Monitoring of current density distribution

I. Biswas, D. Garcia Sanchez, M. Schulze

German Aerospace Center (DLR)
Institute of Engineering Thermodynamics
Electrochemical Energy Technology
Stuttgart, Germany

Knowledge for Tomorrow

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Outline

- Current Density
- Local current density monitoring – technology principles and origins in fuel cell technology
- INSIDE – Diagnostics in Electrolysis
- Application examples
- Outlook

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Current Density

o Key point indicator for electrolysers and fuel cells: efficiency of used materials (PGMs, etc.)
o Faraday´s Law:
  Current density equals chemical turnover
o Local electrochemical turnover is determined by
  local catalytic activity
  local transport limitations
  local degradation
 *local* temperature
  local…

Technology: Segmented Printed circuit boards

- Origin: PEM Fuel cells
- PCB mimicks bipolar plate
- Endplate contact possible
- Gas tightness
- Current take up 8 A/cm²
- Resistor shunt
- Recording of shunt voltage
- Additional T sensors (local)
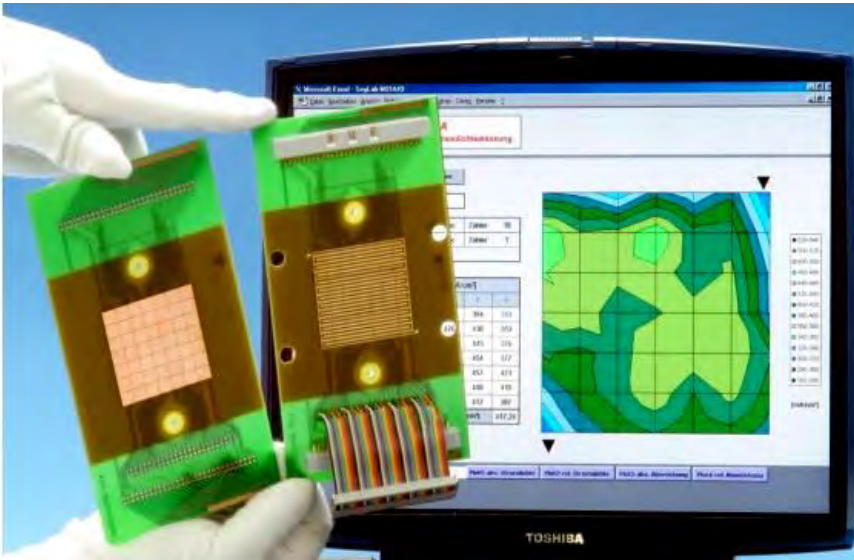- Local EIS (single segment readout)
- Operating temperature max 200°C
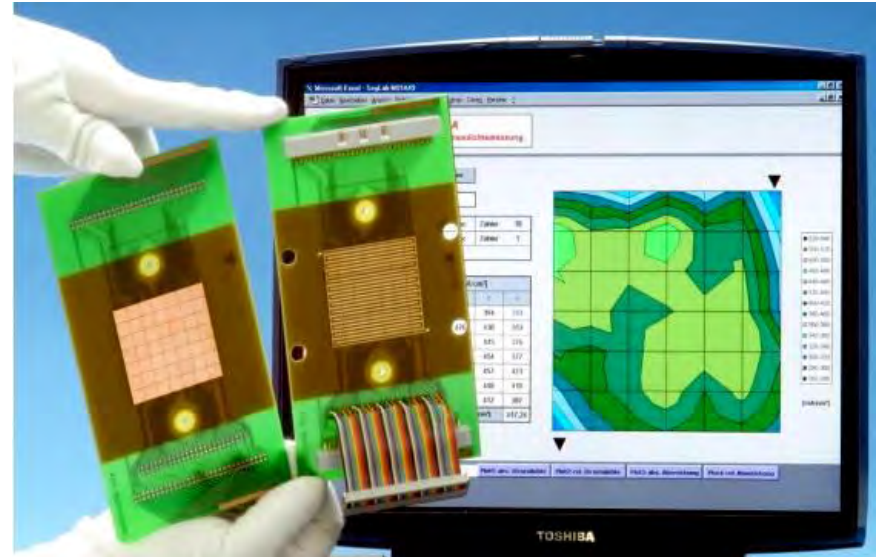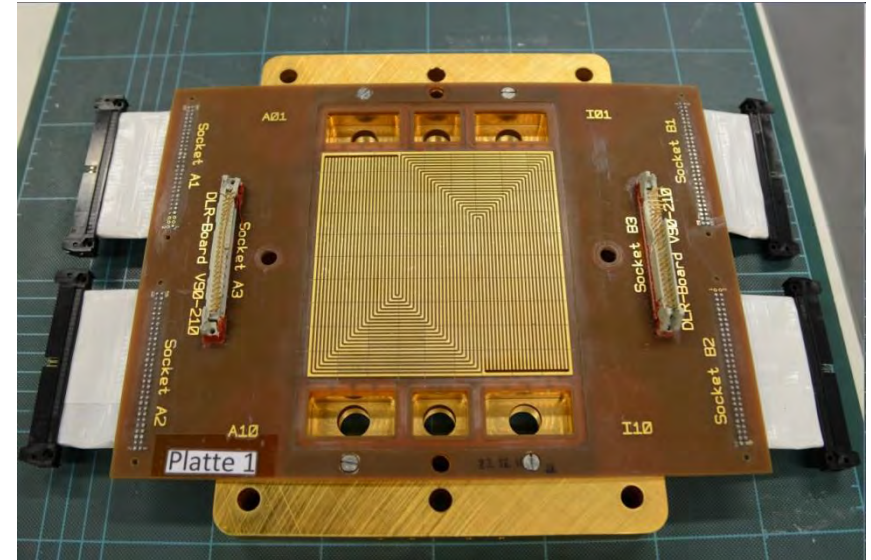
Technology: Segmented Printed circuit boards

o Milling of flow fields possible
o Limit to local resolution by
- Flow field
- PCB layout / thickness / connectors
- Data acquisition
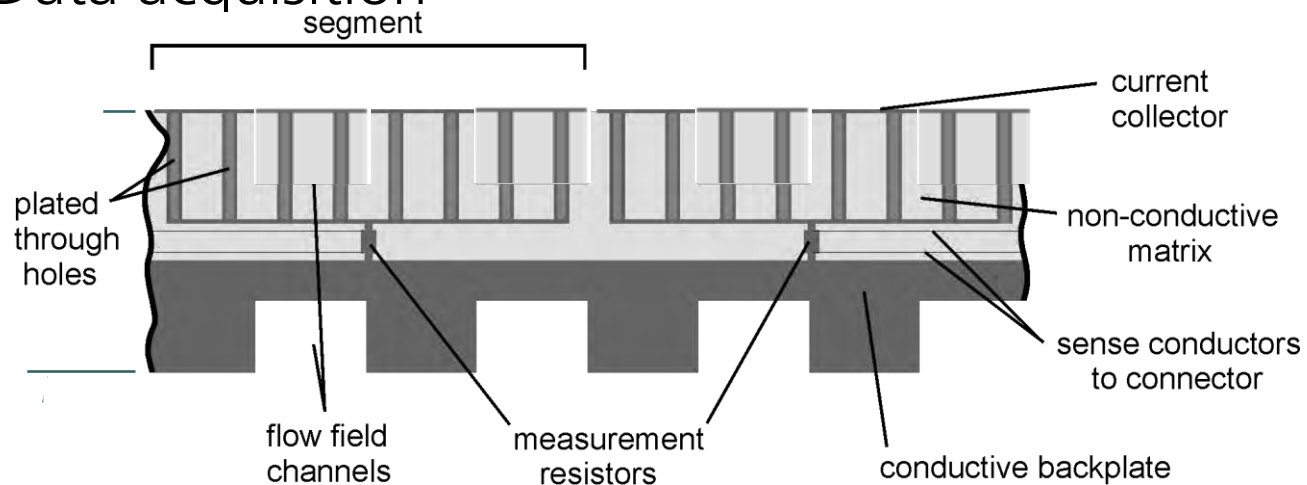
Technology: Segmented Printed circuit boards
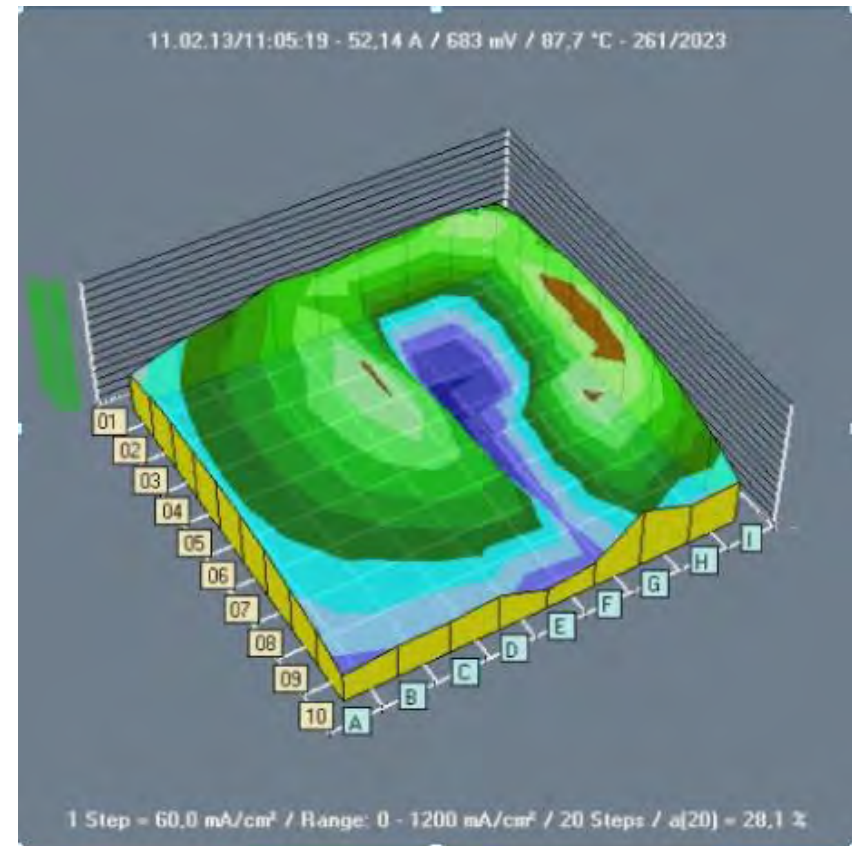

Lab scale single test cell
25 cm², 49 segments

Fuel cell stack size
>150 cm², 108 segments

Technology: Segmented Printed circuit boards

Application

o Systematic studies on fuel cell
o Optimization of Performance
o Malfunctioning
o Humidification
o Heat dissipation
o Oscillating chemical reactions
o Flow field evaluation
o GDL enhancement

Flooding event in PEMFC

INSIDE – In-situ Diagnostics for Water Electrolysers

R&D Project funded by FCH JU:
Adaptation of segmented PCB to
- PEMWE
- AWE
- AEMWE

Consortium: 5 partners
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
- NEL Hydrogen ASA, Norway
- Heliocentris Italy S.r.l., Italy
- CNRS / Université de Strasbourg, France
- Hochschule Esslingen, Germany

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PEMWE	AEMWE	AWE

Targetted development

Grid stabilisation:
- Supply based operation
- Flexibility (KPI 5)
- Durability (KPI 3, 4)

Industry:
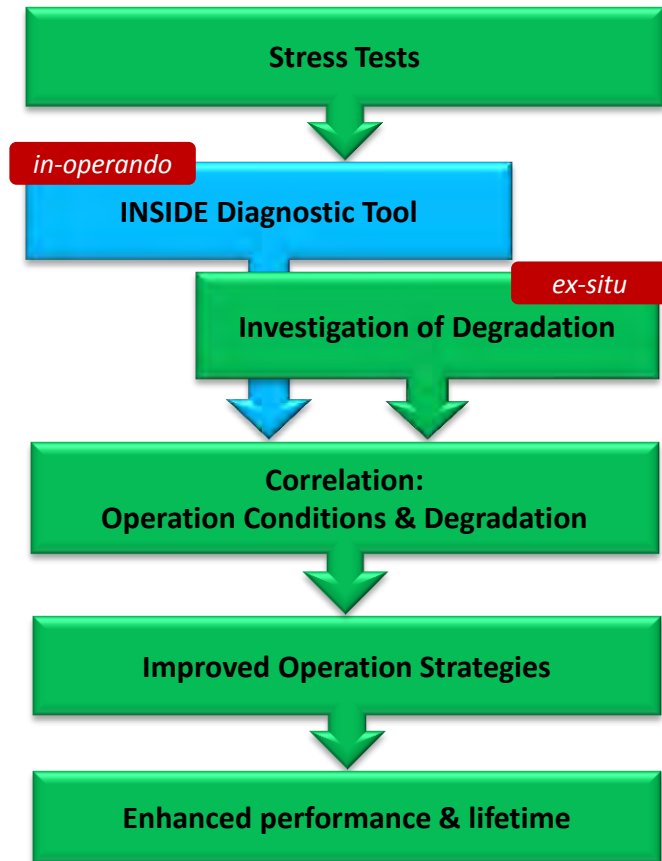- Demand based operation
- Efficiency (KPI 1, 2)

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Objectives

Provide in-operando monitoring for
- Harvesting of hidden performance
- Revealing hidden deficiencies
- Enhancing durability
- Preventing critical operation
- Targeted developments
- Evaluation of modellling
- Evaluation of AST

Stress Tests

in-operando

INSIDE Diagnostic Tool

ex-situ

Investigation of Degradation

Correlation:
Operation Conditions & Degradation

Improved Operation Strategies

Enhanced performance & lifetime

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Challenges & Achievements

Contact Resistance: PCB – instead of BPP
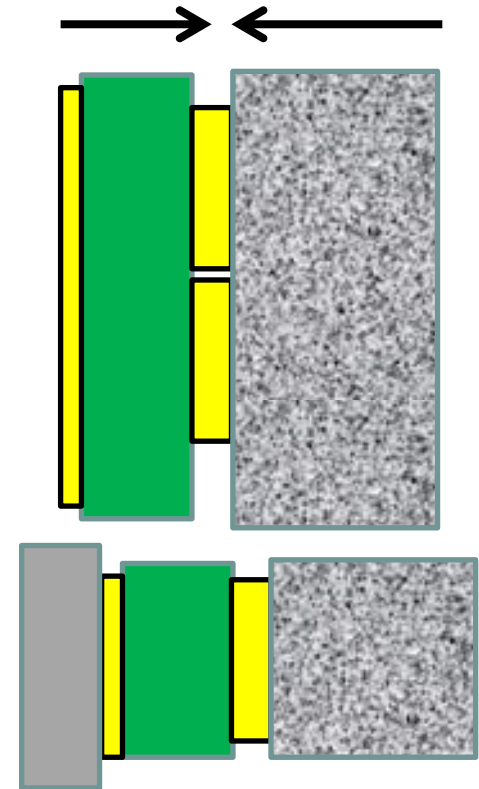Carbon GDLs vs. metal foams/felts
→Increase of gold coating thickness
→graphitic coating (under development)

Differential Pressure
→adjust PCB thickness
→add regular BPP

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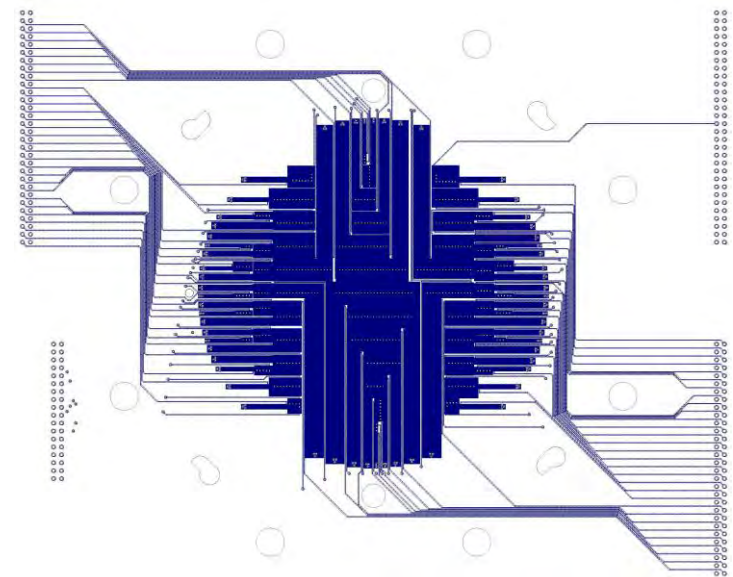
Challenges & Achievements

Number of data recording channels
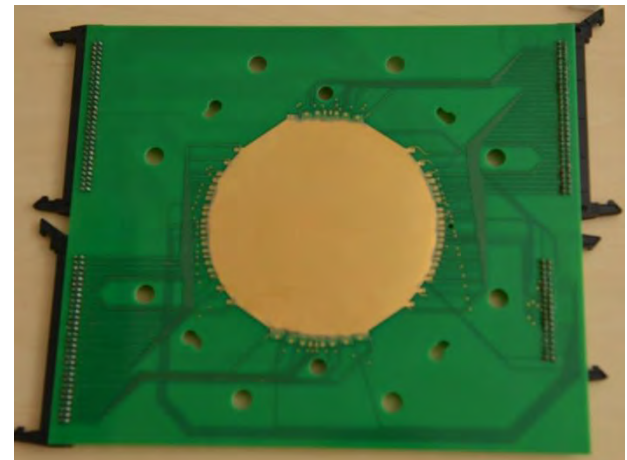Space requirements:
PCB circuits compete with hardware
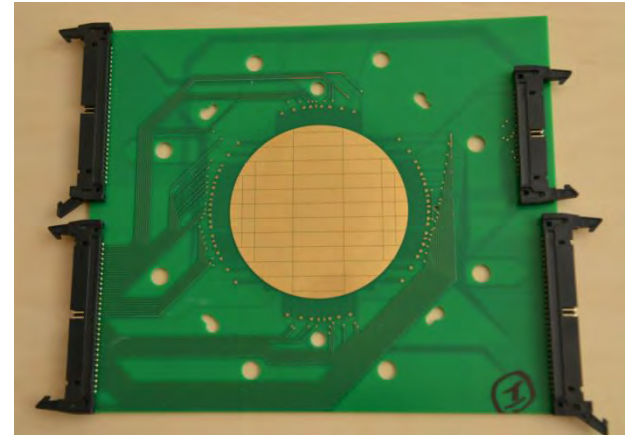→ More complex layouting
→ More PCB layers

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Challenges & Achievements

AEMWE prototype:
Gas & electrolyte tightness
- Pressure
 →adapt sealing concept
- Surfaces
  →metal coating

Prototype for AEMWE

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Challenges: Corrosion

- AWE conditions (30%KOH, >60°C)

Sealings barely stop KOH lye
Lye migrates along copper lines when accessible

- PCB material itself (FR4 epoxy) can be attacked

Invasion between laminated layers
→avoid exposure
→or seal edges of PCB
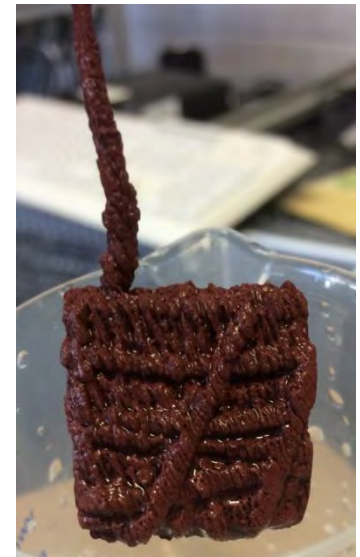
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Data acquisition

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

Data acquisition : Keysight (HP/Agilent) 34980A

Intuitive front panel with self-guiding menus

See results on bright, multiline display

KEYSIGHT 34980A

6 ½ digit DMM measurements with 11 functions

Scan multiple channels, close specified channel list, or monitor results on a single channel

Configure measurements by channel

Set up scan lists

Use keypad to enter channel number or knob to scroll

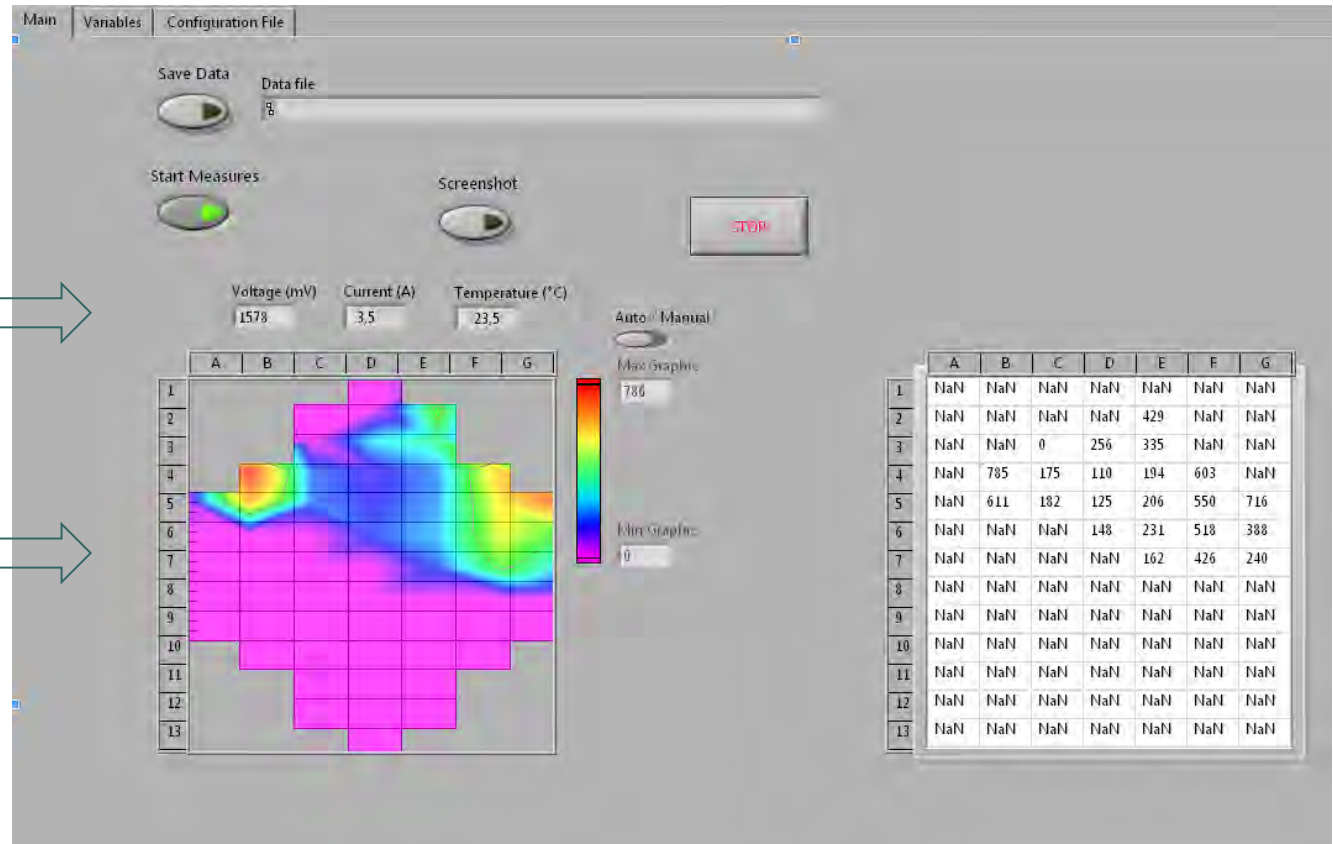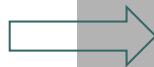Store up to 500,000 readings with timestamp

INSIDE – In-situ Diagnostics for Water Electrolysers

Data acquisition & visualisation

Overall values

Local current
densities

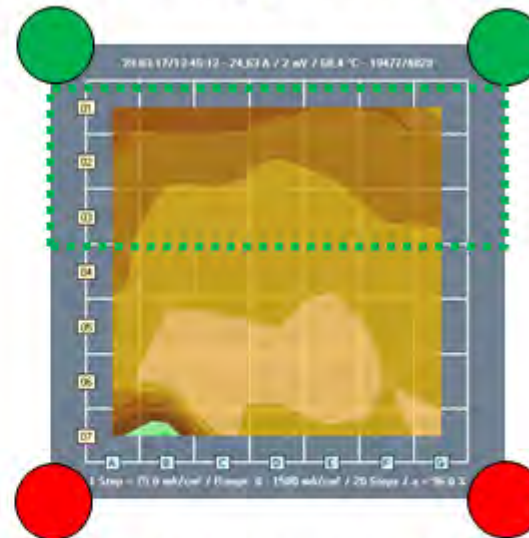# Examples for Application (25 cm² test cells): Contact resistance and pressure

A/cm²

>1.5
1.5

1.0

0.5

0.0

Homogeneous torques

Non- homogeneous torques
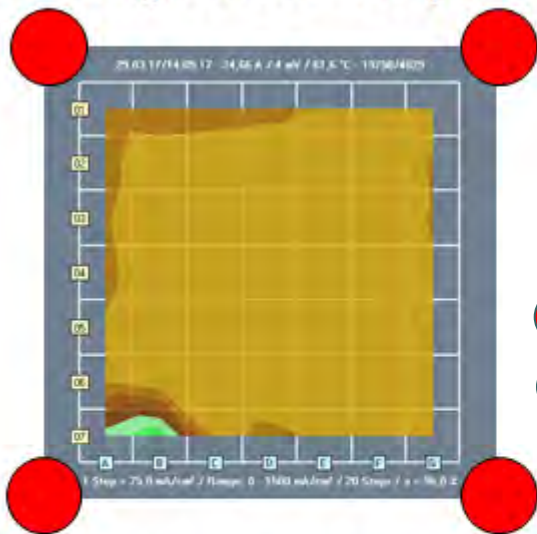
🔴 2.2Nm
🟢 0.5Nm

Homogeneous current distribution
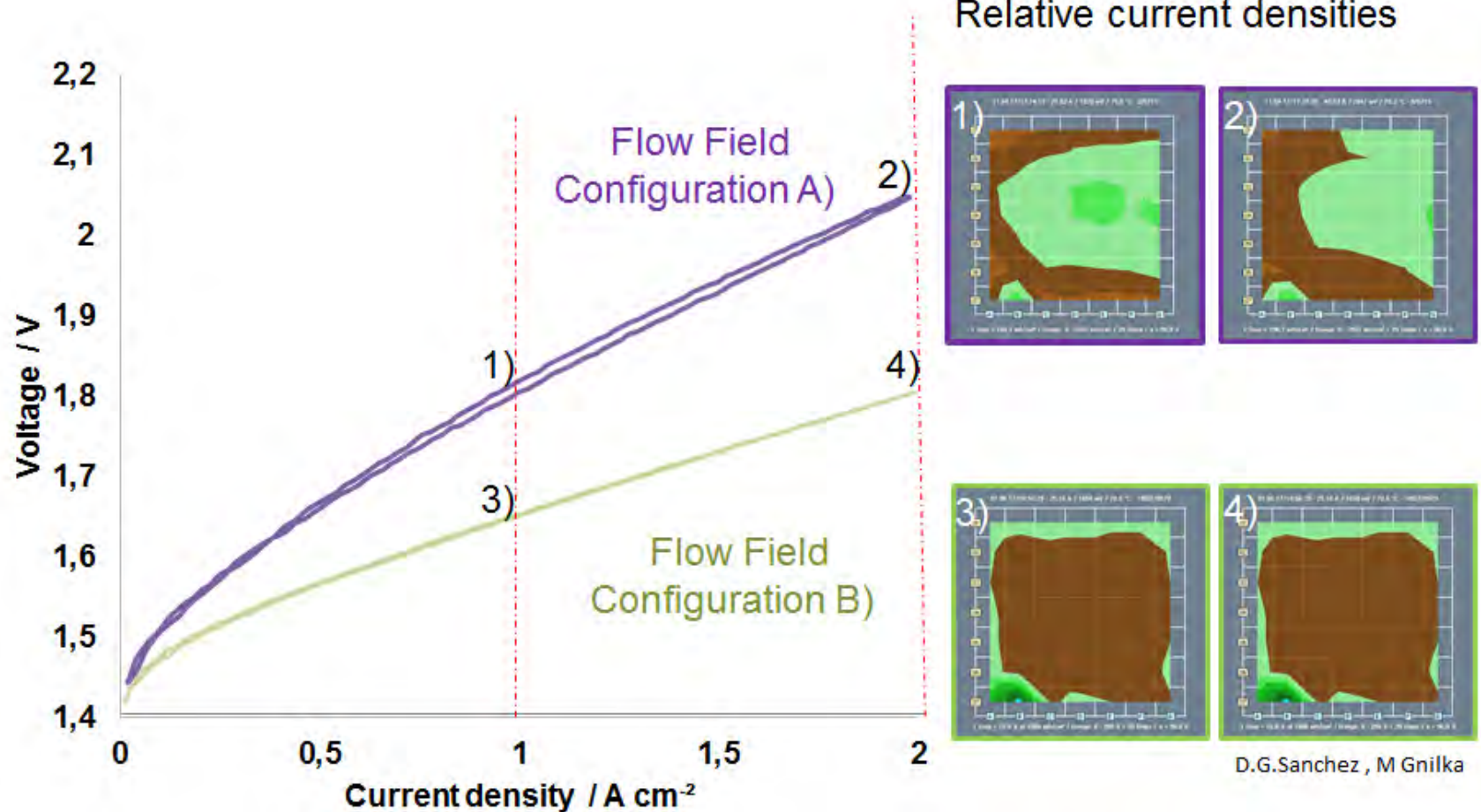
Non - homogeneous current distribution

D.G.Sanchez M Gnilka
(Manuscript in
preparation)

MEA: Greenerity E400E (Nafion 115)
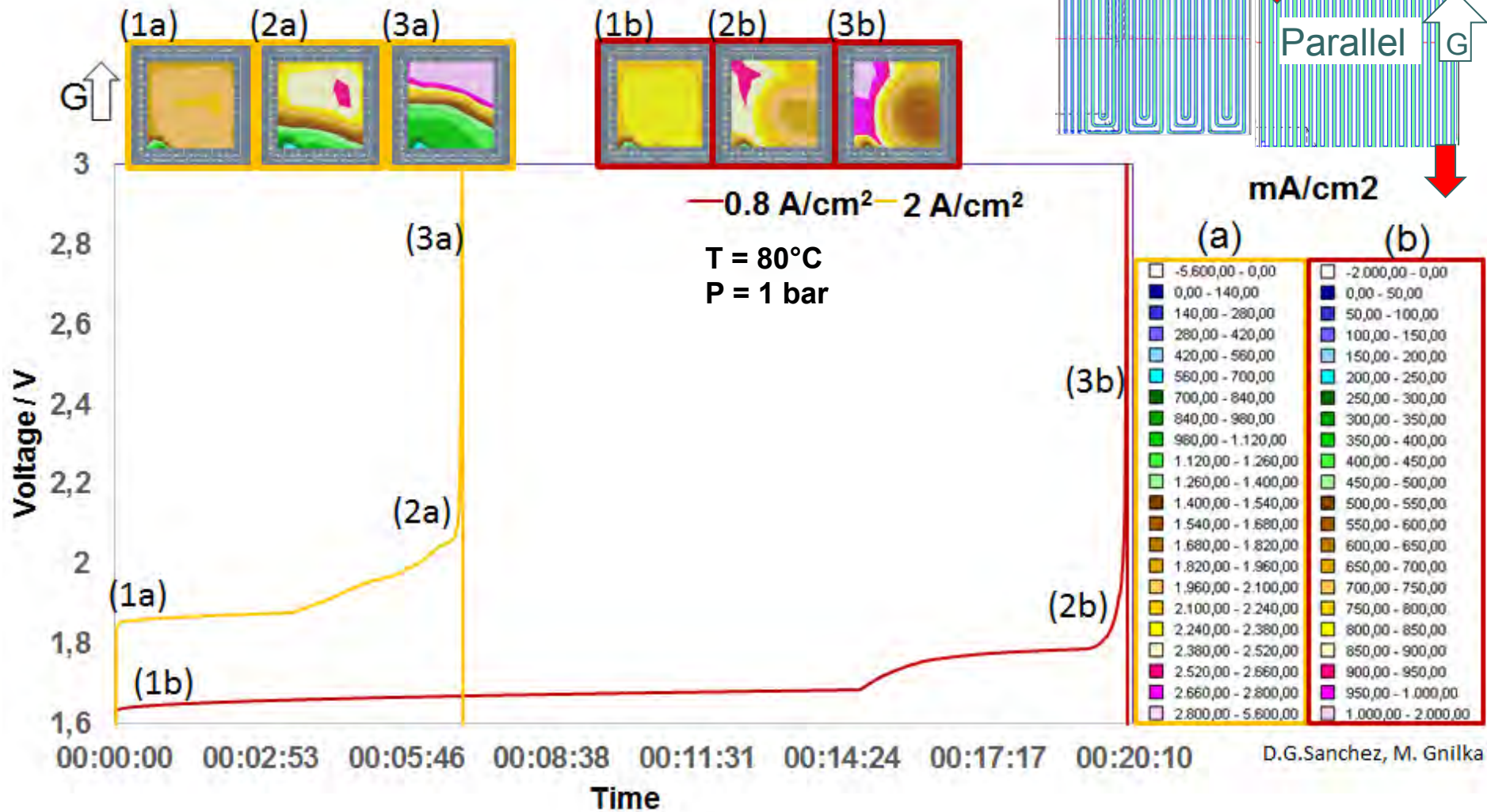Anode GDL: Sinter titanium   Cathode GDL: Carbon paper

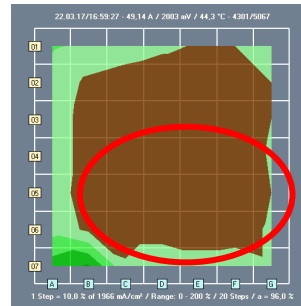DLR

Examples for Application: Flow field evaluation

Relative current densities

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WP4 – PEM electrolysers

Examples for Application: Water starvation

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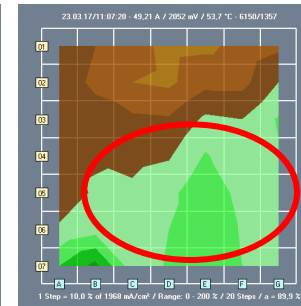# Examples for Application: Irreversible Degradation
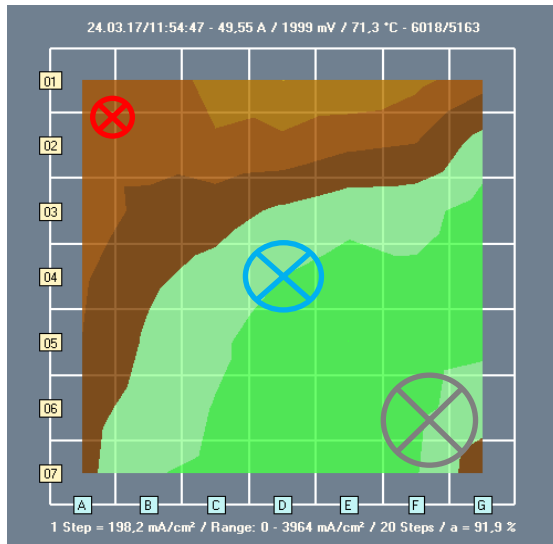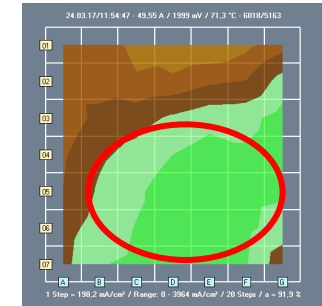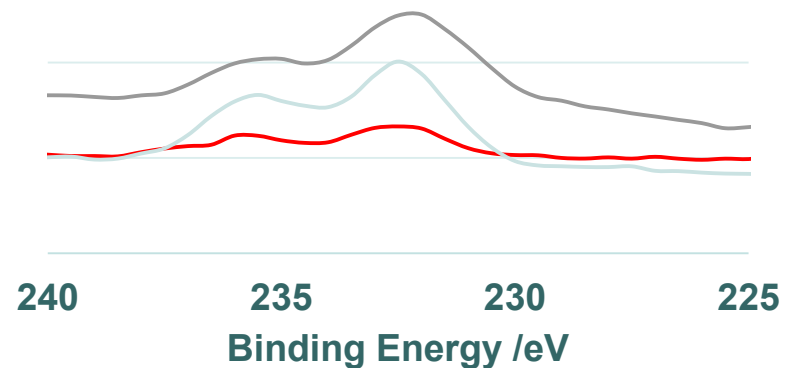
1day   **2 day**   **3 day**

Local post-mortem investigations (XPS):
Mo traces in cathode catalyst layer,
correlating with local irreversible degradation

**Binding Energy /eV**

240   235   230   225

—— A1 Kathode   —— D4 Kathode   —— G7 Kathode

Summary and Outlook

o *In-operando* Diagnostics
o Visualisation
o Little disturbance
o Costs depend on upscaling & data acquisition
o Application:
o Development (Materials, Designs)
o Monitoring
  - Steady monitoring
  - Response to diagnostic cycles
o Evaluation of numerical modelling
o Evaluation of testing protocols & ASTs
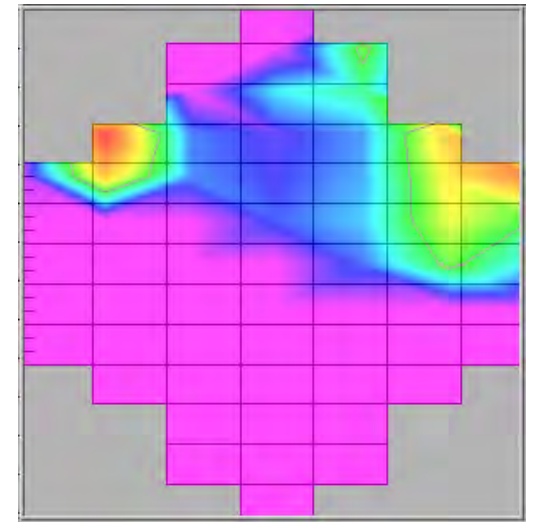
Acknowledgements

INSIDE consortium

Magnus Thomassen
Anders Søreng
Chiara Emiliani
Siegfried Limmer
Elena Savinova
Viktoriia Saveleva
Renate Hiesgen
Tobias Morewietz
Mathias Schulze

EWII

Laila Grahl-Madsen
Theiss Stenstrøm
Bertil Sieborg

People at DLR

Daniel Garcia Sanchez
Olivier Garrot
Michael Gnilka

FCH JU

Thank you for your attention!

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