



Produktionsforschung zur Membranelektrodeneinheit für Brennstoffzellen Ulf Groos, Fraunhofer ISE

H2-Kolloquium Baden-Württemberg | 04.–05. Juni 2024, Baden-Baden

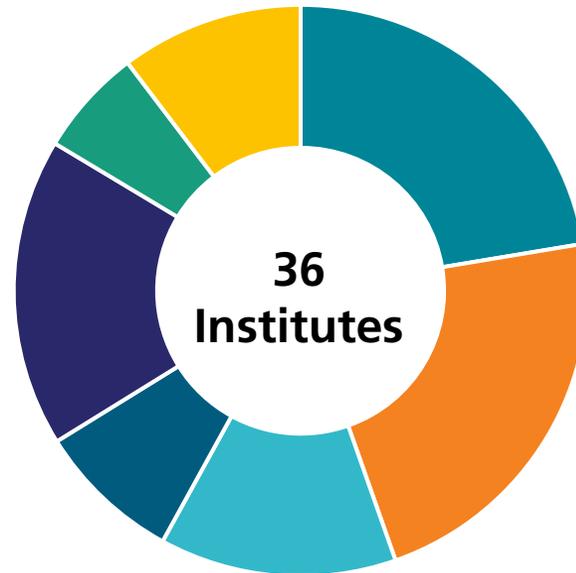
Agenda

- 1 Wasserstofftechnologien am Fraunhofer ISE
- 2 HyFaB – Produktionsforschung für die MEA
- 3 Ausblick

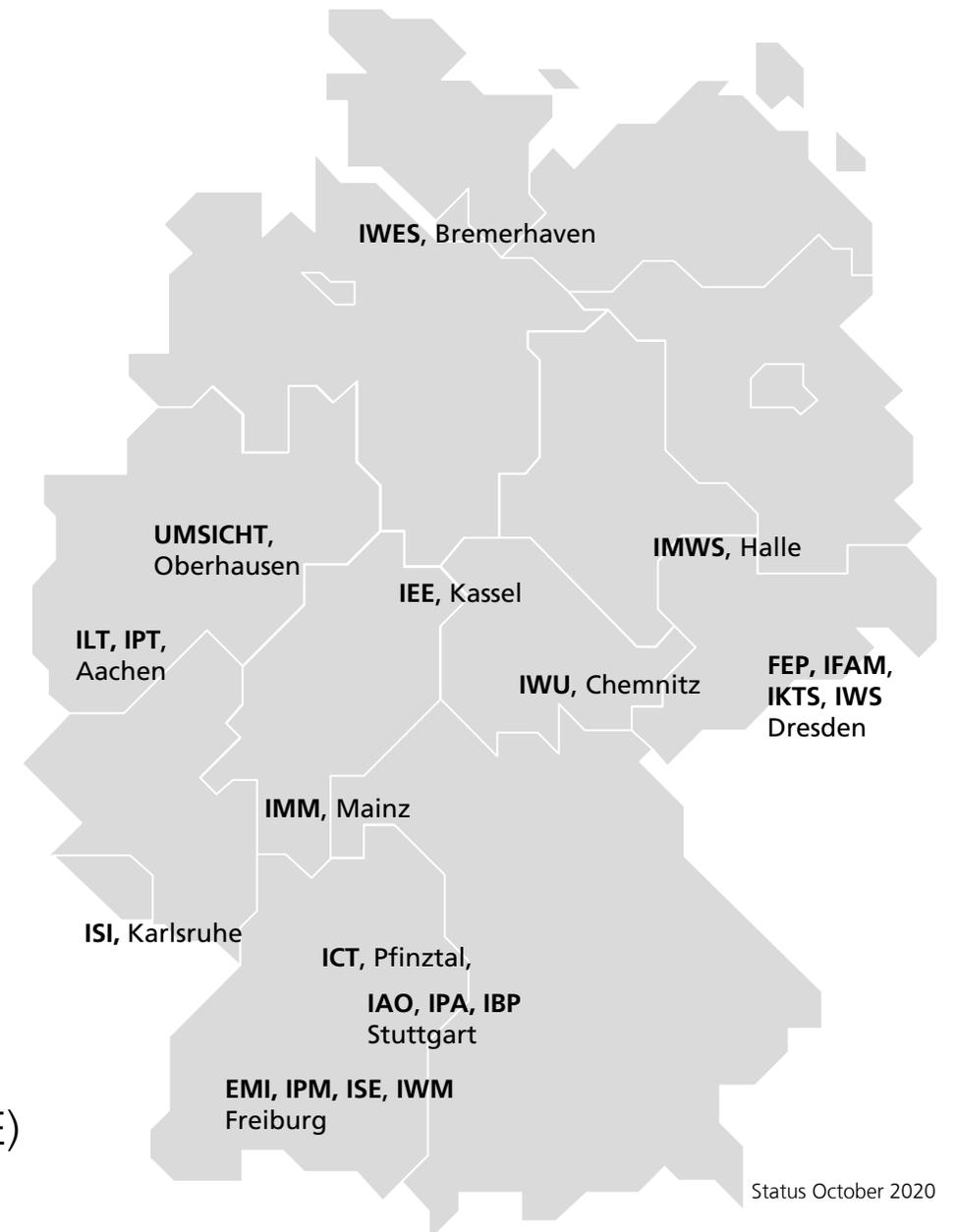
This Is Us



Fraunhofer Hydrogen Network



- Management:
Prof. Christopher Hebling (ISE)
Prof. Mario Ragwitz (IEG)



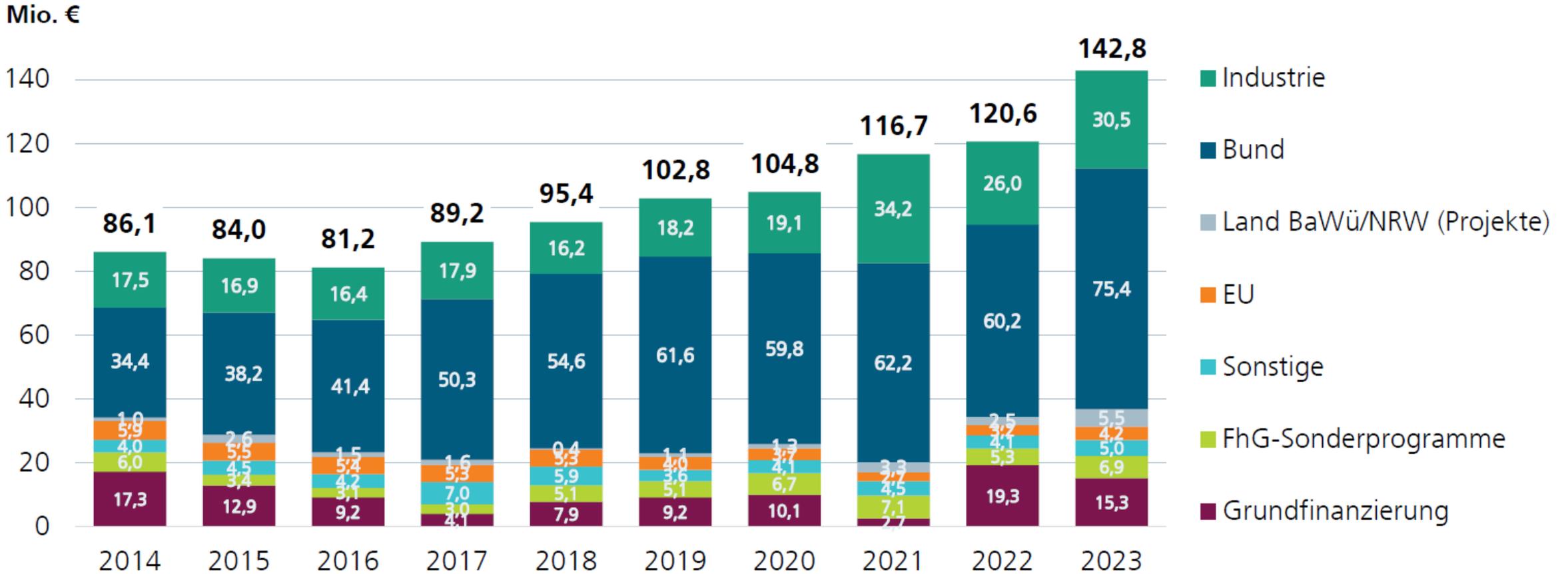
Research Focus of Fraunhofer ISE

The Largest Solar Energy Research Institute in Europe



Fraunhofer ISE

Budget 2023



Status: März 2024

Hydrogen Technologies

Defossilization of Transport, Chemicals, and Industrial Processes



Sustainable Mobility

Membrane fuel cells, sustainable fuel internal combustion engines, and fuel infrastructure



Sustainable Synthesis Products

Catalyst & process development including life cycle and techno-economic assessment



Electrolysis & Power to Gas

Membrane water electrolysis as basic technology for renewable fuels



30 years H₂ experience



170 employees



20 Mio € annual budget

Fuel Cell

Our Customers Rely on Our Results

Scientifically Sound R&D Services

Key Performance Indicators 2023:

- 36 researches plus students
- 6.6 Mio. € annual budget (w/o investments)
- 34% direct revenue by industry contract research
- > 500 m² laboratory area with 13 single cell test stations, 5 short stack test station, 2 climate chambers (all fully automated for 24/7 operation)
- Focus on transport application (membrane fuel cells)

Enjoy our virtual lab tour: https://www.ise.fraunhofer.de/en/rd-infrastructure/center/center-for-fuel-cells-electrolysis-and-synthetic-fuel.html#cop97298897_794300985

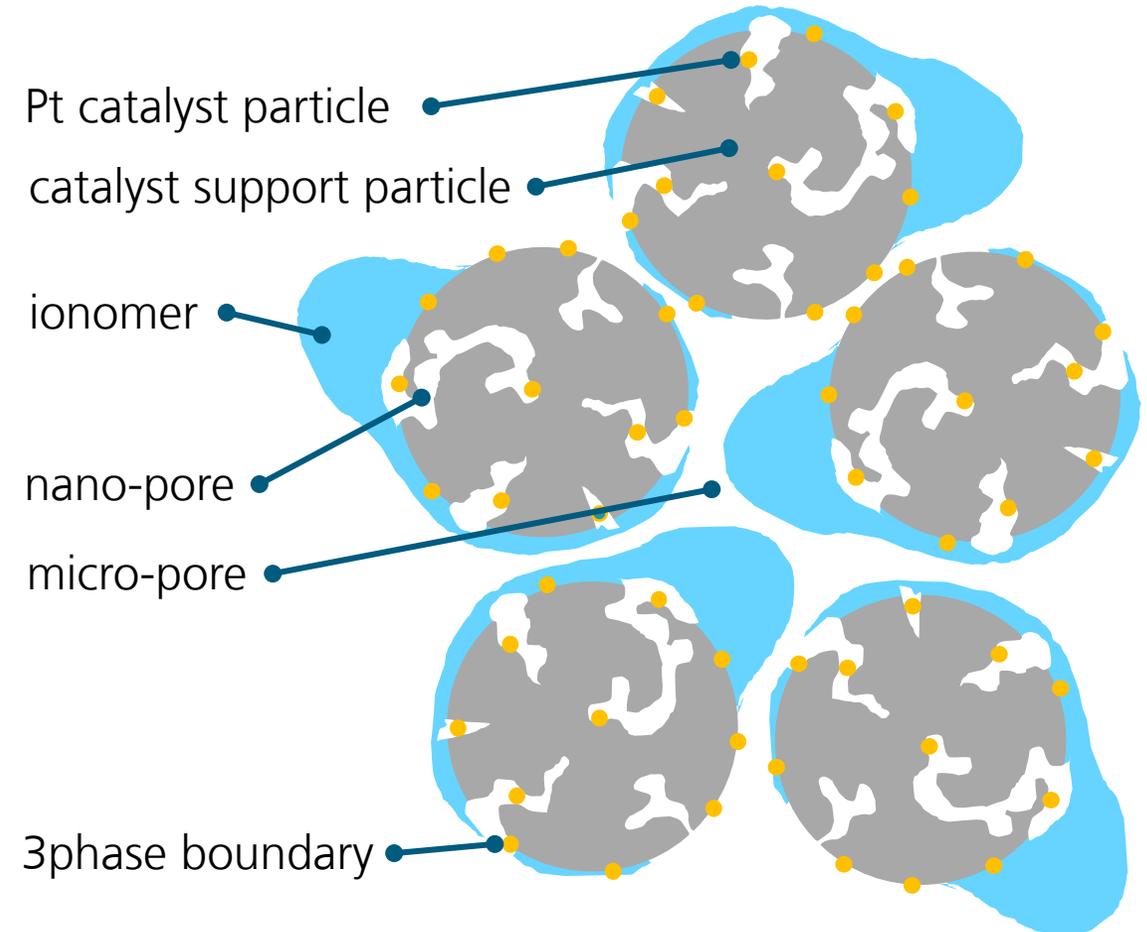


We Concentrate on Membrane Electrode Assemblies

Enabling the Electro-Chemical Reaction and Gas Diffusion Processes

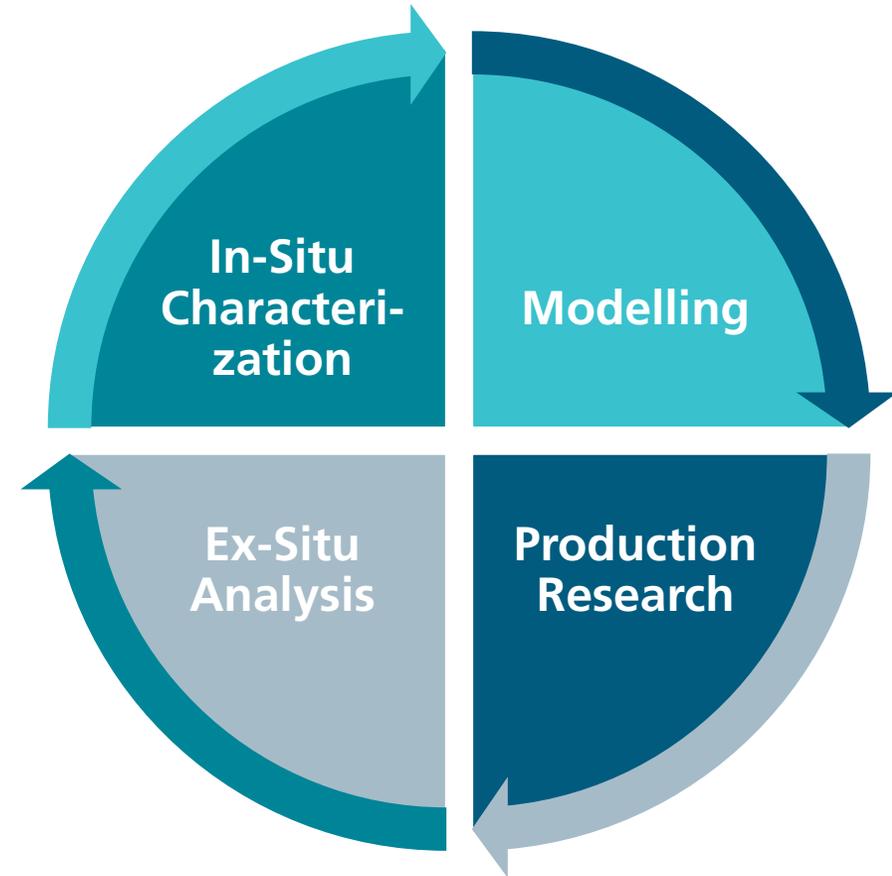
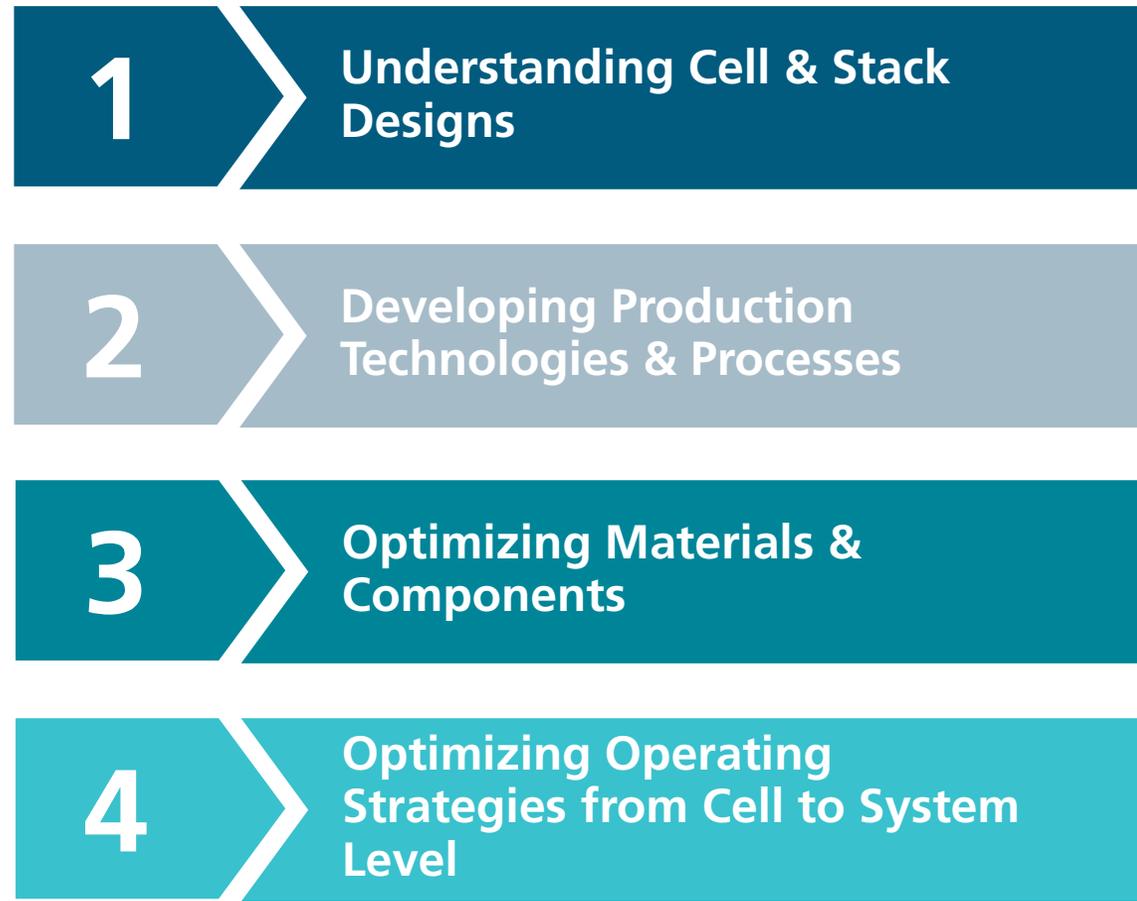
Phenomena

- Gas diffusion in pores, ionomer, and water films
- Proton transport through ionomer and water films
- Proton transport from membrane to catalyst layer
- Electron transport through carbon support particle
- Electro-chemical reaction at Pt particle
- **In-situ characterization** to evaluate all these processes and to assess the different loss mechanisms
- **Ex-situ analysis** to understand the microstructure and element distribution
- **Modelling** to explain the physics
- **Production research** to develop manufacturing processes



Value Proposition to Our Customers

Understanding Process-Microstructure-Performance-Degradation Correlations of MEAs





HyFaB – a Project Family

HyFab: FuE-Platform for Process Development in Fuel Cell Production

- Focus on mobile fuel cell stacks for series production of components, assembly, end-of-line testing and break-in
- Joint project of ZSW together with Fraunhofer ISE, and VDMA with funding from state of Baden-Württemberg and Federal Ministry for Digitalization and Transport

➤ R&D services for industry and SMEs



HyFab: A Project Overview

- Stack Basislinie (ZSW & Fraunhofer ISE - HyFaB-Land): Base line for fuel cell stack production
- HyFab3 (Fraunhofer ISE – HyFaB-Land): MEA production
- Referenzstack (ZSW - HyFaB-Land): Positioning in stack assembly and contamination effects
- MEA – EOL (ZSW – HyFaB-Bund): End-of-line testing of 7-layer MEAs
- Multi Düse (ZSW – HyFaB-Bund): Sealing of bipolar plates
- Bal-O-Stack (ZSW – HyFaB-Bund): Generic stack components
- BPP – Kontaktdruck (ZSW - HyFaB): Coating application technologies for metallic bipolar plates
- BI-FIT (Fraunhofer ISE & ZSW - HyFaB-Bund): Break-In for Fuel Cells Initializing and Testing
- TiKaBe (Fraunhofer ISE - HyFaB-Bund): Ink development for e.g. screen printing, slot die coating, ink jet printing
- QUALLE (Fraunhofer ISE – HyFaB-Bund): Quality control in CCM production
- GIRAFFE (Fraunhofer ISE – HyFaB-Bund): Generic Investigation on Alternative Fluorine Free Electrodes
- DS2S (Fraunhofer ISE – HyFaB-Bund): Direct Stack to Scale with hydrocarbon MEAs

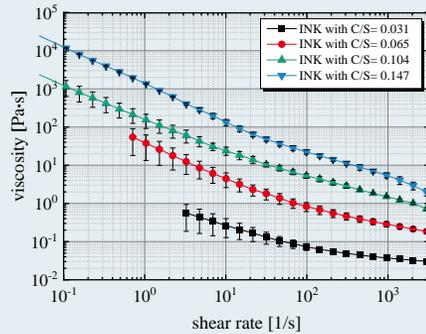
MEA Production Research @ Fraunhofer ISE

Key Topics

Ink Dispersing & Mixing



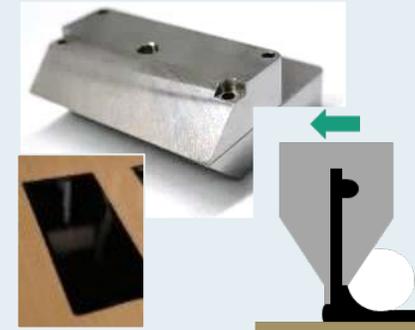
Catalyst ink



Screen Printing



Slot Die Coating



Other Coating Technologies



Drying Process



Transfer Process



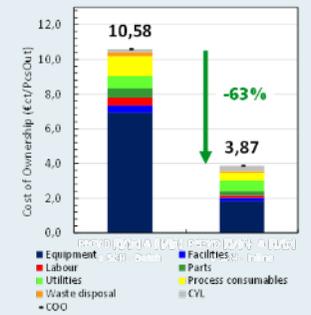
Upscaling Production



Defect Detection & Quality Control

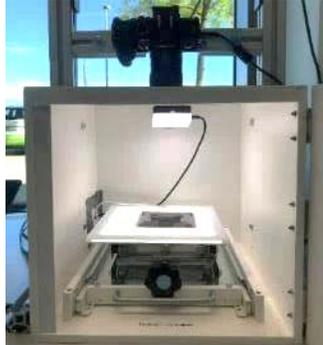


Total Cost of Ownership & LCA



NEW! Virtual lab tour:
https://www.ise.fraunhofer.de/en/rd-infrastructure/center/center-for-fuel-cells-electrolysis-and-synthetic-fuel.html#cop96552011_414506800

Ex-situ Quality Assurance for Ink & Coating Processes



Optical QC



Laser Diff. Particle Size Analyzer



Thermogravim. Analysis



µXRF



Conf. Laser Scanning µScope



N₂-Adsorption



Zeta-Potential measurement



Diff. Scanning Calorimetry



Contact angle

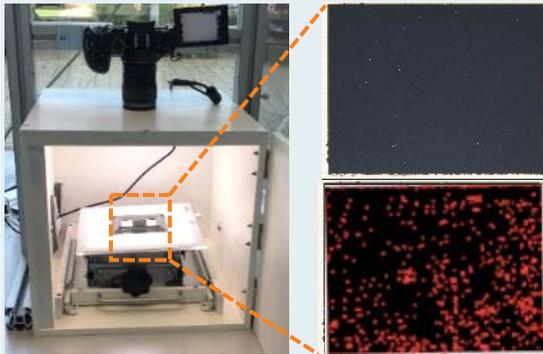


Rotational rheometer

Ex-situ Analysis of Catalyst Layers and Catalyst Coated Membranes

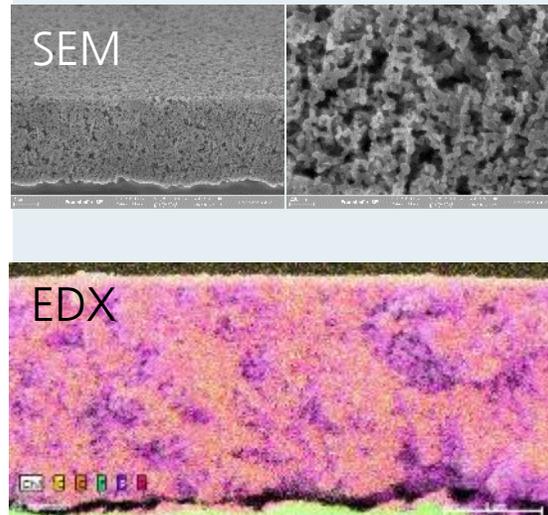
Optical Analysis

- Surface Imaging
- Defects



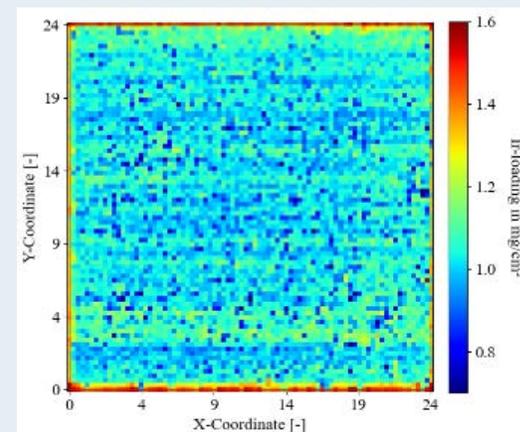
SEM-EDX

- Surface Imaging
- CL-Thickness
- Element Distribution



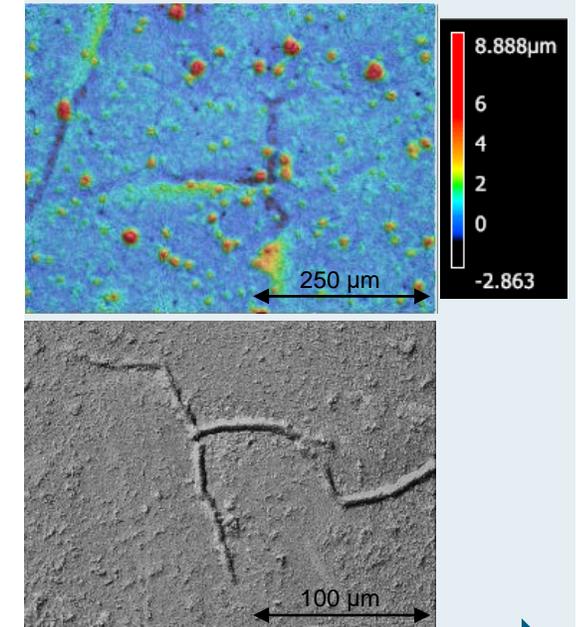
μ XRF

- Surface Imaging
- Catalyst Distribution
- Loading Homogeneity



CLSM

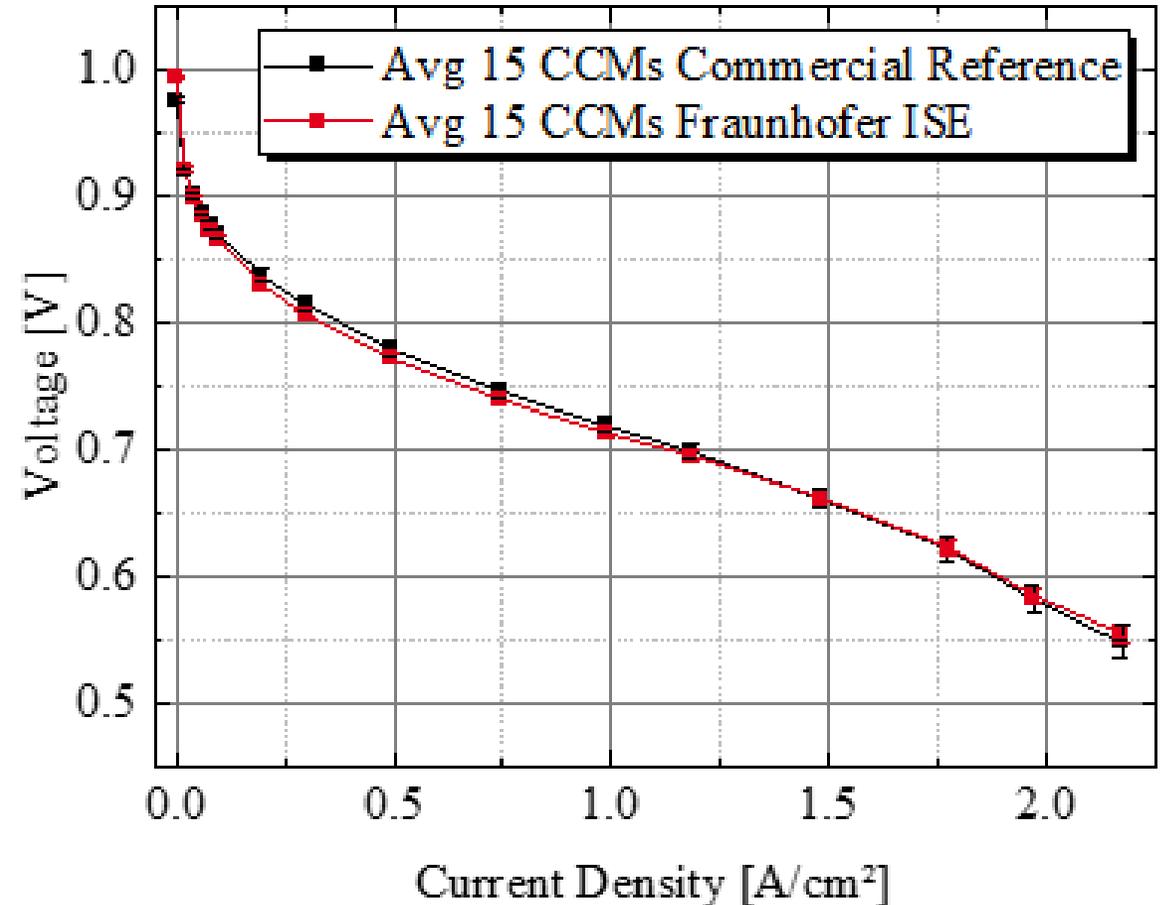
- Surface-3D Imaging
- Profile-Analysis
- Surface Defects



Ex-situ Equipment enables a complete quality assurance of the production process

Performance of Fraunhofer ISE MEAs in Generic Stack

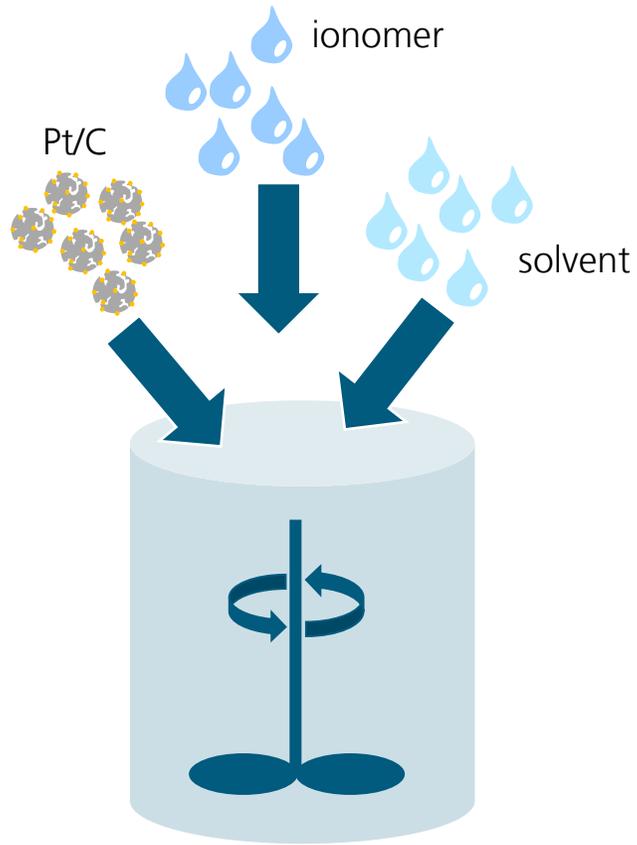
- The polarization curve of a fuel cell stack equipped with Fraunhofer ISE MEAs shows comparable results to a commercial MEA
- Cathode loading: $0.4 \text{ mg}_{\text{Pt}}/\text{cm}^2$
- Anode loading: $0.1 \text{ mg}_{\text{Pt}}/\text{cm}^2$
- Screen printed CCMs (decal route)
- Test conditions:
 - H_2/air ; at 75°C
 - A: Dew Point 57°C ; stoich 2.0; p 1.7 barg;
 - K: Dew Point 63°C ; stoich 2.2; p 1.4 barg
 - measurement by ZSW, Ulm



A woman wearing a blue lab coat and a white hairnet is working in a factory. She is holding a tablet and looking at a large industrial machine. The machine has various pipes, valves, and a large cylindrical component. The background is a clean, industrial environment with bright lighting.

Outlook: R2R MEA Production

Industrial Ink Production: From Catalyst Powder to Catalyst Paste



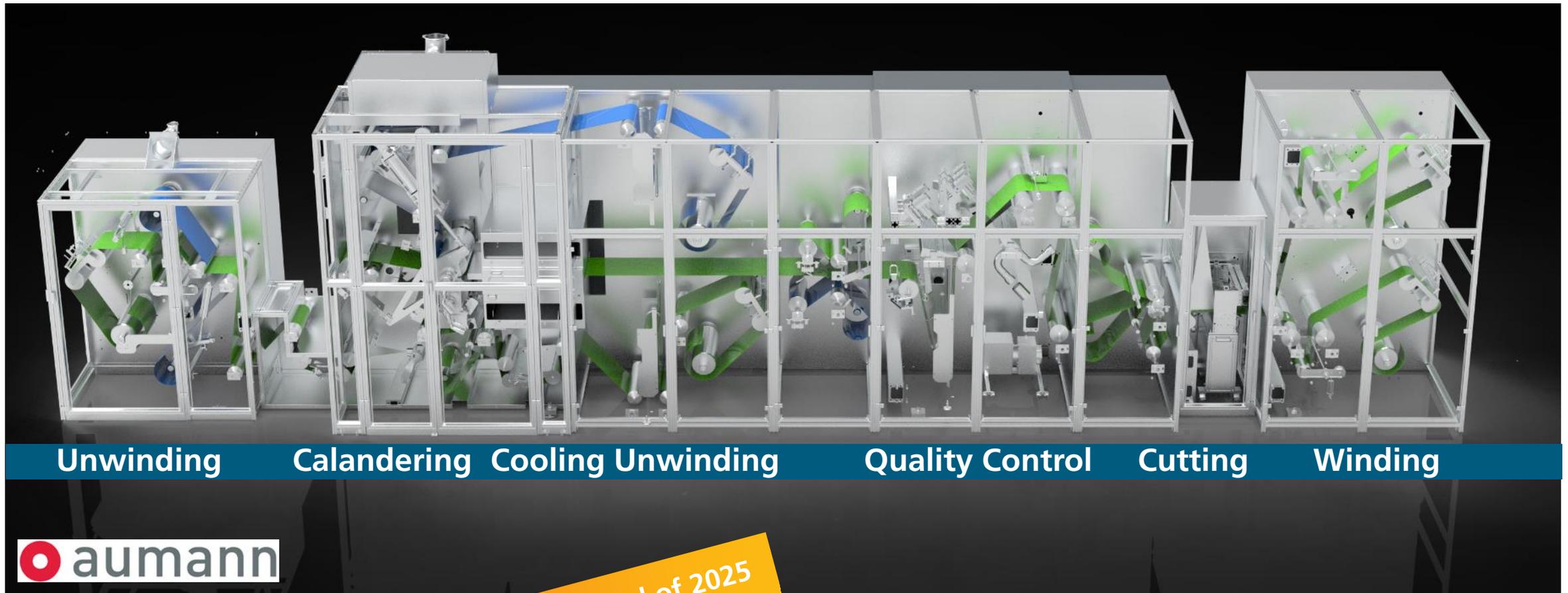
Pilot lab plant for catalyst ink mixing of IFA Technologies, Germany

Ready for research end of 2025

R2R Coating: From Catalyst Paste to Catalyst Layer II

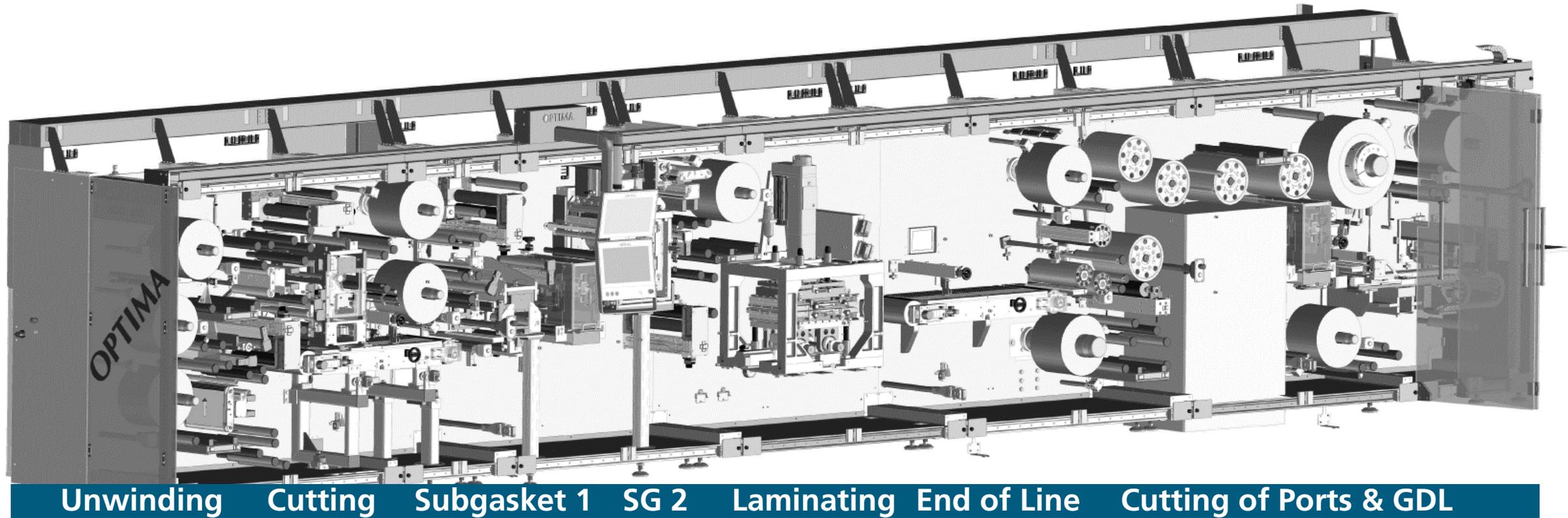


R2R Transfer: From Catalyst Layer to Catalyst Coated Membrane (CCM) II



Ready for research end of 2025

R2R MEA: From CCM to 5-Layer-MEA

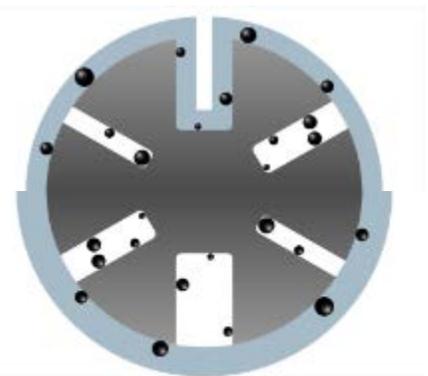
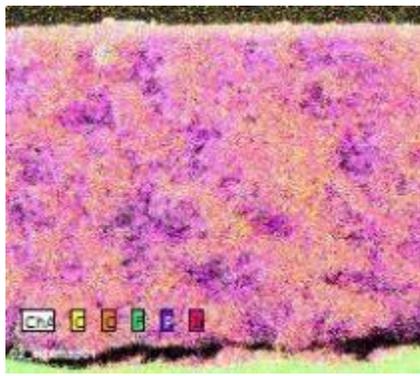
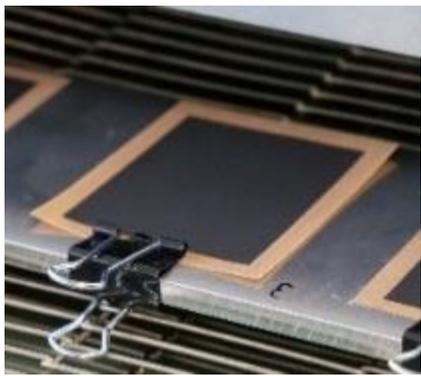


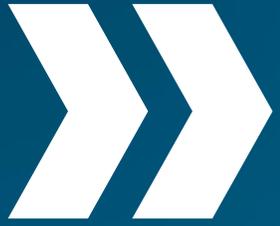
OPTIMA

Ready for research end of 2025

Understanding the Process – Microstructure – Operation Behavior Relationship is Key to Improve Architectures of Membrane Electrode Assemblies

- Understanding MEA production processes and quality control for up-scaling
- Investigating component performance and degradation by in-situ characterization together with ex-situ analytics
- Spatial resolved measurements to evaluate in-plane effects
- Morphology modelling to prove the understanding of fuel cell physics
- Fraunhofer ISE emphasizes on the 4 perspectives of **manufacturing, analytics, characterization & modelling**





Acknowledgements

Please read our comprehensive final report on HyFaB I:
https://www.ise.fraunhofer.de/content/dam/ise/de/documents/infomaterial/brochures/24_de_ise_projektbericht_hyfab-baden-wuerttemberg.pdf





Contact

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See you at hy-fcell in Stuttgart October 8 & 9, 2024
in our 2 days session Fuel Cell Production!