HT-PEM Fuel Cell: Compression Analysis by Electrochemical Characterization and Micro-Computed Tomography

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3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells

Copenhagen/Denmark, 3rd September 2012

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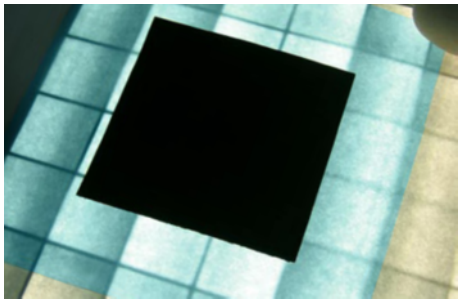
Photovoltaics
Power from light
and thin layers

Energy Storage
From electrochemistry
to grid integration



Fuel Cells
Supplying power
and heat efficiently

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Outline

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- Role of compression
- Electrochemical characterization
- Micro-computed tomography

Role of Compression for Polymer/H_3PO_4-MEA

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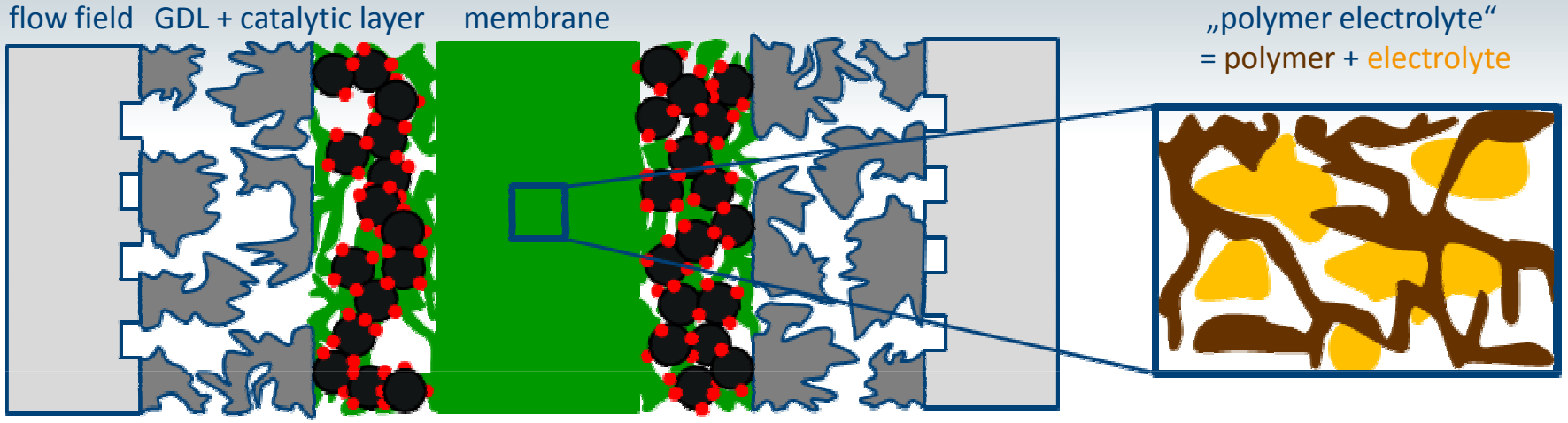

Possible effect on	Possible consequence for	Method
GDL porosity	Reactant supply	EIS, IV
Membrane thickness	Ionic resistance, reactant crossover, internal short circuit	EIS, LSV
H_3PO_4 penetration into CL	3-phase reaction zone, flooding (reactant supply)	CV, EIS
Electrical contact	Electrical resistance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

Outline

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- Role of compression
- Electrochemical characterization
  - » Cell compression unit
  - » Results*
- Micro-computed tomography

* A. Diedrichs, P. Wagner; *ECS Transactions* **2012**, *50*, accepted for publication.

Cell Compression Unit (from Pragma Industries)

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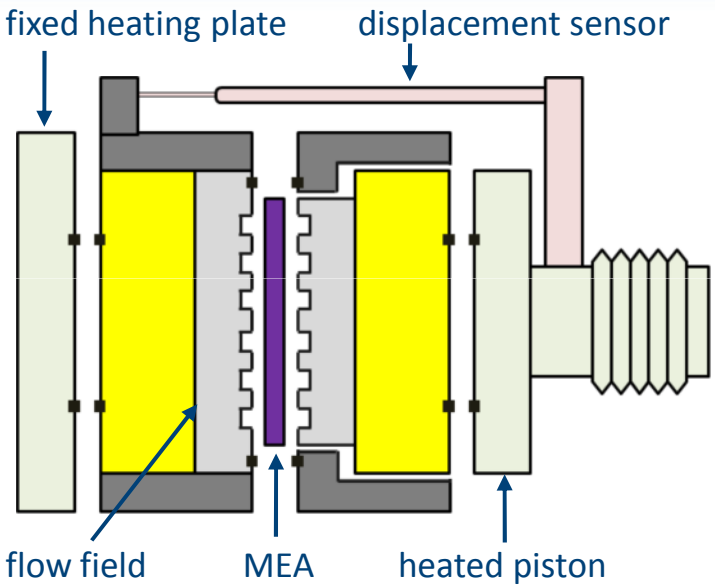
Schematic

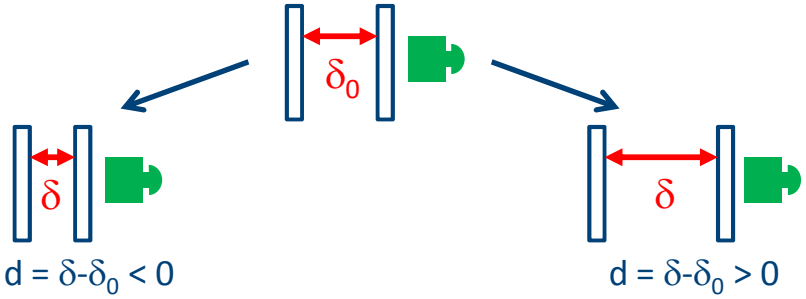


F = 0.5-6.25 kN
(0.2-2.5 MPa for 25 cm²)
T = 20-200 °C
d = 0-2 mm

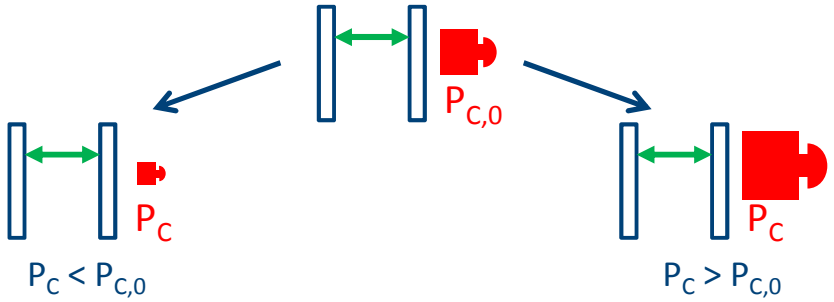
Requirement: steady compression

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

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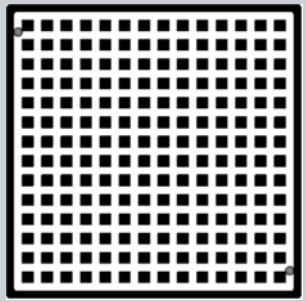
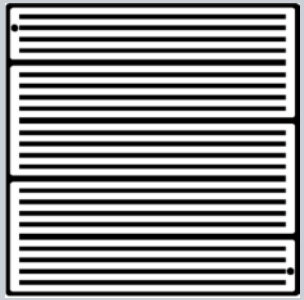
MEA Property	#A	#B
Type (GDL)	Celtec®-P2100 (Woven carbon cloth)	Celtec®-P2100 (Woven carbon cloth)
Serial-Nr.	#14799-037	#14799-038
Thickness [µm]	929	917
Active area [cm²]	20.25	20.25
Flow field design	Grid 	5-Fold serpentine 
• Nominal area [cm²]	25	25
• Total land area [cm²]	9.49	13.35

Flow Field Real Contact Pressure

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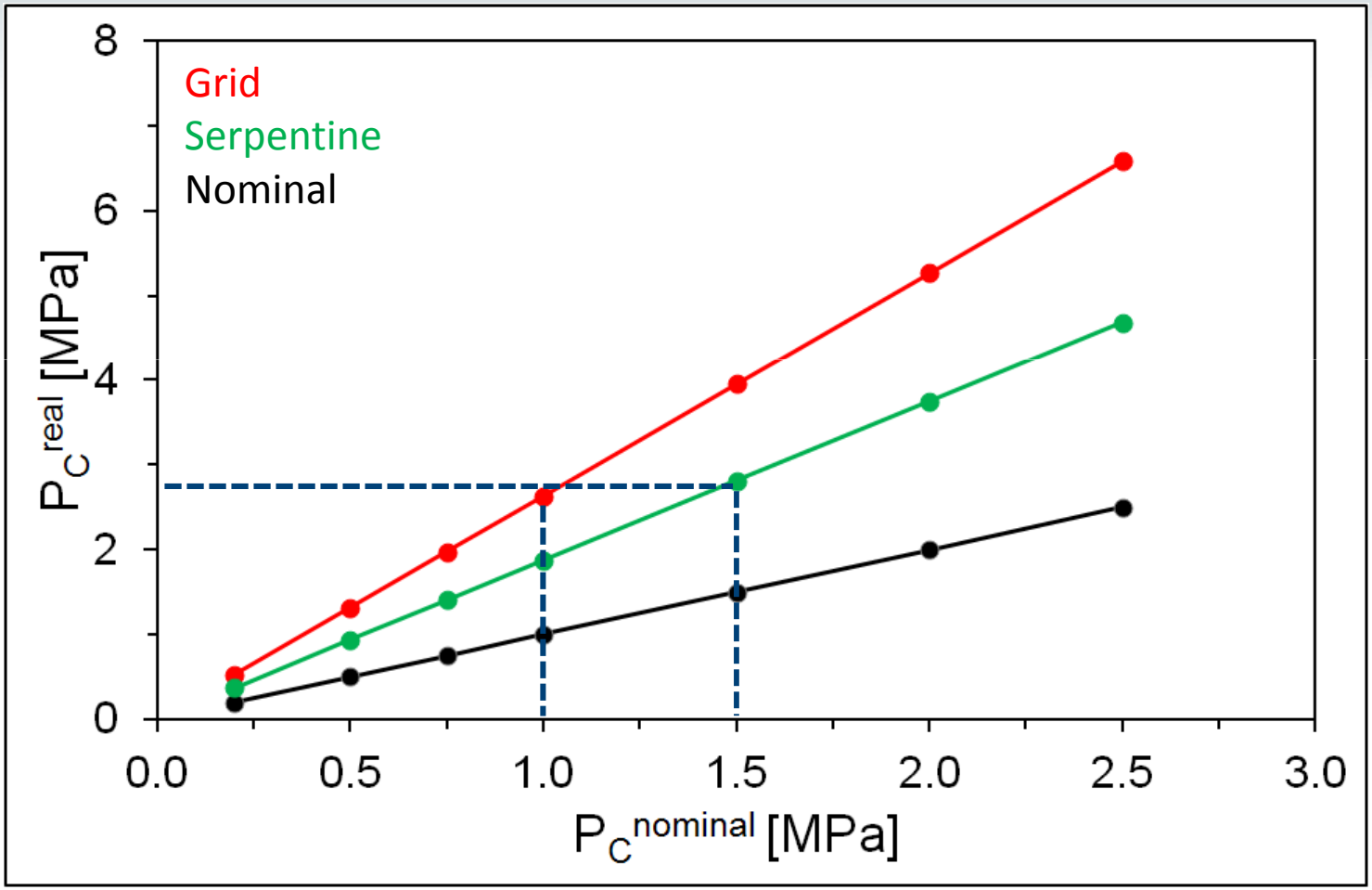

Results: MEA Thickness

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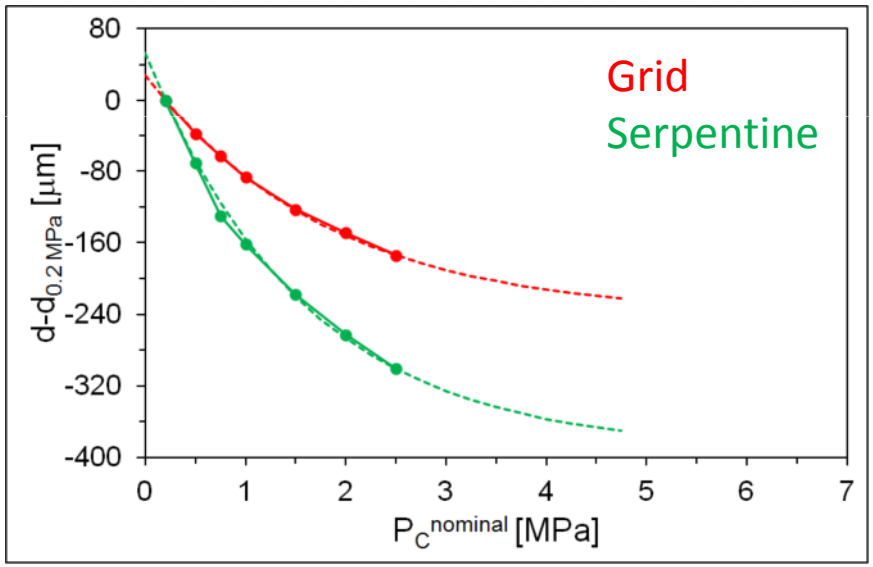
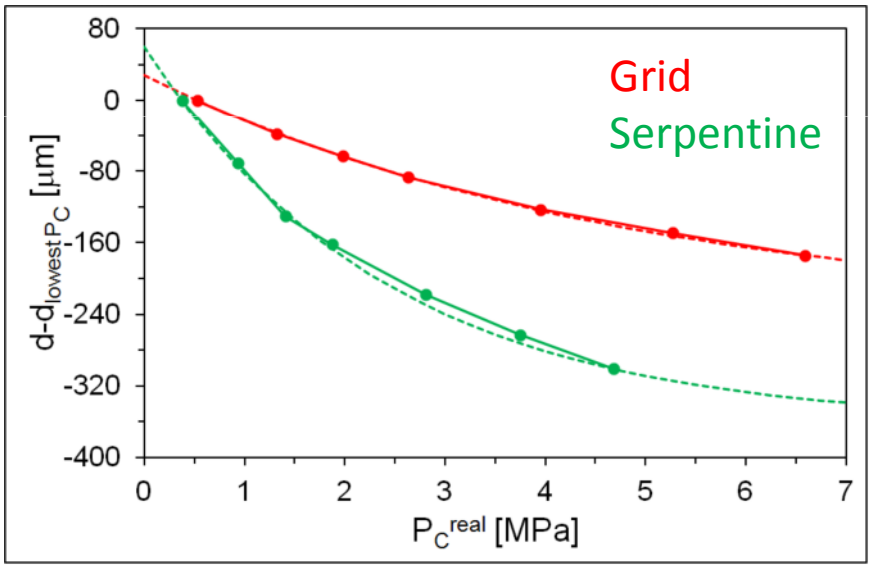
- Contact pressure variation
  - » Nominal contact pressure range: 0.2 MPa – 2.5 MPa
  - » Order of change: from low to high





Results: $IV_{iR\text{-}free}$-Curve (Left) and EIS-Spectra (Right)

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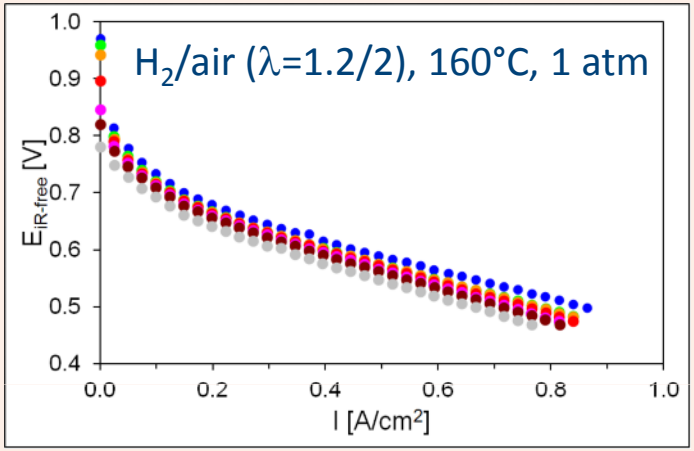
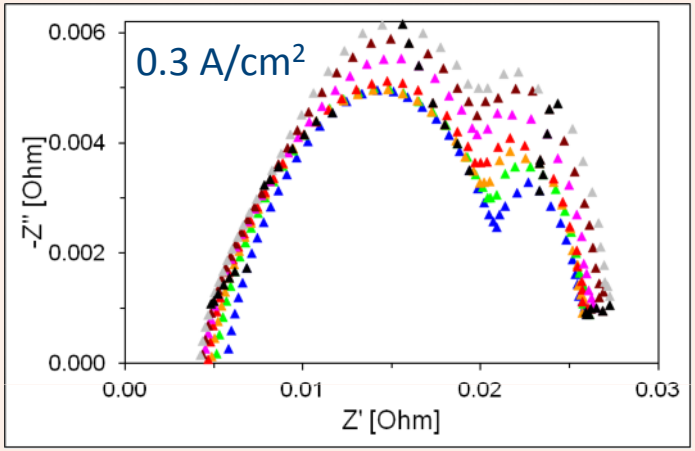
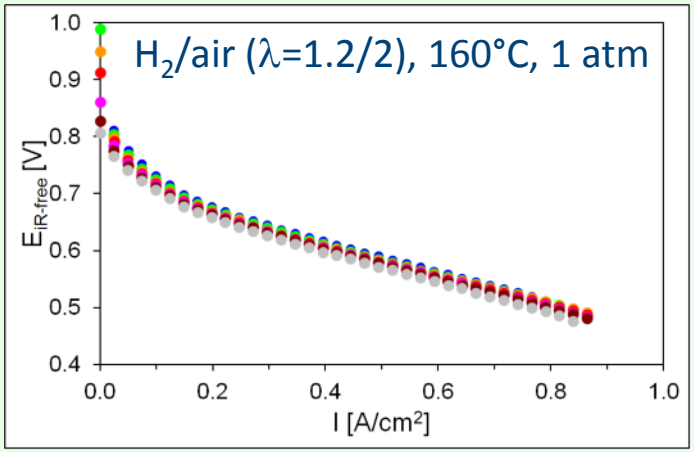
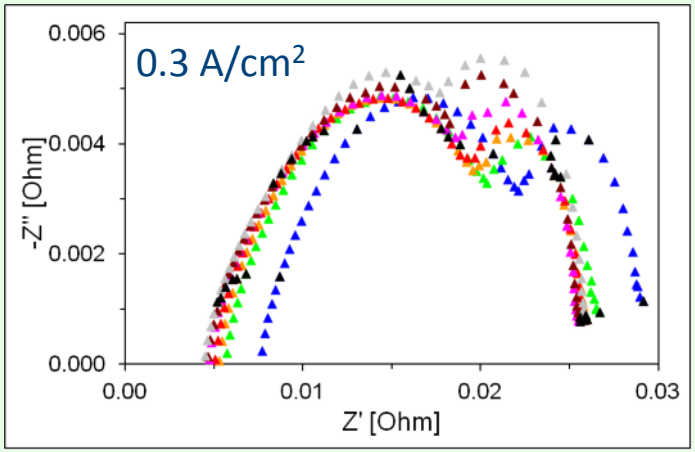
Grid





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 (Left) and LSV-Analysis (Right)

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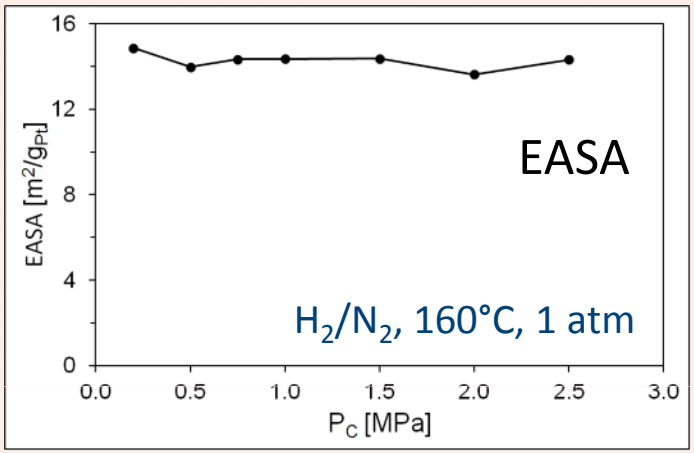

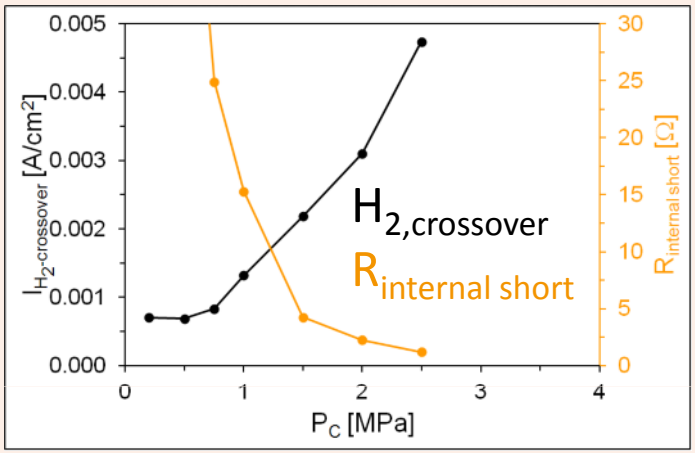

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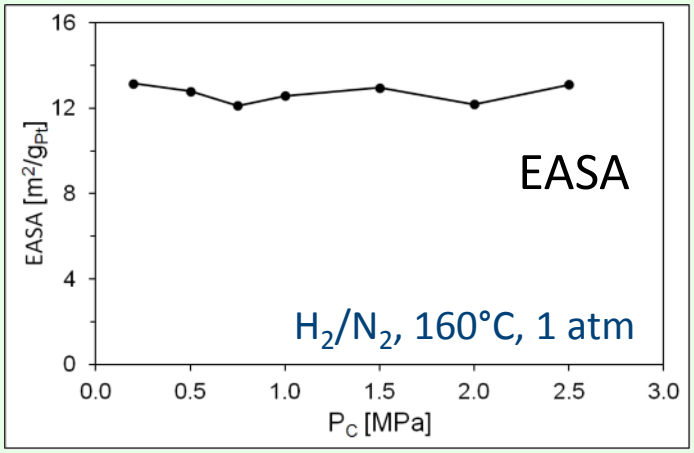

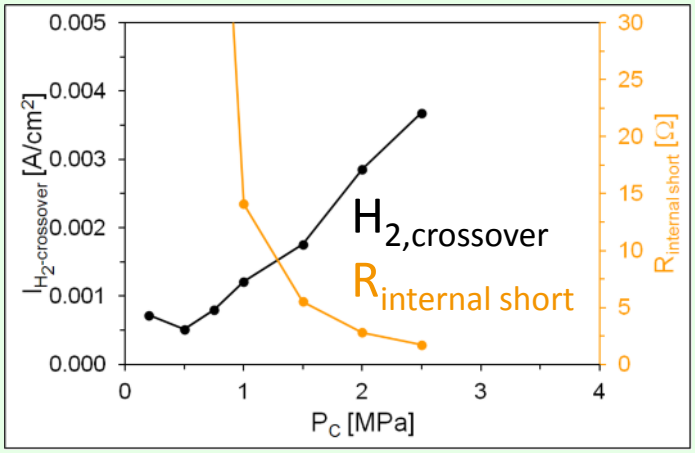

Electrochemical Characterization: Summary

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- EASA almost independent from applied contact pressure
  - → H_3PO_4 not squeezed out at all or EASA not affected by squeezed out H_3PO_4
- Decrease in electrical resistance
  - → Impact of contact resistance at lower contact pressures
  - → Membrane thinning by compression reduces ionic conductivity resistance
- Significant formation of internal shorts and hydrogen crossover
  - → Membrane thinning reduces pathway length for hydrogen and electrons
  - → Electrical connection by penetration of GDL fibers into the membrane is imaginable and may cause pinholes
- Analyzed flow field types differ in MEA thickness and mass transport limitation behavior at the same applied contact pressure
  - → Different deformation behavior of MEA into flow field channels

Outline

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- Role of compression
- Electrochemical characterization
- Micro-computed tomography
  - » Functional principle
  - » Compression tool
  - » Results*,**

* M. Runte; *Bachelor Thesis*, University of Applied Sciences Münster / Germany, **2012**.
** M. Rastedt; *Publication in Preparation*.

Functional Principle of μ-CT

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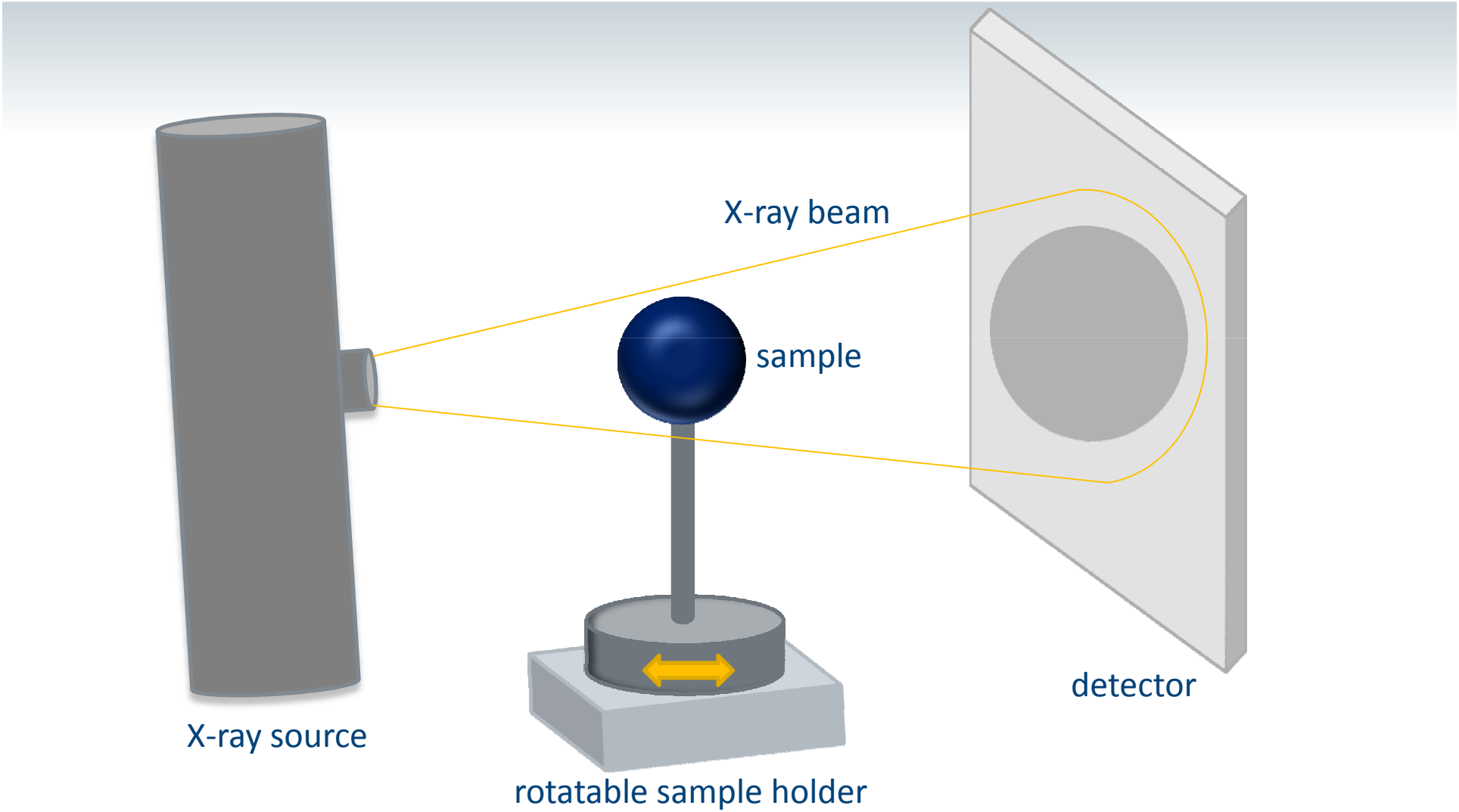

Compression Tool* for μ-CT

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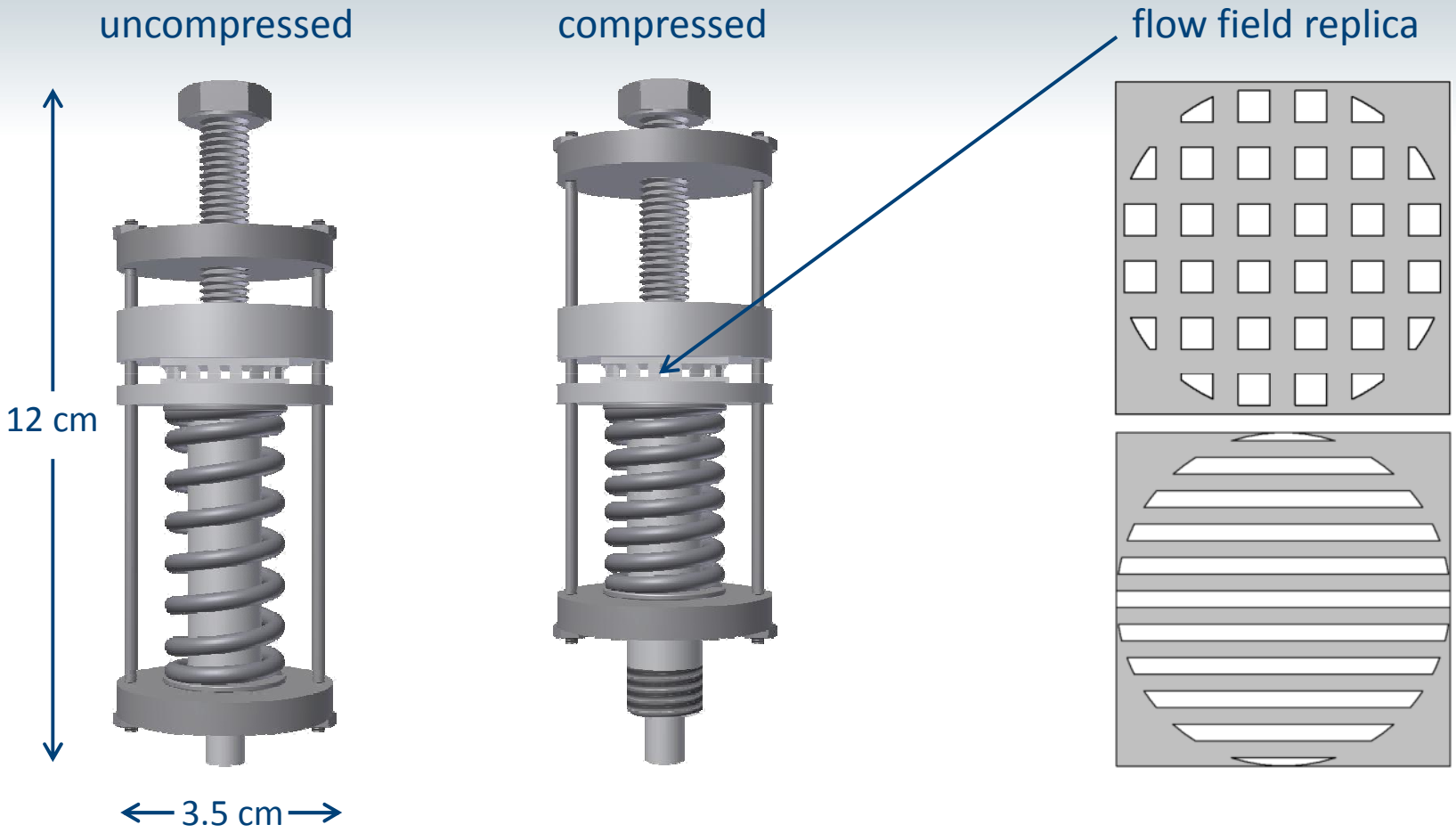

* M. Karwey; *Bachelor Thesis*, University of Applied Sciences Südwestfalen / Germany, **2012**.

Results: MEA Thickness In Channel

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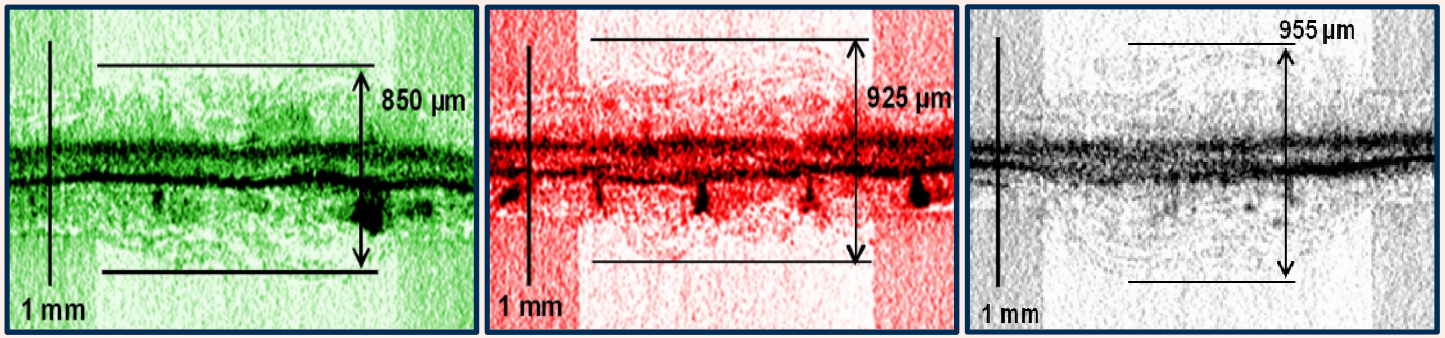
Grid



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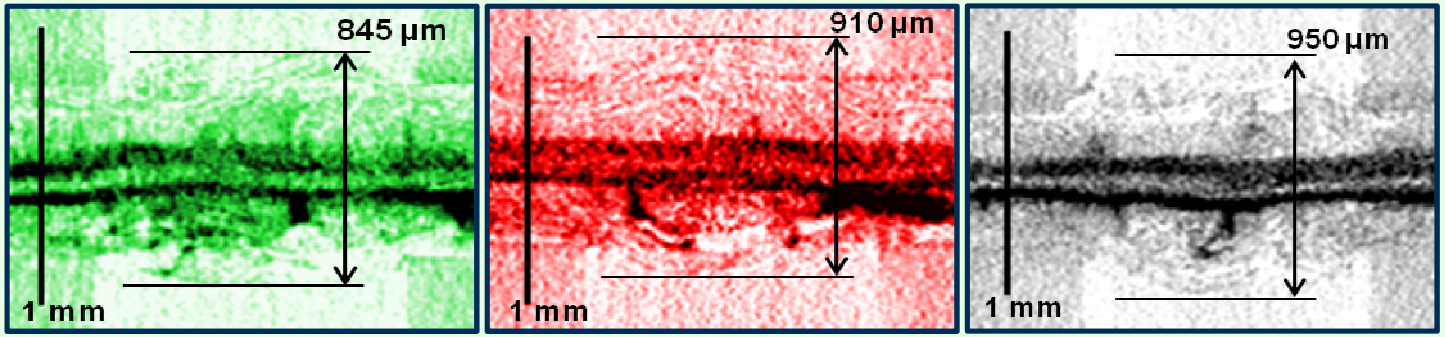

0.5 MPa
1.0 MPa
2.5 MPa

Results: MEA Thickness Under Land

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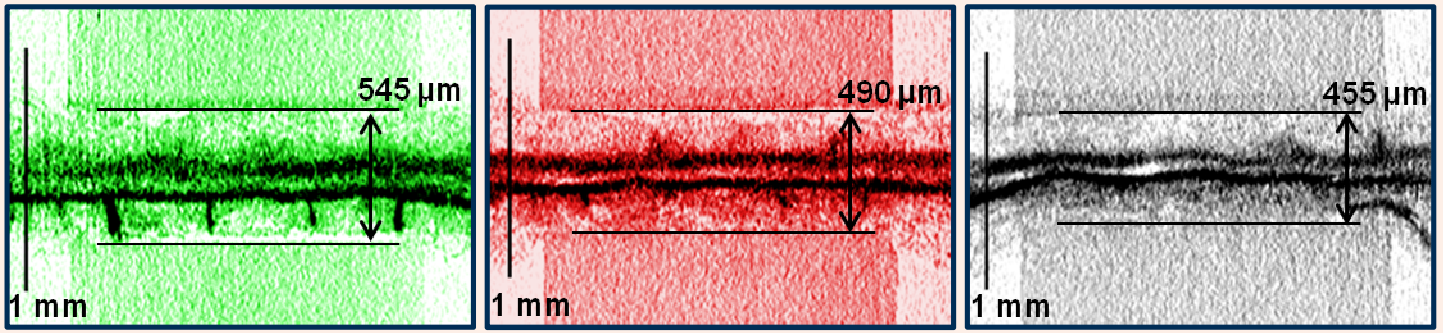
Grid



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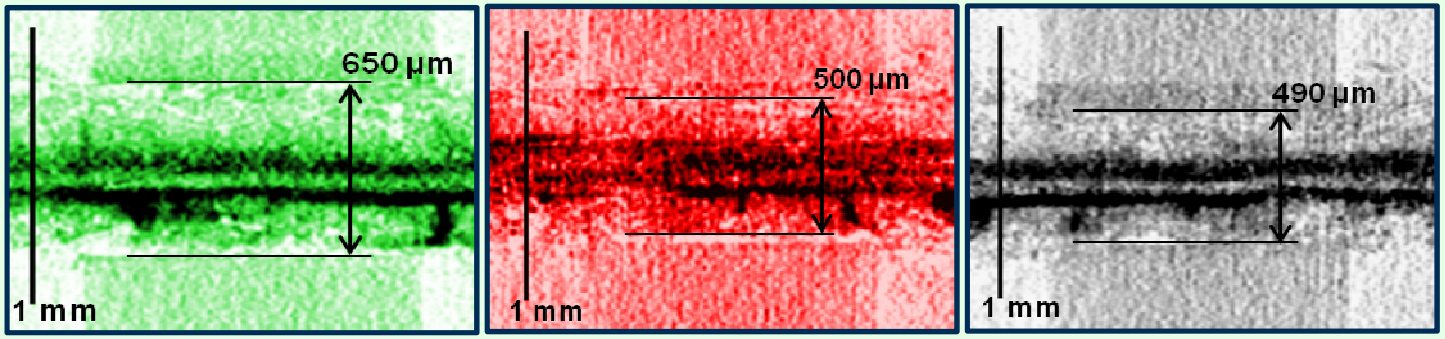

0.5 MPa
1.0 MPa
2.5 MPa

Results:
MEA Thickness In Channel (Left) and Under Land (Right)

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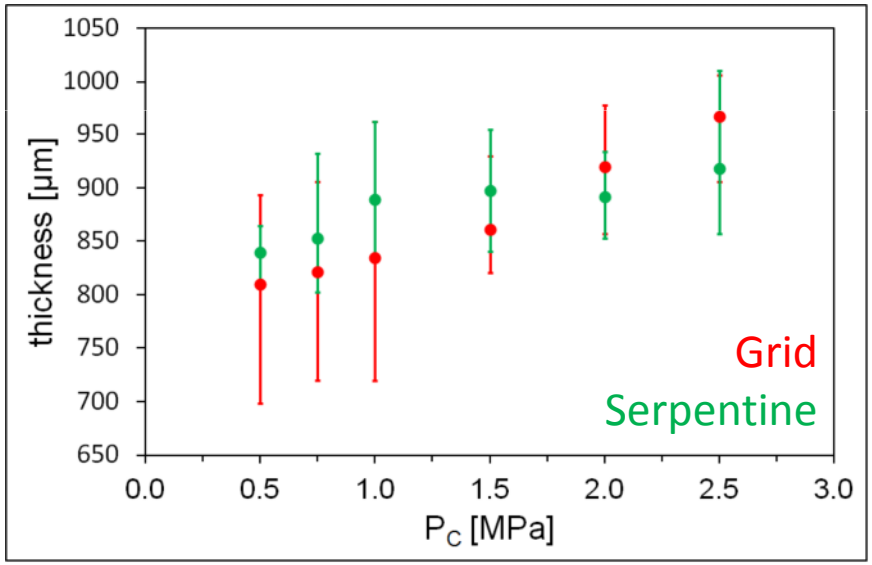
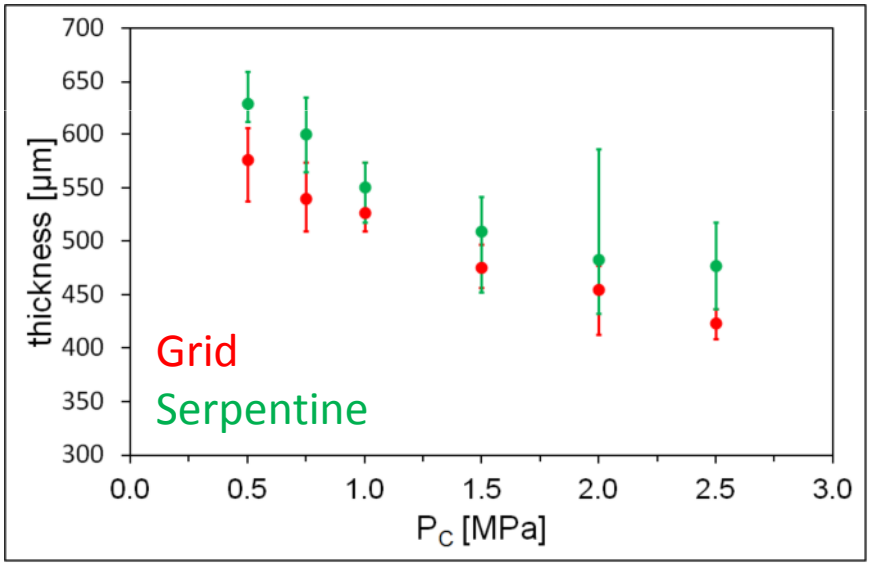
- Thickness determination
  - » Average value of 10 different spots
  - » Minimum and maximum value as error bars





Possibilities of μ-CT

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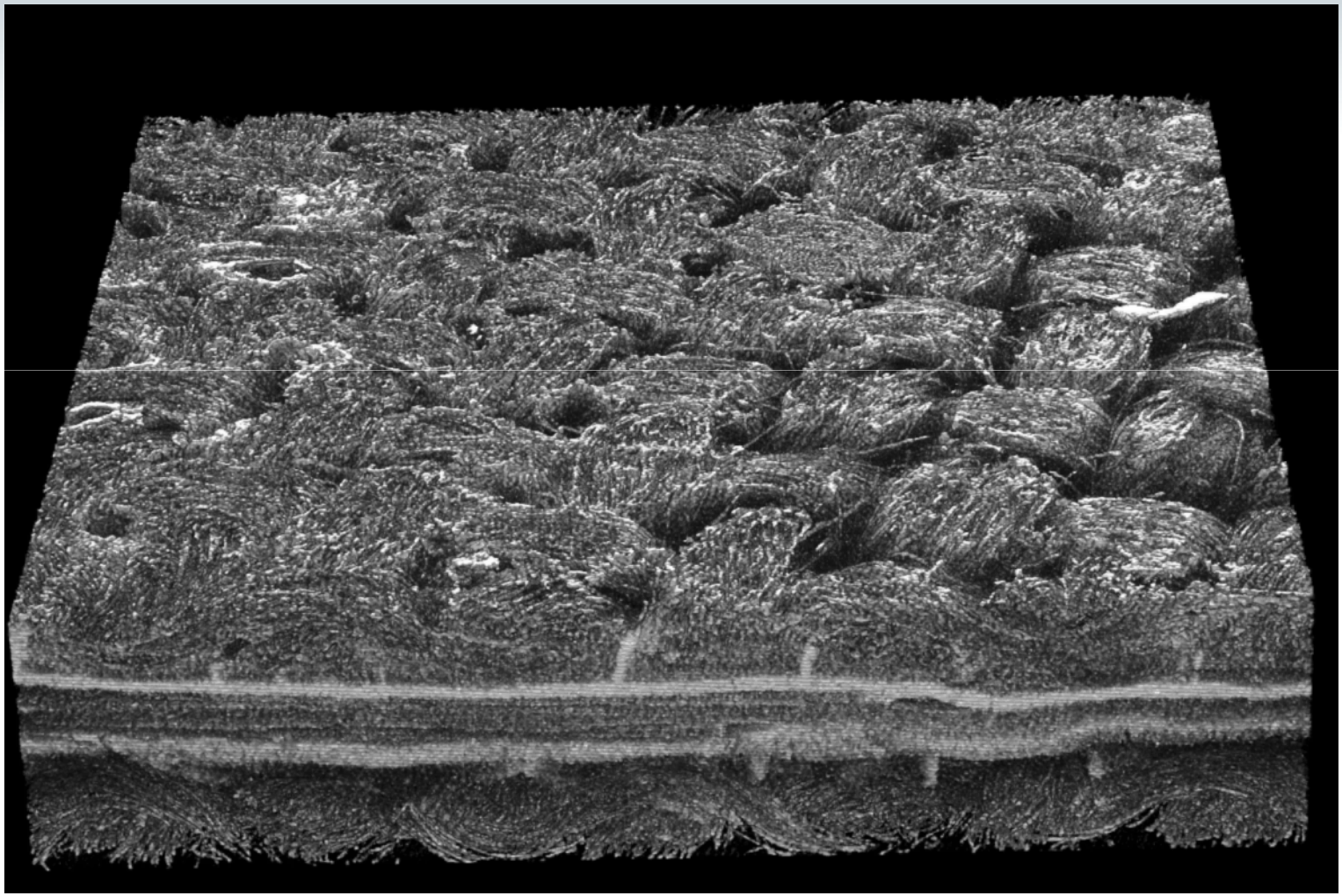

Micro-Computed Tomography: Summary

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- MEA thickness as function of applied contact pressure in flow field channel
  - → GDL bulges into channel
  - → No trend statement with regard to contact pressure possible
- MEA thickness as function of applied contact pressure under flow field land
  - → Thickness reduction with increasing contact pressure
- Modification of compression tool necessary
  - → Improvement in resolution
  - → Prevention of artifacts

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Thank you very much for your attention.

Experimental Set-Up

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