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# Understanding and controlling crack formation in catalyst layers for PEM electrolysis

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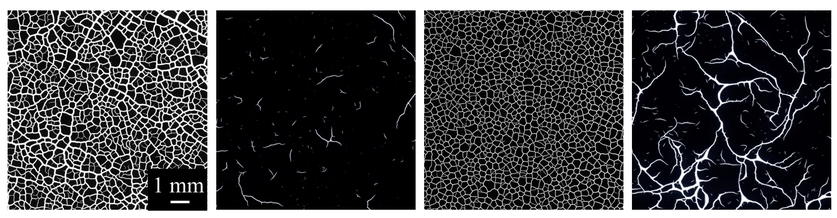
## Crack Formation during Catalyst Layer Production

**Different crack patterns in catalyst layers**




Underlying mechanisms leading to the formation of different crack morphologies are unknown.

Cracks can have both beneficial and detrimental effects on PEM performance and durability

**Positive effects**

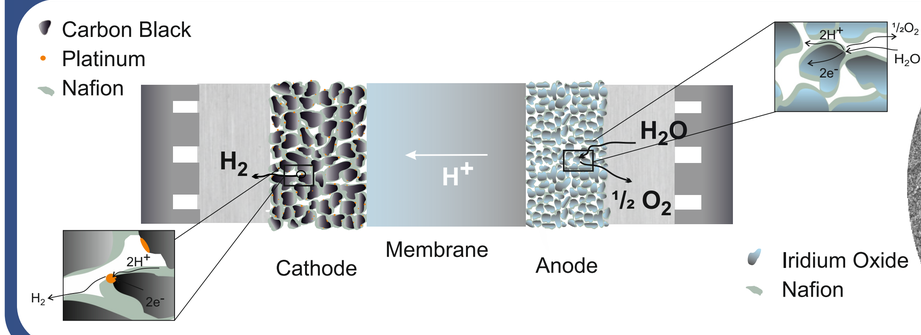
- Enhance mass transport of water and reaction gases within the catalyst layer

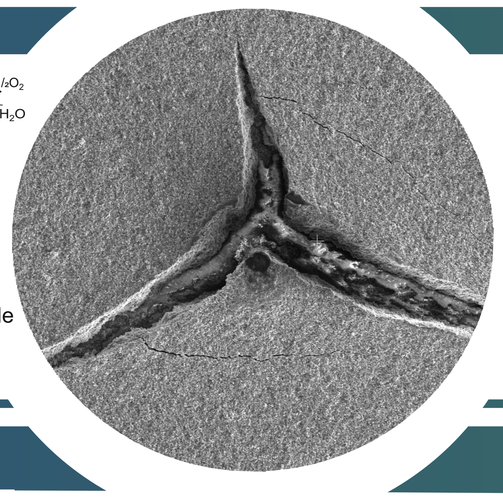
**Negative effects**

- Water accumulation and flooding during operation
  → impairs gas transport and block electrochemically active sites
- Disrupt electronic and protonic conduction pathways
  → impairs efficiency of charge transfer
- Acceleration of (membrane) degradation processes

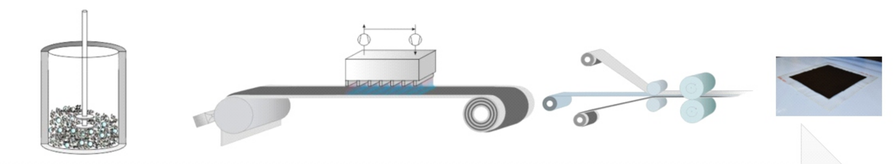
Current CCM design aims to minimize cracking, as a homogeneous layer morphology is crucial for consistent performance and long-term durability. [1-3]

## PEM Water Electrolysis (PEMWE)



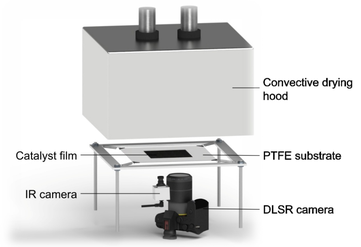
## CCM Production

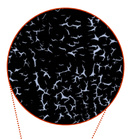


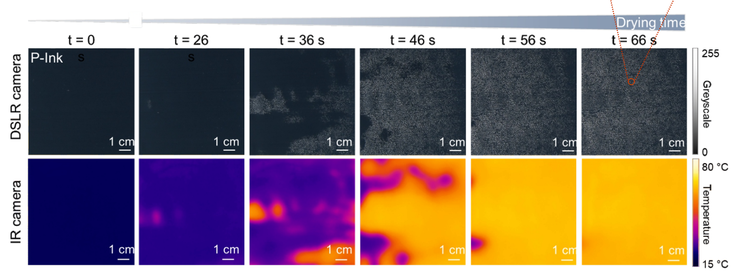

## In-Situ Detection of Crack Formation in Catalyst Layers

### via DSLR Camera and Infrared (IR) Thermography [7]

Experimental Setup

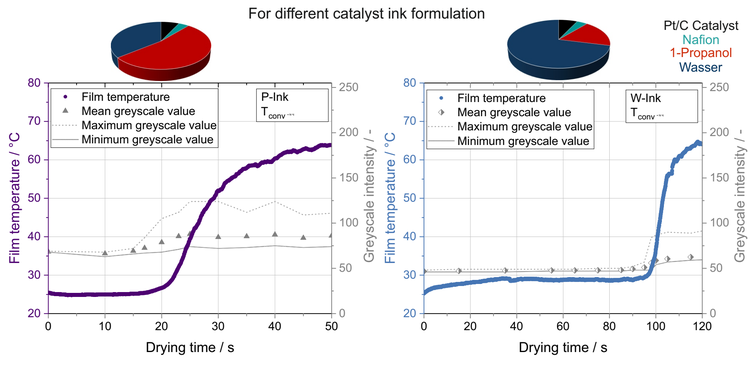





Results

For different catalyst ink formulation





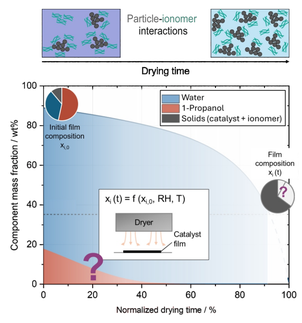


**The start of crack formation during film drying coincides:**

- with the increase in film temperature (= start of falling rate period)
- with the end of film shrinkage (EOFS)

→ The transition from constant- to falling-rate period during drying is identified as the critical point for the onset of crack formation.

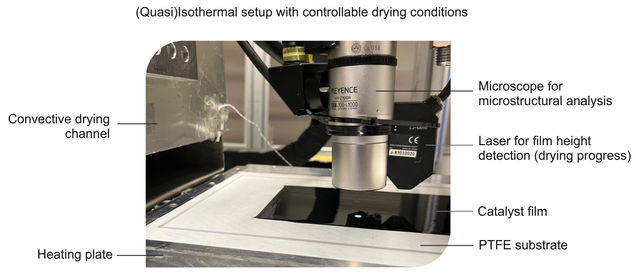
**Understanding changes during the first drying period to influence crack formation** [4-5]

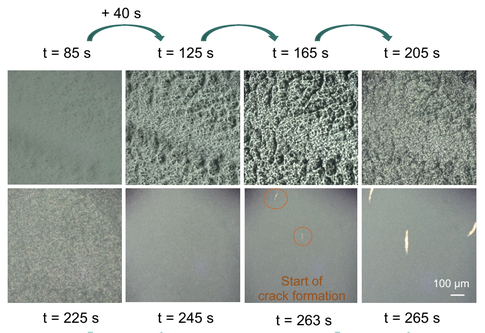



Simulation of changes in solvent composition in the ink leading to the critical cracking point during drying considering selective evaporation.

### via Microscopy and Film Height Detection [8]

Experimental Setup

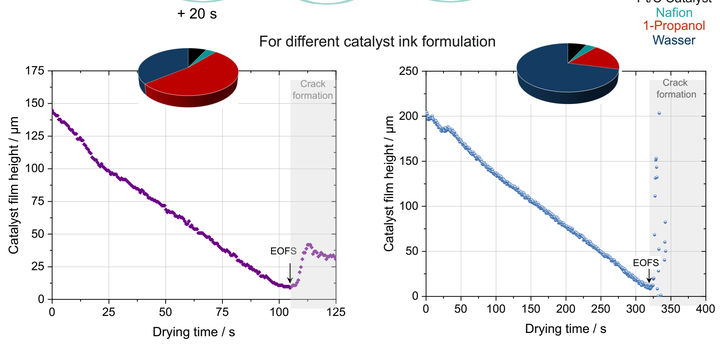



Microscopic images in-situ during drying

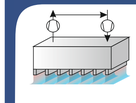
Results

For different catalyst ink formulation



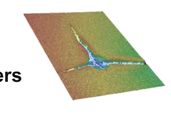

EOFS = End of film shrinkage

## Outlook

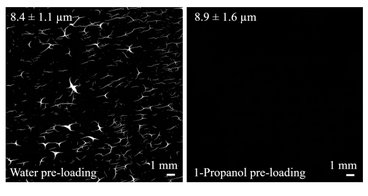


**Targeted adjustment of drying parameters tailors the drying process, enabling the generation of distinct crack morphologies and relative crack areas**

- drying temperature
- air overflow
- relative humidity or air pre-loading with ink solvents



**Prevention of crack formation with pre-loading of the convective drying air is possible.** [6]




## References

[1] J. Zhao, H. Liu & X. Li, Structure, Property, and Performance of Catalyst Layers in Proton Exchange Membrane Fuel Cells. Electrochem. Energy Rev. 6, 13 (2023).
[2] S. Kundu, M.W. Fowler, L.C. Simon & S. Grot, Morphological features (defects) in fuel cell membrane electrode assemblies. J. Power Sources 157, 650–656 (2006).
[3] Y. Singh, F. P. Orfino, M. Dutta & E. Kjeang, 3D visualization of membrane failures in fuel cells. J. Power Sources 345, 1–11 (2017).
[4] **N. Zimmerer**, P. Quarz, E. Terhorst, L. Janning, **P. Scharfer, W. Schabel**, Influence of Ink Formulation and Drying Parameters on Component Composition during Drying of Catalyst Layers for Polymer Electrolyte Membrane (PEM) Fuel Cells and Electrolyzers; Energy Technology (2025).
[5] P. Quarz; **N. Zimmerer; P. Scharfer; W. Schabel**, About drying phenomena of fuel cell and electrolyzer CCM inks: selectivity of the evaporation of 1-propanol/water mixtures, Fuel Cells (2024).
[6] **N. Zimmerer**, L. Janning, P. Quarz, **P. Scharfer, W. Schabel**, Optimizing drying parameters for crack-free catalyst layers in PEM fuel cell and electrolyzer production, Chemical Engineering & Technology (2025); under review
[7] **N. Zimmerer**, P. Quarz, L. Janning, **P. Scharfer, W. Schabel**, In-Situ Investigation of Crack Formation During Drying of Catalyst Layers for Polymer Electrolyte Membrane Fuel Cells"; Colloids and Surfaces A: Physicochemical and Engineering Aspects (2025); under review
[8] **N. Zimmerer**, P. Quarz, L. Janning, **P. Scharfer, W. Schabel**, From Drying to Cracking: Real-Time Monitoring of Catalyst Layer Formation for PEM Fuel Cells; in preparation.