Cell3Ditor
Cost-effective and flexible 3D printed SOFC stacks for commercial applications

Cell3Ditor

Prof. Albert Tarancón

Catalonia Institute for Energy Research, **IREC**

www.cell3ditor.eu

atarancon@irec.cat

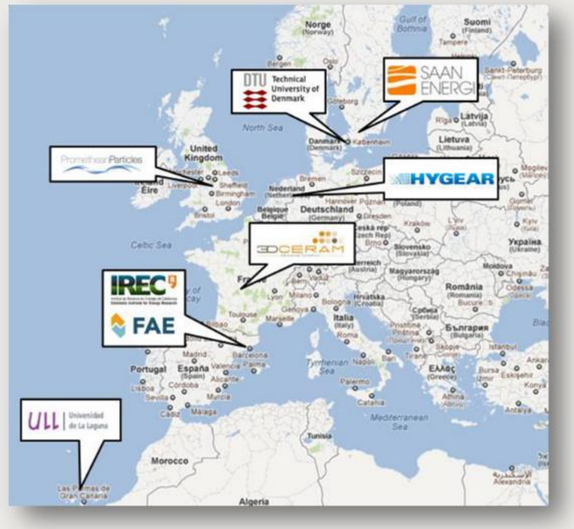
Programme Review Days 2018

Brussels, 14-15 November 2018

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 – 31/12/2019
- **% stage of implementation 01/11/2018:** 70%
- **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

Cell3Ditor

Objective

Development of 3D printing technology for the industrial production of **SOFC parts** (inkjet) **and stacks** (SLA+Robocasting).

Intermediate goals

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

Global positioning vs SoA

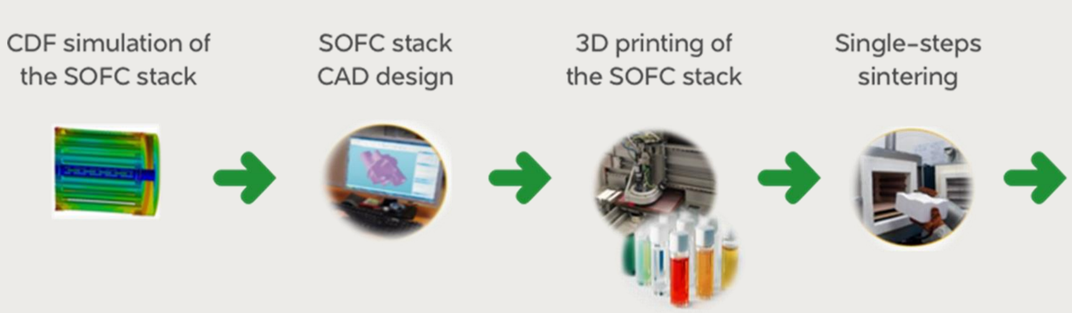
Cell3Ditor	State-of-the-art
• Multi-material ceramic 3D printer	N/A
• Printable inks and slurries of advanced ceramics	N/A
• 3D printed SOFCs	N/A

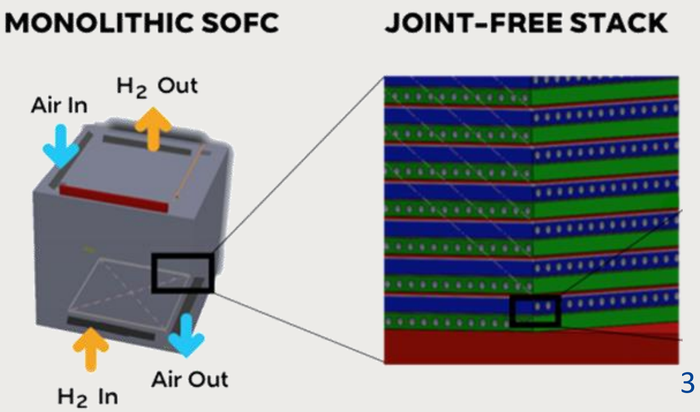
Application and market area

Commercial segment of the stationary fuel cells market

- Huge potential
- Highly heterogeneous

Selected target market: Europe





PROJECT PROGRESS – Printable inks & slurries of functional ceramics

Achievement to-date

Functional ceramic powders or precursors

25% 50% 75%

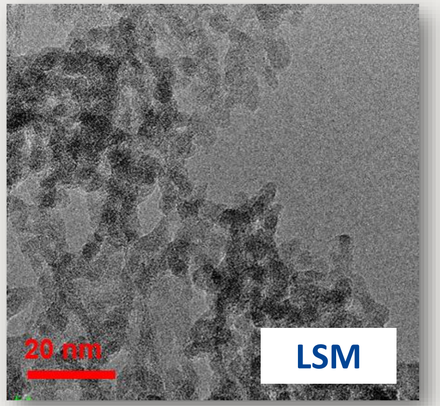
Printable inks & slurries

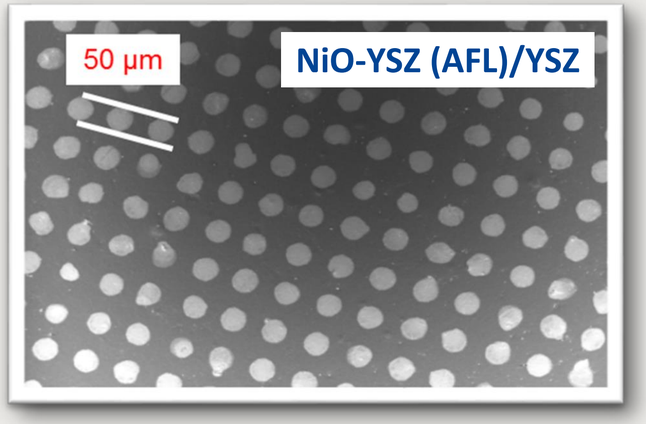
Slurries preparation for SLA process and robocasting

- 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

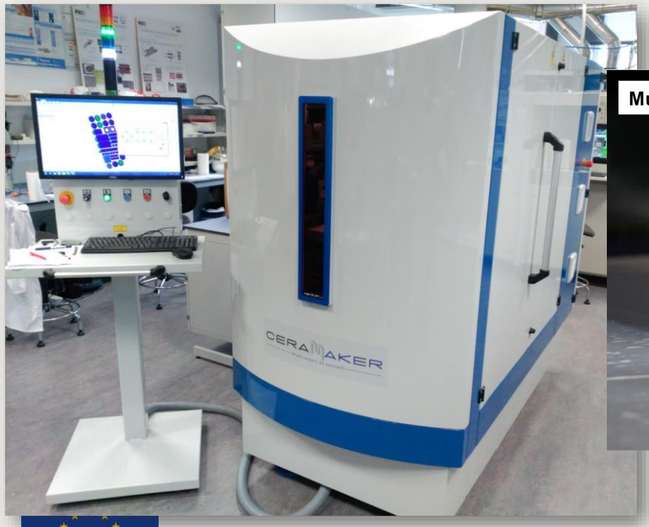
Achievement to-date

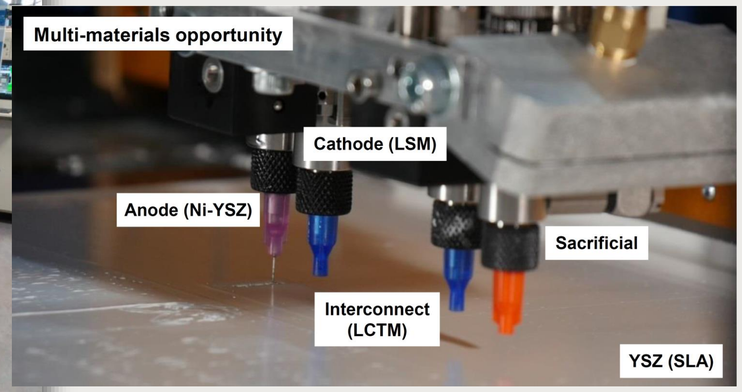
Single material 3D printer → **Multi-material 3D printer**

25% 50% 75% 100%

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

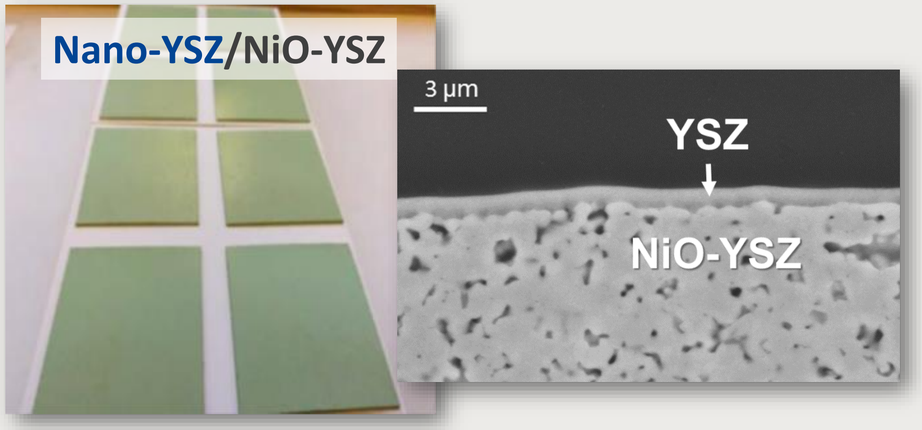
Achievement to-date

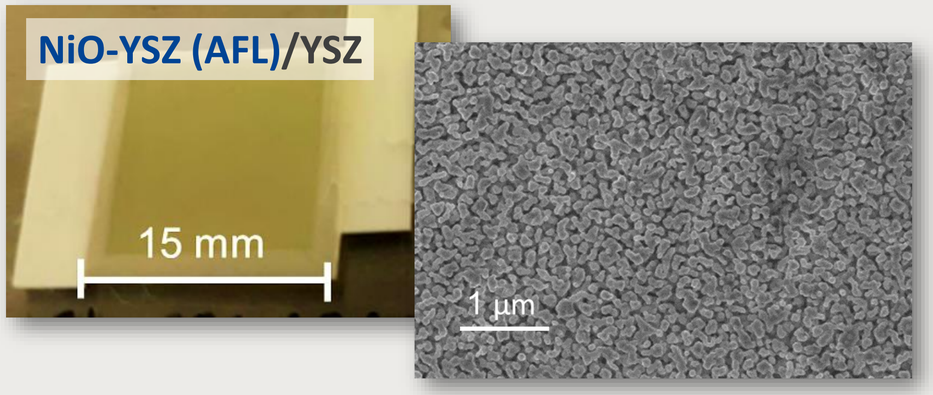
Single material printing → **Multi-material printing**

25% 50% 75% 100%

Multi-material 3D printing

- **SOFC parts** by inkjet (functional layers on commercial substrates)
- **SOFC SRU and stacks** by SLA+Robocasting





PROJECT PROGRESS – Single-step sintering

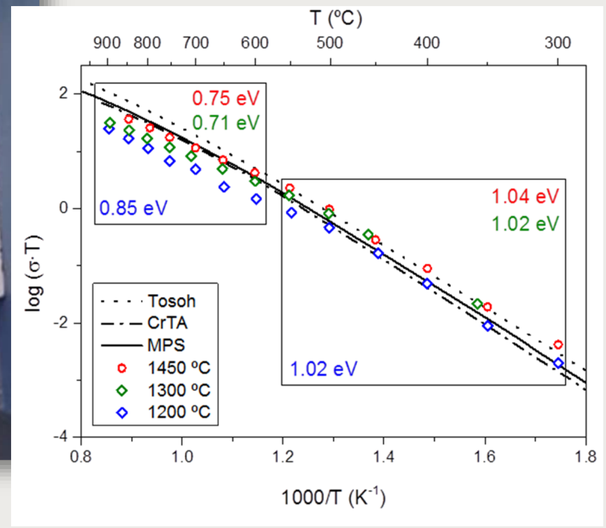
Achievement to-date

Single layer sintering → Co-sintering whole stack

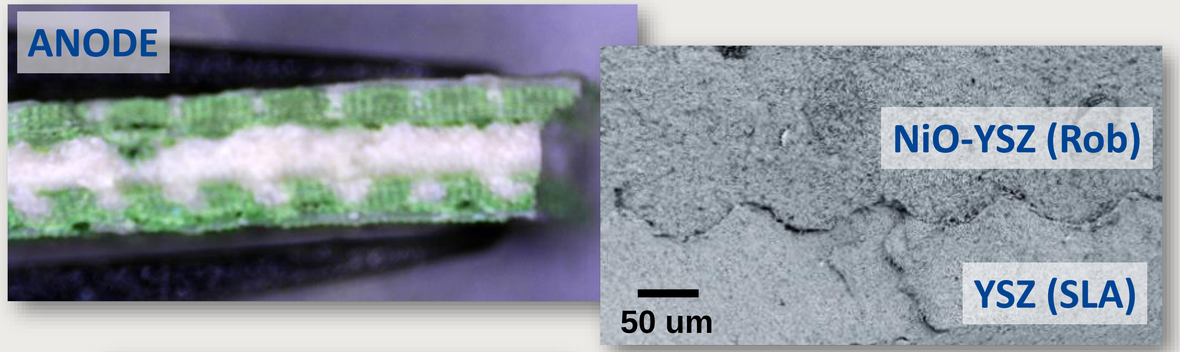
25% 50% 75% 100%

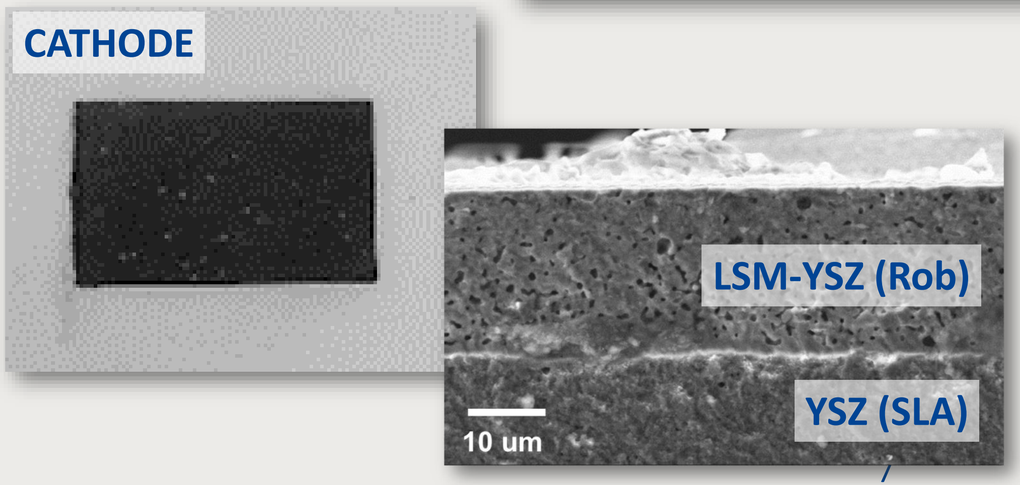
Single-step sintering of the whole SOFC stack

T_{sint}^{YSZ} (SLA)~1250ºC



IONIC CONDUCTIVITY SLA YSZ





Risks and Challenges

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
- Compatibility of dense and porous structures
- Minimize tensile-stress

3D printing of SOFCs

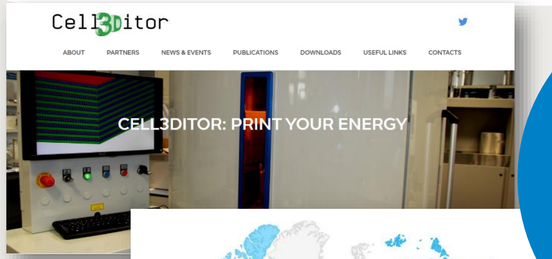
Risk

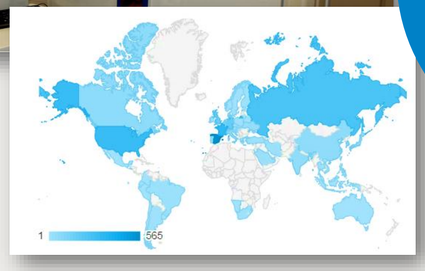
- Low yield of inkjet
- Small fluidics (cleaning)

Mitigation

- Robocasting
- Sacrificial material

Communications Activities

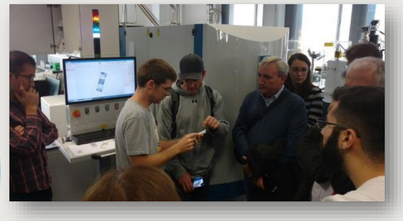


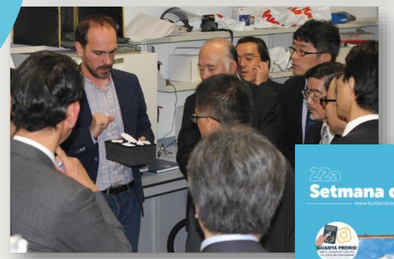


Website
(2500+ visits)

Communication

General Society
(3 actions)

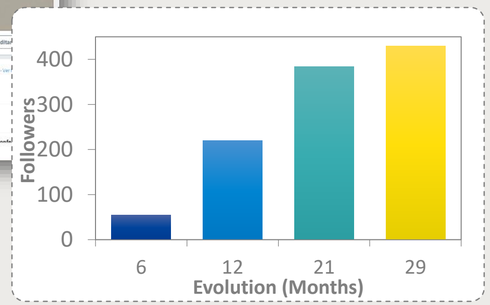


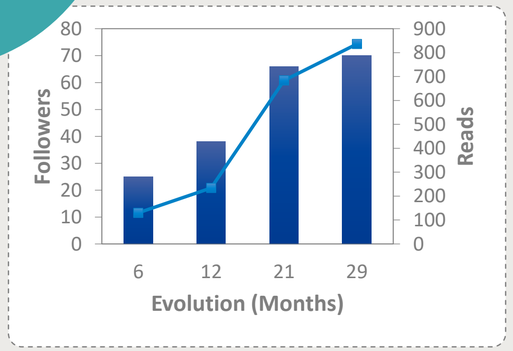


Twitter
(430+ followers)
(100+ tweets)

YouTube
(2 videos)

ResearchGate
(850+ reads)





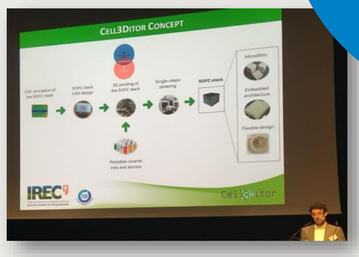
Dissemination Activities

Dissemination

22 Conferences
Plenary/Keynote: 2
Invited: 4
Oral: 9
Posters: 7

EUROPEAN FUEL CELL FORUM

ceramics expo



7 Fairs & Workshops

HANNOVER MESSE

ADDIT3D

8 Publications
Scientific: 7
Industrial: 1

30+ Highlights

fuel CELLS BULLETIN

tct MAG

FCH JU AWARDS 2018

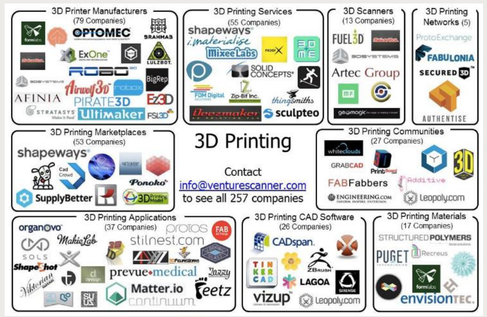
3D PRINTING INDUSTRY

EXPLOITATION PLAN

Exploitation

- **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 of functional ceramics

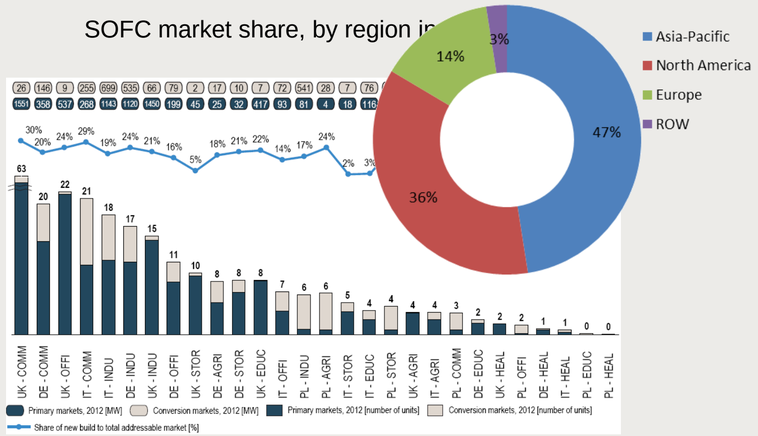


3D Printing Sector Map. Source: Venture Scanner

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

5kW SOFC system



Addressable Market for fuel cells in non-residential buildings 2030

Strengths	Weaknesses
• Highly efficient conversion of fuels + H_2 into electric power and heat • Availability of natural gas pipeline (not in Japan) • Significant reduction in CO_2-emissions • Low NOx- and SOx-emissions • Low noise • Decentralized power generation • Technically mature • High reliability & low maintenance	• Capital expenditure • Currently marketable only by subsidies • „Chicken - egg" situation for cost and price • Power & heat are commodities • Immature H_2 infrastructure • Insufficient awareness of stationary systems among the public
Opportunities	**Threats**
• Sufficient reduction of manufacturing cost seems feasible • Potential for increase in performance of SOFC-systems is existing (life expectancy, robustness, efficiency) • International expansion	• Economies of Scale not deducible • SOFC-systems remain niche product • Additional subsidies are necessary for commercialization • Political support and entrepreneurial will power available? • Low acceptance level due to safety concerns among consumers

SWOT analysis of SOFC technology industry for stationary applications

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

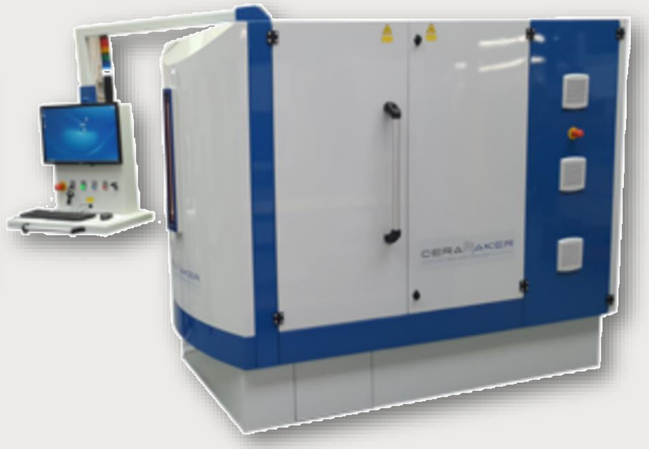
EXPECTED IMPACT

Impact

- **Industry:**
  - **3 Patent** applications.

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

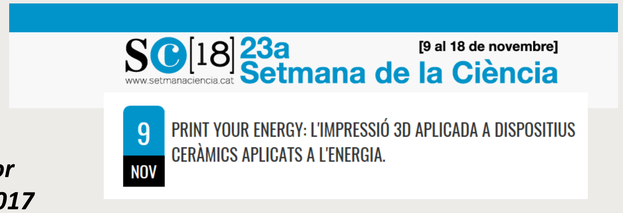
  - Outputs generated within the project already in the partners portfolio:
    - Ceramic nano-dispersions: Promethean Particles Ltd.
    - Extension of ceramic pastes in catalogue: 3DCERAM
    - Multi-material 3D printer: 3DCERAM
- **Environmental:**
  - **LCA** assessment:
    - Reduction of waste material
    - 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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