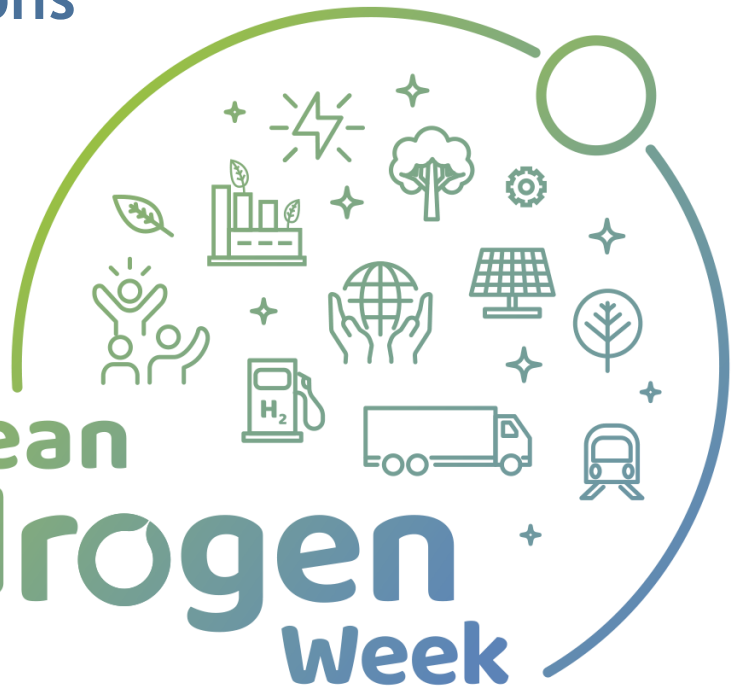
Cost-effective and flexible 3D printed SOFC stacks for commercial applications

Cell3Ditor



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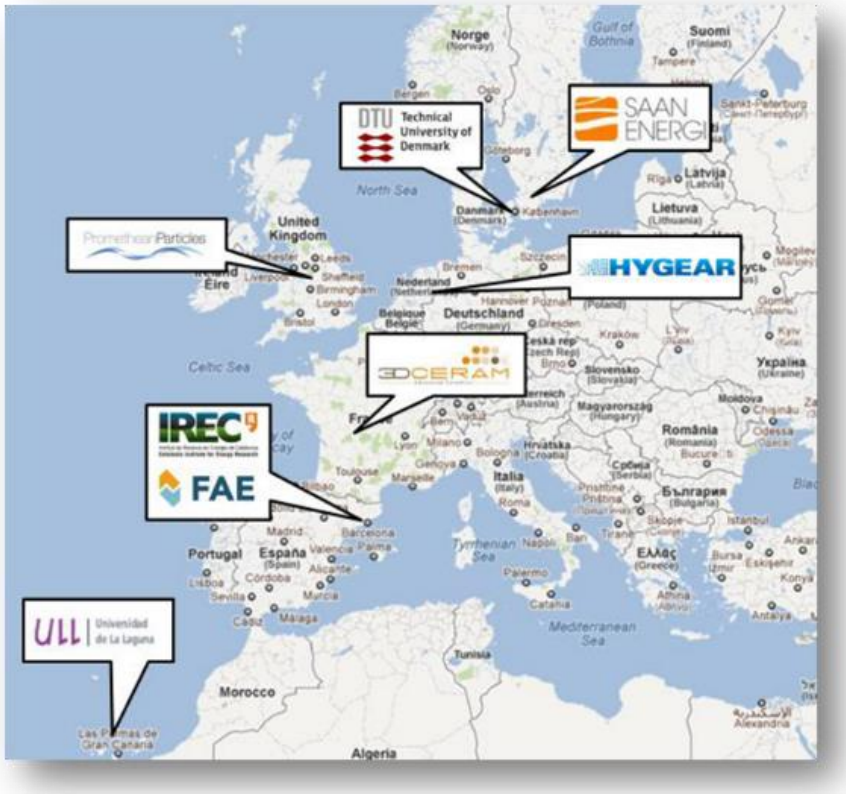
FCH

European Commission

Project Overview

Cell3Ditor



- **Call year:** 2015
- **Call topic:** FCH-02.6-2015: Development of cost effective manufacturing technologies for key components or fuel cell systems
- **Project dates:** 01/07/2016 – 30/04/2020
- **% stage of implementation 01/11/2019:** 100 %
- **Total project budget:** 2,191,133.75 €
- **FCH JU max. contribution:** 2,180,662.50 €
- **Other financial contribution:** 0 €
- **Partners:** DANMARKS TEKNISKE UNIVERSITET (DTU), FRANCISCO ALBERO S.A. (FAE), 3DCERAM (3DCERAM), Promethean Particles Ltd. (PROM), University of La Laguna (ULL), SAAN Energi A.B. (SAAN), HyGear Fuel Cell Systems B.V. (HFCS) and FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA (IREC)

Project Summary

Objective

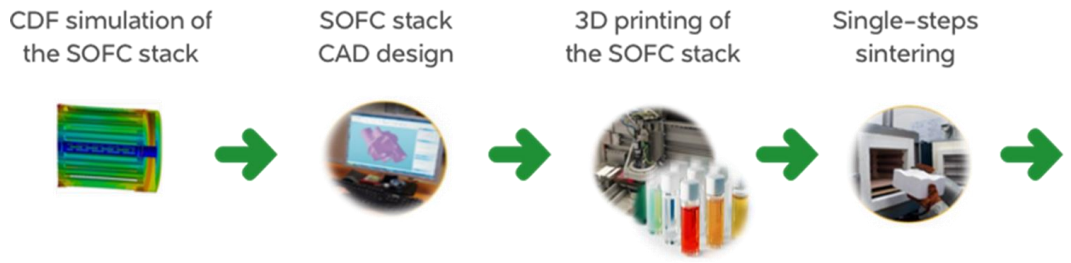
Development of 3D printing technology for the industrial production of **SOFC parts and stacks**.

Intermediate goals

- Printable inks and slurries
- Multi-material ceramic 3D printer
- Single-step sintering
- Enhanced parts

Global positioning vs SoA

Cell3Ditor	State-of-the-art
• Multi-material ceramic 3D printer	N/A
• Printable inks and slurries of advanced ceramics	N/A
• 3D printed SOFCs	N/A

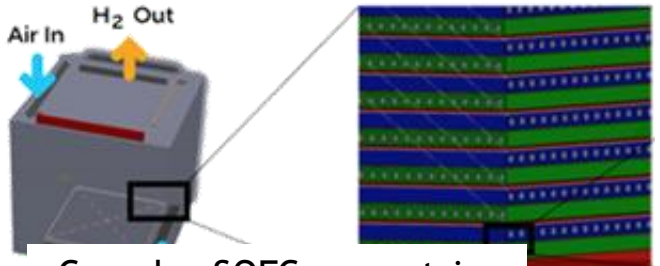


Application and market area

Commercial segment of the stationary fuel cells market

- Huge potential
- Highly heterogeneous

Selected target market: Europe



Complex SOFC geometries and self-supported stacks

Project Progress-Printable functional ceramics

Achievement to-date

Functional ceramic powders or precursors → Printable inks & slurries

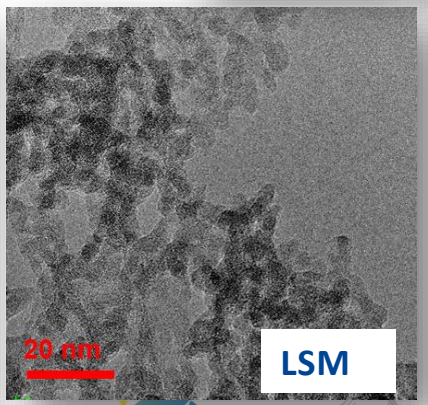
25% 50% 75%

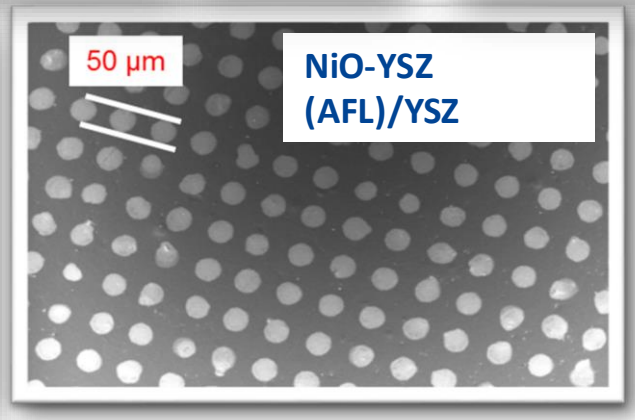
Slurries preparation for SLA process and robocasting

- Formulation (YSZ, NiO-YSZ, LSM, LCTM & sacrificial)
- Rheological analysis
- Printability and Photo-curing properties

Inks preparation for inkjet printing

- In-situ synthesis (YSZ, LSM, NiO-YSZ)
- Rheological analysis
- Printability





Project Progress-Multi-material ceramic 3D printer

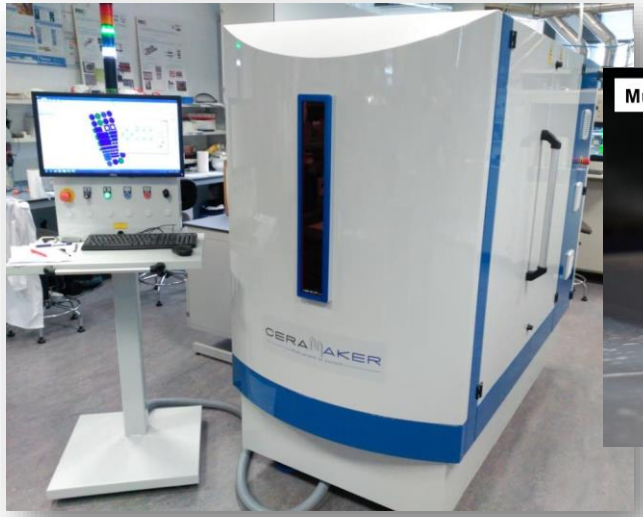
Achievement to-date

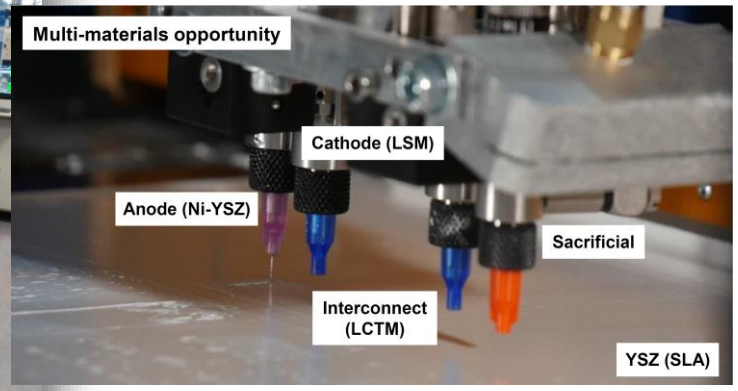
Single material 3D printer → Multi-material 3D printer

25% 50% 75%

3D printer with multi-material capabilities

- **SLA** printer (**YSZ**) upgraded with **robocasting (+4 materials)**
- **Multi-material Software** upgrade





Project Progress- Multi-material 3D printing process

Achievement to-date

Single material printing → Multi-material printing

25% 50% 75%

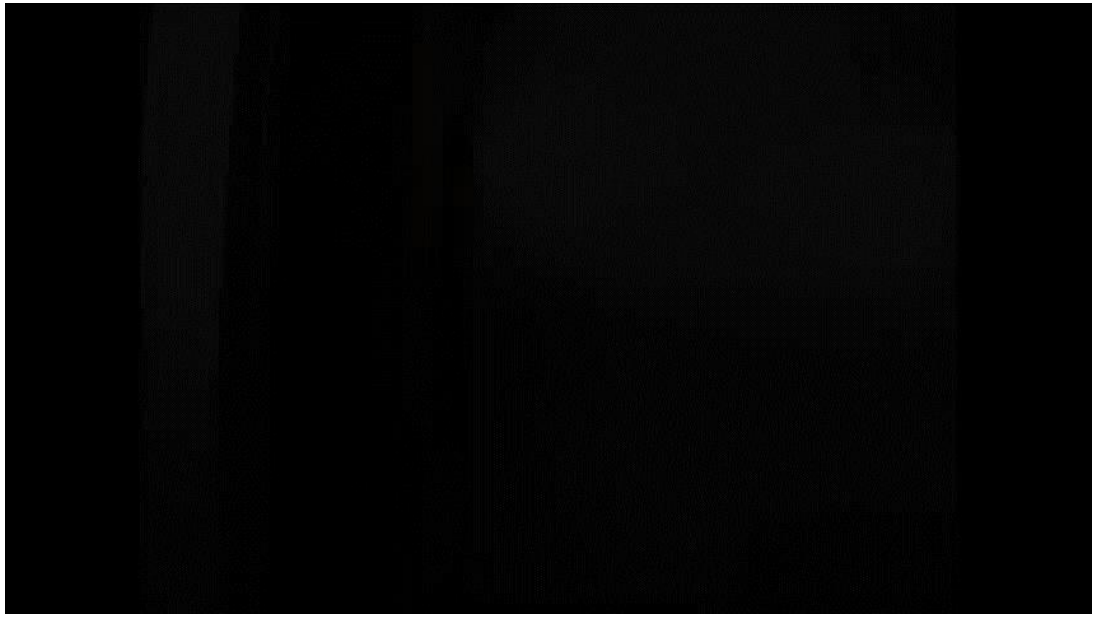
Multi-material 3D printing and sintering

- **SOFC parts** by SLA, inkjet and robocasting
- **SOFC SRU and stacks** by SLA+Robocasting


Sacrificial/YSZ


NiO-YSZ/YSZ


LSM-YSZ/YSZ



Project Progress- Multi-material 3D printing process

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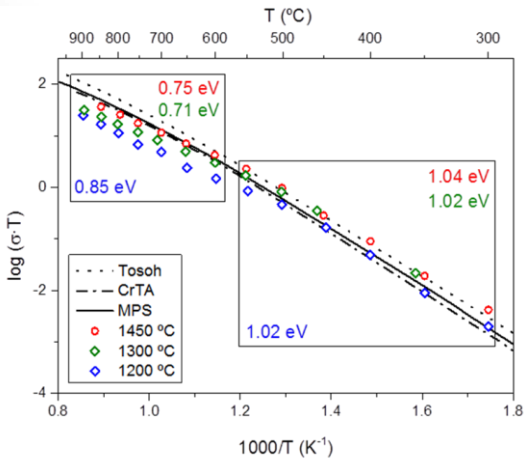
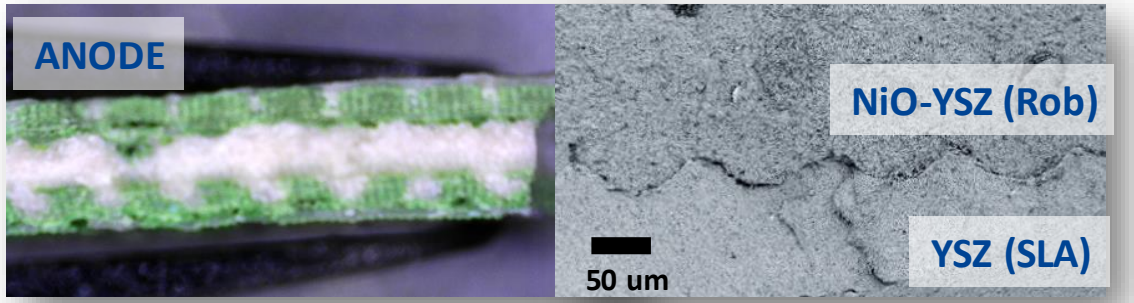
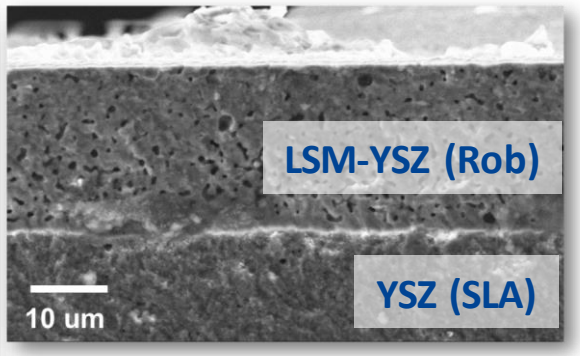


IONIC CONDUCTIVITY SLA YSZ





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Project Progress- 3D printed SOFCs

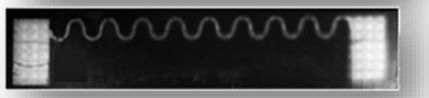
Achievement to-date

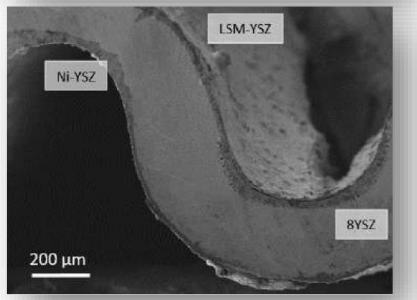
Conventional SOFCs → 3D printed SOFCs

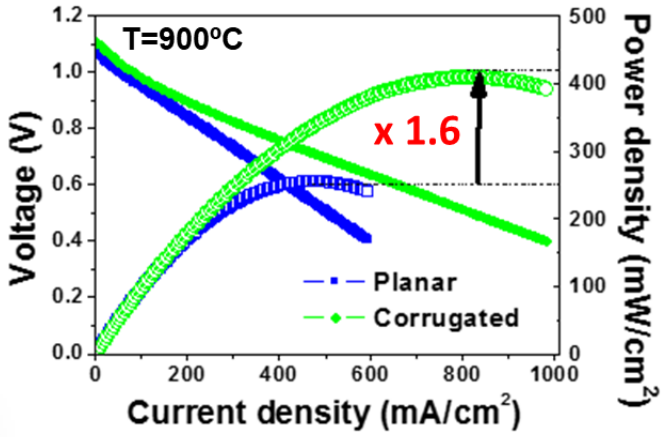
25% 50% 75%

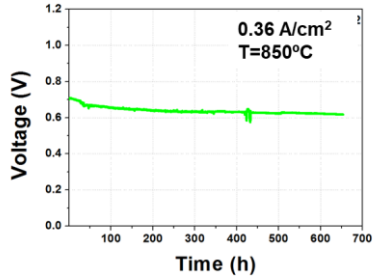
Enhanced Solid Oxide Fuel Cells

3D Solid Oxide Fuel Cells



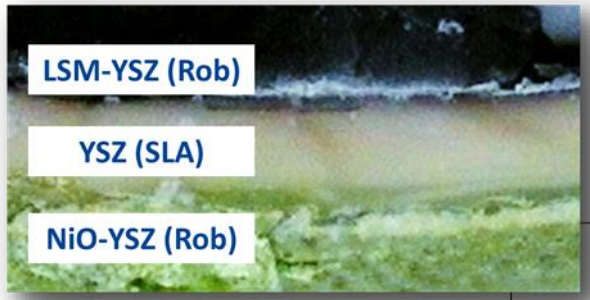


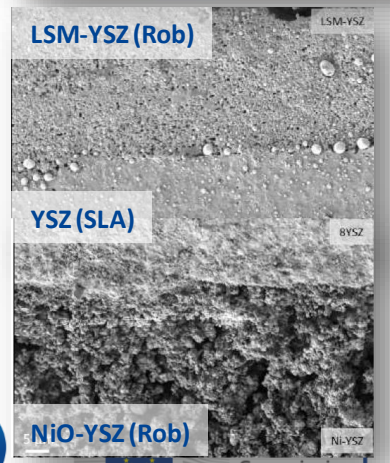




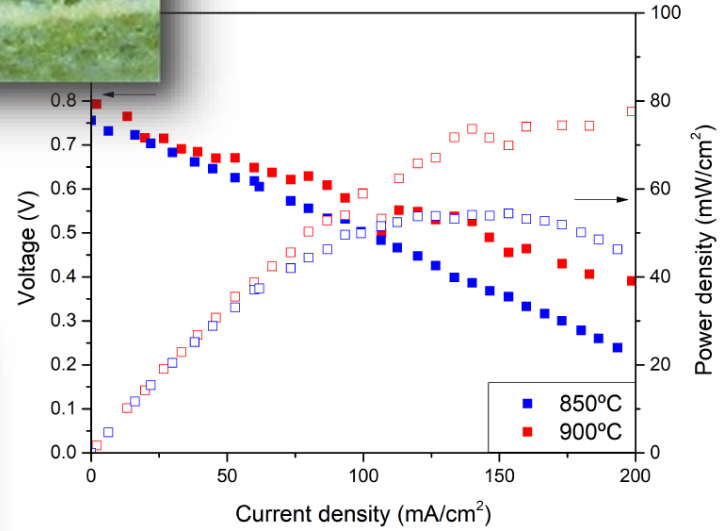
700h

Fully printed SOFC cells





Proof-of-concept



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Risks, Challenges and Lessons Learned

Printable inks/slurries

Risk
- UV-absorbing materials

Mitigation
- Photo-thermal curing

Multi-material 3D printing process

Risk
- Multi-layer architectures

Mitigation
- Laser machining

Single-step sintering

Challenges
- Cosintering

Risk
- Compatibility of dense and porous structures

Mitigation
- Add porous former

3D printing of SOFCs

Risk
- Low yield of inkjet
- Small fluidics (cleaning)

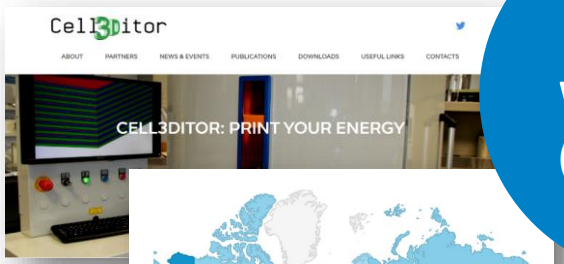
Mitigation
- Robocasting
- Sacrificial material

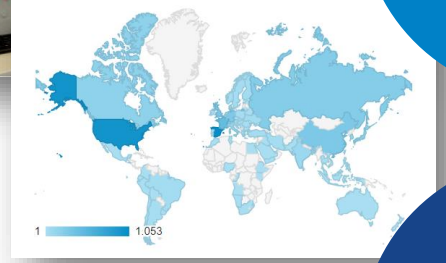
Communications Activities

European Hydrogen Week

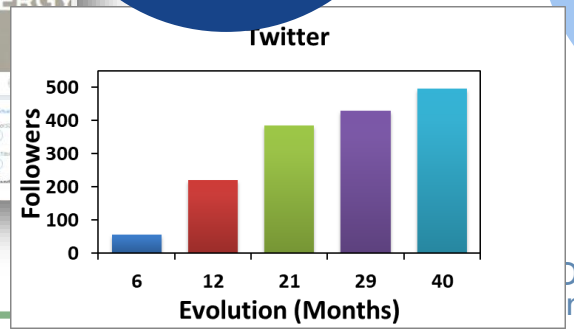
COMM

Website
(5000+ visits)





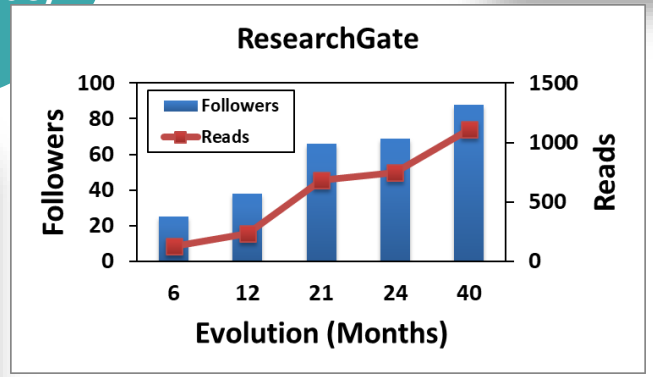
Twitter
(500+ followers)
(125+ tweets)



YouTube
(2 videos)
(1000+ visual.)

ResearchGate
(1100+ reads)

General Society
(5 actions)



Dissemination Activities

DISSEM

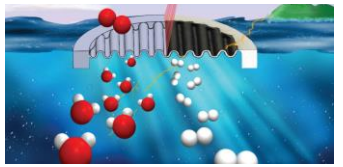
26 Conferences
Plenary/Keynote: 2
Invited: 8

9 Publications
Scientific: 8
Industrial: 1

7 Fairs & Workshops

60+ Highlights

Hot PAPER in JMCA



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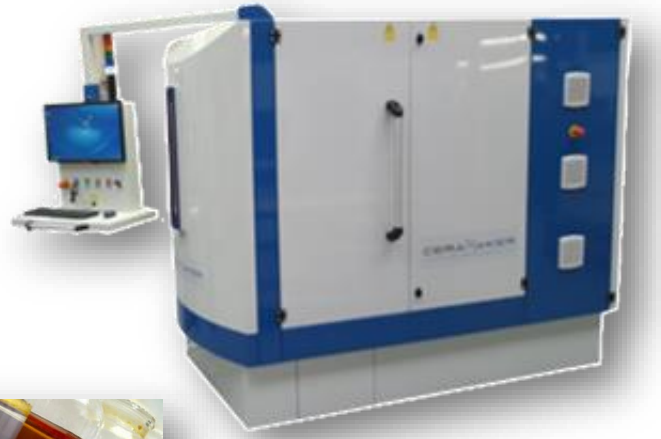
Impact

Code	Concept
B18678 EP/US/JP/KR/RU/CN/FR/UA	HYBRID PRINTING PROCESS
B20377 EP/US/JP/KR/RU/CN/FR/UA	SACRIFICIAL MATERIAL APPROACH
B20887 EP/US/JP/KR/RU/CN/FR/UA	MULTIMATERIAL PRINTING
EP 19382509	SOFC NEW CONCEPT



- **Industry:**
  - **4 Patent** applications.
  - Outputs generated within the project already in the partners portfolio:
    - Ceramic nano-dispersions: Promethean Particles Ltd.
    - Extension of ceramic pastes in catalogue: 3DCERAM
    - Multi-material 3D printer: 3DCERAM
- **Environmental:**
  - **LCA** and technoeconomical assessment:
    - Reduction of waste material
    - Reduction of energy consumption
- **Social:**
  - Growing awareness about 3D printing for energy
  - Influence policy makers

Cerame-Unie Conference Brussels, November 2017

Article devoted to Cell3Ditor exposed at the Bilbao Fair 2017

Cell3Ditor activities at the National Science Days

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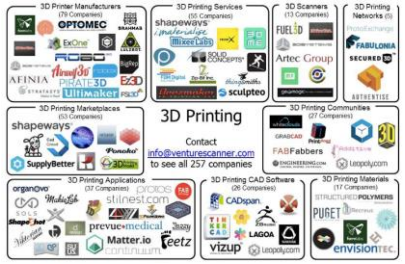
Exploitation Plan

- **Protection of the IPR:** development of a Plan of Use and Dissemination of Foreground (**PUDF**), application for patents and adoption of a 'protecting before disseminating' policy.
- **Exploitation of outputs:** generation of specific **business plans** for exploitable outputs (assessed by SSERR and Innovation Radar).



3D Printing Sector Map.

Strengths	Weaknesses
• Accuracy • Complete automated process to reduce time • Personalized products • On demand tooling	• Quality of end-use products • Post-processing to make finished products • Quality of software solutions • Less research on advanced materials • Less patents in advances manufacturing techniques
Opportunities	**Threads**
• Free to use inventions • Asian and African market penetration • Commercial usage of technology at mass manufacturing level • Development of bio compatible materials	• Increased competition due to increase in number of patent filing companies • Major giants in 3D printing has already started industry penetration • Time taken for printing • Majority of the patents are owned by major players

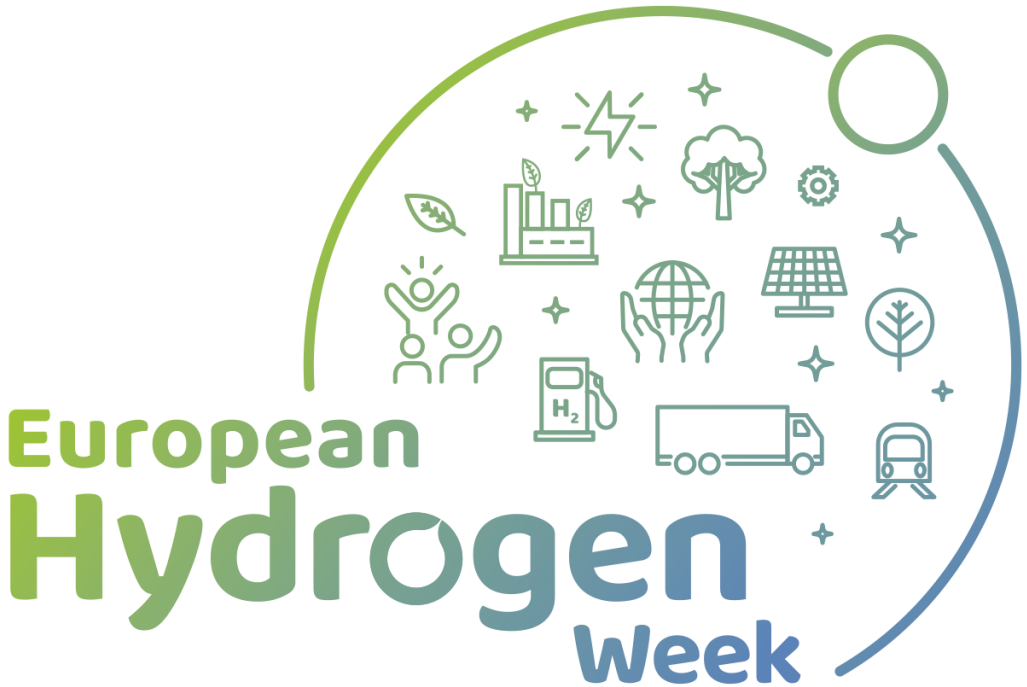
SWOT analysis of 3D printing industry of ceramics

- **Creation of an Industry Advisory Board:** to help on deployment and scalability issues.

- **Actions to deploy the exploitation plan:**

Investors search

Technical funding



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