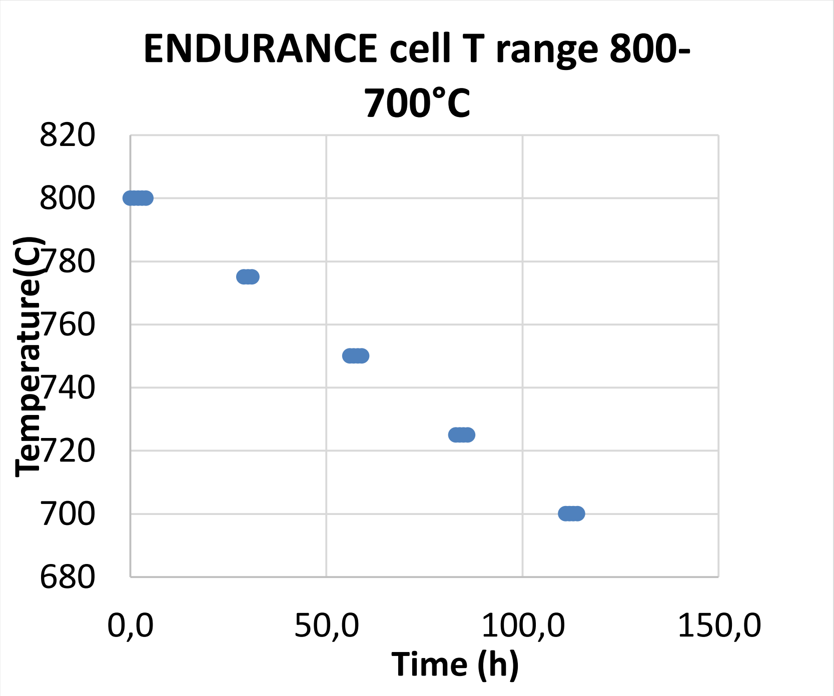
ENDURANCE


anode
electrolyte
glass sealing
cathode
STEEL
STEEL
coating

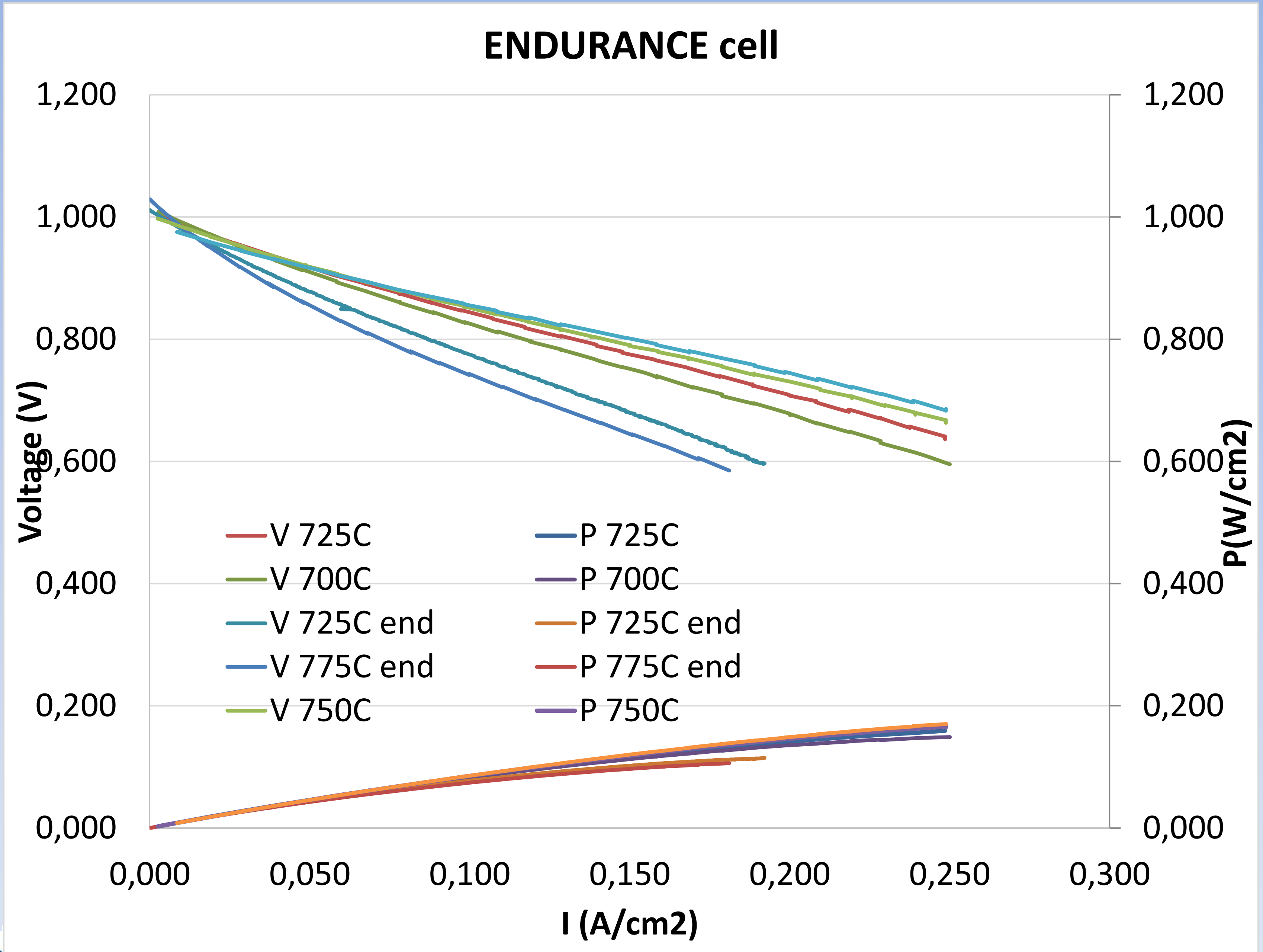



ENDURANCE cell OCV 800°C
Voltage (V)
T (°C)
Time (h)
Voltag
e (V)
1,2
1,0
0,8
0,6
0,4
0,2
0,0
900,0
800,0
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
4,0
9,0
14,0
19,0

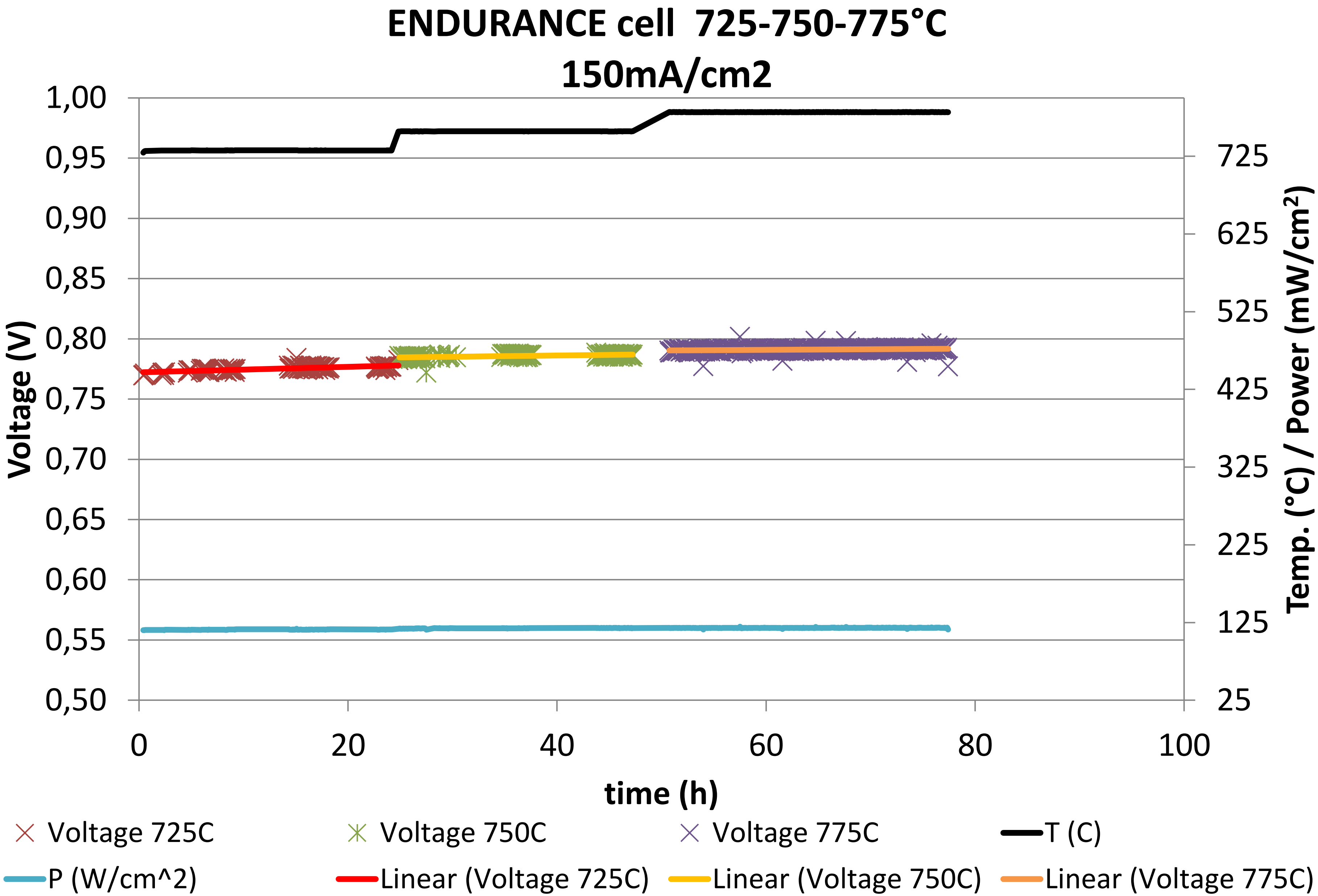

ENDURANCE cell OCV 800-700°C
Voltage (V)
T(°C)
1,010
1,005
1,000
0,995
0,990
0,985
700
750
800


ENDURANCE cell T range 800-700°C
Temperature(C)
Time (h)
820
800
780
760
740
720
700
680
0,0
50,0
100,0
150,0

ƎNDURANCE

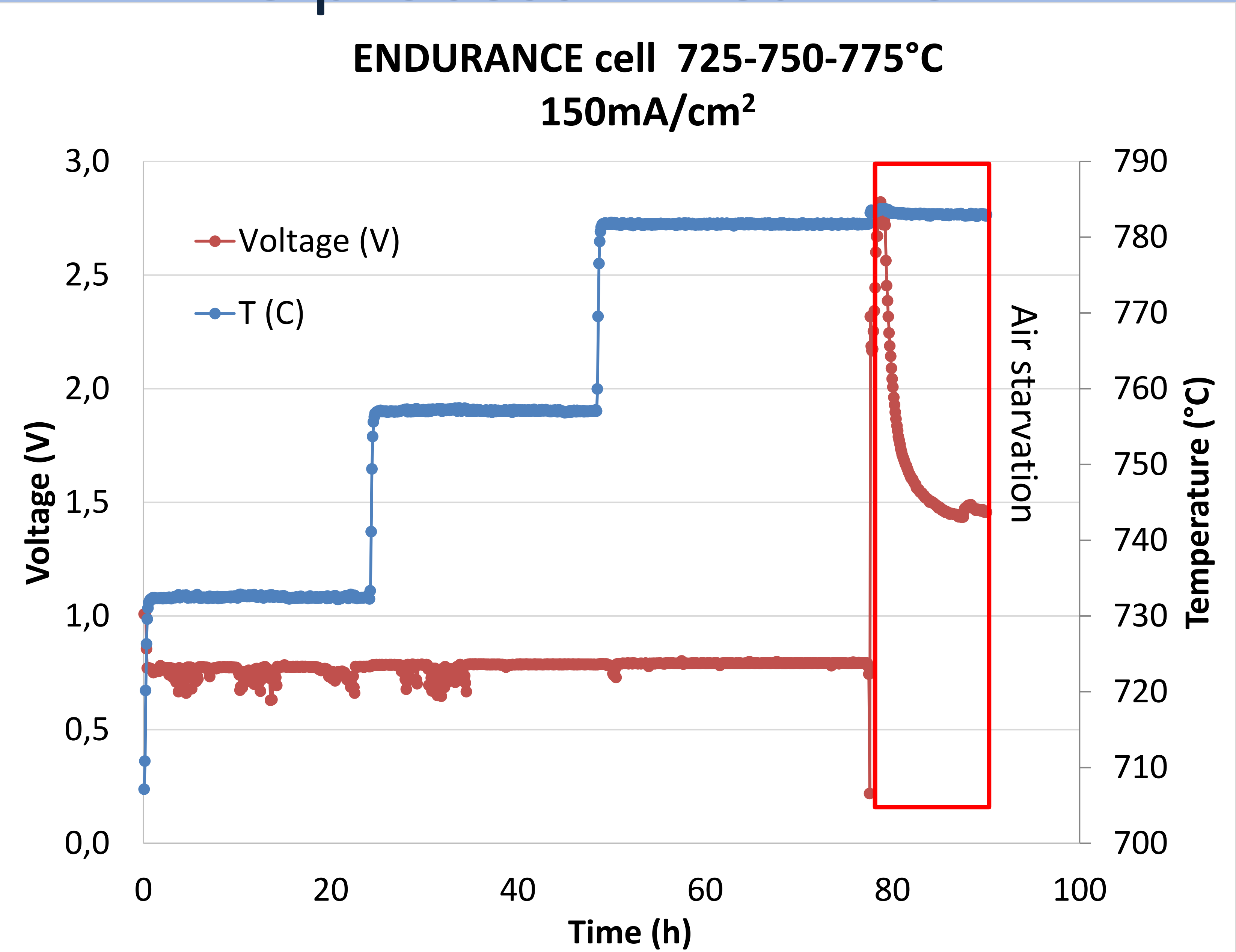

ENDURANCE cell
Voltage (V)
P(W/cm2)
I (A/cm2)
1,200
1,000
0,800
0,600
0,400
0,200
0,000
0,000
0,050
0,100
0,150
0,200
0,250
0,300
V 725C
V 700C
V 725C end
V 775C end
V 750C
P 725C
P 700C
P 725C end
P 775C end
P 750C

ENDURANCE


ENDURANCE cell 725-750-775°C
150mA/cm2
Voltage (V)
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
Temp. (°C) / Power (mW/cm²)
725
625
525
425
325
225
125
25
0
20
40
60
80
100
time (h)
Voltage 725C
Voltage 750C
Voltage 775C
T (C)
P (W/cm^2)
Linear (Voltage 725C)
Linear (Voltage 750C)
Linear (Voltage 775C)

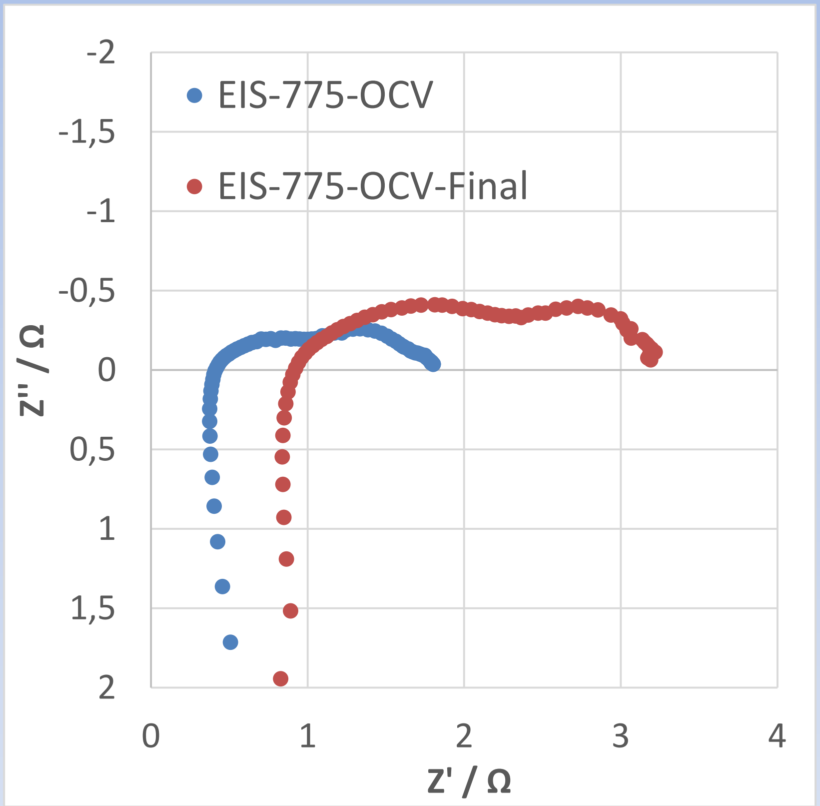
ENDURANCE

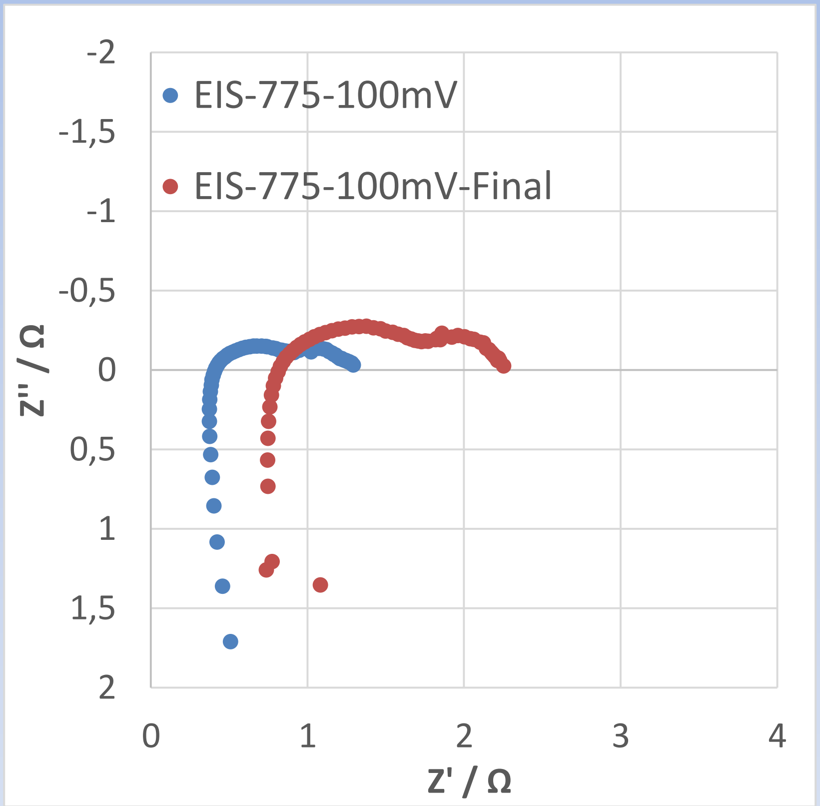
The process in real life



ENDURANCE

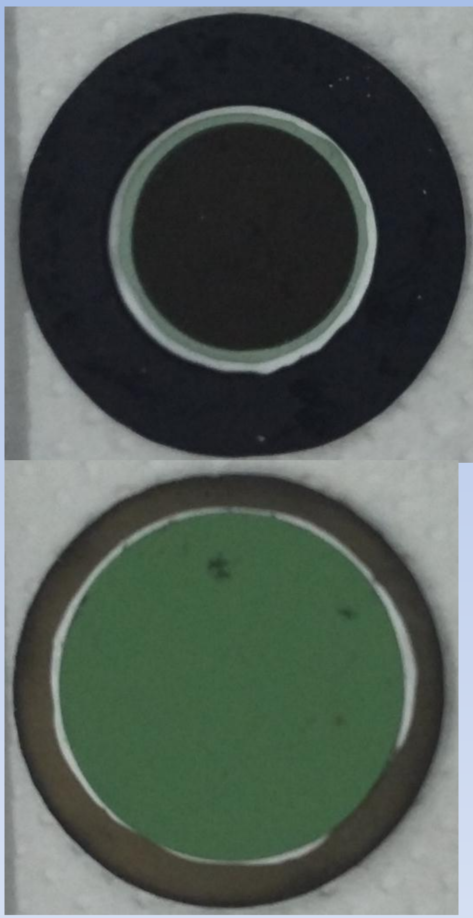
Electrochemical Impedance Spectroscopy

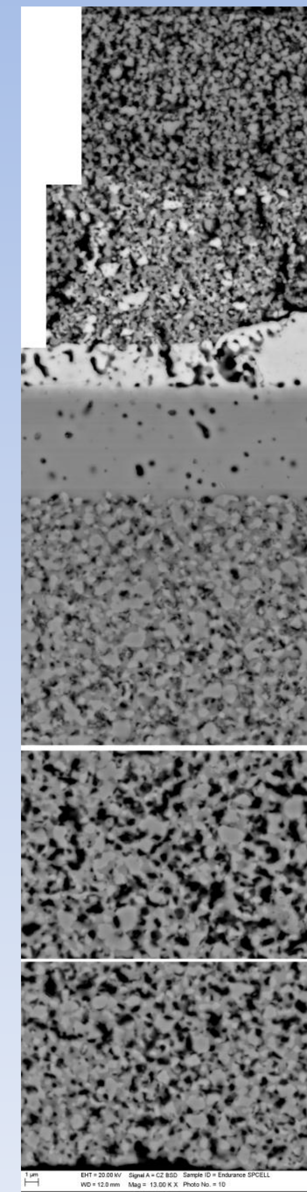




ƎNDURANCE

The before and after the process





ENDURANCE

Next investigation: post-mortem characterization

- Cross section containing Metal, coating, sealant, cell suitable for
  - SEM – EDXS
  - FIB – HRSEM – STEM
  - SIMS
  - Raman microspectroscopy
  - Collection of data for models refining process

ENDURANCE

Conclusions

- The parametrical coordinates describe each point of a stack
- Modifying a single parameter it is possible to investigate its effect on the cell behavior
- All materials together means “interaction”: minima phenomena
- Real Life tests
- Cycling, harsh tests, materials compatibility all in one single cost effective test

Thank you

Acknowledgments

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