METSAPP

Metal supported SOFC technology for stationary and mobile applications

(GA number 278257)

Niels Christiansen
Topsoe Fuel Cell A/S

Project & Partnership

General Overview

- Metal supported SOFC technology for stationary and mobile applications
- 3 years (2012-2014)
- Budget

  Total: 7.886.781 EURO

  EU contribution: 3.396.470 EURO

  Danish top up support: 1.034.732 EURO

Vertical integrated

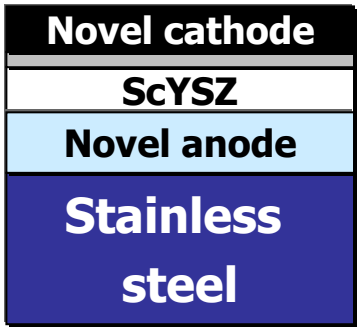
Consortium

Topsoe Fuel Cell A/S (DK)
Sandvik Materials AB (SE)
AVL List GmbH (AT)
ICE Stroemungsforschung GmbH (AT)
DTU Technical University of Denmark (DK)
Chalmars University of Technology (SE)
Karlsruhe Institute of Technology (DE
University of St Andrews (UK)
EC Joint Research Centre (NL)

Project goals, targets, and milestones

The aim of the METSAPP project is to develop novel cells and stacks based on a robust and reliable up-scale-able metal supported technology with the following primary objectives:

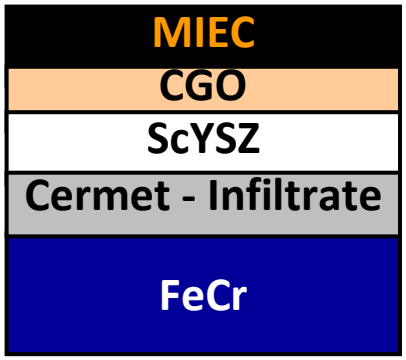
1. Robust metal-supported cell design, $ASR_{cell} < 0.5\ \Omega cm^2$, 650ºC
2. Cell optimized and up-scaled to > 300 cm^2 footprint
3. Improved durability for stationary applications, degradation < 0.25%/kh
4. Modular, up-scaled stack design, stack $ASR_{stack} < 0.6\ \Omega cm^2$, 650ºC
5. Robustness of 1-3 kW stack verified
6. Cost effectiveness, industrially relevance, up-scale-ability illustrated.



Next Gen SOFC development

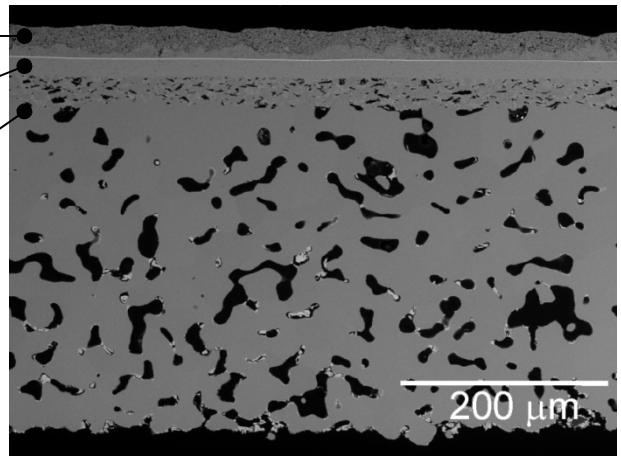
Start platform

EU METSOFC Cell
2008 -2011
5000 h lifetime
Mobile applications

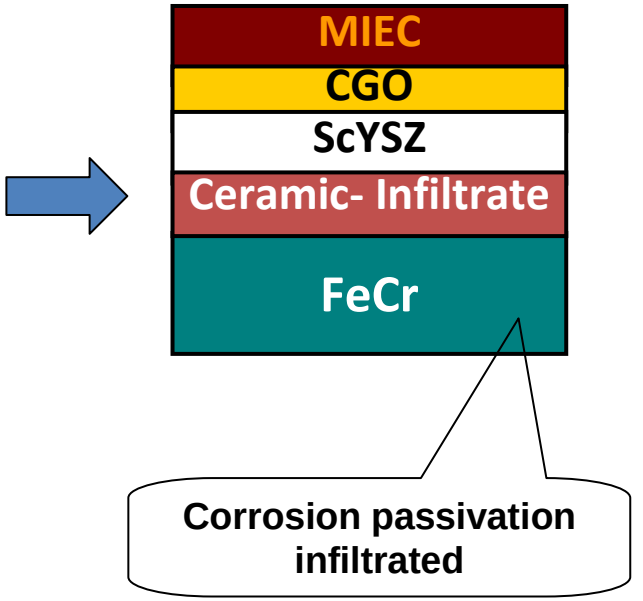


0.9% degradation per 1000 hours during 3000 hours

ASR: 0.27 Ωcm² at 650 °C



EU METSAPP Cell
2012 – 2014
40.000 h lifetime
Stationary applications

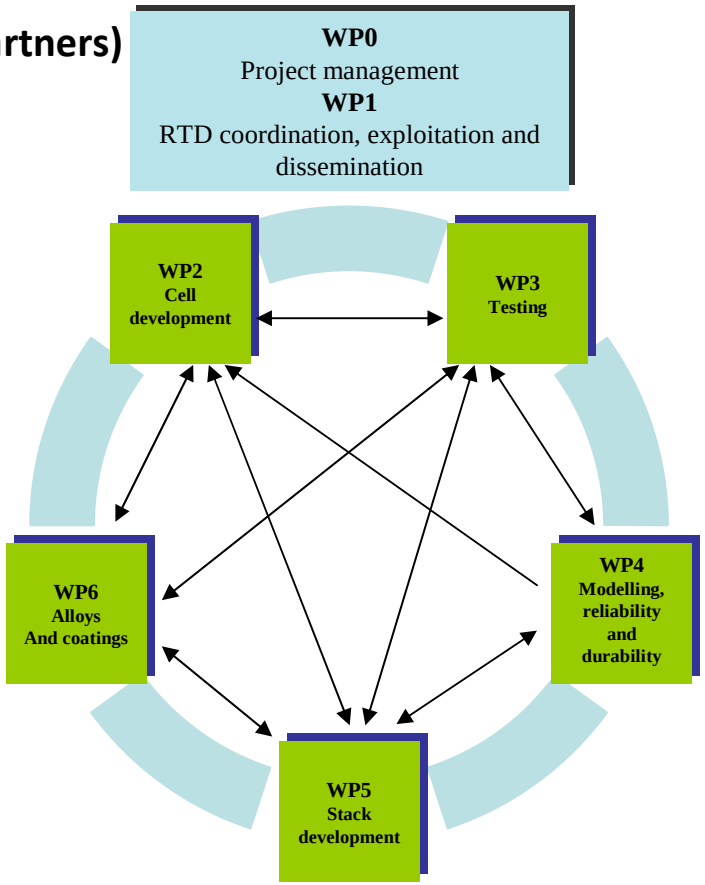


Project concept

LEAN Development in a Complex Technology

- **Project groups (WPs) with a strong background and competences**
- **Vertical integrated project structure (no overlap between partners)**
- **Several links to other SOFC projects (EU, national, in-house)**
- **Rapid cell and stack prototypes at optimal scale for test**
- **Rapid critical optimization loops (critical iteration)**

- **Critical iteration (Lean spirals) based on new acquired knowledge**
- **Effective short cuts for rapid feedback of information and results**



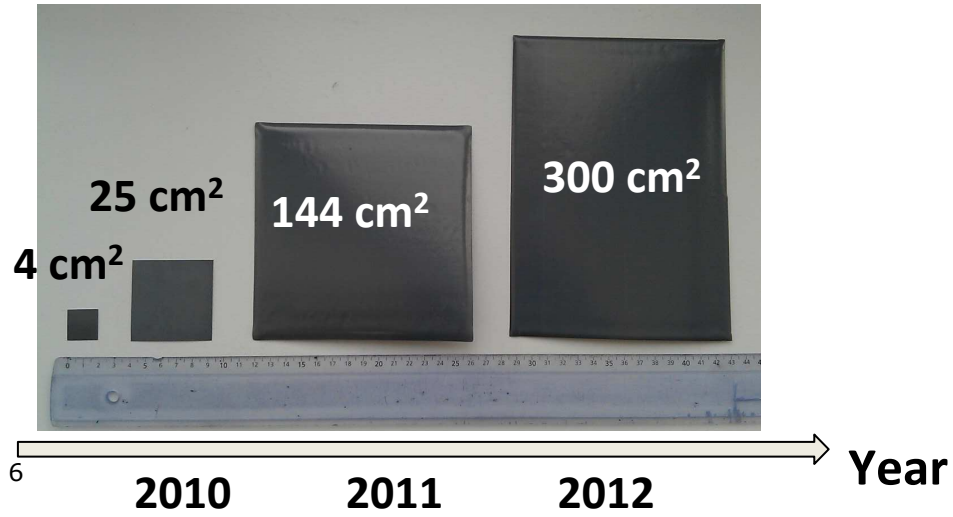
Project achievements - Cell processing

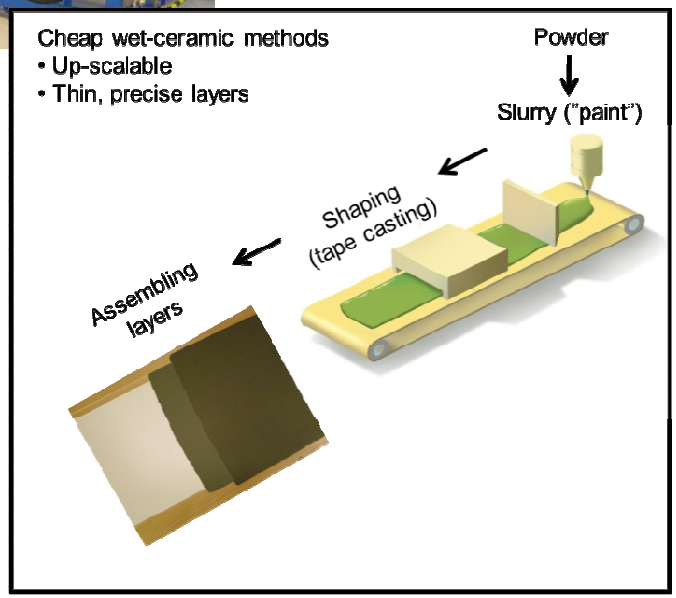
Challenges → Strategies

Co-processing of ceramics and metals

- Multi layer tape casting
- Lamination
- Sintering (atmospheric avoided)
- Screen printing
- Infiltration (nano structuring)

Fabrication routes based on low-cost and upscalable processes





WP2 – Cell development

Tasks

2.1 Metal powder development

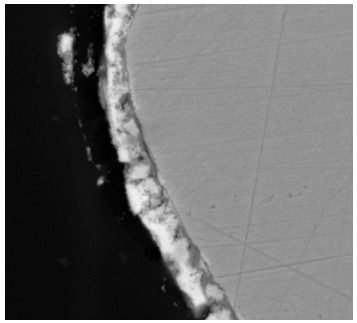
2.2 Development of cermet layer and nano-structured coatings

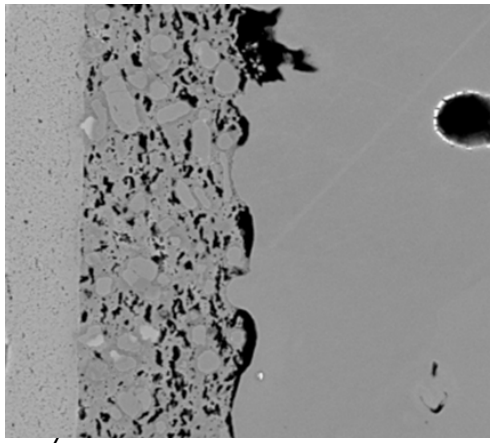
2.3 Development of novel anode designs

2.4 Integration of high performance cathodes

2.5 Integration of components to cells

2.6 Component and cell manufacturing





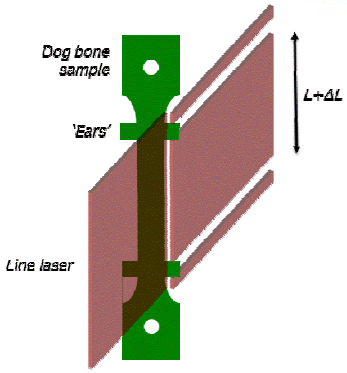
Novel anodes with:

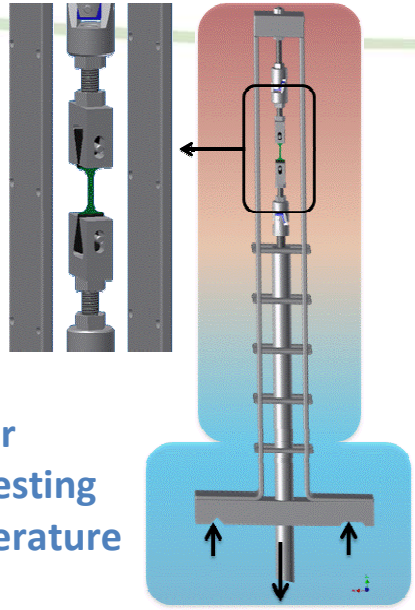
- **High electronic conductivity**
- **Enhanced electro-catalytic activity**
- ***In-situ* growth of catalytically active nano-particles**
- **Improved corrosion protection of metal components**

WP3 – Testing

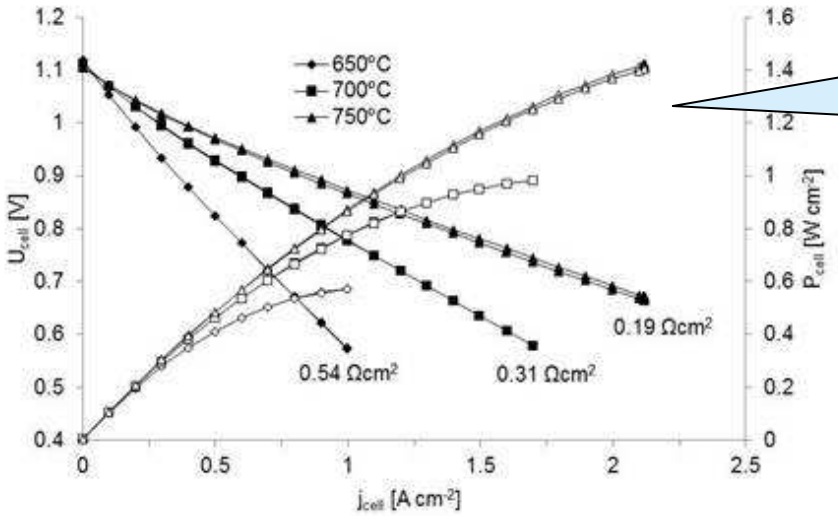
Tasks

3.1 Corrosion testing
3.2 Mechanical testing
3.3 Electrochemical testing of MSCs
3.4 Analysis of the catalytic properties of MSCs
3.5 Long term stability and corrosion of MSCs
3.6 Accelerated testing on cell level
3.7 Accelerated testing on stack level
3.8 Performance monitoring of MSC-stacks
3.9 Vibration tests of MSC-stacks

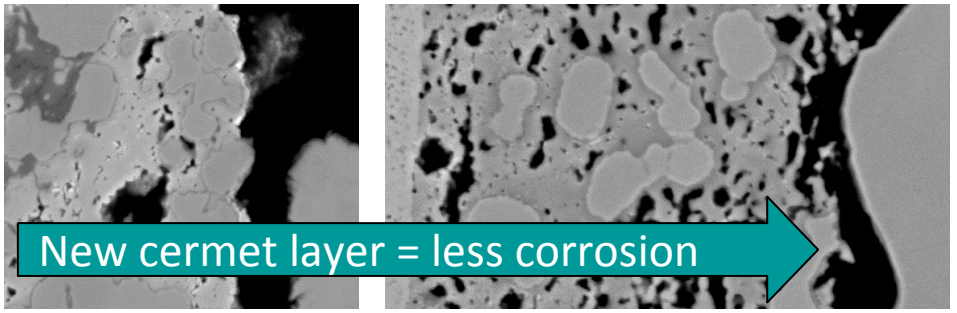




New setup for mechanical testing at high temperature constructed

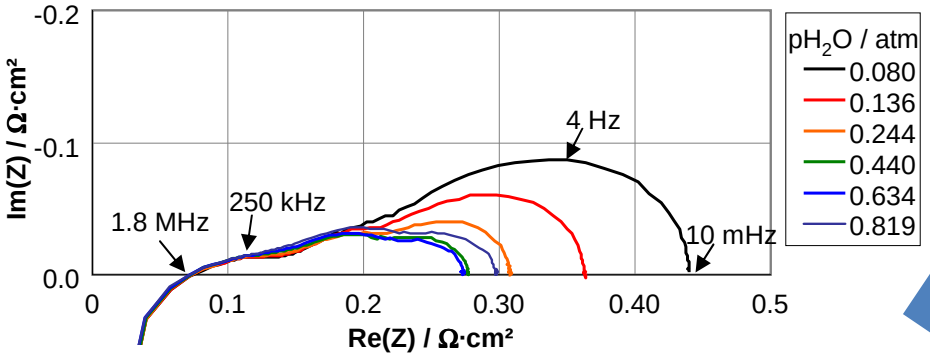


Novel anode



Fundamental electrochemical testing

Impedance spectra

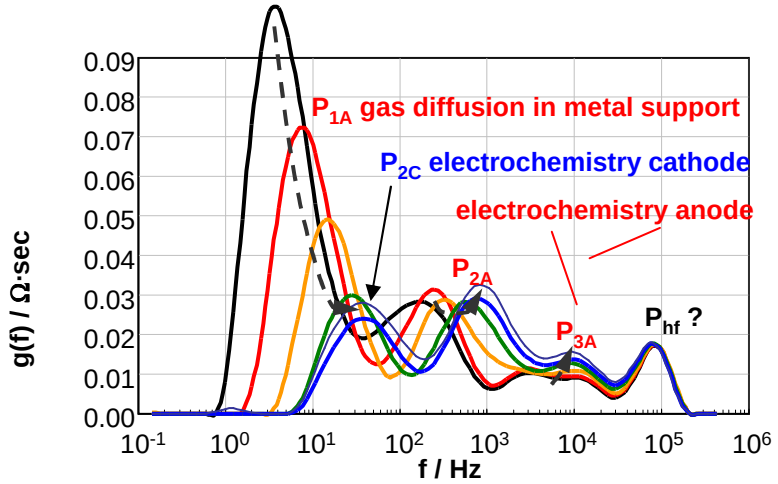


METSAPP G1 cell

1 cm² electrode area, H_2 + H_2O, air, 700°C, OCV

Identification of critical issues

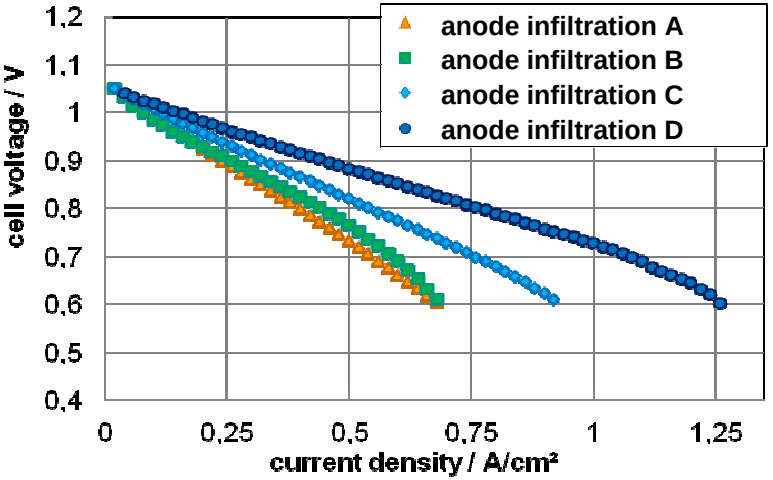
Distribution of Relaxation Times



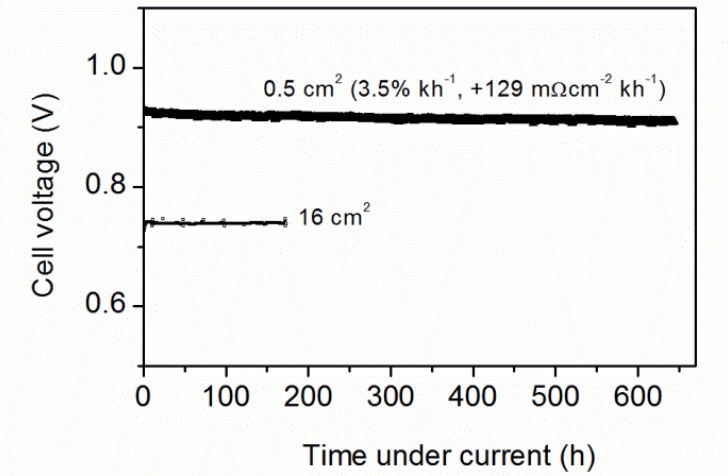
⇒ **cell performance data and model parameters for task 4.2/4.3**

Cell performance and durability

Materials screening

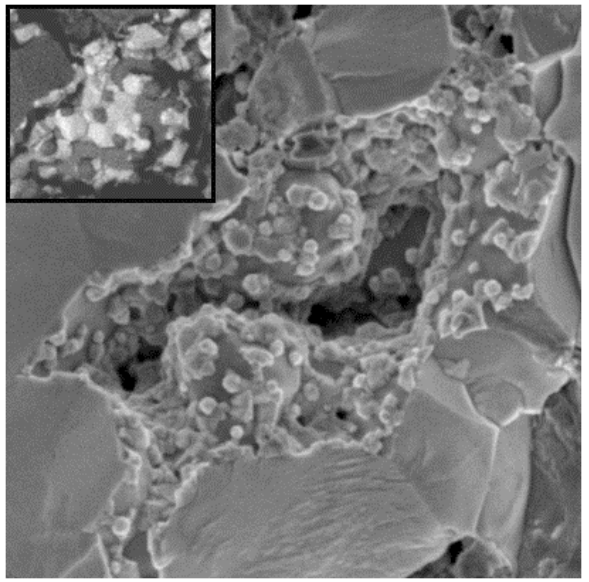


Durability



STN/FeCr anode

Ni/CeO_2 nano infiltrated



(DTU)

WP4 - Modelling, reliability and durability

WP4 – Tasks

4.1 Identification of material parameters

4.2 Electrochemical Modeling of MSCs

4.3 FEM-modelling and simulation of repeat units

4.4 FEM-modelling and simulation of internal reforming in MSCs

4.5 Failure mode identification and assessment

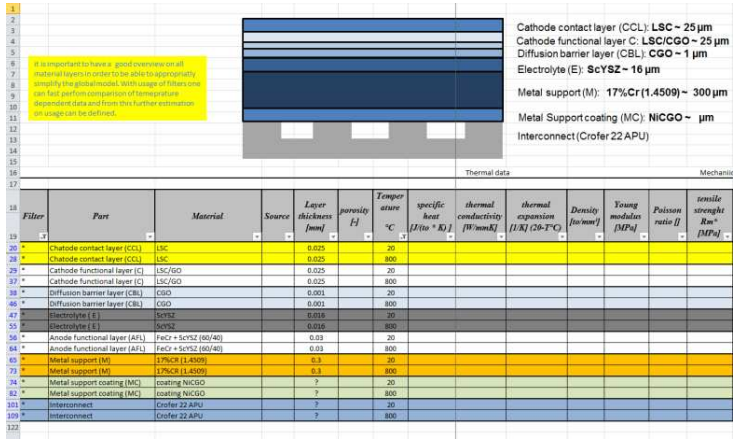
4.6 Failure mode model development

4.7 Development of accelerated test procedures

Failure mode identification and prioritization.

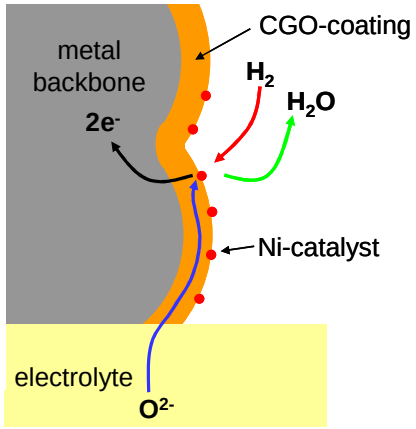
- **A total of 17 “high priority” failure modes have been identified.**
- **These modes are driven by 5 classes of damage drivers.**

Material parameters identified and collected in an database (AVL)

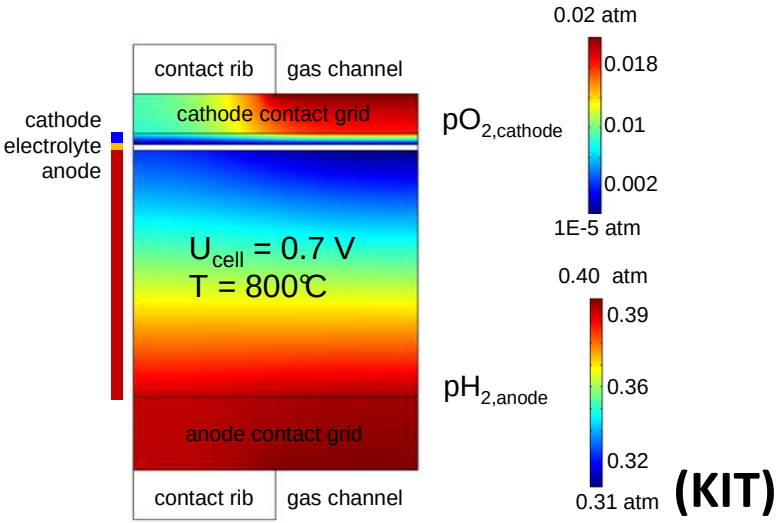


Filter	Part	Material	Source	Layer thickness [mm]	porosity [-]	Temperature °C	specific heat [J/(to * K)]	thermal conductivity [W/mmK]	thermal expansion [1/K] (20-T°C)	Density [to/mm³]	Young modulus [MPa]	Poisson ratio []	tensile strenght Rm* [MPa]
*	Chatode contact layer (CCL)	LSC		0.025		20							
*	Chatode contact layer (CCL)	LSC		0.025		800							
*	Cathode functional layer (C)	LSC/GO		0.025		20							
*	Cathode functional layer (C)	LSC/GO		0.025		800							
*	Diffusion barrier layer (CBL)	CGO		0.001		20							
*	Diffusion barrier layer (CBL)	CGO		0.001		800							
*	Electrolyte (E)	ScYSZ		0.016		20							
*	Electrolyte (E)	ScYSZ		0.016		800							
*	Anode functional layer (AFL)	FeCr + ScYSZ (60/40)		0.03		20							
*	Anode functional layer (AFL)	FeCr + ScYSZ (60/40)		0.03		800							
*	Metal support (M)	17%CR (1.4509)		0.3		20							
*	Metal support (M)	17%CR (1.4509)		0.3		800							
*	Metal support coating (MC)	coating NiCGO		?		20							
*	Metal support coating (MC)	coating NiCGO		?		800							
*	Interconnect	Crofer 22 APU		?		20							
*	Interconnect	Crofer 22 APU		?		800							

From fundamental modelling to stack design optimisation



FEM-modelling of stack repeat units combined with detailed electrochemical model

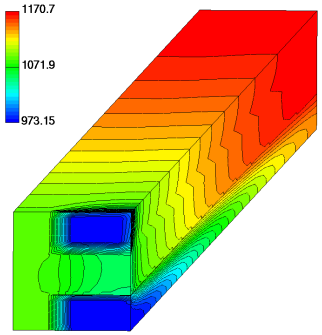


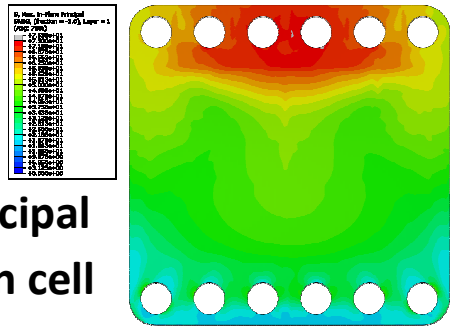
(KIT)

First simulation results show the performance decrease due to gas diffusion limitation under wider stack contact ribs.

Critical failure modes

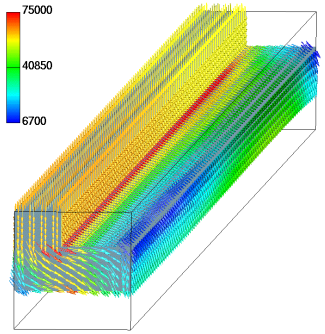
FEM-modelling and simulation of internal reforming in metal supported cells (AVL)





Distribution of principal mechanical stress in cell

3D results with H2: current density (A/m2), surface temperature (K)

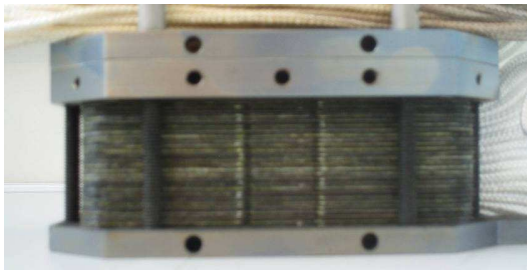


Failure mode model development

- **Determination of diffusion in anode (micro-structure) almost finished.**
- **Started with investigation of corrosion and influence on diffusion.**
- **Next step: Understanding Creep of metal-support**

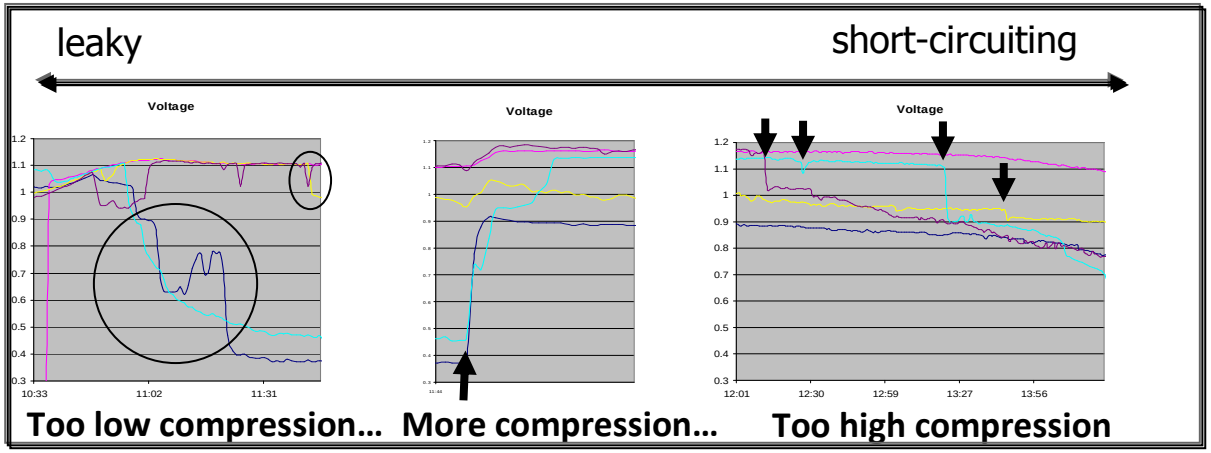
WP5 - Stack development

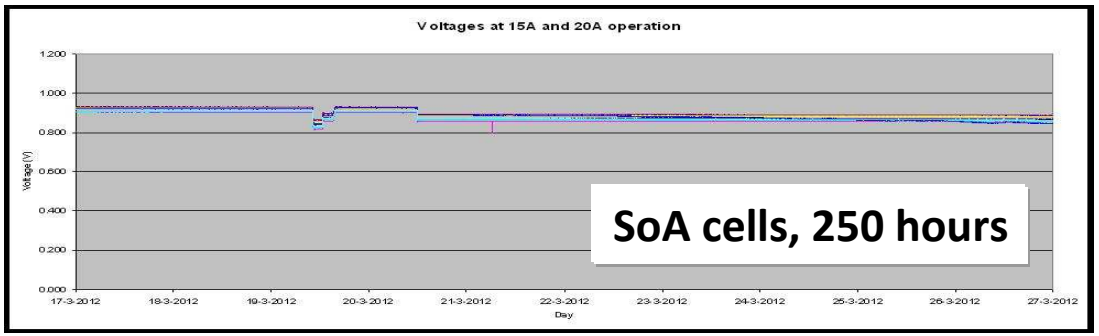
Cells



Stack

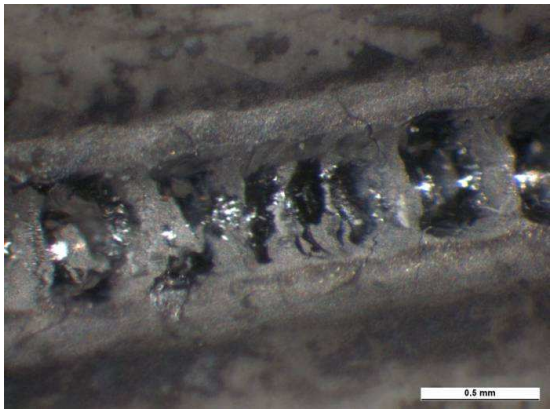
Stack conditioning procedure



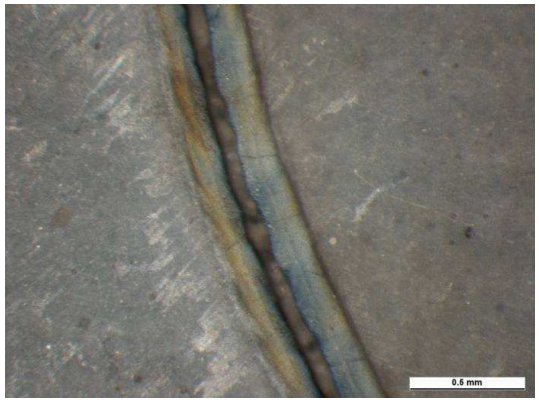


Correct procedure leads to stable operation and high performance

Laser welding of cells and stack components

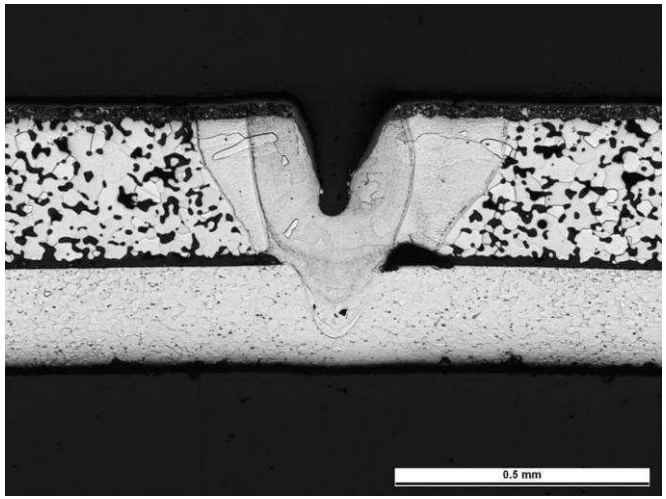


Previous laser welding



Recent result with fiber laser

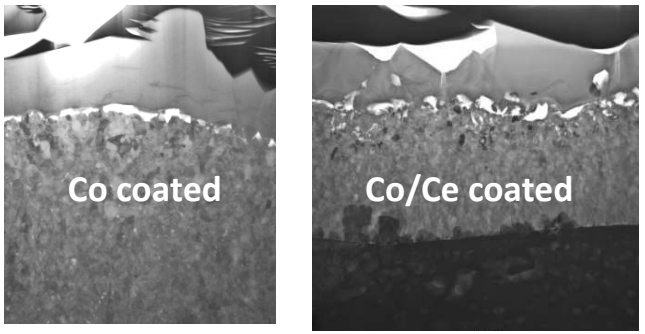
Weld in cross-section

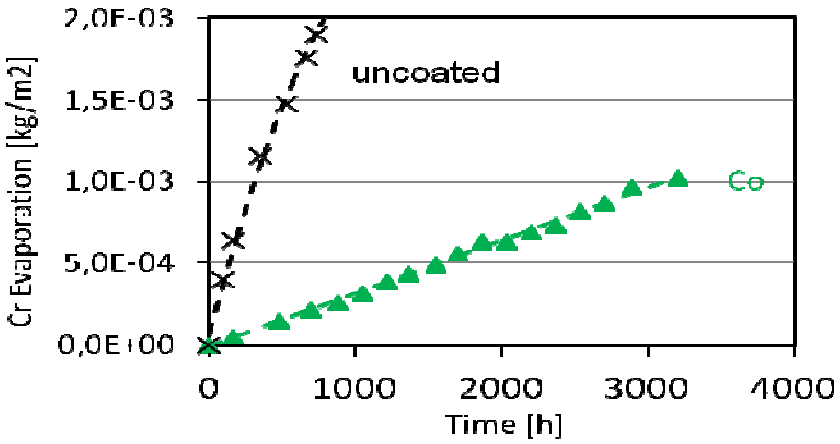


Target: Robust seal optimized for manufacturing

WP6 - Alloys and coatings

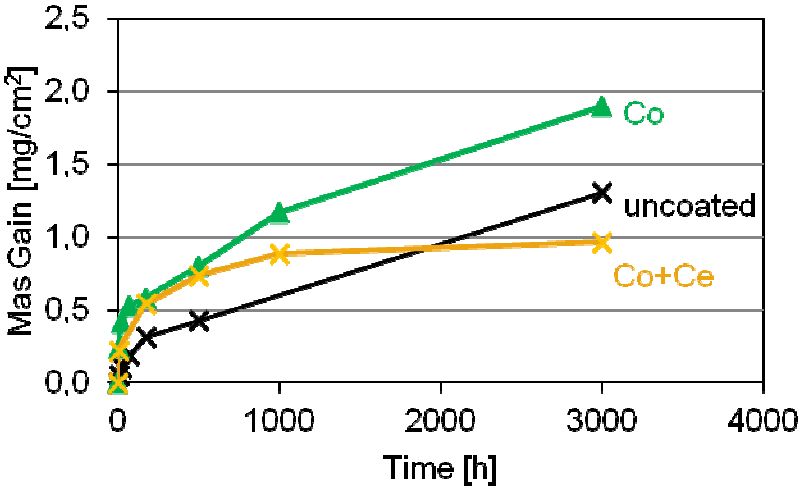
- **Metal interconnects need to be coated**
- **640nm Co are sufficient to block Cr evaporation**
- **10nm Ce coating reduces corrosion substantially**





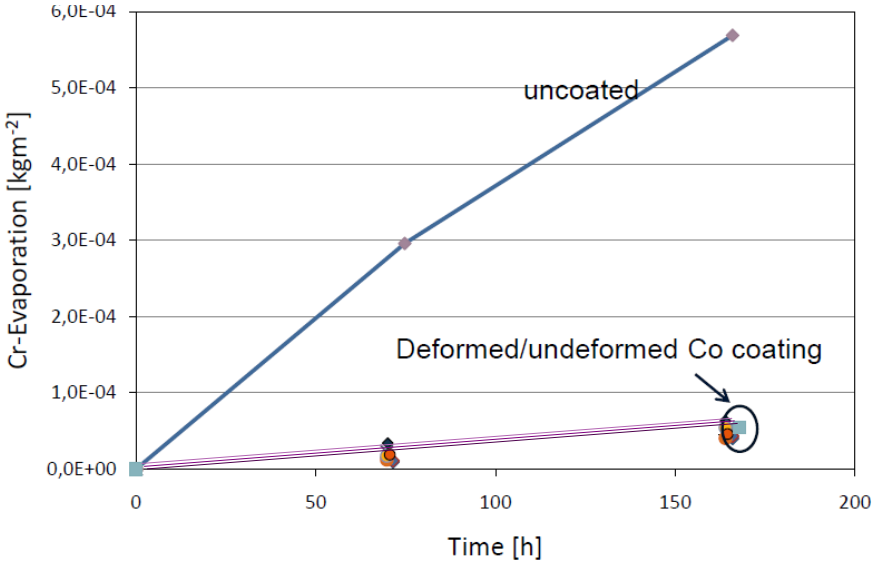
- **Less corrosion → longer lifetime**
- **Thinner scale → lower ASR values**

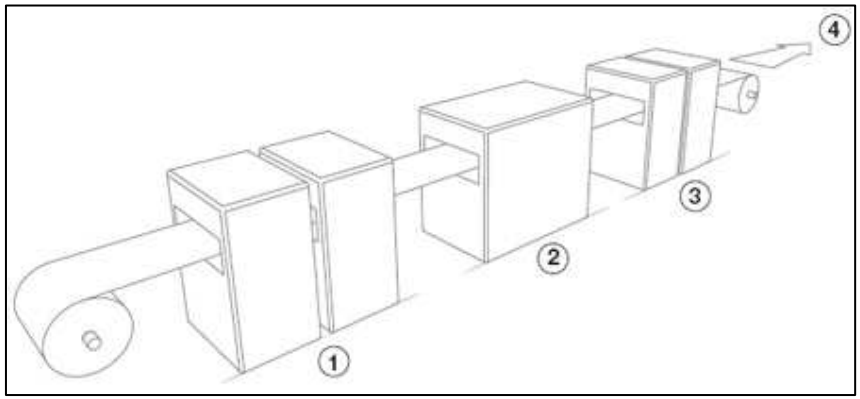
Accelerated test at 850°C in air + 3% H_2O



Upscaled PVD coating of strip steels

Large scale continuous thin film (PVD) coating production established at Sandvik (roll to roll process)





Dissimination & public awareness

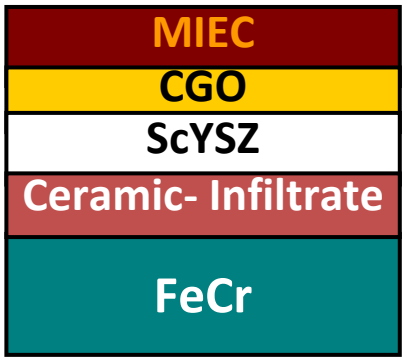
10th European SOFC Forum 2012

Schoenbein Contribution to Science Medal 2012

”For an outstanding contribution to:
Advances in Metal Supported Cells
- In the METSOFC EU Consortium”

Cooperation and future perspectives

METSAPP



2012-2014

Cooperation with other projects

- EuroFC-Life
- SCOTAS
- METPROCELL
- DESTA

EU DESTA
SOFC APU demo project

TOPSOE FUEL CELL

VOLVO

AVL SCHRICK

Eberspächer

JÜLICH FORSCHUNGSZENTRUM

AVL SOFC APU Generation I
STAND ALONE SOLID OXIDE FUEL CELL AUXILIARY POWER UNIT