THE HYDROGEN AND FUEL CELL CENTER

PEMWE und AEMWE im Vergleich: Gemeinsamkeiten und Unterschiede

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ZBT-Wasserstofftage
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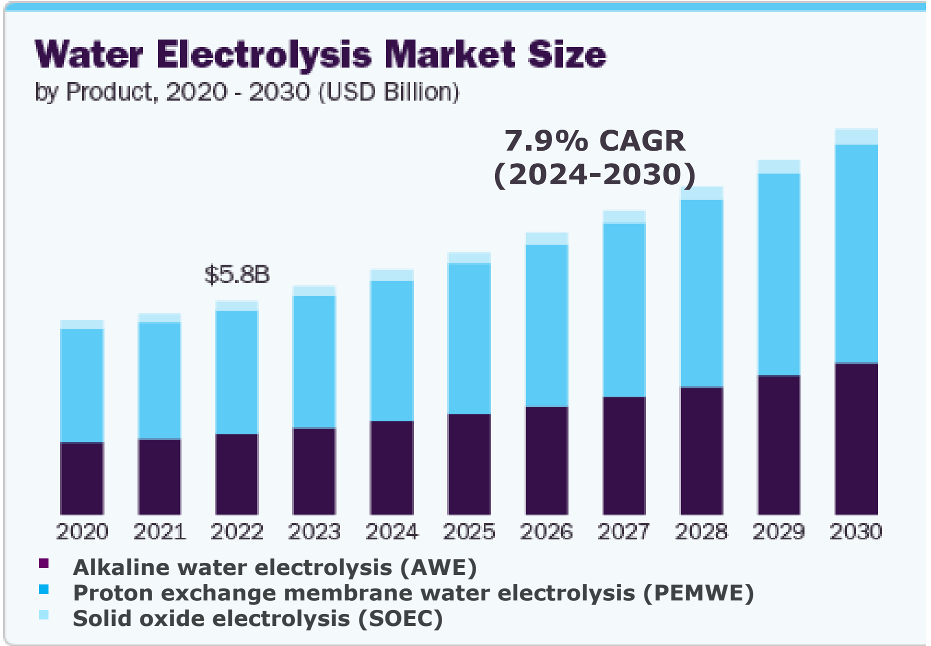
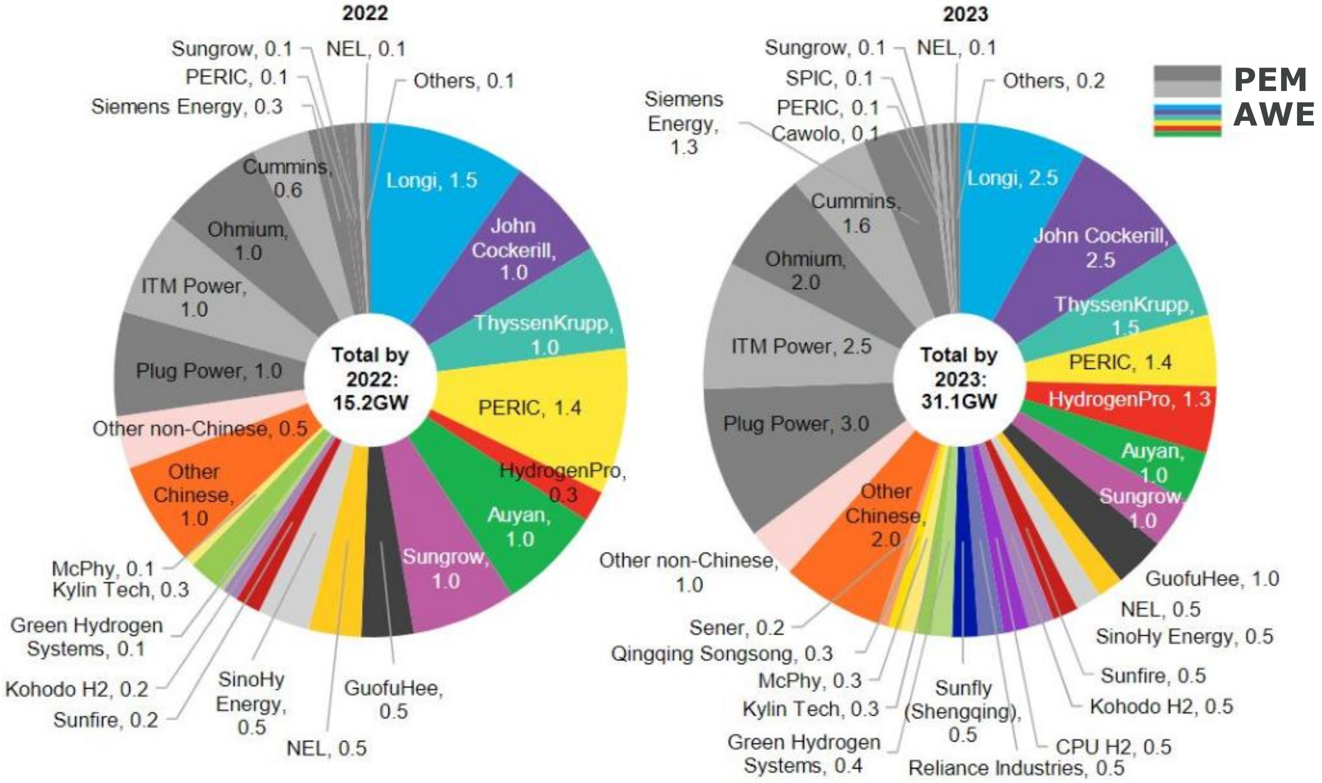
Mature technologies for water electrolysis

- **3 main technologies**



- **PEMWE and AWE market share**



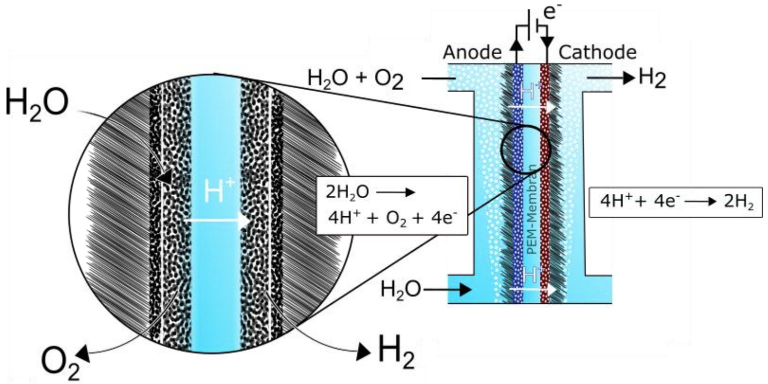
Strictly confidential – no passing on to third parties!

Global Electrolyzer Market, **2024**, Grand View Research, Inc.

A Breakneck Growth Pivot Nears for Green Hydrogen, **2022**, BloombergNEF

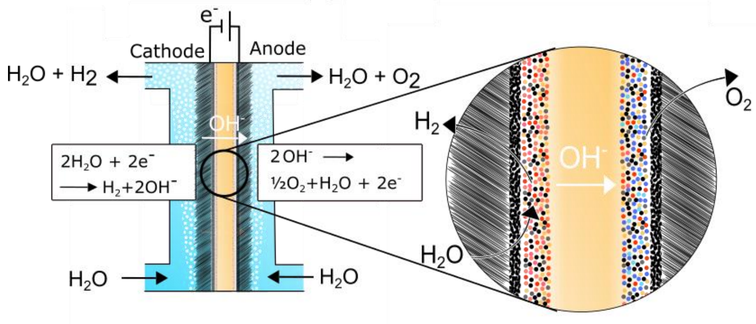
Technologies: Focus on low temperature electrolysis

Proton exchange membrane water electrolysis (PEMWE)



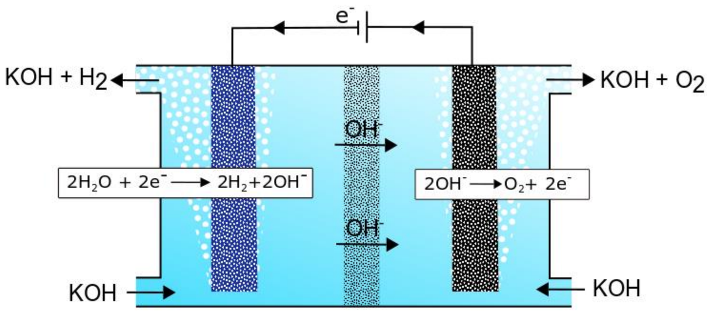
- + Well developed technology
- + High flexibility
- + Flexible power level
- + High pressure H_2 production
- – Critical raw materials (CRM)

Anion exchange membrane water electrolysis (AEMWE)



- + Flexible power level
- + Precious metal free catalysts
- – Lower current densities

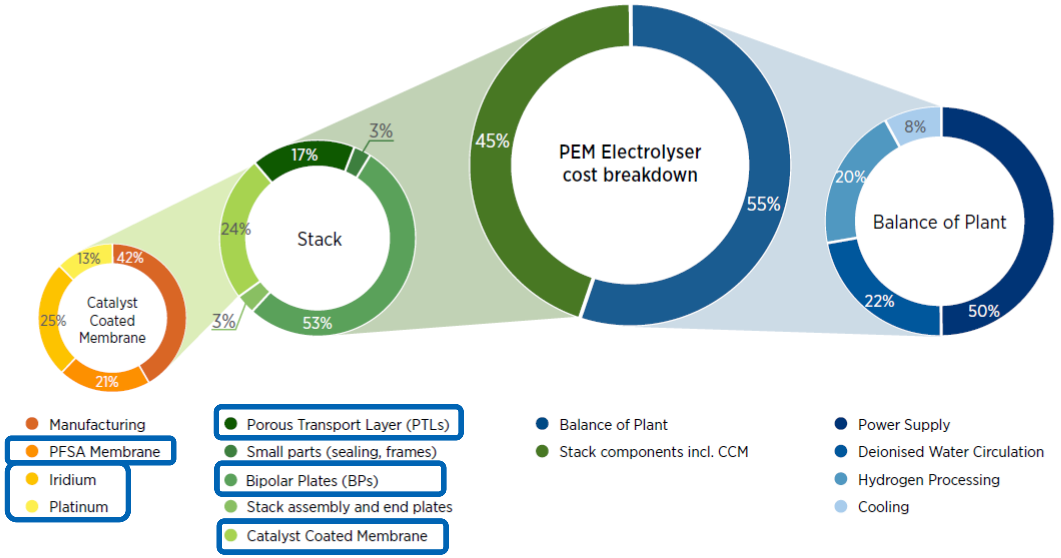
Alkaline Electrolysis (AWE)

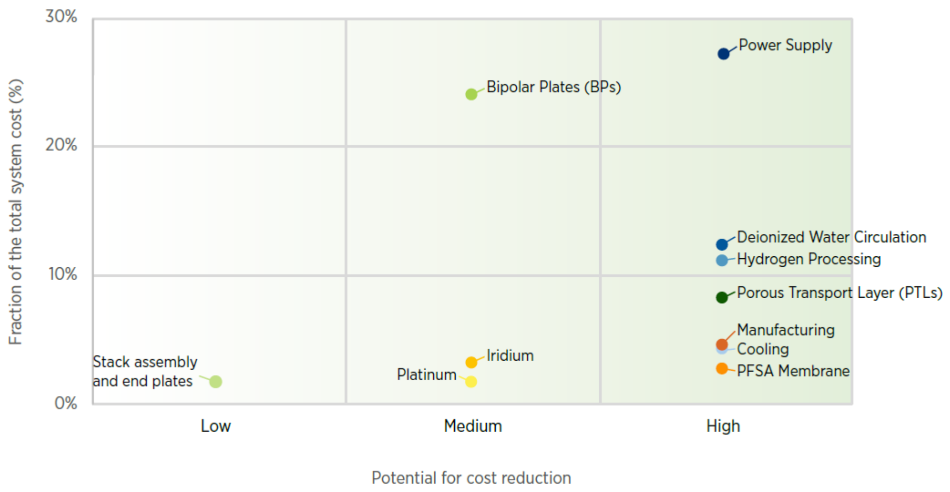


- + Low costs
- + Established technology
- – Lower current densities
- – Lower H_2 purity
- – Limited integration with renewables

Open challenges: PEMWE and AEMWE

▪ PEMWE: Cost breakdown





▪ Open challenges

▪ PEMWE

Ir and Pt

- Costly (<10% cost full PEMWE system)
- Ir: production of Ir/Pt

→ only 3 GW-7.5 GW annual PEMWE manufacturing capacity

PFSA-membranes

- Environmental concerns
- Sustainability issues
- Regulatory challenges

PTL/BPP: Ti(Pt-coated)

- Costly

▪ AEMWE

PGM-free catalysts

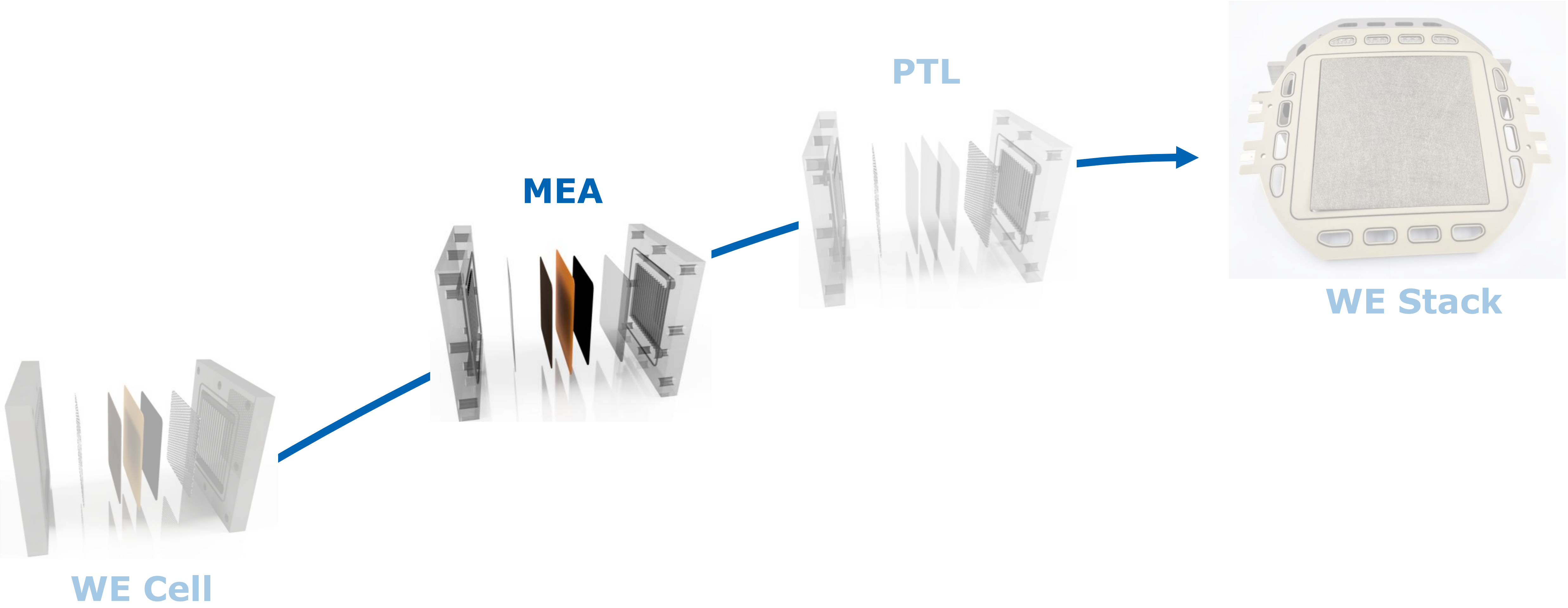
Membranes

- Main challenge for AEM

PTL/BPP: Ni or SS

IRENA: Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal, **2020**, International Renewable Energy Agency

Our research: From single cells to stacks in PEMWE and AEMWE

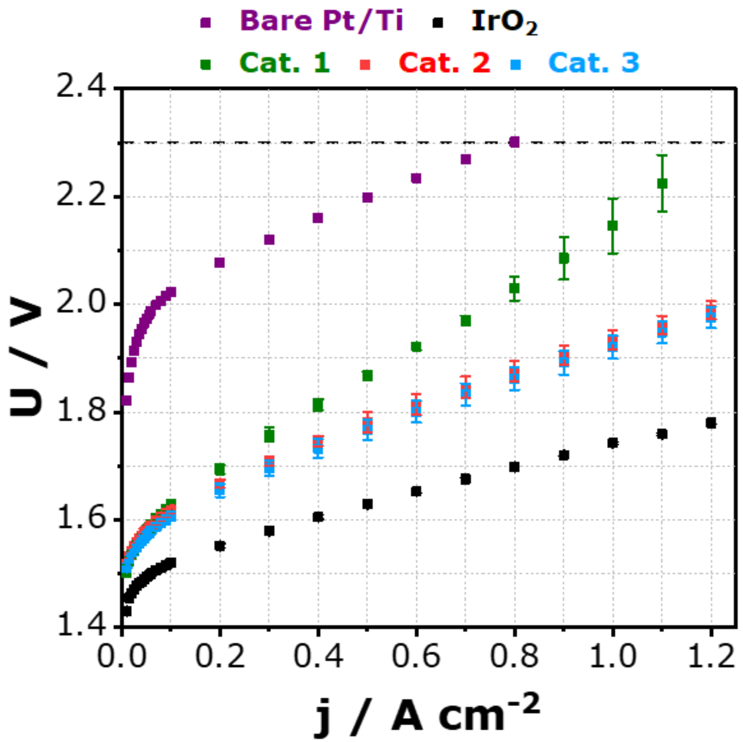


PEMWE: Reducing dependence on CRM → Ir

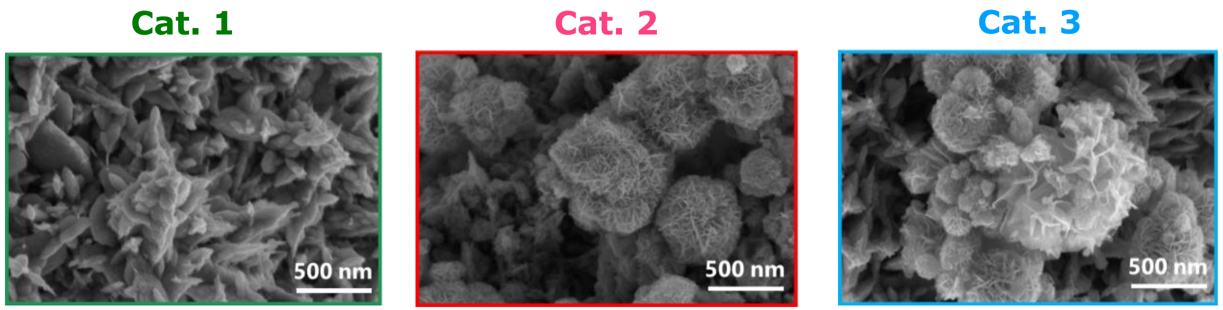
Strategies to reduce dependence on CRM

- Prevention or reduction of use
- Increasing efficiency
- Recycling

Ongoing development:
Noble Metal free PEM Anode Catalyst via Electrodeposition



- **SEM**



- **Next steps**
  - Complement characterization
  - Extend durability studies

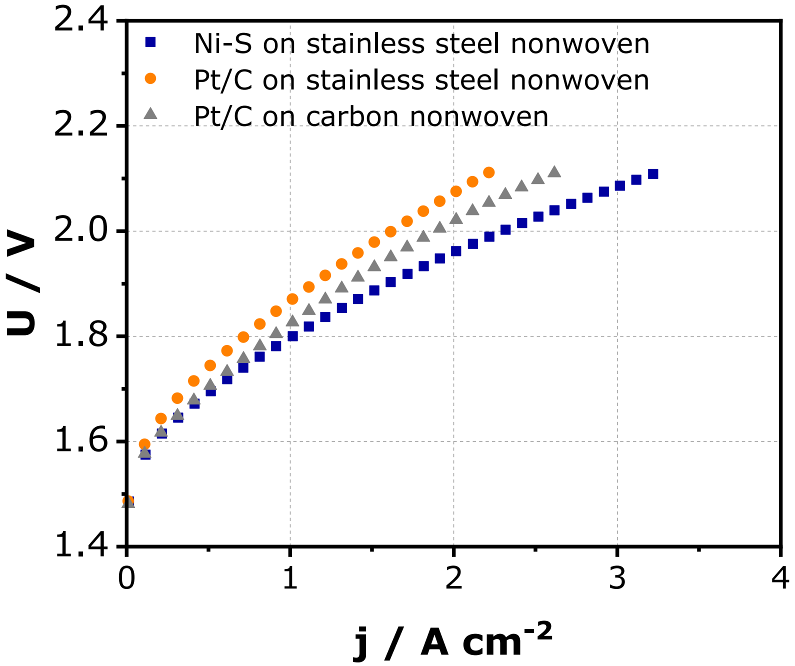
PTL Anode: Pt/Ti felt, Catalyst Anode: (PGM-free): ~8 mg cm^{-2}, (PGM-free dopant): 0.3 mg cm^{-2}, Nafion: 0.5 mg cm^{-2}, Pretreated Nafion®115 (thickness – 127 µm), PTL Cathode: Freudenberg H23, Catalyst Cathode: (Pt/C): 0.2 mg cm^{-2}, 5 cm^2 cell, Electrolyte: pre-heated DI H_2O, Experiment performed at 60 °C.

AEMWE: Alternatives for cost reduction

Cathode catalyst: Pt-based catalyst, as well as PGM-free ones, are widely used

→ Promising cost reduction

IGF N-AEMEL Project:
Noble Metal free AEM Cathode Catalyst via Electrodeposition



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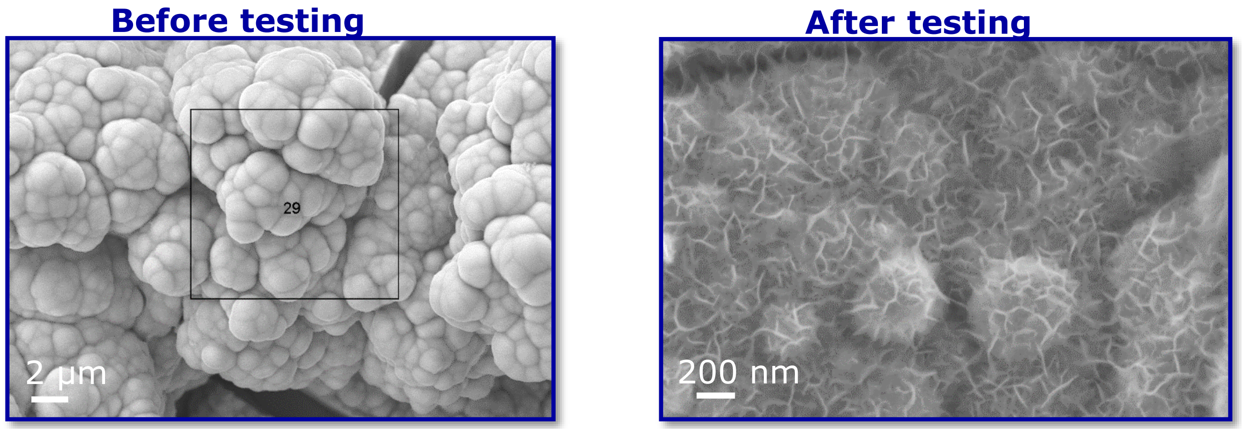
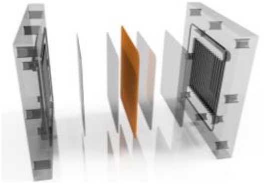


- **Next steps**
  - Complement characterization
  - Extend durability studies

PTL Anode: Bekaert 20FP3, Membrane: Fumatech FAA-3-50, Catalyst Cathode: 0.2 mg cm^{-2} Pt/C or Ni-S, PTL Cathode: Bekaert 20FP3, 5 cm^2 cell, Electrolyte: pre-heated 1 M KOH, Experiment performed at 60 °C.

AEMWE: The most critic component → AEM membrane

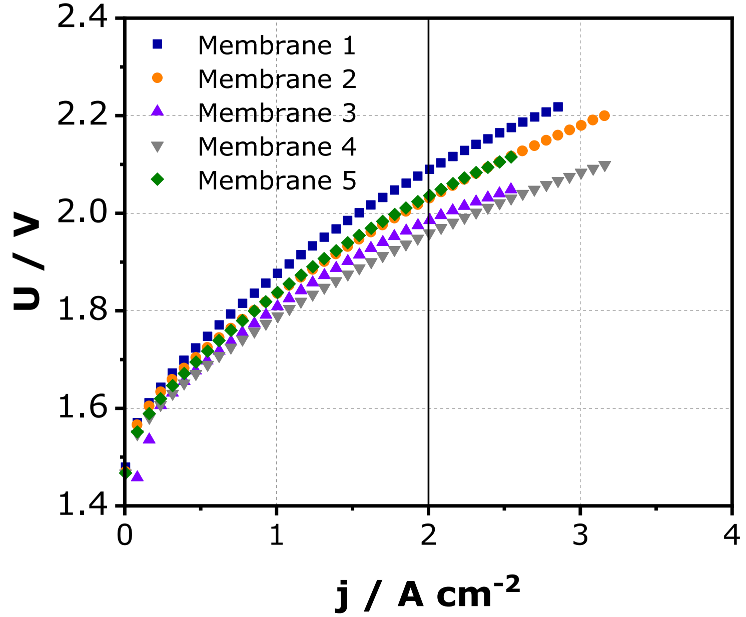


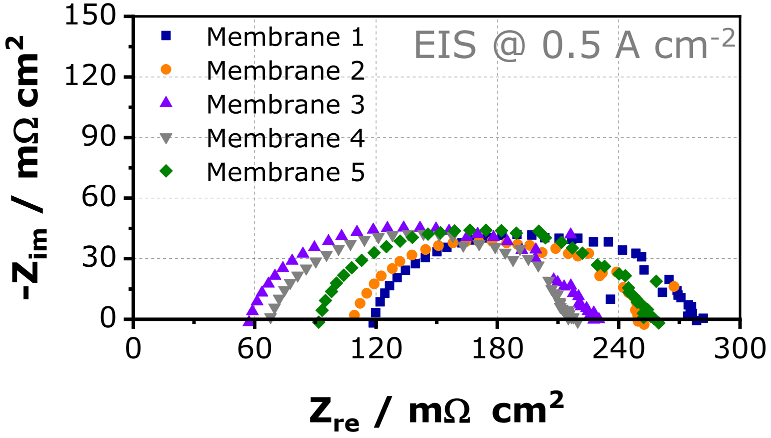
Membranes for AEMWE

- Durability
- Ionic conductivity

Comparison of commercially available membranes

AEM	i @ 2 A cm^{-2} V
Membrane 1	2.01
Membrane 2	2.03
Membrane 3	1.99
Membrane 4	1.96
Membrane 5	2.04



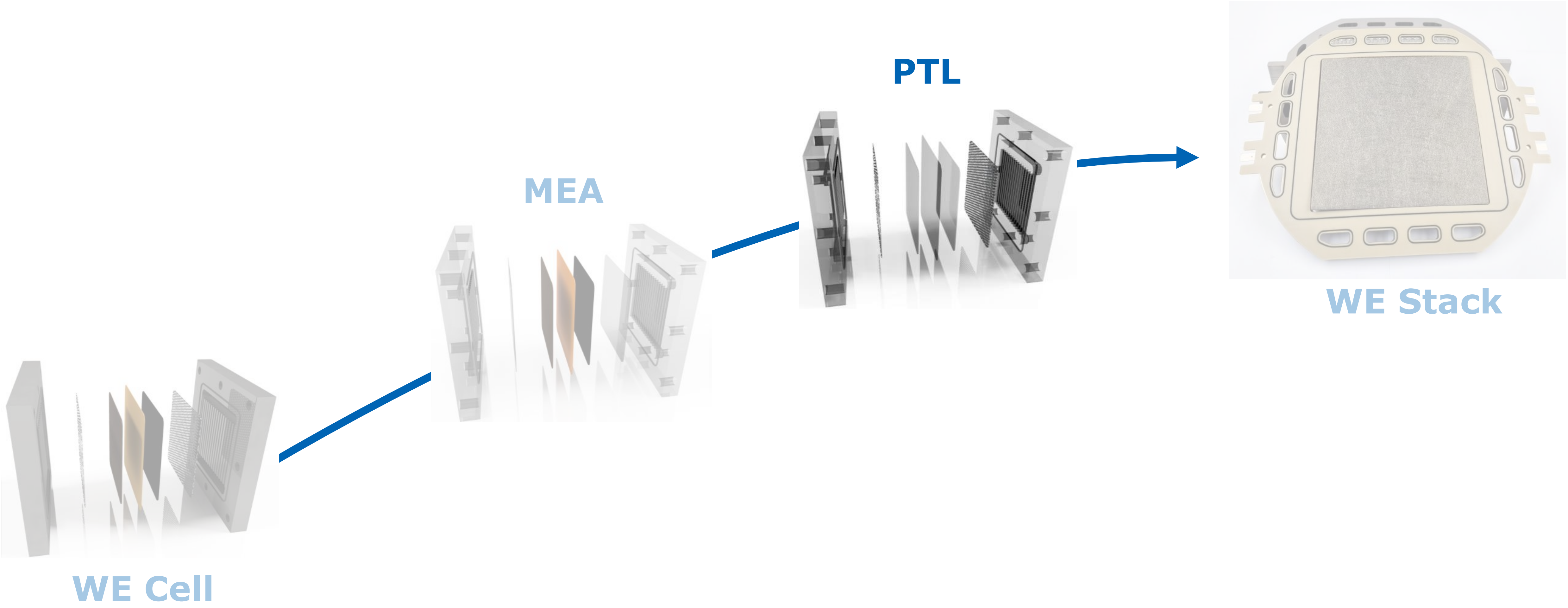


→ Broad variability

→ Still no standard

PTL Anode: Bekaert 20FP3, Catalyst Anode: blank, Membrane: various, Catalyst Cathode: 0.2 mg cm^{-2} Pt/C, PTL Cathode: Freudenberg H23, 5 cm^2 cell, Electrolyte: pre-heated 1 M KOH, Experiment performed at 60 °C.

Our research: From single cells to stacks in PEMWE and AEMWE



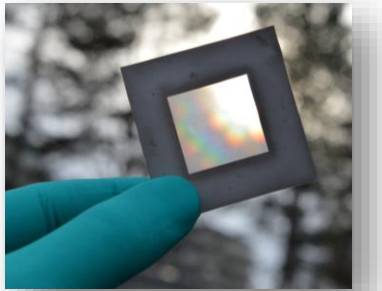
PEMWE: Reducing dependence on CRM → PTL

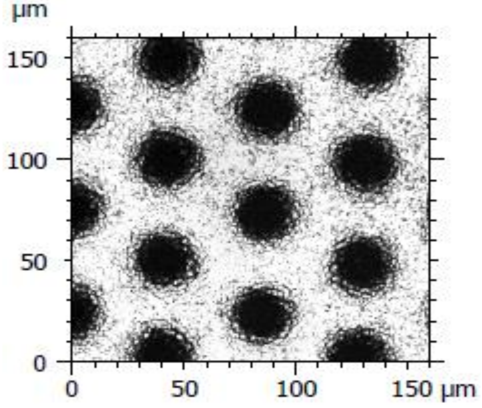
PTL: Ti(Pt-coated)
- High cost
- Develop alternative materials
- Optimised structure ensure homogeneous distribution of H_2O to catalyst layer and gas removal

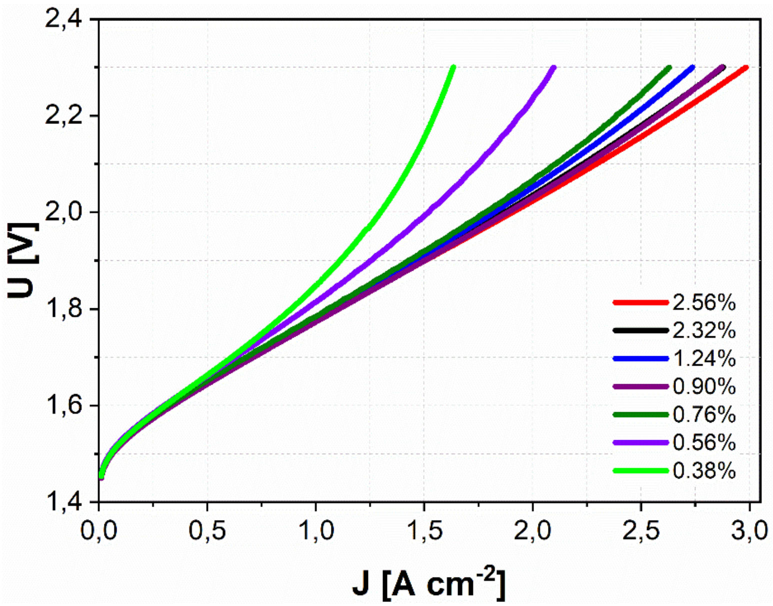
} depends on porosity

IGF MetalFoil-PTL Project: Laser-based structuring of Ti foils

- Parameters: hole size, number of holes, distance between holes
- Precisely adjustable porosity



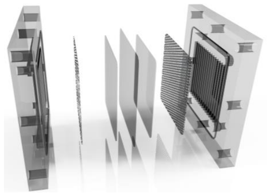




Electrochemical performance

- Higher 2D porosities (>1.24%) → Better water supply and O_2 removal
  → Reduced mass transport resistance

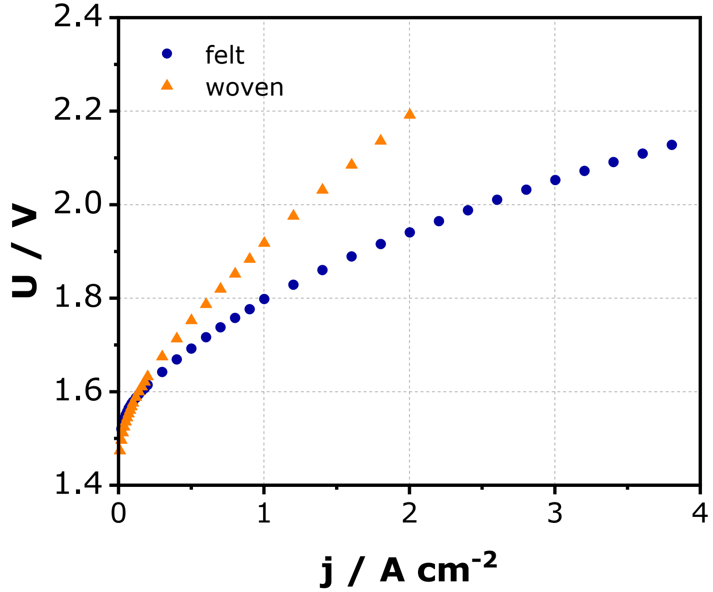
PTL Anode: laser drilled Ti foil, PTL Cathode: Freudenberg H23, CCM: Pretreated Nafion®115 (thickness – 127 µm), anode cat. Layer (IrO_x): ~0.3 mg cm^{-2}, cathode cat. layer (Pt/C): 0.2 mg cm^{-2}, 5 cm^2 cell, Electrolyte: pre-heated DI H_2O, Experiment performed at 60 °C.

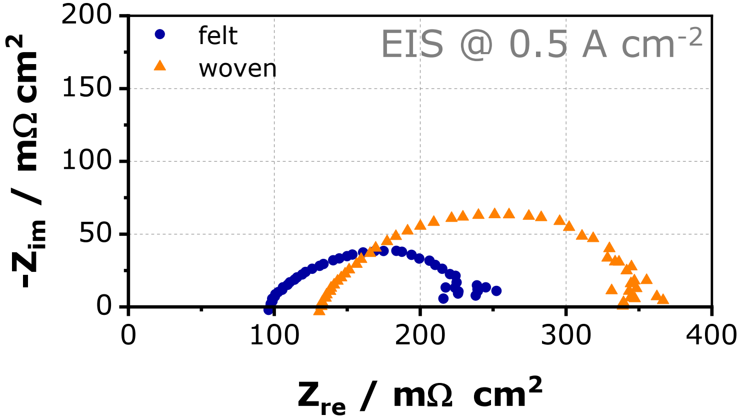


AEMWE: Optimizing selection of PTL

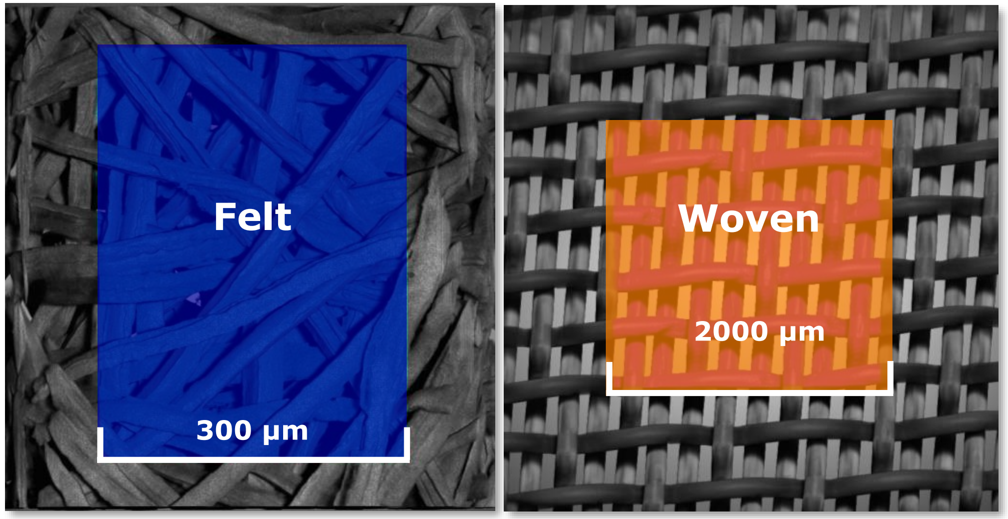
PTL
- Alkaline environment enables use of non-noble metal-based materials
- Ni-based or Stainless steel
- Different structures available

Stainless steel PTL





- **μ-CT**



	Felt	Woven
Surface Area* / $\mu m^2 \mu m^{-3}$:	87	10
Porosity / %:	60	69
Thickness / μm:	300	320

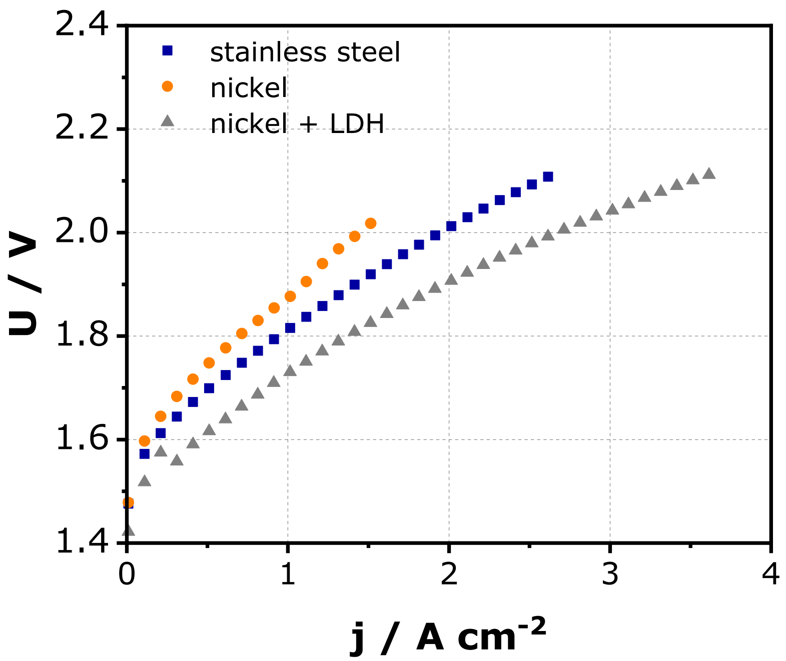
Felt stainless steel → better contact

PTL Anode: Bekaert 20FP3, Catalyst Anode: 2 mg cm^{-2} $NiFe_2O_4$, Membrane: Fumatech FAA-3-50, Catalyst Cathode: 0.2 mg cm^{-2} Pt/C, PTL Cathode: Freudenberg H23, 5 cm^2 cell, Electrolyte: pre-heated 1 M KOH, Experiment performed at 60 °C, *calculated via XRM.

AEMWE: Optimizing selection of PTL

PTL
- Alkaline environment enables use of non-noble metal-based materials
- Materials: Ni-based or Stainless steel
- Different structures available

Felt PTL: Different materials



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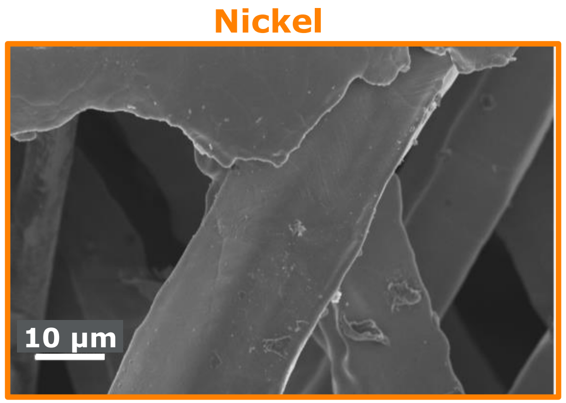
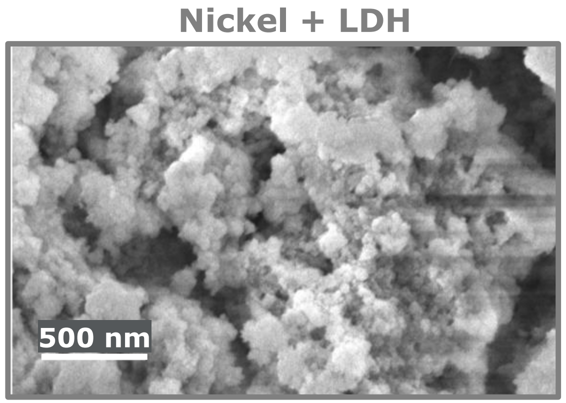




Ni-based PTL + catalyst → better performance

PTL Anode: (SS) Bekaert 20FP3, (Ni) Bekaert 2Ni18-050, Membrane: Fumatech FAA-3-50, Catalyst Cathode: 0.2 mg cm^{-2} Pt/C, PTL Cathode: Freudenberg H23, 5 cm^2 cell, Electrolyte: pre-heated 1 M KOH, Experiment performed at 60 °C.

Our research: From single cells to stacks in PEMWE and AEMWE

ZBT PEMWE Stack:
Development of a modular high-pressure electrolysis stack as a test platform for the qualification of materials and components

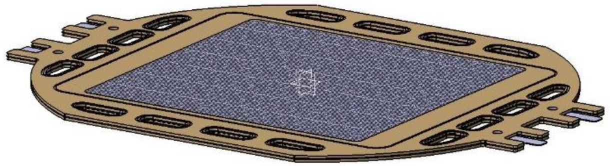
INNOKOM PEMWEST Project: Goals

– 5-10 cells, 100 cm² active, P < 35 bar

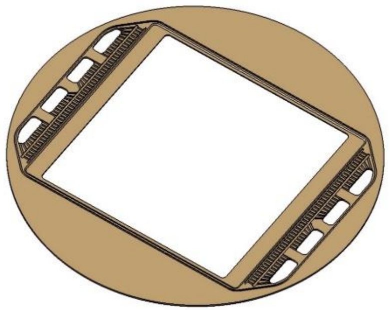
– Separator plates with/without flow structure

– Flexible concept for changing cell components/materials

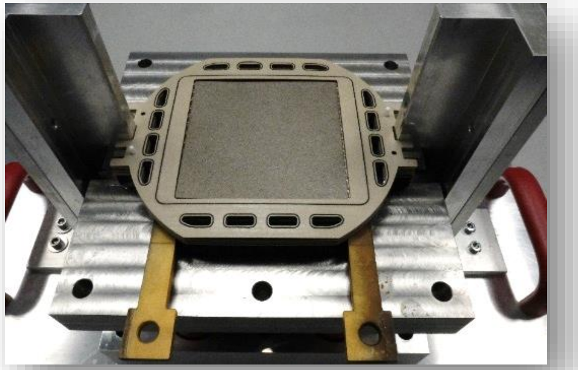
– Easy to stack

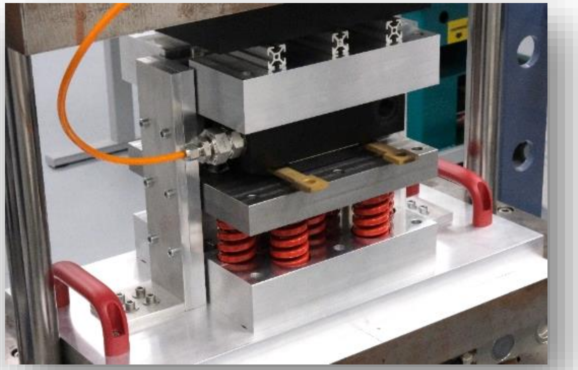


- Plastic-based, t~1mm
- O-rings as gaskets



Anode sealing frame (back side)





Current status

– Functional stack build up with 3 cells

– Tests coming soon

Next steps

– Further developments (e.g. sealings, design)

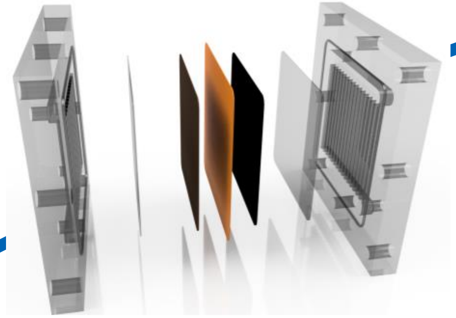
– Adaptation for AEMWE (similar design, replace components)

Summary

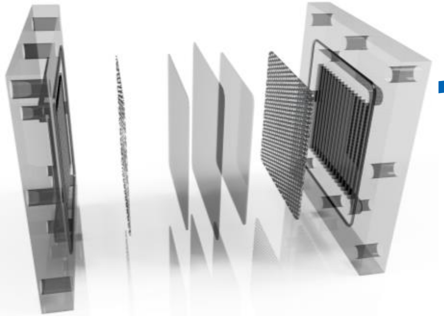
PGM-free catalysts

Membranes

MEA



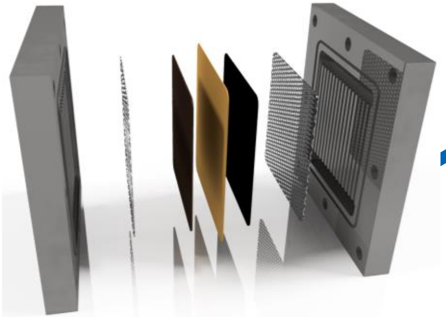
PTL



Alternative materials

Different structures

WE Stack



WE Cell

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Thank you for your attention!

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