Focus Group on Hydrogen

Advanced materials for clean hydrogen production by electrolysis

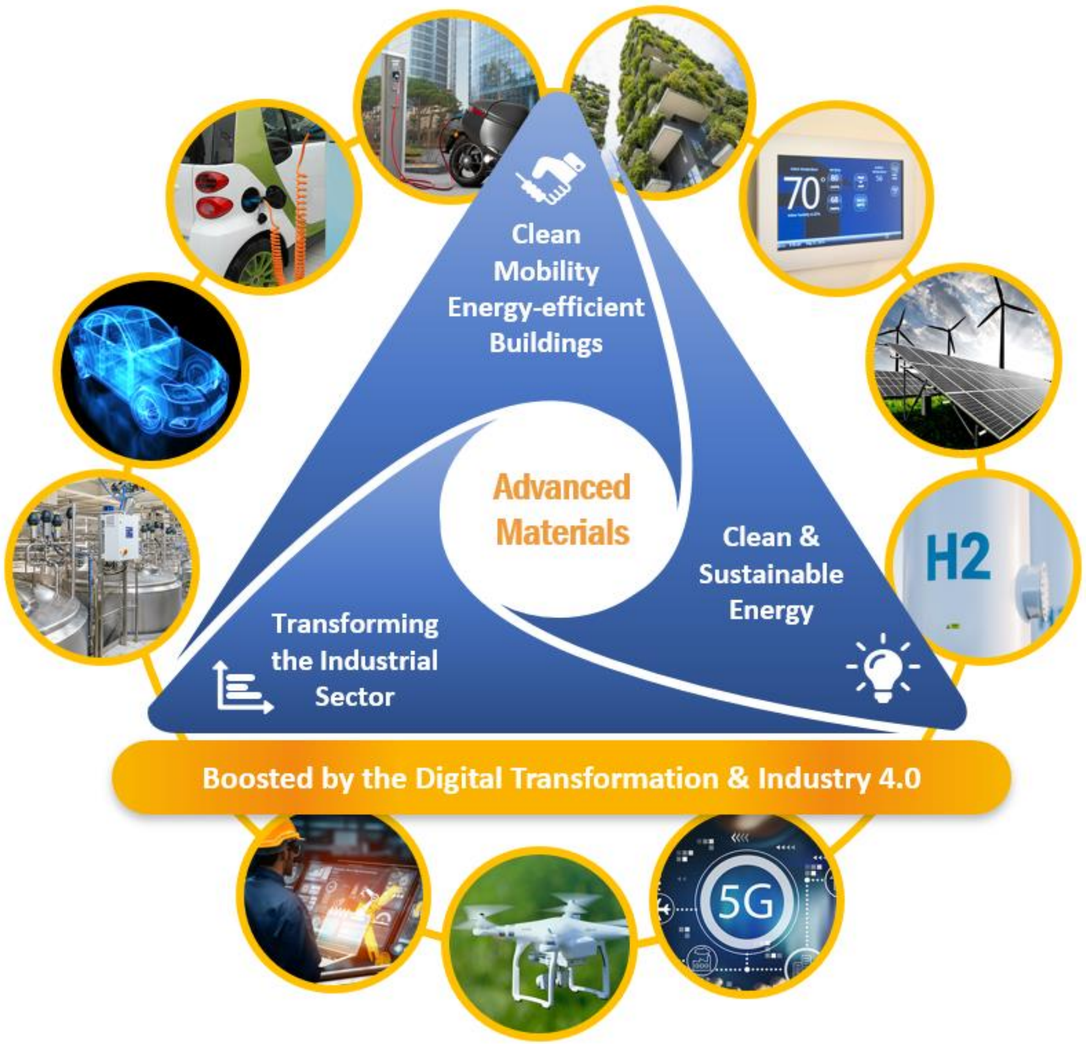
04 May 2022

Focus group hydrogen / TechTalk

Advanced Materials are the backbone of innovation for clean and sustainable energy and mobility technologies

Safer, healthier, smarter, more flexible, more inclusive and more affordable solutions

for an improved well-being to all citizens



Make energy and transport carbon-neutral and durable

Resource-efficient in a circular economy approach

Achieving at the same time strengthened global competitiveness and autonomy

European energy, transport and energy-intensive sectors

EMIRI promotes, facilitates and supports R&I activities in Europe on Advanced Materials for Clean and Sustainable Energy and Mobility Applications

EMIRI
ENERGY MATERIALS INDUSTRIAL RESEARCH INITIATIVE

INDUSTRIAL LEADERSHIP

supports a competitive European Industry developing solutions based on advanced materials innovations

STRATEGIC FIT

shapes and implements EU policies for Advanced Materials Research and Innovation

INNOVATION ECOSYSTEMS

collaborates with public institutions for the implementation of FPs on research & innovation, demonstration and pilots

NETWORK

acts as catalyst to share knowledge, create a network and facilitate the alignment of the key priorities

FOCUS

facilitates the co-construction between stakeholders of technology roadmaps for areas in which Advanced Materials make the difference

SINCE 2012

Building on 9+ years of experience and trust

EMIRI is an Industry Community coming together ...

Supported by Research & Technology Organizations

With key Associations bringing in their expertise

EMIRI Technology roadmap

Focus on areas where Advanced Materials make the difference

EMIRI
ENERGY MATERIALS INDUSTRIAL RESEARCH INITIATIVE

MAIN DRIVERS

- Decarbonisation
- Sustainability / Circularity
- Competitivity / Autonomy
- Digitalisation

Energy sector

- Renewable energy
- Energy storage
- Energy infrastructures

Energy-intensive sectors

- Mobility
- Buildings
- Industry

Focus Areas

- Batteries
- Hydrogen
- Solar Energy Harvesting
- Wind Energy Harvesting
- Low Carbon Industries
- Light weighting for mobility
- Buildings

Workshop objectives

Summary of the previous episodes:

A First TechTalk of the Hydrogen Focus Group took place on Nov. 5, 2021, resulting in the **identification of advanced Materials challenges and R&I needs regarding the main technologies for production, conversion and storage of hydrogen.** Members of the focus group then voted for **prioritising the challenges** where advanced materials potentially impact the most the development of Hydrogen technologies.

In the meantime, some possible advanced materials solutions addressing these technological challenges have been proposed.

On this basis, **technology sheets have been produced on 4 H2 production clean technologies:** PEM electrolysis, Alkaline electrolysis, Solid Oxide electrolysis and AEM electrolysis.

Each technology sheet is organized as follows:

a) Short description of the technology
b) State of the Art and future targets at the system level
c) Overview of technology challenges & advanced materials solutions
d) Prioritization of technology challenges & focus on advanced materials solutions

H2 technology sheet examples

1. Technology description

PEM (Proton Exchange Membrane) electrolysis uses an extremely thin (20-300 micrometers) gas-tight polymer membrane as electrolyte with a strongly acidic character that allows H+ ions (protons) to pass through. The charge carrier H^+ can migrate from the positively charged anode, where oxygen is formed, to the negatively charged cathode, where hydrogen is formed. The principle of PEM electrolysis differs from alkaline electrolysis in that the electrolyte is a solid electrolyte, composed of a proton-conducting membrane; the electrodes are deposited on both sides of this polymer material.
More specifically, PEMWEs are made from pure polymer membranes or composite membranes where the materials form a polymer matrix.
The electrodes are composed of a layer of catalytic material (catalysts + ionomer) and a diffusion layer. The diffusion layer is used to improve the current flow and to facilitate the transport of reactants and products.
Bipolar plates are used to supply the current and remove the gases. These are the plates with perpendicular trenches (grooves). They are subjected to difficult constraints: high potential and acidic environment.
The current density is high with values in between 0.6-2.0 A/cm² and the current operating pressure is around 30 bar.
One of the main challenge in PEM water electrolysis is to reduce the production cost by increasing the durability while maintaining the high efficiency.
Reducing iridium and platinum loading in polymer electrolyte membrane (PEM) electrolysers is also one of the main challenge.

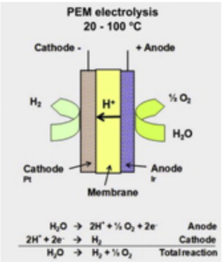


Figure 1 PEM electrolysis principle

Figure source: Marcelo Carmo, David L. Fritz, Jürgen Mergel, Detlef Stolten, A comprehensive review on PEM water electrolysis, International Journal of Hydrogen Energy, Volume 38, Issue 12, 2013, Pages 4901-4934, ISSN 0360-3199, https://doi.org/10.1016/j.ijhydene.2013.01.151.

State-of-the-art advanced Materials:

- At the cathode, platinum is usually used and at the anode, iridium or ruthenium oxide are used
- Bipolar plates are made of Titanium (or a titanium coating)
- Most common materials used by proton exchange membrane manufacturers are based on PFSA (PerFluoro Sulfonated Acid) structure.

CLEAN HYDROGEN PRODUCTION - TECHNOLOGY SHEET #3 – PEMWE (Proton exchange membrane water electrolysis)

Draft 15-04-2022

2. Technology targets (PEMWE)[1]

TECHNOLOGY SHEET #4 – SOEC (Solid oxide electrolysis cell)

1. Technology description

There are different electrolysis technology to produce hydrogen. High Temperature Electrolysis (HTE), less mature technology than PEMWE or AELWE, has a strong disruptive potential to produce massively hydrogen at high efficiency and low cost. The basic component of this modular technology is a ceramic cell. Increasing the temperature during an electrolysis reaction allows energy input in the form of heat, decreasing the amount of electrical energy required for water decomposition. High temperature also leads to the elimination of noble catalysts (platinum or iridium). Depending on the nature of the shuttle proton or oxygen ion, two high temperature electrolysis technology are being studied, involving protonic or anionic conducting ceramics. The most advanced technology, based on anionic ceramics, is the Solid Oxide Electrolysis Cell (SOEC). SOEC electrolysis operates between 700 and 900°C.

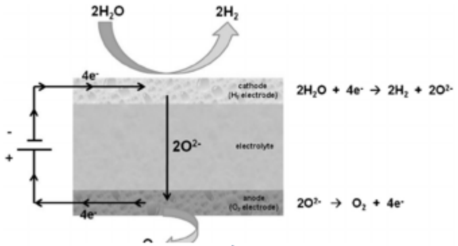


Figure 1 SOEC principle

Figure source: Nechache et al, Solid oxide electrolysis cell analysis by means of electrochemical impedance spectroscopy: A review, 2014, Journal of Power Sources

A significant part of the energy required for the electrolysis process is provided in the form of heat, this technology exhibit electrical yields that can exceed 90% (LHV). It has also the advantage of being able to operate in a reversible mode: as an electrolyser or as a fuel cell. The main challenges of SOEC technology are the long-term stability and durability of the system and particularly the material durability upon high current density or high hydrogen production fluxes at high temperature operation (and in wet environment).

State-of-the-art advanced Materials:

- The most commonly used materials for SOEC cathodes and anodes are respectively is nickel-doped yttria-stabilized zirconia, or Ni:YSZ and Strontium-doped lanthanum ferro-colbaltite (LSCF) $La_{1-x}Sr_xCoFeO_3$.

- The electrolyte used classically is yttria-stabilized zirconia (YSW).

CLEAN HYDROGEN PRODUCTION - TECHNOLOGY SHEET #4 – SOEC (Solid oxide electrolysis cell)

Draft 15-04-2022

Prioritisation example

Technology challenge		Weight	Advanced materials solutions
#1	Lowering Ir & Pt loading while preserving performance	**100**	
#2	Increase stack lifetime	**83**	
#3	Stainless steel use, properties (H2 embrittlement), and cost	**65**	
#4	PFAS issue	**54**	
#5	Expensive PGM-based coatings for PTLs and BPP	**48**	
#6	Materials integrity under pressurised systems	**47**	
#7	Self-conditioning of the MEA (membrane)	**36**	
#8	Gasket integrity and compatibility at high pressure	**27**	
#9	Improve cold idle ramp time	**9**	

Workshop objectives

What are we targeting on May 4?

This **second TechTalk will be dedicated to H2 production by water electrolysis.**

During the morning session (open to all), experts from Hydrogen Europe and key European universities and RTOs will present technology updates on PEM electrolysis, Alkaline electrolysis, Solid Oxide electrolysis and AEM electrolysis.

The afternoon session (restricted to the EMIRI members) will consist of a workshop aiming at further identifying the most promising advanced materials solutions for every electrolysis technology and building policy recommendations prioritizing the related R&I needs. Our objective during the afternoon session will be :

First, to review the **4 H2 production technology sheets** ;

Then, to identify - per technology - the **advanced materials KPIs most impactful for the system KPIs;**

For the TOP 10 advanced materials KPIs, to put **values on SoA and targets,** for short term and long term development;

To build a « qualitative matrix » showing the relation (and the impact) of each advanced materials KPIs on system KPIs (“Heat map”).

Workshop objectives

Heat map Example :

	System KPI 1	…..	…..	…..	System KPI n
Advanced materials KPI 1					
…					
…					
…					
…					
…					
…					
Advanced materials KPI n					

And then? the next steps

From this work, we will update the technology sheets with **the key advanced materials KPIs**, including SoA and target values, the **Heat maps** pointing out the most impactful links between advanced materials and system KPIs, highlights on **priority R&I needs**.

Agenda

Session	Time	Talk	Speaker	Organisation
PUBLIC SESSION - *EVERYBODY IS WELCOME*		Overview of the different technologies for clean hydrogen production by electrolysis		
	10:30	Update on EMIRI FG H2 & Introduction to the event	Karim SIDI ALI CHERIF & Fabrice STASSIN	CEA & UMICORE
	10:35	Introduction to the Clean Hydrogen Partnership & Focus on electrolysis-related EU calls	Prof. Luigi CREMA	HYDROGEN EUROPE RESEARCH / FONDAZIONE BRUNO KESSLER
	10:50	Technology Update - SO electrolysis	Dr Julie MOUGIN	CEA
	11:10	Technology Update - Alkaline electrolysis	Prof. Stefan LOOS	FRAUNHOFER IFAM
	11:30	Coffee break		
	11:40	Technology Update - AEM electrolysis	Dr Aldo GAGO	DLR
	12:00	Technology Update - PEM electrolysis	Prof. Tom SMOLINKA	FRAUNHOFER ISE
	12:20	Wrap up	Dr Marcel MEEUS	SUSTESCO
	12:30	Lunch break		
SESSION FOR EMIRI MEMBERS ONLY		Workshop to identify the most promising advanced materials solutions and prioritise the R&I needs		
	13:30	Step 1 - Review of the 4 Electrolysis Technology Sheets prepared by the EMIRI FG H2 team and experts		
	14:10	Step 2 – Selection of KPIs driving advanced materials innovation		
	14:50	Coffee break		
	15:00	Step 3 – Identification of target values for the selected KPIs		
	15:50	Step 4 – Correlation of the selected KPIs with the KPIs of the Clean H2 Partnership		
	16:40	Wrap up	Dr Marcel MEEUS	SUSTESCO
	17:00	End of the session		

Speakers

Luigi Crema - Hydrogen Europe Research and Fundazione Bruno Kessler

Julie Mougin - Head of High-temperature electrolysis development at CEA => SOEC

Stefan Loos - Fraunhofer IFAM => AEL

Aldo Gago - Team Leader, German Aerospace Center (DLR) => AEM

Tom Smolinka - Head of Department Chemical Energy Storage - Fraunhofer ISE => PEM

FOCUS GROUP ON HYDROGEN

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LEITAT Technological Center

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HZB Helmholtz Zentrum Berlin

Blue World Technologies

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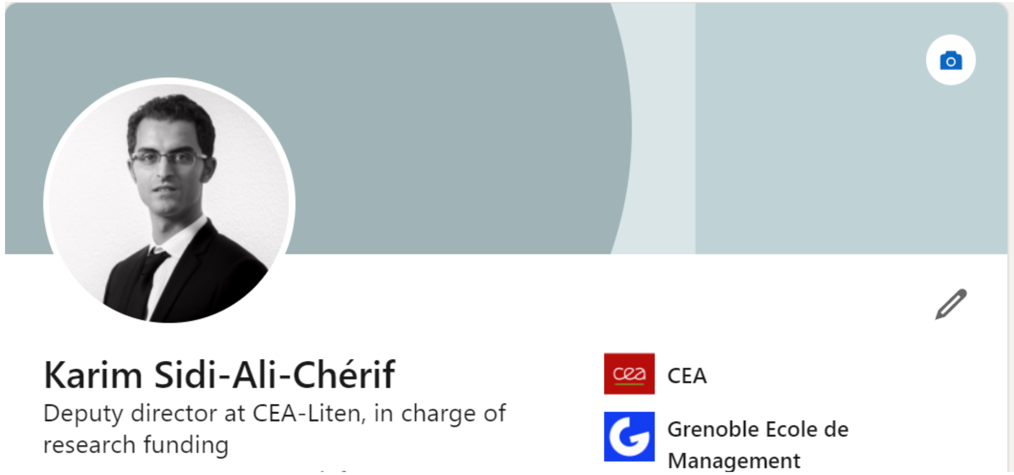
AZTERLAN

Focus group H2 Gouvernance

Leader

Co - Leader



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Organisation

Production

Karim Sidi-Ali-Chérif

Fuel

Fabrice Stassin

Storage

Marcel Meeus

SMART KEY PERFORMANCE INDICATORS (KPI)

Please think about unit when you propose a KPI

Online / MIRO Board

To determine advanced materials KPI :

Technology challenge		Weight	Advanced materials solutions	Advanced materials KPI	unit	Comment		Color code	
#1	Material degradation	100	• New electrode compositions/composites for improved durability (e.g. towards high steam contents) and performance (targeting low overpotentials)						at electrode level
									at electrolyte level
									at BOP level

To determine target value

	SoA	2024 target	2030 target
Advanced materials KPI			

Link to the MIRO board

https://miro.com/welcomeonboard/Q3FqaE5HNEZScFczbzN3QjBiRjVBVEx3bnVEeFBXR0dLN1J4VE13N1lTYWhBZXNNR0FwUm5vTkNxanZLeFVVYnwzMDc0NDU3MzY2MzIwMTM0OTQ0?share_link_id=270727452571

OFFLINE / Heatmap

Heat map Example :

	System KPI 1	…..	…..	…..	System KPI n
Advanced materials KPI 1					
…					
…					
…					
…					
…					
…					
Advanced materials KPI n					

THANK YOU!

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