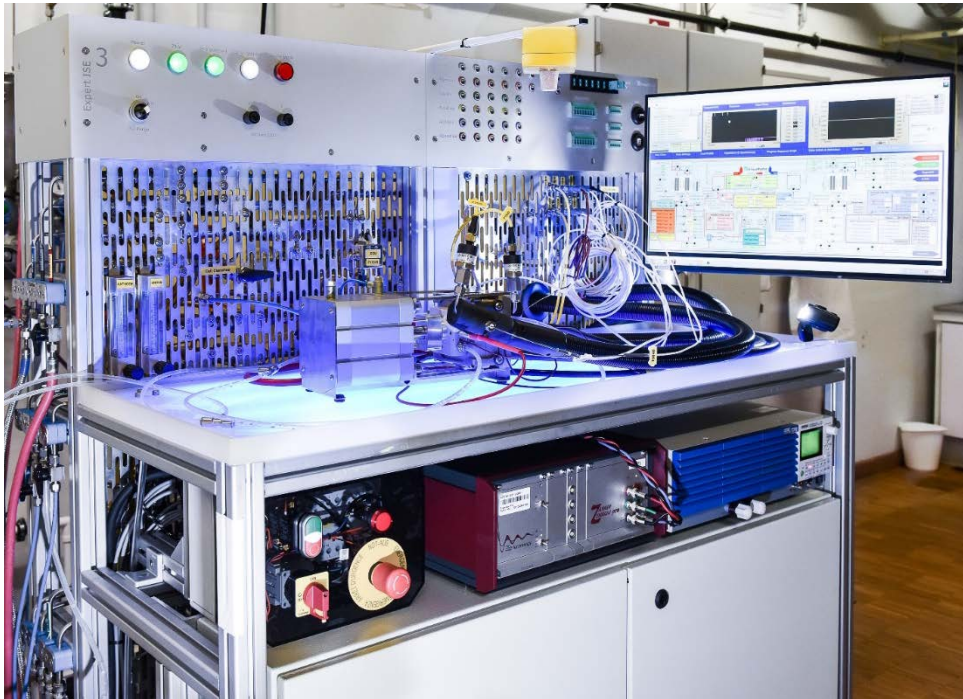


QUBK*: QUALIFIZIERUNG VON BRENNSTOFFZELLENKOMPONENTEN

*: spoken as „cubic“ to promote the validation of test protocols from DOE, EU, and NEDO



Ulf Groos, Dr. M. Klingele, P. Schneider
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Deutsche Wasserstoffversammlung

January 27, 2021

<http://www.ise.fraunhofer.com>

<http://www.h2-ise.com>

Fraunhofer Institute for Solar Energy Systems ISE

Research for the Energy Transformation



Directors

Prof. Dr. Hans-Martin Henning

Prof. Dr. Andreas Bett

Staff

ca. 1300

Scientists, engineers, students

Budget 2019

Operation	93,5 Mio. EUR
Investment	10,6 Mio. EUR
Total	104,1 Mio. EUR

Hydrogen Technologies @ the Fraunhofer Institute for Solar Energy Systems

Defossilization of Transport, Chemicals and Process Heat



Sustainable Mobility

Fuel cell car at the solar hydrogen filling station at Fraunhofer ISE



Synthetic Fuels and chemicals

Development of catalysts and processes incl. LCA analyses for Power-to-Liquid processes



Power-to-X Technologies

Water electrolysis as basic technology for renewable fuels; Power-to-Gas simulations

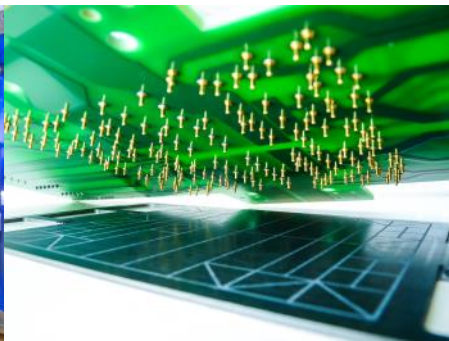
Fuel Cell Research at Fraunhofer ISE

Providing scientific sound services to our customers

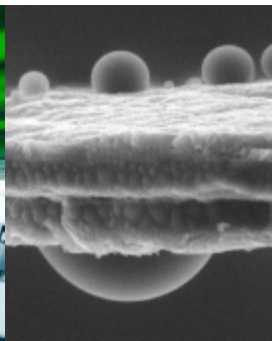
- > 25 years of fuel cell research
- 20 researchers plus students
- Ca. 3 Mio € annual budget (2020)
- 470 m² laboratory area
- Focus on transport application (LT PEMFC)
- Research from catalyst to system



stack testing



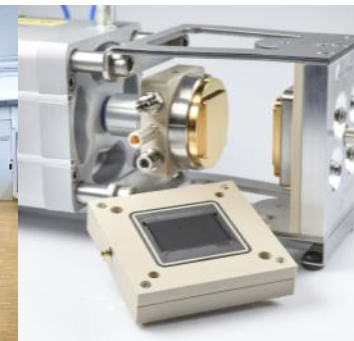
analysis of local effects



SEM analysis



MEA laboratory



test cell



environmental test of BoP

Motivation: The Membrane Electrode Assembly (MEA)

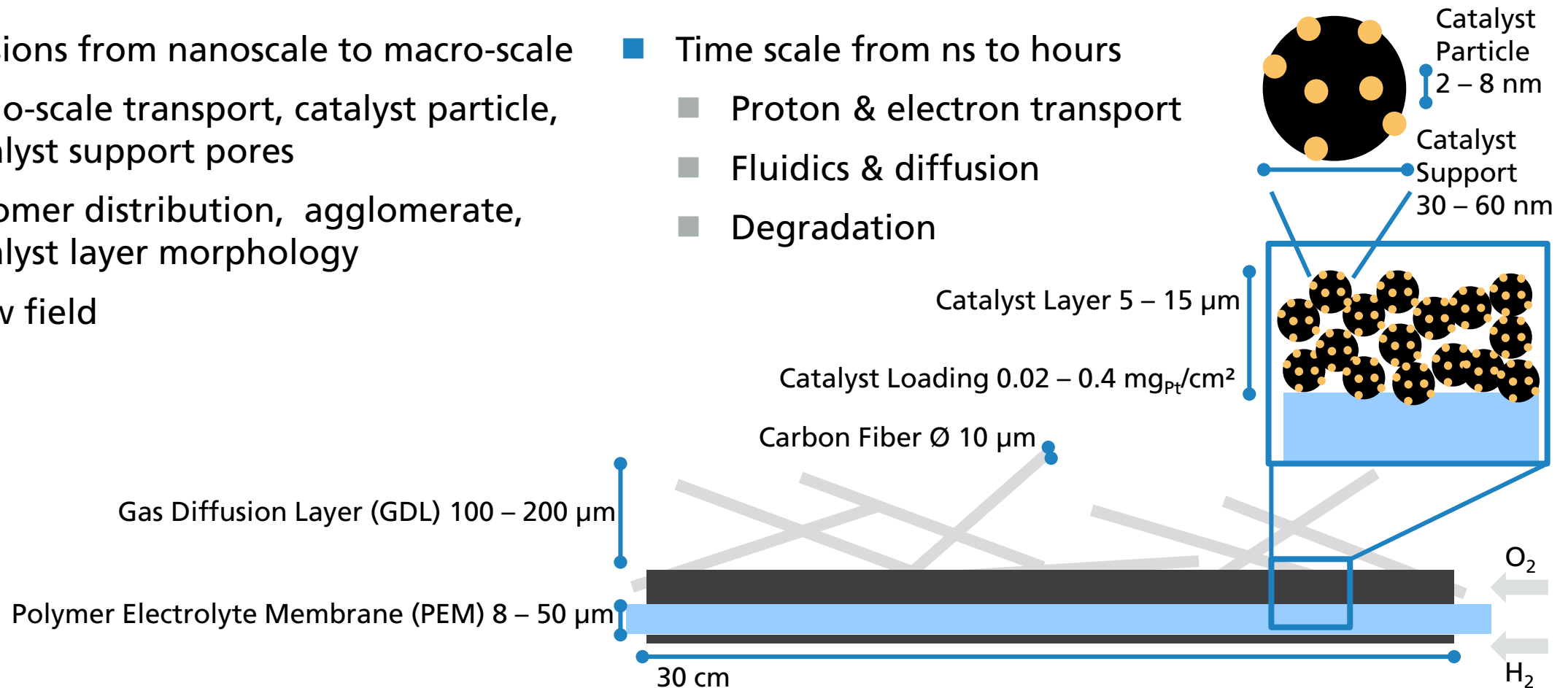
A multi-scale problem

■ Dimensions from nanoscale to macro-scale

- Nano-scale transport, catalyst particle, catalyst support pores
- ionomer distribution, agglomerate, catalyst layer morphology
- Flow field

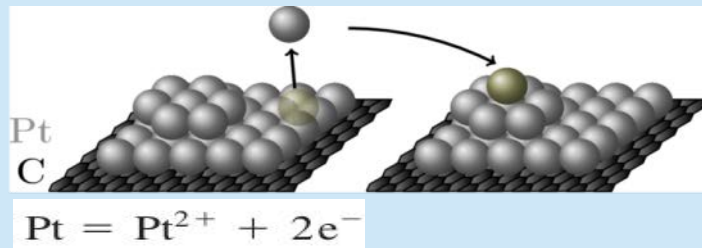
■ Time scale from ns to hours

- Proton & electron transport
- Fluidics & diffusion
- Degradation

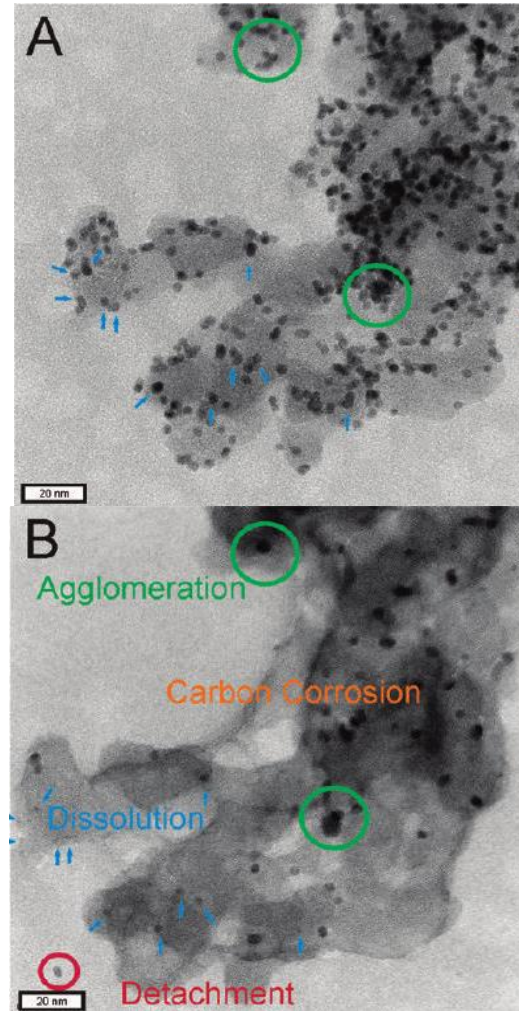
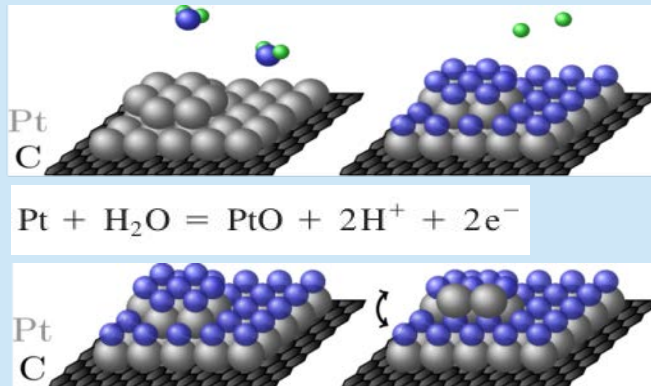


Degradation Mechanisms in Catalyst Coated Layers

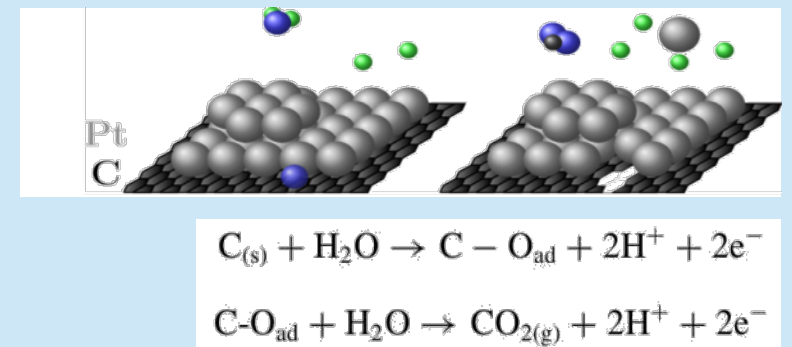
Electrochemical dissolution and re-deposition (Ostwald ripening)



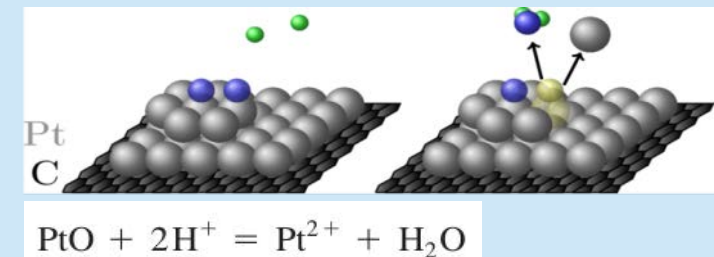
Platinum oxidation, reduction and place exchange



Carbon corrosion



Chemical dissolution of PtO



Fraunhofer ISE Test Stations

High quality material characterization

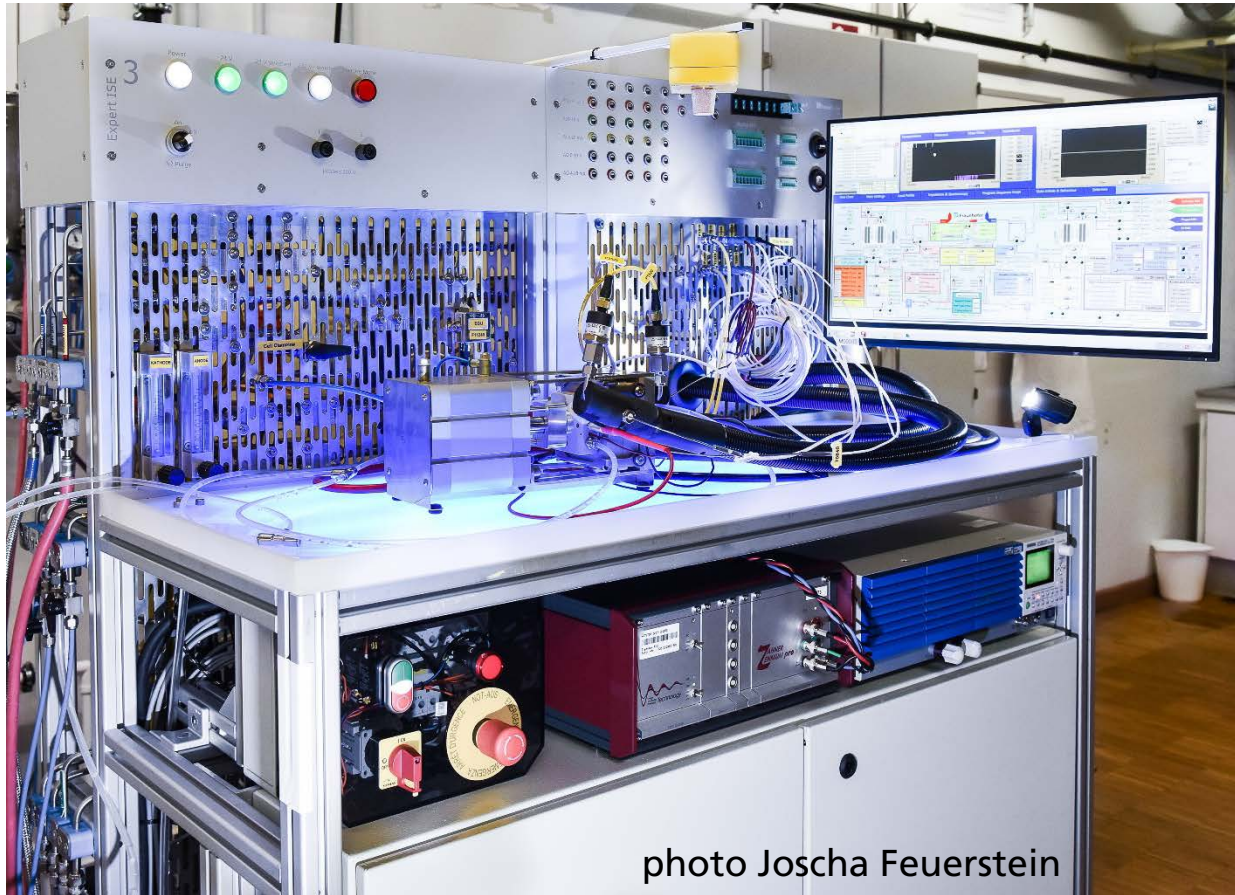


photo Joscha Feuerstein

- 3rd generation of own developed test station
- Fully automated for 24/7 operation
- Operation with air, oxygen, hydrogen, nitrogen, or contaminants
- Dynamic humidification
- State-of-the-art electro-chemical in-situ characterization for polarization curve, electro-chemical impedance spectroscopy, cyclic voltammetry, linear sweep voltammetry, limited current measurement

Fraunhofer-baltic PEM Fuel Differential Cell Test Cell

High quality material characterization

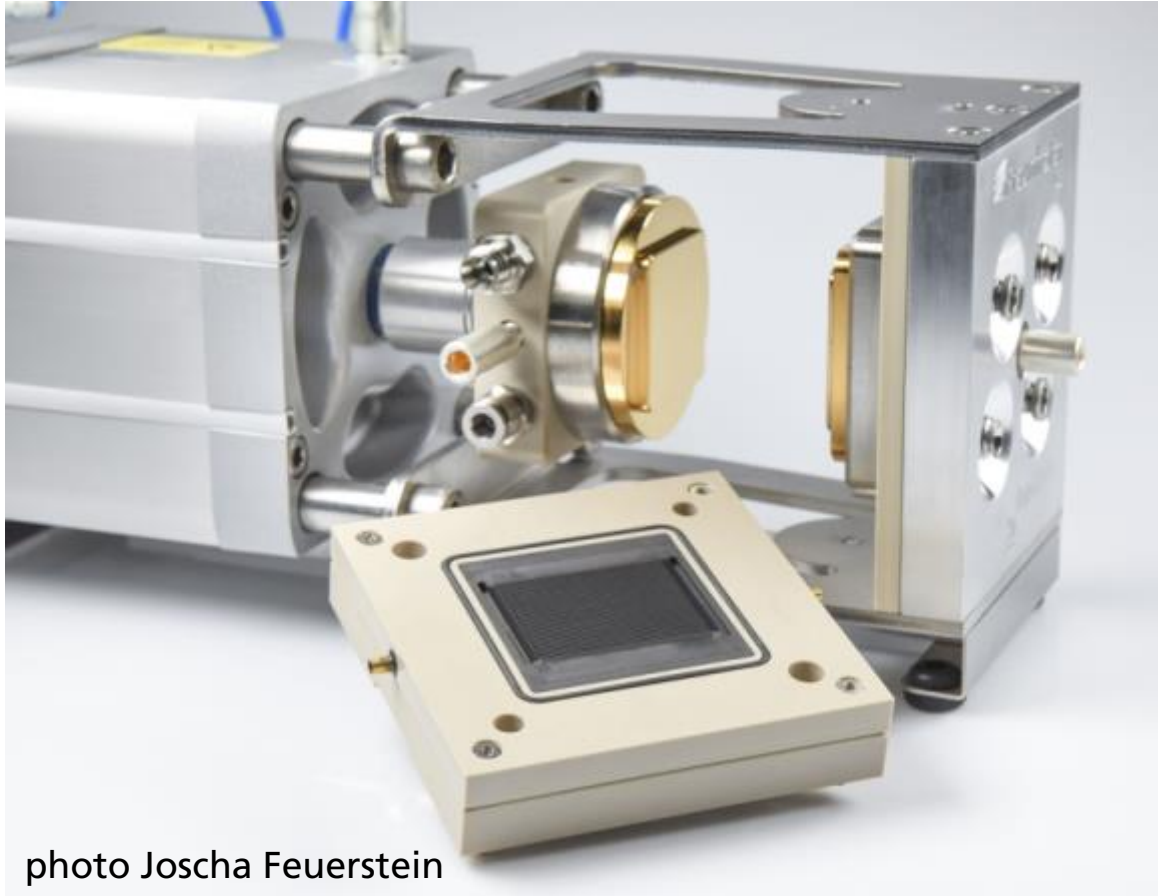
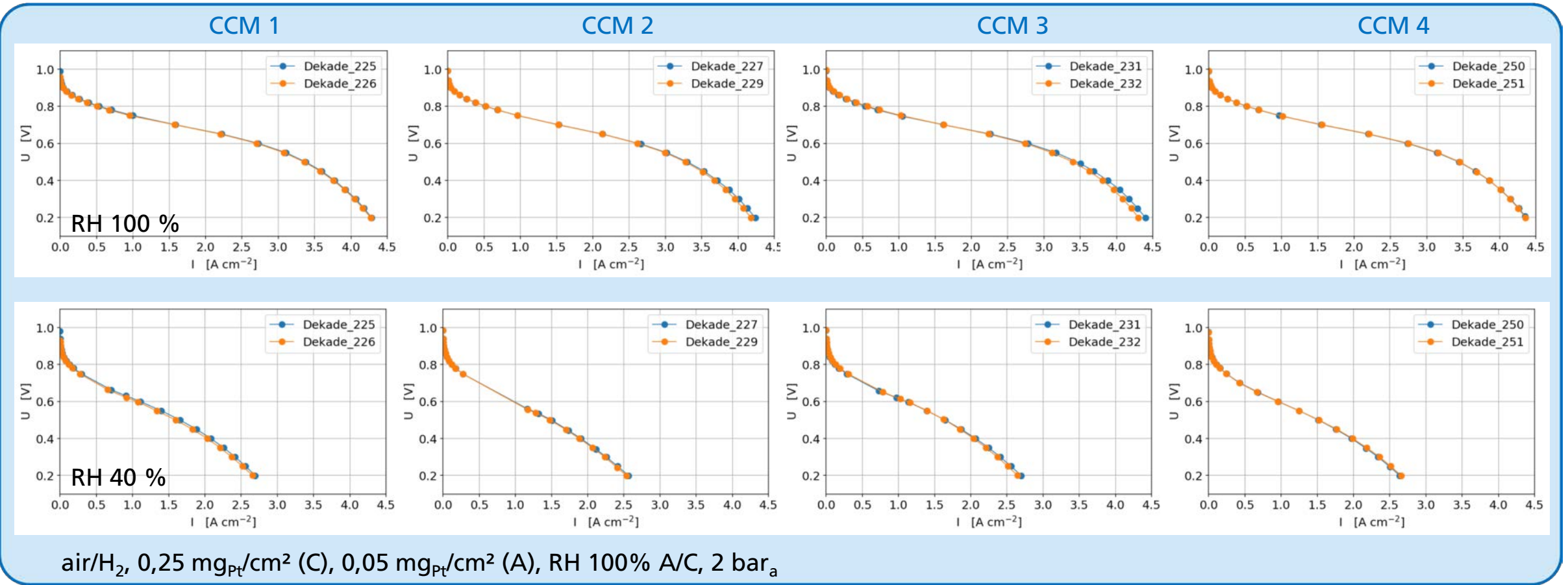


photo Joscha Feuerstein

- differential test cell (zero-gradient) even for high current densities up to 5 A/cm^2
- liquid cooling
- controllable (pneumatic) clamping pressure directly on the active area (GDL thickness variable & no gasket compression set-off)
- easy handling for fast component exchange

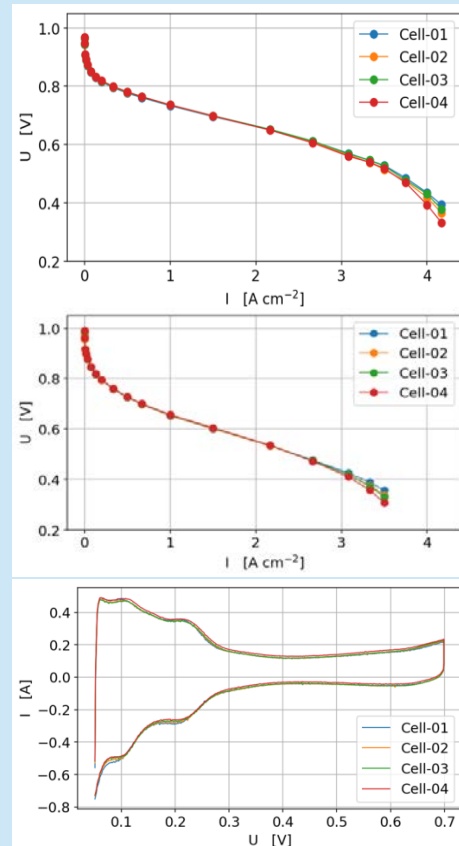
High Reproducibility of In-Situ Characterization

Polarization Curves, wet & dry conditions



Fraunhofer ISE Multicell-Characterization

High quality material characterization



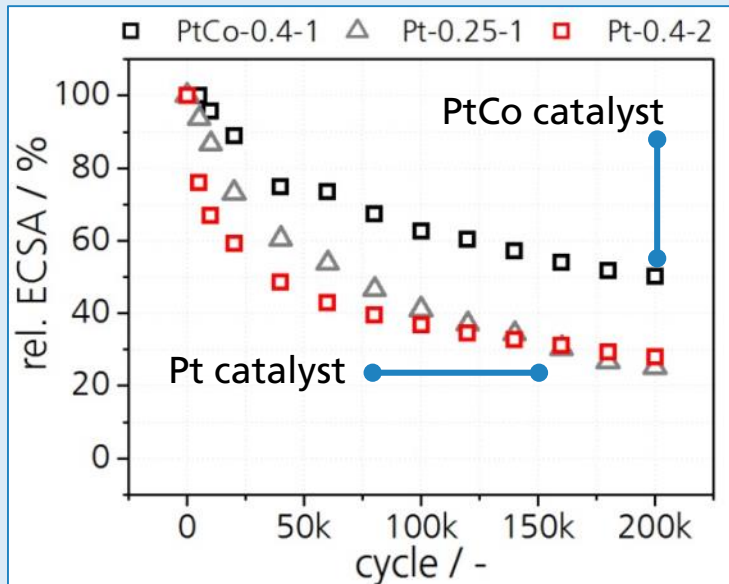
- Simultaneous characterization of 4 zero-gradient test cells
- Product water collection separate for each cell and cathode and anode (e.g. for element analysis by ICP-MS)
- Best suited for long-term evaluation (e.g. membrane degradation, drive-cycle testing)

Polarization curve for same material in 4 test cells @ 100% r.H (above) and 40% r.H. (middle). ECSA for same material in 4 test cells.

Degradation Mechanisms in Catalyst Coated Membranes

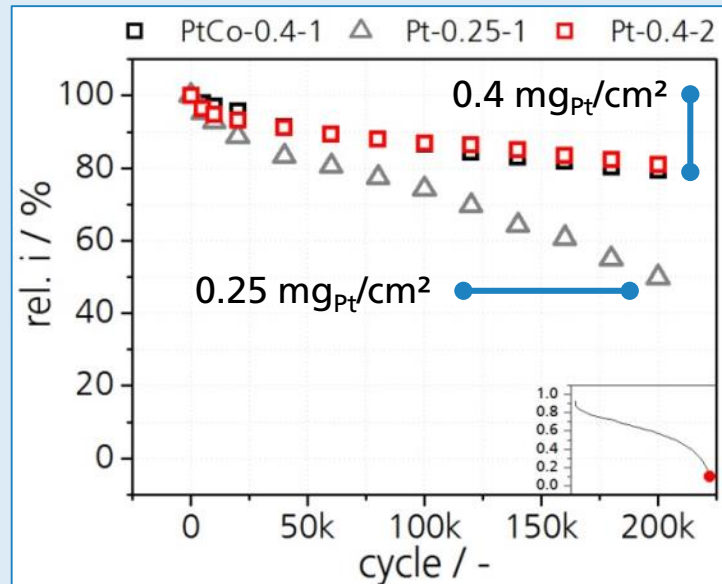
Accelerated Stress Tests for catalyst

(NEDO	1,00 V)	
DOE	0,95 V	
	0,60 V	



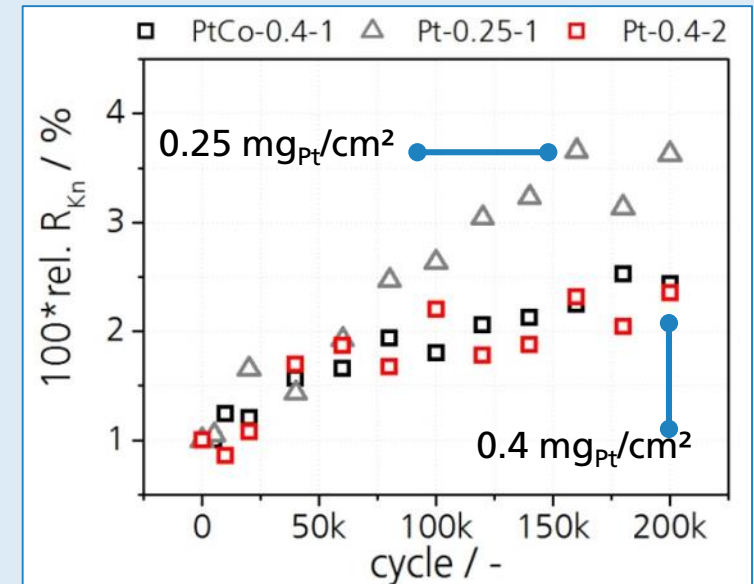
ECSA

- PtCo catalyst degradation slower than for Pt catalyst



Current density

- Low catalyst loading with stronger degradation



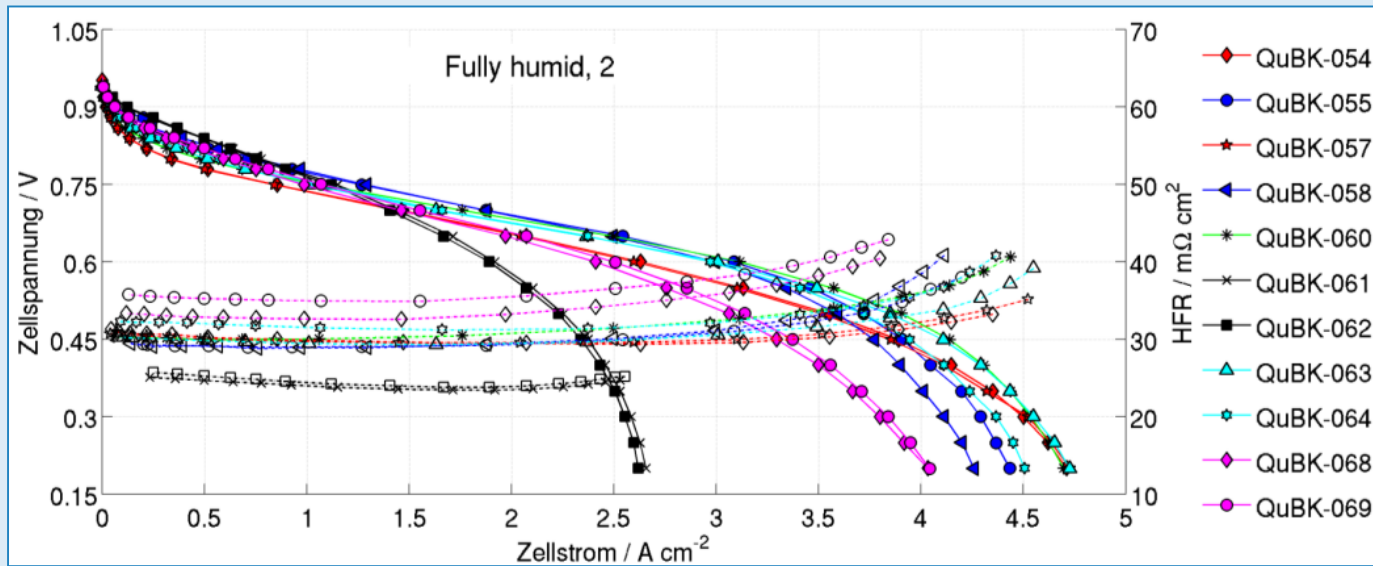
Morphology

- Low catalyst loading with stronger degradation

Degradation Mechanisms in Catalyst Coated Membranes

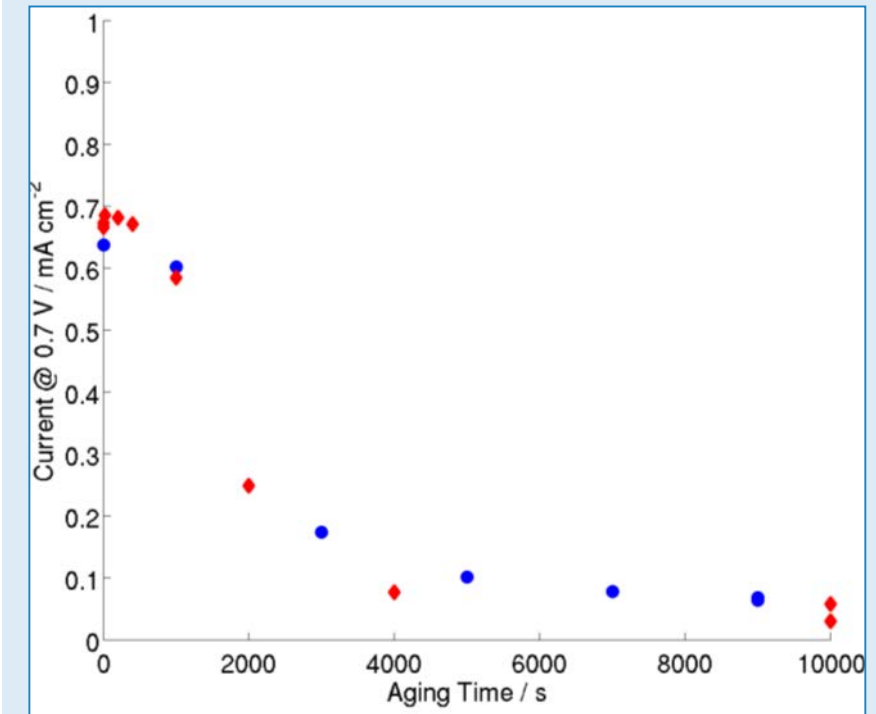
Accelerated Stress Tests for catalyst support

NEDO
&
DOE 1,5 V
1,0 V H_2/N_2
2s 2s



Begin-of-Test polarization curves and high frequency resistance with 5 materials for AST (catalyst support) according to DOE and NEDO

- Different characterization intervals do not affect the degradation behaviour

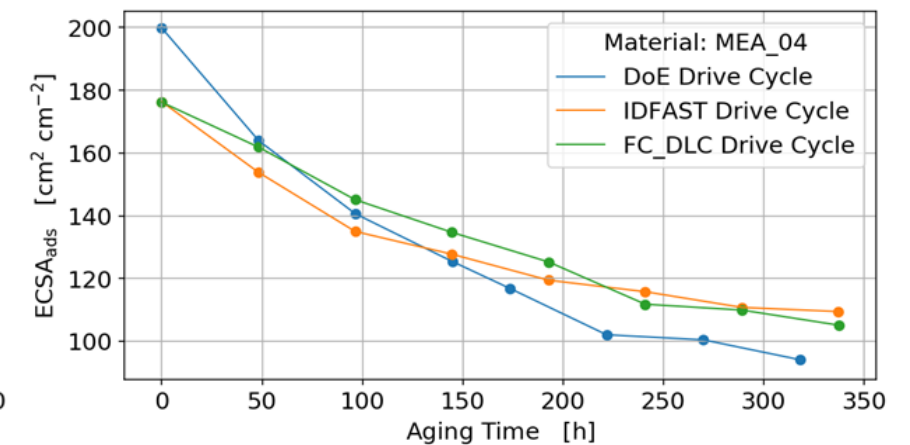
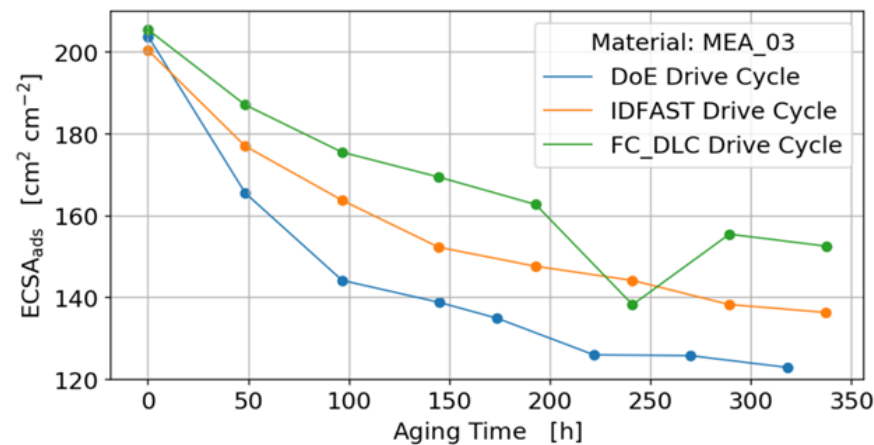
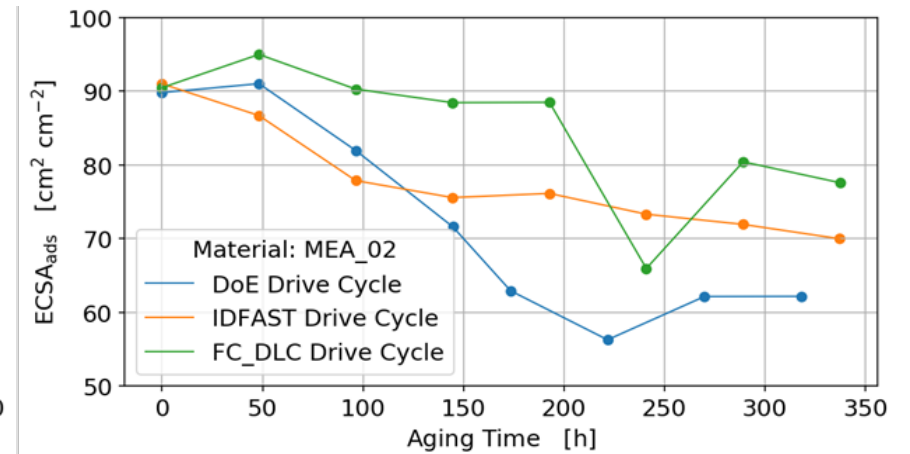
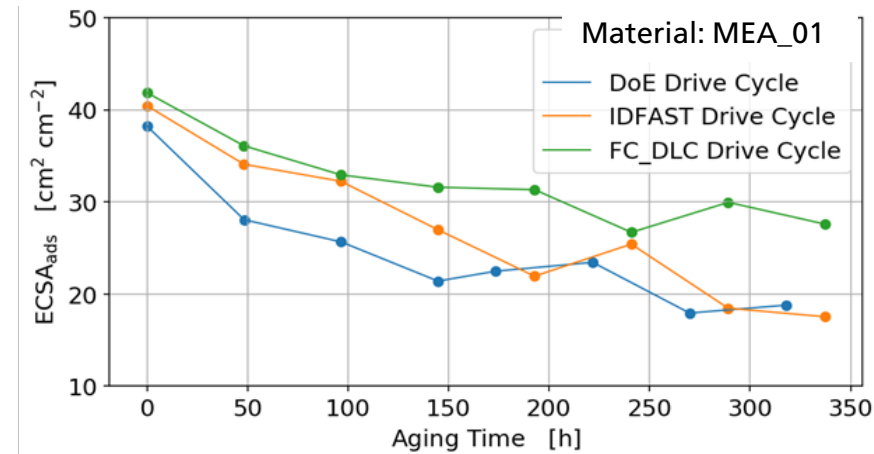


Current density @ 700 mV for one material according to ASTs from DOE (red) or NEDO (blue)

Degradation Mechanisms in Catalyst Coated Membranes

Drive Cycle Testing of MEAs

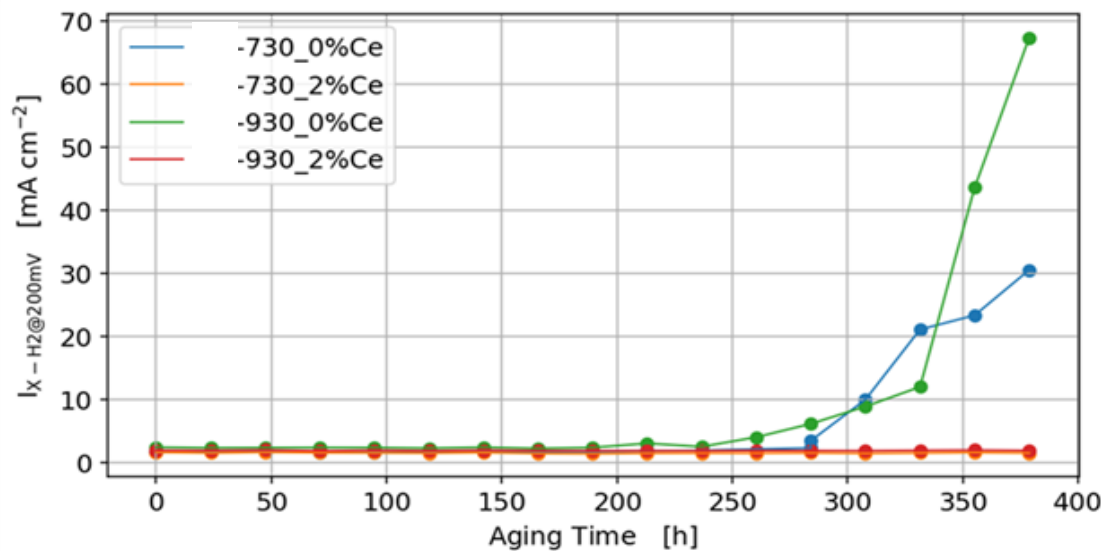
- 3 different drive cycles
- 4 different MEAs
- ECSA loss depends on cycle profile and catalyst loading



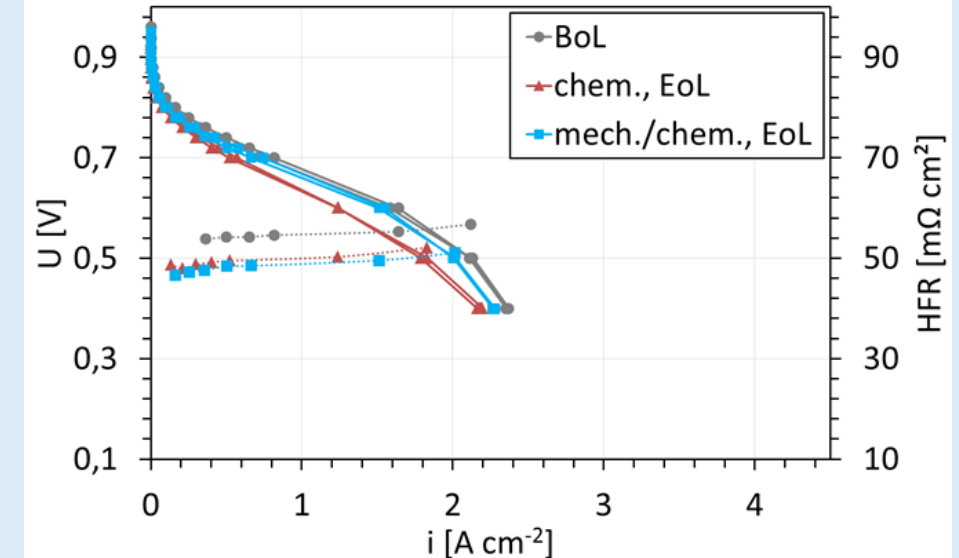
Degradation Mechanisms in Membranes

Accelerated Stress Tests for Polymer Electrolyte Membranes

NEDO & DOE	H ₂ /air OCV	air/air 150 % rH	4 min.
		0 % rH	



Chemical aging of different membranes w & w/o Ce stabilization (OCV hold): the chemical stabilized membranes show no degradation over 350 h

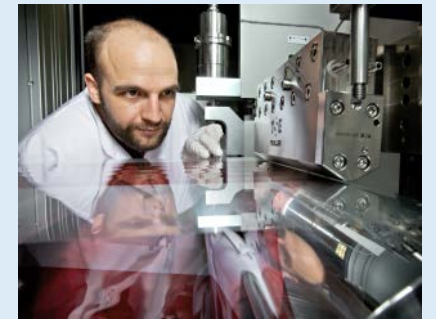
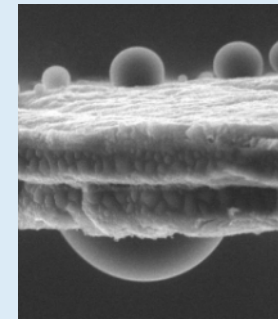
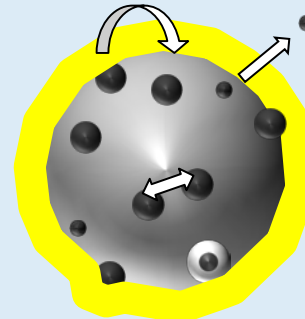


Comparison of chemical and mechanical aging of a membrane

- Chemical aging dominates over mechanical aging

Take home messages

- Fully automated **test set-ups** are available
- Automated **test, characterization and break-in protocols** are validated
- A **variety of materials** was tested
- Process technology for **manufacturing of different catalyst layers** was established
- Effects of **different test protocols, characterization and materials** were investigated



Thank You for Very Much for Your Attention!

Detailed information (in German) is given in the final project report:

<https://www.ise.fraunhofer.de/en/research-projects/qubk.html>



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