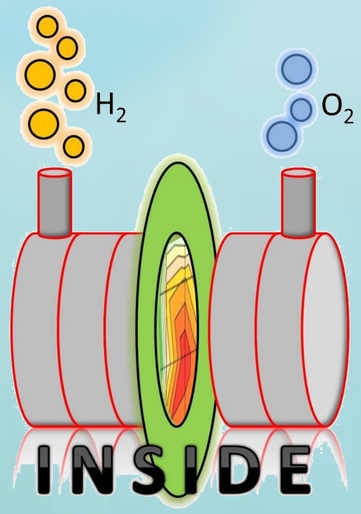
FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

INSIDE



Programme Review Days 2018

Brussels, 14-15 November 2018

Indro BISWAS

German Aerospace Center (DLR)

www. inside-project.eu

Indro.Biswas@dlr.de

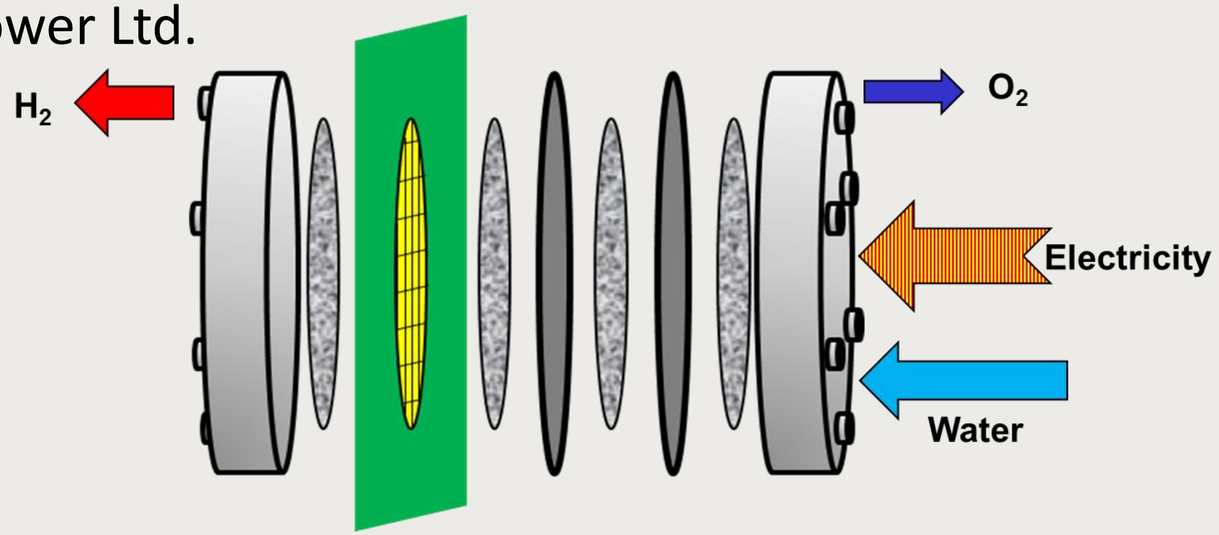
PROJECT OVERVIEW

- Call year: 2013
- Call topic: SP1-JTI-FCH.2013.2.2 Diagnosis and monitoring of electrolyser performance
- Project dates: Nov 2014 – Oct 2018 (initially Oct 2017)
- % stage of implementation 01/11/2018: 100%
- Total project budget: 3,656,756.20 €
- FCH JU max. contribution: 2,176,624,80 €
- Other financial contribution: 0 €
- Partners:

PROJECT SUMMARY

INSIDE – In-situ Diagnostics in Water Electrolysers

- Objectives: Local current density distribution as indicator for local electrochemical turnover in industrial hardware: PEMWE, AWE, AEMWE
- Segmented bipolar plate inside stack
- Integrated array of temperature sensors
- Based on patented technology for in-situ diagnostics in fuel cells
- Similar activities in PEMWE:
  - CEA / Uni Grenoble / Uni Paris Sud / S++ Simulation Services
  - Imperial College, London / ITM Power Ltd.
- Applications:
  - Efficiency
  - Flexibility vs. Durability
  - Targeted design



PROJECT PROGRESS/ACTIONS – PEM water electrolysis

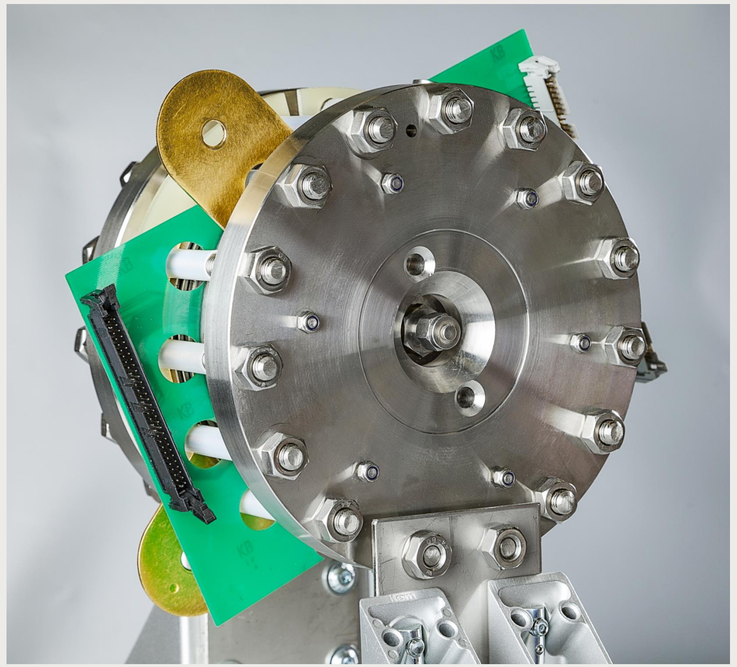
Achievement to-date

PEMFC technology

25% 50% 75%

Operating Prototype

- Transfer of Measurement technology from fuel cells to electrolysis
- Transfer from coated PCB to graphitic bipolar plates
- Pronounced relevance of precise geometry (self pressurising!)
- Acquisition of industrial hardware and legal aspects for R&D requirements
- Development steps:
  Lab cell test (PEMFC hardware)
  → graphitic BPP prototype (internal contact issues)
  → redesigned prototype as graphitic BPP
- Similar activities:
  - Imperial college, ITM: 1D-cell demonstrated
  - CEA, Grenoble, Paris Sud: Application of hardware by S++ (license by DLR)



Segmented BPP integrated in PEMWE short stack

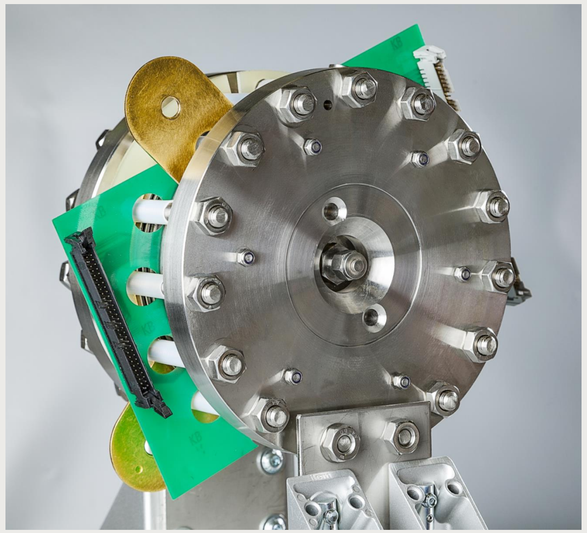
PROJECT PROGRESS/ACTIONS – PEM water electrolysis

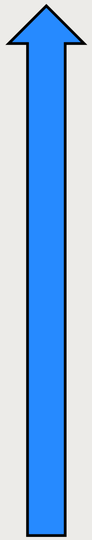
Achievement to-date

PEMFC technology

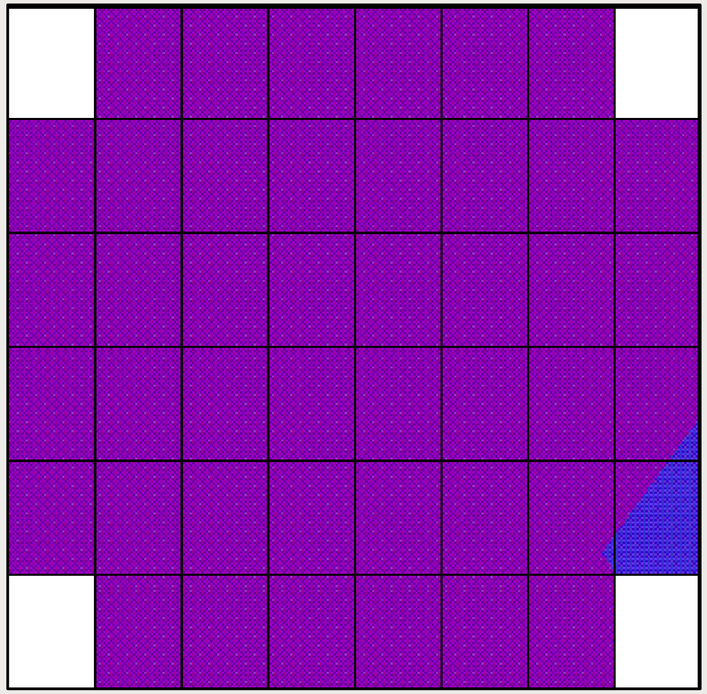
25% 50% 75%

Operating Prototype





Water flow direction



Intuitive false colour display of locally resolved current density distributions, visible during operation

Example: deactivation due to insufficient water supply:

- Regional deactivation before voltage response
- Local current density distribution is becoming increasingly inhomogeneous
- Some regions with over-nominal current densities
- Extreme hot spots could be avoided in advance

PROJECT PROGRESS/ACTIONS – Alkaline Water Electrolysis

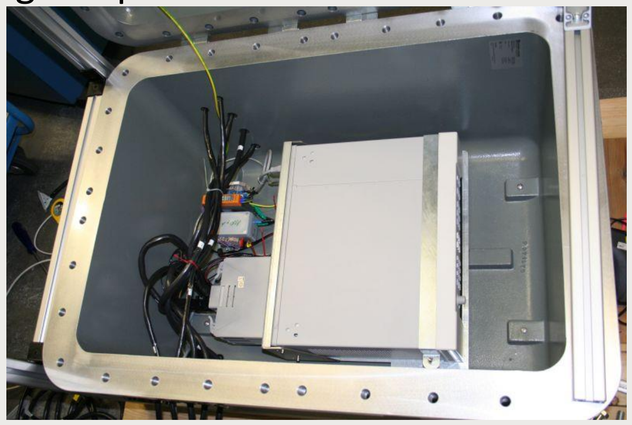
Achievement to-date

PEMFC technology

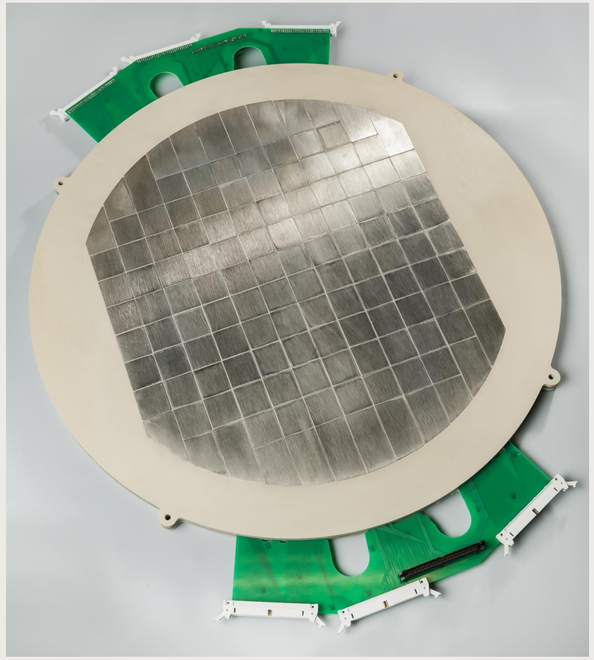
25% 50% 75%

Operating Prototype

- Transfer to alkaline ambience
- Upscaling:
  - Large active area: high number of segments *or* larger individual segments
  - (high number of segments: extensive data acquisition and handling effort while no need for the local resolution)
  - Larger segment area: larger total current per segment
  - Larger total current per segment: Sensor redesign required
- Regulatory bottleneck:
  ATEX housing for data acquisition:
  Short analogue cables (>200 channels parallel!)
  → data acquisition close to stack,
  digitalised data line to control room



ATEX safety housing



Modular segmented BPP for AWE

PROJECT PROGRESS/ACTIONS – Alkaline Water Electrolysis

Achievement to-date

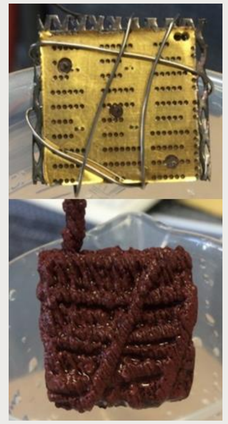
PEMFC technology

25% 50% 75%

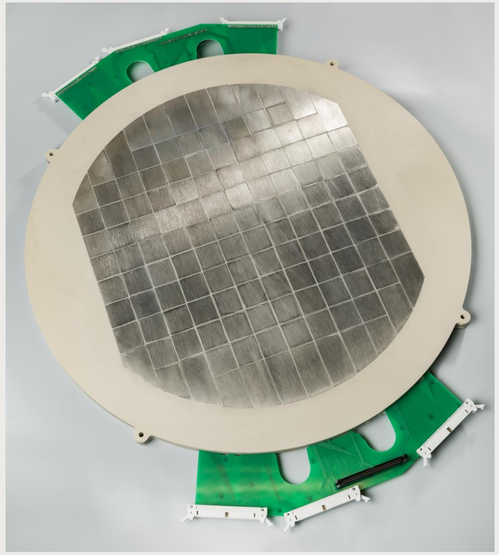
Operating Prototype

Development steps:

- Lab cell (PCB based): surprisingly promising - main issue in protection of circuitry
  Tests with cut pieces revealed: edges of PCB are prone to KOH invasion and corrosion
- Alternative concepts:
  - PCB based on different material ?
  - PCB with coating ?
- Final Prototype: PEEK frame, integrated and individually sealed sensor modules
  - Sensitive PCB components separated from manifolds
  - Cross-talk sensitivity reduced by reduced sensor resistance
  - Modular design facilitates upscaling and bulk production of sensor modules



corroded PCB parts



Segmented BPP modules

PROJECT PROGRESS/ACTIONS – AEM water electrolysis

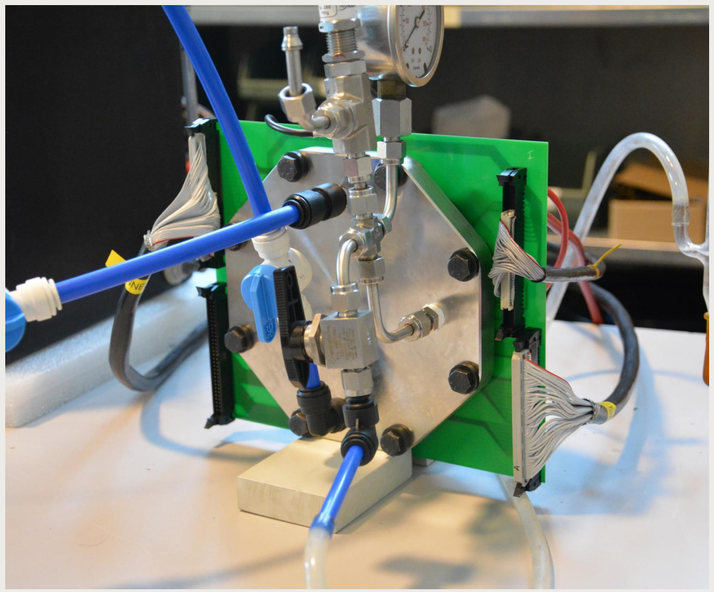
Achievement to-date

PEMFC technology

25% 50% 75%

Operating Prototype

- Transfer of Measurement technology from PEMFC to AEM electrolysis
- Development steps:
  Lab cell test (PEMFC hardware)
  → Straightforward design concept
  → Prototype
  → Prototype with segmented contact sheet
- Bottlenecks:
- Sealing of bipolar plates (PCB vs. metal, self pressurising technology)
- Lateral cross-talk between segments (while segment size inhomogeneous)



AEMWE cell in short stack at >20 bar differential pressure

PROJECT PROGRESS/ACTIONS – AEM water electrolysis

Achievement to-date

PEMFC technology

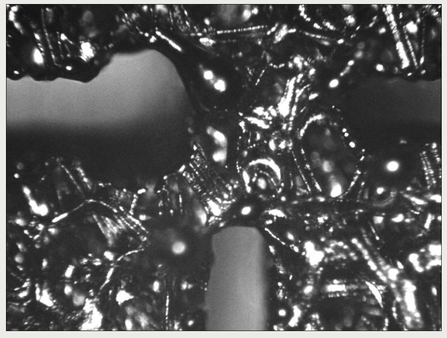
25% 50% 75%

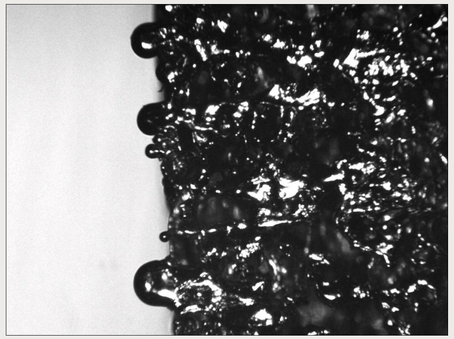
Operating Prototype

Segmentation of contact sheets to reduce signal cross-talk

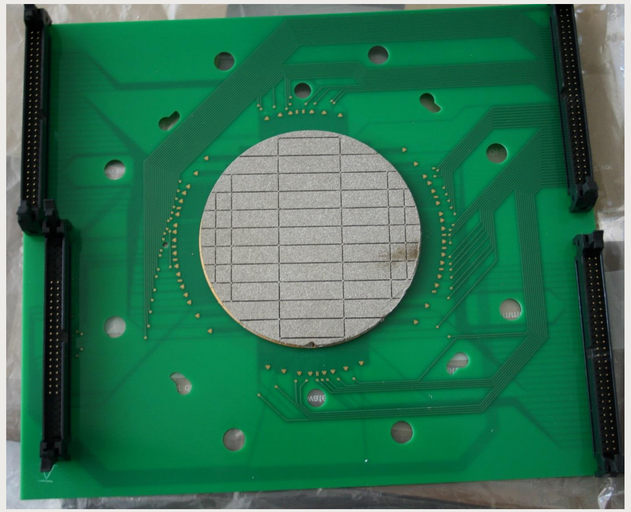
- Milling: compression and smearing out of porous material
- Wire spark erosion: functional but inhomogeneous
- Laser cutting:
  - Droplets of molten metal <200 µm (only bottom)
  - Self-supporting due to connected segment corners
  - Significant reduction of signal cross-talk

Mechanically machined (left) and wire spark eroded (right) contact foams





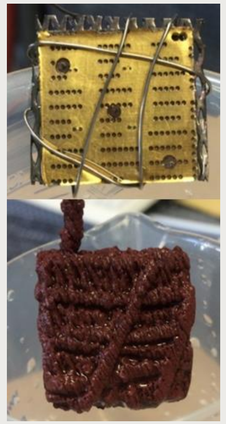
Laser cut contact sheet: segment junction (left), edge profile (right)



Segmented BPP with segmented contact sheet

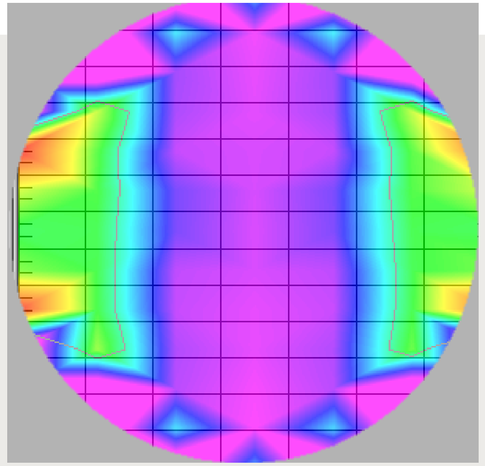
Risks and Challenges

- Technical challenges:
  - Chemistry & Corrosion
  - Geometry & Sealing
  - Signal cross-talk
  - Safety requirements



Corrosion!

Measured current density distribution with signal cross-talk is displaying *inverse segment areas*



- Organisational challenges:
  - Acquisition of PEMWE hardware & corresponding legal aspects
  - Restructuration of industrial partners

- Cost neutral extension by 12 months

Communications Activities

Scientific Communications:

- 2 workshops
- 9 publications
- 10 conference talks
- 11 posters

more to come...

Technology design award “f-cell award”, issued by the Ministry of Environment, Climate and Energy of Baden-Württemberg

Website and facebook page:

www.inside-project.eu

fb.me/insideelectrolysis.eu

f-cell award 2018 – special recognition: Modular and Scalable Design for AWE Segmented Bipolar Plate

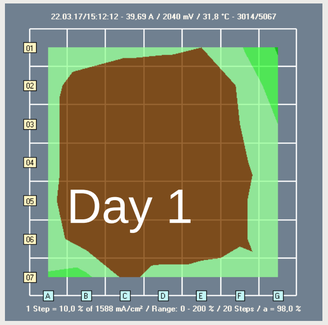
EXPLOITATION PLAN/EXPECTED IMPACT

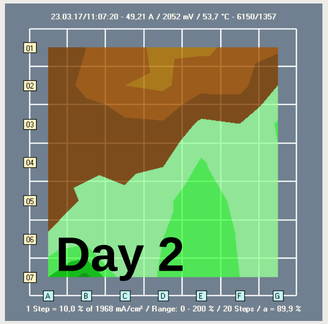
	Scientific	Technological	Economic
NEL	• More fundamental knowledge about electrolysis / electrolyser operation	• Facilitation of developments towards flexible electrolysers • Instrument for in-situ failure detection	• Reduction of development costs • Reduction of simulation efforts • Reduction of post-mortem analyses
Enapter	• Insights in lifetime and failure modes for a new technology	• Targetted development of new stack generations • Improvement of durability and reliability	• Reduced expenses for planned new stack generation
DLR	• Scientific Publications • Basis for scientific cooperations	• Advance of in-situ diagnostics technology	• New patent(s) • Financial flowback in licenses • Basis for future third-party funding • European High-Tech strategy • Strengthening of cooperation possibilities
CNRS / Uni Strasbourg	• Scientific Publications	• Joint patents	• Strengthening of institutes profile • Basis for future third-party funding
Hochschule Esslingen	• Scientific Publications	• Joint patents	• Strengthening of institutes profile • Basis for future third-party funding • Increase of attractivity for students

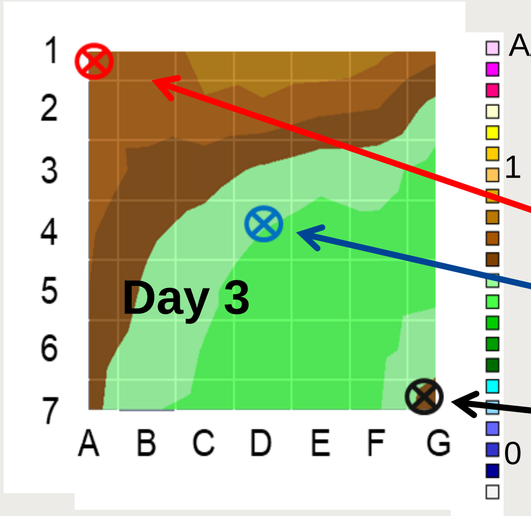
OPTIONAL SLIDES

Correlated ex-situ measurements

- PEMWE (lab cell experiment)
- Slowly and steadily occurring performance loss with region pattern
- Poisoning of membrane
- Correlation with Nickel content in membrane

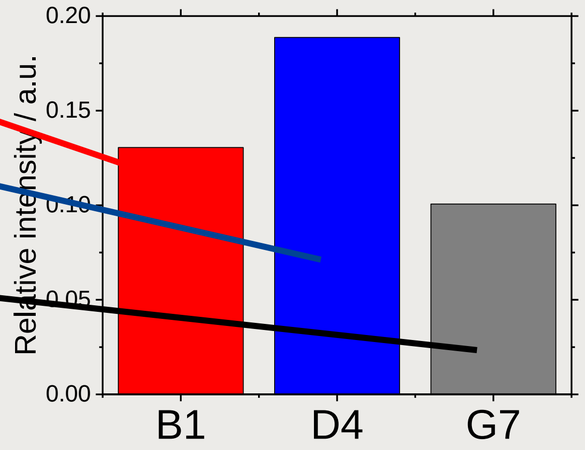


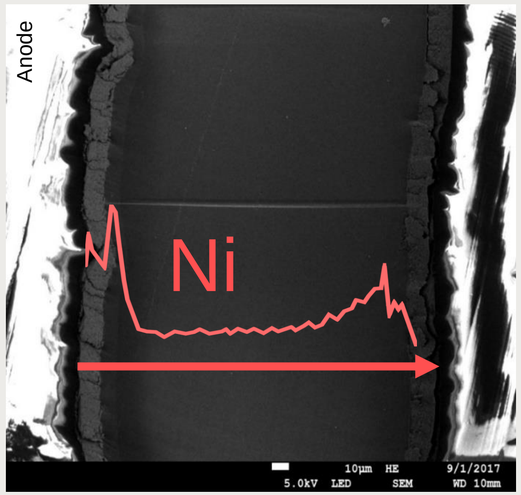




Current density distributions with characteristic patterns

SEM/EDX cross section: Ni profile in PEMWE membrane





Correlation between local performance loss and local poisoning

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES

Interactions with projects funded under EU programmes

- PREMIUM ACT, IMPACT, IMPALA, Nano-CAT, SECOND ACT (FP7): Practical experience in segmented bipolar plate technology (fuel cell related)
- RESelyser (FP7): Practical experience in Alkaline electrolysis and corrosion related topics

Interactions with national and international-level projects and initiatives

- Elykon (Germany – BMBF/HYPOS): Intelligent control system for PEM electrolysers (exp. 2019)

Acknowledgements

Consortium

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Svenja Stiber

EWII

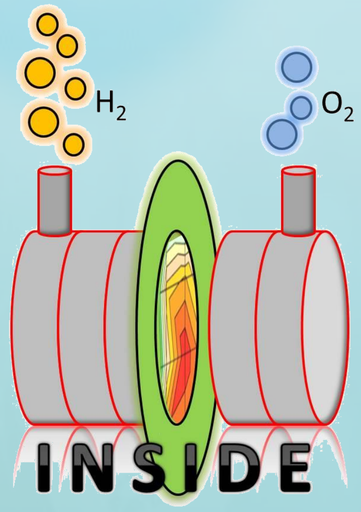
Laila Grahl-Madsen
Theiss Stenstrøm
Bertil Sieborg

FCH JU

Nikolaos Lymperopoulos

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

INSIDE



Programme Review Days 2018

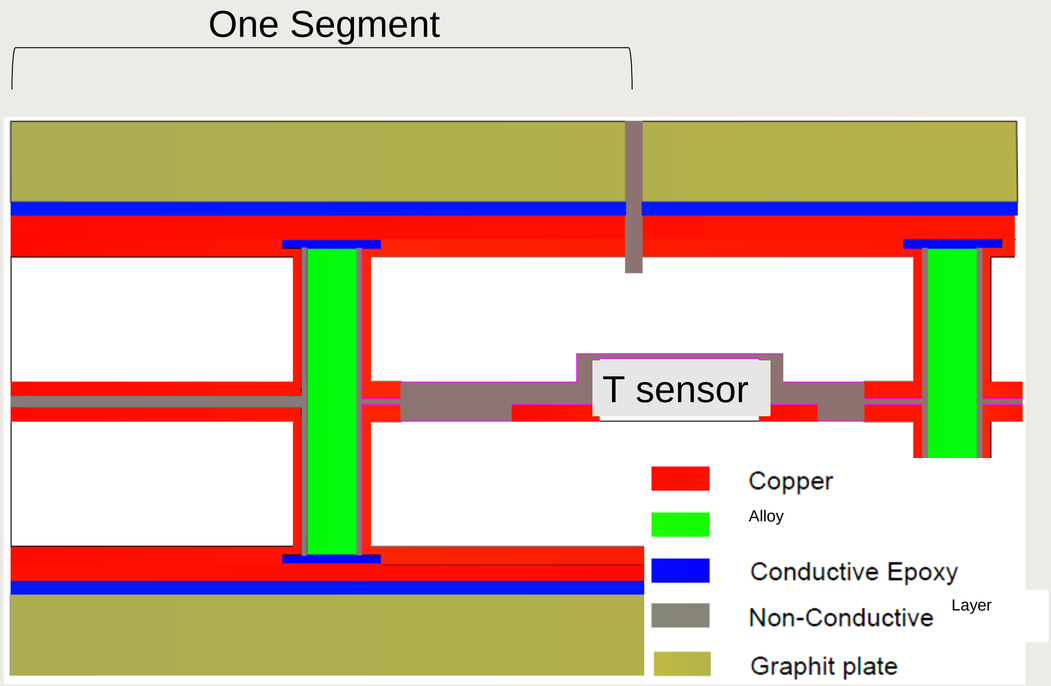
Brussels, 14-15 November 2018

Thank you for your attention!

Auxiliary Slides

Proton Exchange Membrane Water Electrolysis – diagnostic bipolar plate

General design concepts, overall current density



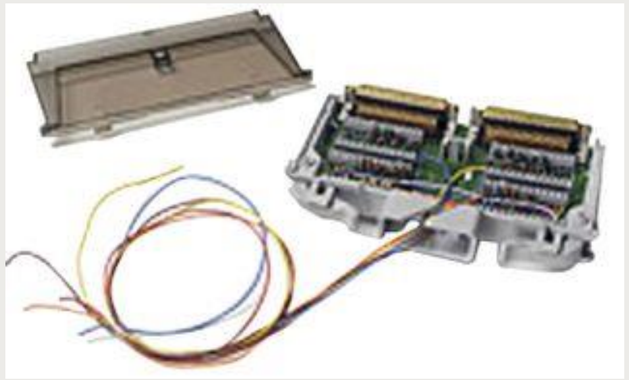
Design upgrades:

- Current transducers: accuracy unaffected at current densities >>2 A/cm²
- Miniaturised temperature sensors
- Graphitic bipolar plate

Auxiliary Slides

Data acquisition

- Voltage recording
- Modular setup
- Multiplexer for up to 560 channels
- USB interface
- Labview ™ compatibility



Data acquisition : Keysight (HP/Agilent) 34980A