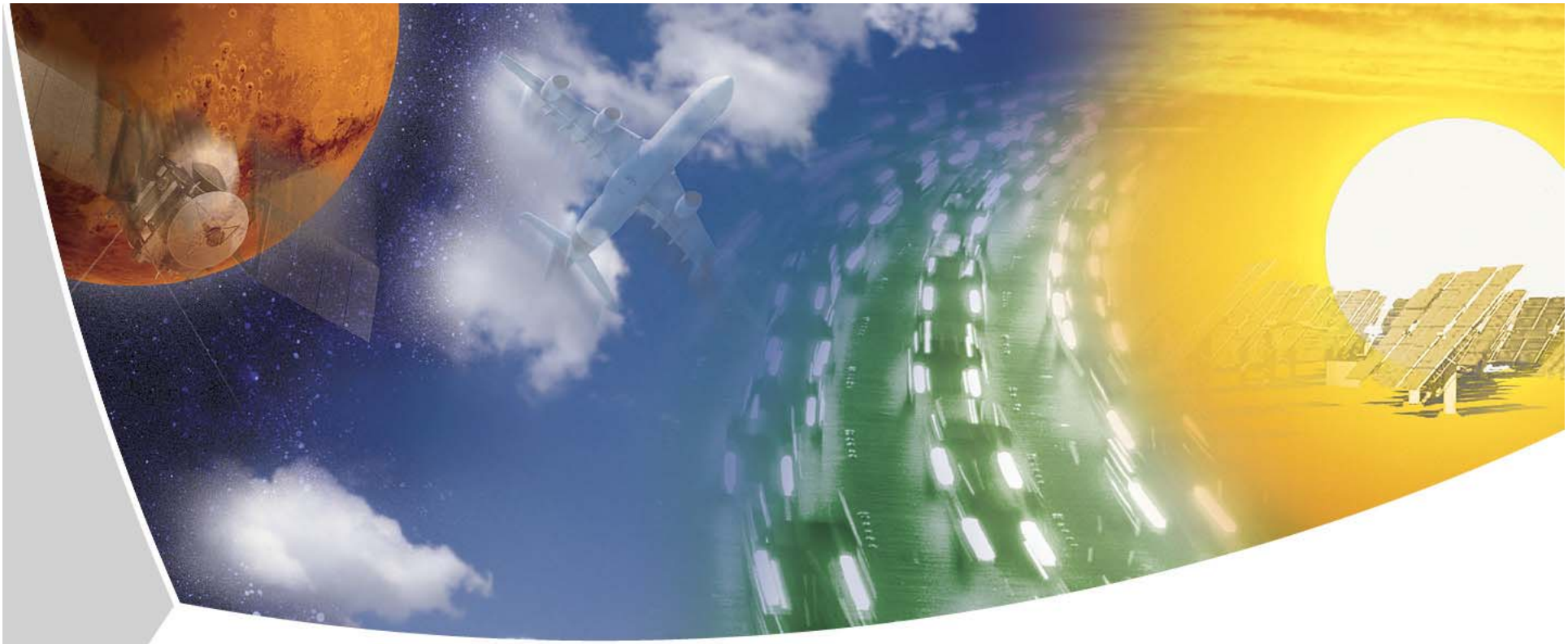

High Temperature Water Electrolysis Using Metal Supported Solid Oxide Electrolyser Cells

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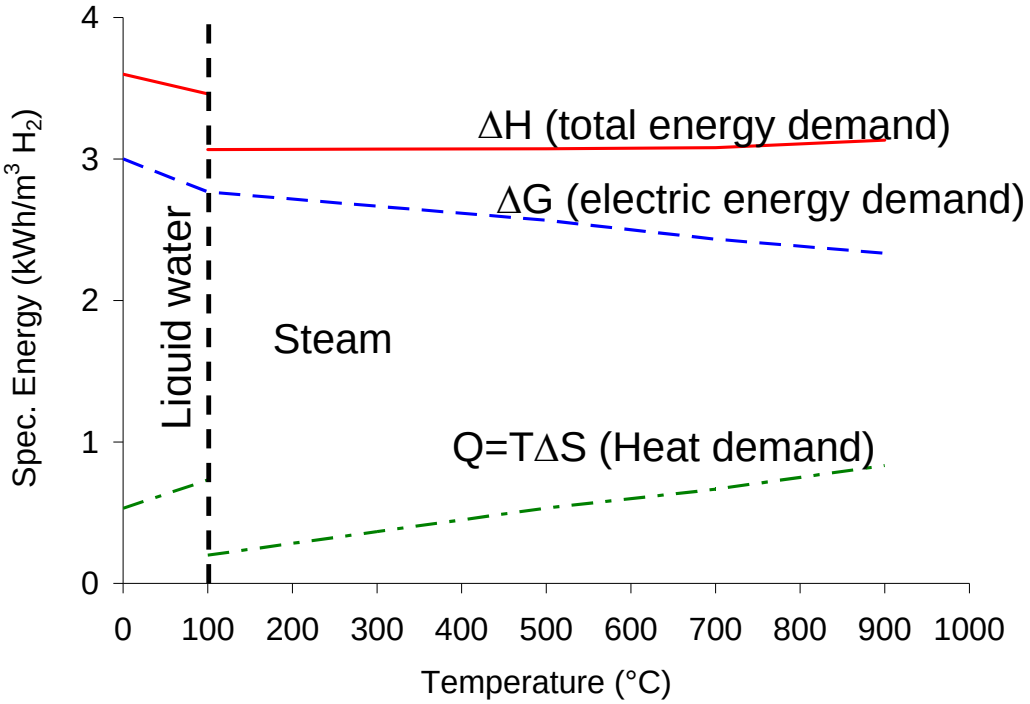
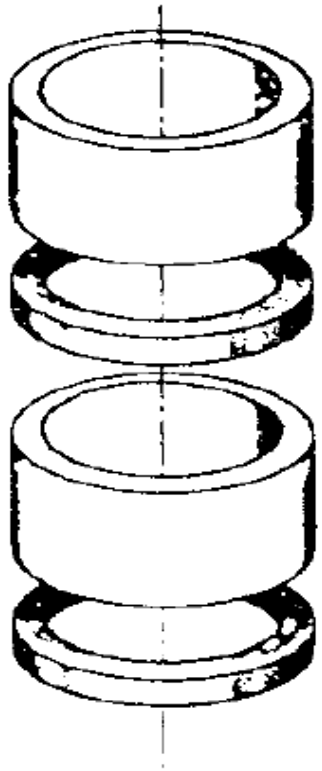
Outline

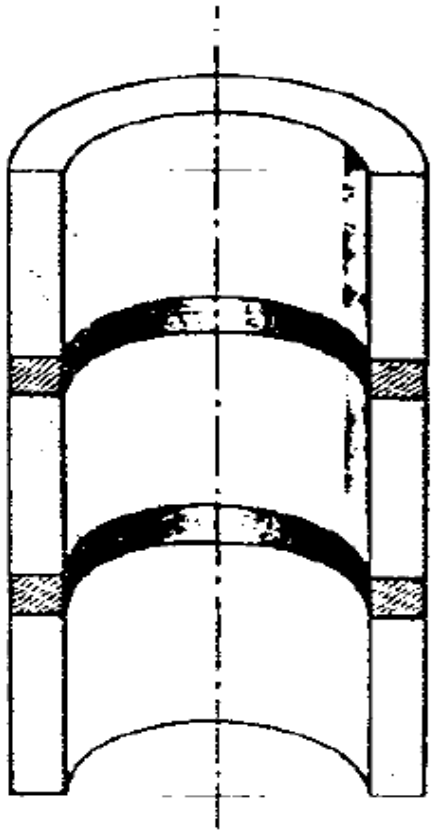
- Introduction
- Metal supported cells (MSC) according to DLR spray concept
- Results of electrochemical characterisation of MSC cells and single repeating units (SRU)
- Degradation behaviour during electrolysis operation
- Conclusion

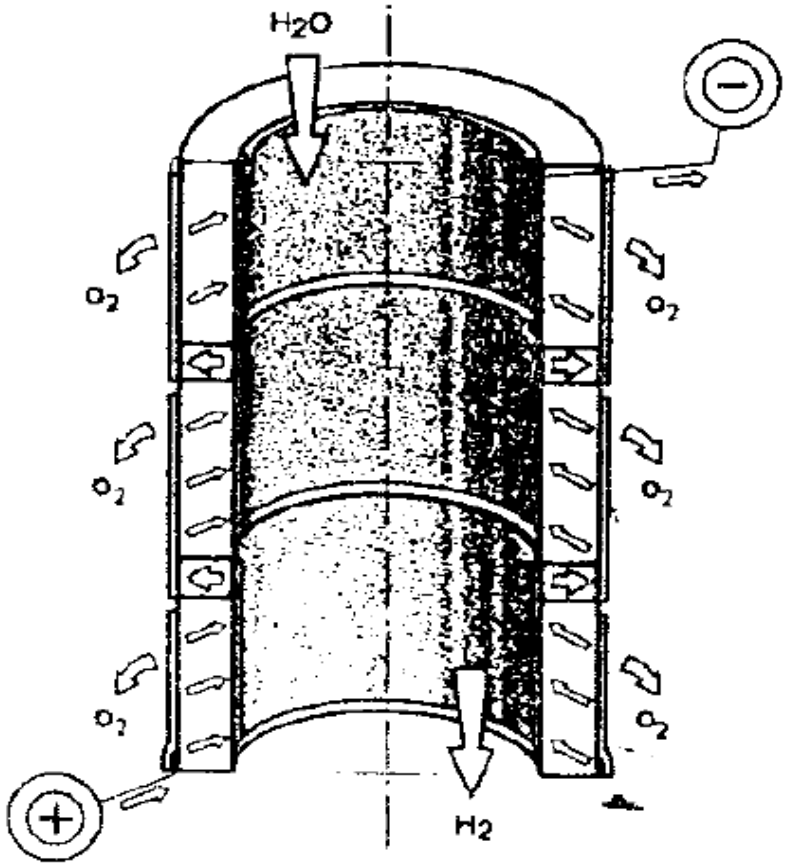
Thermodynamics of Electrolysis Reaction



Hot Elly de DORNIER







Metal-Supported SOFC

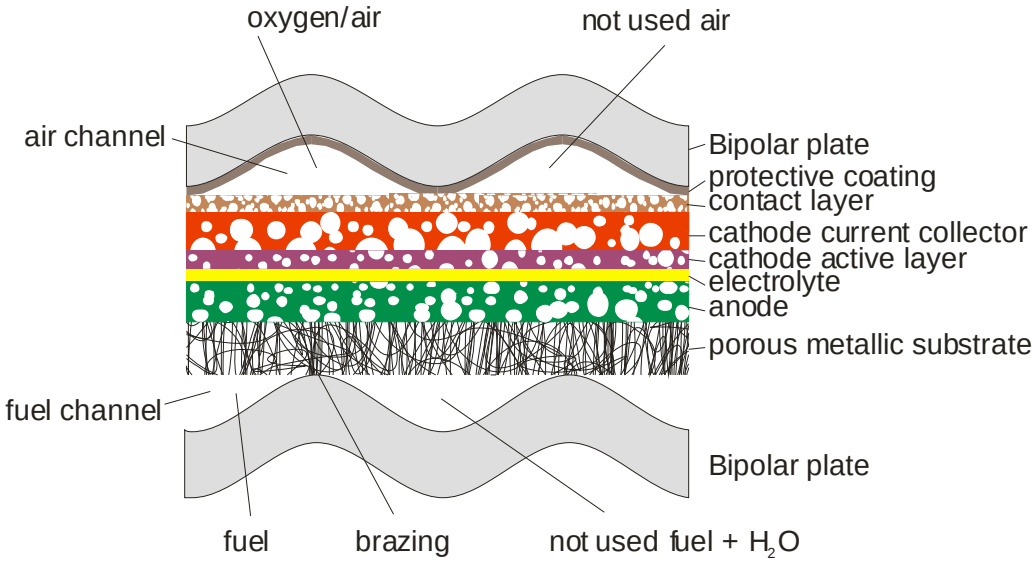
Plasma Deposition Technology

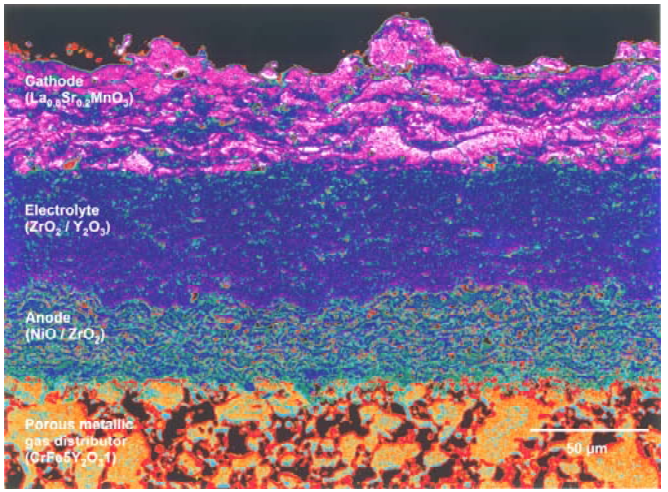
Thin-Film Cells

Ferritic Substrates and Interconnects

Compact Design with Thin Metal Sheet Substrates

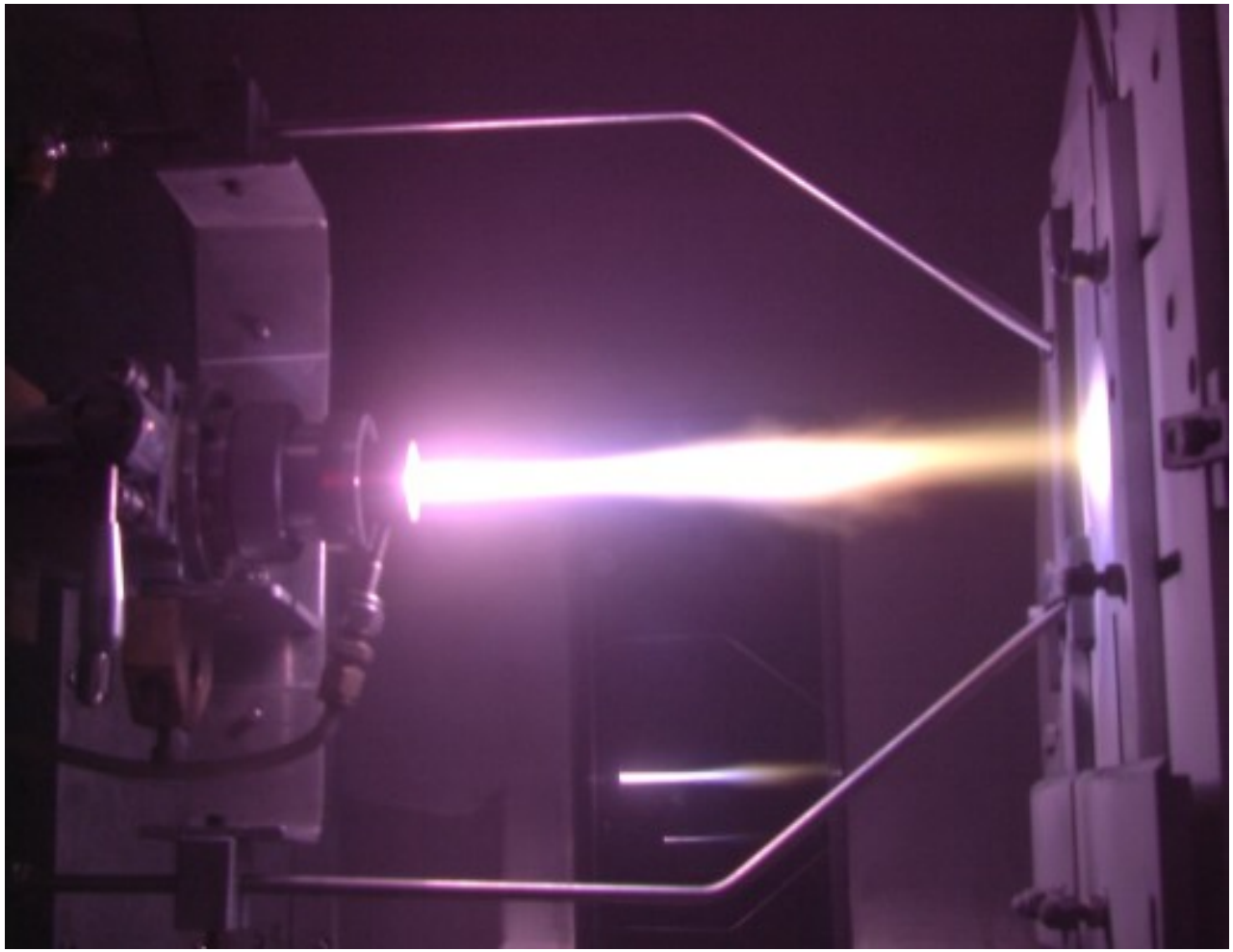
Brazing, Welding and Glass Seal as Joining and Sealing Technology





(not in scale)

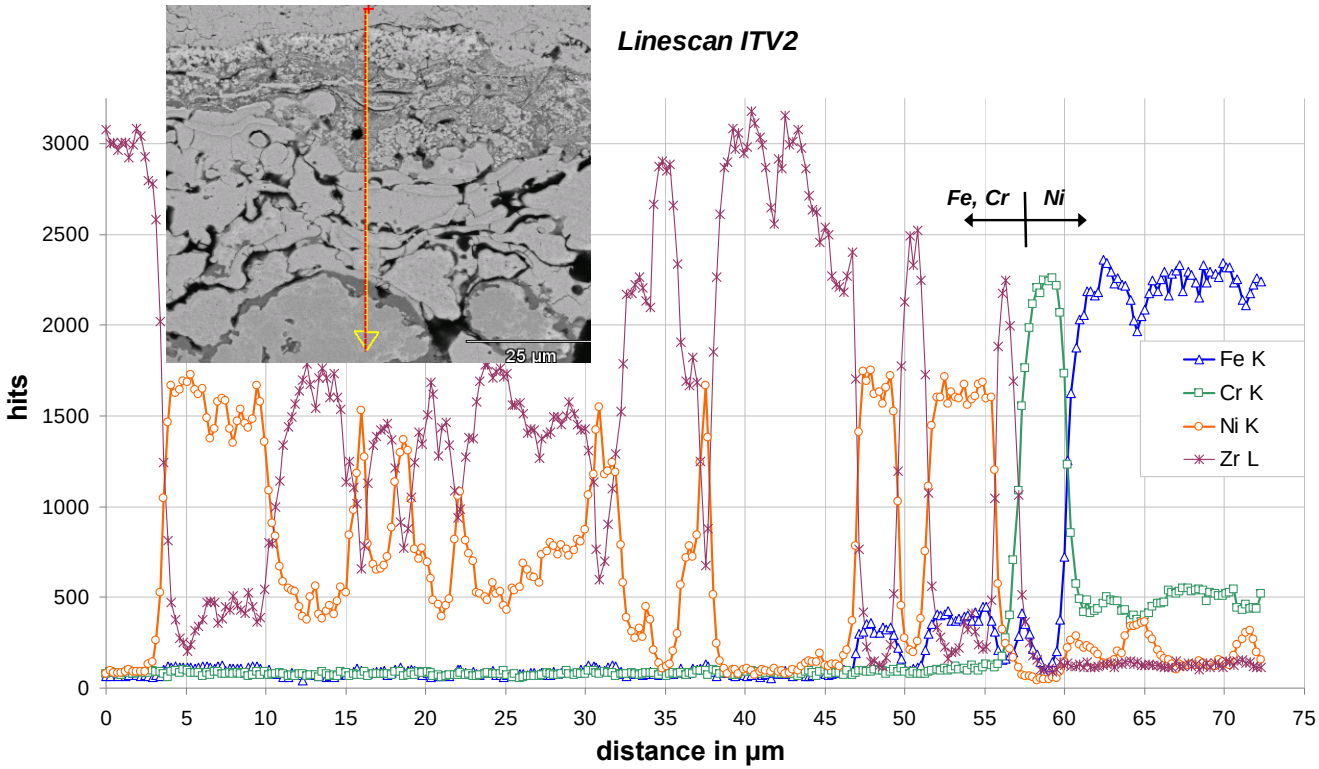
Vacuum Plasma Spraying of SOFC Cells



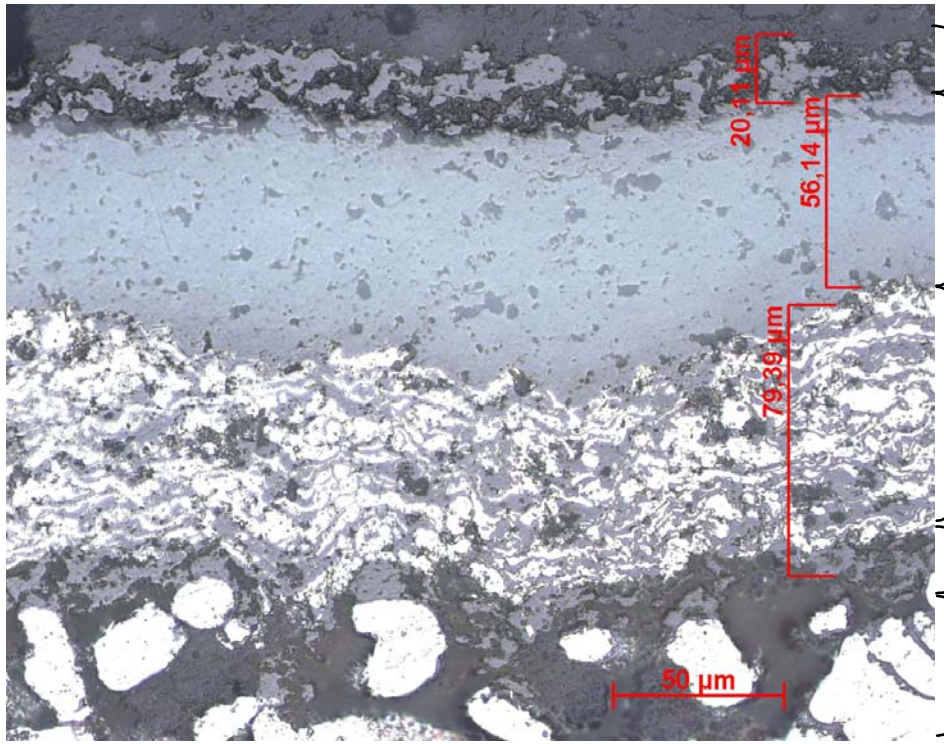
Properties of VPS cells on IT11 substrates

Functional Layer	Reference	Composition	Thickness (µm)	Fabrication route
Substrate	Plansee IT11	Fe-26Cr (Mn, Mo, Ti, Y_2O_3)	950-1050	PM
Barrier Layer	H.C. Starck	$La_{0.6}Sr_{0.2}Ca_{0.2}CrO_3$	30-50	APS
Anode	Gen4	NiO-YSZ (1:1 mass)	40-60	APS
Electrolyte	Gen3	9.5 mol% YSZ	40-60	VPS
Cathode	Gen3	LSM/LSCF LSM/LSCF	25-35 15-40	APS Screen printed

Interdiffusion of metallic species (Ni into substrate, Fe into anode)

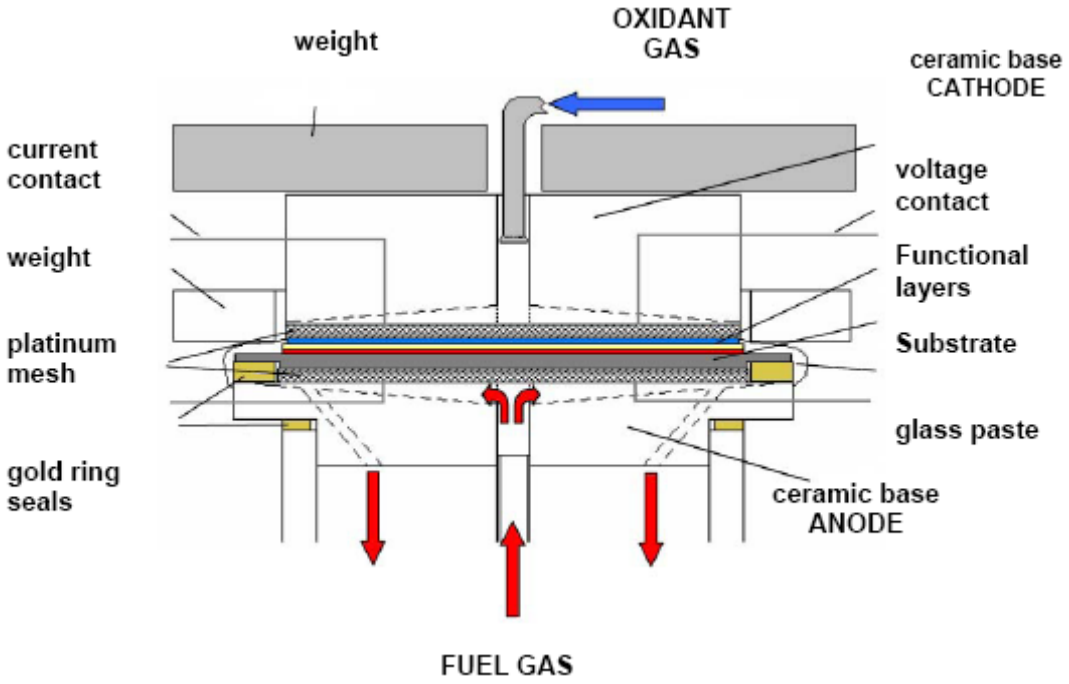


Metallographic cross section of a VPS cell with diffusion barrier layer

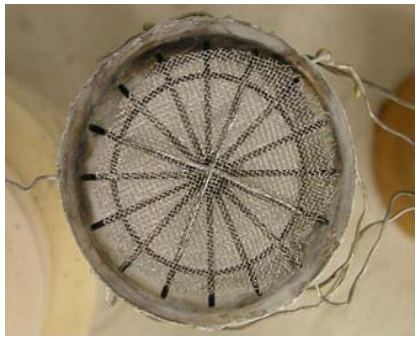


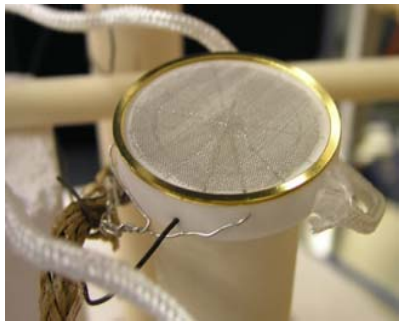
- $LaSrMnO_3$-cathode
- 8YSZ-electrolyte
- Ni/8YSZ-anode
- $La_{0.7}Sr_{0.15}Ca_{0.15}CrO_3$-barrier layer
- Porously sintered ferrite plate

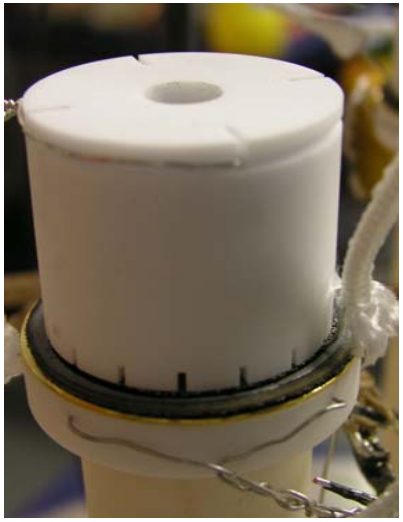
Experimental set-up for cell characterisation

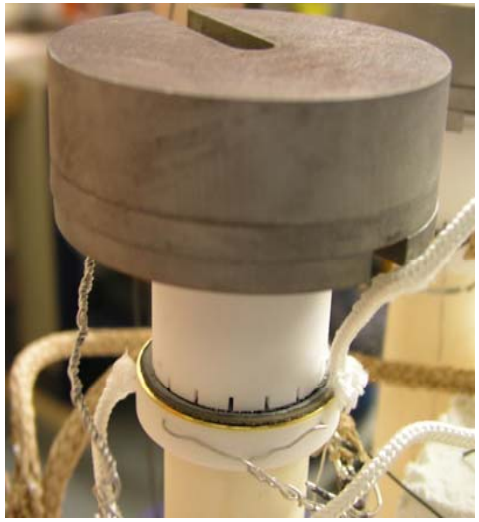


Experimental set-up for characterisation of circular cells





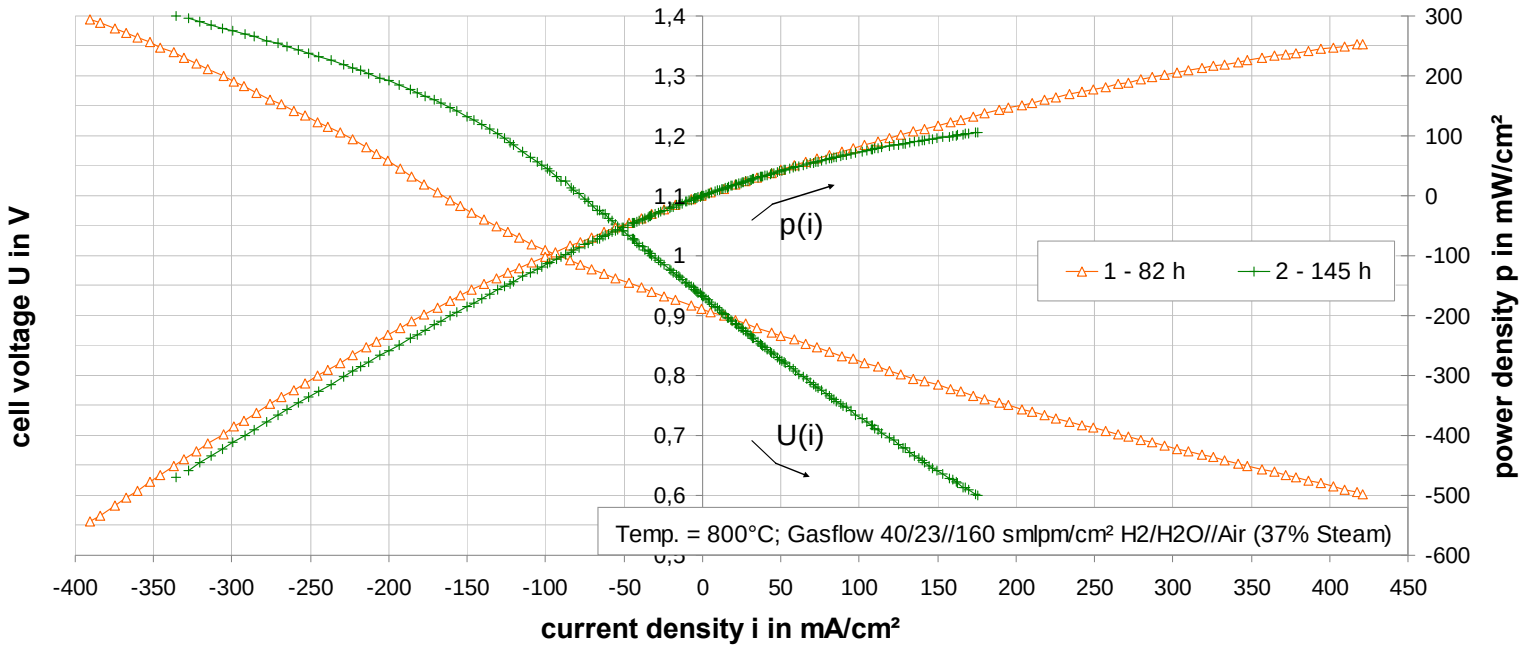




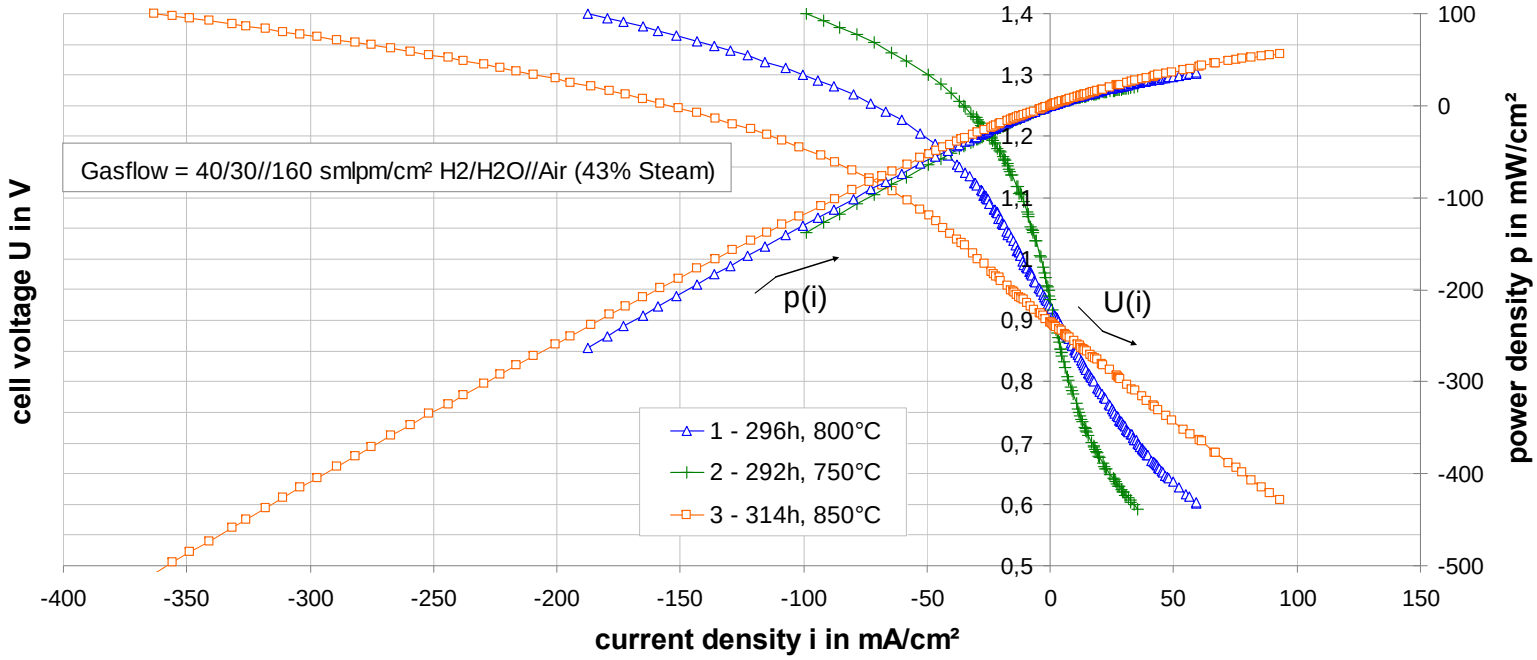
Overview of cells tested at DLR

Nomenclature	Substrate	Barrier layer	Cathode	Period	Comment	Fuel Cell Mode	Electrolysis Mode	Variations	Long-Term Measurement	EIS ocv loaded	Polished Micrograph Section	Further Investigation
BekNi 274-3	Ni-Felt		LSM Screenpr.			x	x	50/70%	320 h			
BekNi 275-3			LSM Screenpr.			x	x		221 h			
ITV3_060703	IT11		LSM Screenpr.	16.09.-22.09.	Air cut off	x	x		114 h, 0.20 Acm^{-2}			
ITV3_060702				27.09.-28.09.	Reduction, Reference							to EMPA
ITV2_060703			LSM Screenpr.	30.11.-19.12.	Performance Collapse	x	x		50 h, 0.20 Acm^{-2} 98 h, 0.15 Acm^{-2}	x		to EMPA, Linescan
IT 126		VPS	LSM Screenpr.	19.01.-01.02.	Canceled due to Thermocycle and Restart Problems	x	x		36 h, 0.15 Acm^{-2} 75 h, 0.2 Acm^{-2}	x	x	to EMPA Fractured, Point/EDX
IT 125		VPS	LSM Screenpr.	01.02.-05.02.	Reduction, Reference							
IT 100		VPS	LSM Screenpr.	08.02.-05.03.	Furnace Breakdown	x	x	50-90% Temp.	166 h, 0.15 Acm^{-2} 10 h, 0.25 Acm^{-2}	x	x	to EMPA
IT 18		VPS	LSCF VPS	15.03.-18.03.	Reduction, Reference							
IT 28		PVD	LSCF VPS	19.03.-29.06.	Completely Plasmasprayed	x	x	Temp.	>2200 h, 0.3 Acm^{-2}	x		
IT 4 and IT 5		VPS	LSCF VPS	22.06.-	Interconnect Measurements	x	x	Temp.	400 h, 0.3Acm^{-2}	x		
IT 25		PVD	LSM VPS	09.07.-10.07.	Reduction, Reference							
IT 27		PVD	LSM VPS	10.07.-	Interconnect Measurements	x	x		115 h, 0.3 Acm^{-2}	x		

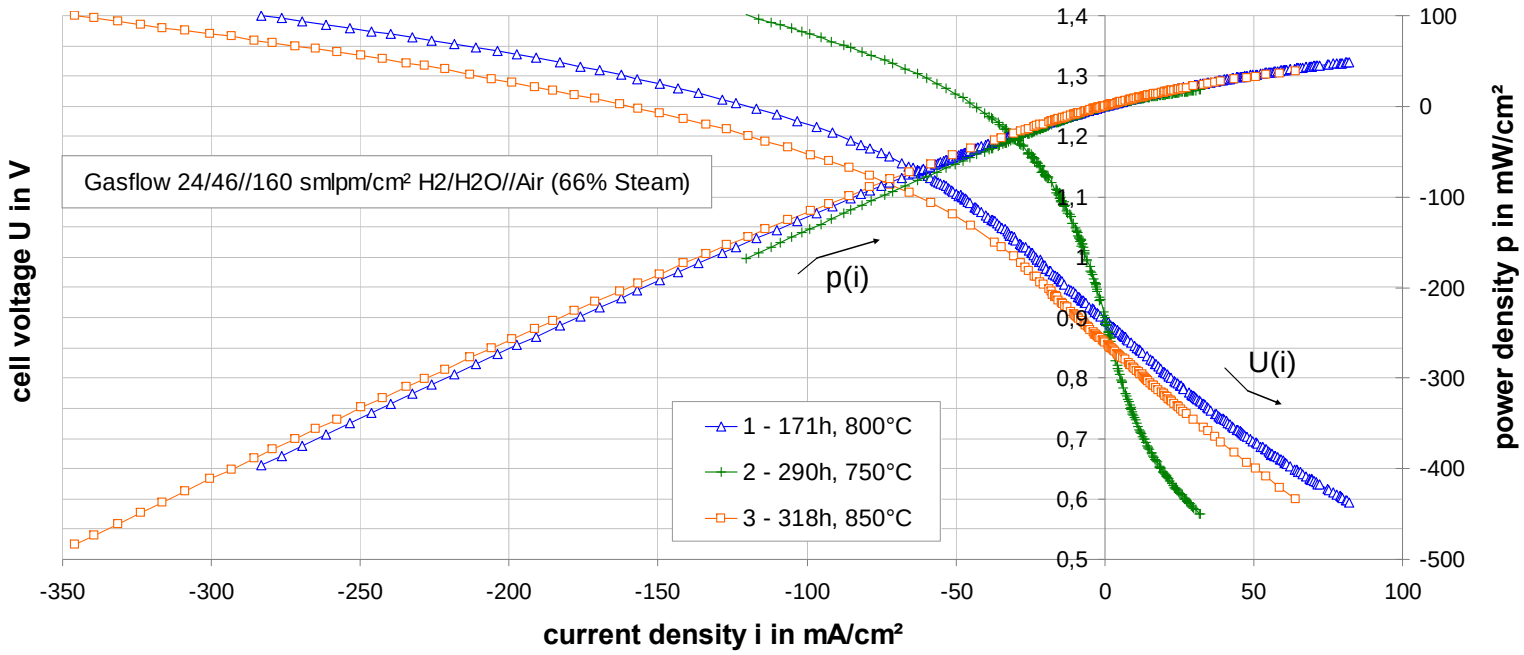
I-V curves of cell IT100 in fuel cell and electrolysis mode



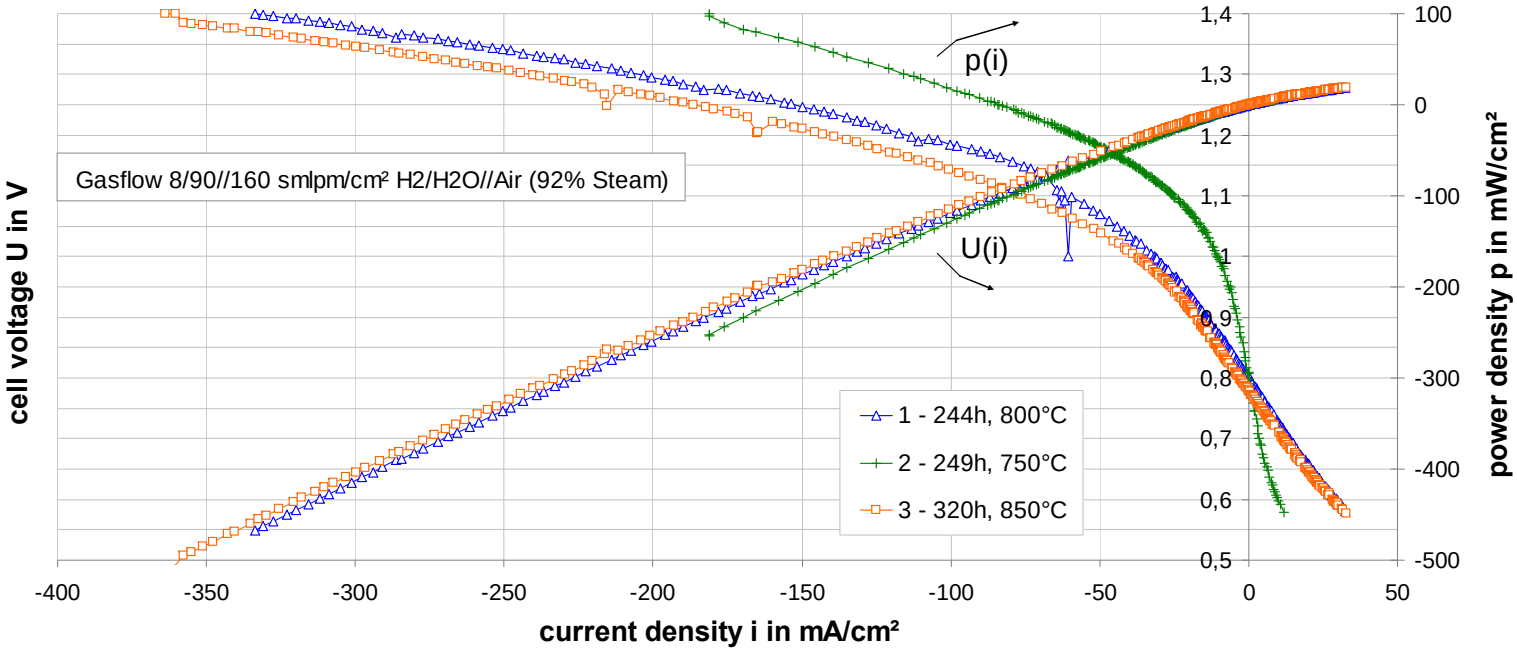
I-V curves of cell IT100 as a function of temperature at 43% humidification



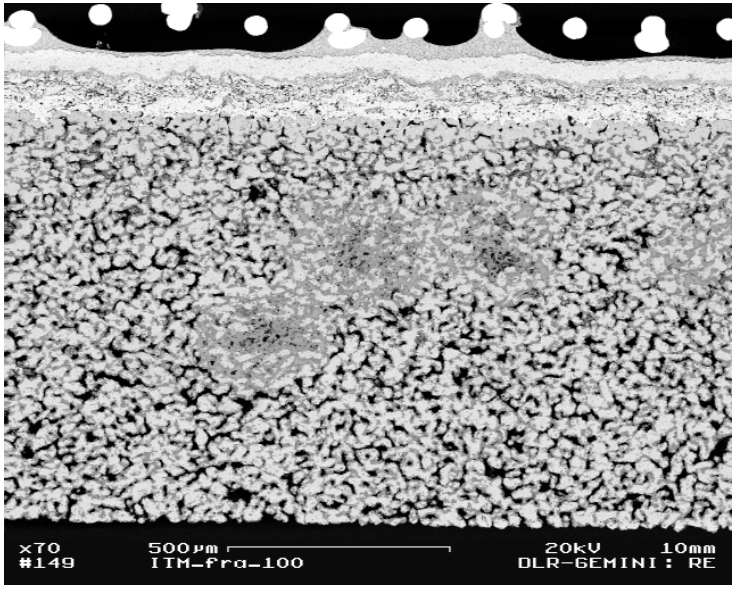
I-V curves of cell IT100 as a function of temperature at 66% humidification

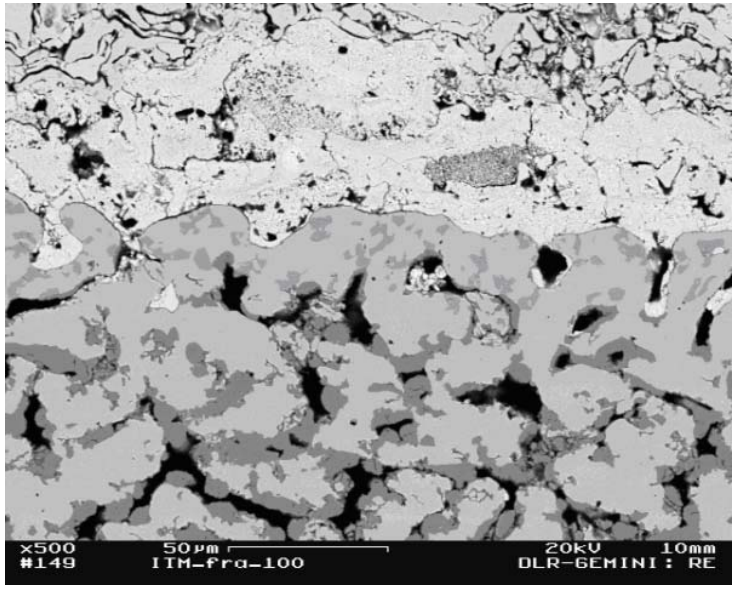


I-V curves of cell IT100 as a function of temperature at 92% humidification

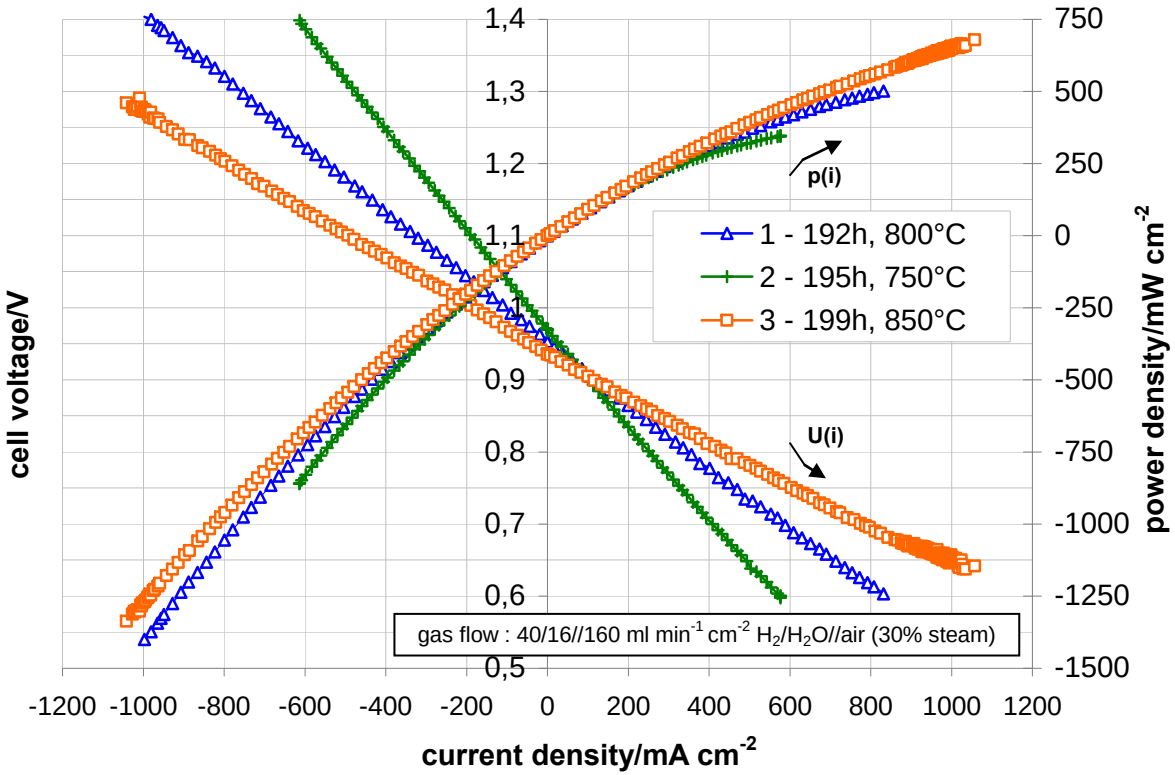


Microstructure of cell IT100 after 500 h of operation

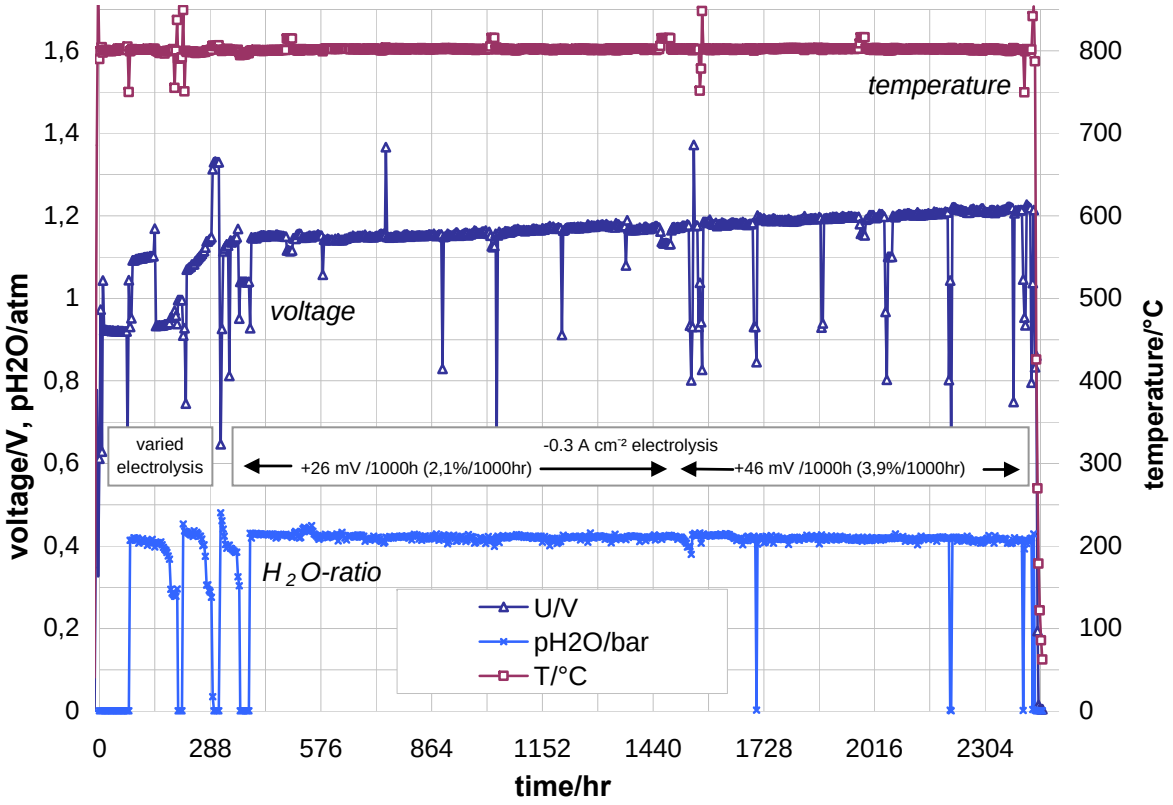




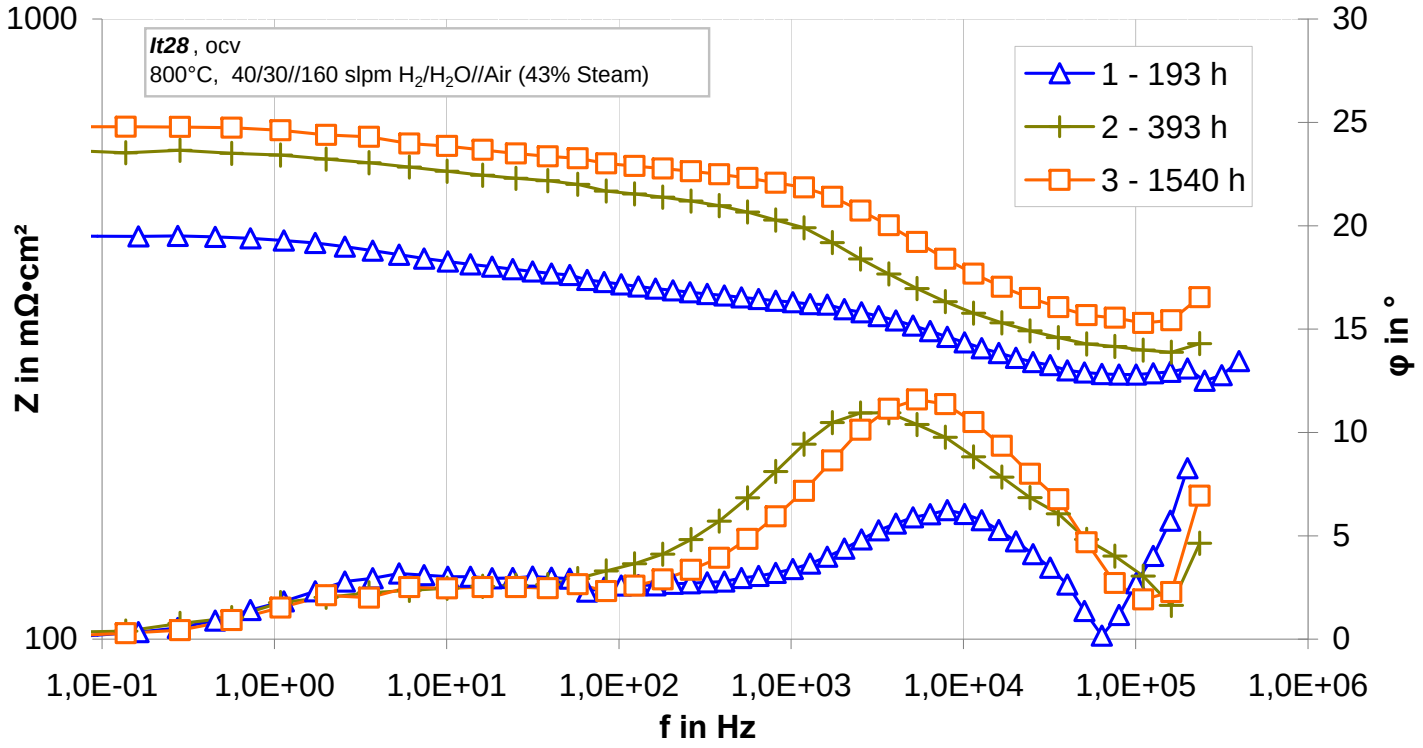
I-V curves of cell IT28 in fuel cell and electrolysis mode as a function of temperature



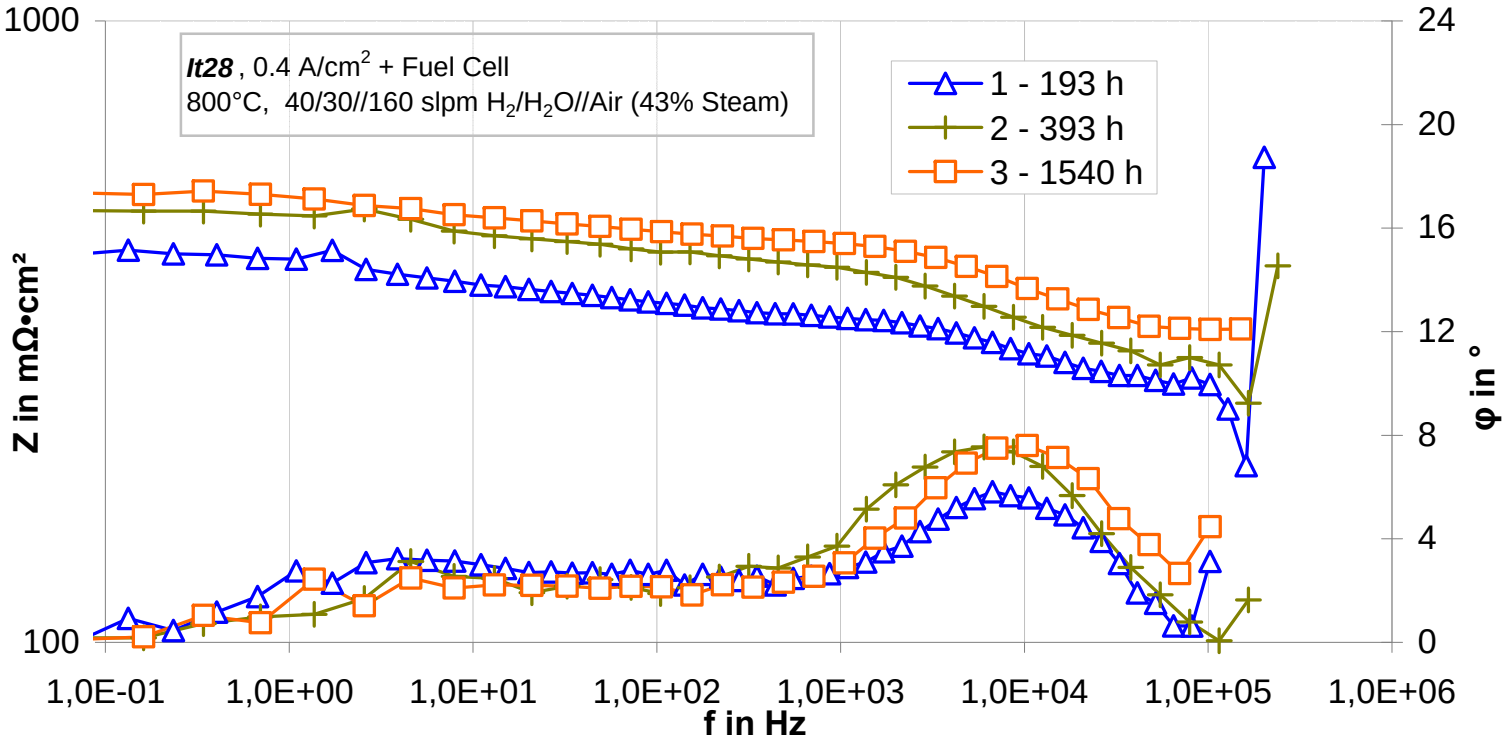
Complete test run of cell IT28



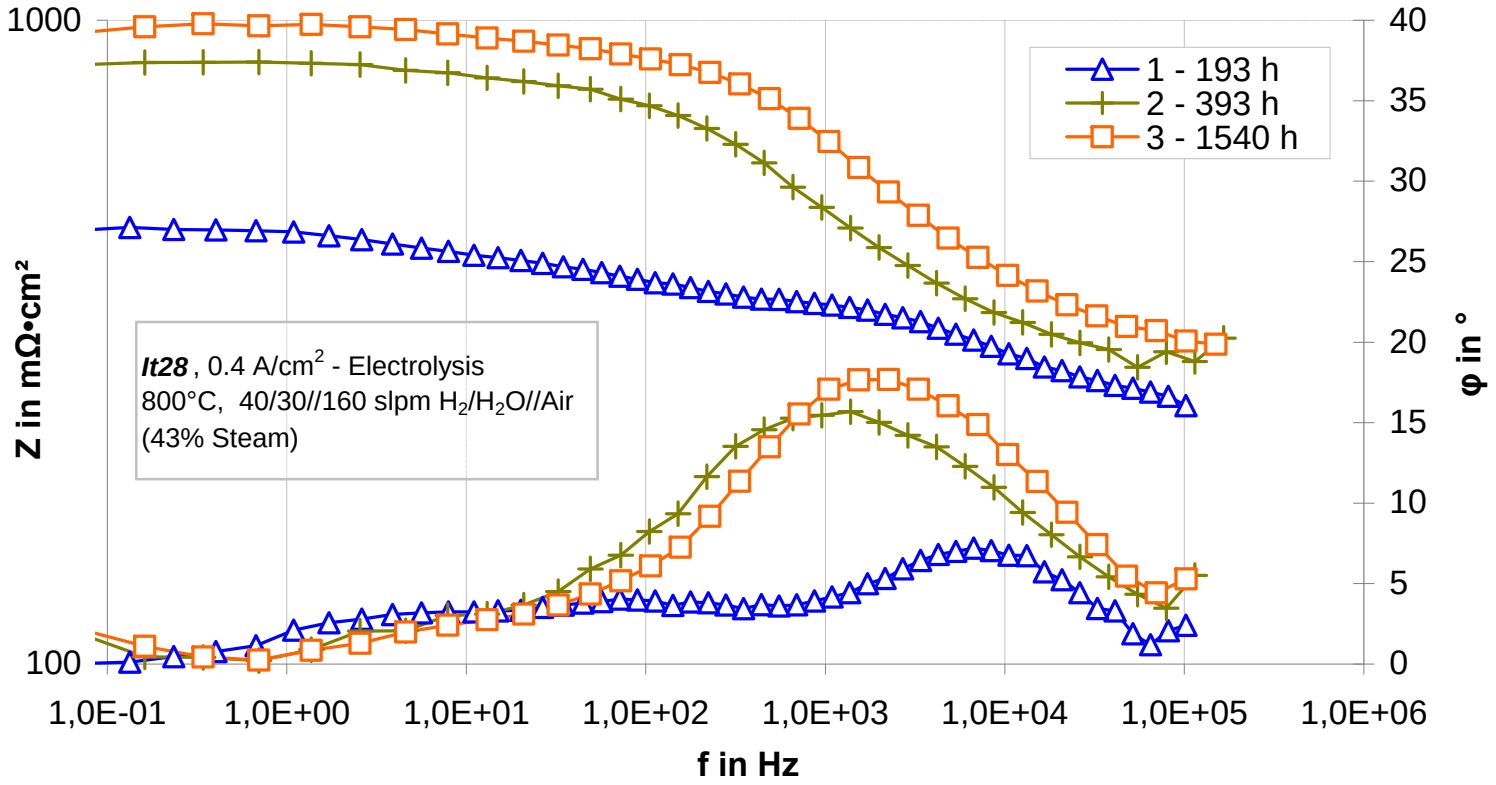
Change in impedance spectra of cell IT28 at OCV during long-term electrolysis



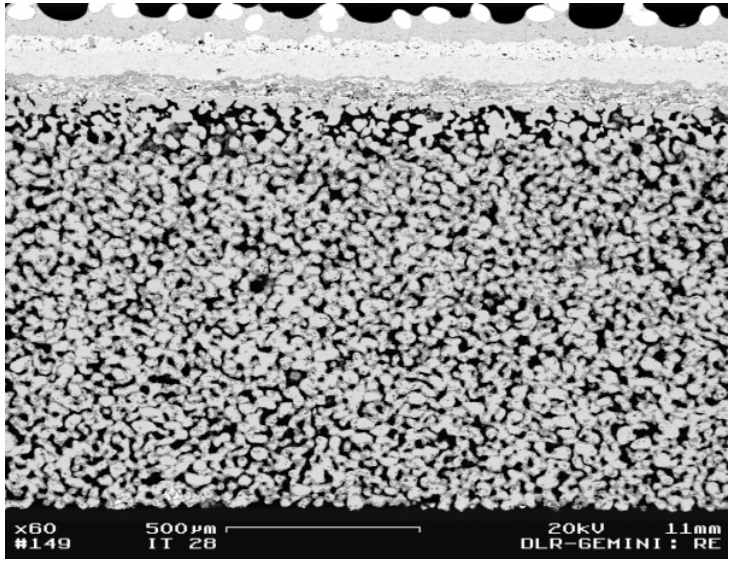
Change of impedance spectra of cell IT28 at 400 mA/cm² in fuel cell mode

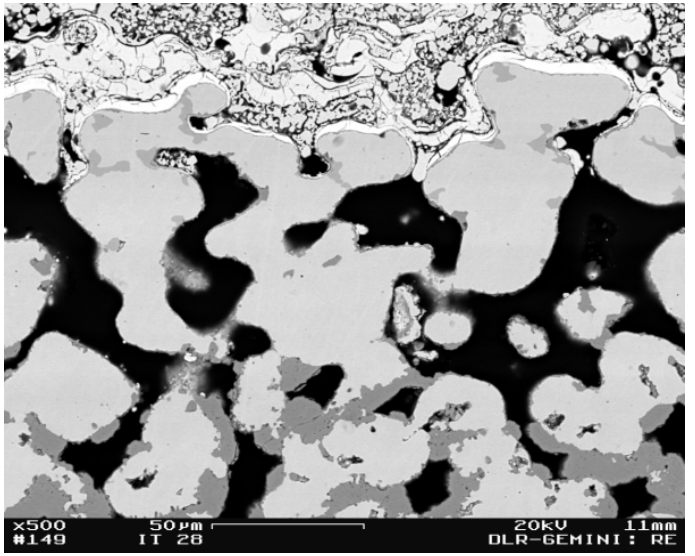


Change of impedance spectra of cell IT28 at 400 mA/cm² in electrolysis mode

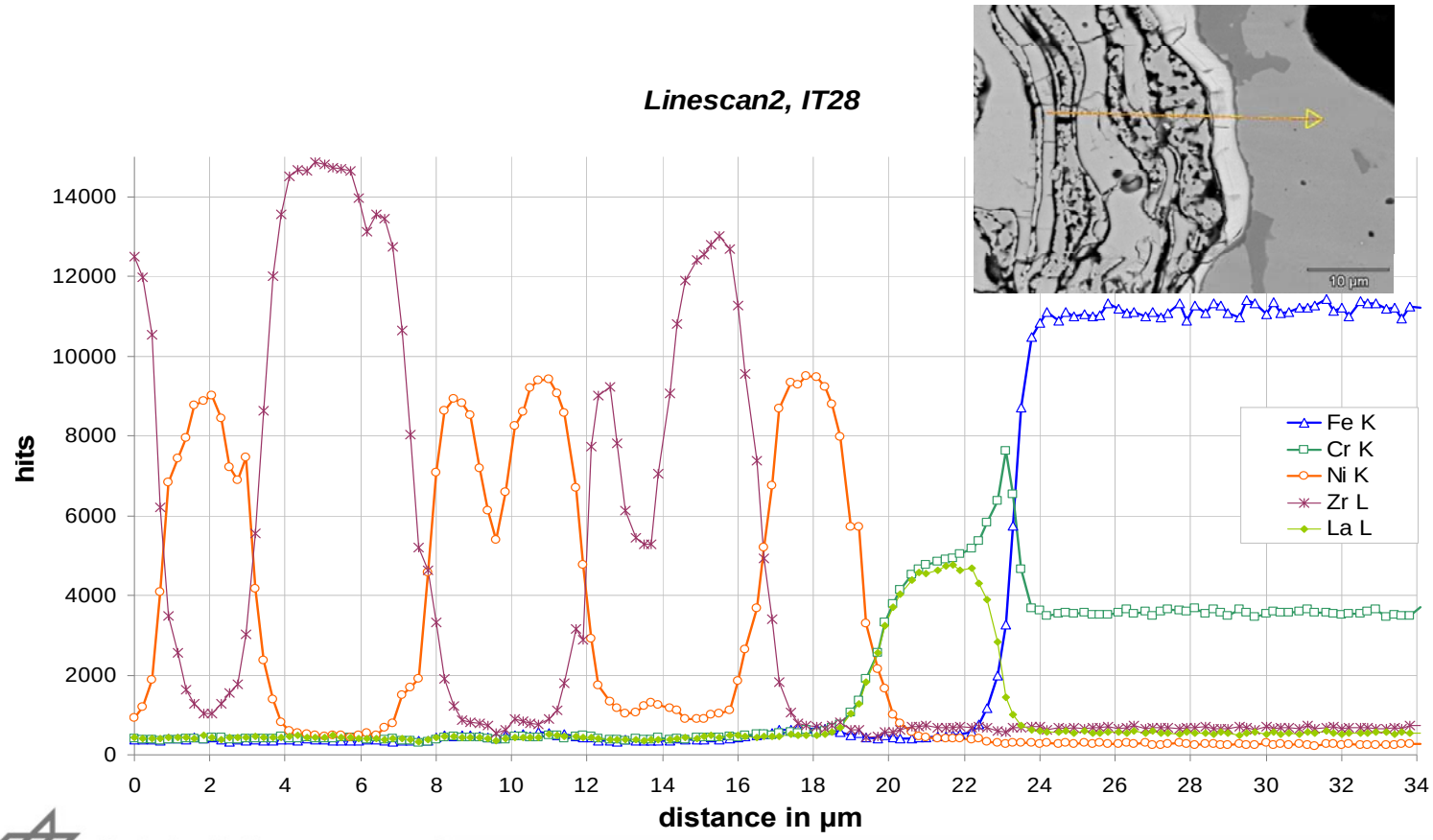


SEM micrographs of cross sections of cell IT28 after 2425 h of operation

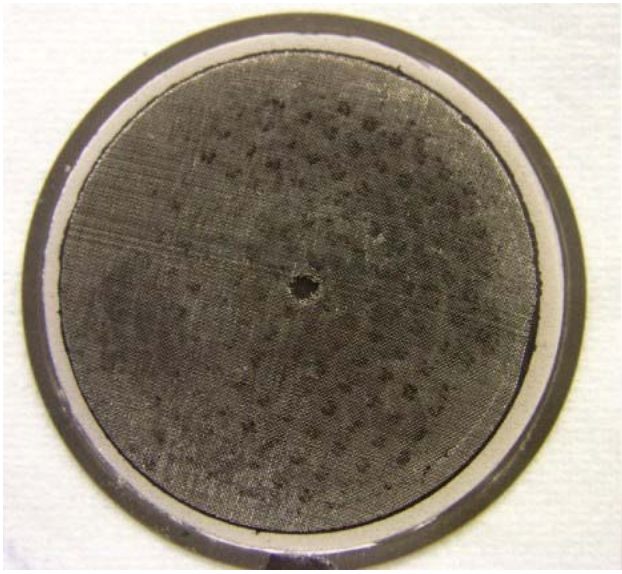


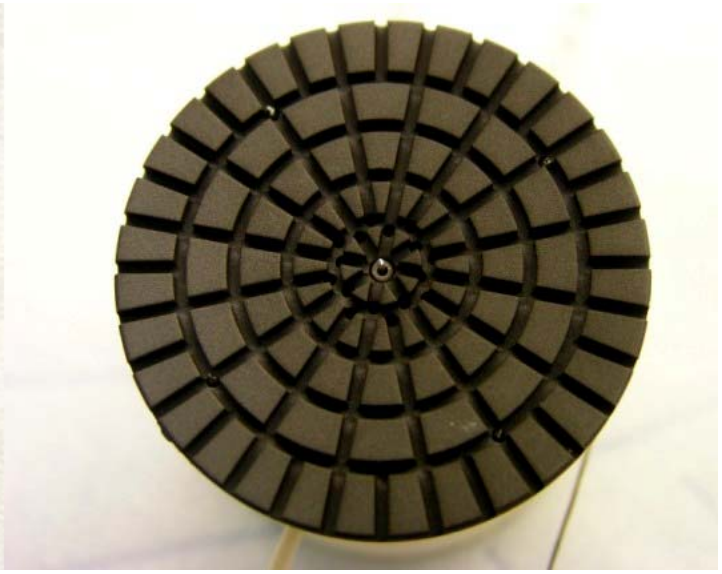


EDX linescan of cell IT28 after 2425 h of operation

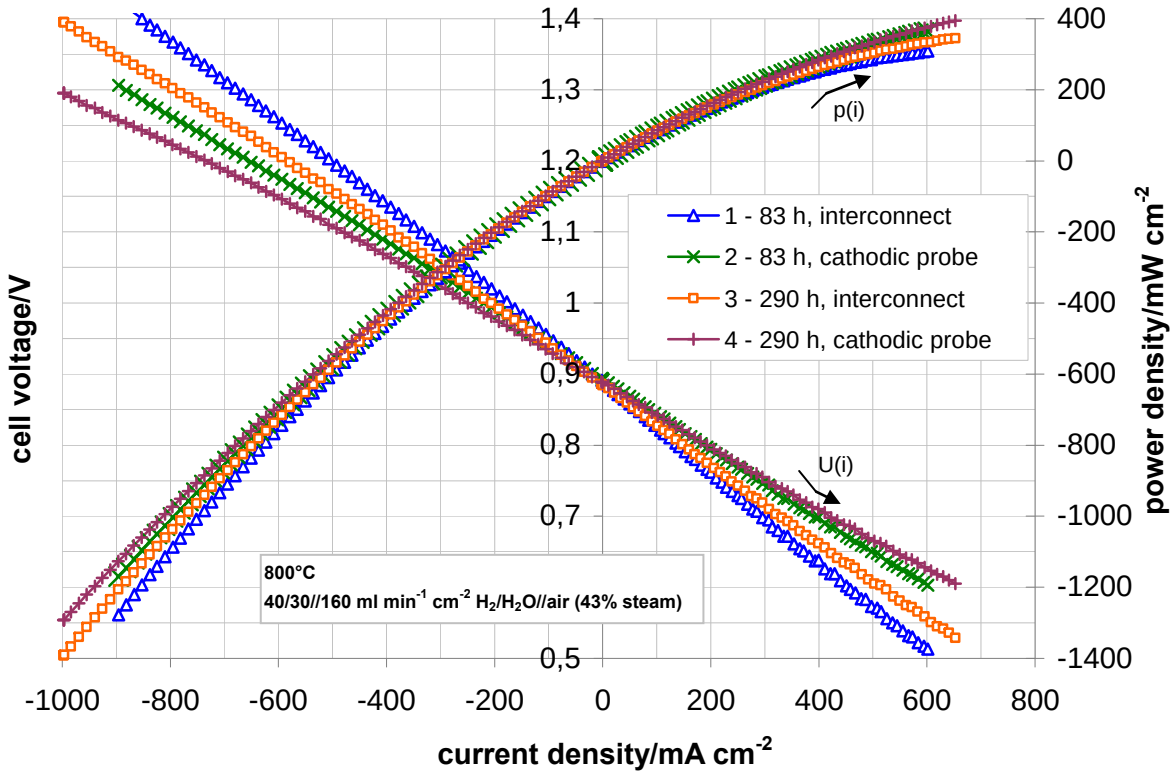


Cell IT4 (LSM O_2-electrode with Pt mesh) and coated interconnect

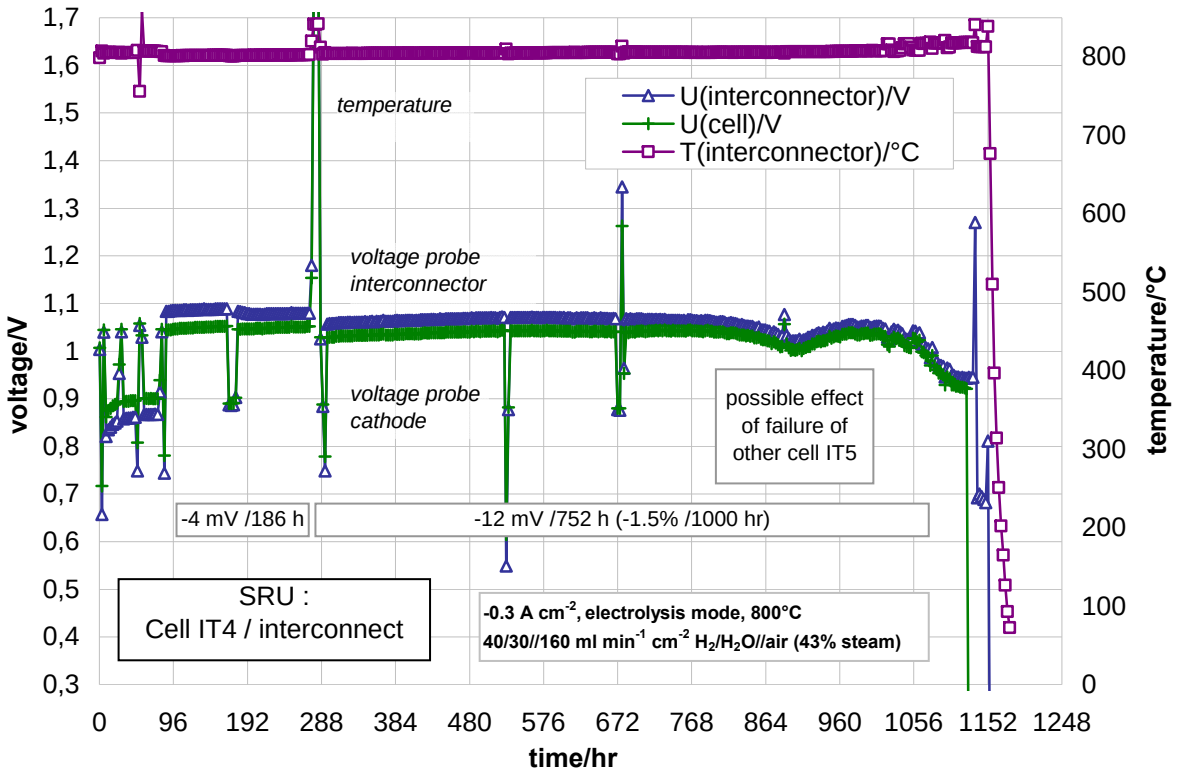




I-V characteristics of cell IT4 with Pt mesh and interconnect in fuel cell and electrolysis mode



Complete test run of cell IT4



Conclusion

- Metal supported cells show good electrochemical performance during electrolysis operation:
  - 1.3 V at 1 A/cm^2 at 850 °C
  - 1.4 V at 1 A/cm^2 at 800 °C

  For comparison: Electrochemical performance of alkaline water electrolysers
  - 1.6 V at 0.3 A/cm^2 at 80 °C (advanced Raney-Ni electrodes)
  - 1.9–2.3 V at 0.3 A/cm^2 at 80 °C (standard Ni electrodes)

- Cell performance is improving with higher temperature and higher steam content

- Degradation during electrolysis operation (3.2%/1000 h) is significantly higher than in fuel cell operation and needs further improvement

- Impedance spectra revealed a significantly enhanced polarisation resistance during electrolysis operation compared to fuel cell operation which was mainly attributed to the hydrogen electrode.

Acknowledgment

- I‘d like to thank my co-workers Dr. Asif Ansar, Dr. Michael Lang, Dorothea Lehmann and Olaf Patz for their scientific work and strong effort.

- Financial support within the EU project „Highly Efficient High Temperature Hydrogen Production by Water Electrolysis“ (Hi2H2) is gratefully acknowledged.