Karlsruhe Institute of Technology

IAM
Institute for Applied Materials

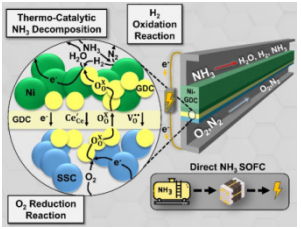
Institute for Applied Materials – Electrochemical Technologies (IAM-ET)

Fuel Cells and Electrolyzer

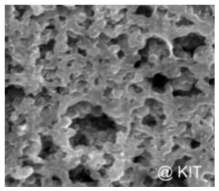
André Weber

Fuel Cells and Electrolyzer at KIT

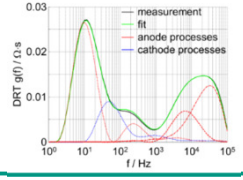
KIT ITCP
Olaf Deutschmann
- Solid Oxide Cells
- multiscale modeling
- complex fuels (CH_4, biogas NH_3)



KIT TFT
Philipp Scharfer, Wilhelm Schabel
- PEM FC and electrolyzer
- CCM processing
- from inks to cells
- coating and drying technologies



KIT IAM-ET
André Weber, Philip Röse, Ulrike Krewer
- low and high temp. fuel cells and electrolysis
- microstructure and material characterization
- electrocatalysis
- characterization – material to cell level
- multiscale modeling
- Fuel Cell Test Lab



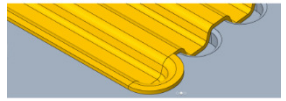
ElfER (KIT&EDF)
Aline Leon, Mathieu Marrony
- various fuel cell and electrolyzer technologies
- heavy-duty mobility & stationary applications
- testing from cell to system level
- Fuel Cell Test Lab at KIT

KIT IMVT
Peter Holtappels, Roland Dittmeyer
- Energy Lab 2.0
- fuel cells and electrolyzers
- system level testing
- coupling to grid and downstream chemical reactors

KIT ISTM
Alexander Stroh, Bettina Frohnapfel
- PEM fuel cells and electrolyzers
- CFD modeling
- multiphase flows & heat transfer
- optical in-situ experiments

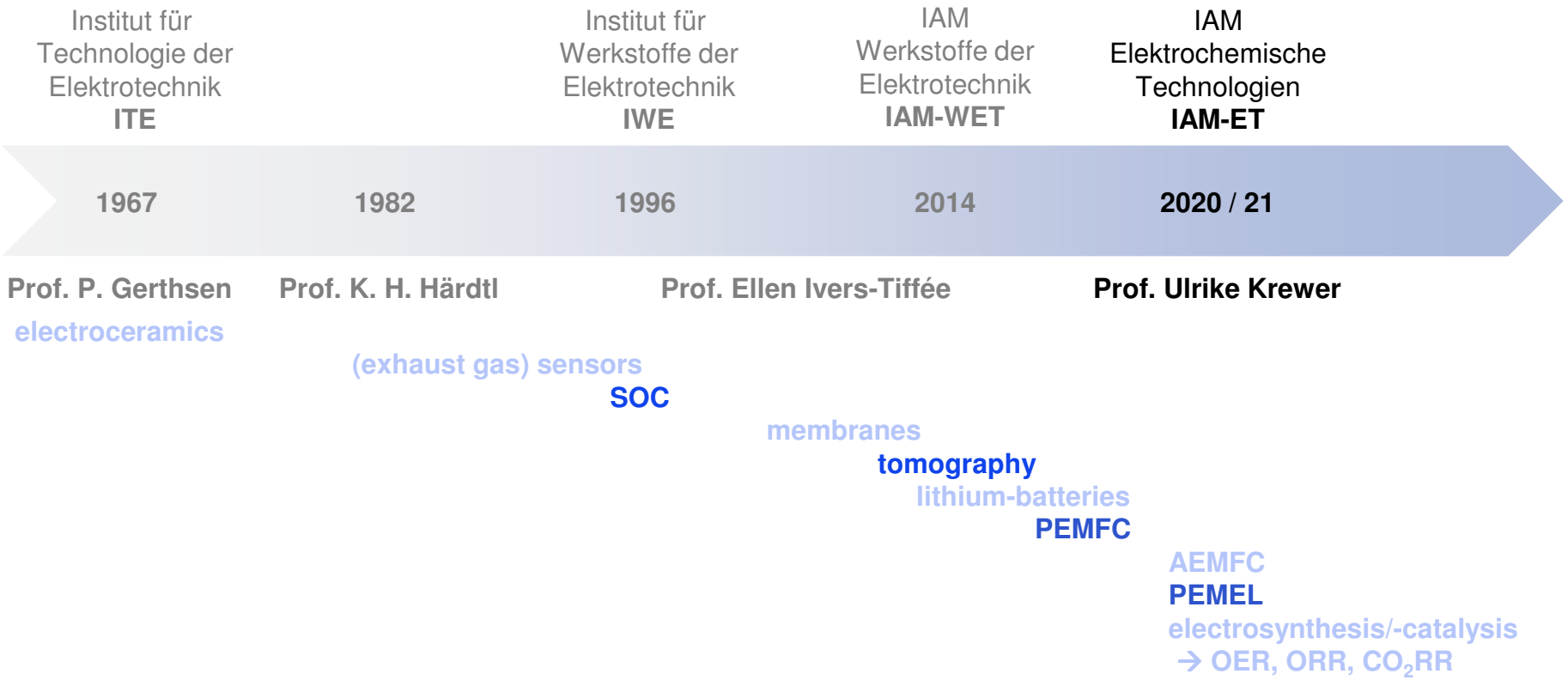
KIT IAM-MMS
Michael Selzer, Britta Nestler
- PEMFC & SOFC
- material and microstructure design
- phase field modeling of aging phenomena

KIT IPEK
Jan Haußmann
- PEM fuel cells
- stack level development
- sensor based monitoring
- diagnosis & control



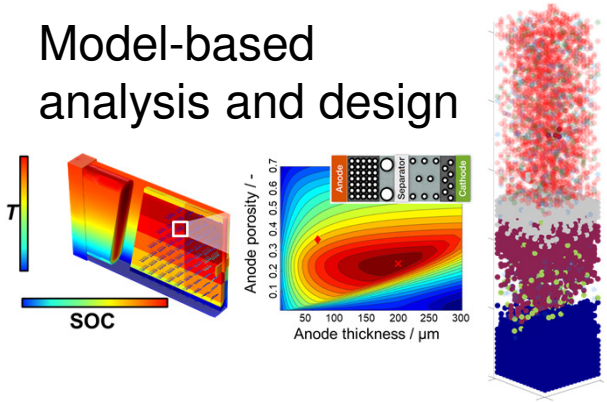
KIT WBK
Gisela Lanza, Jürgen Fleischer
- manufacturing of FC and electrolyzers
- machine and process development
- scalable production and automation concepts
- in-line and in-process quality control
- factory and production planning

Institute for Applied Materials – Electrochemical Technologies History

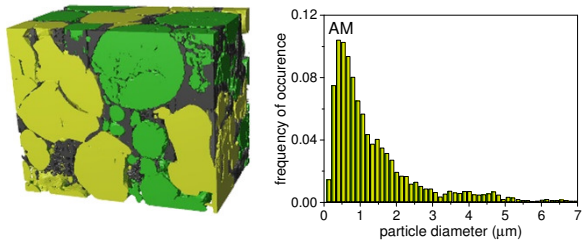


Institute for Applied Materials – Electrochemical Technologies
Research Areas

Model-based analysis and design

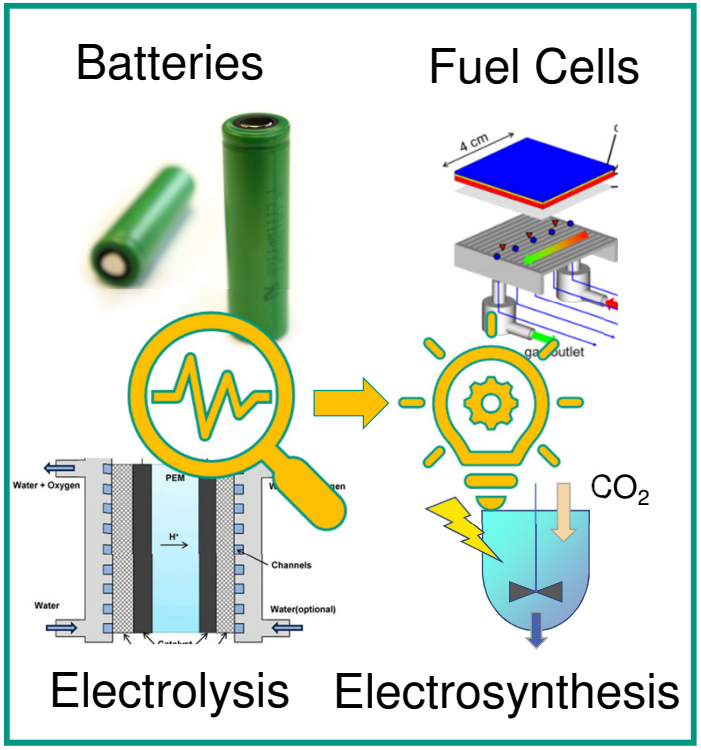


Microstructure analysis



Batteries

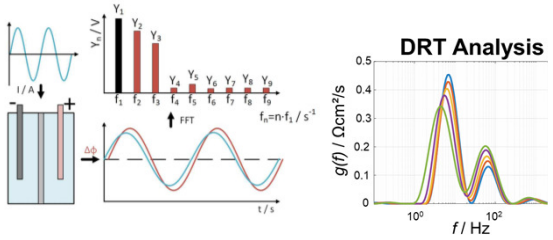
Fuel Cells



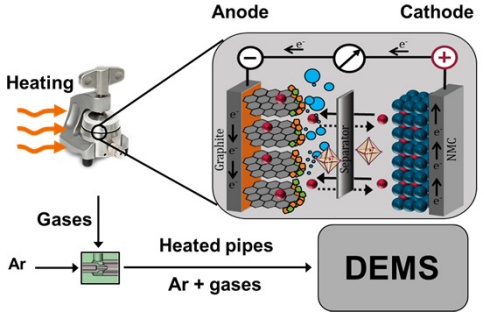
Electrolysis

Electrosynthesis

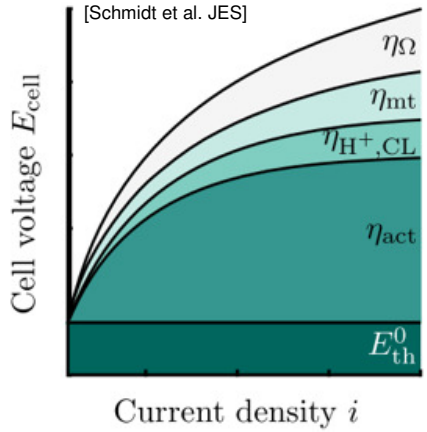
Dynamic analysis



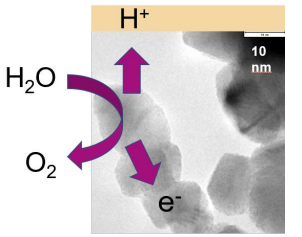
Operando analysis



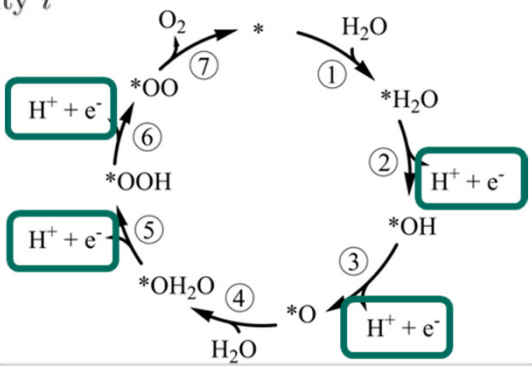
Model-assisted Catalyst Analysis
Performance Limitations in PEM Water Electrolysis

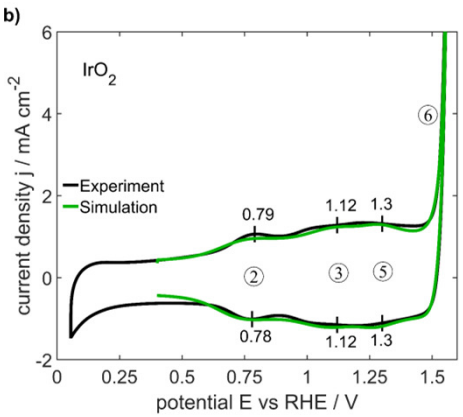


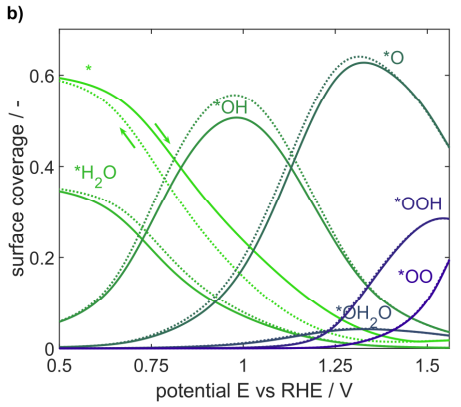
- **Sluggish Oxygen Evolution Reaction** (**OER**) limits PEM electrolysis performance: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
- **Goal: knowledge-driven catalyst design via microkinetic model-based analysis**
- Model reproduces CVs and reveals slow reaction steps (e.g. water sorption)



IrO_2, Grunwaldt, KIT

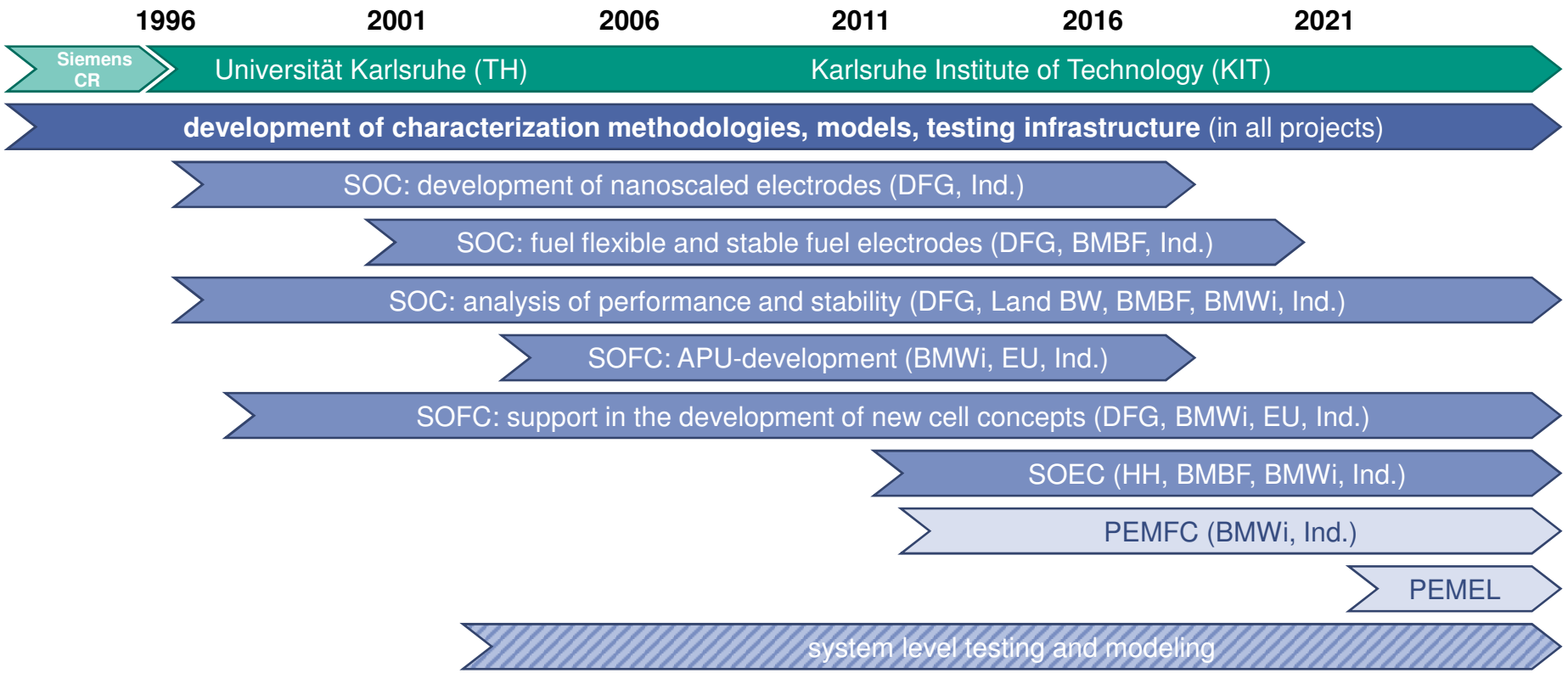






Geppert et al. J. Am. Chem. Soc. 2022, 144, 13205-13217.

Fuel Cells and Electrolyzers at IAM-ET
Research Topics



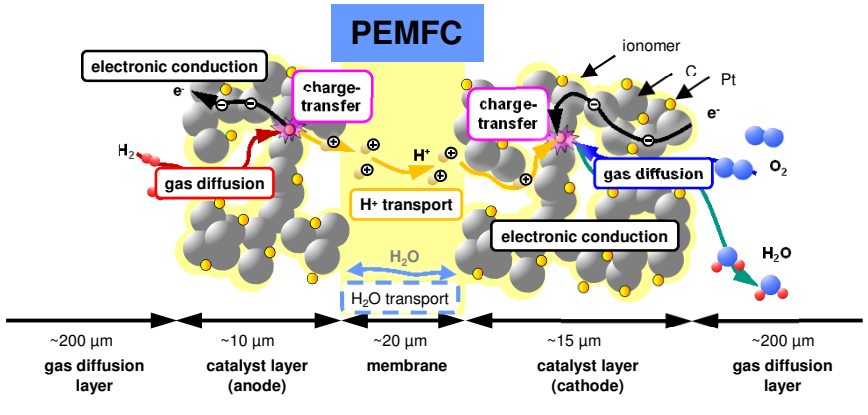
Polymer Electrolyte Membrane and Solid Oxide Cells
Transport and Reaction - Loss Mechanisms

transport in the gas phase: gas flow and diffusion

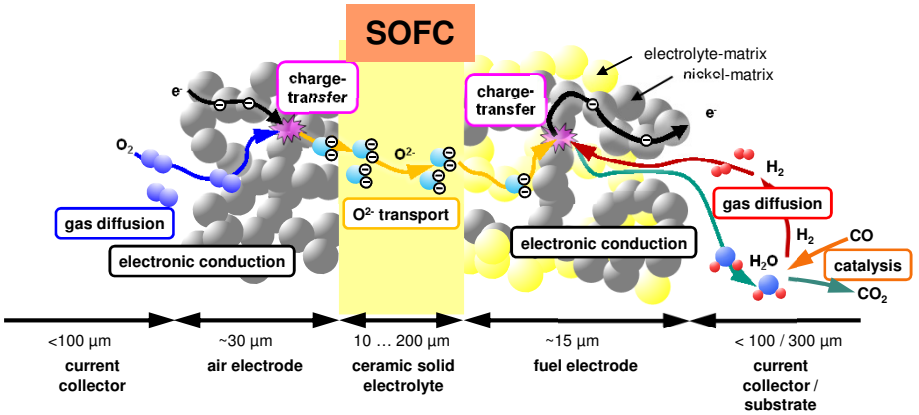
transport in the solid phase: electronic and ionic current

electrochemical reactions: charge transfer at an electrocatalyst

water management, 2 phase flow



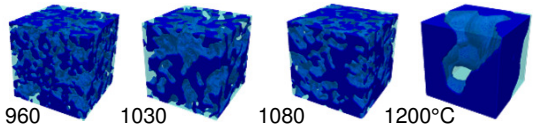
internal reforming, water-gas shift

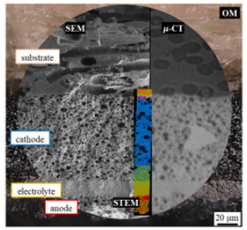


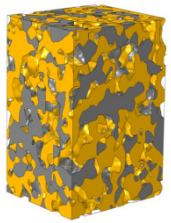
Aim: Understanding of polarization phenomena (electrochemical processes, dielectric polarization) in electrodes (and other components) of the investigated cell.

Fuel Cells and Electrolysis
Solid Oxide Cells (SOC)

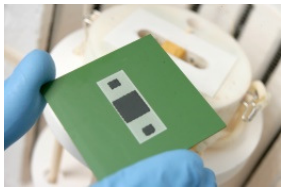
tomography (FIB-SEM, µCT)



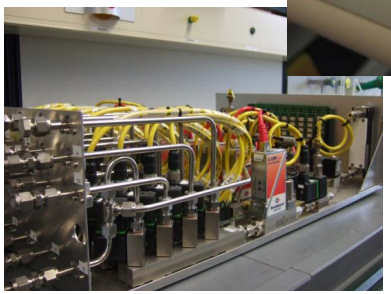




dynamic characterization



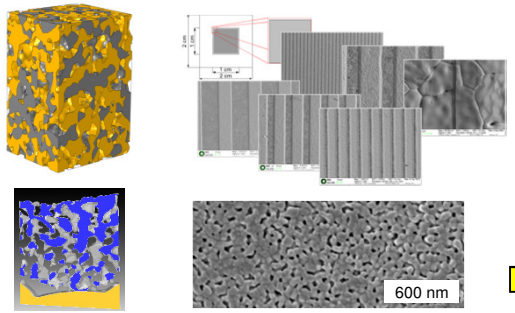
cell testing – performance and durability



Fuel Cells and Electrolysis
Solid Oxide Cells (SOC)

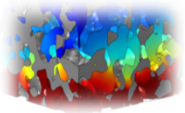
Karlsruhe Institute of Technology

tomography & (model) electrodes



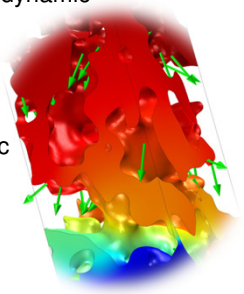
microstructure modeling

- stationary
- dynamic



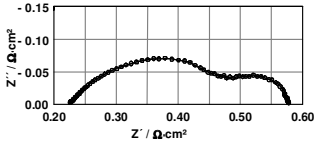
coupling of
- gas transport
- ionic and electronic conduction
- charge transfer

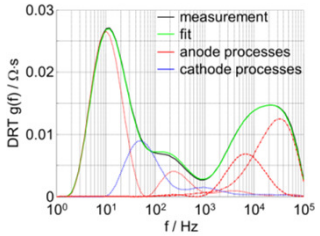
in porous electrodes



dynamic characterization

- impedance spectroscopy
- performance and durability





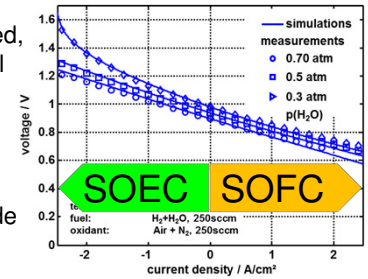
DRT analysis

$$\underline{Z}(j\omega) = R_{pol}\int_0^\infty \frac{\gamma(\tau)}{1+j\omega\tau}d\tau$$

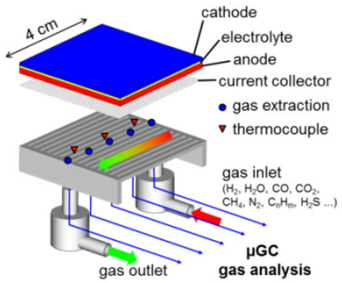
- deconvolution of losses

cell performance and losses

- impedance based, physicochemical models
- performance-prediction for fuel cell and electrolyzer mode



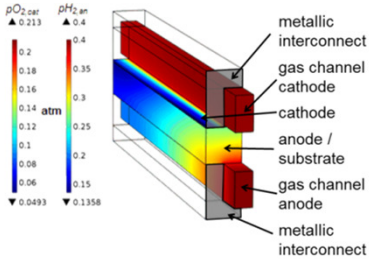
cell testing: performance and durability



- space resolved gas analysis
- internal reforming
- reformate operation
- catalyst poisoning
- alternative fuels
- Co-electrolysis, Power to Gas, Power to Molecules

repeat units and stacks

incremental repeat units



FEM multiphysics simulation

Institute for Applied Materials
Electrochemical Technologies
source: IAM-ET

C. Peters et al., J. Electrochem. Soc. 155, B730-B737 (2008)
A. Utz et al., J. Electrochem. Soc. 157, B920-B930 (2010)
A. Häffelin et al., J. Electrochem. Soc. 160, p. F867-F876 (2013)
J.-C. Njodzefon et al., J. Electrochem. Soc. 160, p. F313-F323 (2013)

Fuel Cells and Electrolyzers at IAM-ET

main partners (in funded projects 2000-2020):

Opportunities for Cooperation

Solid Oxide Cells

- Performance and durability, accelerated aging
- Electrochemical characterization / dynamic methods
- Modeling – electrode to stack
- Correlation of cell design / microstructure and performance

PEM / Alkaline Membrane Cells

- Performance and durability testing
- Electrochemical characterization / dynamic methods
- Modeling – electrode to system level
- Operando characterization

Electrocatalysis, CO_2-conversion

- Electrochemical characterization / dynamic methods
- Physico-chemical Modeling – electrode to cell level
- Operando characterization
- Focus on “Power-to-Fuels/Chemicals”