Study on the effect of Mo on the performance and durability of PGM-free anode catalysts for AEMWE

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[1] Rise Research Institutes of Sweden AB

[2] KTH Royal Institute of Technology

[3] Umeå University

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Who are we?

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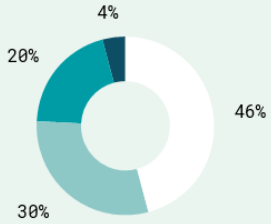
Who are we?

RISE Research Institutes Of Sweden

3,993

SEK million, net sales

Operating results: 22 SEK million
Operating margin: 0,6%



Distribution of net sales

Business sector	1,831 MSEK
Public funds	1,179 MSEK
State funds	812 MSEK
EU funds	171 MSEK

Nearly

3,300

employees

130+

Testbeds and demonstration environments

We are represented at

35

locations around Sweden

78

Customer Satisfaction Index

PUSH research center 2020-2025

Production, use and storage of hydrogen (PUSH) – in sustainable energy systems

SSF Agenda 2030 Research Centers (ARC) 2019 in the area of Hydrogen/Fuel Cells

Focus area 1 Hydrogen production using electrolysis (AEMEC and more…)

Focus area 2 Hydrogen storage and distribution (Systems, LOHC and more…)

Focus area 3 Hydrogen conversion in fuel cells (PEMFC and more….)

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NiFeMo anode Umeå University ,surface coating and catalyst development

KTH Royal Institute of Technology, Programleader, electrodes and cells (test and modelling, hydrogen stored in LOHC and other, system studies)

Chalmers, catalyst development

RISE , Long term testing

Lund University, membrane development

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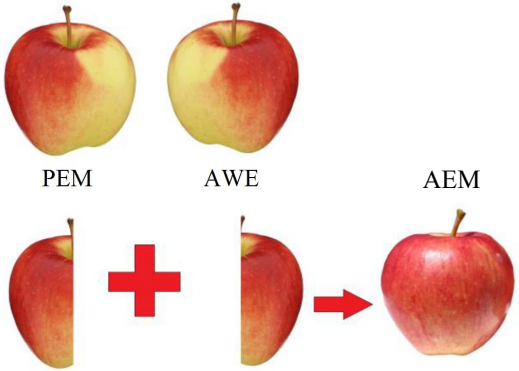
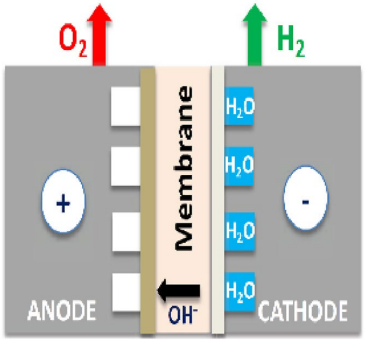
Why Anion Exchange Membrane water electrolyzer? (AEMWE)

Anion Exchange Membrane Water Electrolyzer (AEMWE)





AEMWE

- Cheap catalyst material (AWE)
- High current density (PEMWE)
- High hydrogen purity (PEMWE)
- Compressed gas (PEMWE)

Dokhani et al, Techno-economic assessment of hydrogen production from seawater, International Journal of Hydrogen Energy, Volume 48, Issue 26, 2023

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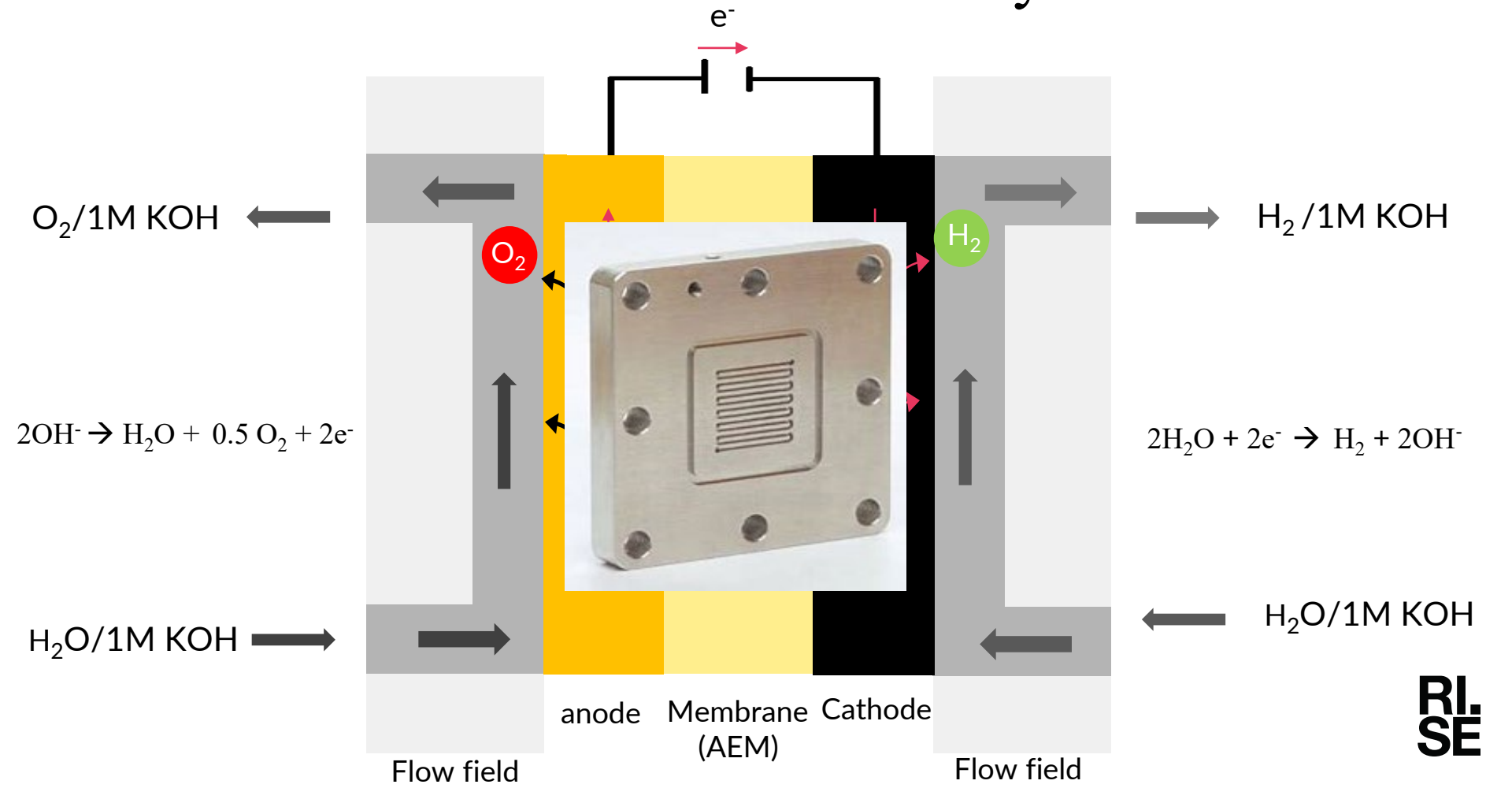
AEM Water Electrolyzer



III

Durability and stability measurements on AEMWE

Issues in AEMWE

- Chemical degradation within the membrane.
- Leaching out of catalyst into electrolyte
- Catalyst layer degradation.
- And other issues.

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III

Durability and stability measurements on AEMWE

Issues in AEMWE

- Chemical degradation within the membrane.
- Leaching out of catalyst into electrolyte
- **Catalyst layer degradation.**
- And other issues.

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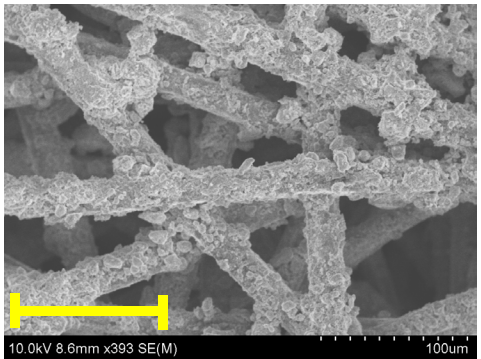
Benchmark results Vs. NiFeMo anode plasma coating

Benchmark MEA (CCS)

- Catalyst Coated Substrate (CCS)
- Membrane:
  - Aemion + (50 micron)
- Cathode electrode:
  - NiFeCo (Commercial hand painted on nickel fiber paper, Dioxide Materials Inc.)
- anode:
  - $Ni_2Fe_2O_4$ (Commercial hand painted on stainless steel fiber paper, Dioxide Materials Inc.)

Bar = 100 μm



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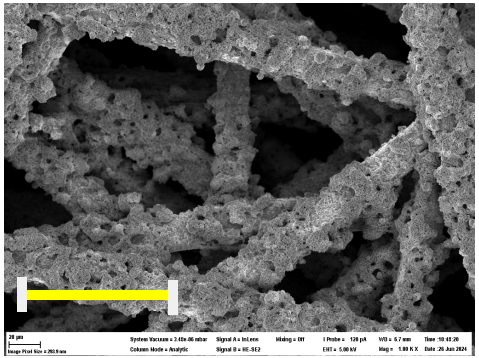
Benchmark results Vs. NiFeMo anode plasma coating

NiFeMo anode MEA (CCS)

- Catalyst Coated Substrate (CCS)
- Membrane:
  - Aemion+ (50 micron)
- Cathode electrode:
  - NiFeCo (Commercial hand-painted on nickel fiber paper, Dioxide Materials Inc.)
- anode:
  - NiFeMo (Plasma spraying on stainless steel fiber paper, Umeå University)

Bar = 100 μm



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Benchmark results Vs. NiFeMo anode plasma coating

Why molybdenum?

- Non-PGM, no critical raw materials.
- Enhances the catalyst material performance.
- Increases the surface area of the material.
- Provides more active sites for electrochemical reactions.

Platinum	$1013.00 oz	Sept 30, 2024
Molybdenum	$1.92 oz	Sept 30, 2024

Ref. Daily Metal Price: Molybdenum Price (USD / Pound) Chart for the Last 5 Years

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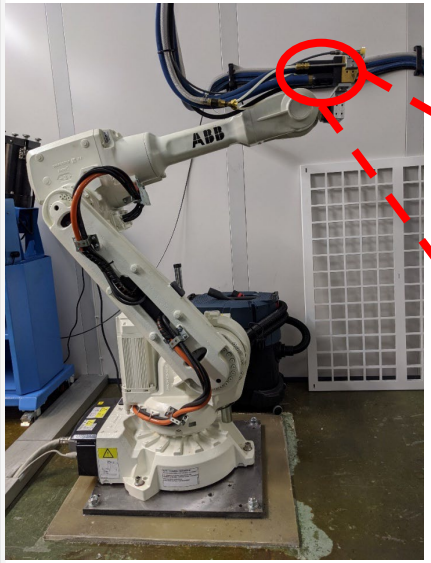
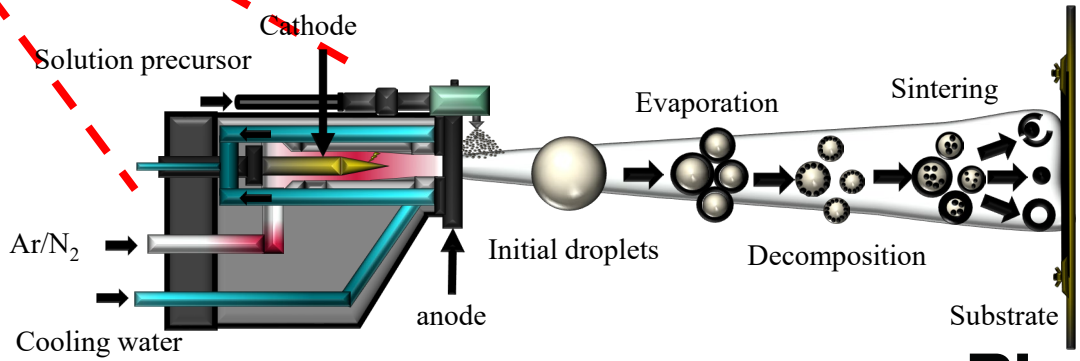
Benchmark results Vs. NiFeMo anode plasma coating

Plasma Spraying Facility at Umeå University

Why Plasma Spraying?

- Scalable and fast synthesis process.
- Large variety of materials can be sprayed.
- Do not need post treatment.





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Test protocol

IV

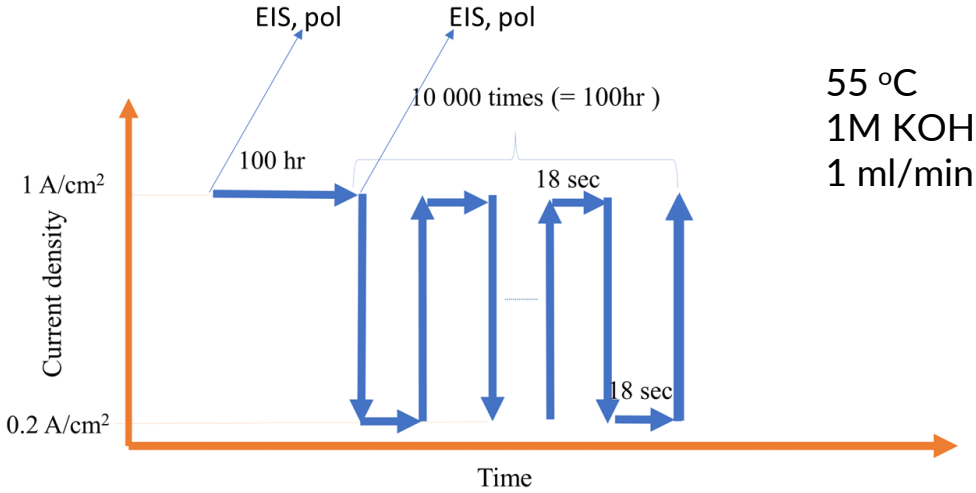
Benchmark results Vs. NiFeMo anode plasma coating

2 steps:

Step 1: Cell will be held at 1 A/cm^2 for 100 hr

Step 2: Maintaining 1 A/cm^2 for 18 s and then 0.2 A/cm^2 for 18 s.

* Step 2 is repeated 10,000 times (= 100 hr) of dynamic aging.



55 °C
1M KOH
1 ml/min

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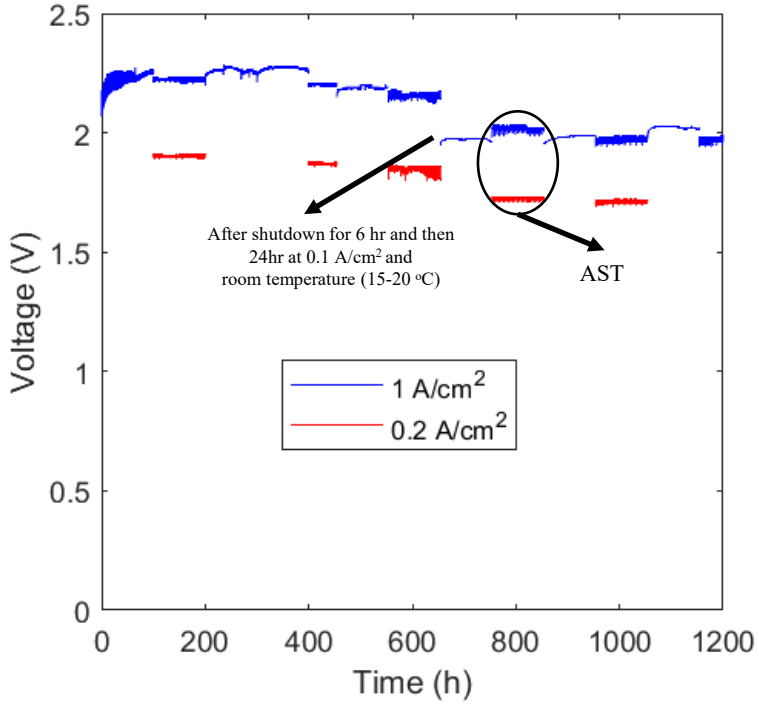
Benchmark results Vs. NiFeMo anode plasma coating

Test protocol result
Benchmark



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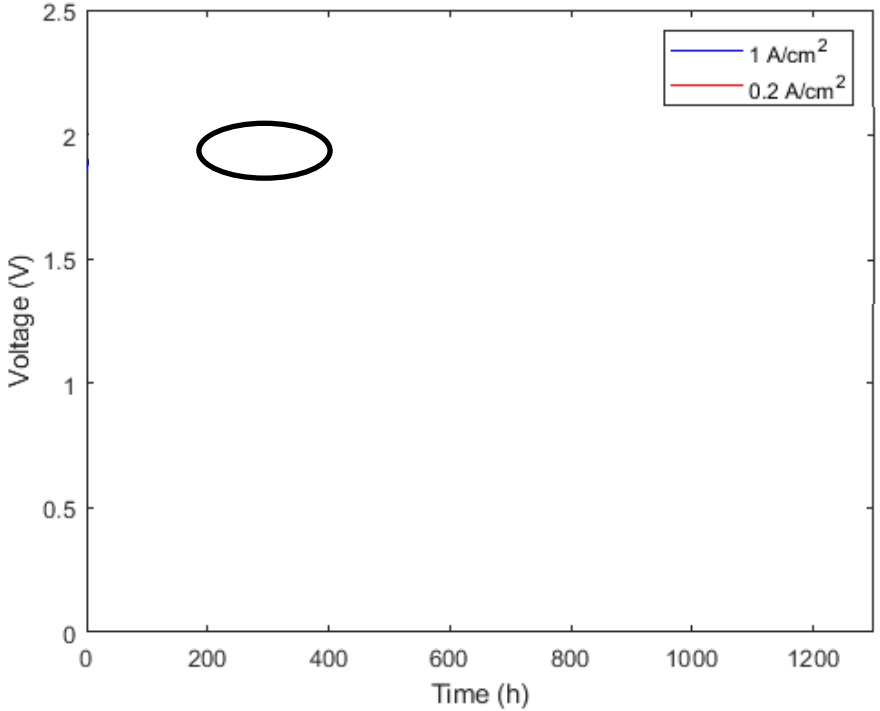
Benchmark results Vs. NiFeMo anode plasma coating

Test protocol result
NiFeMo anode (Plasma coating)



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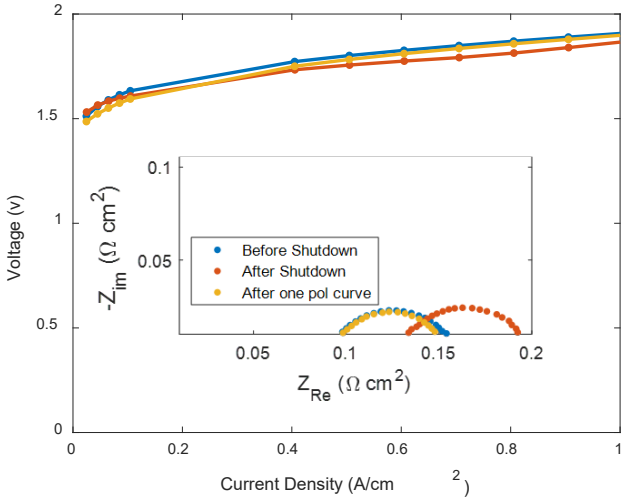
Benchmark results Vs. NiFeMo anode plasma coating

Unexpected shutdown for 11min (Storm caused the shutdown)



HFR (High frequency resistance)	
Before shut down	0.0911
After shut down	0.1264
After a Polarization curve	0.0906

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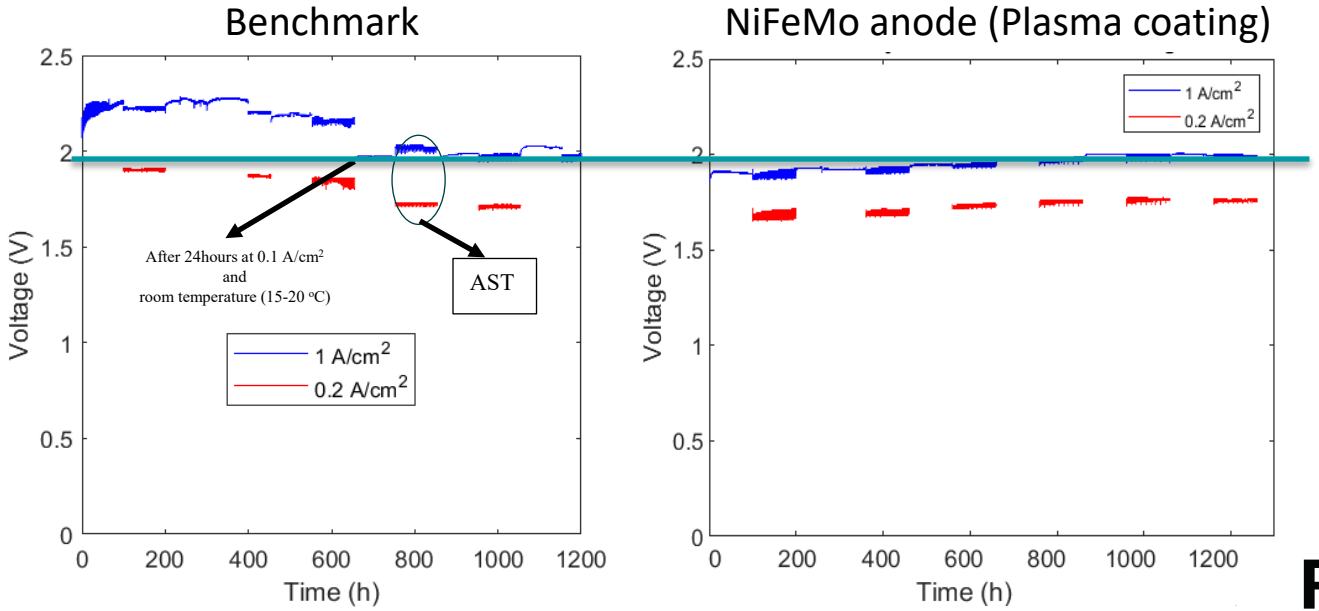
Benchmark results Vs. NiFeMo anode plasma coating

Stability measurement comparison

(Benchmark Vs, NiFeMo anode(Plasma coating))



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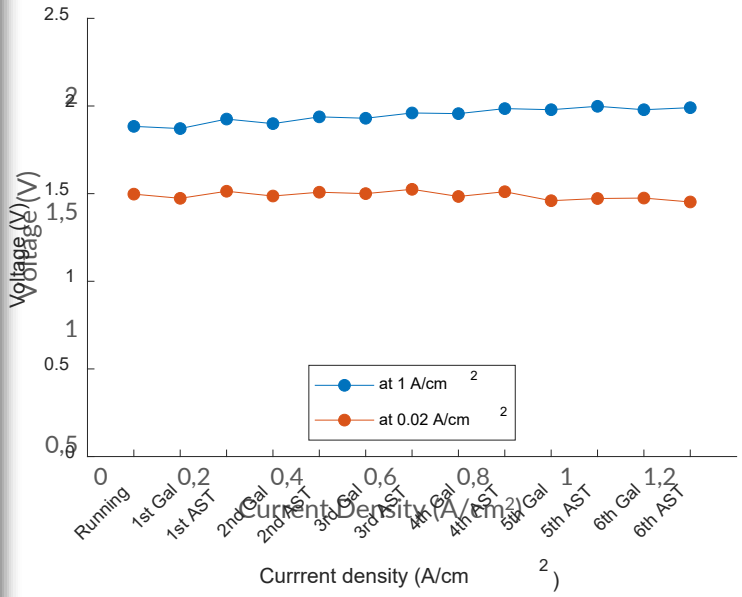
Benchmark results Vs. NiFeMo anode plasma coating

Polarization Curves
(NiFeMo anode (Plasma Coating))



Polarization curves comparison

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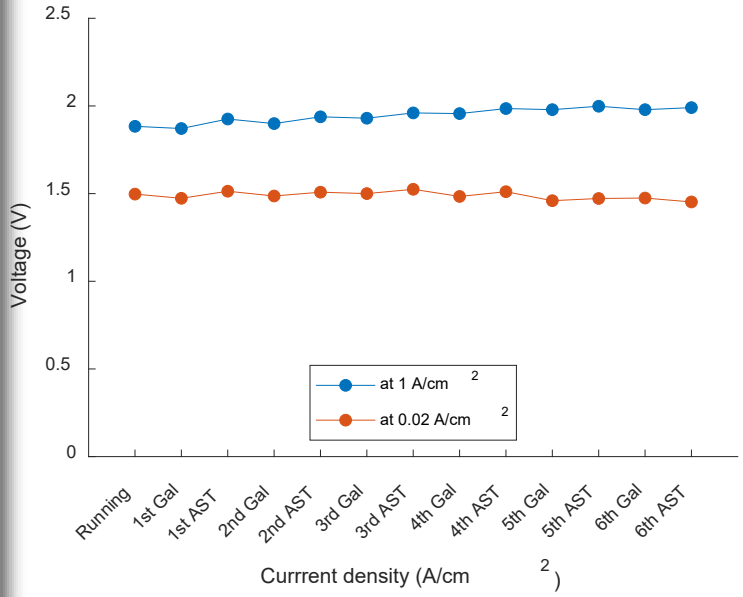
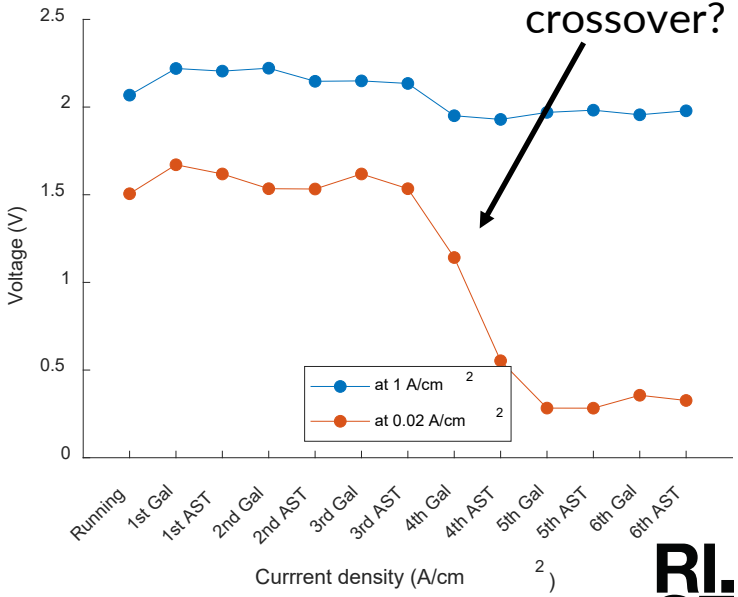
Benchmark results Vs. NiFeMo anode plasma coating

NiFeMo anode (Plasma Coating)



Benchmark



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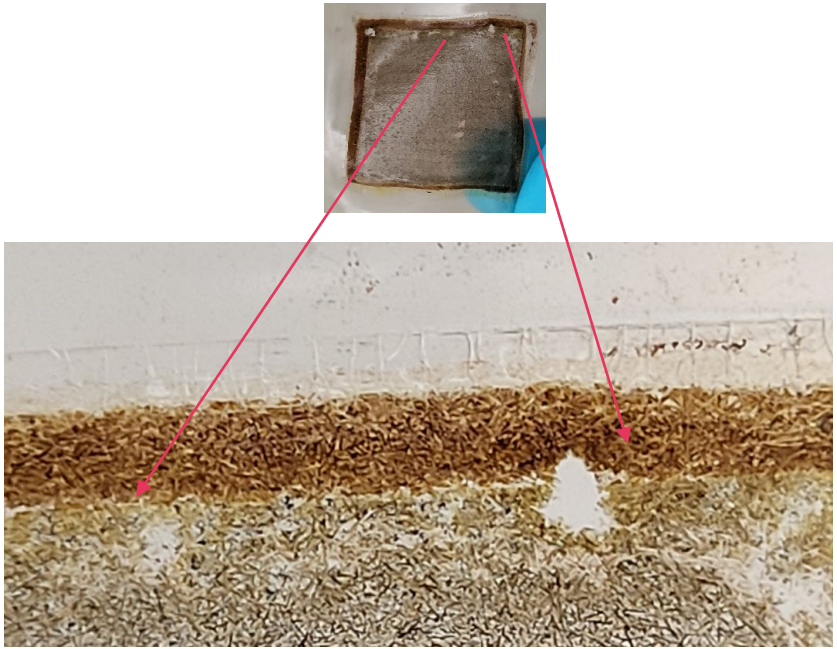
Benchmark results Vs. NiFeMo anode plasma coating

Microscope image of benchmark membrane



Microscope images of membrane (NiFeMo anode)

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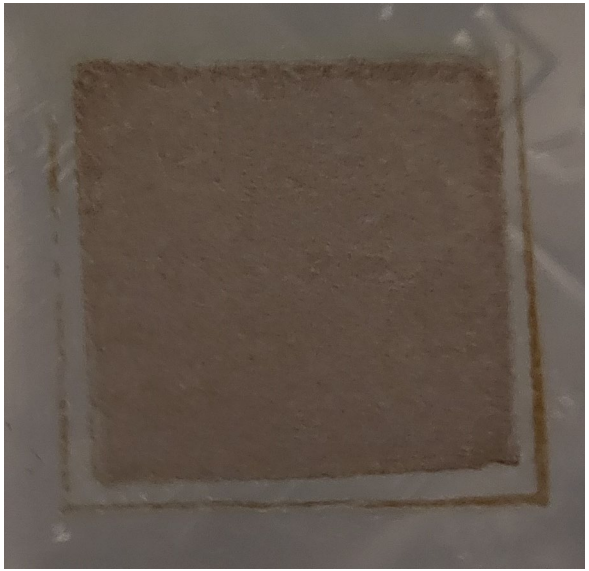
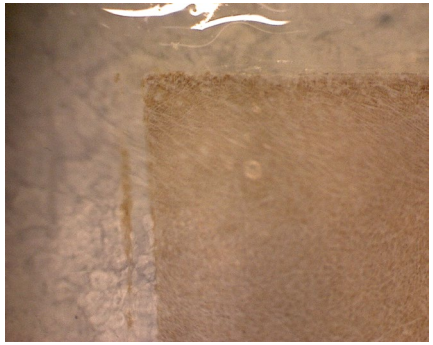
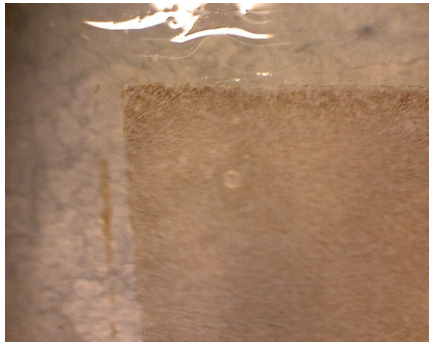
Benchmark results Vs. NiFeMo anode plasma coating







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Benchmark results Vs. NiFeMo anode plasma coating

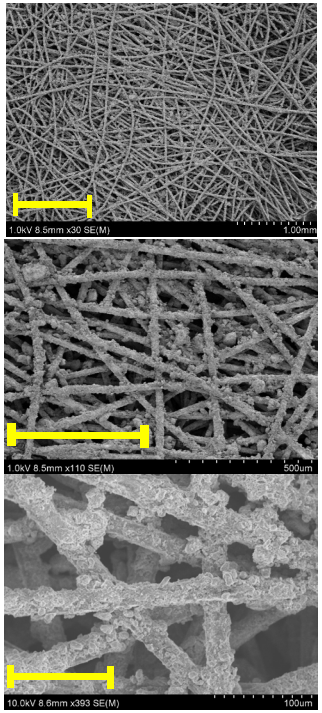
SEM (Benchmark anode)

Bars =1 mm

Bars = 500 μm

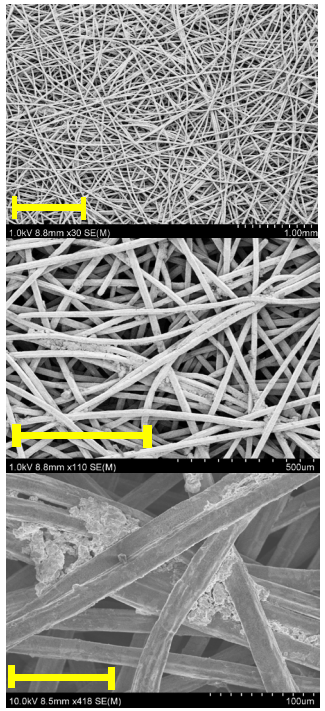
Bars = 100 μm

a



a) Before test

b



b) After test

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Benchmark results Vs. NiFe Mo anode plasma coating

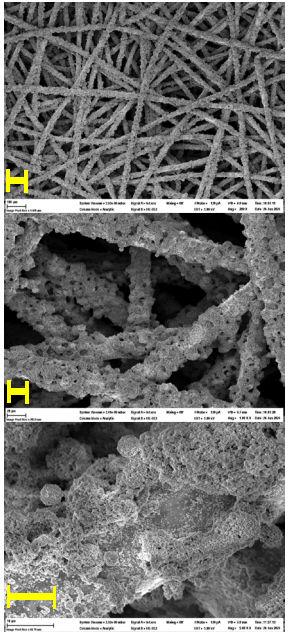
SEM
(NiFe Mo anode (Plasma coating))

Bars=100 μm

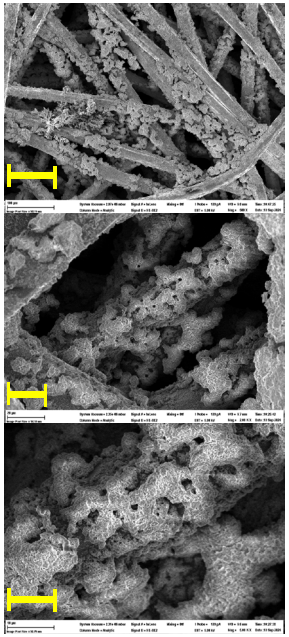
Bars = 20 μm

Bars = 10 μm

a



b



a) Before test

b) After test

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Conclusions and future work

- AEMWE: low-cost materials and high efficiency.
- Plasma-sprayed NiFeMo anode shows promising results to compare with the benchmark.
- SEM from NiFeMo anode demonstrated the catalyst material's higher stability on the substrate.
- The accelerated degradation due to the AST procedure is apparent.
- Future work: New benchmark AST test with commercial electrodes for 1200hr test.

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Acknowledgment

- This work is financially supported by the Swedish Foundation for Strategic Research (SSF). Project No. ARC19-0026 (Production, use and storage of hydrogen (PUSH))
- Research Institutes of Sweden (RISE).
- KTH Royal Institute of Technology.
- Umeå University

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KTH VETENSKAP OCH KONST

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