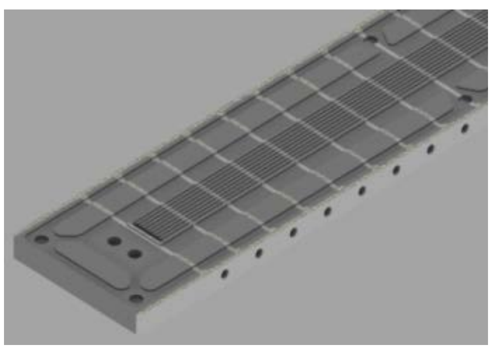
IN-SITU TESTING METHODS FOR MEMBRANE-ELECTRODE-ASSEMBLIES



Ulf Groos
Head of Department Fuel Cell Systems
Fraunhofer Institute for Solar Energy Systems ISE

Stuttgart, October 11, 2017

www.ise.fraunhofer.de

www.h2-ise.de

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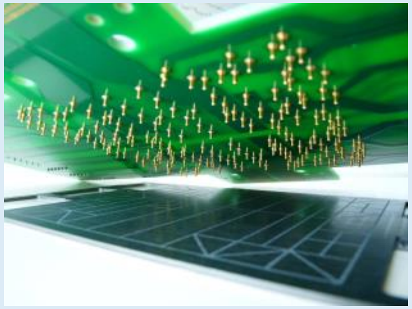
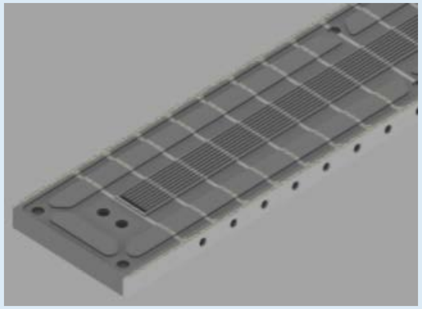
AGENDA

- Fraunhofer ISE: Business Area Hydrogen Technologies
- Test Methods for membrane electrode assemblies
  - Differential test cells
  - Full cells
  - Along-the-channel test cell
  - Stack tests
- Summary

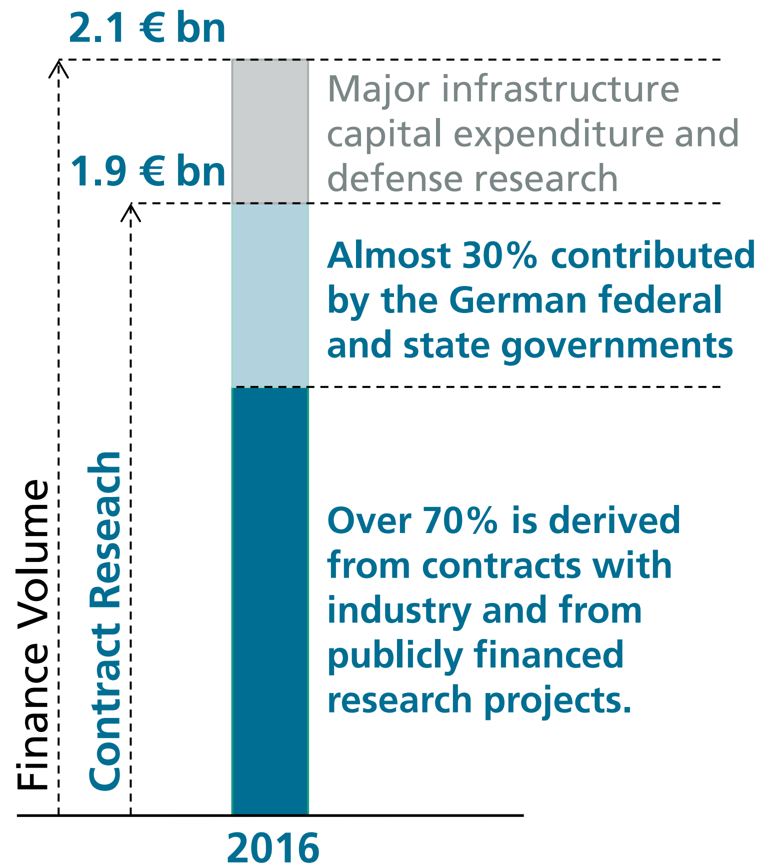





The Fraunhofer-Gesellschaft

Largest Organization for Applied Research in Europe

24,500
Total staff

69 institutes and research units



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Fraunhofer Institute for Solar Energy Systems ISE
At a Glance

Fraunhofer ISE

Director:	Prof. H-M. Henning and A. Bett
Staff:	ca. 1.200
Budget 2016:	81 Mio. €
Established:	1981

Photovoltaics

Solar Thermal Technology

Building Energy Technology

Hydrogen Technology

Energy System Technology

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Business Area Hydrogen Technologies
Research topics of our three departments

Department Thermochemical Processes (Dr. Achim Schaadt)

- Thermochemical H2 generation from hydrocarbons
- Synthesis of H_2 and CO_2 to liquid energy carriers/fuels (PtL)
- Catalytic evaporation of liquid hydrocarbons

Department Chemical Energy Storage (Dr. Tom Smolinka)

- Hydrogen generation by PEM water electrolysis
- Energy storage in H_2 systems and redox flow batteries
- Power-to-Gas: Interconnection of the power and gas grid

Department Fuel Cell Systems (Ulf Groos)

- Scientific characterization of fuel cell components
- Degradation research (load profile, various climates)
- Customer specific, self-sufficient PEM systems up to 20 kW

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MEA testing – what is the target behind?

- Understand and optimize my component (at defined conditions) ?

Differential test cell:
- Little effort
- Analysis of material characteristics
- Does not represent the behaviour in real cells/stacks

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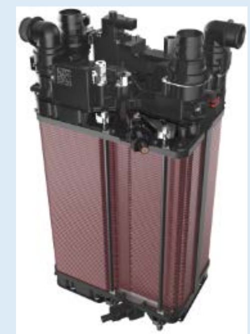
MEA testing – what is the target behind?

- Understand and optimize my component (at defined conditions?
- Select the best component for a given design and operation strategy?



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Differential test cell:
- Little effort
- Analysis of material characteristics
- Does not represent the behaviour in real cells/stacks

Real cell / stack
- High effort
- Interaction of many processes
- Realistic data for stack operation

*https://www.elringklinger.de/en/products-technologies/fuel-cells

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MEA testing – what is the target behind?

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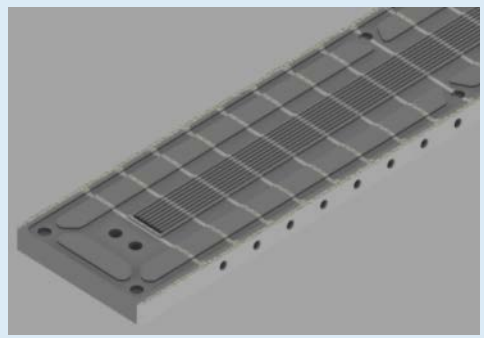
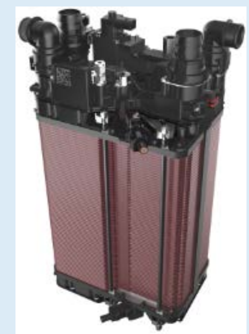


Along the channel test cell:
- Little effort
- Behaviour from inlet to outlet in real cells
- Difficult regarding material characteristics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Real cell / stack
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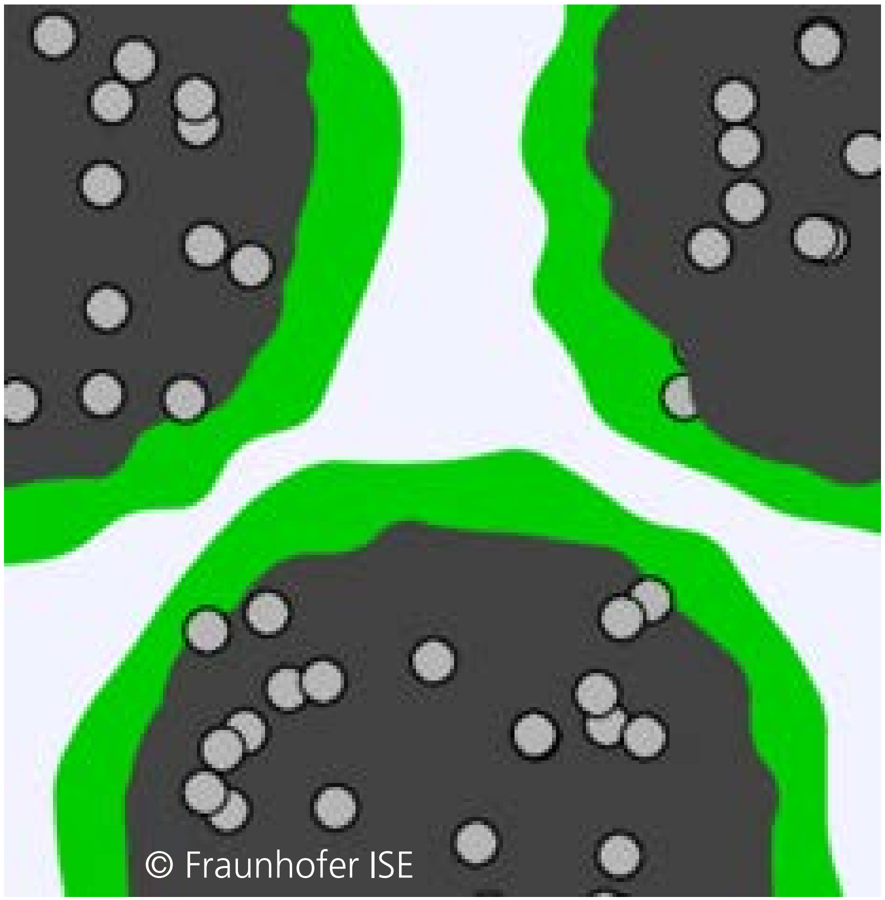
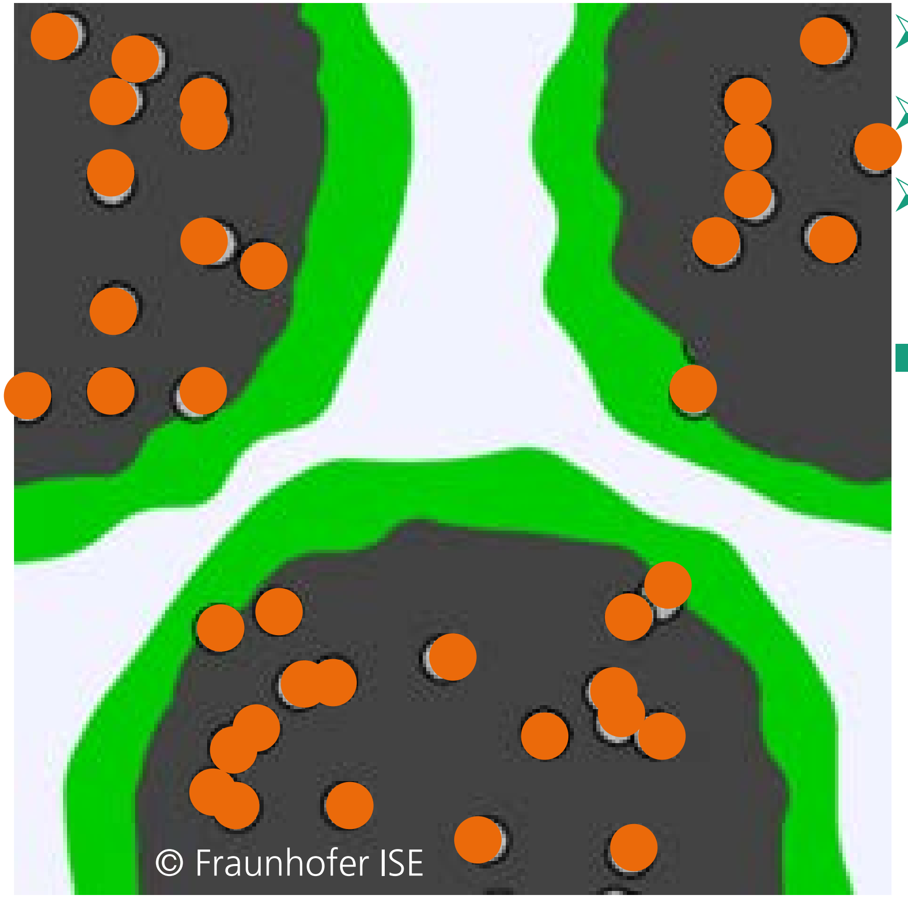
Material characterization
Foto Joscha Feuerstein

Understanding membrane electrode assemblies



- Power / current density
- Efficiency
- Stability (water management)

Understanding membrane electrode assemblies



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- Electrochemical active surface area (ECSA)

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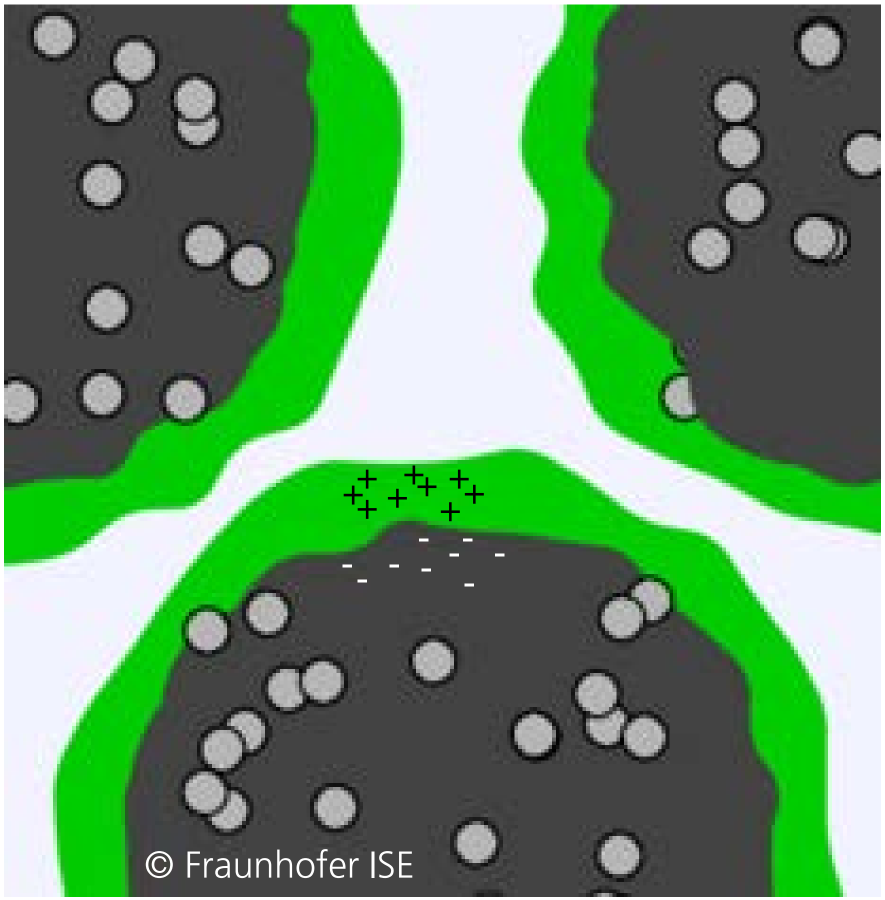

- Power / current density
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- Electrochemical active surface area (ECSA)
- Double layer capacity

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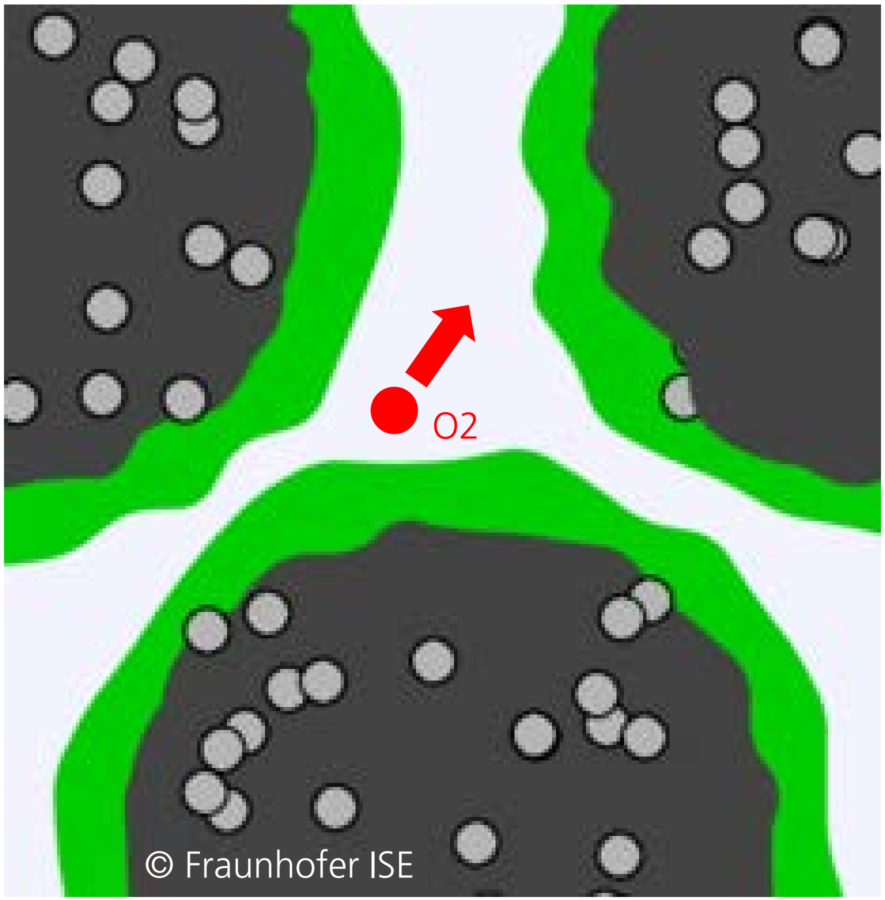
Understanding membrane electrode assemblies



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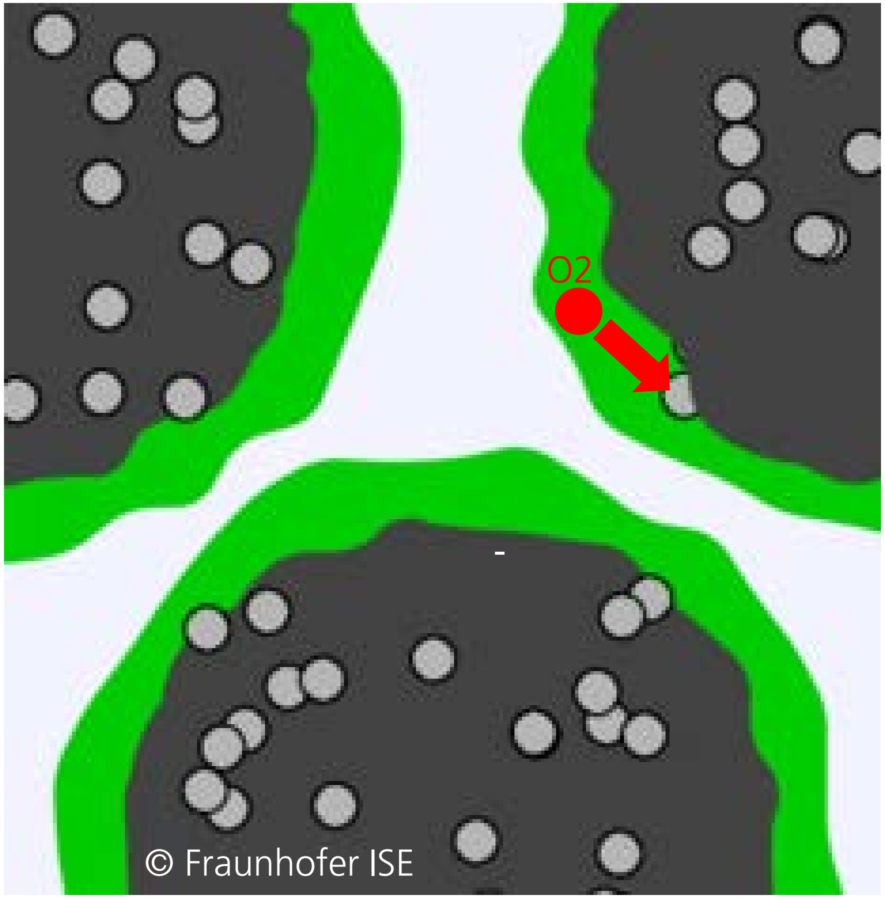
Understanding membrane electrode assemblies



- Power / current density
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- Electrochemical active surface area (ECSA)
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- Molecular diffusion
- Knudsen diffusion

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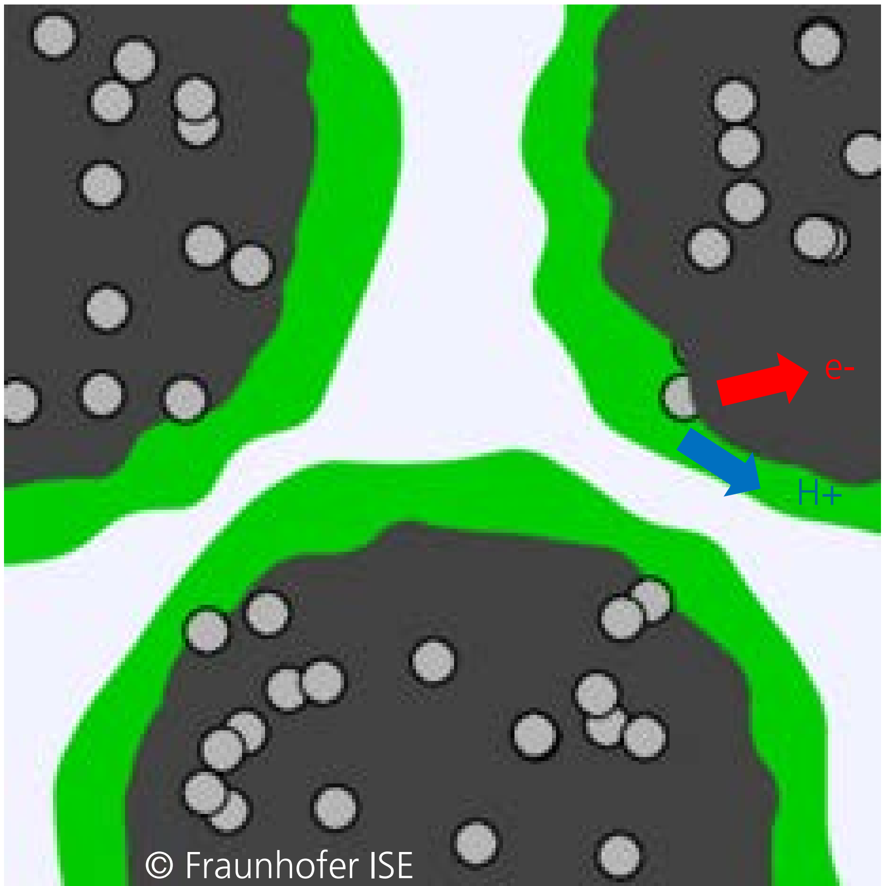
Understanding membrane electrode assemblies



- Power / current density
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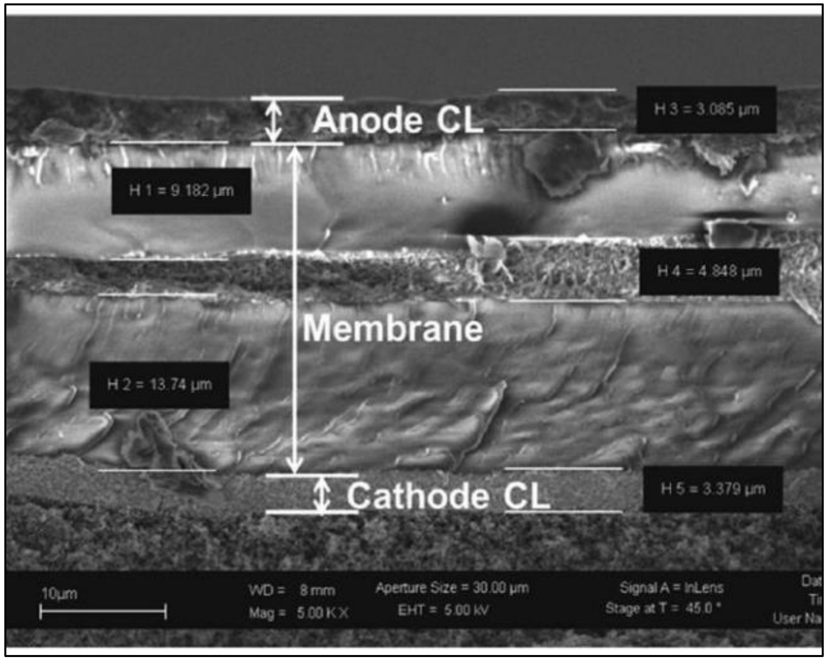
- Electrochemical active surface area (ECSA)
- Double layer capacity
- Molecular diffusion
- Knudsen diffusion
- Electronic and protonic conductivity

Understanding membrane electrode assemblies



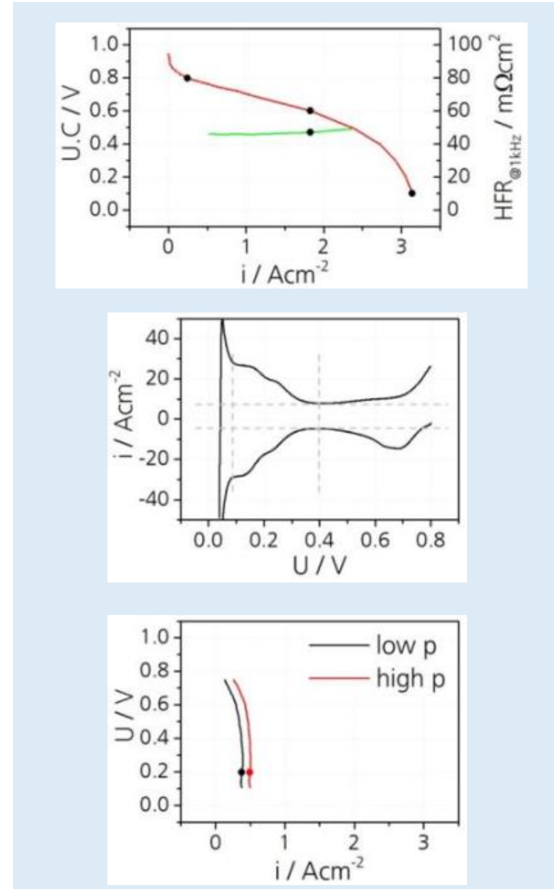
Bona, Curtin, Pedrazzo and Tresso, Journal of Fuel Cell Science and Technology, 2013

- Power / current density
- Efficiency
- Stability (water management)

- Electrochemical active surface area (ECSA)
- Double layer capacity
- Molecular diffusion
- Knudsen diffusion
- Electronic and protonic conductivity
- Gas cross over

Component characterization with multiple methods to analyse the crucial parameters

polcurve	CV	limited current density	EIS
$i_{@0.8\ V}$	ECSA	R_{MD}	R_{mem}
$i_{@0.6\ V}$	$i_{x\text{-}Over}$	R_{Kn}	R_{CL}
$i_{@0.1\ V}$	R_{SC}		R_{LFR}
R_{HFR}	C_{DL}		
	Q_{PtOx}		
	$U_{min,PtOx}$		



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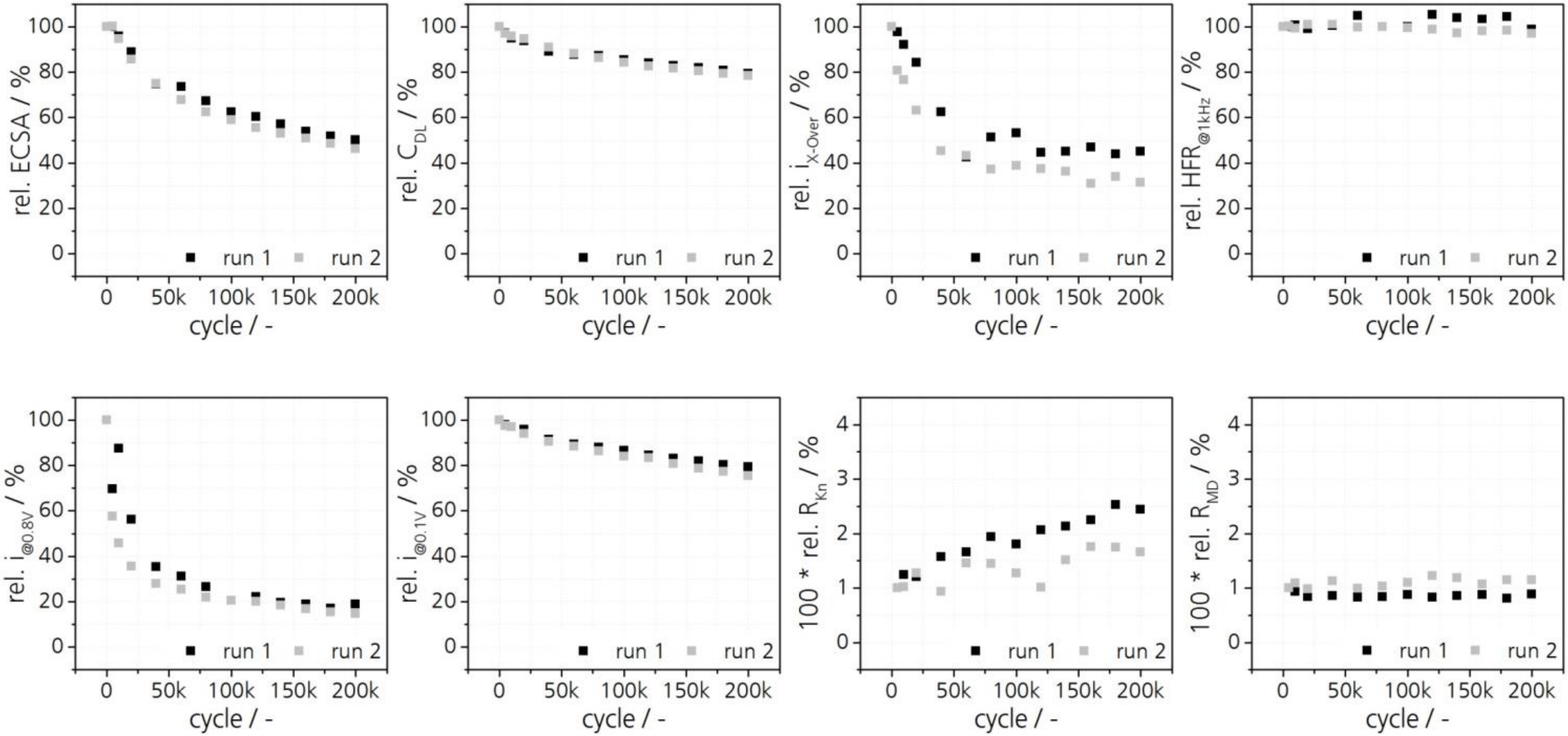
Good reproducibility in degradation studies is proved



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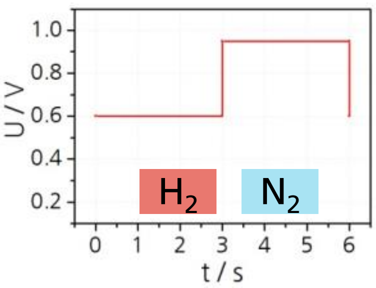
Influence of electrode material
DoE AST catalyst protocol



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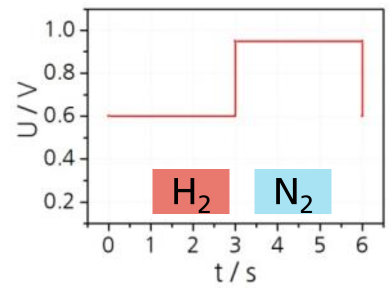
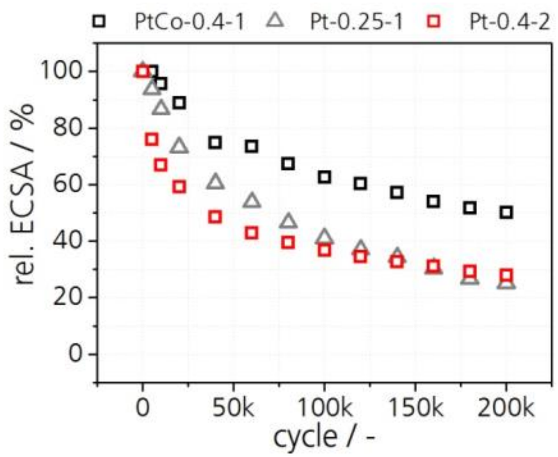


- PtCo exhibits slower ECSA loss



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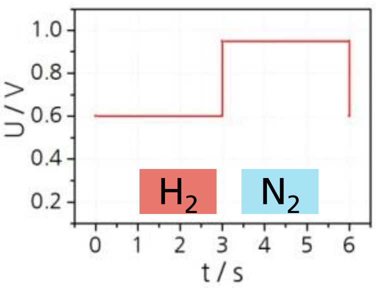
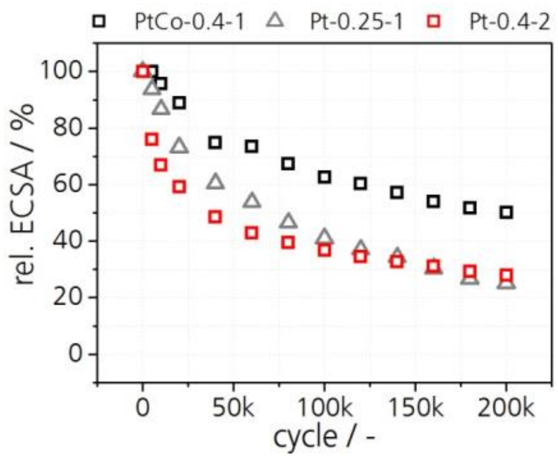
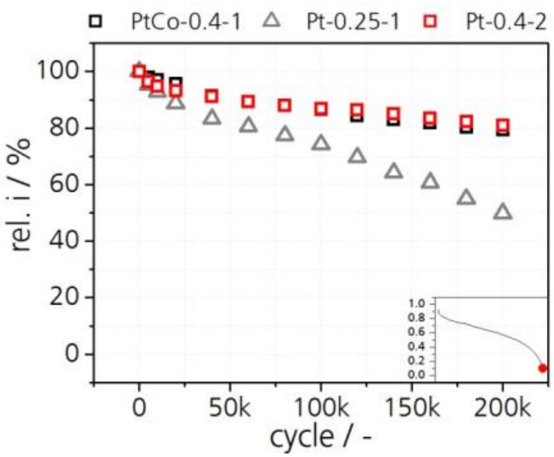


- PtCo exhibits slower ECSA loss
- High loss in "limited" current density (i@0.1 V) for low Pt loading





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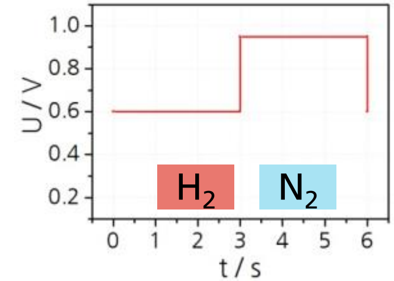
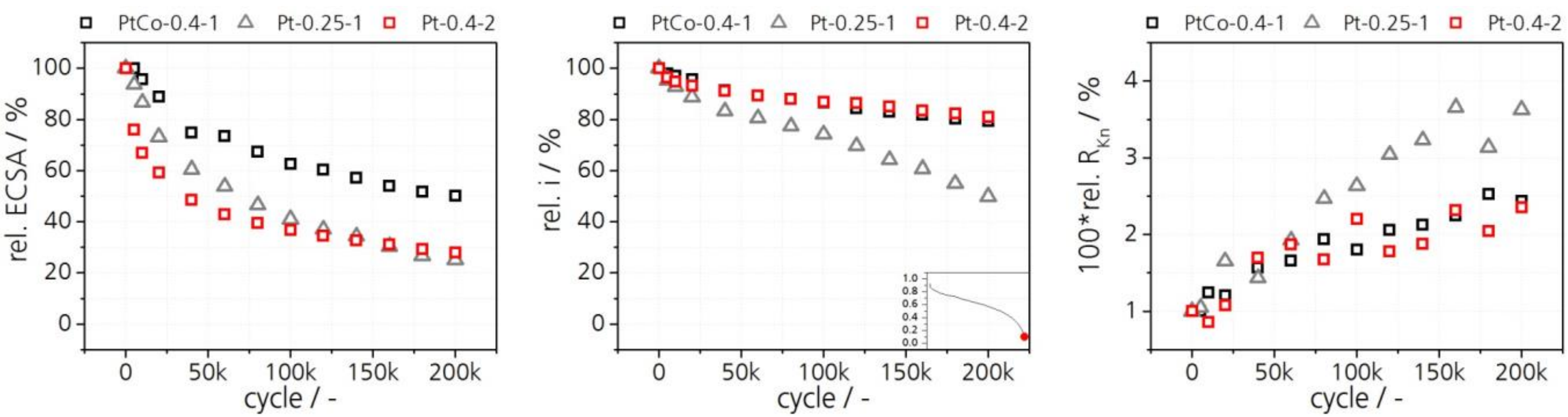


- PtCo exhibits slower ECSA loss
- High loss in “limited“ current density (i@0.1 V) for low Pt loading
  - due to higher diffusion resistance in catalyst layer (R_{Kn})



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Influence of electrode material
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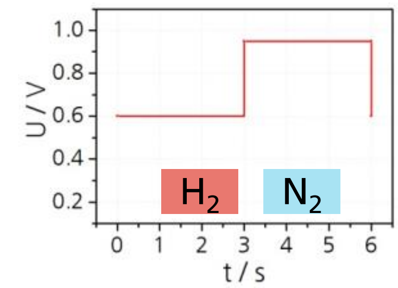
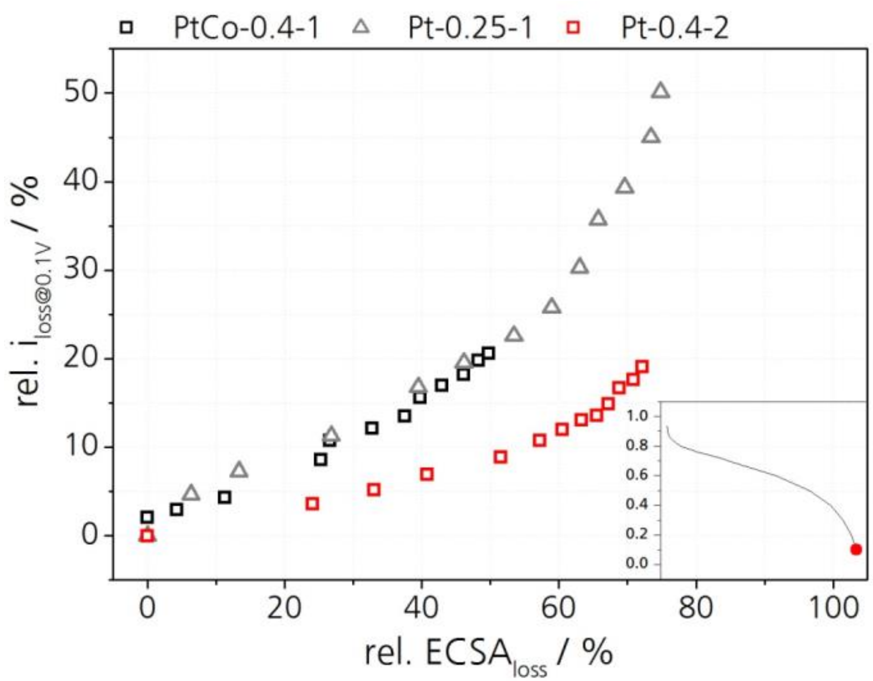


- Influence of electrode structure independent from catalyst loading or catalyst system
- Possibly due to
  - different ionomer content
  - different electrode manufacturing process
  - different support material

Relative loss in limited current density vs. relative loss in ECSA for two different suppliers, two different loadings, and two different catalyst systems



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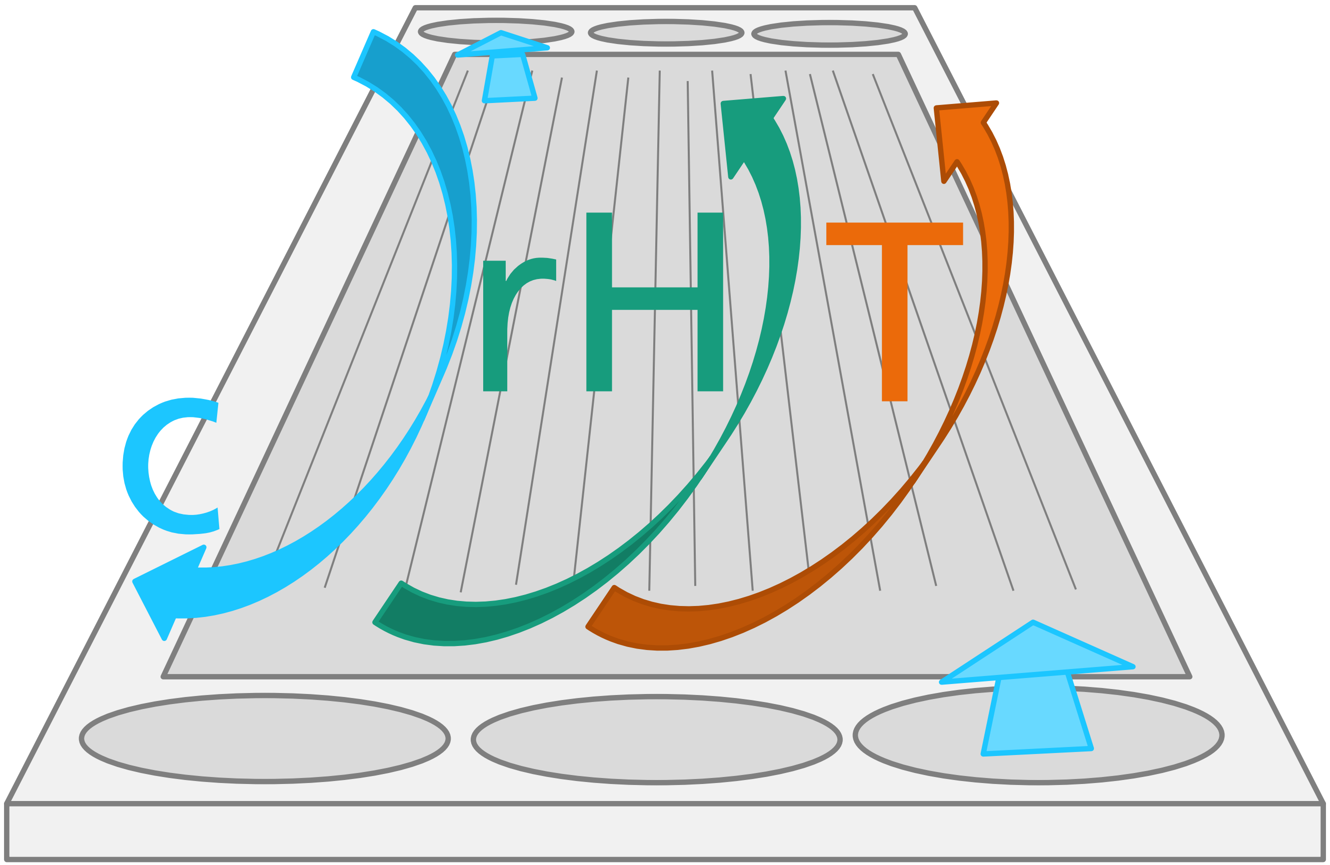
Understanding local effects



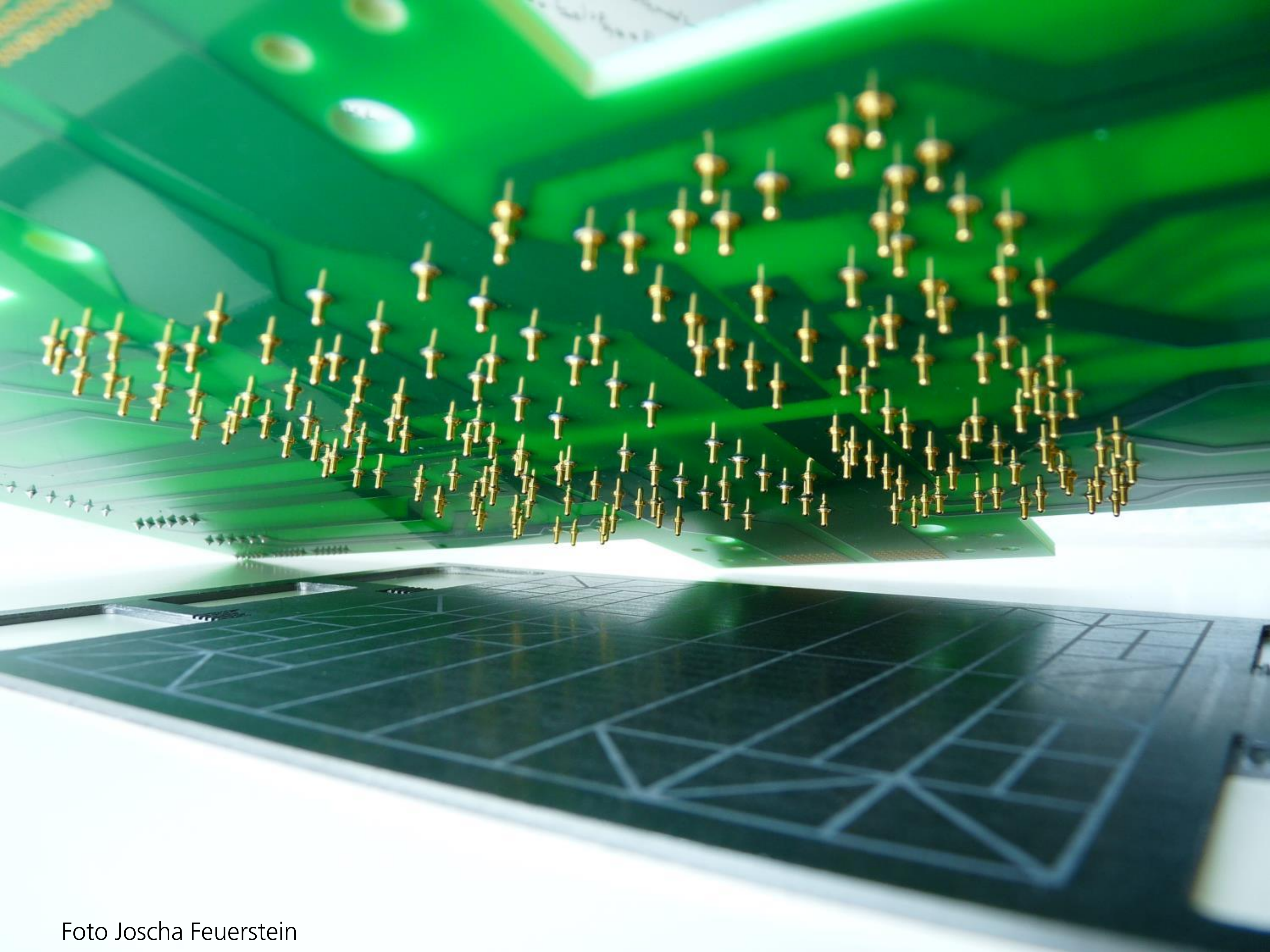
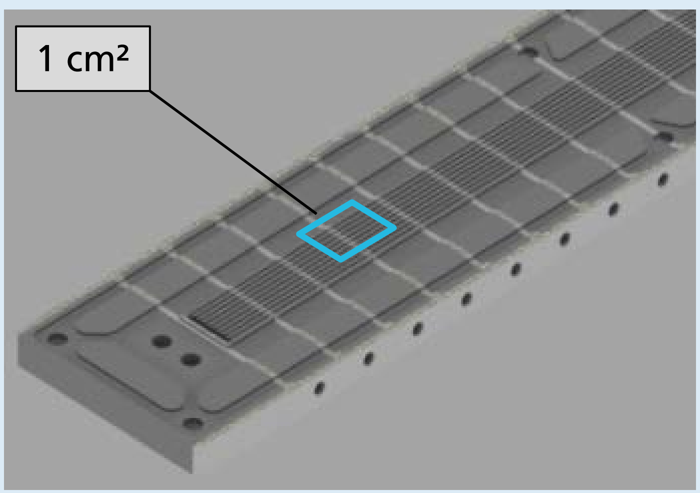


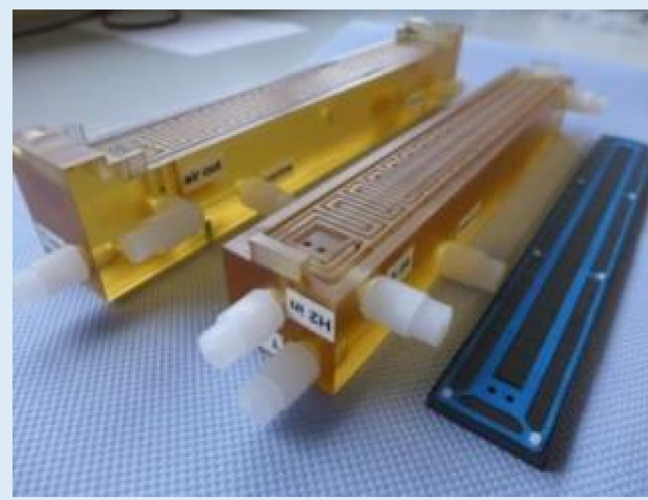
Foto Joscha Feuerstein


FuelCon

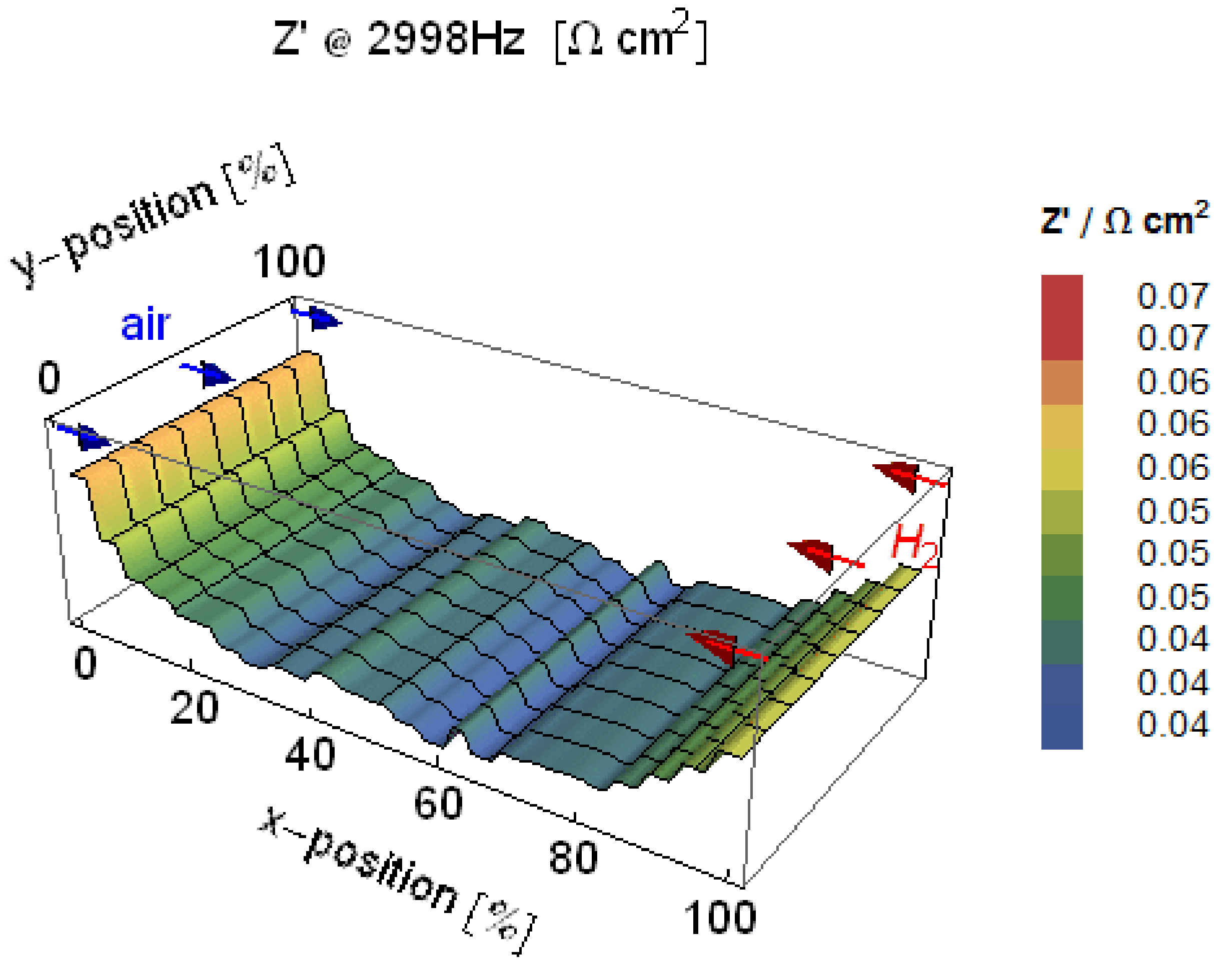
Component characterization @ realistic conditions

- Material screening with stoichiometric operation
- Studying effects of real (customer specific) channel-land geometries
- Along-the-channel test cell: 1 x 25 cm², 5 channels, co- & counterflow configuration possible
- Realistic operation conditions





Along the channel test cell



Local dynamics of membrane hydration / dehydration

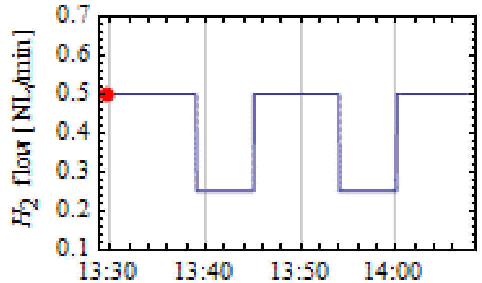


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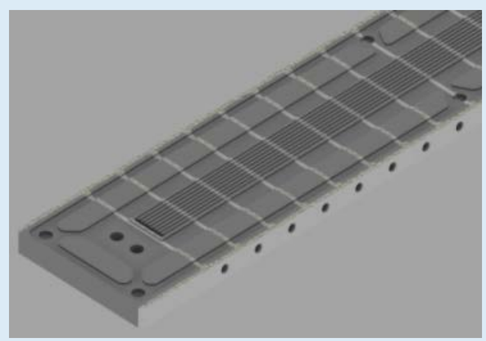
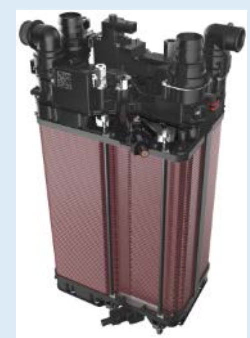
Foto Joscha Feuerstein

Material testing in „rainbow“ stacks.

Tests for material characterization have to be selected according to the test targets.

- Differential test cells are best for material qualification independently from concrete designs and operation conditions
- Fraunhofer ISE approved a along-the-channel test cell for qualifying components with respect to a certain channel-land design and operation conditions
- Tests with full cells or (short / full) stacks are necessary to verify the single cell tests





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Thank you for your attention!

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