Monitoring of current density distribution

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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
Current Density

- Key point indicator for electrolyzers and fuel cells: efficiency of used materials (PGMs, etc.)
- Faraday’s Law:
  Current density equals chemical turnover
- 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

- Milling of flow fields possible
- 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

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

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

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

Targeted development
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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 modelling
• Evaluation of AST
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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
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Data acquisition & visualisation

Overall values

Local current densities
Examples for Application (25 cm² test cells):
Contact resistance and pressure

Homogeneous torques

- 2.2Nm
- 0.5Nm

Non-homogeneous torques

MEA: Greenerity E400E (Nafion 115)
Anode GDL: Sinter titanium
Cathode GDL: Carbon paper
Examples for Application: Flow field evaluation

![Graph of Voltage vs. Current Density]

Flow Field Configuration A)

Flow Field Configuration B)

Relative current densities

1. [Image of current density distribution]
2. [Image of current density distribution]
3. [Image of current density distribution]
4. [Image of current density distribution]

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WP4 – PEM electrolysers

Examples for Application: Water starvation

T = 80°C
P = 1 bar

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Examples for Application: Irreversible Degradation

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

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