Elektrolysforskning med fokus på driftsbetingelser och livslängd

Sepanta Dokhani och Anders Lundblad, RISE Research Institutes of Sweden AB

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Who are we?

II

Why Anion Exchange Membrane water electrolyzer? (AEMWE)

III

Durability and stability measurements on AEMWE

IV

Benchmark results

V

Conclusion and future work

I

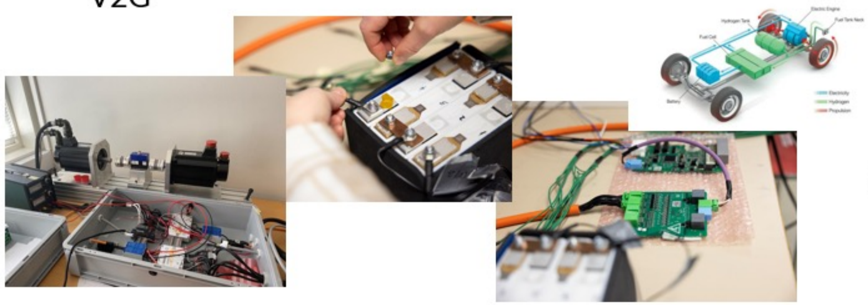
Who are we?

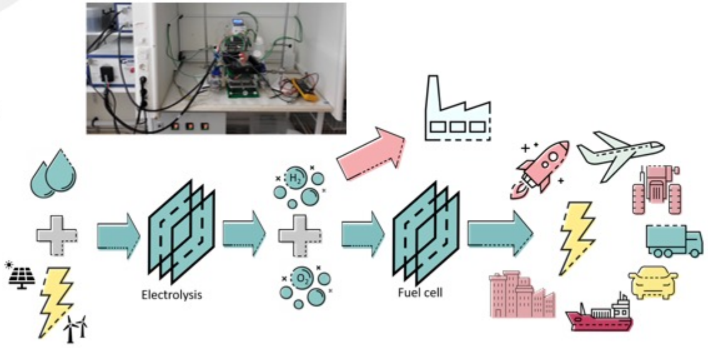
Energy Conversion Research areas

Batteries
- Durability
- 2nd Life
- Battery analysis
- Training
- Safety and handling

Powertrain
- Energy storage
- BMS
- Simulation for energy optimization
- V2G

Hydrogen Components and applications
- Electrolysers
- Fuel Cells
- Safety
- Test bed for Fuel cell components
- Contact Resistance
- Training





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II

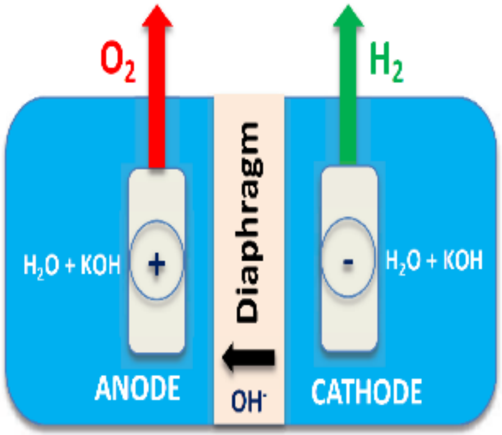
Why Anion Exchange Membrane water electrolyzer? (AEMWE)

Different type of electrolyzers

Alkaline water electrolyzer (AWE)

- ✓ Mature technology
- ✓ Cheap catalyst material
- ✓ Long term operation

- × Need strong alkaline electrolyte
- × Slow start up and shout down time
- × Current density low (0.7 A/cm²)
- × Low hydrogen purity at low load



Dokhani et al, Int. J. Hydrog. Energy., 48, (26), 9592-9608, 2023

II

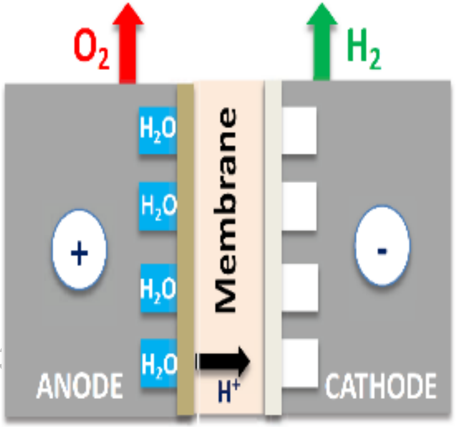
Why Anion Exchange Membrane water electrolyzer? (AEMWE)

Different type of electrolyzers

Proton exchange membrane water electrolyzer (PEMWE)

- ✓ High hydrogen purity
- ✓ Good for dynamic load operation
- ✓ Current density high (2.4 A/cm²)

- × Using Platinum Group Metals (PGMs)
- × Expensive



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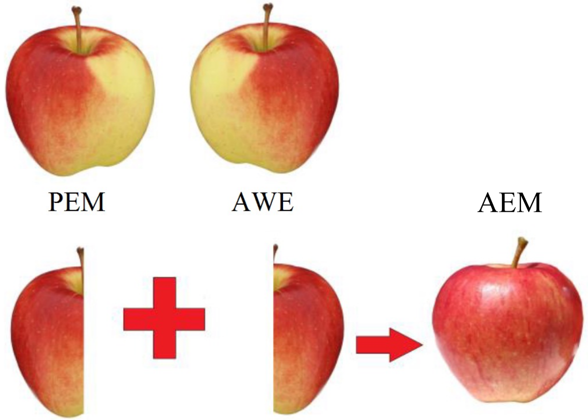
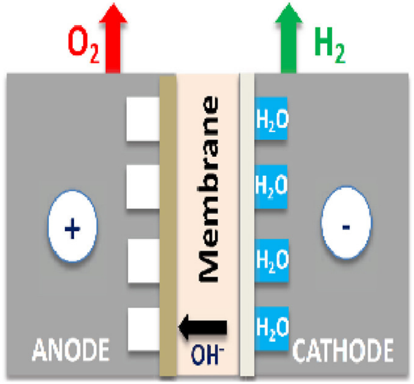
Anion Exchange Membrane water electrolyzer (AEMWE)

II

Why Anion Exchange Membrane water electrolyzer? (AEMWE)





AEMWE

- ✓ Cheap catalyst material (AWE)
- ✓ High current density (PEMWE)
- ✓ High hydrogen purity (PEMWE)
- ✓ Dynamic load operation (PEMWE)
- × Promising but still not mature

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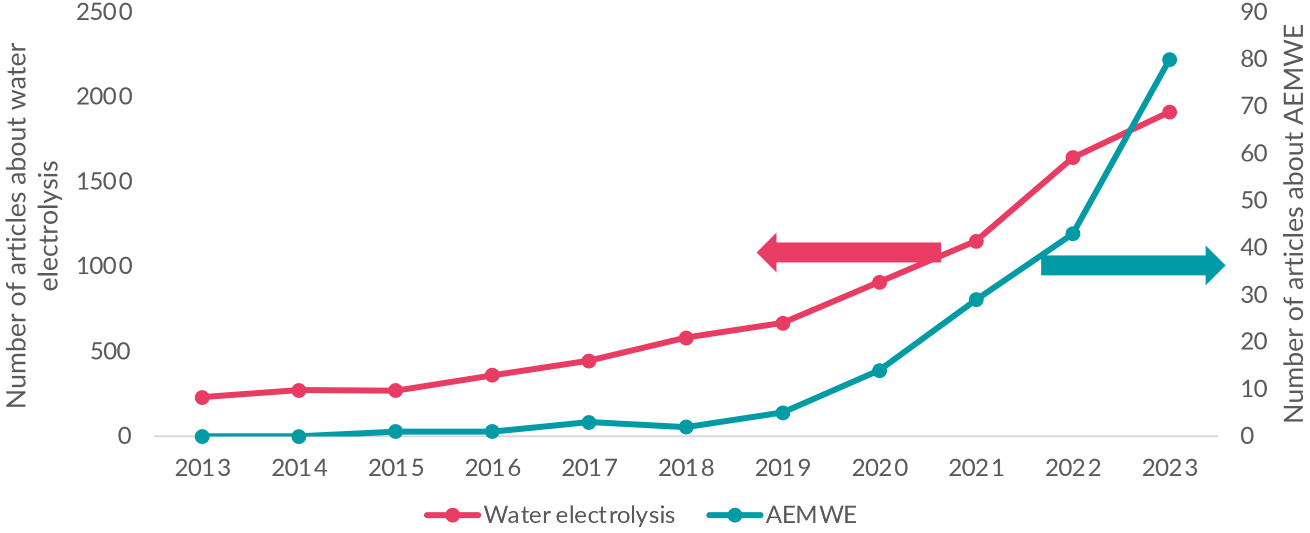
III

Durability and stability measurements on AEMWE

AEMWE has gained attentions



Scopus - document search results.

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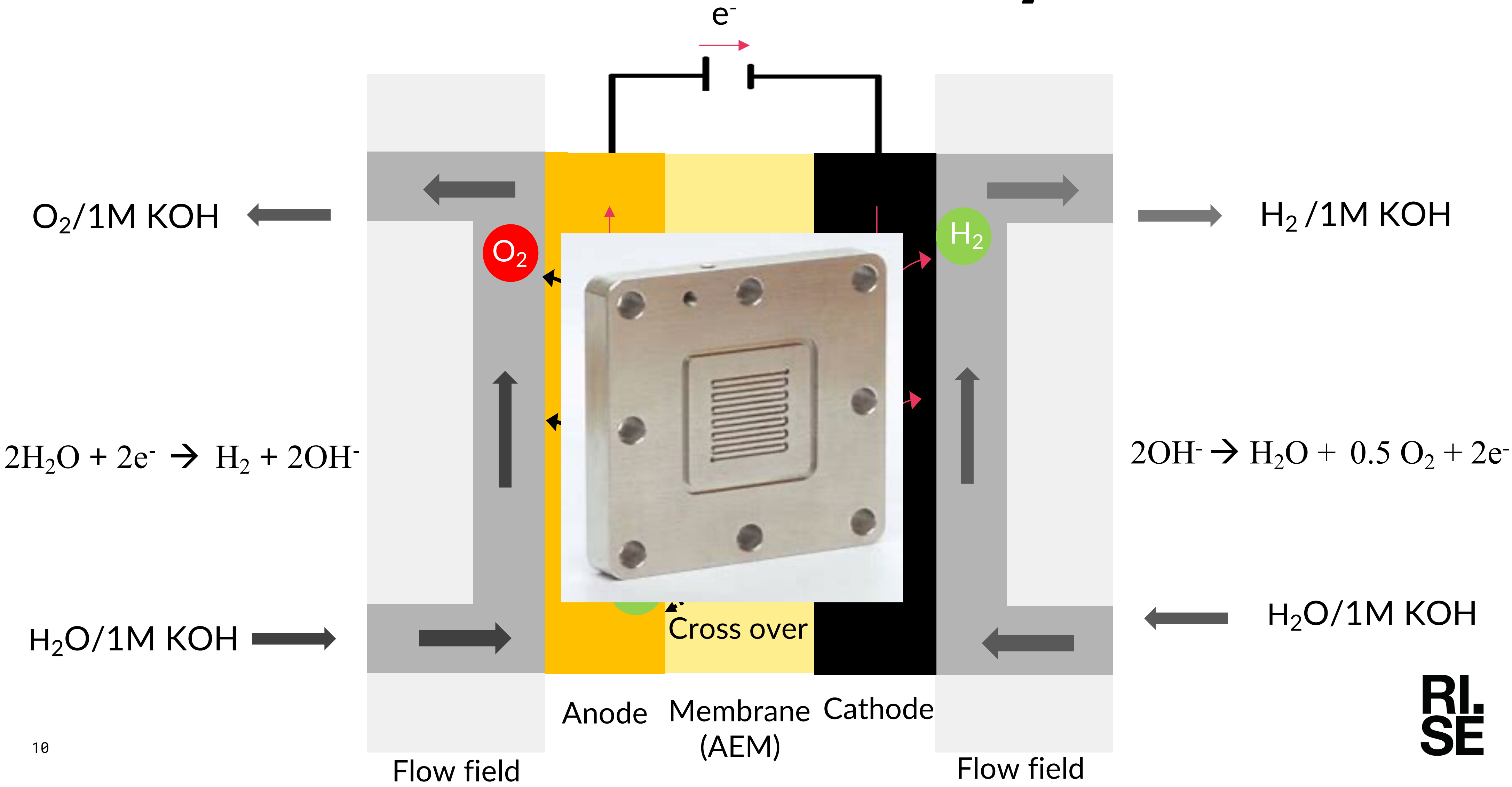
AEM Water Electrolyzer



III

Durability and stability measurements on AEMWE

Issues in AEMWE

- Chemical degradation within the membrane and electrodes results in the following issues leading to low stability in AEMWE:
  - Membrane thinning, causing hydrogen crossover.
  - Reduced ion exchange capacity, consequently increasing ohmic resistance.
- Carbonate formation of the supporting electrolyte and chemical degradation of the membrane and ionomer in the catalyst layer
- Leaching out of catalyst into electrolyte
- And other degradations ....

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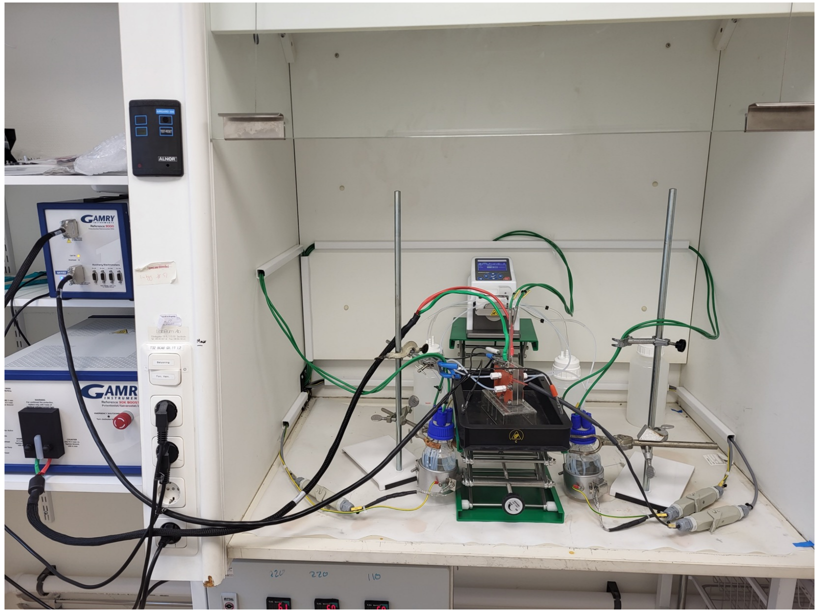
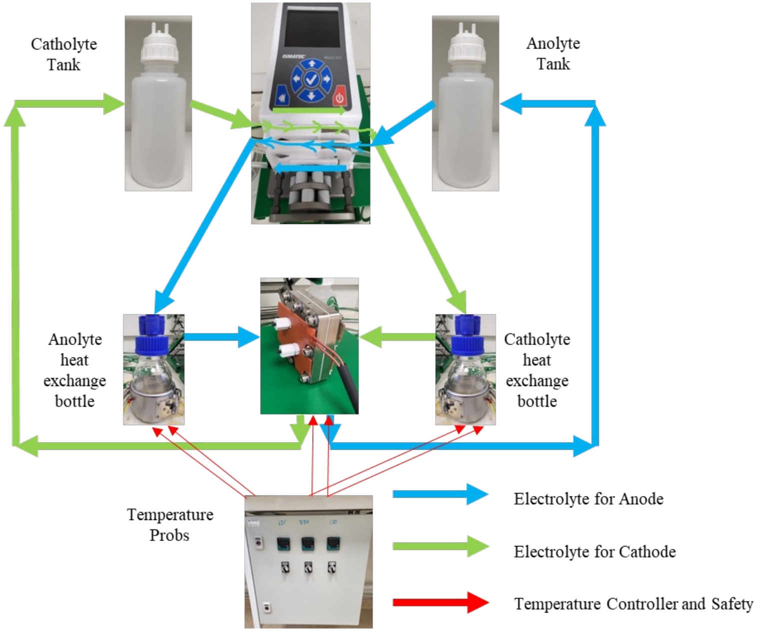
Benchmark results

AEMWE system build up in RISE





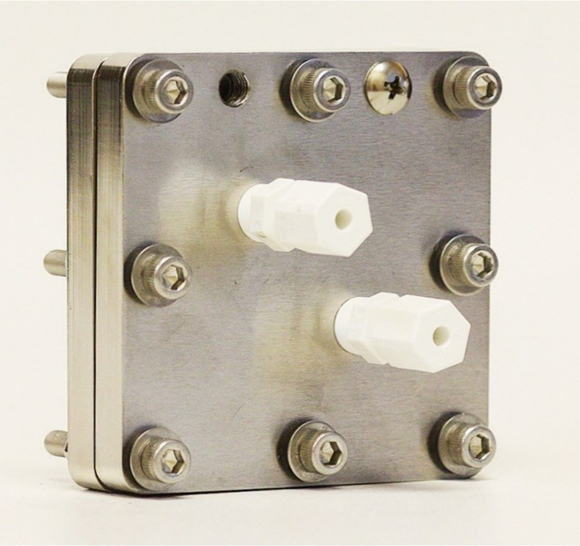
- Temperature controller
- Good for long term condition
- Gamry potentiostat for electrochemistry characterization

IV

Benchmark results

Electrolyzer Cell (5 cm^2)

- Membrane:
  - Aemion AF3 (Commercial membrane from Ionomer Inc)
- Cathode electrode:
  - NiFeCo (Commercial hand painted on nickel fiber paper)
- Anode:
  - $Ni_2Fe_2O_4$ (Commercial hand painted on stainless steel fiber paper)

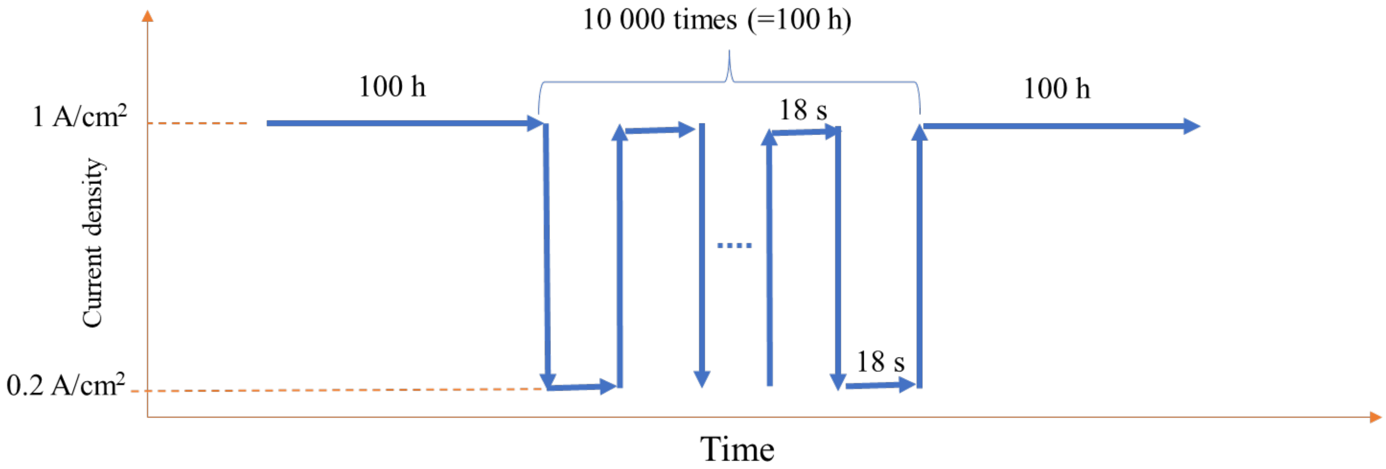


IV

Benchmark results

Test protocol

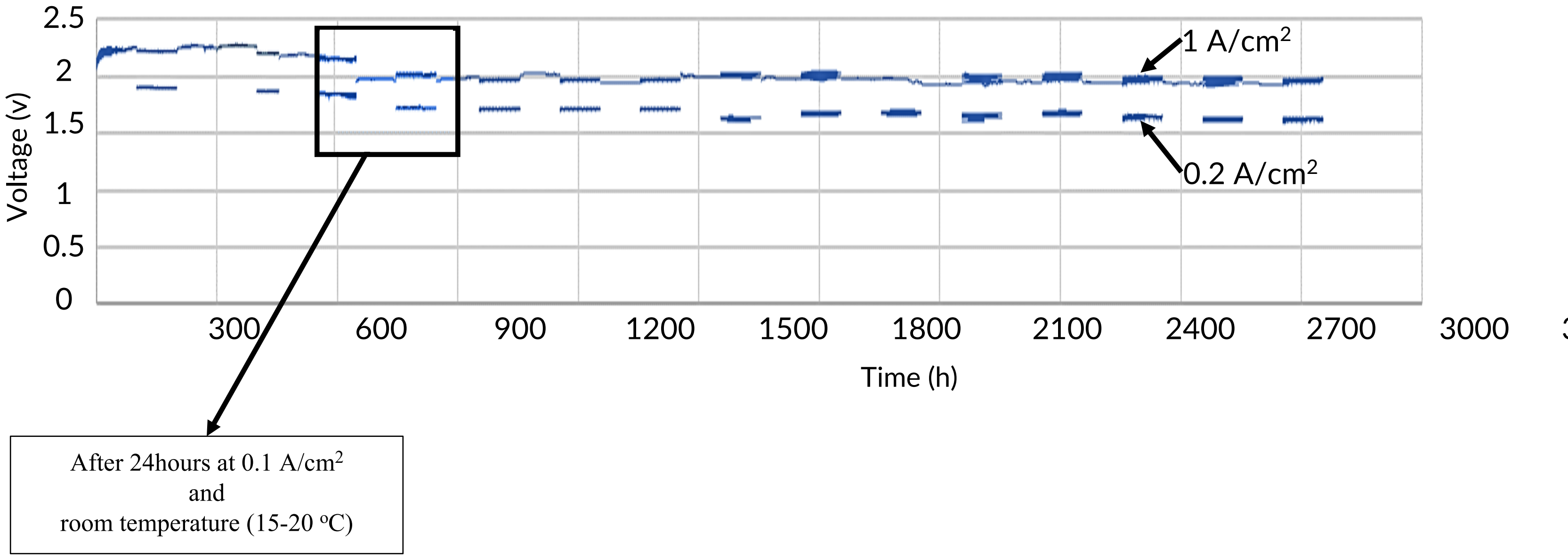
- Cell will be hold at 1 A/cm² for 100h and the electrochemical characterization will be performed.
- Then an Accelerated stress test (AST) consisting in maintain 0.2 A/cm² for 18 s and then 0.2 A/cm² for 18 s and two steps repeated 10,000 timed (= 100hr) times of dynamic ageing.



Galvanostatic stability Measurement and AST testing at 1 and 0.2A/cm²

IV

Benchmark results



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Additional and future tests

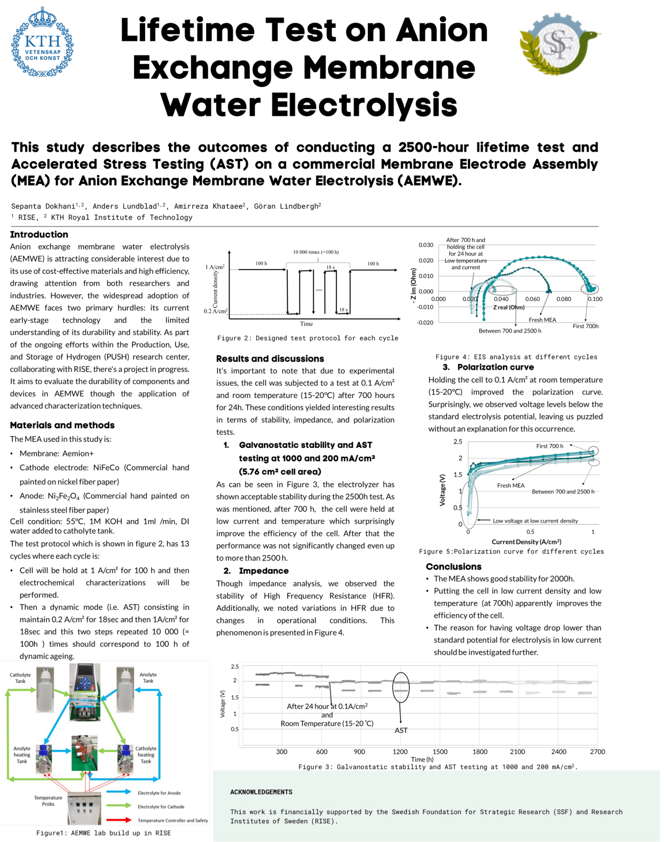
IV

Benchmark results

- Electrochemical characterization
  - Impedance
  - Polarization curve

- Post test like Scanning Electron Microscope (SEM)

- Gas crossover measurement.



Lifetime Test on Anion Exchange Membrane Water Electrolysis

This study describes the outcomes of conducting a 2500-hour lifetime test and Accelerated Stress Testing (AST) on a commercial Membrane Electrode Assembly (MEA) for Anion Exchange Membrane Water Electrolysis (AEMWE).

Sepanta Dokhani[1,2], Anders Lundblad[1,2], Amirreza Khataee[2], Göran Lindbergh[2]
[1] RISE, [2] KTH Royal Institute of Technology

Introduction

Anion exchange membrane water electrolysis (AEMWE) is attracting considerable interest due to its use of cost-effective materials and high efficiency, drawing attention from both researchers and industries. However, the widespread adoption of AEMWE faces two primary hurdles: its current early-stage technology and the limited understanding of its durability and stability. As part of the ongoing efforts within the Production, Use, and Storage of Hydrogen (PUSH) research center, collaborating with RISE, there's a project in progress. It aims to evaluate the durability of components and devices in AEMWE though the application of advanced characterization techniques.

Materials and methods

The MEA used in this study is:

- Membrane: Aemion+
- Cathode electrode: NiFeCo (Commercial hand painted on nickel fiber paper)
- Anode: $Ni_2Fe_2O_4$ (Commercial hand painted on stainless steel fiber paper)

Cell condition: 55°C, 1M KOH and 1ml /min, DI water added to catholyte tank.

The test protocol which is shown in figure 2, has 13 cycles where each cycle is:

- Cell will be hold at 1 A/cm² for 100 h and then electrochemical characterizations will be performed.
- Then a dynamic mode (i.e. AST) consisting in maintain 0.2 A/cm² for 18sec and then 1A/cm² for 18sec and this two steps repeated 10 000 (= 100h) times should correspond to 100 h of dynamic ageing.

Figure1: AEMWE lab build up in RISE

Figure 2: Designed test protocol for each cycle

Results and discussions

It's important to note that due to experimental issues, the cell was subjected to a test at 0.1 A/cm² and room temperature (15-20°C) after 700 hours for 24h. These conditions yielded interesting results in terms of stability, impedance, and polarization tests.

1. **Galvanostatic stability and AST testing at 1000 and 200 mA/cm² (5.76 cm² cell area)**

As can be seen in Figure 3, the electrolyzer has shown acceptable stability during the 2500h test. As was mentioned, after 700 h, the cell were held at low current and temperature which surprisingly improve the efficiency of the cell. After that the performance was not significantly changed even up to more than 2500 h.

2. **Impedance**

Though impedance analysis, we observed the stability of High Frequency Resistance (HFR). Additionally, we noted variations in HFR due to changes in operational conditions. This phenomenon is presented in Figure 4.

Figure 4: EIS analysis at different cycles

3. **Polarization curve**

Holding the cell to 0.1 A/cm² at room temperature (15-20°C) improved the polarization curve. Surprisingly, we observed voltage levels below the standard electrolysis potential, leaving us puzzled without an explanation for this occurrence.

Figure 5:Polarization curve for different cycles

Conclusions

- The MEA shows good stability for 2000h.
- Putting the cell in low current density and low temperature (at 700h) apparently improves the efficiency of the cell.
- The reason for having voltage drop lower than standard potential for electrolysis in low current should be investigated further.

Figure 3: Galvanostatic stability and AST testing at 1000 and 200 mA/cm².

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Conclusion and future works

- AEMWE has gained attention due to low-cost materials with relatively high efficiency for hydrogen production.

- The key technical questions regarding AEMWE: The maturity and its long-term durability.

- Future works
    - To ensure the durability of AEMWE, a range of methods must be employed to obtain the most accurate results.
    - Conduct a durability and lifetime test on an MEA prepared with other partners of the PUSH program and compare with current results.

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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)).

References

[1] H2 Production by Water Electrolysis ,

[2] https://h2-international.com/2017/06/06/h2-production-by-water-electrolysis-technology-trends/, 2017

[3]https://th.bing.com/th/id/OIP.X_g1OCb43yjA7r6GR54ihgHaJ4?w=2448&h=3264&rs=1&pid=ImgDetMainPut in the slides

Thank you for your attention