HYP3D

HYDROGEN PRODUCTION IN PRESSURIZED 3D-PRINTED SOLID OXIDE ELECTROLYSIS STACKS

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PRR 2025	Pillar 1 - H_2 Production
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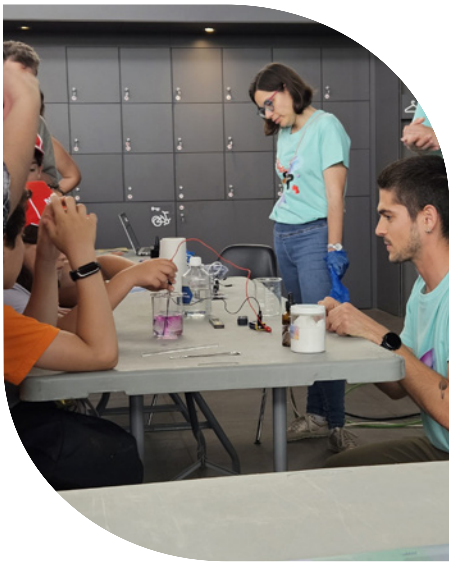
Clean H_2 JU Max. Contribution	2 543 398.75
Project Period	01-01-2023 - 31-12-2025
Coordinator Beneficiary	FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES
Beneficiaries	VAC TRON SA, SNAM S.P.A., H$_2$B2 ELECTROLYSIS TECHNOLOGIES SL, SAS 3DCERAM SINTO, BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION, POLITECNICO DI TORINO, DANMARKS TEKNISKE UNIVERSITET

https://hyp3d.eu/

PROJECT AND GENERAL OBJECTIVES

The main goal of the HyP3D project is to deliver a new generation of ultra compact high pressure stand-alone solid oxide electrolyser cell (SOEC) stacks able to convert electricity into compressed hydrogen for power-to-gas (P2G) and hydrogen refuelling station (HRS) applications.

HyP3D manufacturing technology represents a breakthrough compared with traditional ceramics SOEC processing due to a significant reduction in the time to market (from years to months), the use of raw material (76% reduction) and the required initial investment (42% reduction from conventional cell manufacturing plants, from the first MW) while introducing great flexibility and scalability of the production lines.



NON-QUANTITATIVE OBJECTIVES

- Develop disruptive electrolyte-supported Solid Oxide Electrolysis Cells based on 3D-printed 3YSZ and 8YSZ with non-flat geometry.
- Design high-pressure sealing based on 3D-printed self-tightening joints and optimised glass sealants with enhanced adhesion by surface modification.
- Fabricate ultra-compact and lightweight kW-range stacks based on 3D-printed HyP3D cells, cost-effective flat coated interconnects and surface-modified sealants.
- Build up a neural network-based digital twin of the HyP3D stack able to run in high performance computing environments.
- Design simple SOEL systems based on standalone HyP3D stacks for the particular applications of H_2 injection in the gas grid and on-site generation for hydrogen refuelling stations.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The cell design design has been optimised, taking into account both printing and post-printing processes. The first generation of designed cells feature large active area corrugated membranes (45 cm^2 of projected and 72 cm^2 of real one) with embedded functionalities (gas channels) that allow the use of flat thin (200 µm) interconnects at stack level with foreseen advantages in terms of power densities.
- Large area cells 3D-printing processes (pastes formulation, printing and post-printing) were successfully optimised. 3YSZ 3D-printed cells were produced with good reproducibility, free of cracks and deformation.
- 3YSZ 3D-printed cells were successfully tested at SRU and sub-stack (three cells) level at atmospheric pressure, with performance in line with the literature considering the thickness of the electrolyte and its ionic conductivity; OCV of 0.8 V/cells in SOEC mode, injected current of 25 A corresponding to 0.55 A/cm^2 and 35 W/cell.
- One stack (18 cells) was successfully built and tested in SOEC mode at atmospheric pressure with the following recorded performances: 330 W, corresponding to: 508 W/L, 274 W/kg, 290 mA/cm^2, 3.65 kg/kW.
- Commercial glass-ceramic sealants were successfully modified in order to increase their viscosity at operating temperatures with a refractory behaviour and enhance their resistance to differential pressures and

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shear stresses generated during operations in real conditions for HyP3D stacks.

- Laser-milling of metallic interconnects and 3D printed YSZ was developed in order to increase the surface roughness of the metals in the sealing regions. Through increasing the interlocking effect and the resistance to shear stresses a roughness of 5.7 um and 4.9 um was reached respectively for Crofer22APU and YSZ. The developed joints demonstrated excellent compatibility between the interfaced materials with sound and continuous interfaces and good infiltration of the glass-ceramics inside the tracks of the milled materials.
- Interlocking sealing concept was successfully tested at room temperature and under high differential pressures. The joint laser-milled-Crofer22APU/modified glass-ceramic/laser-milled-YSZ demonstrated leakages rates below the detection limit at room temperature with 4 bar applied pressure.
- Compressive sealing concepts for high pressure were also developed by introducing 3D-structures on YSZ thanks to 3D-printing. The developed non-flat sealing geometries are suitable to be coupled with compressive mica-based sealants. The introduction of notches on YSZ improved the gas tightness with respect to the flat geometries up to 5 times at high pressures (5 bar).
  - » HyP3D 3YSZ cells have been demonstrated to withstand up to 1.5 bar of unbalanced pressure across the membrane.
- Protective coatings deposition via EPD (Electrophoretic Deposition) was developed, and the sintering treatment was optimised. The resulting coatings exhibit suitable thicknesses (>10 μm) and satisfactory densification (>80%).
- Initial simplified thermo-mechanical and fluid-dynamic simulations were successfully performed on both cell and SRU models.

FUTURE STEPS AND PLANS

- Increase the level of complexity of the simulations including further elements in the assembly; current collection Ni and Ag foams. By carrying out fluid dynamic simulations of 30 cells hyP3D stack.
- Building and testing HyP3D short stack (five cells) at high pressure.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Pressure	bar	5	Ambient pressure for SRU and short stacks. HYP3D cells demonstrated to be able to resist up to 1.5 bars of unbalanced pressure across the membrane. The high pressure sealing concepts demonstrated to be able to operate at high pressures (4-5 bars).	
	Power per stack	kW	2.14	0.85 kW by (3 cells sub-stack)	
	Injected current density	A/cm^2	-0.9 at 1.3V	-0.55 at 1.4V	
	Use of critical raw materials	kg/kW	0.9	2.2	
	Footprint	kW/L	3.4	0.6	
	Degradation	%/1 000h	1	5	
	Electrical consumption nominal capacity	kWh/kg	38	37.7	✓
	Cold start ramp time	hours	8	3	

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