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

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)

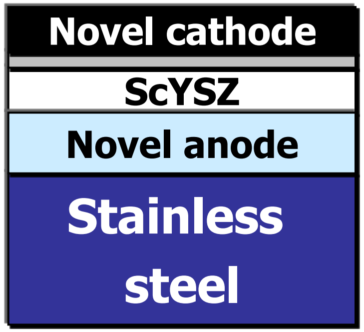
EC Joint Research Centre (NL)

Vertical integrated

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.

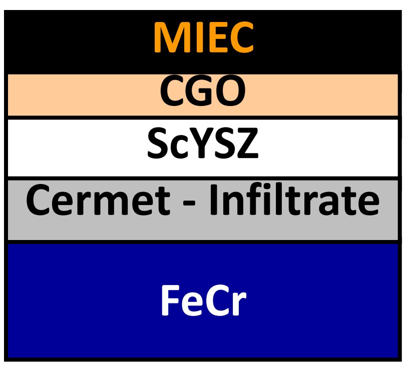


Next Gen SOFC development

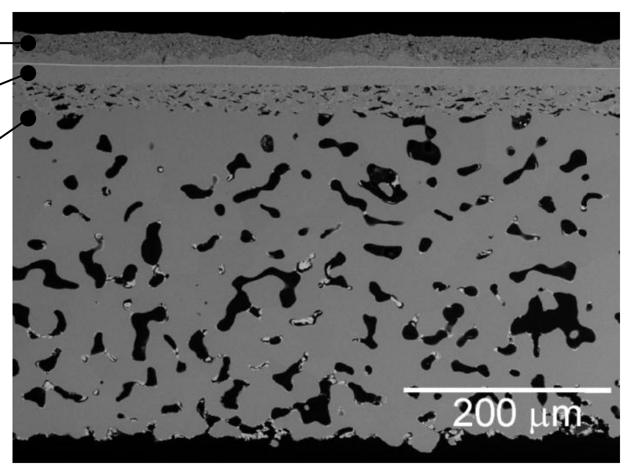
Start platform

Novel "beyond state of art" concept

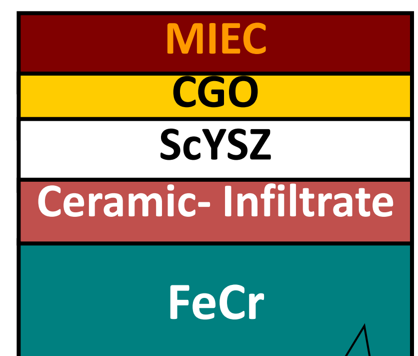
EU METSOFC Cell
2008 -2011
5000 h lifetime
Mobile applications



ASR: 0.27 Ωcm^2 at 650 ºC



EU METSAPP Cell
2012 – 2014
40.000 h lifetime
Stationary applications

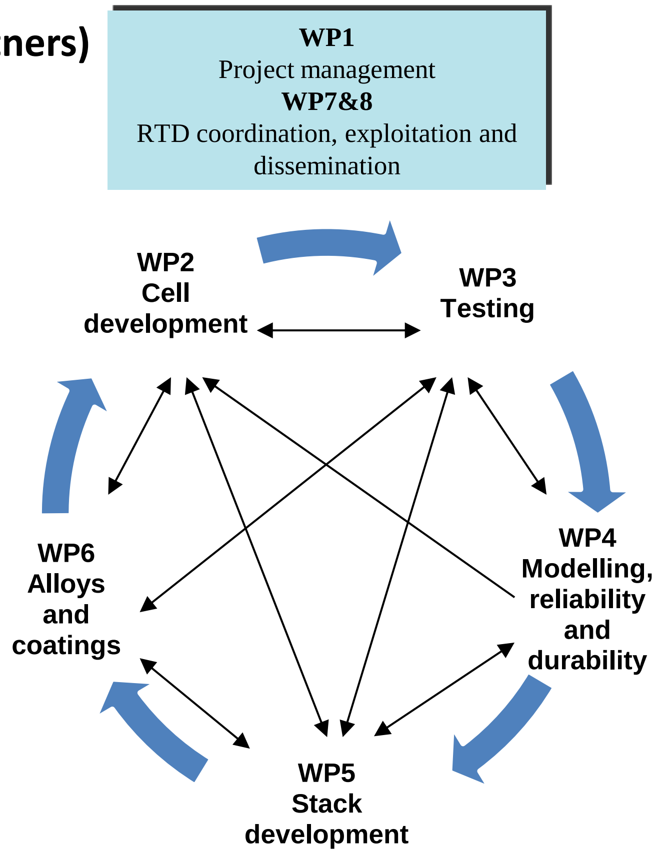


Corrosion passivation infiltrated

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

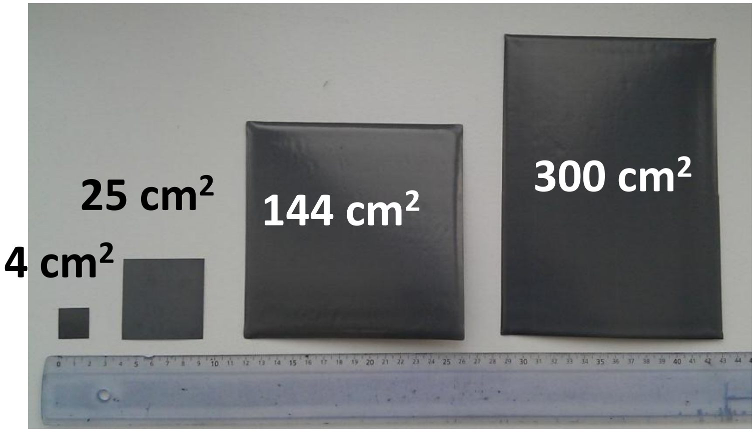
Project achievements - Cell processing

Challenges → Strategies

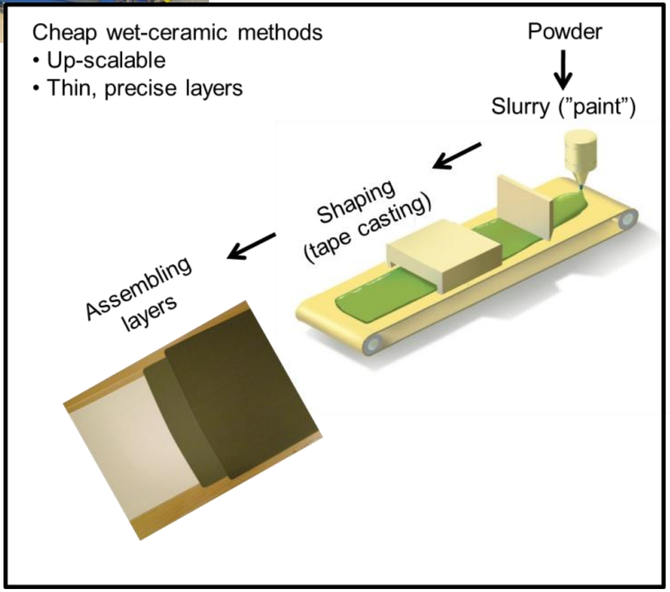
Co-processing of ceramics and metals

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

Fabrication routes based on low-cost and upscalable processes



2010 2011 2012 Year



Material and Processing R&D

Tasks

2.1 Metal powder development

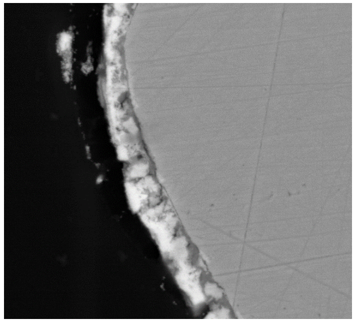
2.2 Development of cermet layer and nano-structured coatings

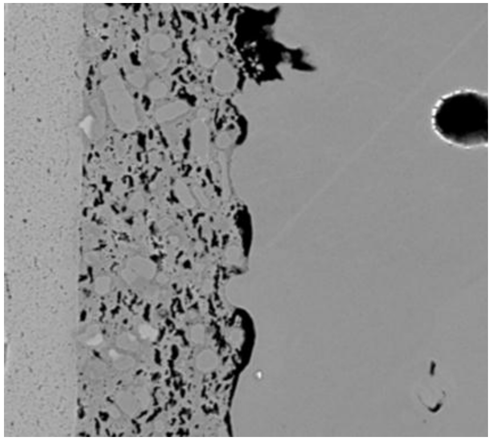
2.3 Development of novel anode designs

2.4 Integration of high performance cathodes

2.5 Integration of components to cells

2.6 Component and cell manufacturing





Novel anodes

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

Tasks

3.1 Corrosion testing

3.2 Mechanical testing

3.3 Electrochemical testing of MSCs

3.4 Analysis of the catalytic properties of MSCs

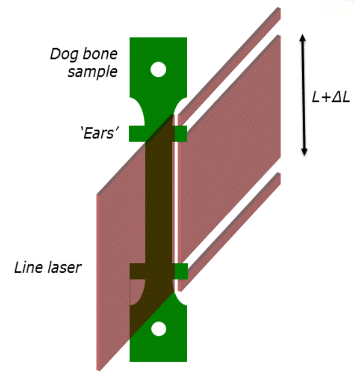
3.5 Long term stability and corrosion of MSCs

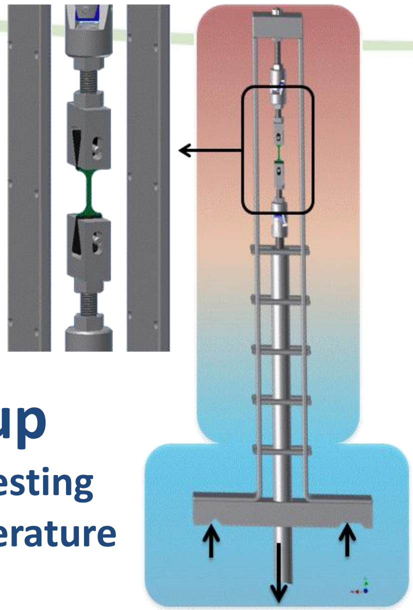
3.6 Accelerated testing on cell level

3.7 Accelerated testing on stack level

3.8 Performance monitoring of MSC-stacks

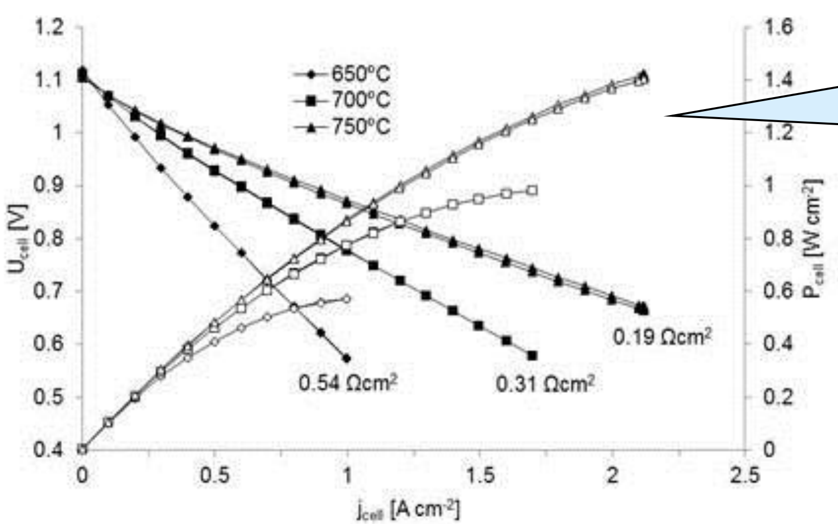
3.9 Vibration tests of MSC-stacks



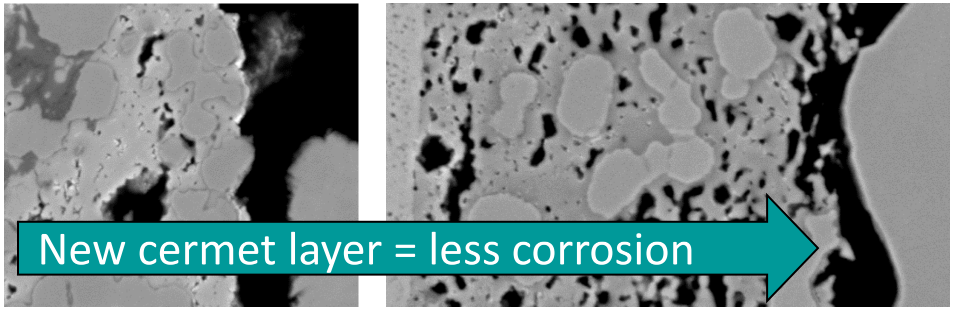


New setup

mechanical testing at high temperature constructed

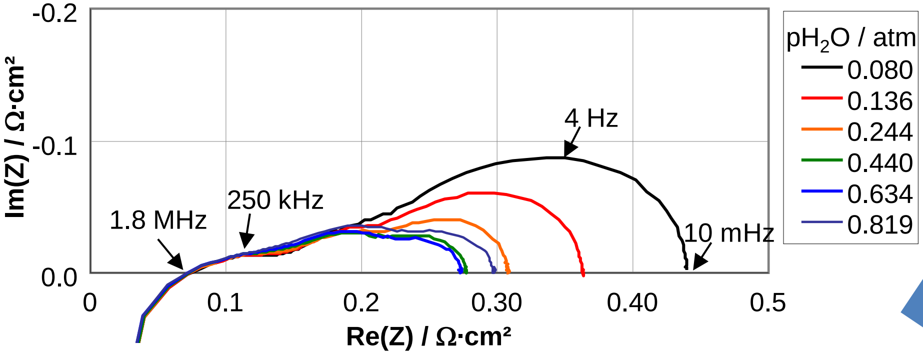


Novel anode



Fundamental electrochemical testing

Impedance spectra



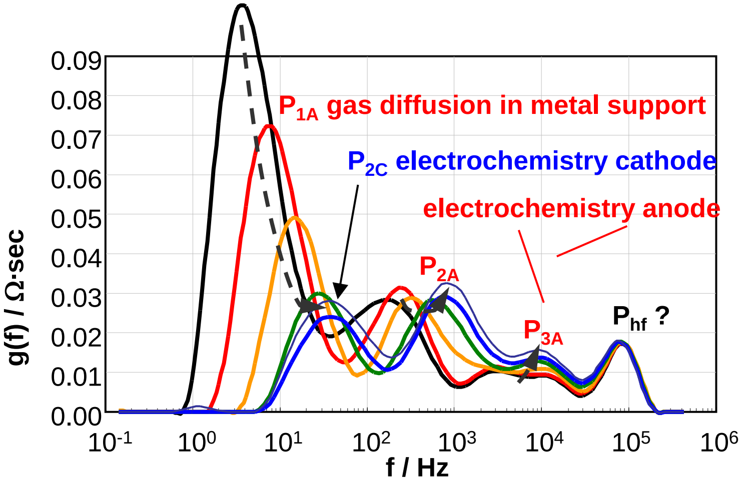
METSAPP G1 cell

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

Identification of critical issues

Improvement of basic knowledge

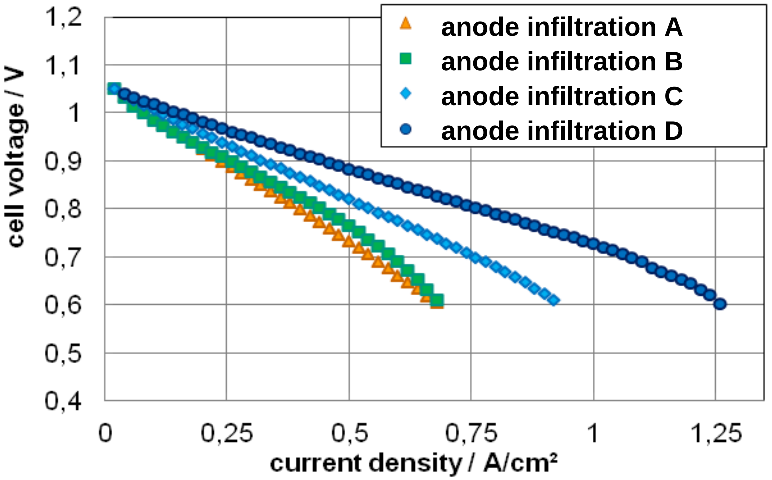
Distribution of Relaxation Times



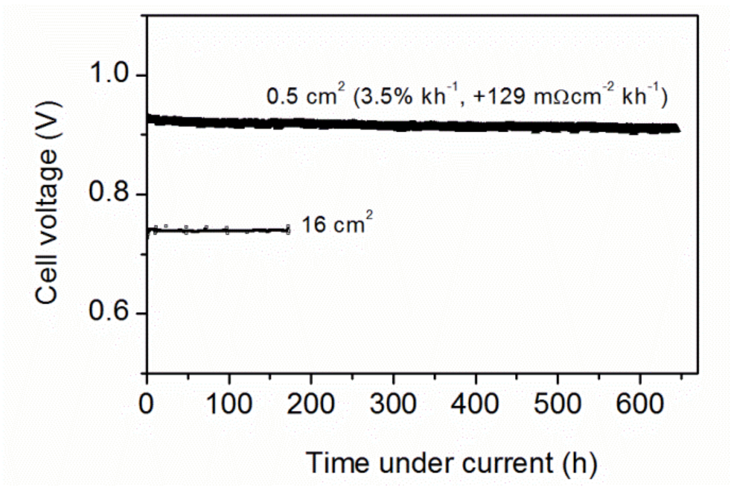
⇒ **cell performance data and model parameters for task 4.2/4.3**

Cell performance and durability

Materials screening

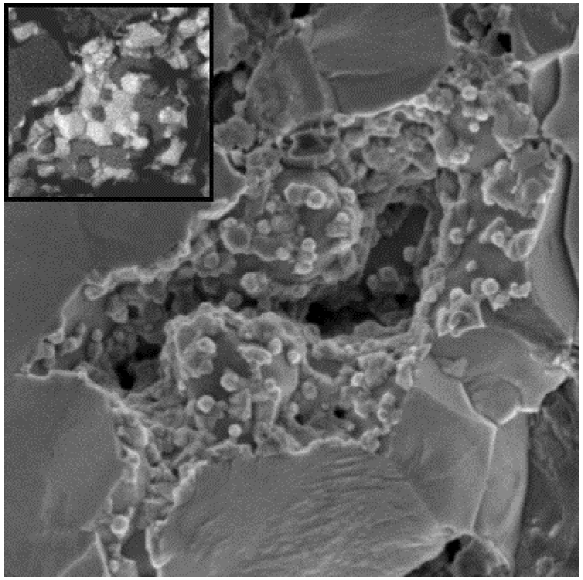


Durability



STN/FeCr anode

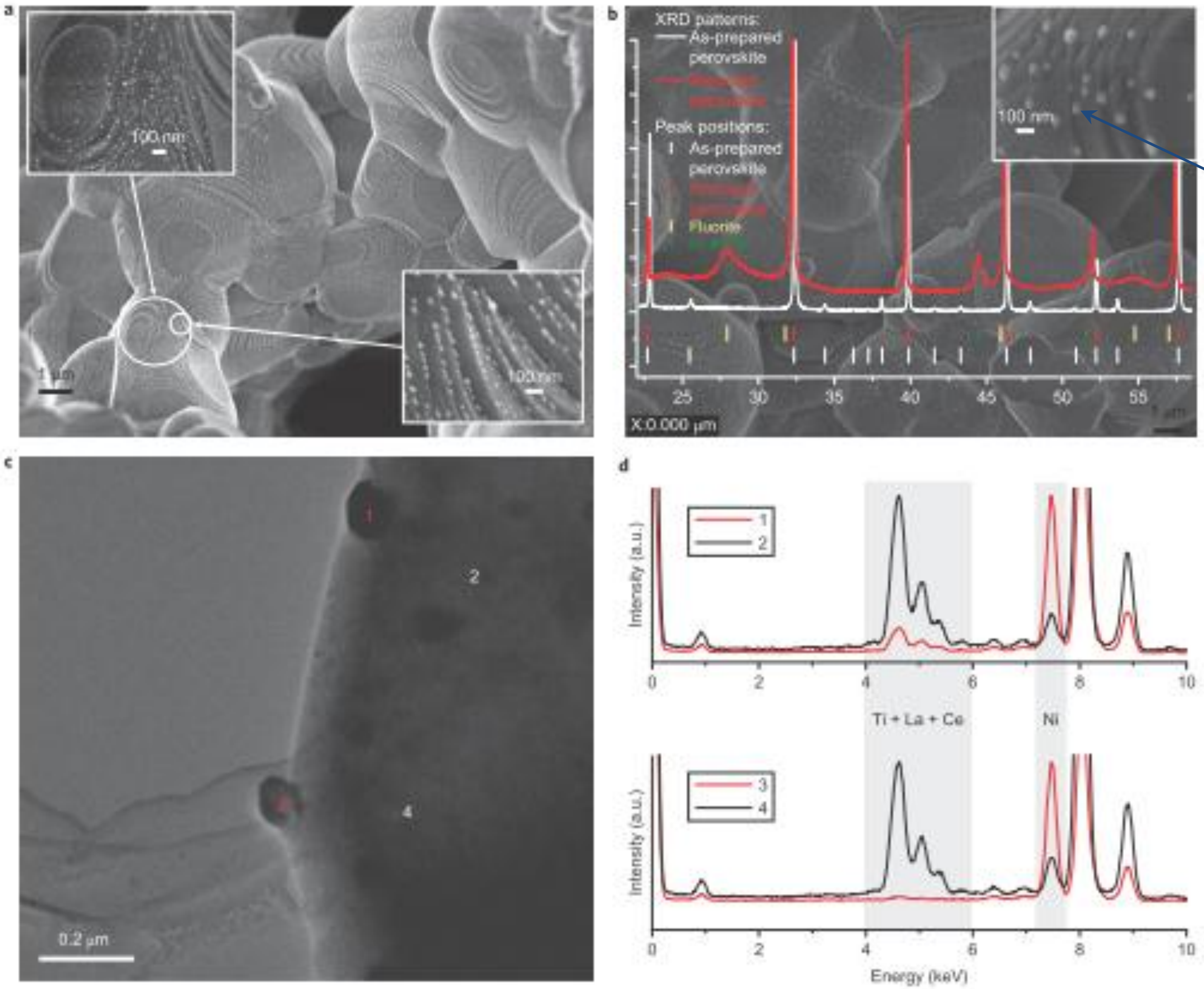
Ni/CeO_2 nano infiltrated



(DTU)

Break through in new anode materials

In situ growth of metal nanoparticles



Exolution of both
Ni and CeO_2 nanoparticles
from
$La_{0.8}Ce_{0.1}Ni_{0.4}Ti_{0.6}O_3$

D. Neagu et al., In situ growth of nanoparticles through control of non-stoichiometry, Nature Chemistry, October, 2013

WP4 – Tasks

4.1 Identification of material parameters

4.2 Electrochemical Modeling of MSCs

4.3 FEM-modelling and simulation of repeat units

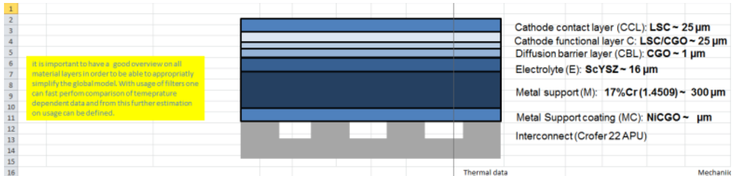
4.4 FEM-modelling and simulation of internal reforming in MSCs

4.5 Failure mode identification and assessment

4.6 Failure mode model development

4.7 Development of accelerated test procedures

Material parameters identified and collected in an database (AVL)

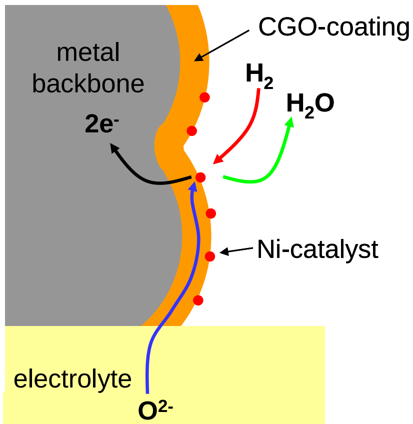


	Filter	Part	Material	Source	Layer thickness [mm]	porosity [-]	Temperature °C	specific heat [J/(to * K)]	thermal conductivity [W/mmK]	thermal expansion [1/K] (20-T°C)	Density [to/mm³]	Young modulus [MPa]	Poisson ratio []	tensile strenght Rm* [MPa]
20	*	Chatode contact layer (CCL)	LSC		0.025		20						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

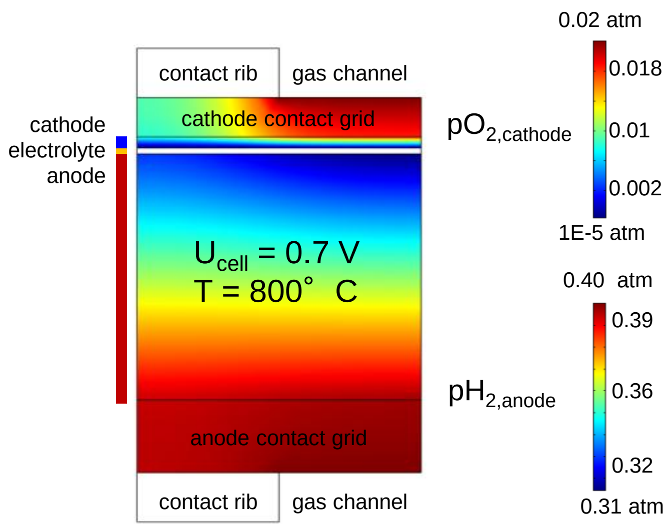
Failure mode identification and prioritization.

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

From fundamental modelling to stack design optimisation



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



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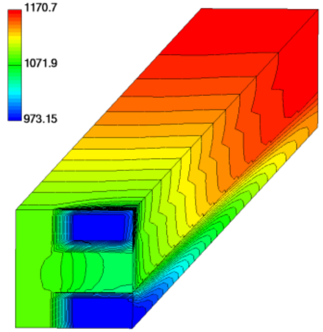
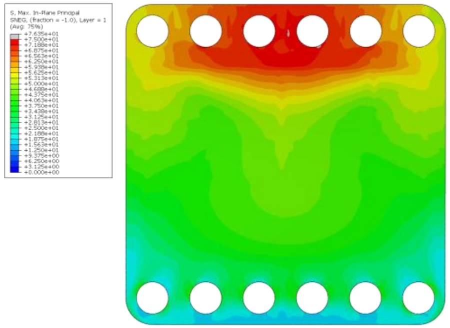
Critical failure modes

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



Distribution of principal mechanical stress in cell

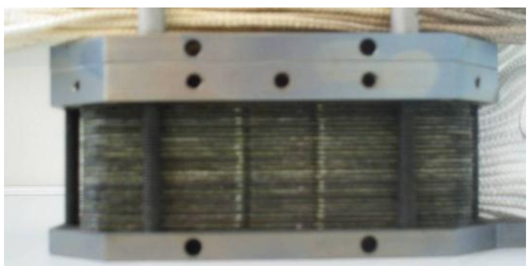


Failure mode model development

- Determination of diffusion in anode (micro-structure).
- Investigation of corrosion and influence on diffusion (in progress)
- Next step: Understanding Creep of metal-support

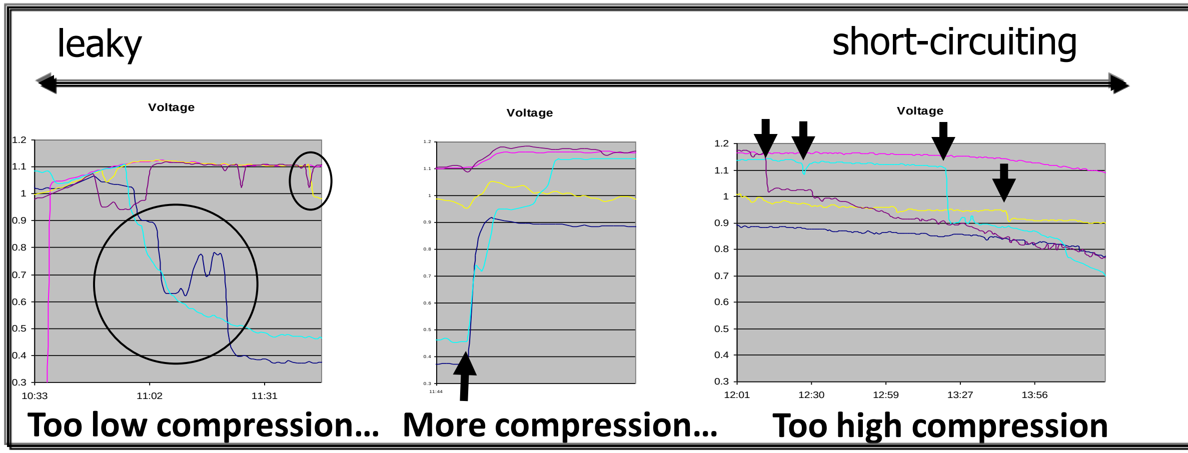
WP5 - Stack development

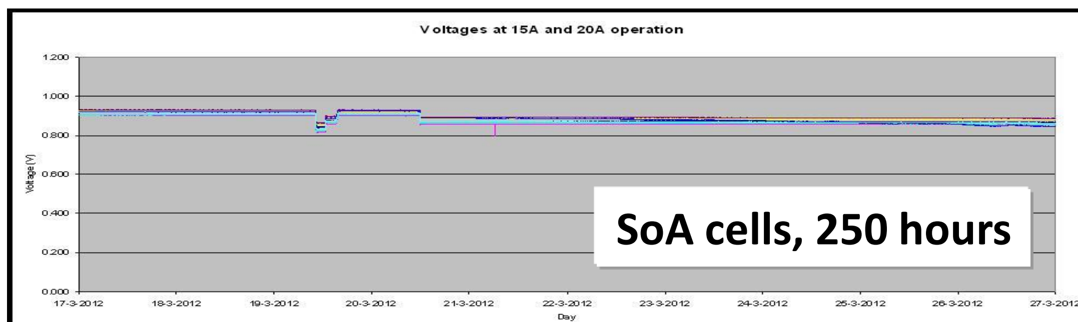
Cells



Stack

Stack conditioning procedure

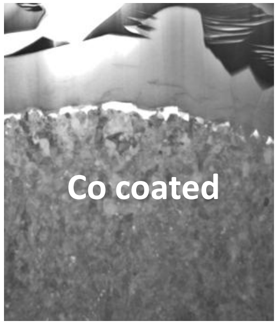


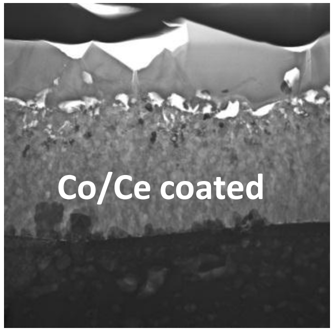


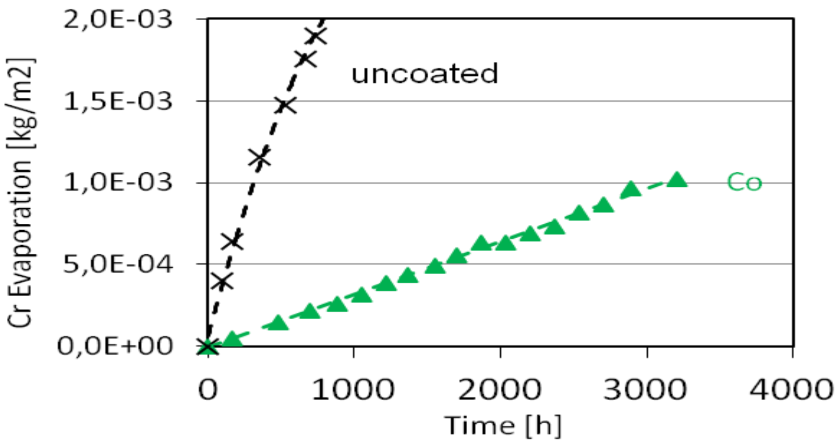
Correct procedure leads to stable operation and high performance

WP6 - Alloys and coatings

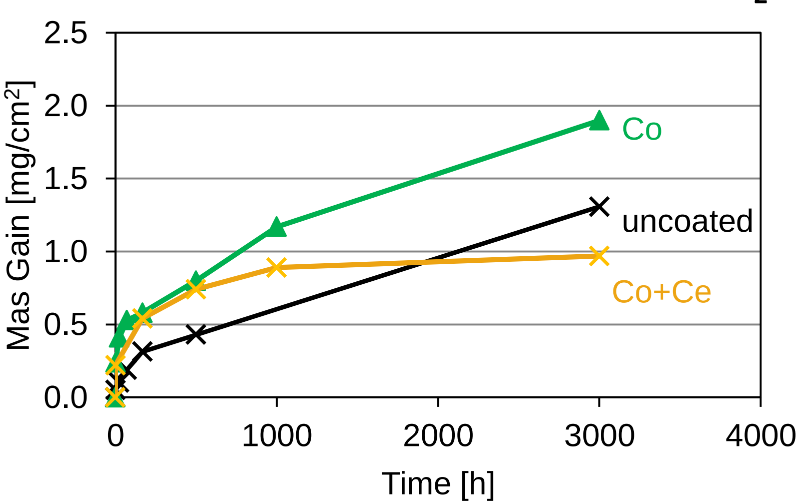
- **Metal interconnects need to be coated**
- **640nm Co are sufficient to block Cr evaporation**
- **10nm Ce coating reduces corrosion substantially**







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

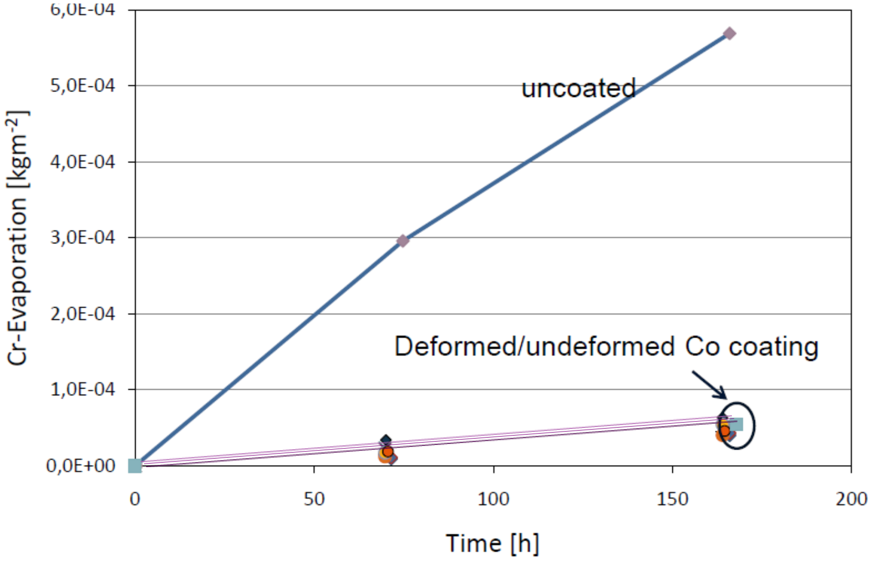


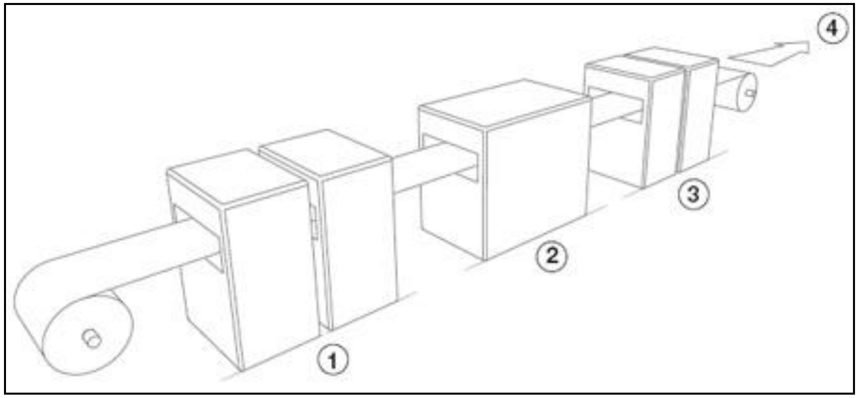
- **Less corrosion → longer lifetime**
- **Thinner scale → lower ASR values**

Upscaled PVD coating of strip steels

Novel cost effective coated interconnect concept

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





New industrial steels and coatings

- Interconnectors for SOFC
  - Specialized Steel – Sandvik SanergyHT
  - Standard Ferritic Steel – AISI441, 430
  - Continuous PVD Coatings
- Bipolar plates for PEMFC
  - Standard Steel – 316L, 304L
  - Continuous PVD Coatings

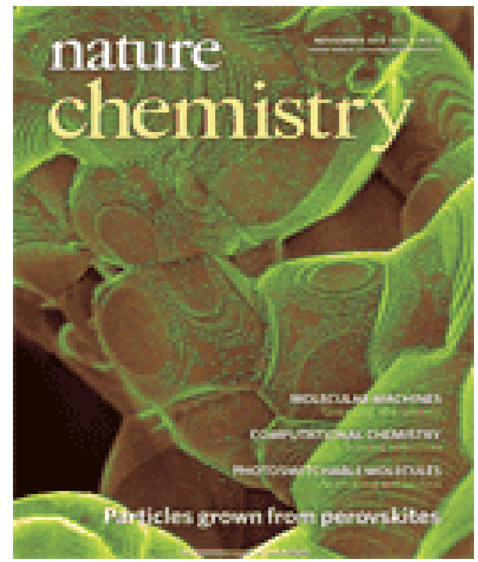
SANDVIK

Dissimination & public awareness

10th European SOFC Forum 2012

Schoenbein Contribution to Science Medal 2012

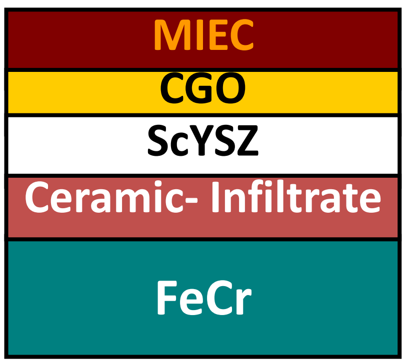
"For an outstanding contribution to:
Advances in Metal Supported Cells"



D. Neagu et al.,
In situ growth of nanoparticles through control of non-stoichiometry,
Nature Chemistry, October, 2013

Cooperation and future perspectives

METSAPP



2012-2014

Cooperation with other projects

- EuroFC-Life
- ProSOFC
- SCOTAS
- METPROCELL
- DESTA

Demonstration network established