

Motivation

Why electrochemical CO₂ Reduction on Gas Diffusion Electrodes (GDEs)?

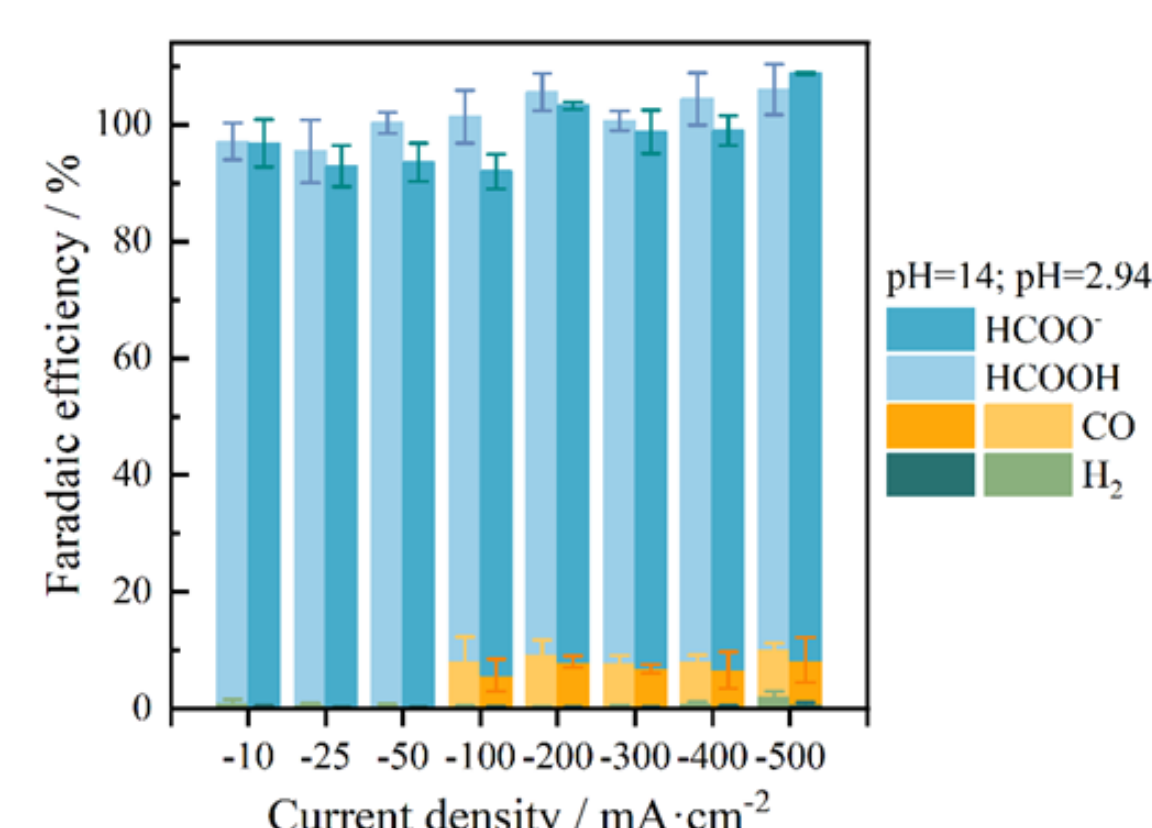
- Sustainable pathway:** Employs renewable electricity to reduce CO₂, supporting greenhouse gas neutrality and climate targets.
- Scalable technology:** Converts CO₂ from industrial point sources (waste incineration, cement, biogenic processes) into value-added products such as CO, ethylene, and formic acid.

- Acidic electrolysis to formic acid is preferred over alkaline conditions due to significant advantages for down-stream processing; no requirement for protonation of formate and less carbonate accumulation.
- Current densities and FE already in the range but long-term stability and achievable formic acid concentrations are still far from the industrial requirements for economically competitive formic acid production.

Acidic CO₂RR

Electrochemical performance

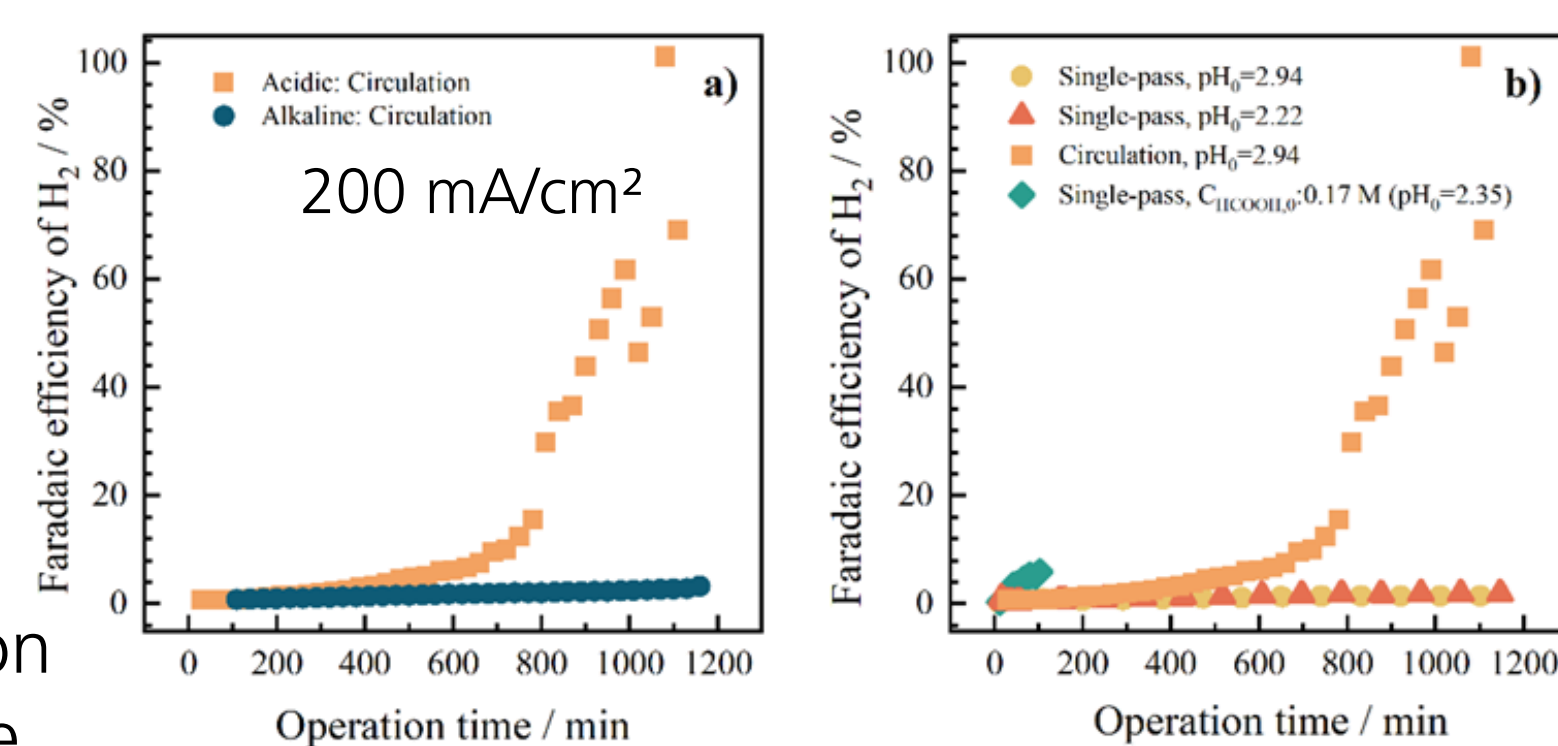
- We showed comparable performance in bulk acidic and in alkaline conditions
- HCOOH production up to 500 mA/cm² with ~90% Faradaic efficiency.
- Local pH in both cases similar due to product accumulation within GDE structure



Chen et al. (2023) *Chemical Engineering Journal* 476, 146486

Long-term stability

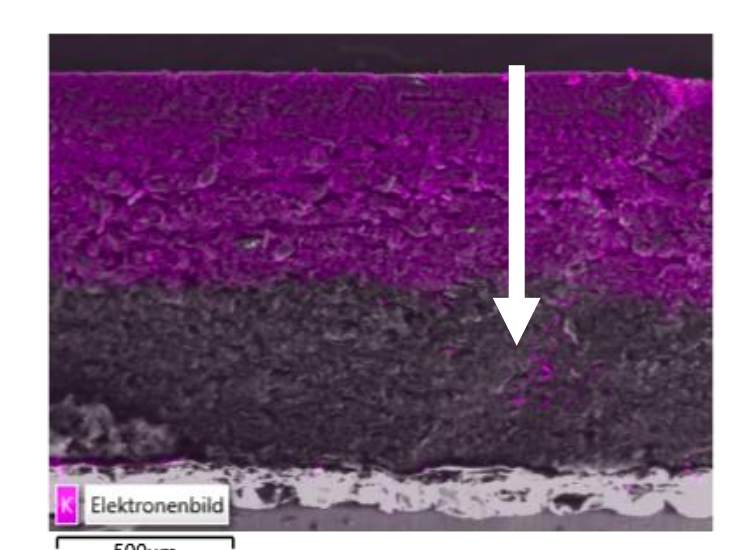
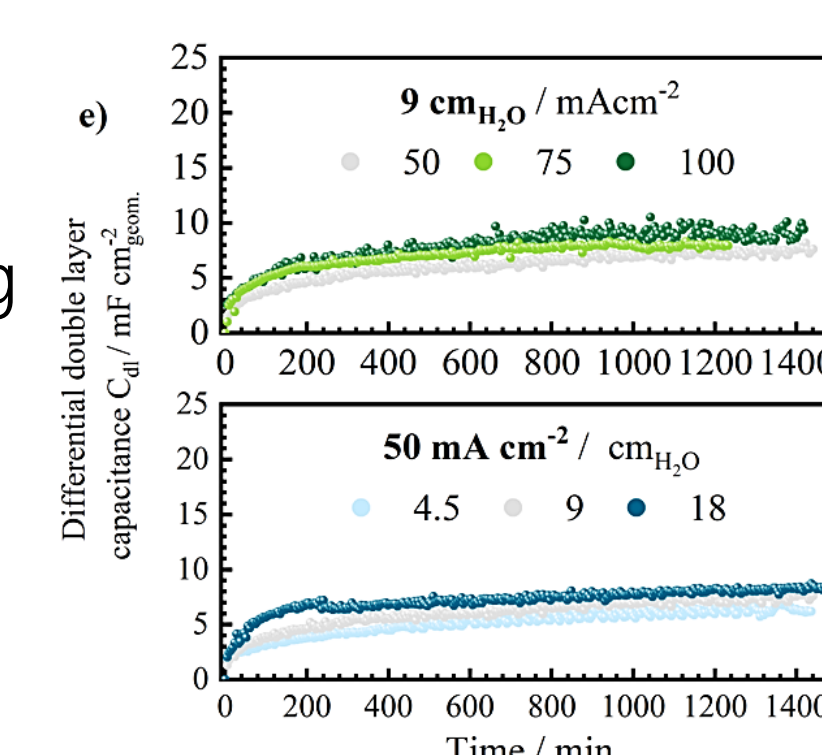
- In circulating flow performance breaks down in acidic conditions caused by HCOOH accumulation
- In single-pass mode stable behavior up to 20h demonstrated
- Very low HCOOH concentration achievable in single-pass mode



Electrode Design

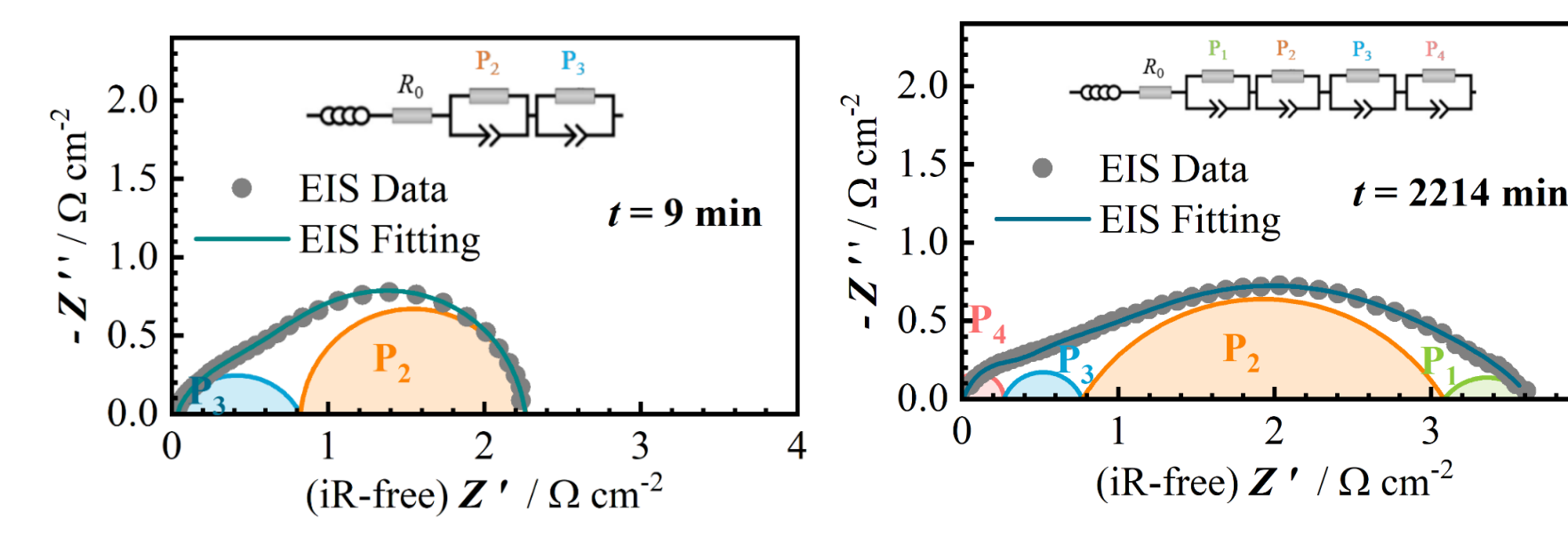
Limitations of thick single-layer electrode design

- Continuous electrolyte intrusion into the GDE caused by electrowetting during prolonged operation.
- Extended diffusion pathways which limit mass transport



Double layer capacitance via EIS SEM/EDX on cross-section shows electrolyte penetration

100 mA/cm², 12°C to accelerate degradation, increase of H₂ FE from 1% to 15%



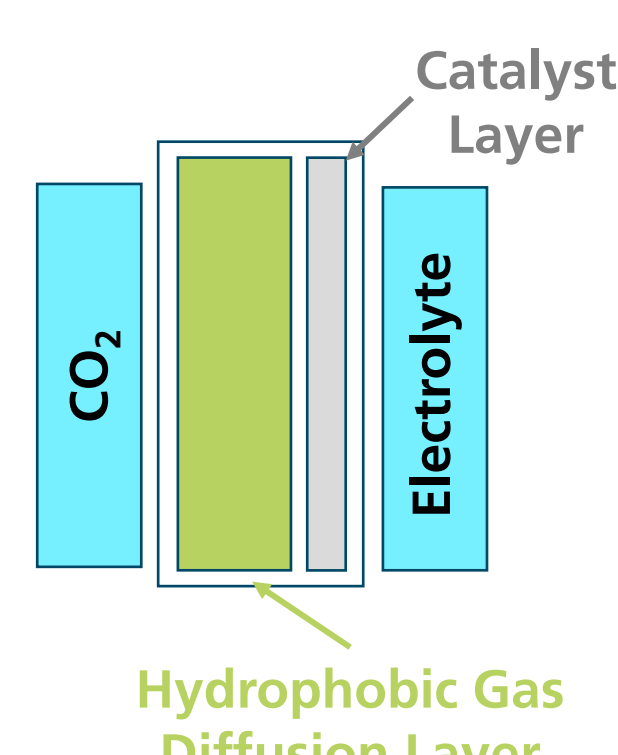
Chen et al. (2024) *ACS Energy Letters* 9, 6096-6103.

Degradation study

- Long-term degradation governed by carbonate precipitation in GDE
- Systematic study via EIS and DRT
- Shorter diffusion path into bulk electrolyte desired

Multilayer design with hydrophobic polymer backing

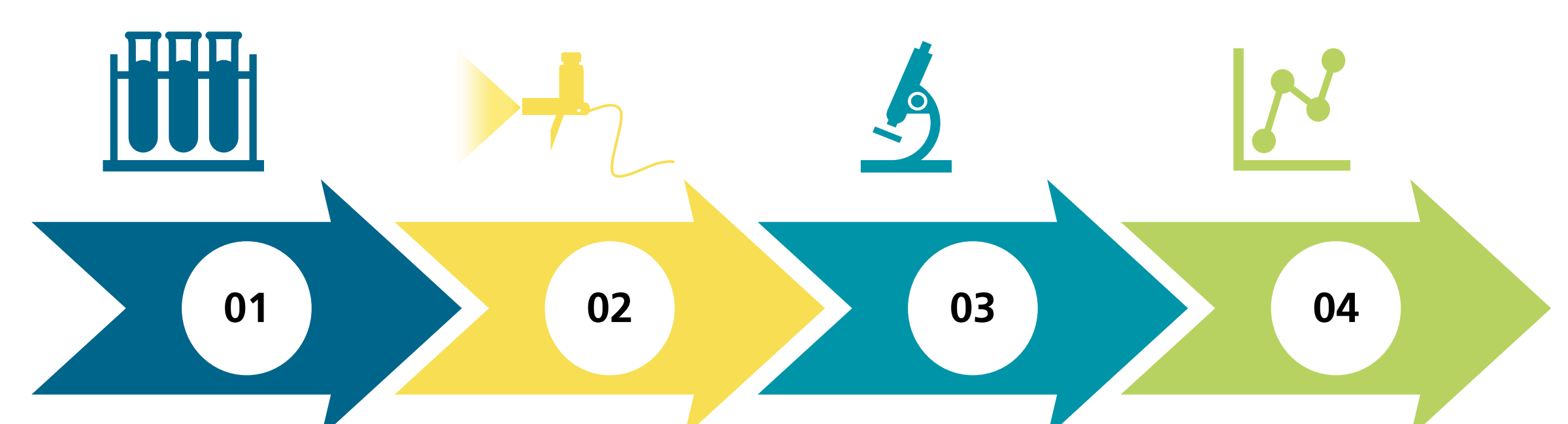
- Commercial carbon-based GDLs unsuitable for long-term stability due to too low hydrophobicity and electro-wetting.
- Porous polymer membranes could serve as effective GDLs due to their **high hydrophobicity**.
- PTFE membranes resist flooding and prevent electrolyte intrusion caused by electrowetting.
- Expected durability under prolonged operation in comparison with commercial GDLs.



From single- to multi-layer GDE assembly (Multilayer approach)

- Highly hydrophobic gas diffusion layer (GDL): Prevents electrolyte intrusion and enhances gas transport.
- Thin catalyst layer: Minimizes product accumulation and improves reaction efficiency.

Approach and Methods



Ink Preparation

- Catalyst: Bi-coated acetylene black
- Binder: Fumion FAA-3
- Method: Ultrasonic Dispersion

Air Brushing

- Uniform thickness
- Parameters: Flow rate and volume of catalyst ink

Physical Characterization

- Thickness measurement
- Catalyst loading
- SEM/EDX

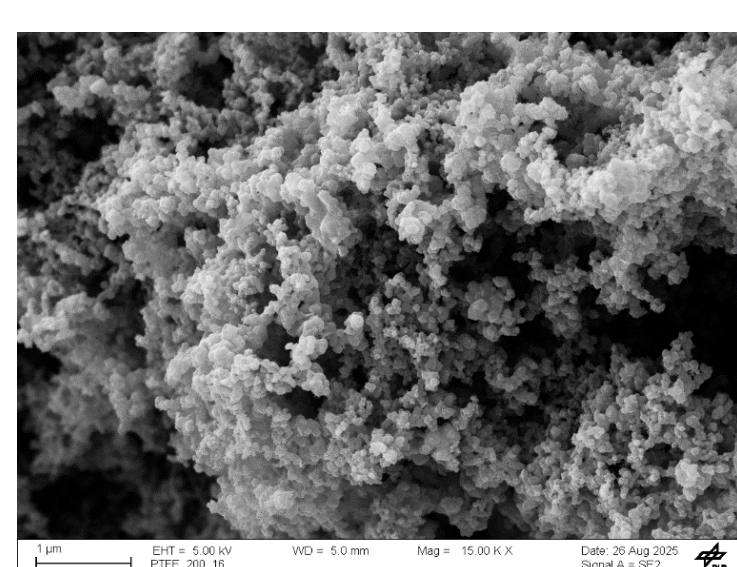
Electrochemical Characterization

- Multistep-Chronopotentiometry
- Range: 0 – 250 mA/cm²
- Step size: 20 minutes

Preliminary Results

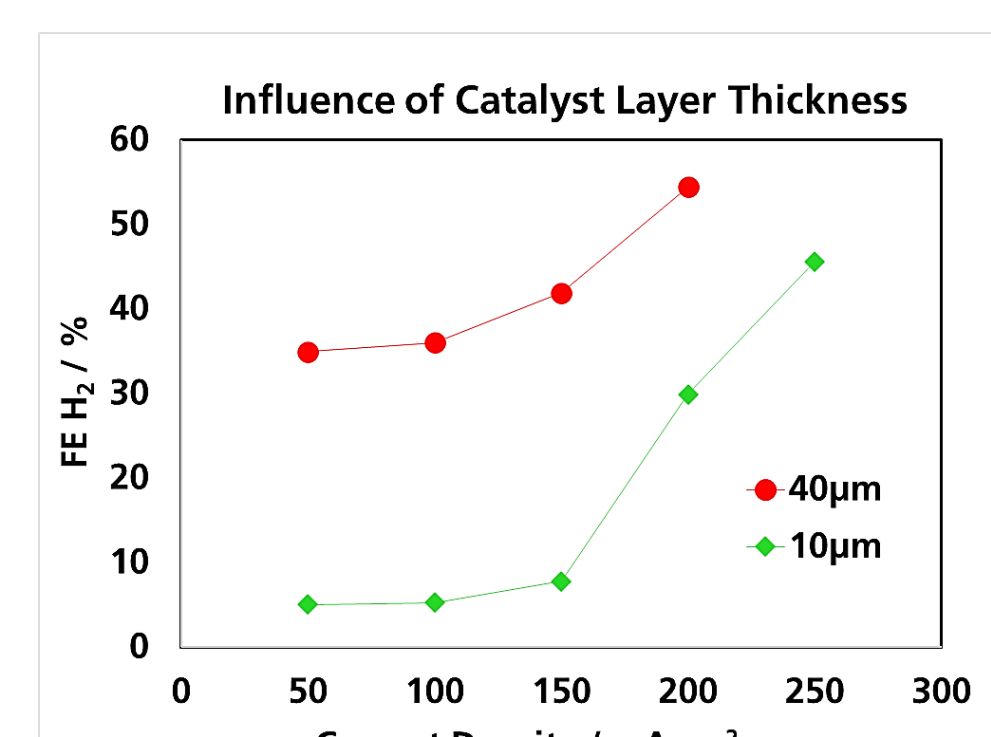
Material Characteristics

GDE	Binder:Catalyst Ratio	Catalyst Loading / mgcm ⁻²	Coating Thickness / μm
GDE_A	1:4	0.703	40.28
GDE_B	1:4	0.281	9.28



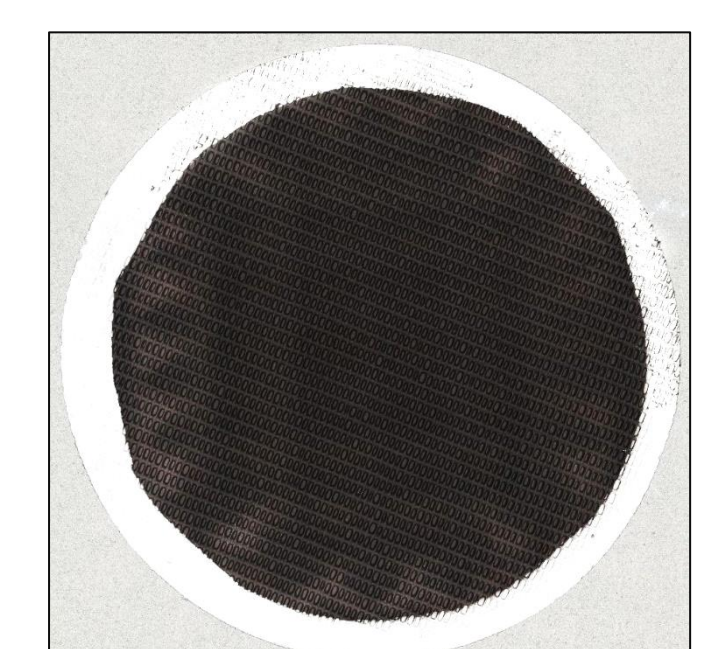
Performance Evaluation

- Both electrodes show similar overall trends..
- Catalyst layer with 10μm thickness largely suppresses HER up to 150 mA/cm².
- Thicker layer (40μm) exhibit transport limitation and yield higher HER.



Conclusion

- Successfully fabricated robust PTFE-based GDEs.
- Electrodes demonstrated catalytic activity with performance trends indicating that reduced catalyst layer thickness suppresses HER.
- Further systematic studies are required to understand electrode structure–performance relationships.
- Optimizing contacting methods remains a key challenge.
- Long-term stability and benchmarking versus thick single layer GDEs currently under investigation.

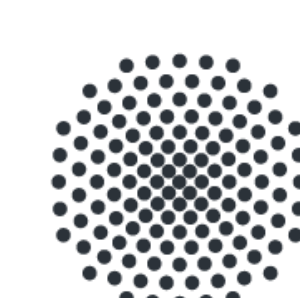


➤ PTFE membrane electrode

Acknowledgements

The IGF project Galmatrod II (01IF23102N) is funded by the Federal Ministry for Economic Affairs and Climate Protection.

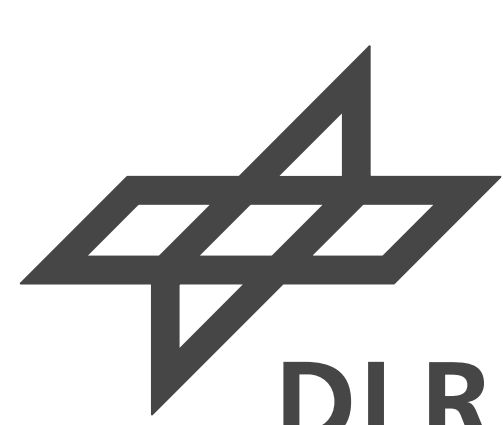
We gratefully acknowledge the great cooperation with the partners: University of Stuttgart and fem (Forschungsinstitut Edelmetalle & Metallchemie).



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