Development of High-Temperature Electrolysers

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8th Estonian Hydrogen Day
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ABOUT H2ELECTRO

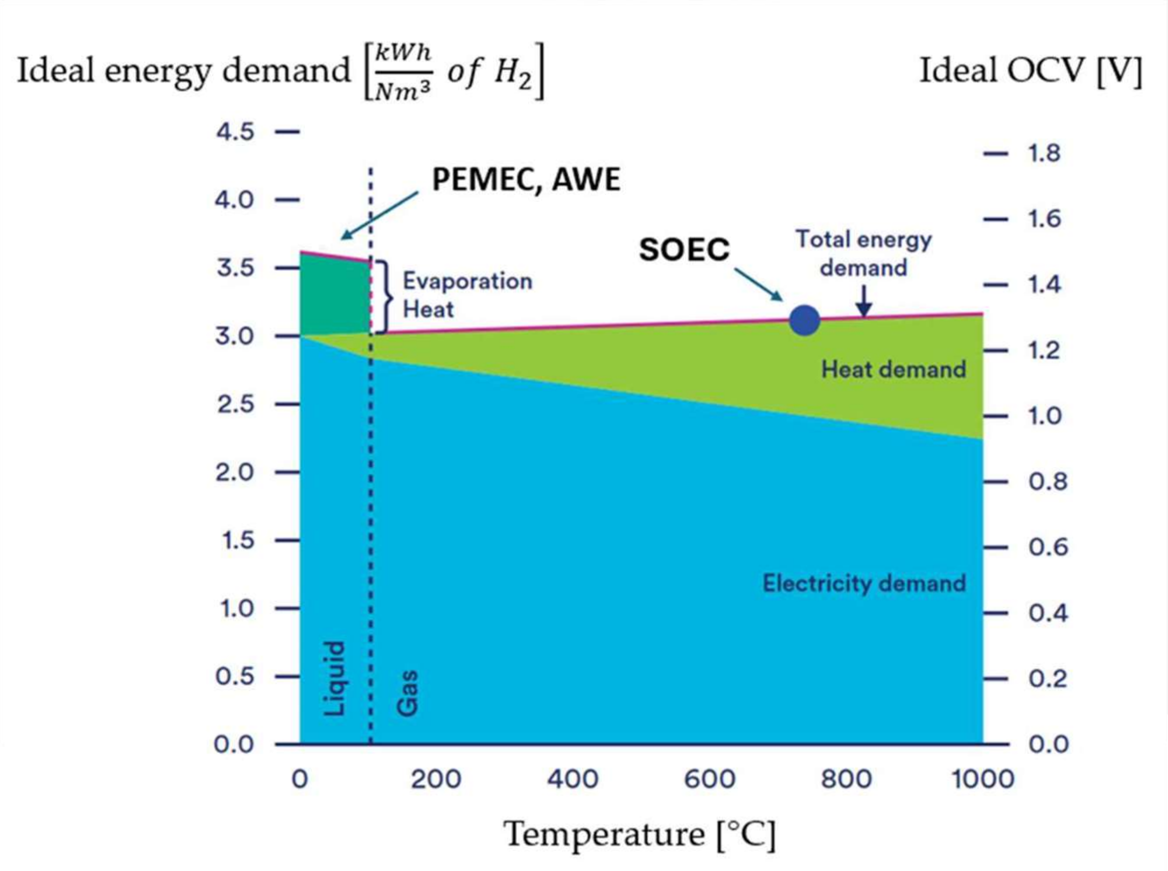
H2Electro was founded in 2021 and is a deep-tech start-up company that is developing and producing core technology for high-temperature electrolysers (HTEs), enabling the replacement of fossil fuels with renewable energy.

On 01.09.2021, H2Electro initiated a collaboration with the University of Tartu to develop an electrolyser demo stack and to test the proof-of-concept of all-ceramic fuel electrodes.

COMPARISON OF SOLID OXIDE ELECTROLYSERS WITH OTHER TECHNOLOGIES

Type of electrolyser	Alkaline technology	PEM technology	Solid oxide technology
Operating temperature	70 - 90°C	50 - 80°C	650 - 850°C
Efficiency	50-65%	60-75%	**80-85%**
Lifetime	10 years	6 years	5 years (goal is 10 years)
Electrolyte	KOH aqueous solution	PFSA membrane (Nafion)	Solid oxide
Electrode	Nickel alloys, Pt	Platinum, iridium	**Mixed ion-electron conductors (MIEC)**

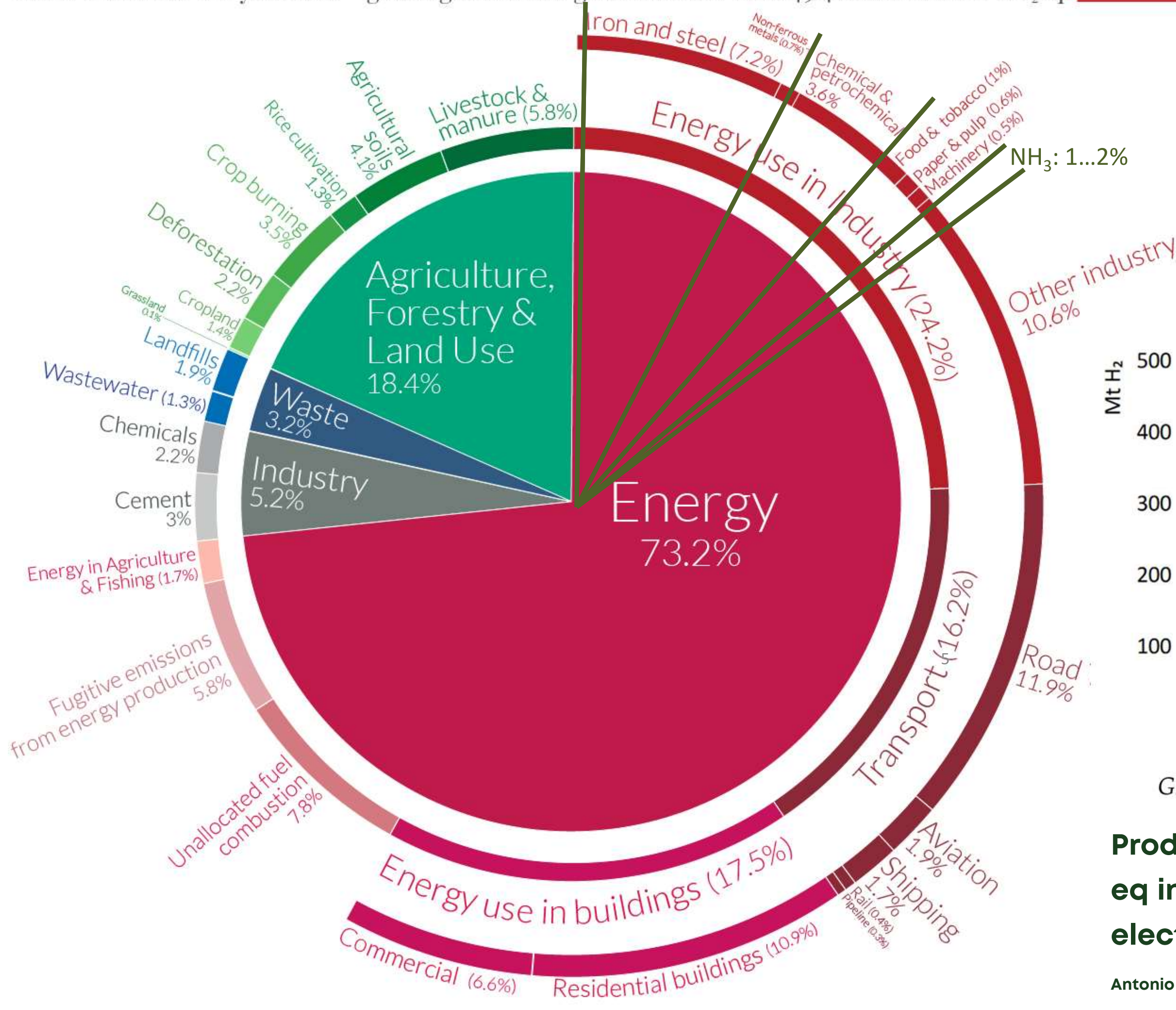
Ideal Energy Demand in Water Electrolysis as a Function of Temperature

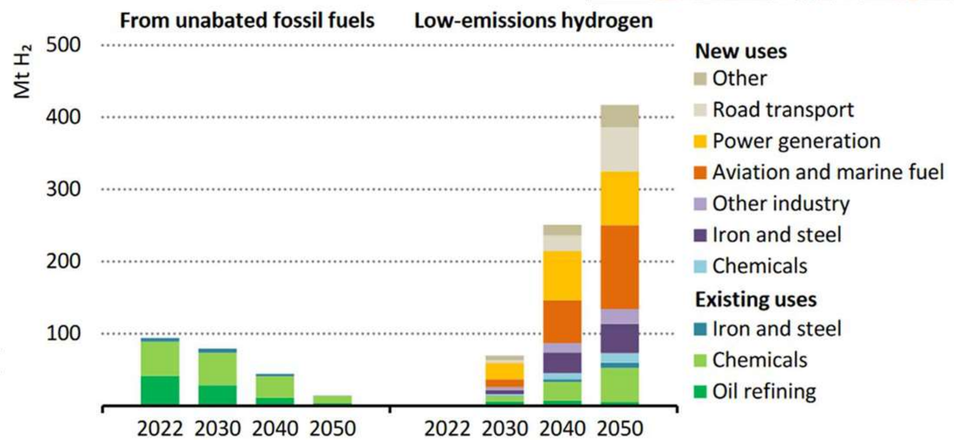


*Adapted from: G. Flis e G. Wakim, «Solid Oxide Electrolysis: A Technology Status Assessment».

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.



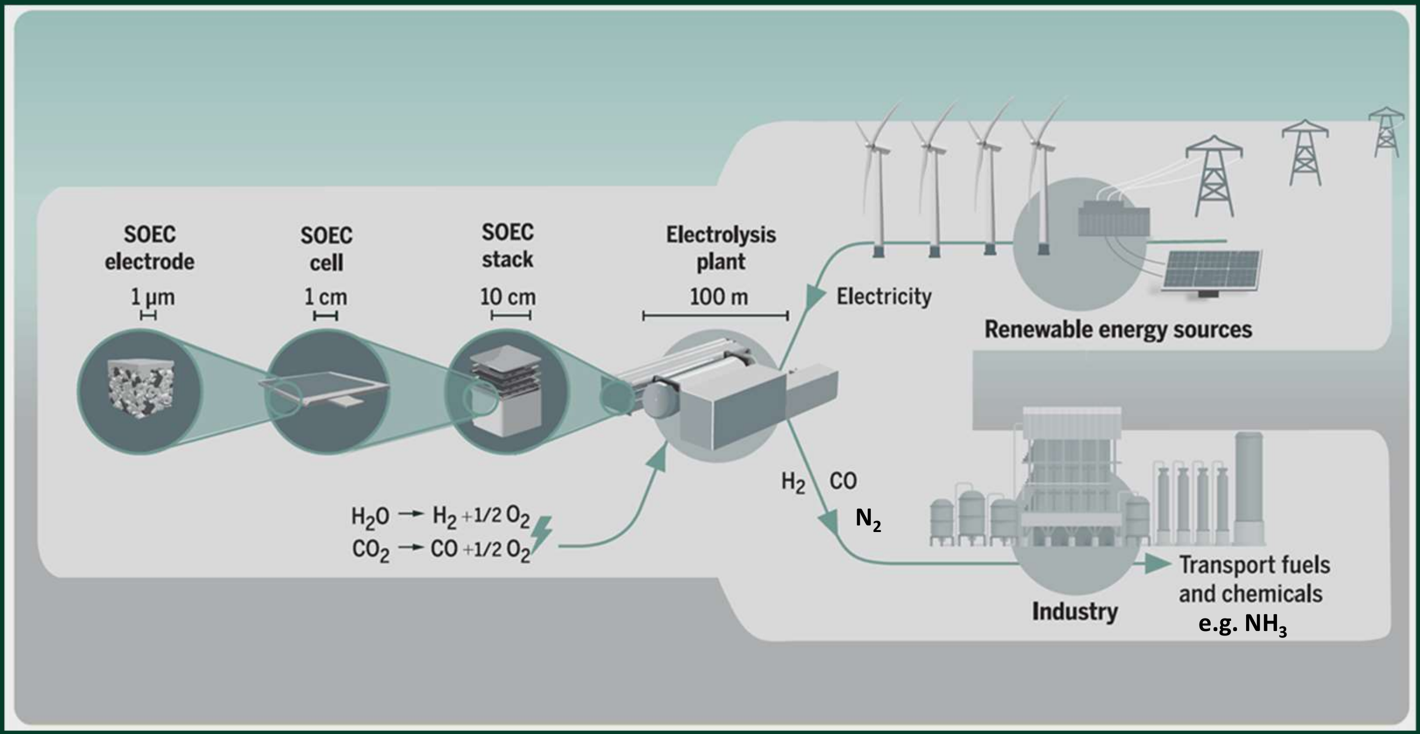


Global hydrogen demand in the NZE Scenario, 2022-2050

Producing 1 kg of H2 using SMR emits on average 11.43 kg CO2 eq in contrast to on average 1.16 kg CO2 eq. emitted from the electrolysis of water using wind energy.

Antonio Valente, et al Comparative life cycle sustainability assessment of renewable and conventional hydrogen, Science of The Total Environment, Volume 756, 2021,

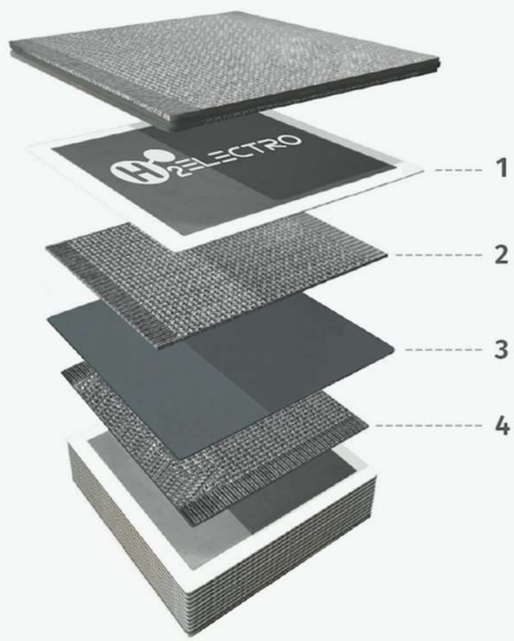
AMMONIA PRODUCTION and CO-ELECTROLYSIS



Hauch, A., et al., Recent advances in solid oxide cell technology for electrolysis, Science 09 Oct 2020: Vol. 370, Issue 6513

- **Efficiency**
- **High-Purity**
- **Medium-Pressure Hydrogen**
- **Waste Heat Utilization**
- **Durability**
- **Impurity Tolerance**
- **Modularity**
- **Sustainability**

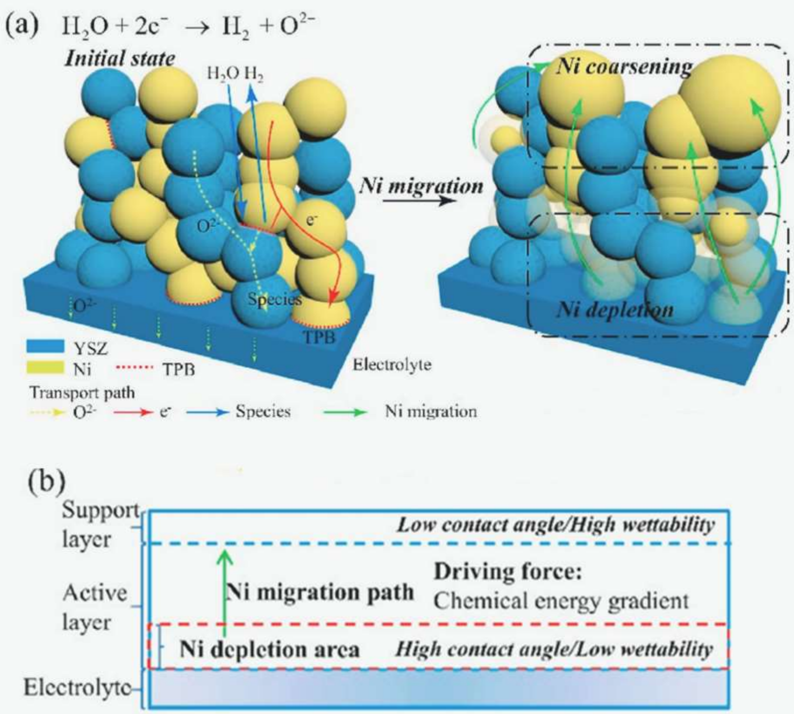
SCHEME OF SOEC



1 - Electrolyte with electrodes
2 - Oxygen flow field
3 - Interconnect
4 - Steam/hydrogen flow field

- 30% INCREASED EFFICIENCY
- NO RELIANCE ON PRECIOUS METALS
- UTILIZE INDUSTRIAL WASTE HEAT
- MODULAR DESIGN
- ADVANCED CERAMIC ELECTRODE MATERIALS
- PRODUCE SYNGAS (H_2 + CO) FROM H_2O AND CO_2
- IMPROVED REDOX STABILITY
- A LARGER ACTIVE SURFACE AREA
- HIGHER RESISTANCE TO CONTAMINANTS

Fuel electrode: Ni-Cermet vs MIEC

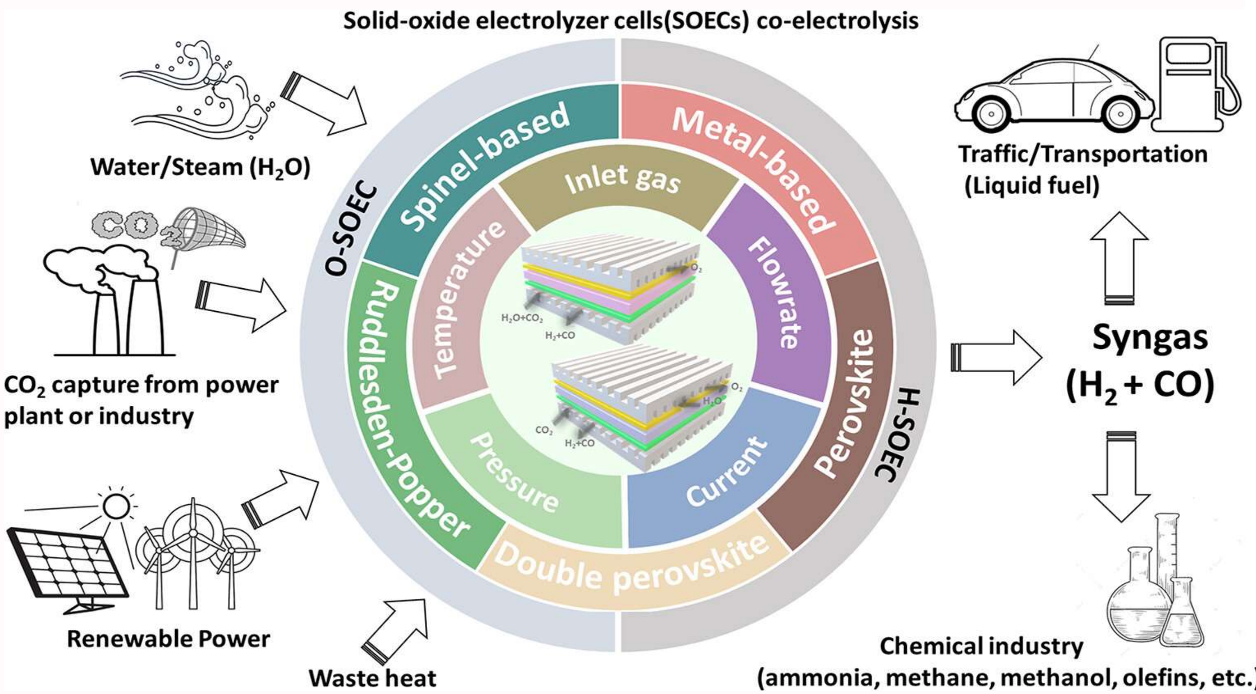


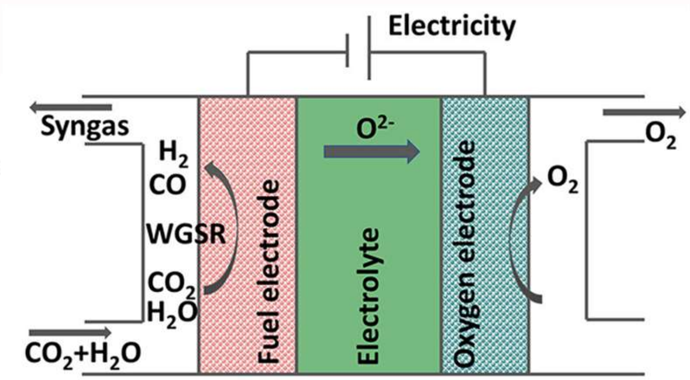
- Ni-Cermets exhibit:
  - Ni coarsening
  - Ni agglomeration
  - Ni depletion
  - Low redox stability
- Mixed Ionic-Electronic Conductors (MIECs) exhibit:
  - RESILIENCE TO SULFUR AND CARBON
  - LARGER ACTIVE SURFACE AREA
  - HIGHER REDOX STABILITY

(a) Yang Wang et al, “Ni migration of Ni-YSZ electrode in solid oxide electrolysis cell: An integrated model study”, J. Power Sources, 516 (2021), 230660. https://doi.org/10.1016/j.jpowsour.2021.230660.

(b) M. Trini et al, “Comparison of microstructural evolution of fuel electrodes in solid oxide fuel cells and electrolysis cells”, J. Power Sources, 450 (2020), 227599. https://doi.org/10.1016/j.jpowsour.2019.227599.

Ideal routes for producing syngas in SOECs





Sabatier reaction:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Reverse methane steam reforming

$CO + 3H_2 \leftrightarrow CH_4 + H_2O$

Reverse dry reforming

$2CO + 2H_2 \leftrightarrow CH_4 + CO_2$

Boudouard reaction on Ni catalyst:

$2CO \leftrightarrow CO_2 +$ **C**

$CO + H_2 \leftrightarrow$ **C** $+ H_2O$

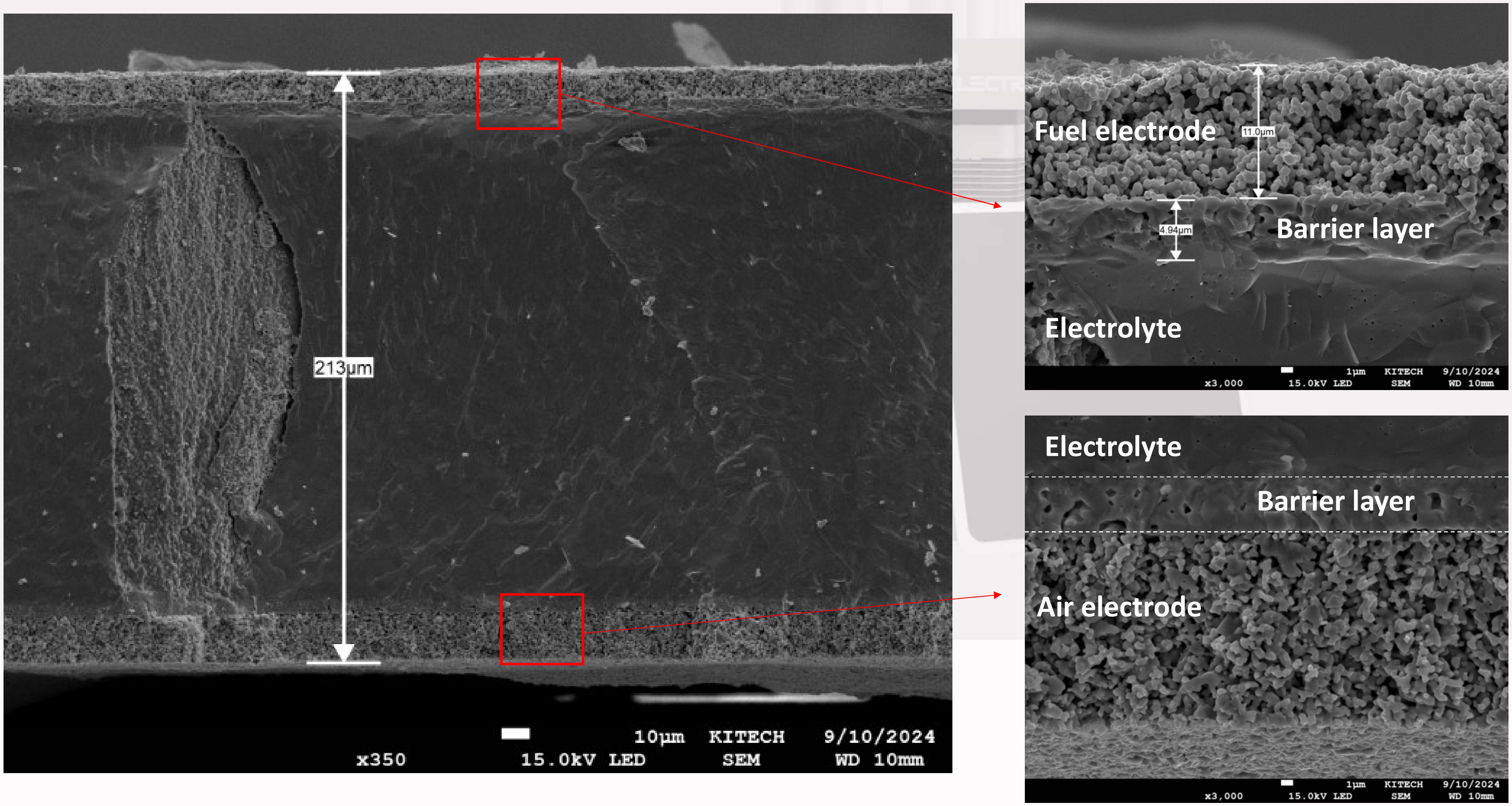
Hou et al, Chemical Reviews 2024, 124, 8, 5119-5166 DOI: (10.1021/acs.chemrev.3c00760)

H2ELECTRO'S SOLID OXIDE ELECTROLYSIS CELLS

Model	HC-12	HC-16
Electrolyser type	Solid Oxide	Solid Oxide
Size	12×12 cm	16×16 cm
Active area	121 cm^2	225 cm^2
H2 production*	55 g / 24h	105 g / 24h
Operating temperature	800–850 °C	800–850 °C

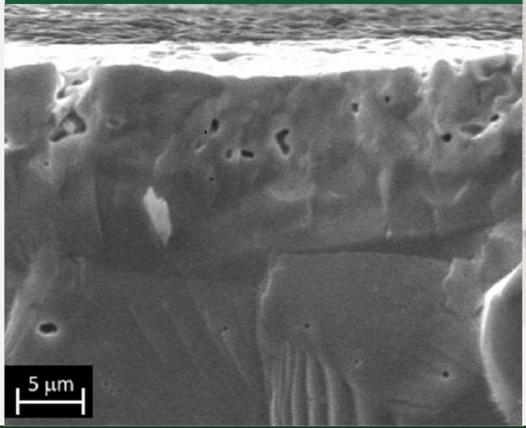
**Presuming a specific energy consumption of 39 kWh/kg of H_2*

SEM images of the cell



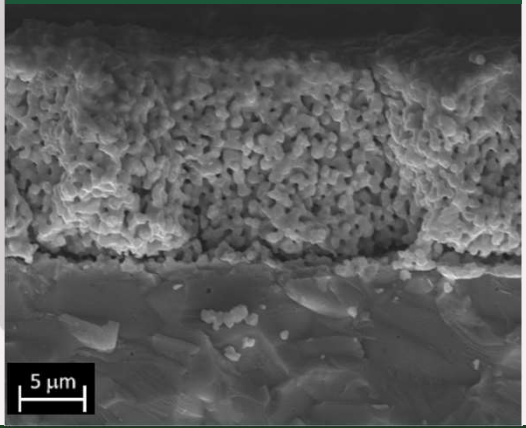
COMPARISON OF H2ELECTRO'S CELL LAYER WITH COMMERCIAL CELL LAYER

H2Electro's barrier layer



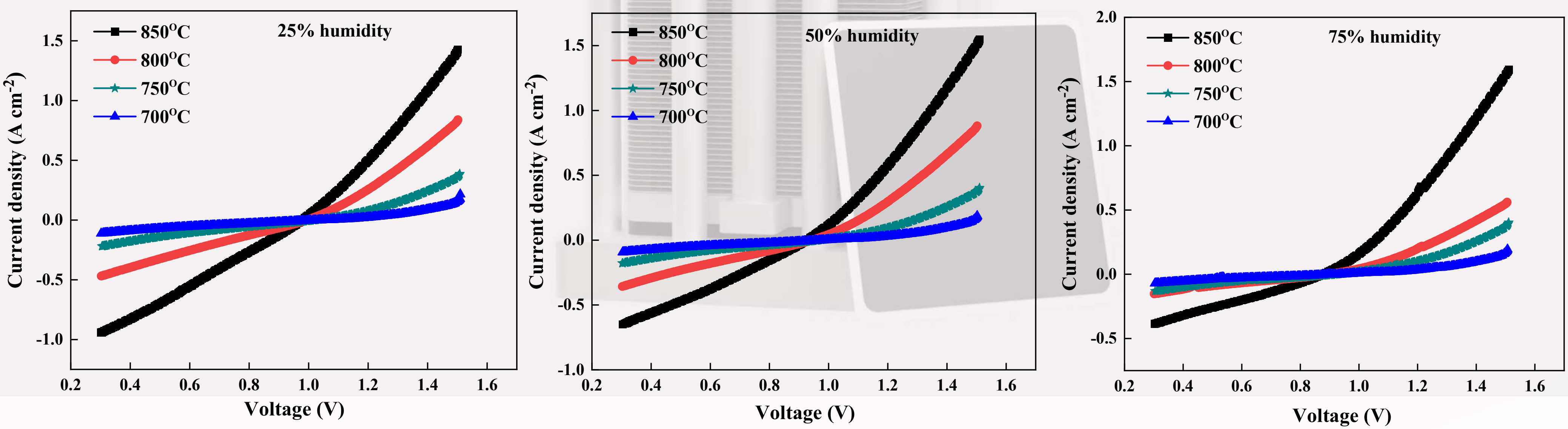
H2E's barrier layer is dense, thinner, and has lower resistance, achieving higher SOEC efficiency.

Commercial barrier layer

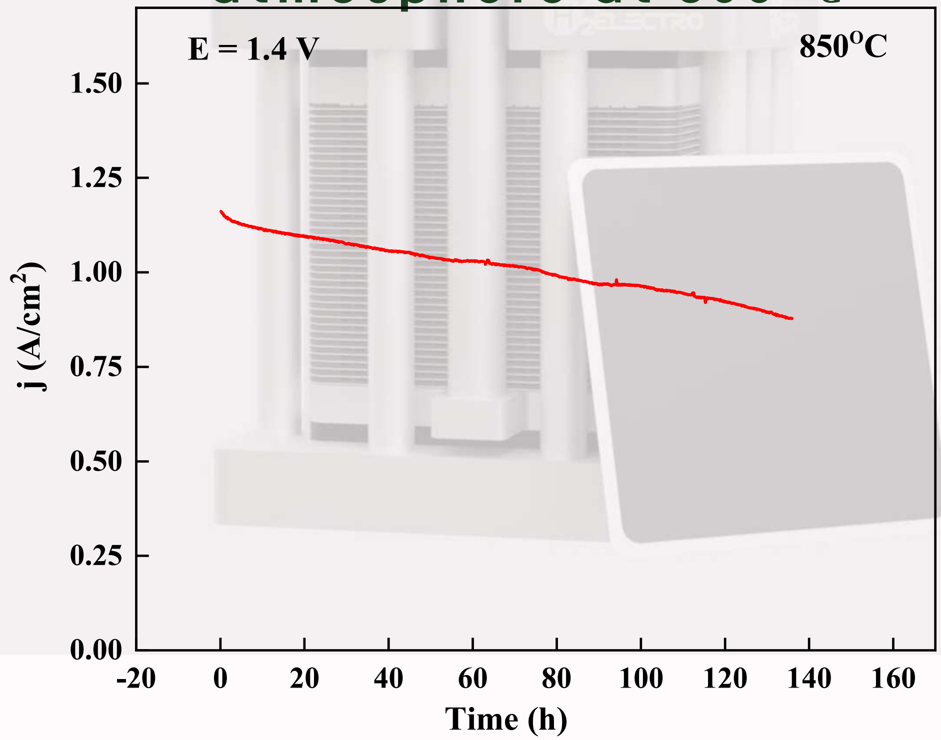


Commercial barriers, being porous, thicker, and with higher resistance, result in lower SOEC efficiency.

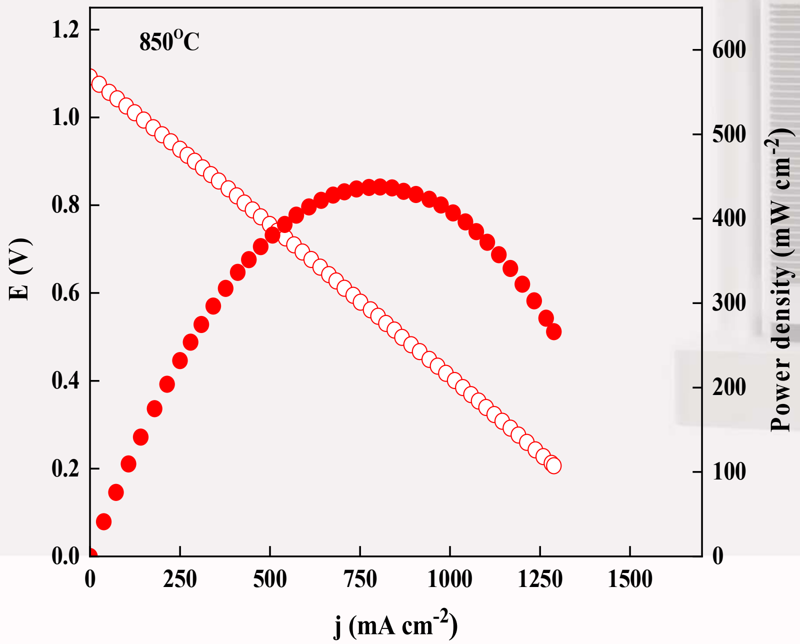
I-V curves in different humidity (H_2O/H_2 = 25/75, 50/50, 75/25) and at different measuring temperatures.

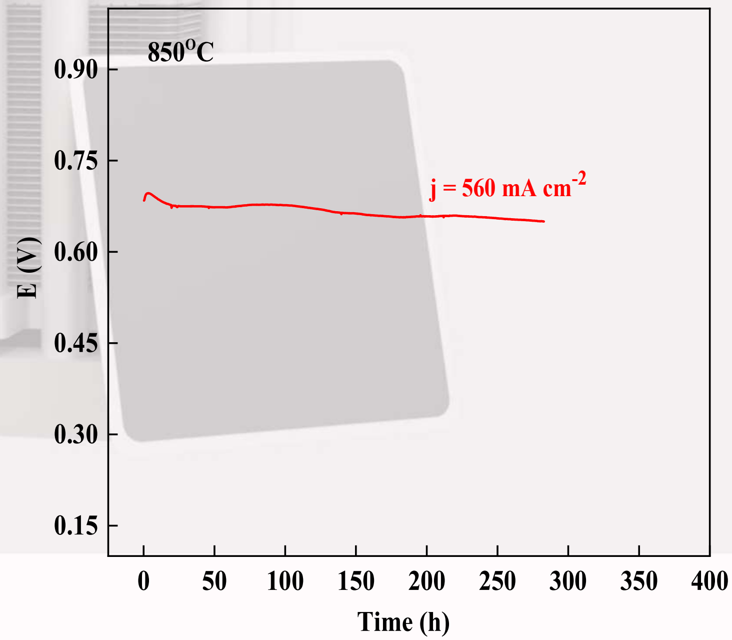


Stability result of Solid Oxide electrolysis cell in 50% H_2 + 50% H_2O atmosphere at 850 ℃

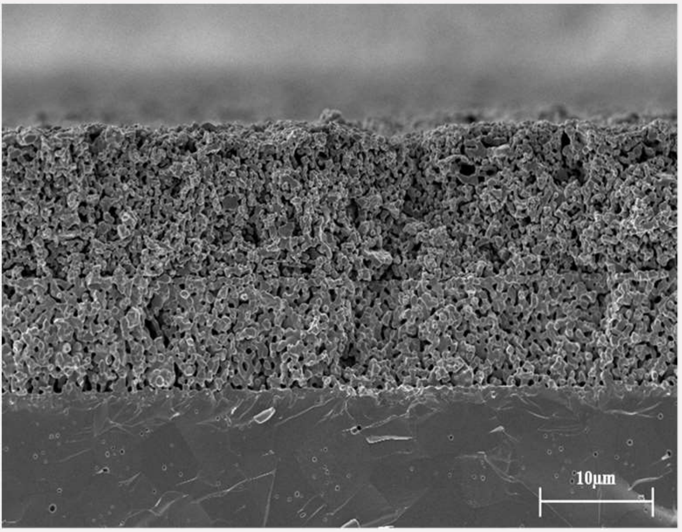


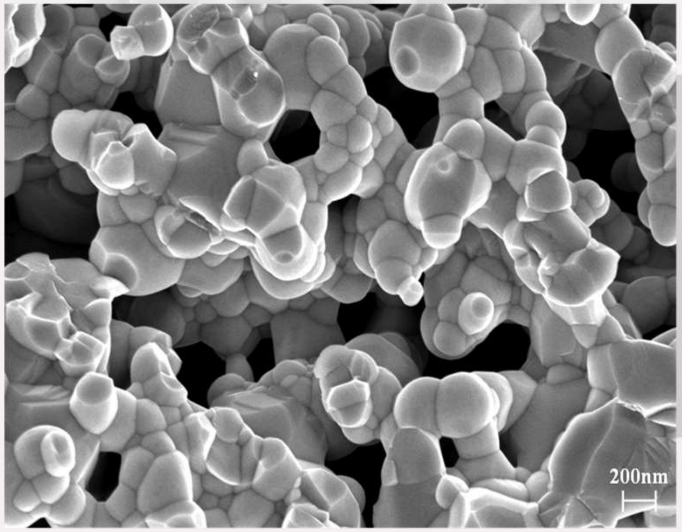
I-V and I-P curves and stability results of Solid Oxide Fuel Cell test in 98.3% H_2 + 1.7% H_2O atmosphere at 850 ℃

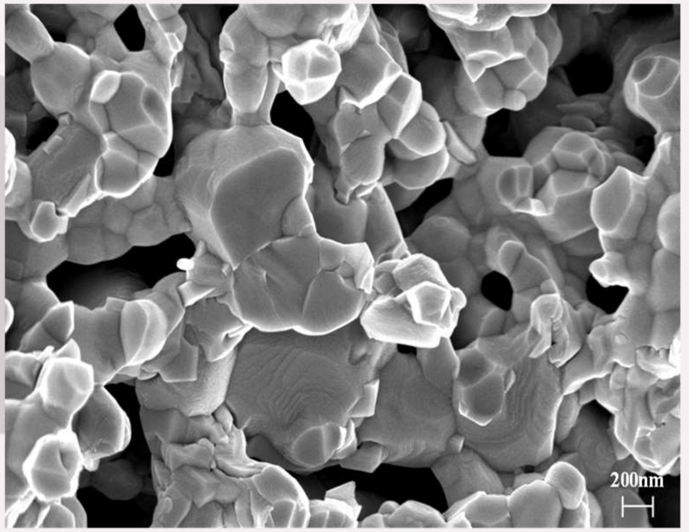




SEM result of cross-sections from selected symmetrical cells before and after 100 h stabilization at 800℃ in 98.3% H_2 + 1.7% H_2O atmosphere



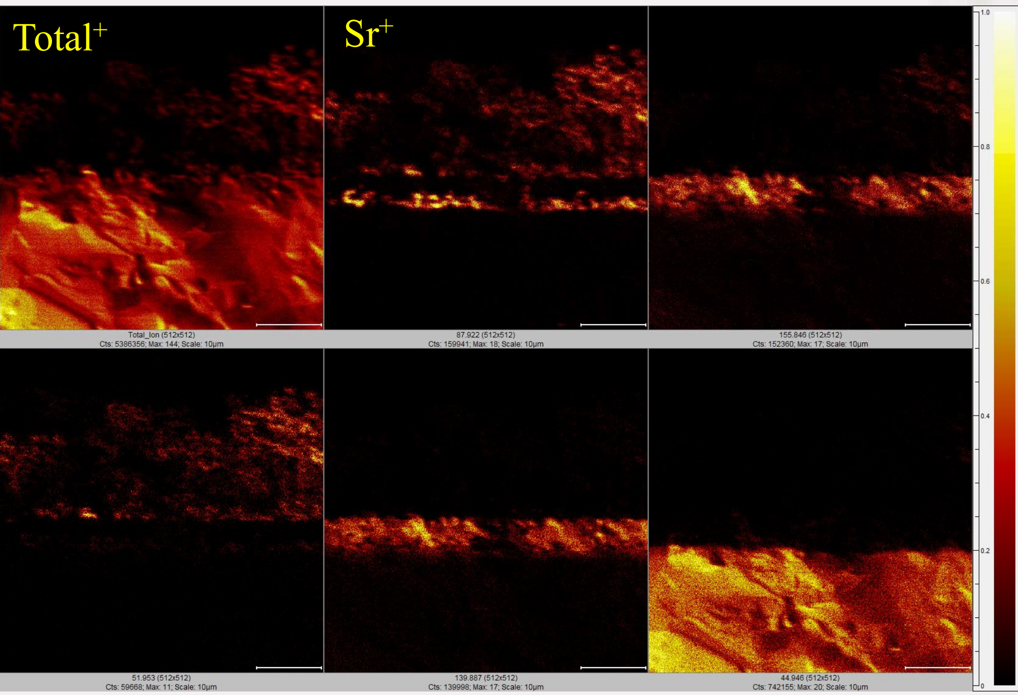




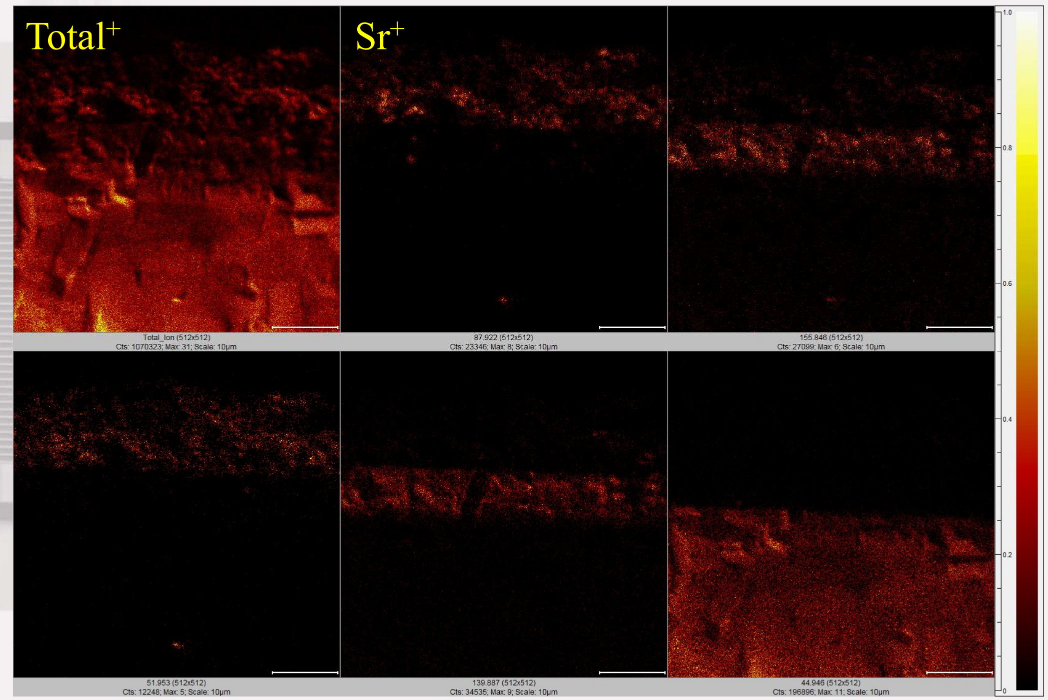
Before the

After the test

TOF-SIMS results



Electrode sintered at 1250°C



Electrode sintered at 1200°C

PROJECT WITH ENEFIT SOLUTIONS

Delfi ärileht

Majandus Investeeri Energeetika Tehnoloogiaäri Kinnisvara Reisijuht Õigus

Energeetika — Kõik uudised | Elekter | Gaas

ENERGEETIKA 24.04.2024, 17:07

Enefit hakkab katsetama vesiniku tootmise tehnoloogiat (3)

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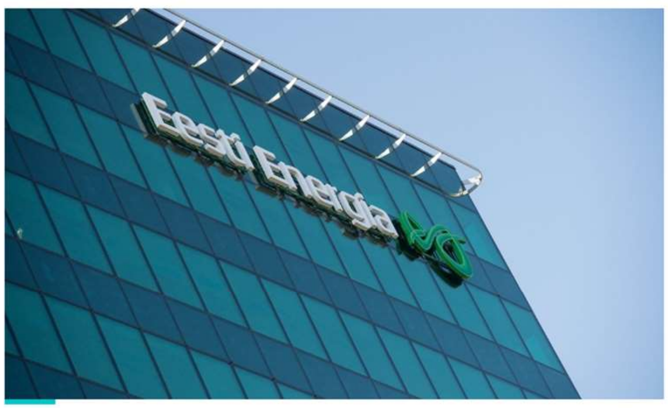

Enefit Solutions arendab Eesti Energiale tehnoloogiat. FOTO: FOTO: MADIS VELTMAN

Kuula artiklit 3 min | Lisa | Delfi Tasku

Eetsi Energia tütarettevõte Enefit Solutions ja iduettevõte H2Electro sõlmisid ühiste kavatsuste koostöölepingu, mis on aluseks koostööle vesiniku tootmise tehnoloogia arendamises ja täiustamises.

Äripäev foundME

Kõik uudised Arvamused Podcastid Videod Telli

Autor: foundME • 24. aprill 2024 Jaga:

H2Electro hakkab koos Enefit Solutionsiga katsetama vesinikutehnoloogiat

Elektrolüüsi rakud virnas.
Foto: H2Electro

Enefit Solutions ja idufirma H2Electro sõlmisid ühiste kavatsuste koostöölepingu, mis on aluseks eelseisvale koostööle vesiniku tootmise tehnoloogia arendamises ja täiustamises.

Conclusion

- SOECs can be used in different applications
- MIECs have fundamental advantages over the traditional Ni-Cermet fuel electrodes
- Production is affordable and flexible
- SOEC Market size and its growth pace favours H2Electro
- Excellent team with technical capacity

OUR TEAM MEMBERS

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Thank you!