Efficient Use of Energy Converting Applications

Nadine Jacobs

Agenda

- Introduction NEXT ENERGY
- EURECA
  - Principal objectives
  - Research areas
  - Test protocols
- Stacktest
  - Stadardisation
- DEMMEA
  - Degradation Mechanisms in HT-PEM MEAs
  - Compression Unit Instrumentation
  - Results from recent experiments
- Summary and outlook

Energy Research for the Future

- New building since August 2009
- 4150 m² floor space
- 2330 m² space for R&D-activities

NEXT ENERGY – Facts and Figures

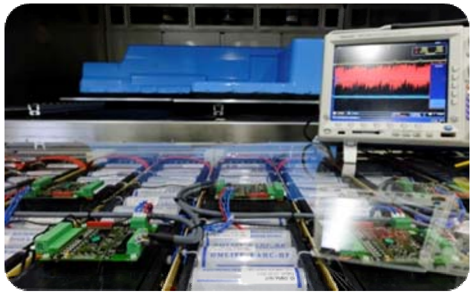
- About 95 employees in R&D and administration
- Founded in March 2007 as independent Research Institute at the Carl-von-Ossietzky-University Oldenburg
- Organised as a non-profit association with EWE as a main sponsor as well as the University of Oldenburg and the state Lower Saxony as members
- Research in the fields of Renewable Energies, Energy Infrastructure and Energy Efficiency

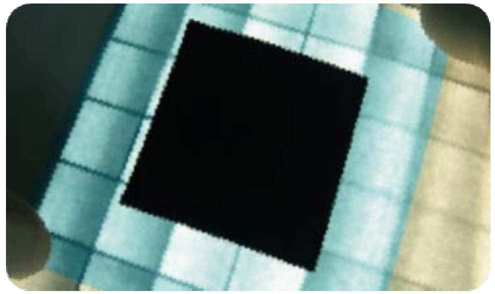
Research and Development

Photovoltaics
Power from light and
thin layers

Energy Storage
From electrochemistry
to grid integration

Fuel Cells
Power and heat
efficiency with future



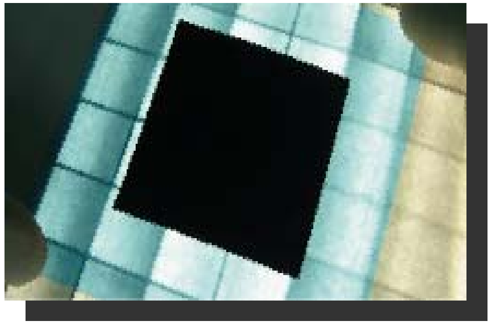


Head of Division
Dr. Karsten von Maydell

Head of Division
Dr. Wedigo von Wedel

Head of Division
Dr. Alexander Dyck

Fuel Cell Research Topics



Fuel Cells

Power and heat efficiency with future

Division Head:
Dr. Alexander Dyck

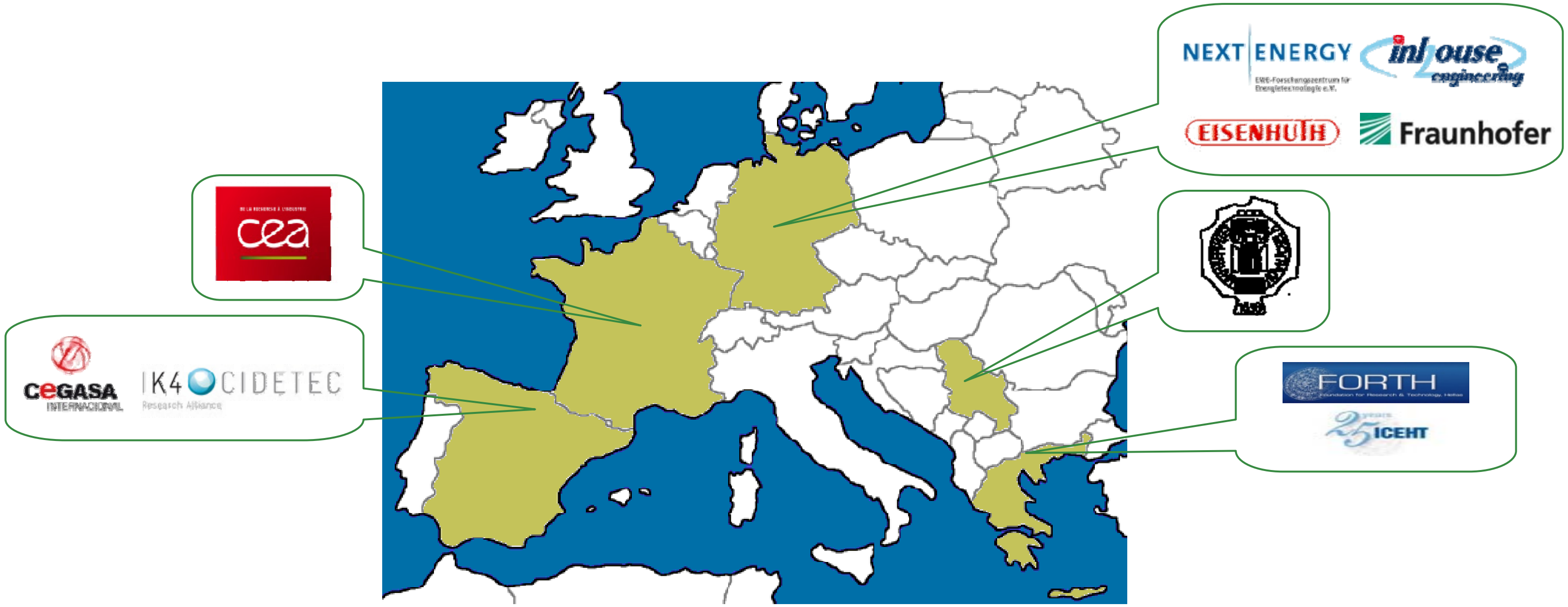
Micro-CHP-Systems
System Test and Integration, HEMS

Characterisation
Analytics and Methods, Coatings, Degradation

Materials
Catalysts and Membranes for AEMFC and Electrochemistry

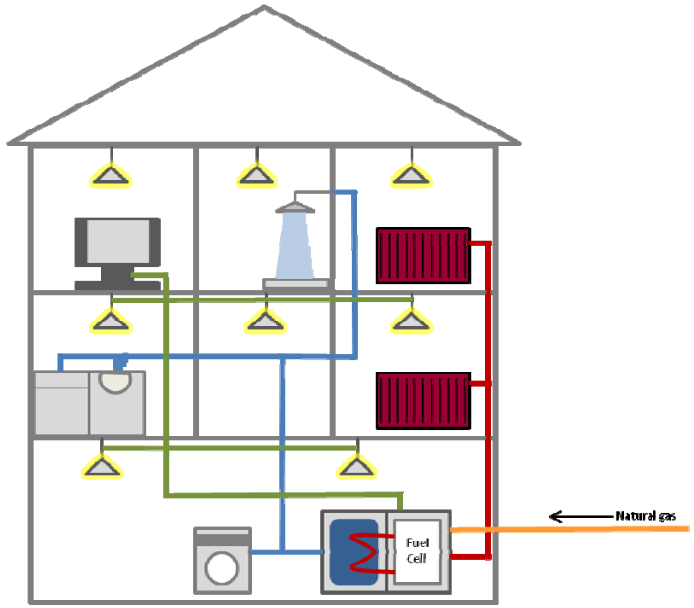
EURECA - Consortium

- Efficient Use of Energy Converting Applications (Grant Agreement N° 303024)
- Project run time: 01/07/2012 – 30/06/2015
- Consortium:



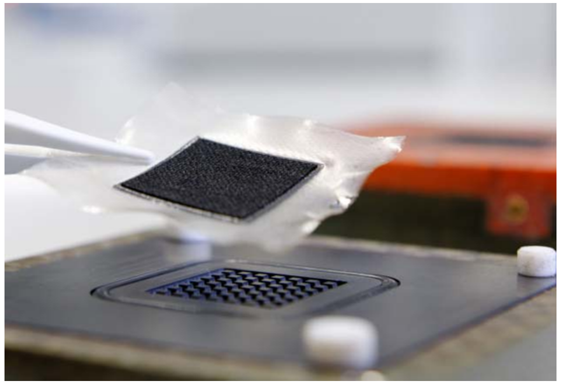
Principal Objectives

- Developing the next generation of a micro combined Heat-and-Power (µ-CHP) systems based on advanced PEM stack technology
- Overcome the disadvantages of complex gas purification, gas humidification, and the low temperature gradient for heat exchangers in a heating system
- Developing a new stack generation with operating temperatures of 90 to 120 °C
- A less complicated, high efficient, and therefore a robust µ-CHP system with reduced costs



Development on MEA and BBP

- **MEA**
  - Development and qualification of membranes
  - Development and qualification of catalyst materials and active layers
  - Performance, lifetime and degradation analysis
  - MEA preparation, up-scaling and manufacturing of EURECA MEAs



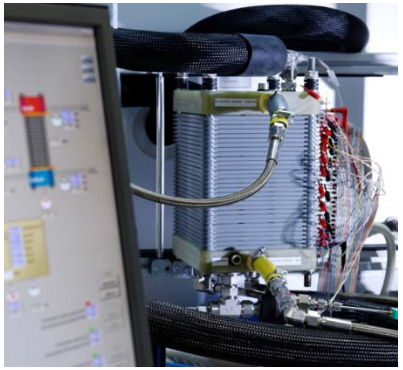
- **Bipolar Plate and Gaskets**
  - Improvement of BBP materials
  - BBP production
  - New Gasket concept
  - Modelling the flow
  - Testing the BBP (Conductivity, Cycling, CV)

http://www.eisenhuth.com/pages/bipolar.html

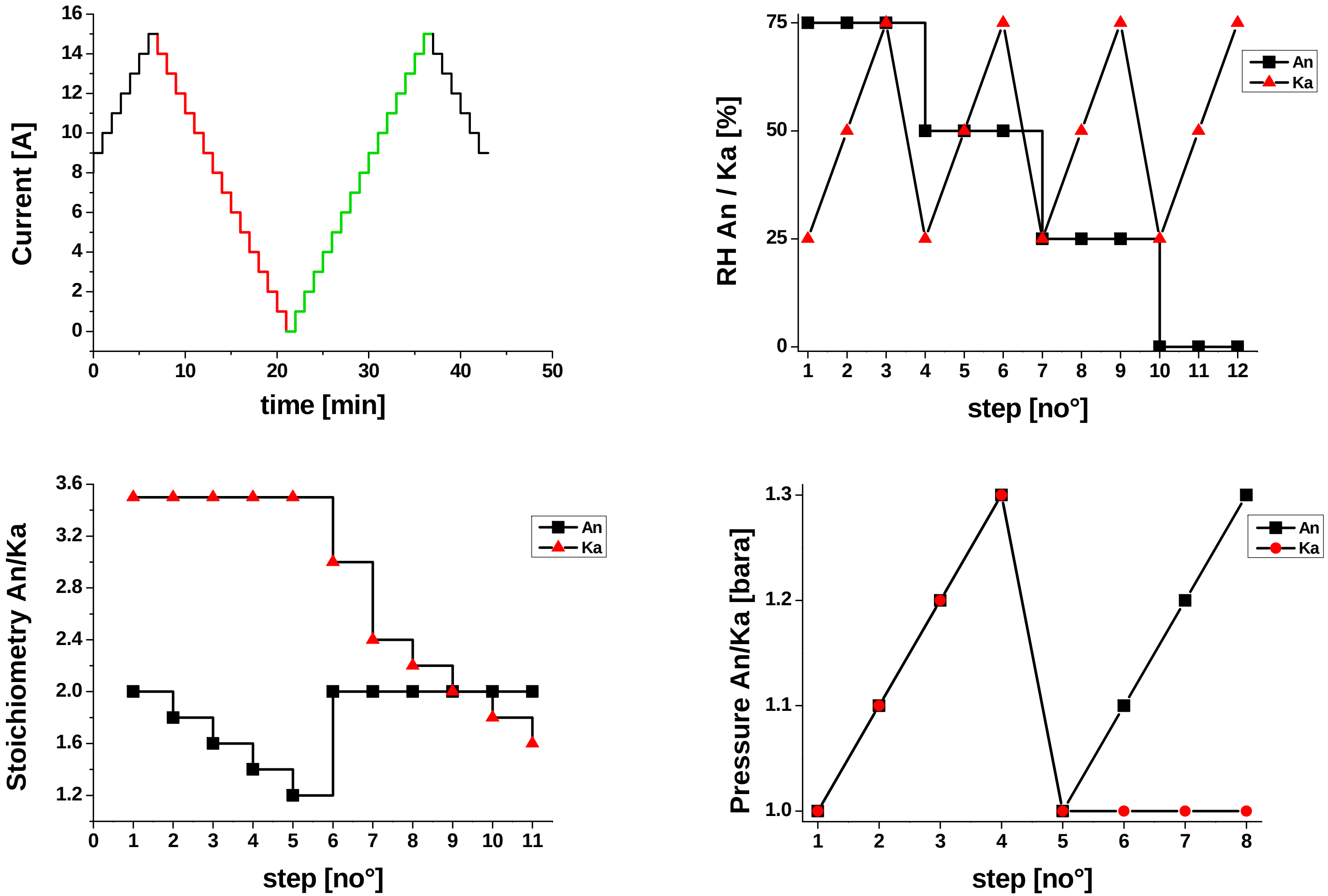
Development on Stack and System

- **Stack**
  - Adaption of cell design, stack design and materials to EURECA stack
  - Modelling on flow and concentration distribution
  - Stack performance and degradation
  - Integration into the system

- **System**
  - Integration of EURECA stack into µ-CHP system
  - µ-CHP-system performance and degradation



Stack Testing Procedures



Stacktest

- Developing a full set of testing procedures addressing:
  - Function and performance
  - Durability and degradation
  - Safety and environment

- Indentify test modules and programs to address degradation under different conditions and for various applications

Different Levels of Degradation Investigations

- Investigation of the loss of efficiency as a function of time on:
  - CHP Units
  - Fuel Cell Stacks
  - **MEAs**
  - Single Components
- Each component in a MEA contributes to the overall efficiency loss!

Parameters Influencing the Degradation of a MEA

- Extrinsic parameters (may directly be influenced by the operator)
  - Operating temperature
  - System pressure
  - Mechanical MEA fixture and Compression (commercial or individual ones, flow fields ...)
  - Cooling
  - Gas volume flows, composition, impurities, temperatures and humidification (anode and cathode)
  - FC test station or setup
  - Startup protocols and conditioning
  - Electronic load profiles
  - Start-stop cycling
  - ......

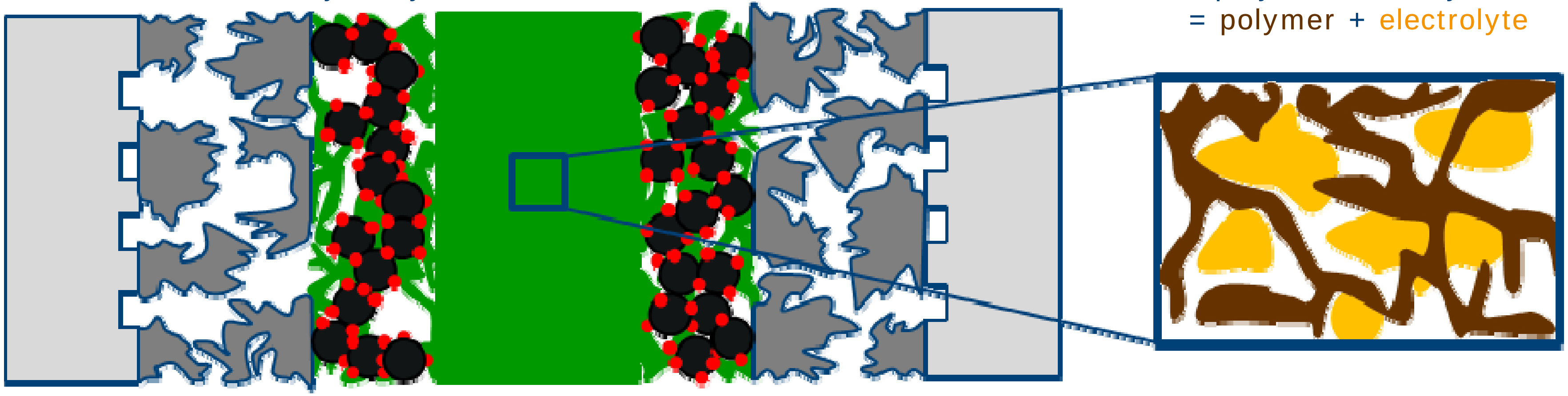
Parameters Influencing the Degradation of a MEA

- Intrinsic parameters (not directly influenced by the operator)
  - Membrane materials and composition
  - GDL materials and surface modification for hydrophobicity
  - Catalyst materials and composition
  - Electrolyte (HT-PEM)
  - Chemical resistance of all components against hot H_3PO_4
  - Catalyst dissolution, migration, precipitation and agglomeration
  - Carbon corrosion
  - Chemical reactions caused by different radicals or H_2O_2
  - (Gasket materials)
  - (Bipolar plate materials and composition, surface coatings and flow fields)
  - …. More? …..

Role of Compression for Polymer / H_3PO_4-MEA

Flow field GDL + catalytic layer membrane

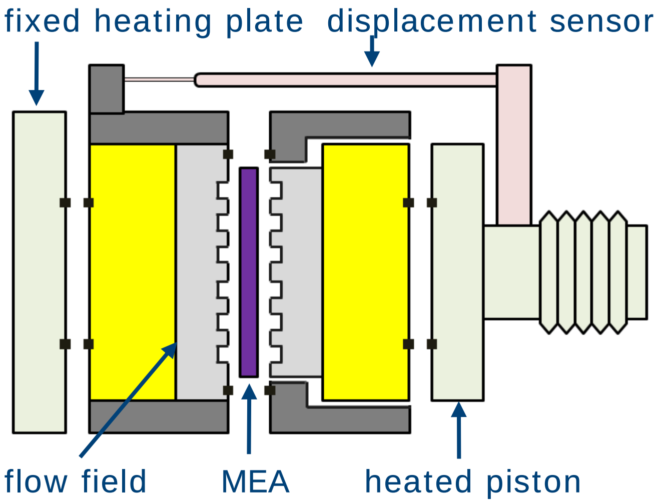
„polymer electrolyte“
= polymer + electrolyte



Possible effect on	Possible consequence for	Methods
GDL porosity	Reactant supply	EIS, IV
Membrane thickness	Ionic resistance, reactant crossover, internal short circuit	EIS, LSV
H_3PO_4 penetration into CL	3-phase reaction zone, flooding (reactant supply)	CV, EIS
Electrical contact	Electrical resistance	EIS, IV
Material integrity	Physical modifications and damages	Imaging techniques

Cell Compression Units

Schematic

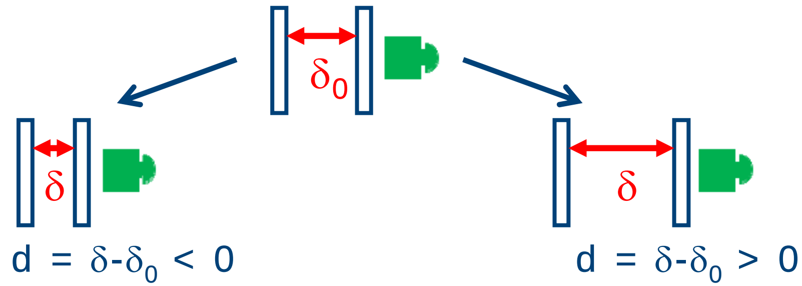


F = 0.5-6.25 kN
(0.2-2.5 MPa for 25 cm²)
T = 20-200 °C
d = 0-2 mm

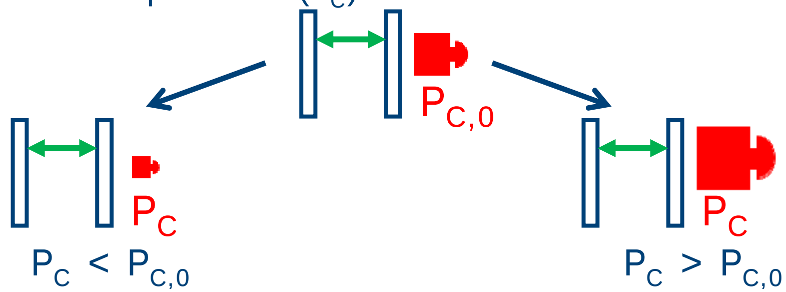
Requirement: steady compression

Operation mode

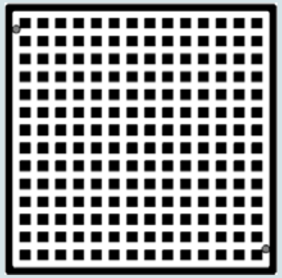
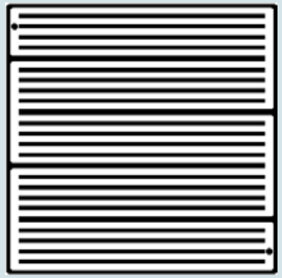
1. Constant contact pressure
   → Displacement change (d) as measured variable



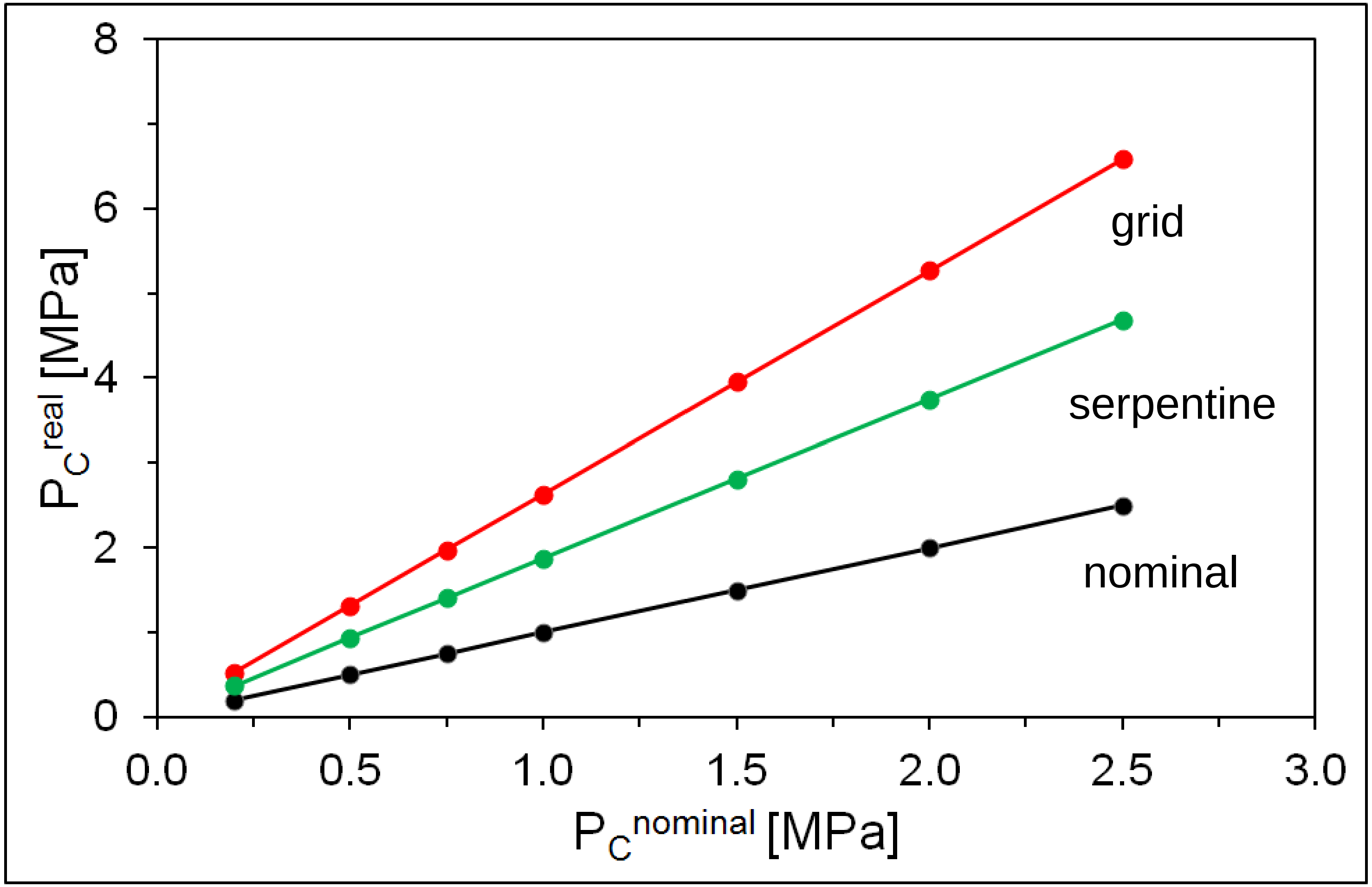
2. Constant displacement
   → Contact pressure (P_C) as measured variable



MEA Analysis: Details

MEA Property	#A	#B
Type (GDL)	Celtec®-P2100 (Woven carbon cloth)	Celtec®-P2100 (Woven carbon cloth)
Serial-Nr.	#14799-037	#14799-038
Thickness [µm]	929	917
Active area [cm^2]	20.25	20.25
Flow field design	Grid 	5-Fold serpentine 
• Nominal area [cm^2] • Total land area [cm^2]	25 9.49	25 13.35

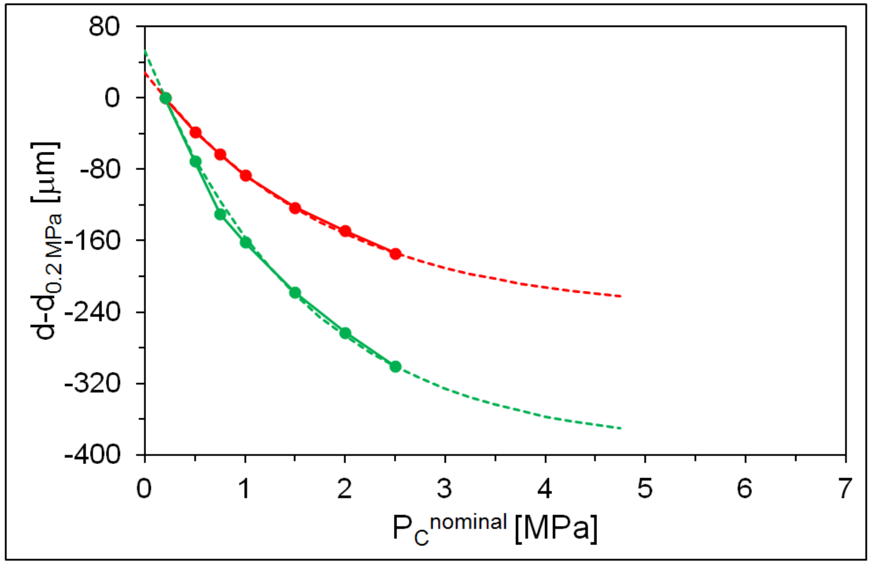
Flow Field Real Contact Pressure

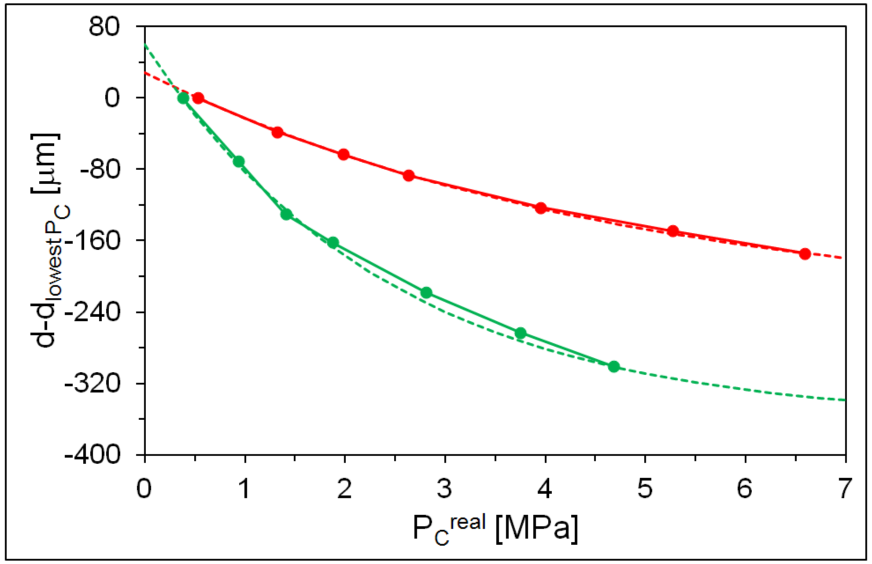


Dietrichs, A.; Wagner, P. ECS Transactions 50(2) 1137-1153 (2012)

Results: MEA Thickness

- Contact pressure variation
  - Nominal contact pressure range: 0.2 – 2.5 MPa
  - Order of change: from low to high





Grid Serpentine

Dietrichs, A.; Wagner, P. ECS Transactions 50(2) 1137-1153 (2012)

Results: IV_{iR}-free-Curves and EIS-Spectra

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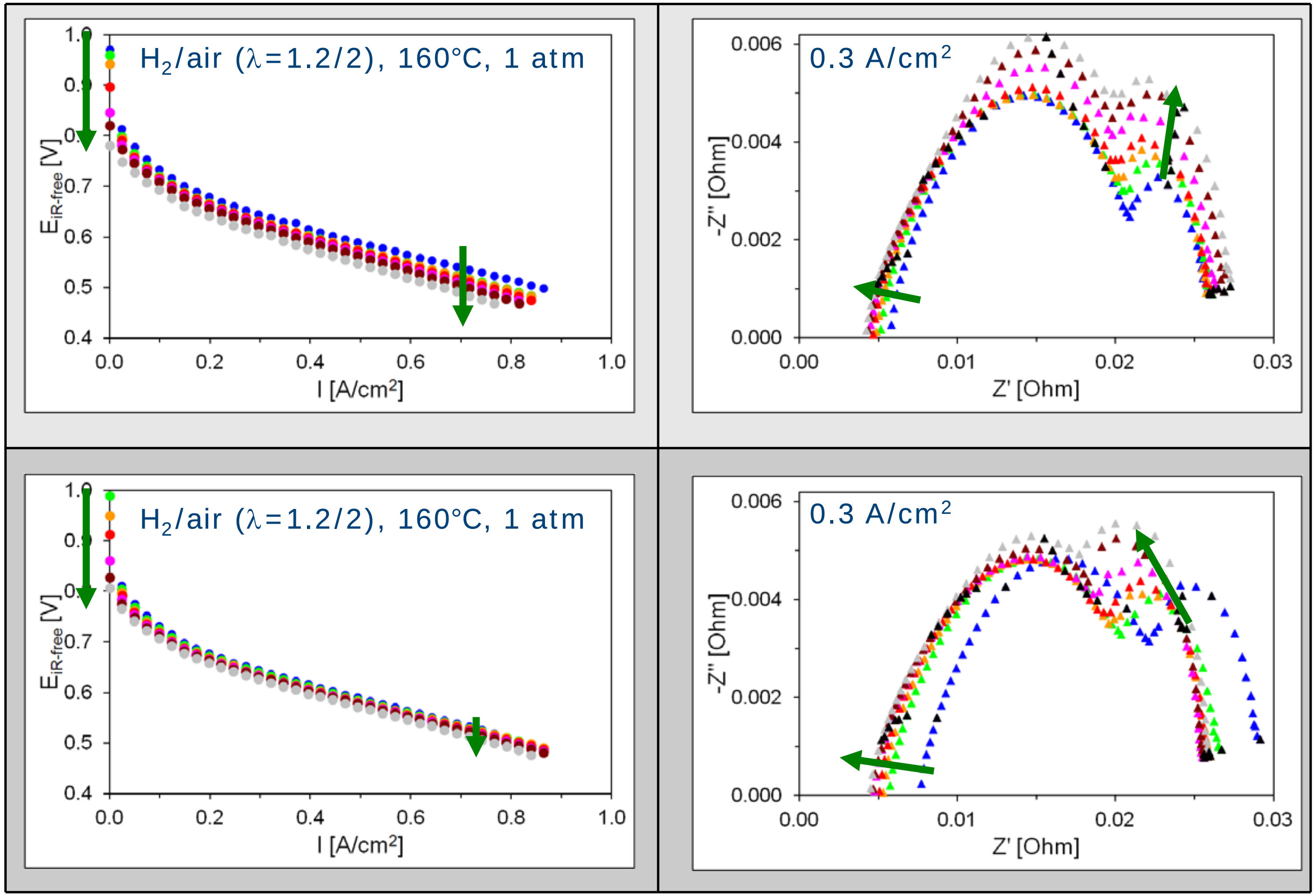
Grid

Serpentine

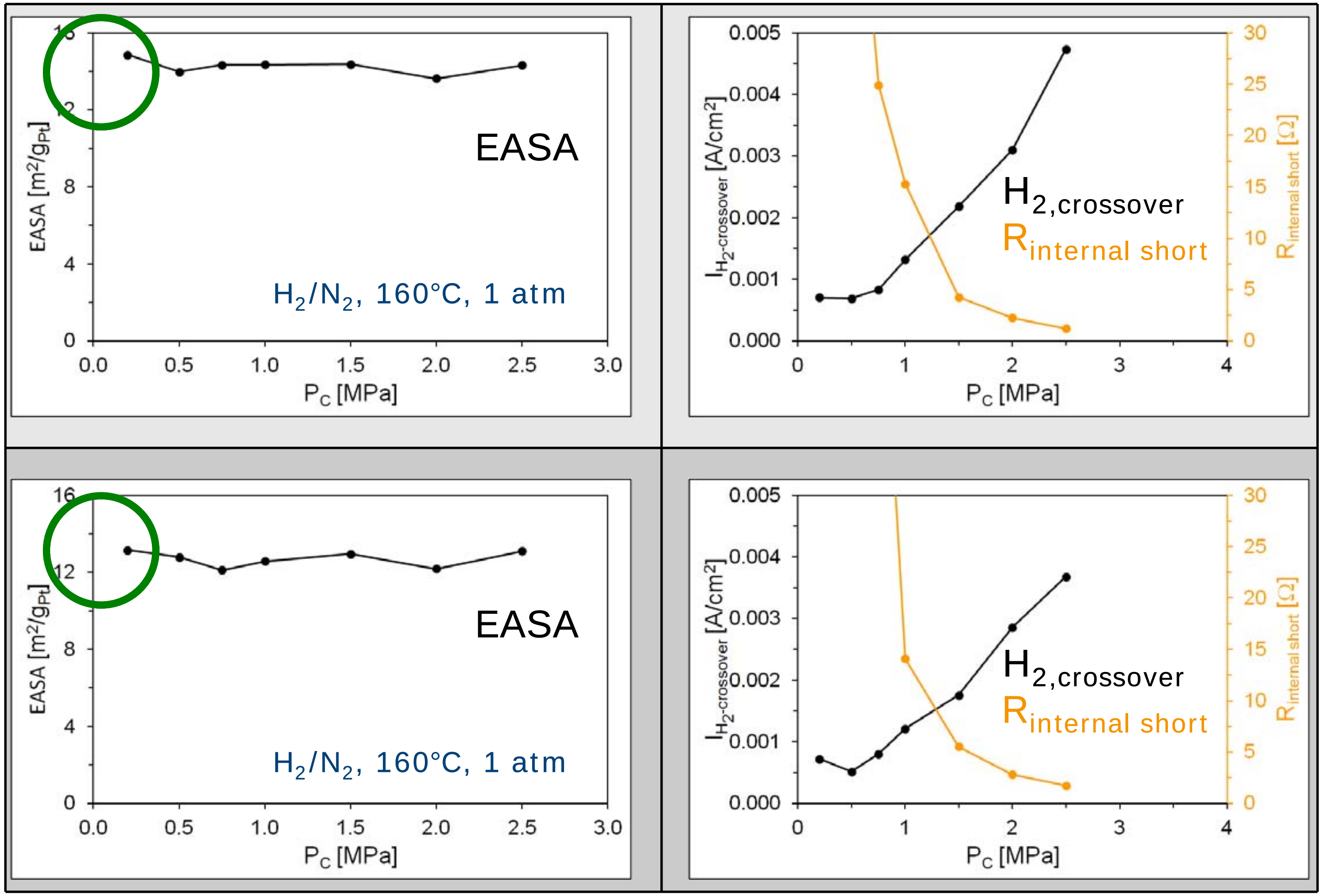


0.2 MPa
0.5 MPa
0.75 MPa
1.0 MPa
1.5 MPa
2.0 MPa
2.5 MPa

Results: CV-Analysis and LSV-Analysis

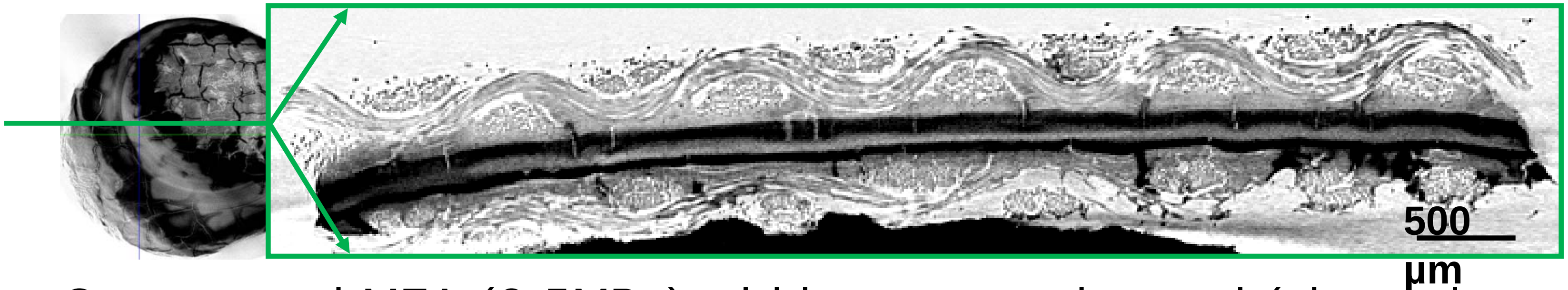
Grid

Serpentine

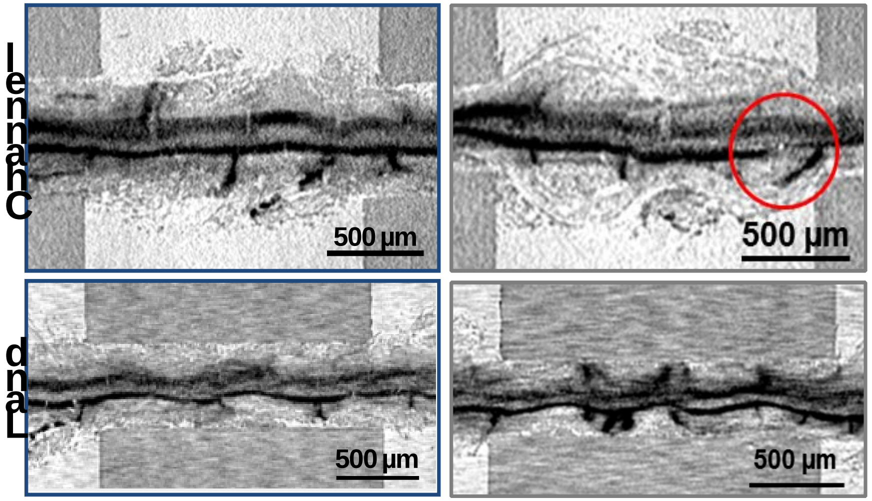


Imaging with µ-CT

- Fresh MEA



- Compressed MEA (2.5MPa) within compression tool (channel-land)



Submitted for publication: Dietrichs et al., Journal of Applied Electrochemistry, Special Issue „ELMEMPRO“

Coupling of Results to Imaging with µ-CT

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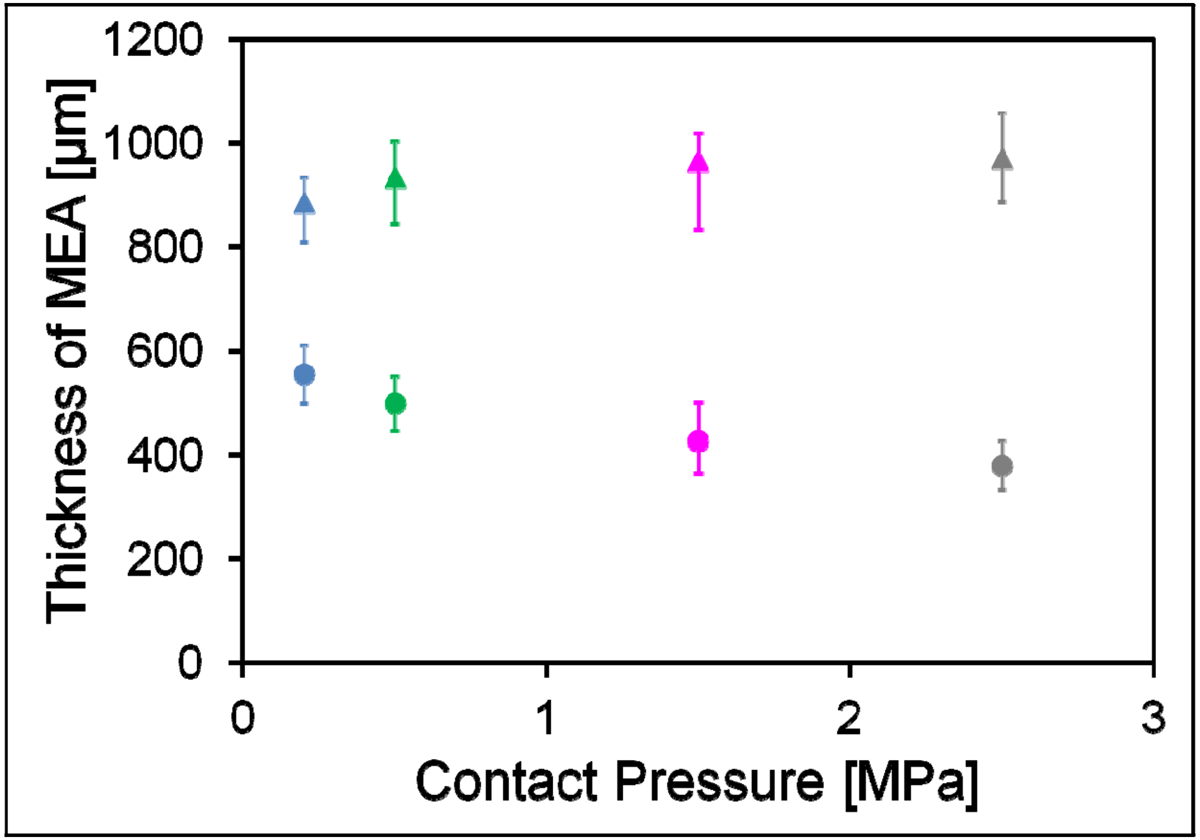
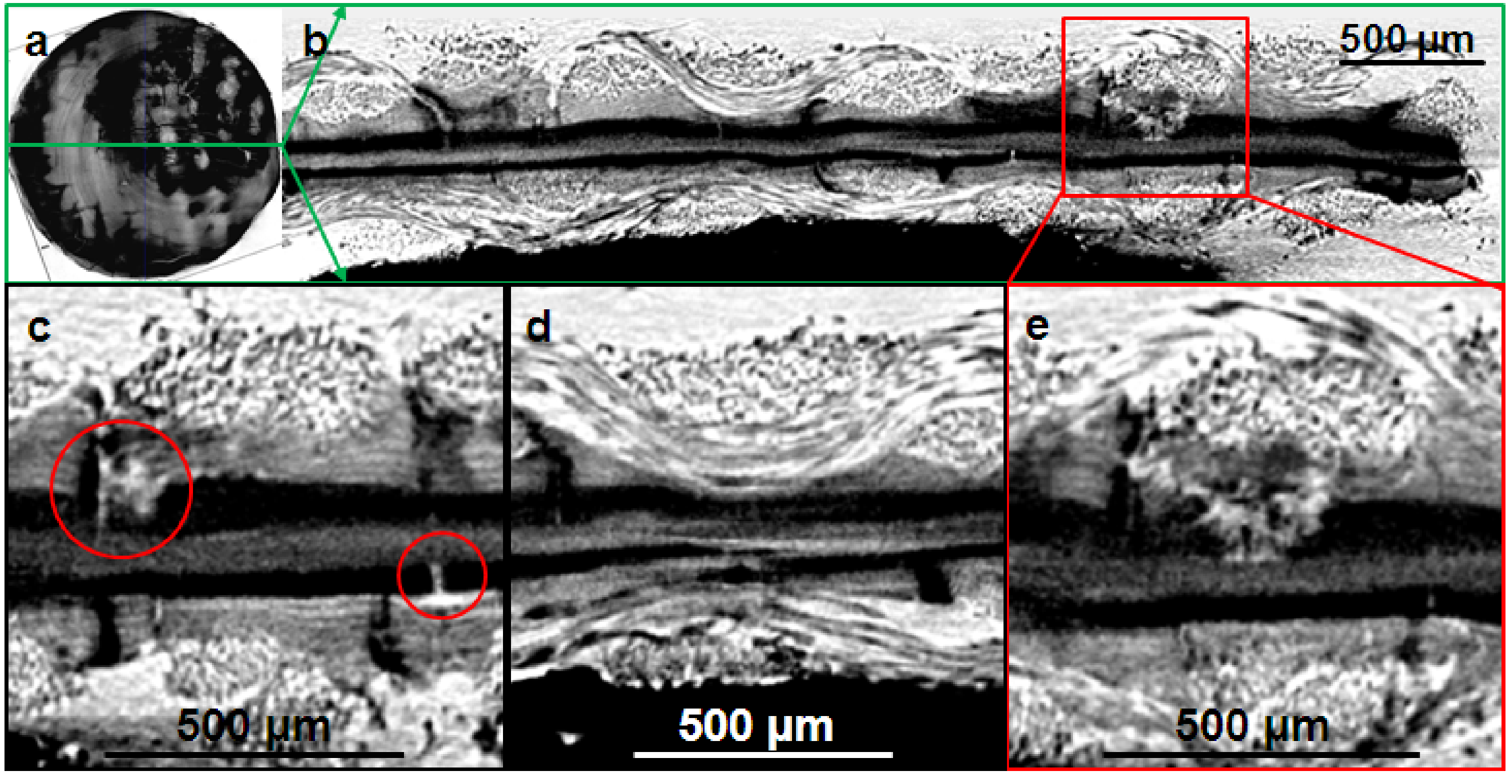
- MEA thickness changes und compression



Submitted for publication: Dietrichs et al., Journal of Applied Electrochemistry, Special Issue „ELMEMPRO“

Coupling of Results to Imaging with µ-CT

- MEA compressed at 2.5 MPa
  after removal from compression tool and 22h relaxation time



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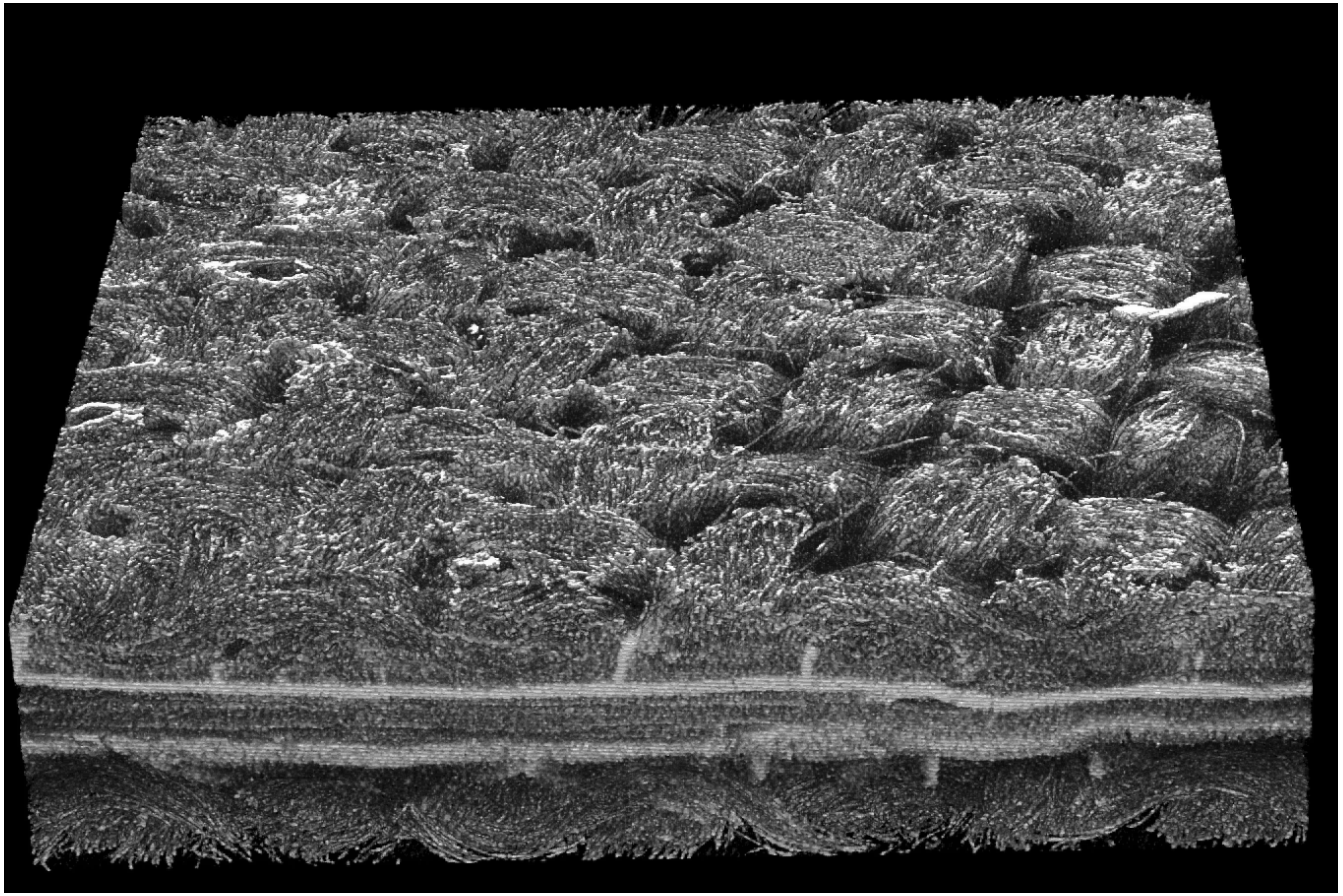
µ-CT imaging through a MEA



Summary and Outlook

- Development of next generation μ-CHP
  - MEA, BBP, Stack, System
- Comparable testing conditions ($FCTES^{QA}$)
- Improving performance and lifetime, reduce degradation

- Standardization of testing for FCs and Stacks

- Use of electrochemical and imaging techniques (μ-CT, SEM)
- Influence of compression during operation with varying experimental conditions
  - Distinction of reversible and irreversible effects
- Determination of membrane and contact resistances during compression

Competences at NEXT ENERGY

Methode	Application example
EIS	MEA- degradation
CV	Active area
LSV	
EQCM	Catalyst dissolution
IV	MEA performance
RRDE	Catalyst
IC	Product water analysis
ICP-MS	Product water analysis
TGA/GC-MS	Membrane degradation
Thermal analysis (DSC, TGA, DMA)	
μ-CT	Mechanical Damages
SEM, EDX, FIB	
Chemical analysis	

PART 1

Components investigated	Conditions applied - please fill in actual operating details in green fields
membrane	conductivity as a function of humidification and temperature
MEA	influence of compression, range 0.2MPa-2.5MPa HT-PEM (constant load 1000h, load cycling 1000h, cathode: air/O_2) OCV (4min, 0.3 A/cm^2 16 min) humidification (dry/humid; RH=0) … Temperature (high/low; T=160/170°C) …
catalyst/electrode	EASA ICP-MS: product water analysis (Pt-loss) IC/ICP-MS: H_3PO_4-loss
GDL	influence of compression, range 0.2MPa-2.5MPa imaging methods SEM, EDX, µ-CT, microscopy
cell plates	imaging methods SEM,EDX, microscopy phosphate loss of MEA long term corrosion in hot H_3PO_4 (160°C)
seals	imaging methods SEM,EDX, microscopy

PART 2

Main degradation mechanisms (irreversible/reversible) - rank from 1-6 confirmed/expected contribution to cell voltage decay (Anode/Cathode)		Further details - please specify further if possible
Contamination (A/C)	**5**	A: CO, S or other, C: S-compounds, Nox, NH_3, organics
ECSA loss (A/C)	1	particle growth/Pt dissolution or carbon corrosion (hot H_3PO_4)
increase electronic resistance (A/C)	4	electronic vs. proton resistance
membrane - increase of proton resistance	3	
membrane - increase in H2 X-over	3	
flooding / loss of hydrophobicity (A/C)	6	(for HT-PEM)
influence of compression	2	ECSA, distribution of H_3PO_4, flow field design

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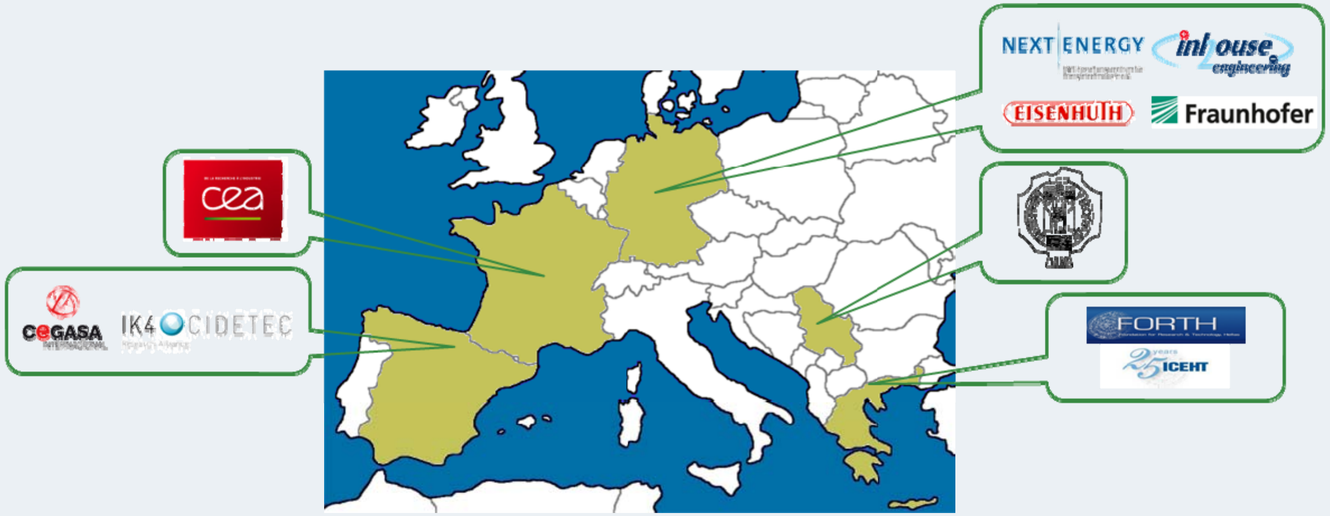

Thank you for your attention !

www.next-energy.de

www.project-eureca.com
http://demmea.iceht.forth.gr

EURECA – Efficient Use of Energy Converting Applications
The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2077-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° [303024], [245156].