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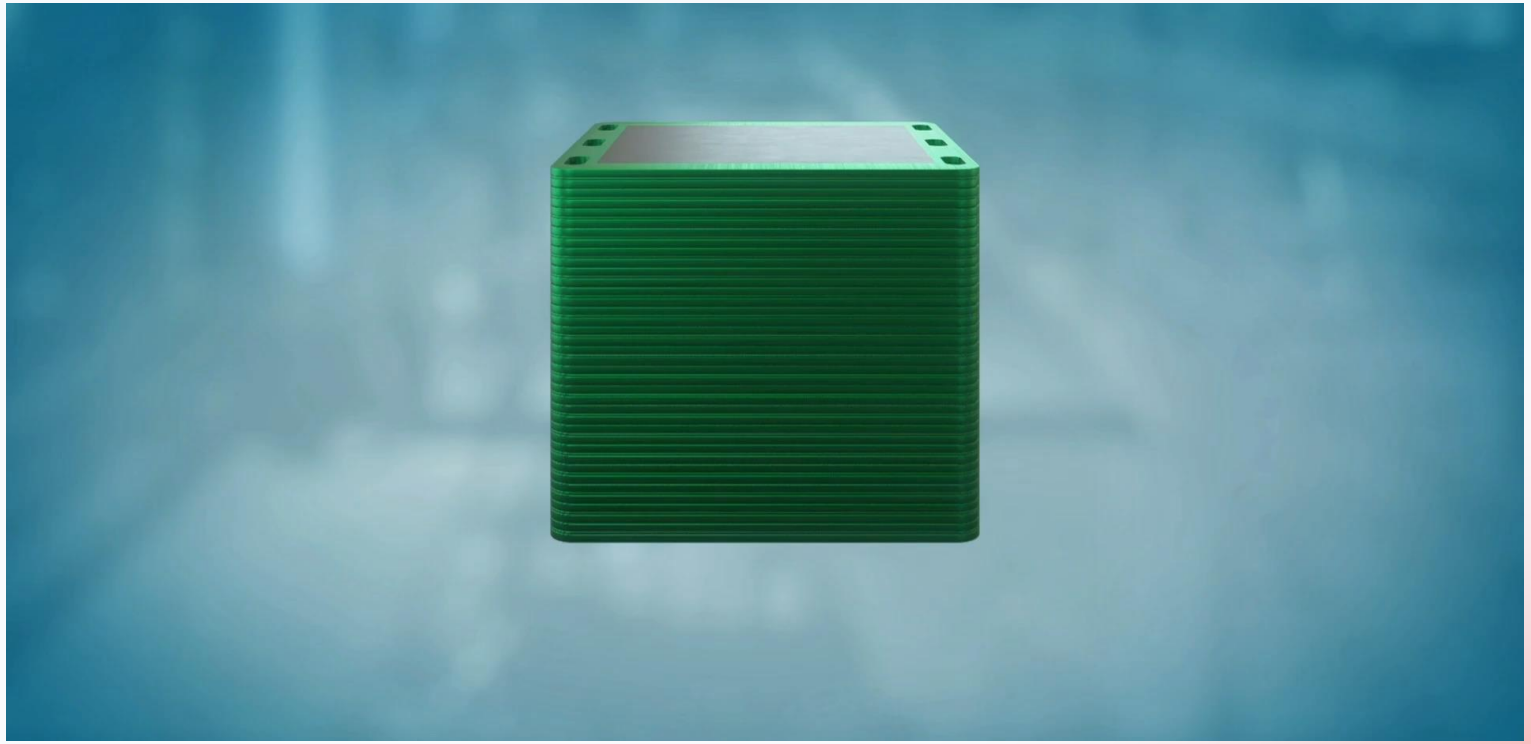
Additive Manufacturing: A Game-Changer for Clean Hydrogen Production

Meeting climate challenge

An Objective

A Method

SOEC HIGH PRESSURE H2 PRODUCTION



EU AMBITIOUS CLIMATE TARGETS

2023 — 2030 — 2040 — 2050

-55% of greenhouse gas emissions

- Climate neutrality: zero emissions
- Climate stabilization : end of excessive warming

Main challenges:

- ❑ Promote the **integration of renewable energies**
- ❑ **Offer technological and economical alternatives** to highly polluting energies

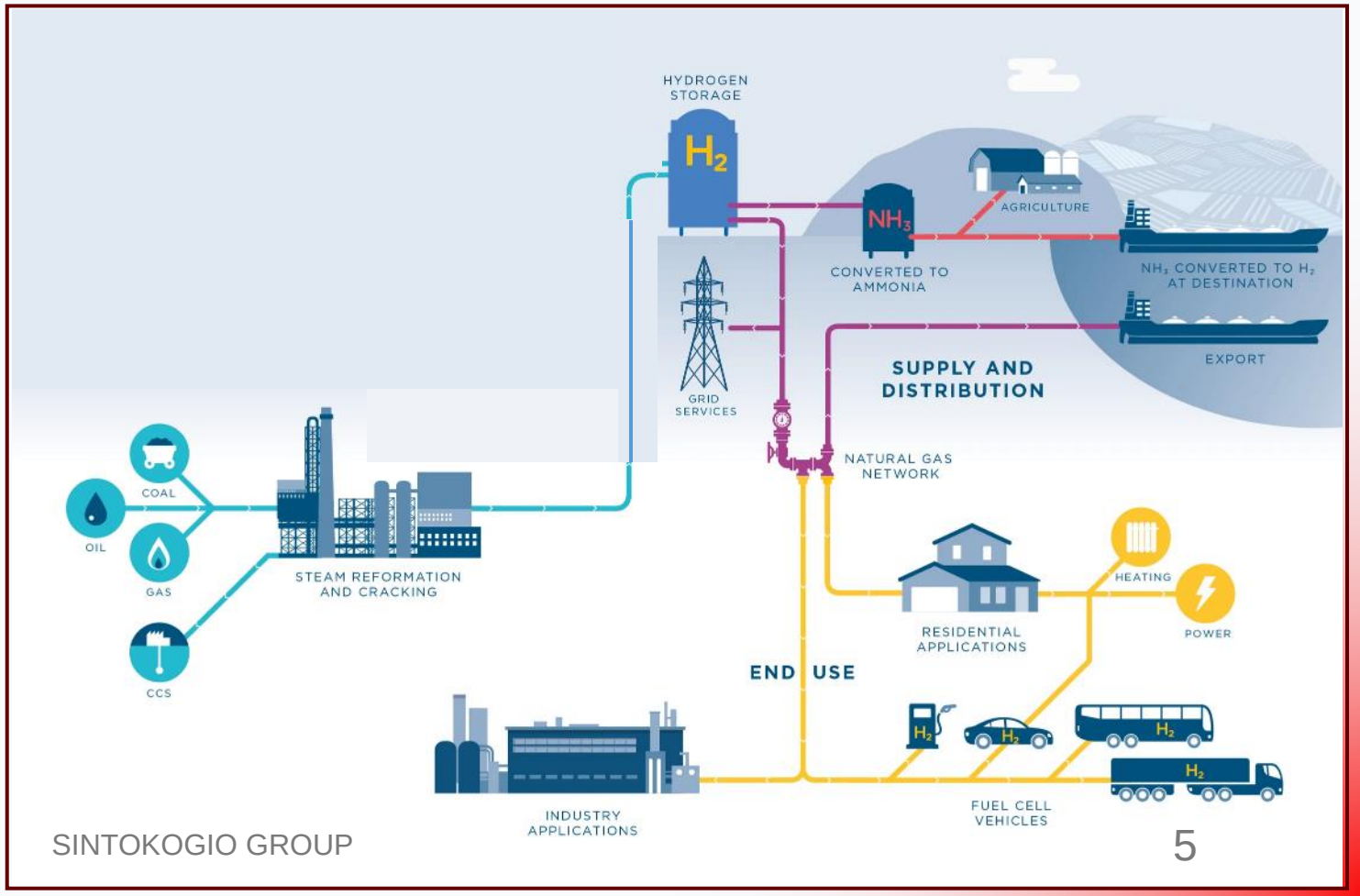
- ✓ Clean energy carrier IF produce with renewable energies
- ✓ Energy storage possibilities

HYDROGEN: A MAJOR CHALLENGE IN EU

European Green Deal

Key solution for the decarbonization of our society = Hydrogen production by **electrolysis**

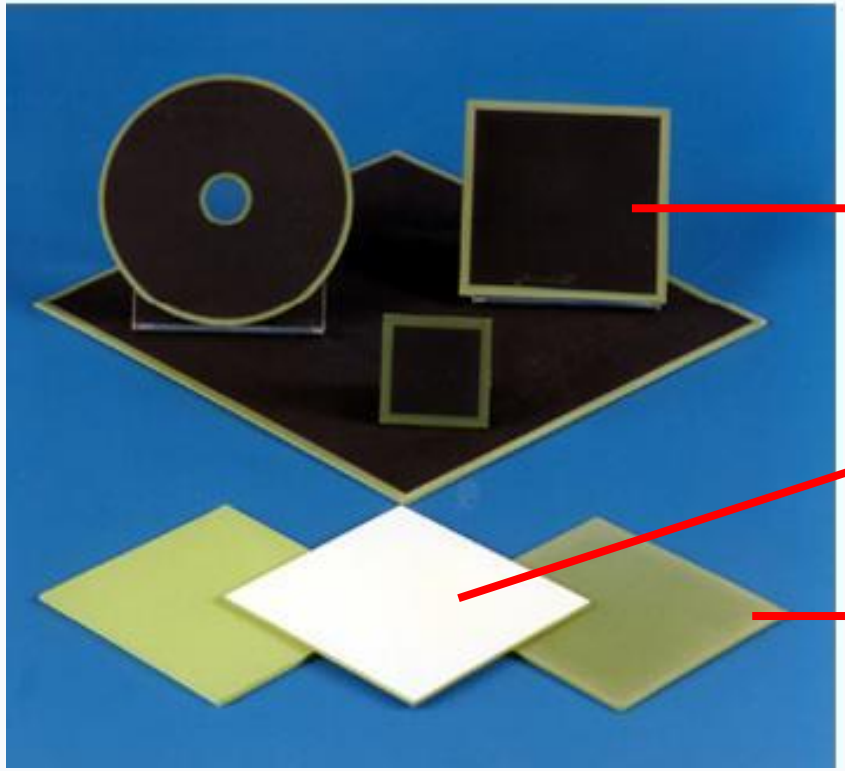
- Increase electrolysis capacity :
  - 2024 : 60GW
  - 2030 : 80GW
- Investment of 52 billions of €
- Reduction by 80 million of tons of CO2 emissions
- Creation of 850,000 new jobs



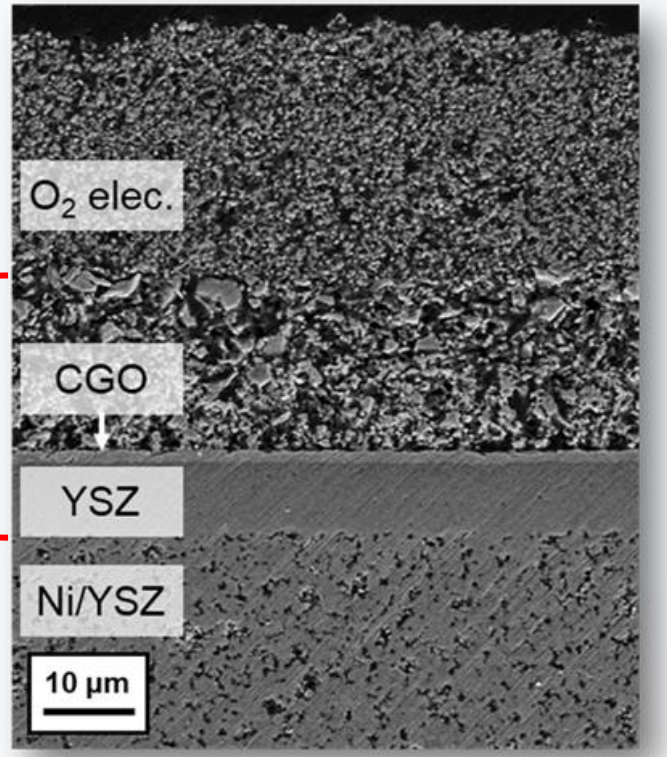
SOLIDE OXIDE ELECTROLYSIS (SOEL)

State of the art (in ceramic):

- Ceramic planar cells (tape casting/screen printing)



Multilayers Ceramic planar cells



Cross section of the cell

Porous Electrode, ex : LSM

Porous buffer layer

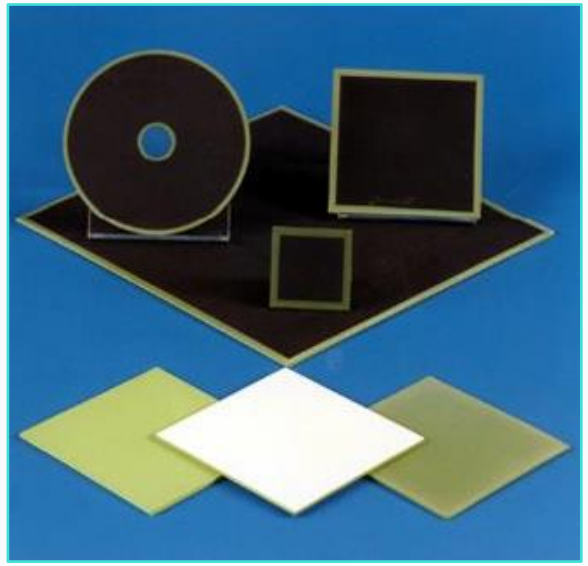
Dense YSZ Planar electrolyte

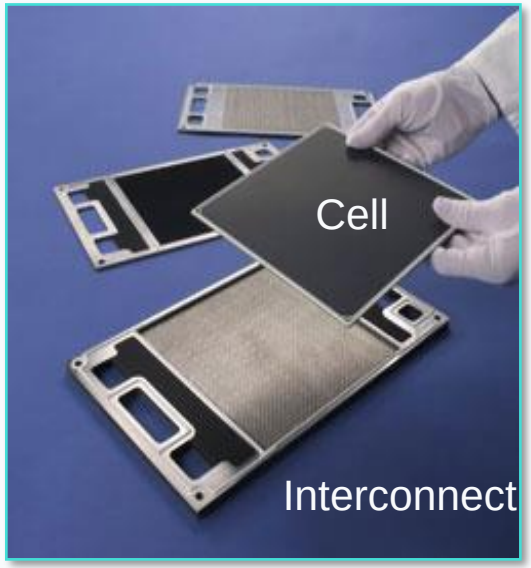
Porous Electrode Ni-YSZ

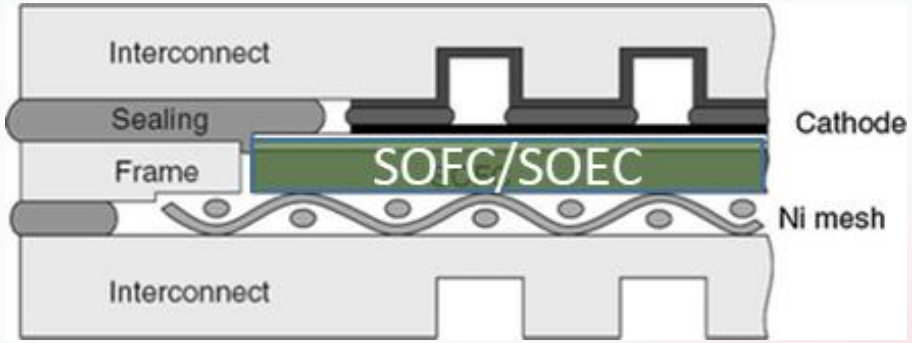
SOLIDE OXIDE ELECTROLISIS (SOEC)

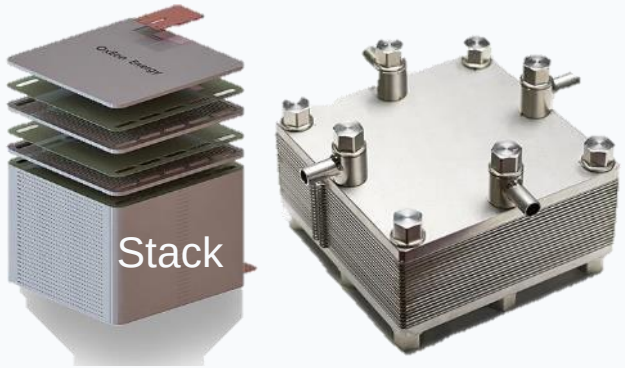
State of the art :

- Ceramic planar electrolytes (tape casting)
- Complex metal interconnects









Main limitation: work at atmospheric pressure

- ✓ How to inject H2 into the grid ?
- ✓ How store H2 in case of filling station

EUROPEAN COLLABORATIVE PROGRAM

HyP3D

Hydrogen Production in Pressurized 3D-Printed Solid Oxide Electrolysis Stacks (SOEC)

2.5 millions € over 3 years (2023 -2026)

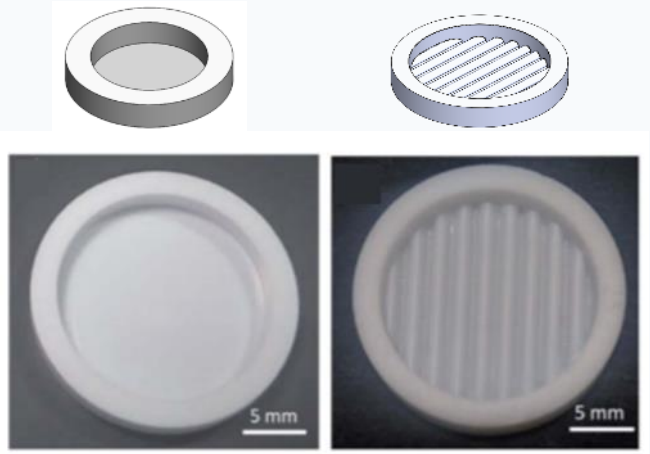
Ultra compact stack of 30 cells made of ZrO2 8Y capable of converting electricity into compressed hydrogen

- ✓ 850°C
- ✓ 5 bars
- ✓ 1.2V

- ✓ Reduce use of raw materials
- ✓ Lower energy consumption
- ✓ Lower capex

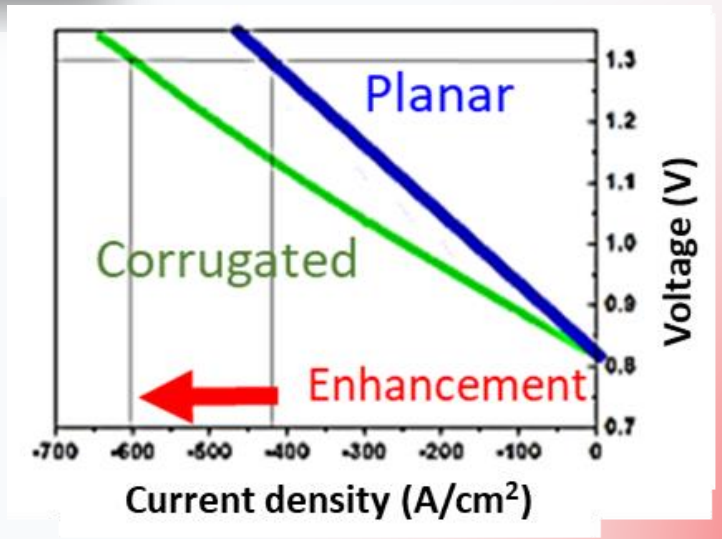
3D PRINTING OF CORRUGATED CELLS

ZR3Y prototypes : lab cells SOFC made by IREC (Collaborative Project CELL3DITOR)

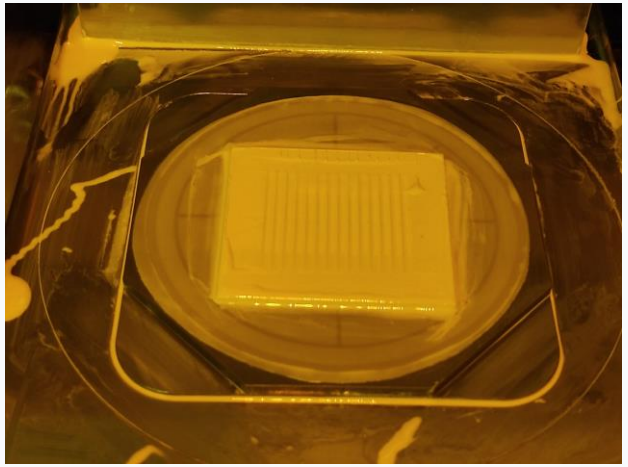


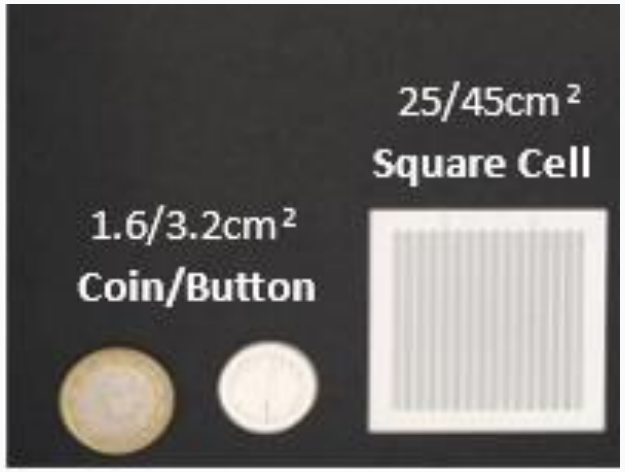
Improvement of the properties thanks to corrugated shape :

- Lower voltage needed to obtain same current density



C101: DEVELOP, TEST AND FINE TUNE



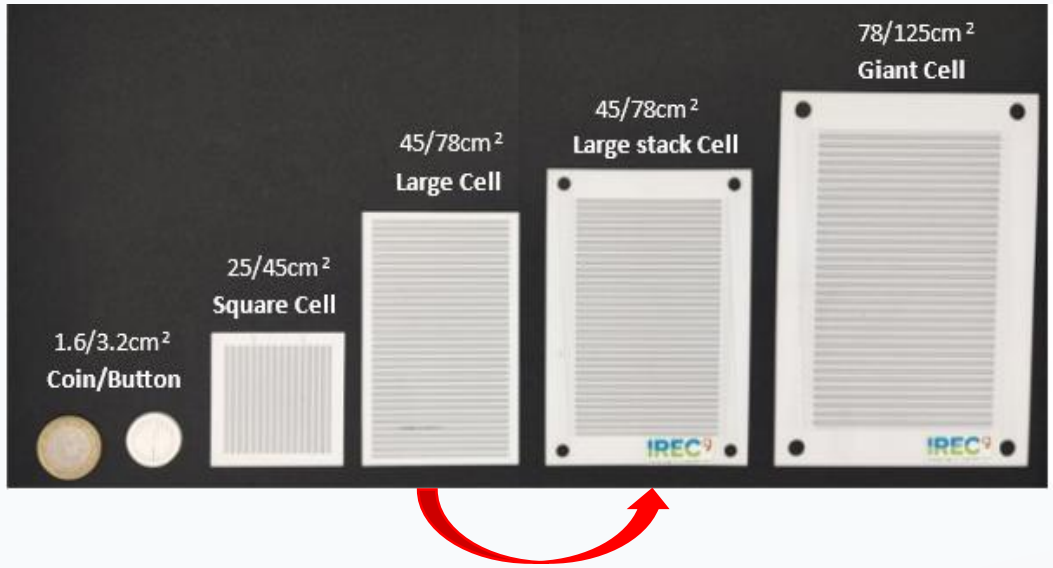


Platform 100*100

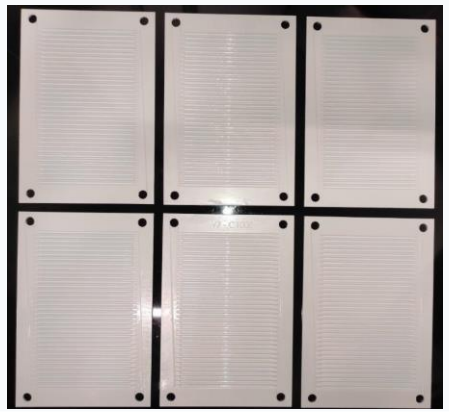
Green stage:55x51x1.6mm

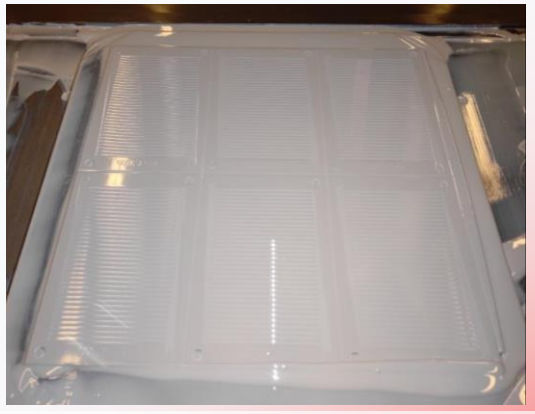
Sintered parts: 43x40x1.3mm

SCALE UP ON C1000



Green: 141x97x2mm

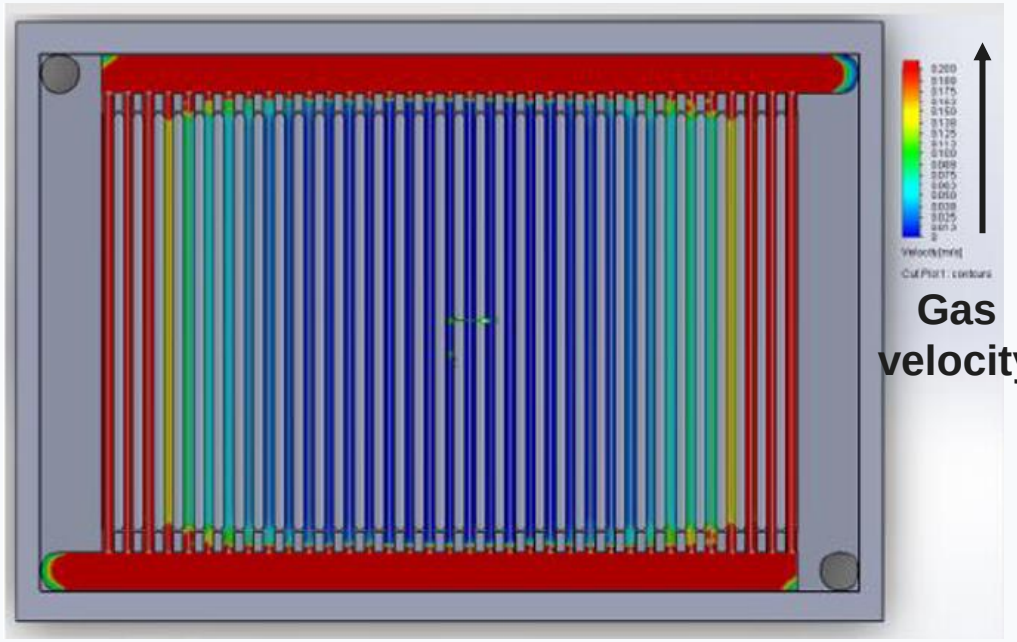


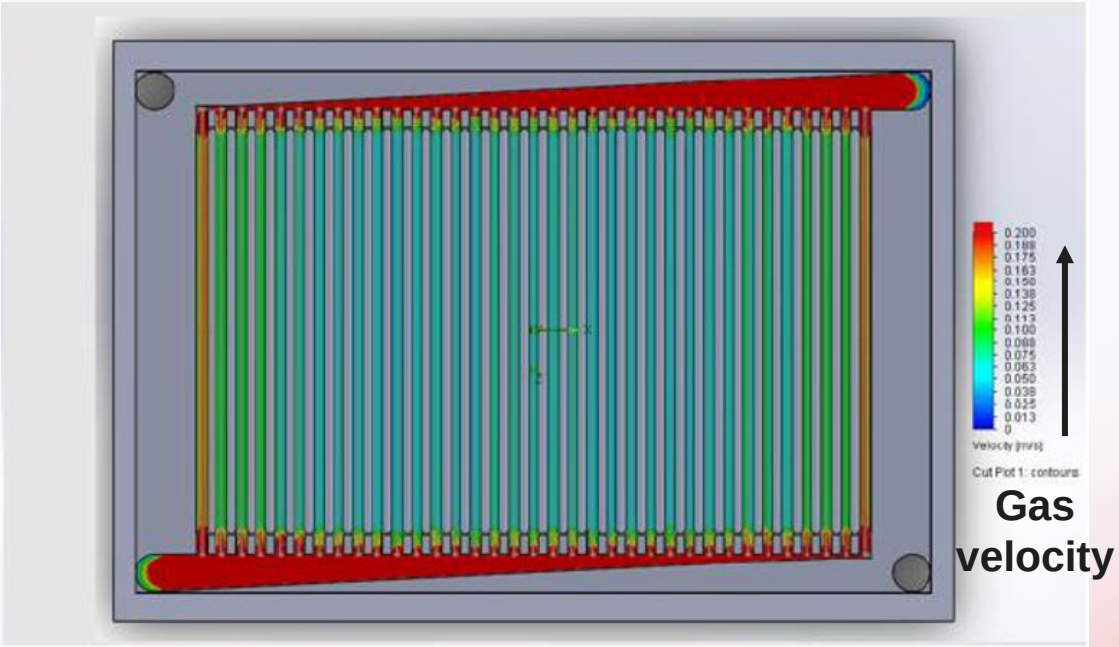


6 SOEC cells printed simultaneously in 8 hours on C1000 FLEXMATIC printer

FLOW SIMULATION

To improve gas flow homogeity, several frame channels have been studied by CFD simulations





Rectangular frame channels = heterogeneous gas flow distribution

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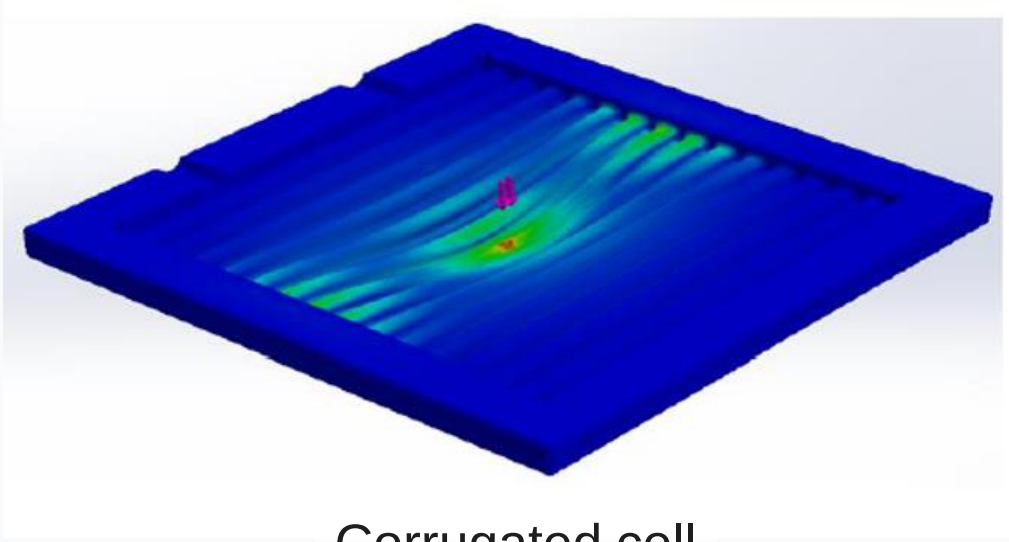
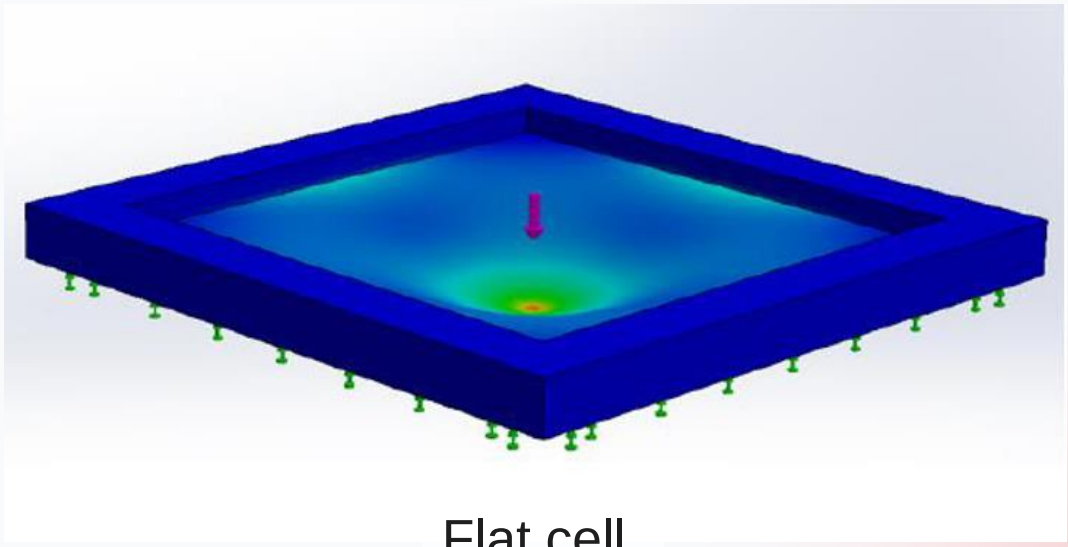
Tapered frame channels = more homogeneous gas flow distribution

MECHANICAL SIMULATION

Finite element simulation : stress and strain distributions in membranes : corrugated cell vs flat cell



Corrugated cell



Flat cell

For same applied force, stresses and strains are much smaller in the case of the corrugated cell

MECHANICAL SIMULATION

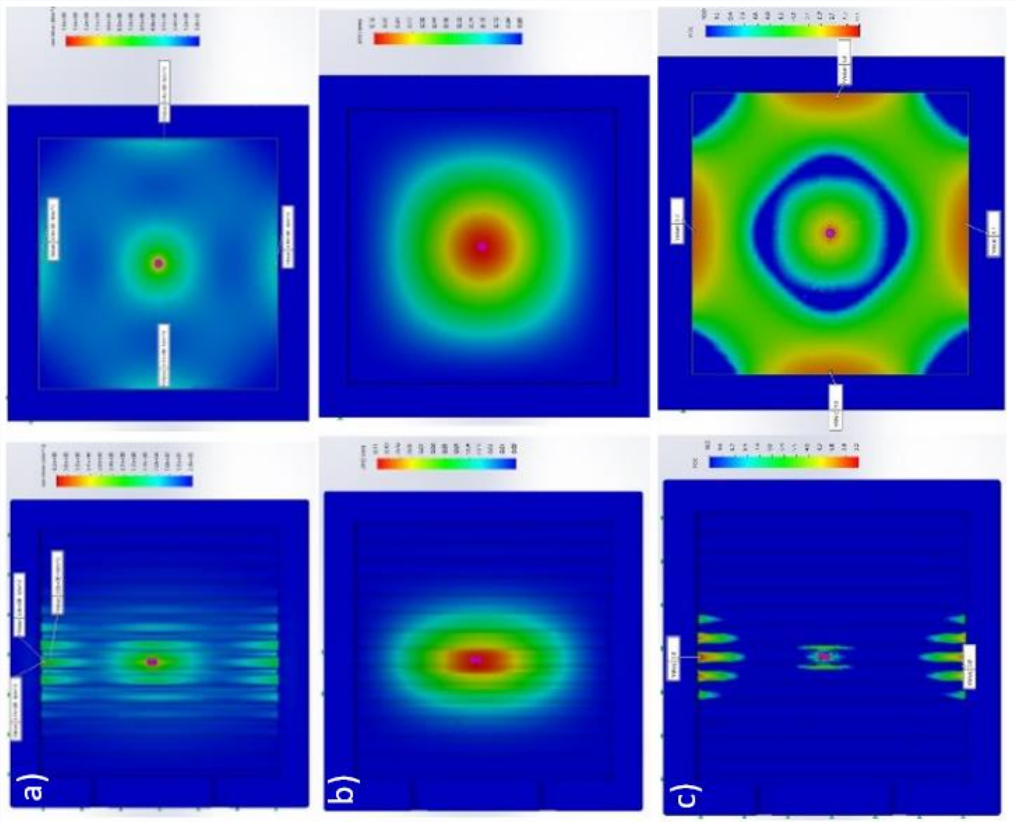
Von Mises stress

Strain

FOS (Factor of safety)

Flat cell

Corrugated cell

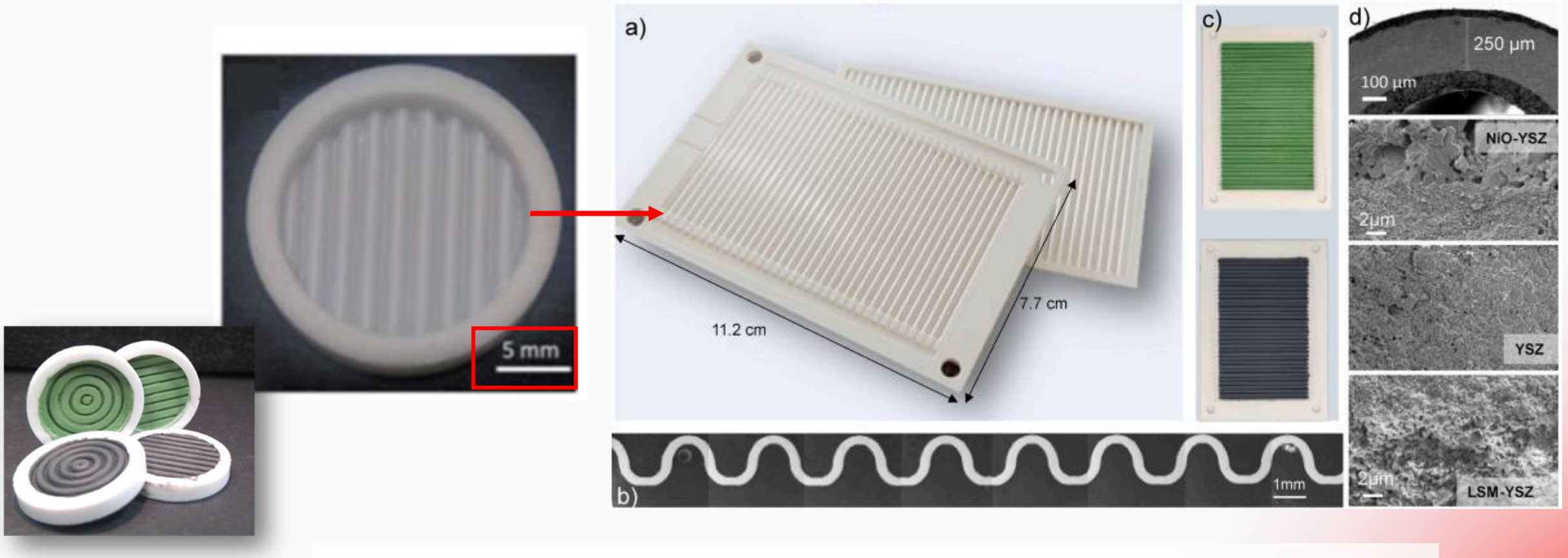


Corrugated membranes are much stronger

and stiffer than flat membranes (same thickness)

ELECTROLYTE CELL WITH ANODE AND CATHODE

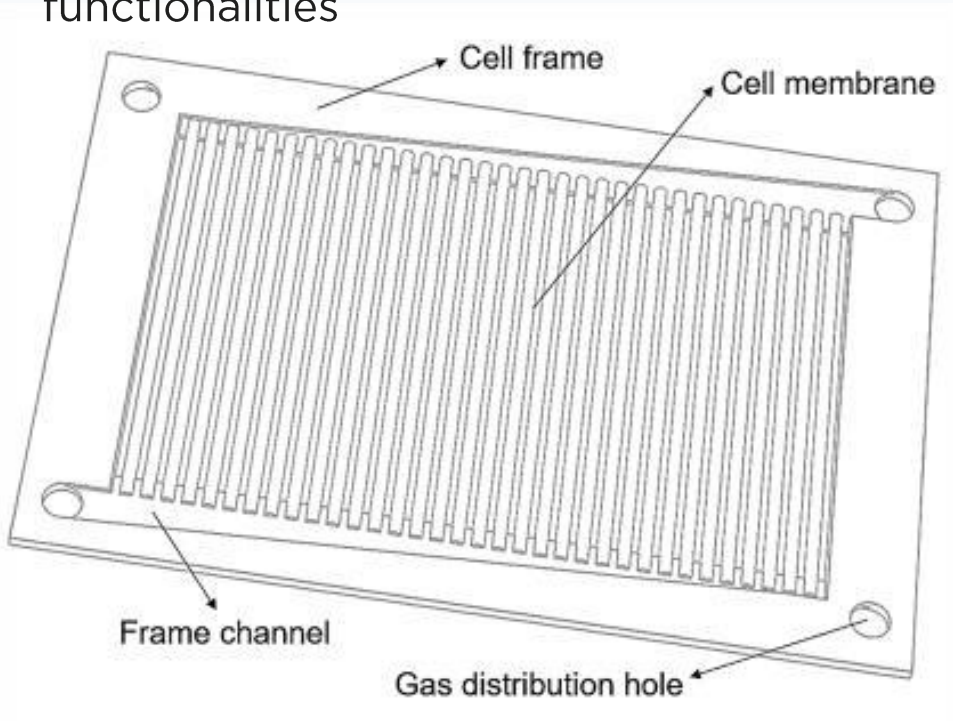
Scale-up



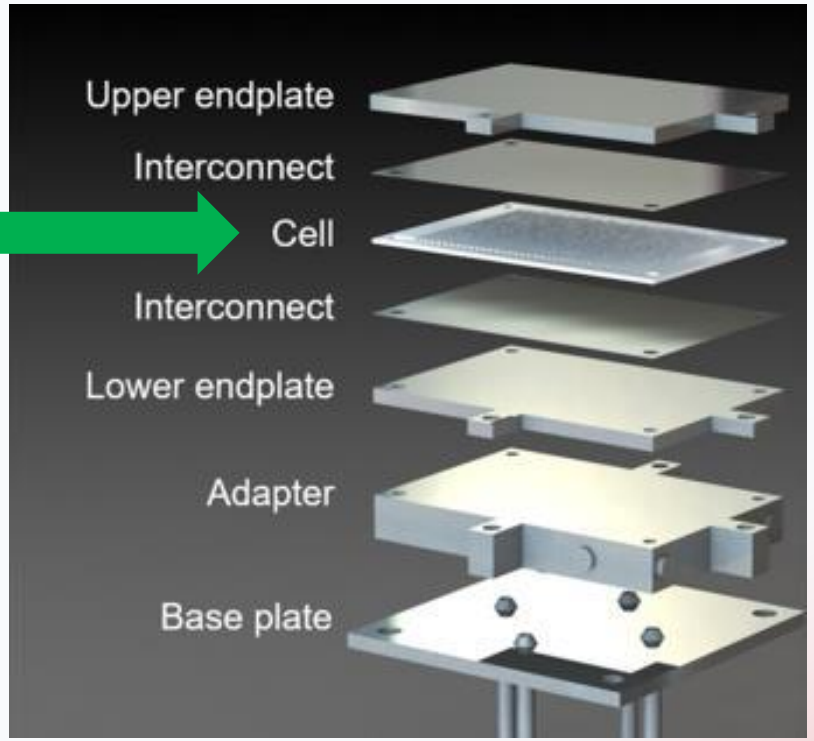
- Corrugated YSZ Electrolyte made by 3D printing
- After electrolyte sintering, electrodes manually applied and sintered

HYP3D CHALLENGE : HIGH-PRESSURE ELECTROLYS

3D printing ceramic electrolytes with embedded functionalities



- ✓ 850°C
- ✓ 5bar
- ✓ 1.2V



- ✓ Mechanical properties optimisation
- ✓ Increase in reactive surface
- ✓ Functionalization of the cell

→

- Resistance to differential pressure
- Efficiency
- Compact design

What CERAMAKER Printers to produce?

	C101 EASY LAB	C101 EASY FAB	C1000 FLEXMATIC	C3601 ULTIMATE
				
DIMENSIONS (WxDxH)	1020 x 1005 x 1976 mm	1020 x 1005 x 1976 mm	1150 x 1850 x 1950 mm	2100 x 1800 x 2500 mm
BUILD PLATFORM	100*100*150 mm	100*100*150 mm	320*320*200 mm	600*600*300 mm
LASER	1	1	1 or 2	4

Discover the automatic line we've developed to achieve the industrial production you're looking for…

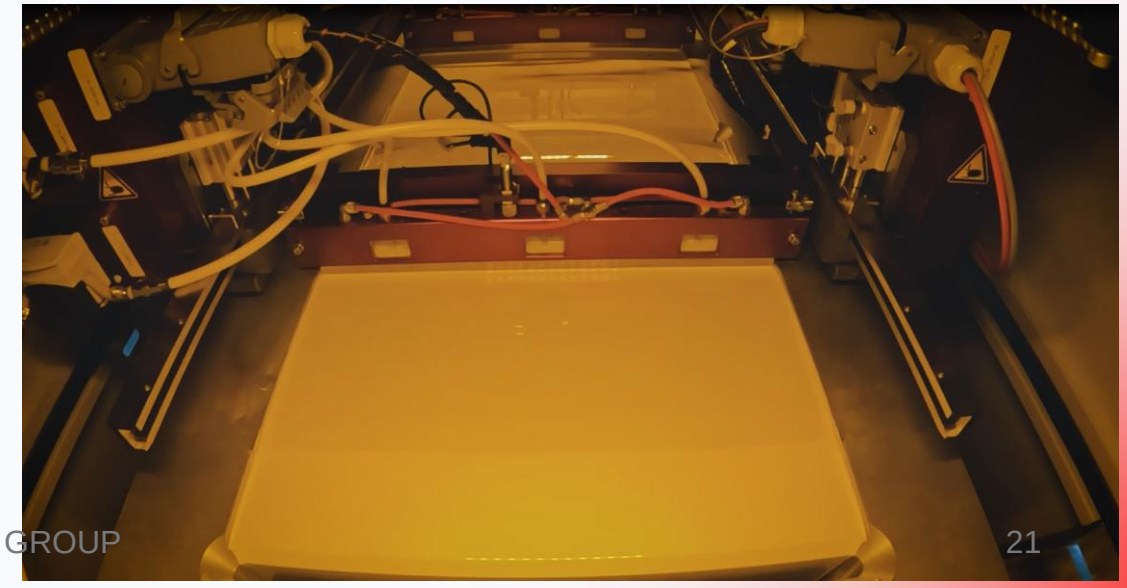
Designed for production, the C2000 DUALMATIC

- Efficient SOEL reaction is a must for **high performance** solution,
- However it has to be **cost effective** also: reducing manufacturing cost is also mandatory
- Reducing Opex: Develop **specific printers** for production of electrolytes to **reduce cost** and **increase productivity**

Improve automation on C2000 DUALMATIC

Workflow efficiency & Automation

- **2 stations** for unloading, preparation, and cleaning in parallel.
- **Continuous Printing**: No downtime, automatic platform switching ensures constant production flow.
- **Improved Throughput**: Dual platforms with 18 cells, 6 lasers, and automatic handling



Advancement Perspectives:

Continue **Automation** of the remaining manual tasks to:

- Simplify steps for the operator
- Eliminate the risks of human error
- Reduce downtime in the production chain

Feed **CERIA**, 3DCeram's **AI**, with data to enable:

- Integration of all pre-process functionalities
- Design validation to ensure the firing phase
- Adjustment of laser parameters to optimize printing time

To reach:
Simplicity, freedom of use, and reliability…

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