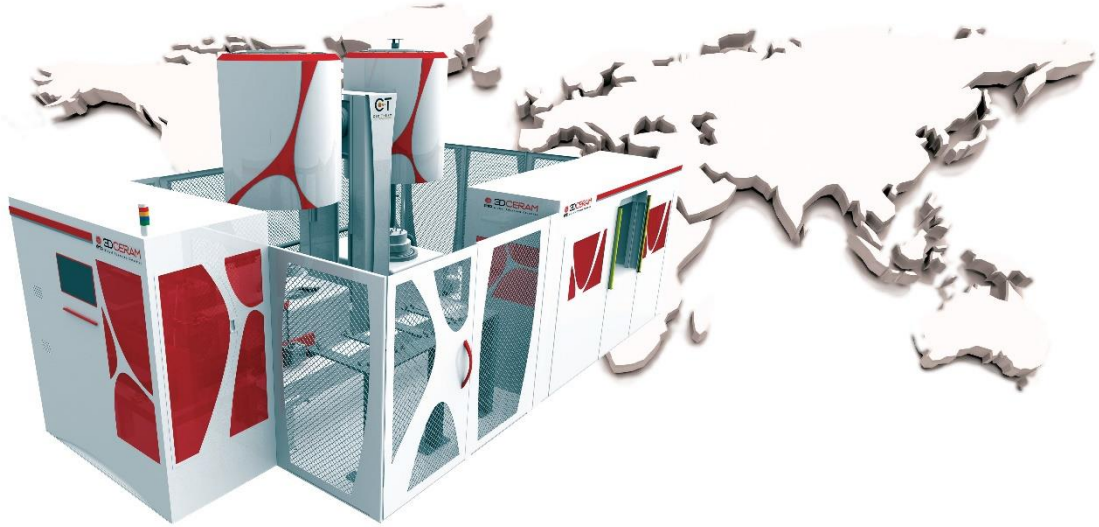
From Lab to Fab



Richard GAIGNON
CEO

NAE webminar

AGENDA

1. 3DCeram presentation
2. One technology?
3. Advantages per technologies?
4. Are the differrent technologies in competition?
5. Are all materials available on the market?
6. An alternative technology or breakthroug technology?
7. Impact on current company organisation?

GLOBAL SOLUTION FOR CERAMIC 3D PRINTING

3DCeram supplies complete **turnkey solutions** for **technical ceramic** 3D printing

- **Complete line** (Printers, hybrid Printers, kilns,…)
- Ceramic **3DMix** for our Printer
- **Services** (training, on demand part printing)

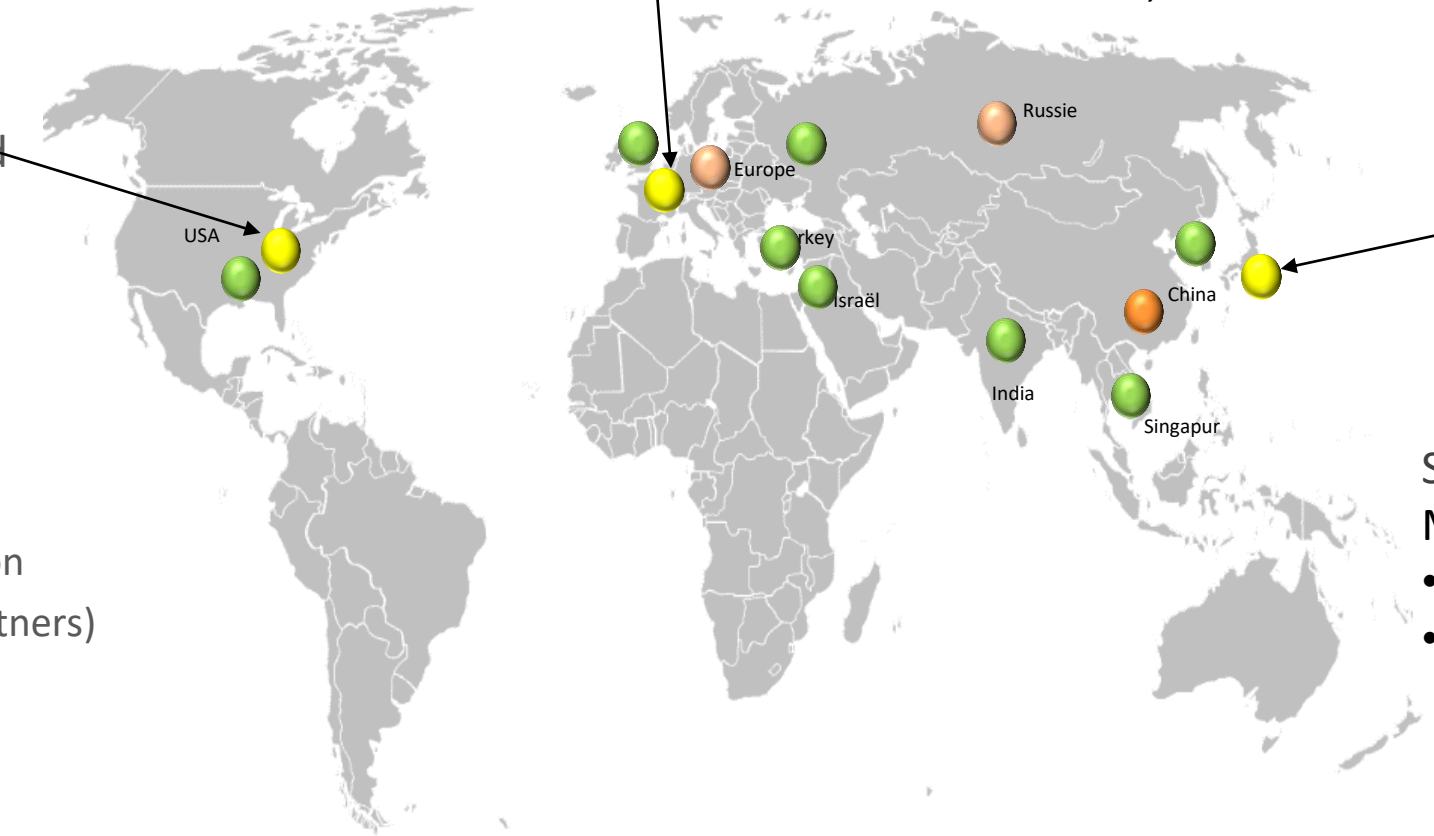
AN EXTENDED RANGE OF PRINTERS

GLOBAL PRESENCE, WORLD WIDE DISTRIBUTION

3DCERAM SINTO French company located in Limoges and created in 2001 by C. Chaput and R. Gaignon.

- 26 employees
- at the heart of European scientific ceramic cluster CNRS, technical centers,

Grand opening in
May 19 Wallingford
Connecticut

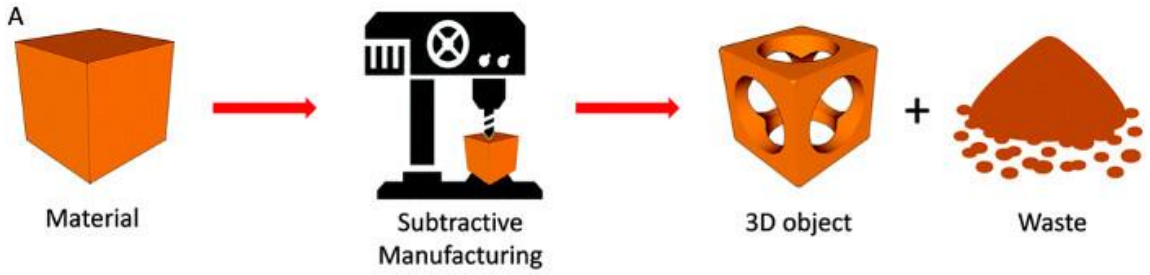


Sinto, Japanese company
Major share holder since 2017

- 4000 employees
- Revenue 2017 : 1 000 M€

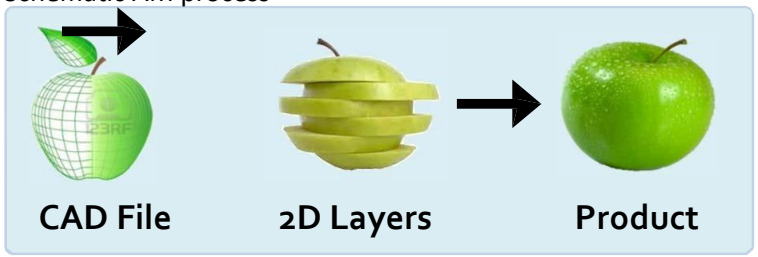
- Direct distribution
- Distributors (partners)
- Représentatives
- Subsidiaries

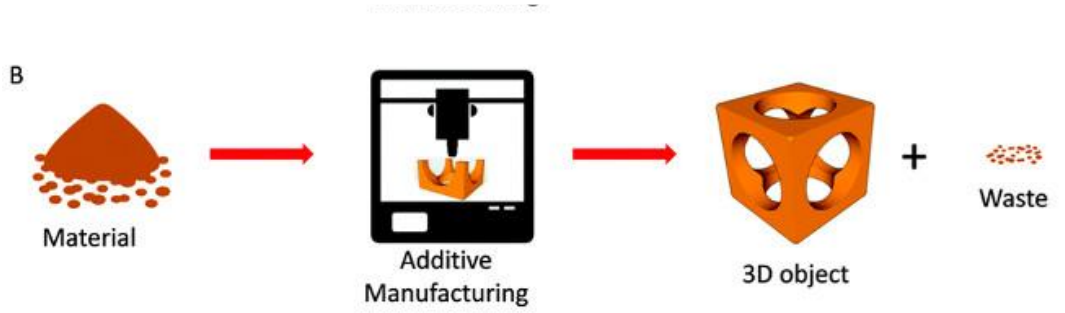
ADDITIVE VS SUBSTRACTIVE MANUFACTURING



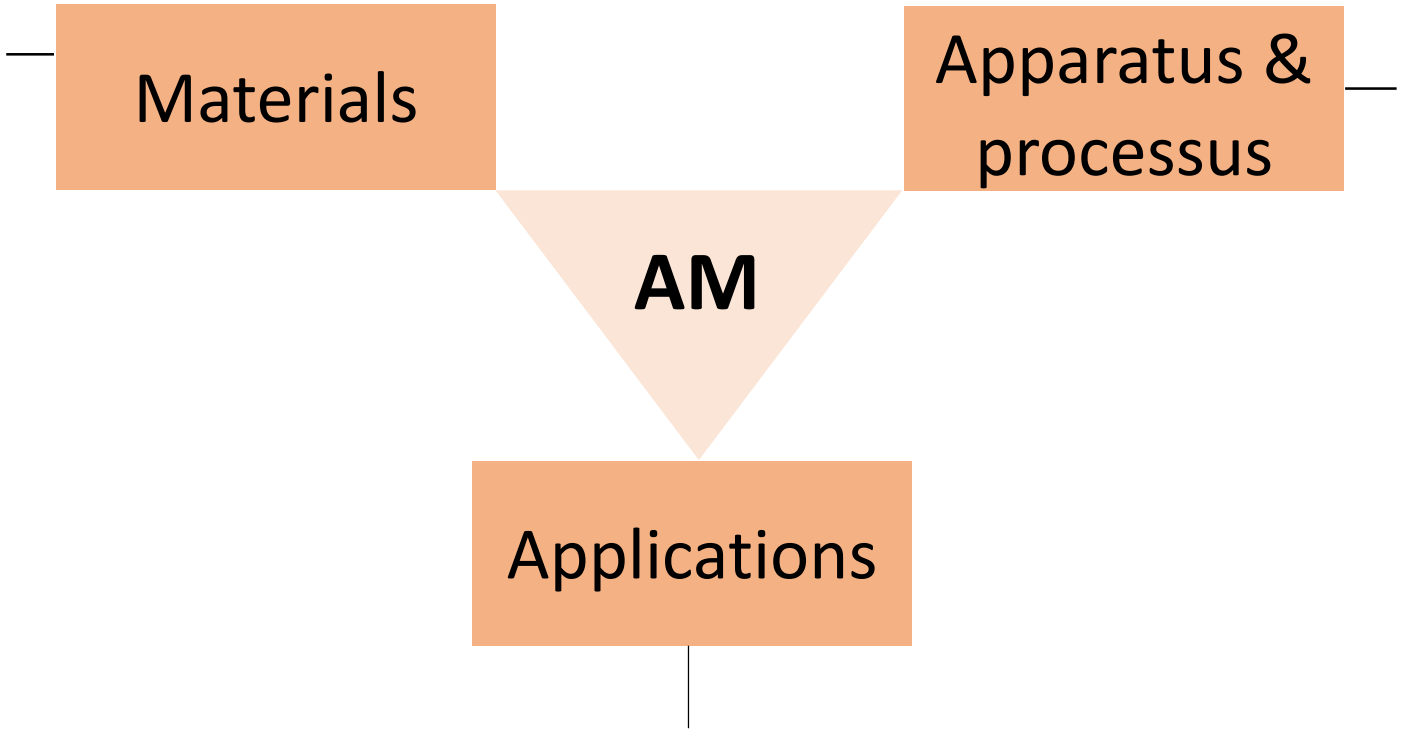
1. Usually substractive manufacturing is done on fired/sintered parts with fine diamond;
2. Substractive manufacturing is extremely precise but limitated by the design

Schematic AM process





AM CARTOGRAPHY



Fashion or real trend in Ceramic Additive manufacturing?

4 YEARS AGO…

1. Presentation of the technology at Ceramitec 2015
   - Advantages of this SLA technology
   - 3Dprinting machine suppliers (only 2), no end user showing parts,
   - More than 150 attendees at the conference
2. A wonderfull technology but the feeling was:
   - not for me…
   - we need real technology !
   - What are the markets ? Are there any markets?
   - Only for University …

3 YEARS LATER…

1. Ceramitec 2018
   - Many 3Dprinting products shown or display of 3Dprinting technology,
   - 3DPrinting is foreseen as the « renouveau » of technical ceramic,
   - Industrial end user are investing such as Bosch

2. What has changed????

Best Component Award at Ceramitech: a double reward for 3DCERAM-SINTO!

20 April 2018

3DCERAM received an honorary award for their services in the Technical ceramics field through the optimization of printed parts during the Technical Ceramics day at Ceramitech the 12th of April.

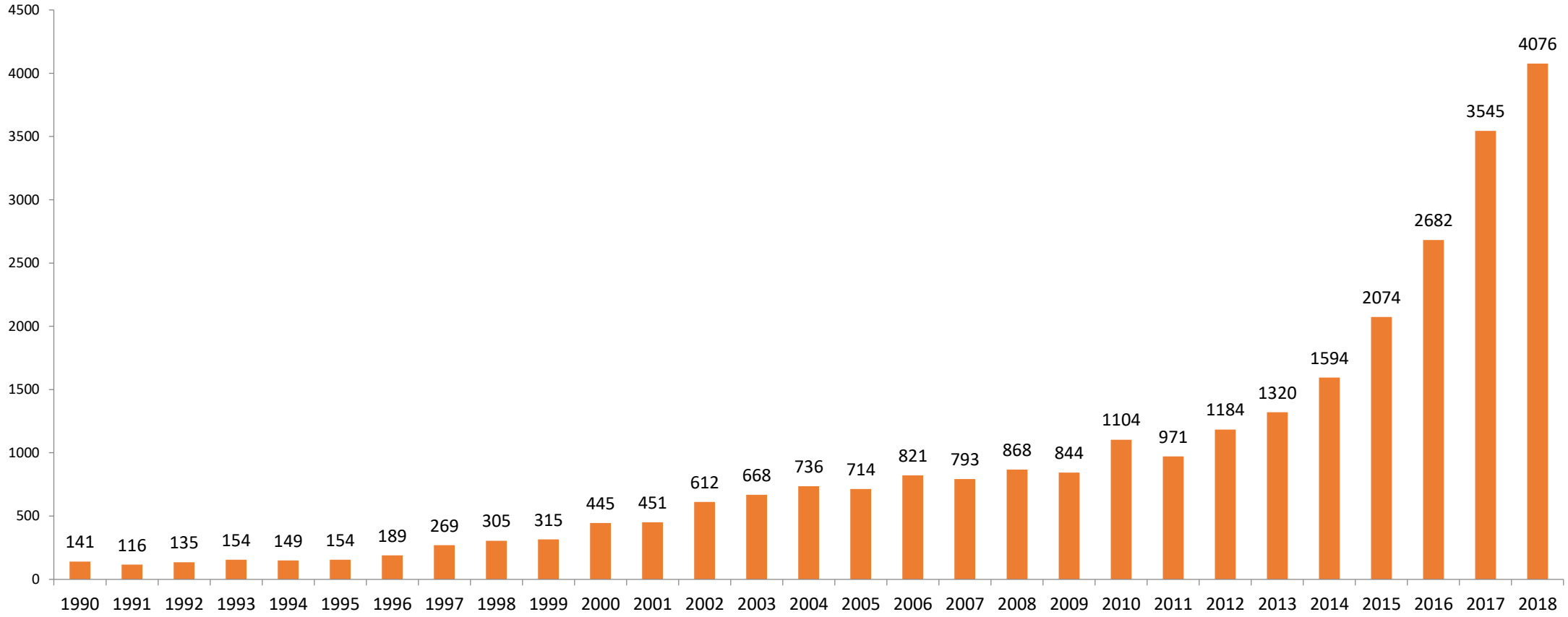
This services incorporates the companies expertise and experience in the domain of technical ceramics, 3D printing and aeronautical expertise to provide a choice of options and tools to produce innovative products, notably shaping optimization in general but also methods of calculating mechanical and thermic structures present in the parts.

This is a double reward for the company, as it was produced in house by the 3DCERAM-SINTO production team on behalf of Ceramic Application, the magazine who organize the competition. Produced in Alumina with optimized lightened structure, it highlights the many possibilities offered by printing on the CERAMAKER 900®

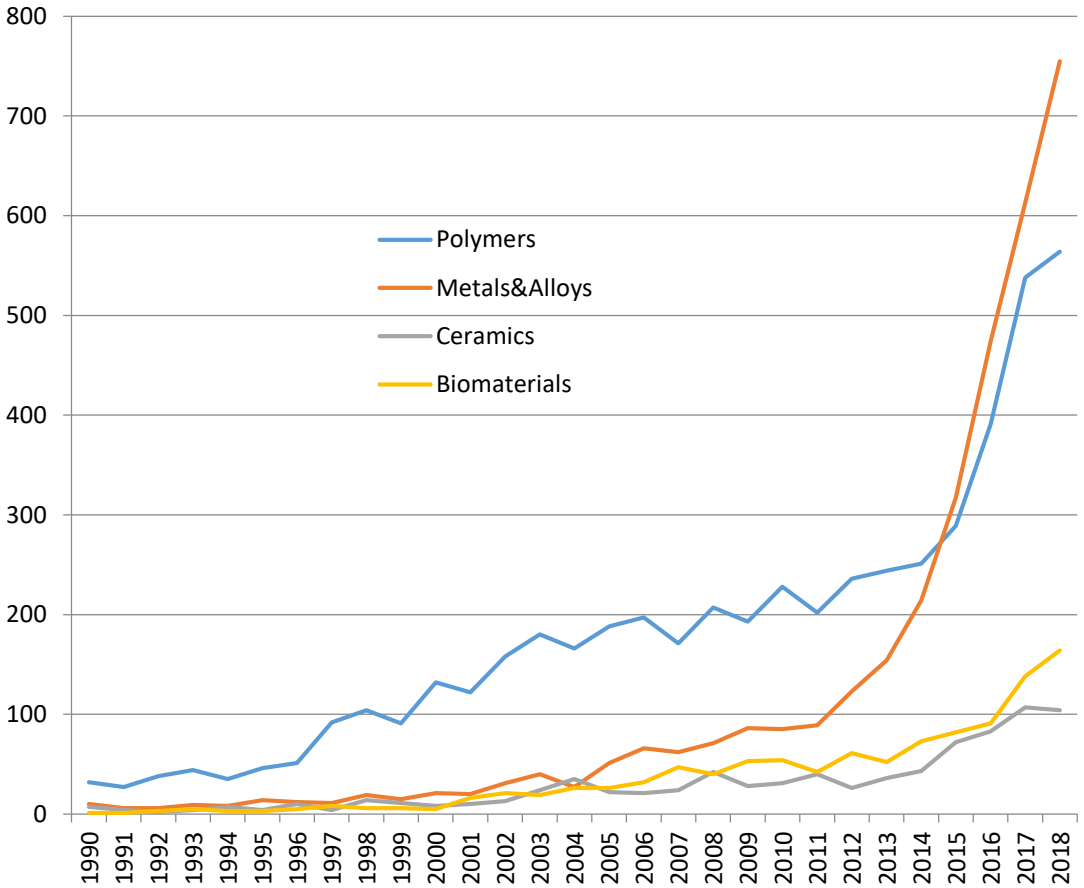
WHAT HAS CHANGED?

1. Markets are adopting this techno (IP is a good sign)
2. More and more feedstock available on the market
3. Design to performance (and not to process)
4. Technology:
   - maturation of the technology towards industrial tool,
   - Multi material printing

AM IP APPLICATIONS, 1990-2018



IP


800
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Ceramics
Biomaterials
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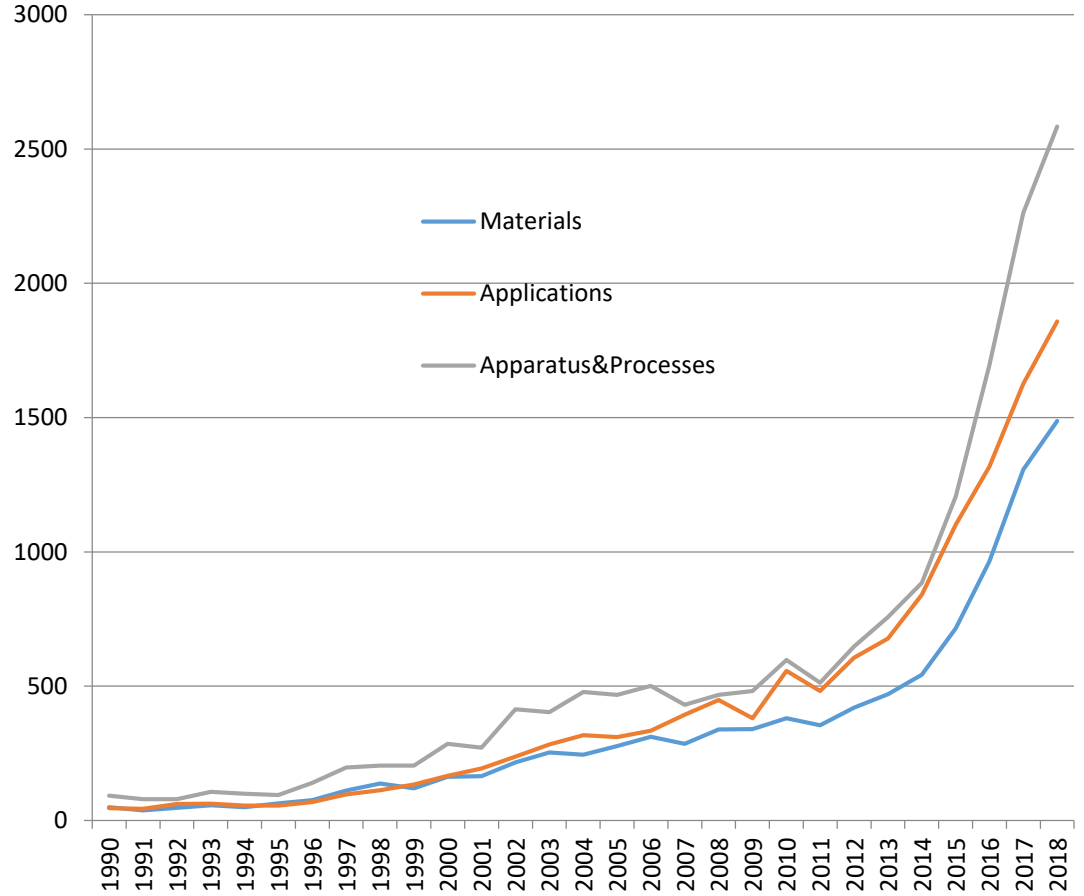
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Materials
Applications
Apparatus&Processes
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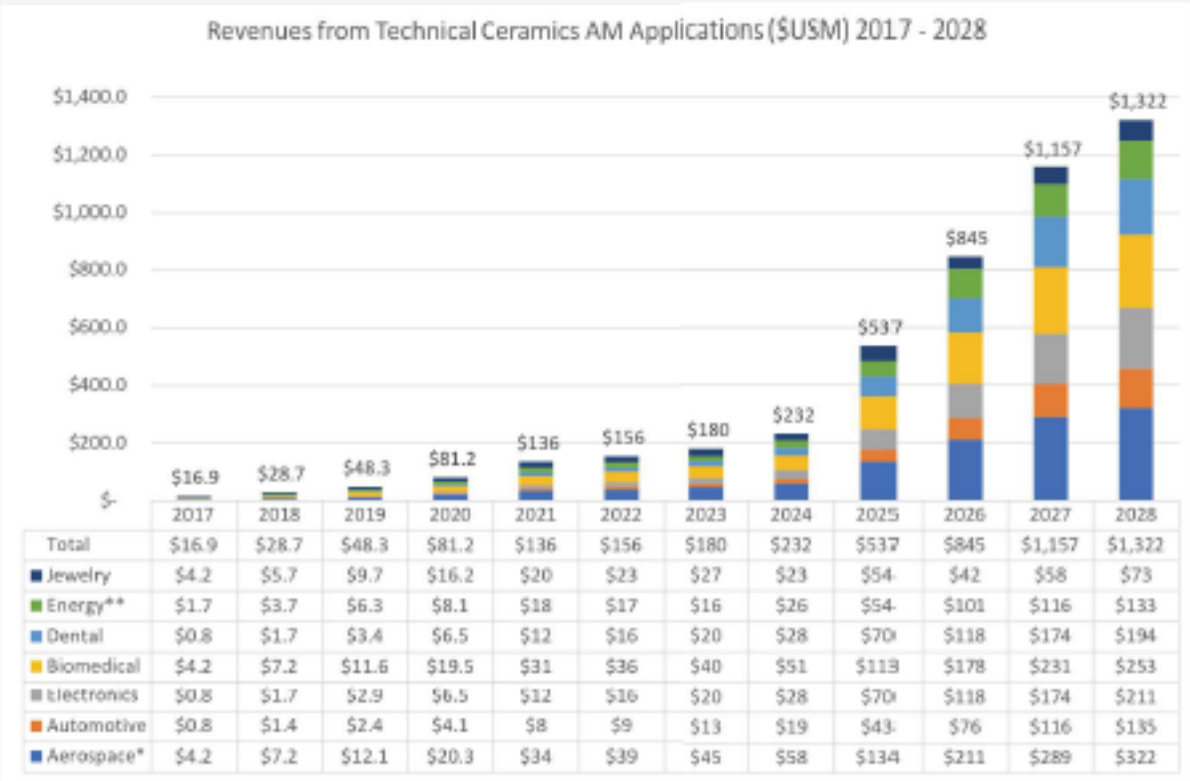
2015
2016
2017
2018

TECHNICAL CERAMIC AM MARKET

- According to the Smartech survey Market forecast by 2028 for **ceramic AM parts** will reach 1,322 million $
- Several Markets are starting to use more and more 3D parts (biomedical, space, energy, aeronautics…)
- Aerospace ceramic AM market value up to **322 million $**

Exhibit 4-10: Technical Ceramics AM Parts Value ($USM)



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total	$16.9	$28.7	$48.3	$81.2	$136	$156	$180	$232	$537	$845	$1,157	$1,322
Jewelry	$4.2	$5.7	$9.7	$16.2	$20	$23	$27	$23	$54	$42	$58	$73
Energy**	$1.7	$3.7	$6.3	$8.1	$18	$17	$16	$26	$54	$101	$116	$133
Dental	$0.8	$1.7	$3.4	$6.5	$12	$16	$20	$28	$70	$118	$174	$194
Biomedical	$4.2	$7.2	$11.6	$19.5	$31	$36	$40	$51	$113	$178	$231	$253
Electronics	$0.8	$1.7	$2.9	$6.5	$12	$16	$20	$28	$70	$118	$174	$211
Automotive	$0.8	$1.4	$2.4	$4.1	$8	$9	$13	$19	$43	$76	$116	$135
Aerospace*	$4.2	$7.2	$12.1	$20.3	$34	$39	$45	$58	$134	$211	$289	$322

Technologies

3D PRINTING CERAMIC OVERVIEW

Additive manufacturing offers a variety of technologies and process

BINDER JETTING / POWDER BED

ExOne

voxeljet

SLS

3D SYSTEMS

MATERIAL JETTING

XJET

Ceradrop MGI Group

FDM/EXTRUSION

Lynxter

nSCRYPT

3d-figo®

WASP

PHOTOPOLYMERISATION

SLA TECHNOLOGY

3DCERAM

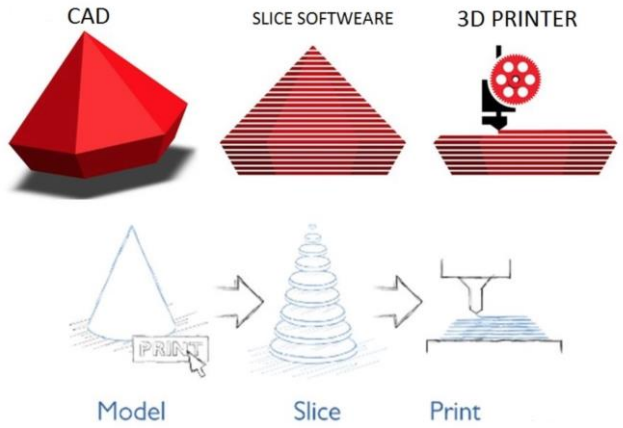
DLP TECHNOLOGY

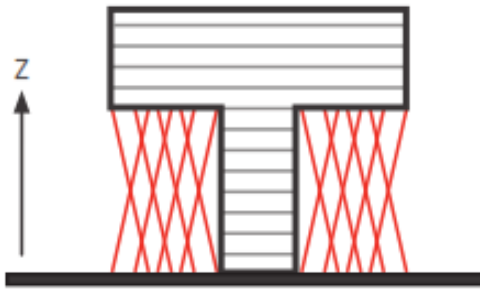
LITHOZ

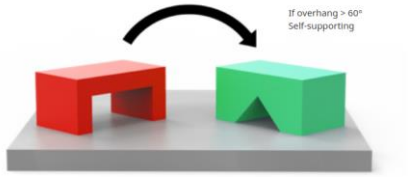
ADMATEC Additive Manufacturing Technologies

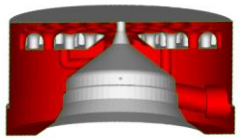
DDM SYSTEMS

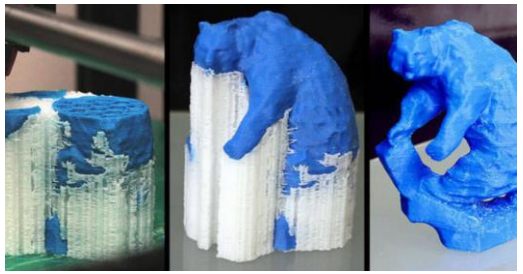
3D PRINTING

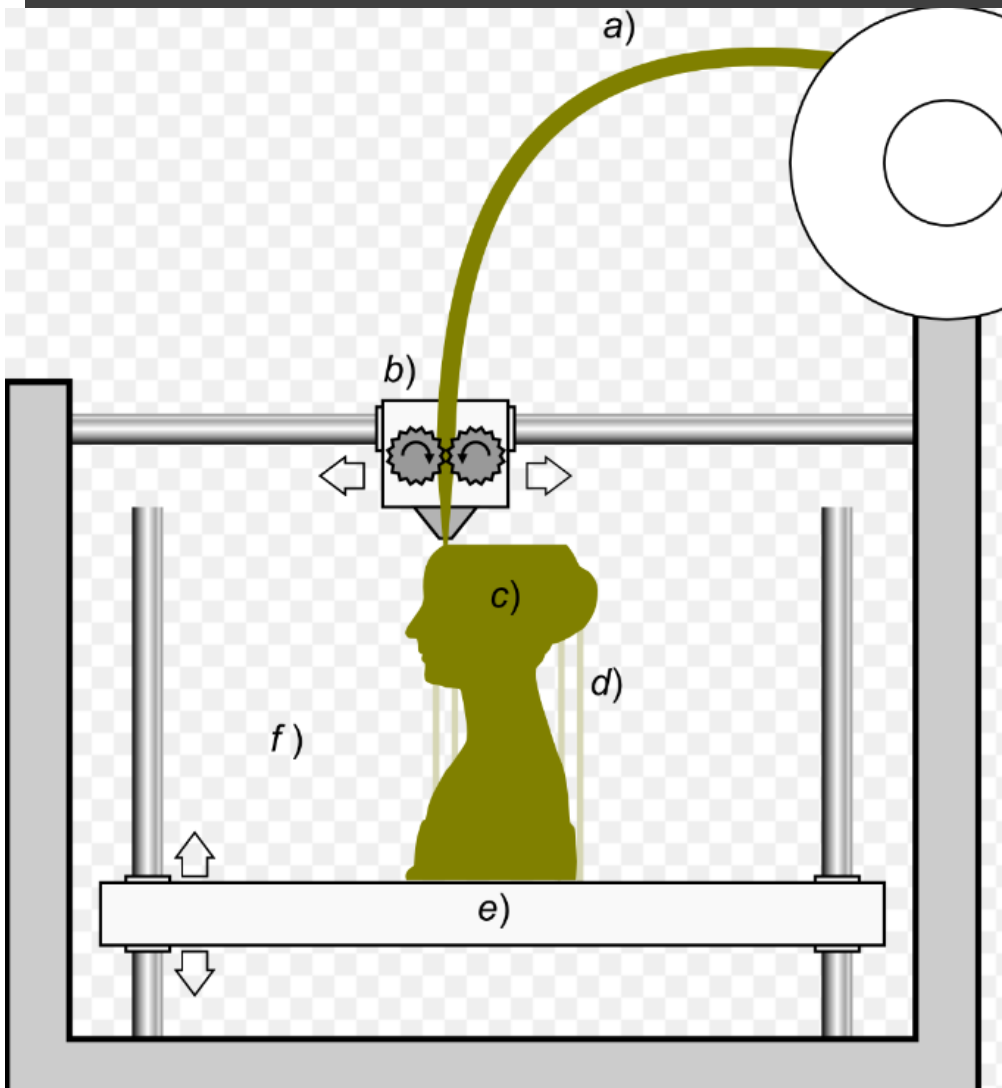

CAD
SLICE SOFTWEARE
3D PRINTER
PRINT
Model
Slice
Print


Z


If overhang > 60°
Self-supporting

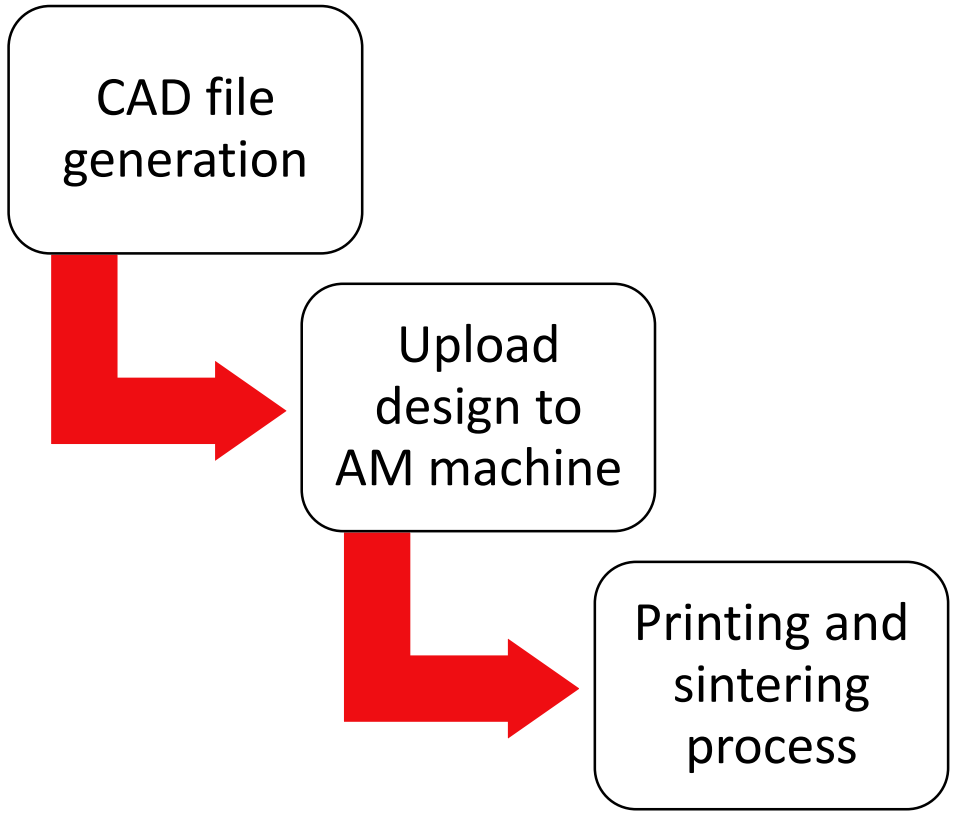





a)
b)
c)
d)
e)
f)

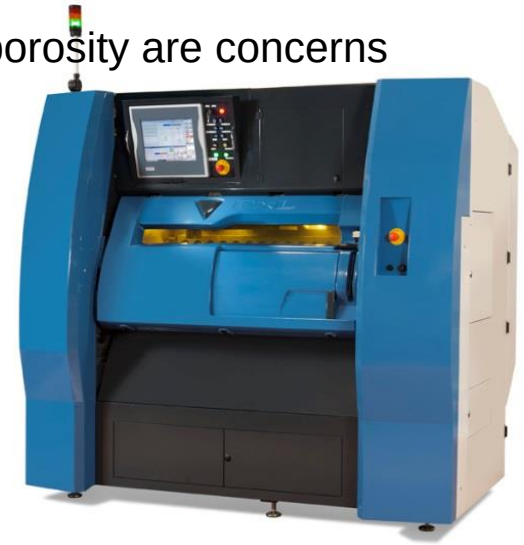
3D PRINTING OF CERAMIC

- Consists of 1 stage

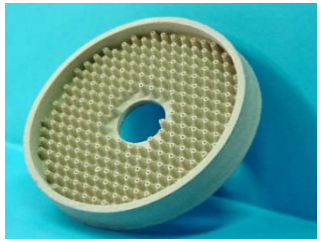


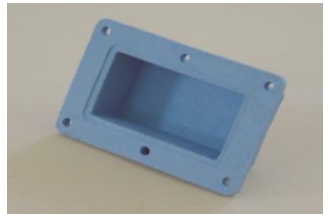
SLS

- **Selective Laser Sintering**: thermal energy (laser-electron beam) selectively sinters regions of a powder bed
  - One step process
  - Low properties, low density
  - Doesn't require supports
  - Shrinkage,
  - poor surface finish, porosity are concerns
  - No market known



Phenix systems, Riom, France

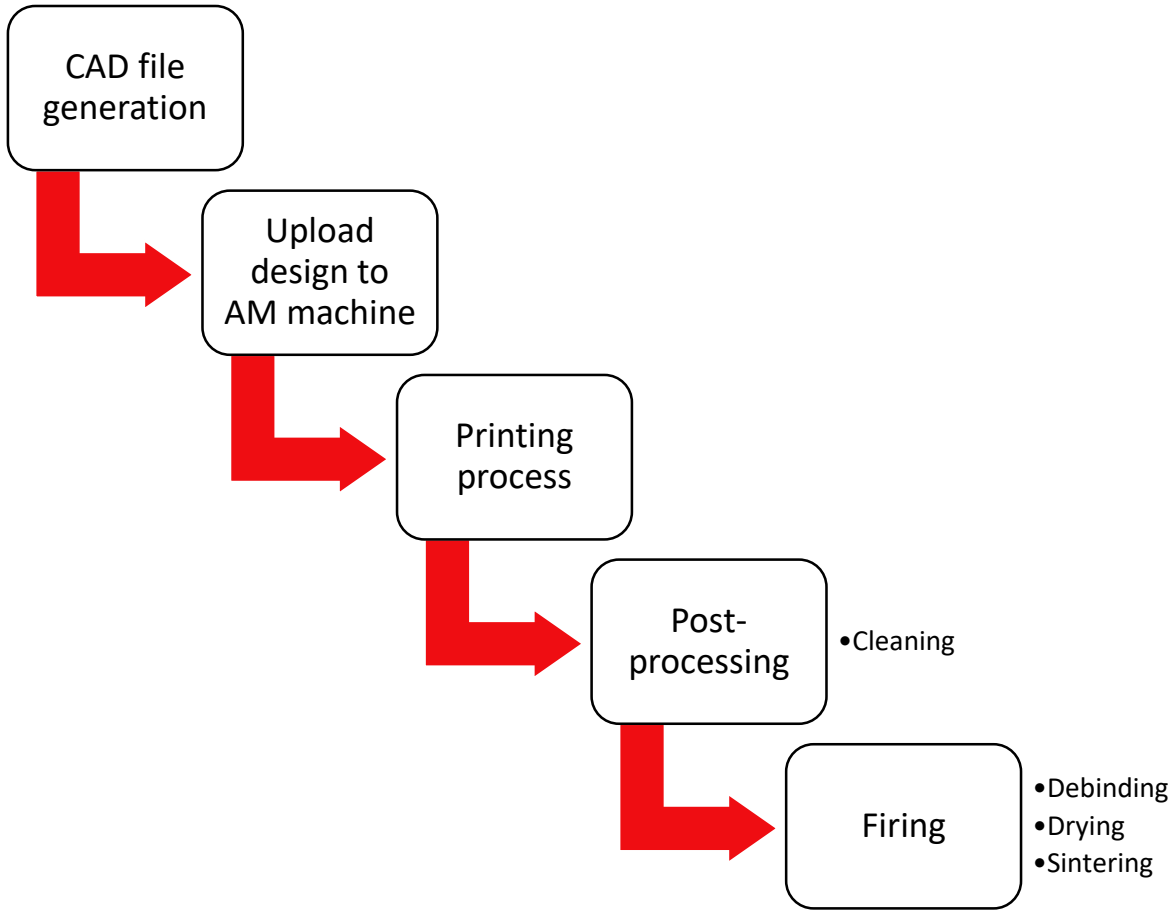




IRCER, Limoges, France

3D PRINTING OF CERAMIC

- Consists of 2 general stages- “forming” & firing stages

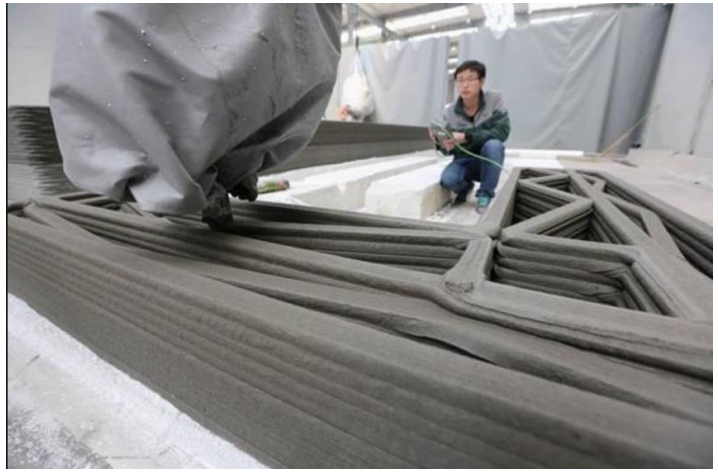


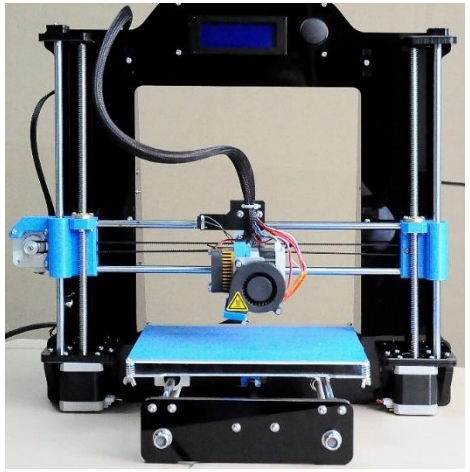
EXTRUSION

- Primarily for traditional ceramics (clays, cement, etc.)
- Can make thicker parts

FDM / EXTRUSION

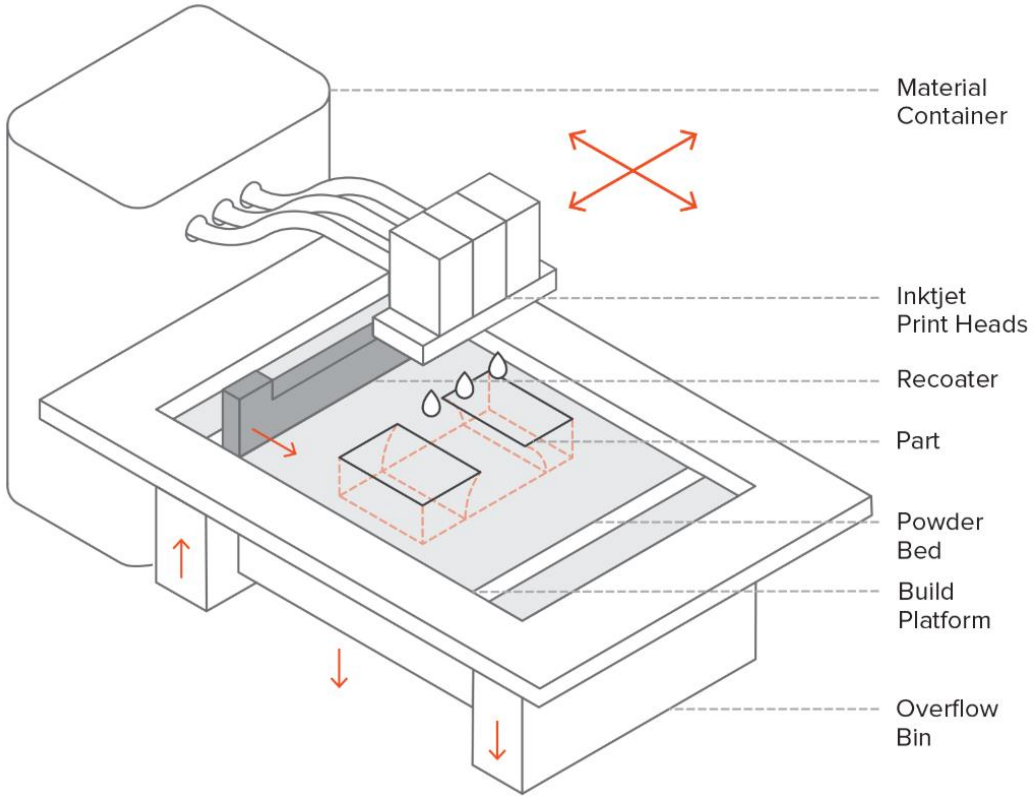
- Fused Deposition Modeling (FDM) –Filament based – thermoplastic binder with ceramic particles
- **Material extrusion** (material is selectively dispensed through a nozzle or orifice)
  - Low definition
  - Low mechnical property for technical ceramic
  - No real market in technical ceramic but building





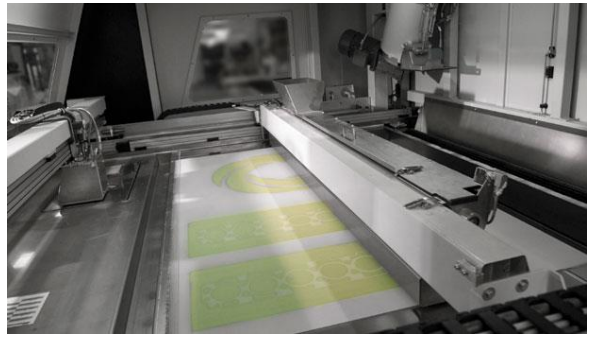
BINDER JETTING

- Powder bed surface leveled, nozzle deposits binder (“glue”) over the powders
- Print bed moves down, levels another layer of powder, etc

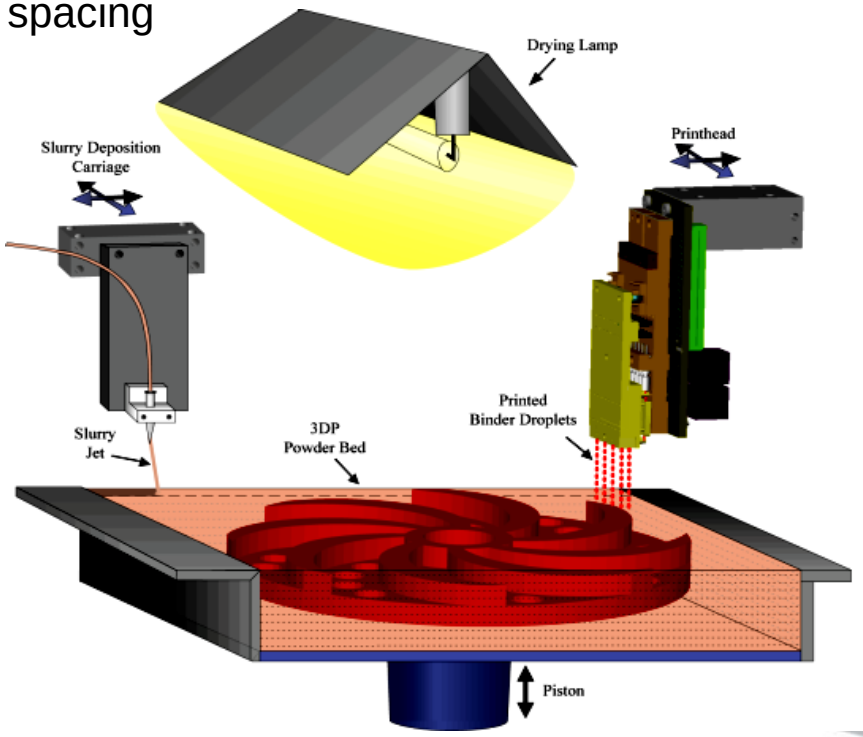


BINDER JETTING

- **Binder jetting** : a liquid bonding agent is selectively deposited to consolidate a powder bed
  - High porosity parts
  - Fast print speed
  - Low density final part
  - Unique parameters- droplet size & spacing
  - Big parts
  - Low detail level
  - Mould industry for foundries



ExOne, Houston, USA



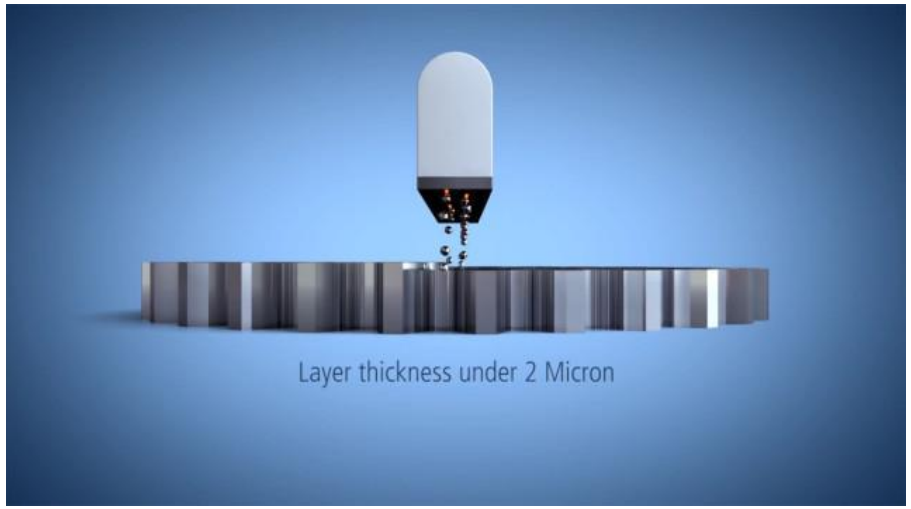
M. Cima, MIT, USA

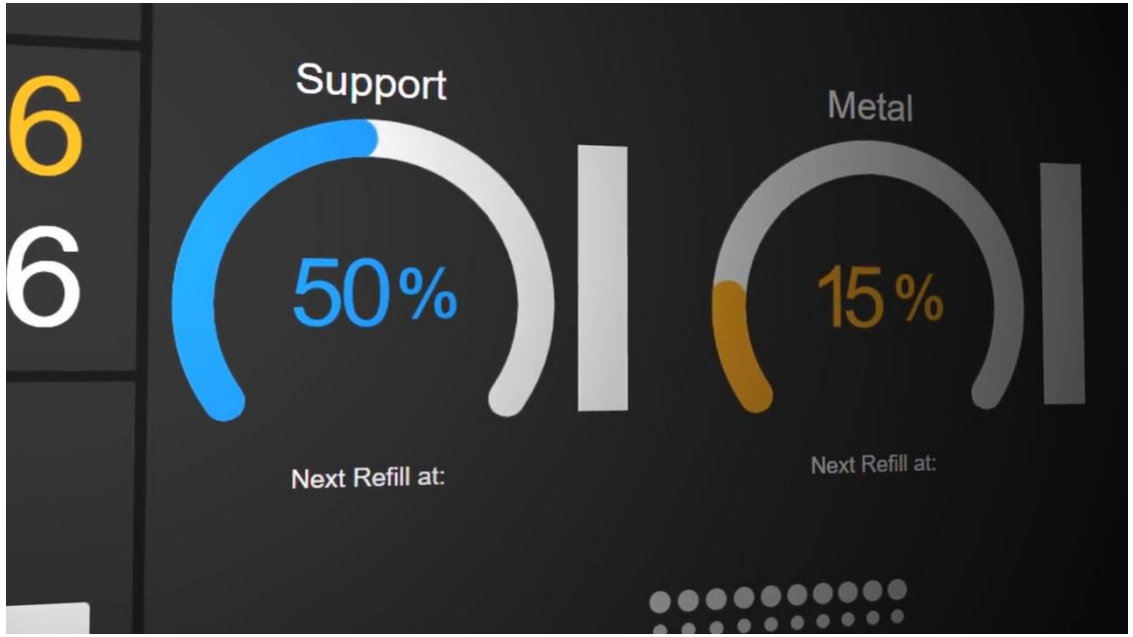
Voxeljet, Friedberg, Germany

MATERIAL JETTING

NanoParticle Jetting

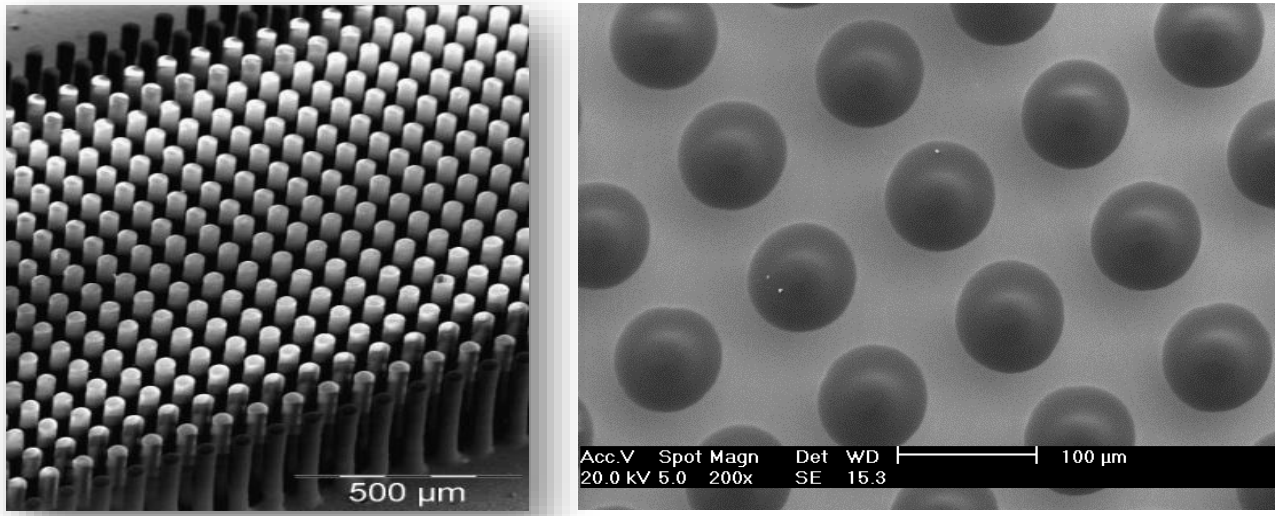
- Inkjet print heads distribute material
- Nozzles spray fine droplets of build & support material
- Nano sized ceramic particles used
- Parts are sintered after printing





MATERIAL JETTING

- **Material jetting** (Ink-jet printing): droplets of build material are selectively deposited
  - High precision
  - 2D+
  - Electronic industry

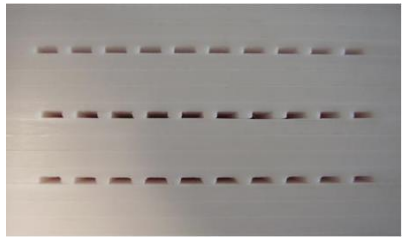


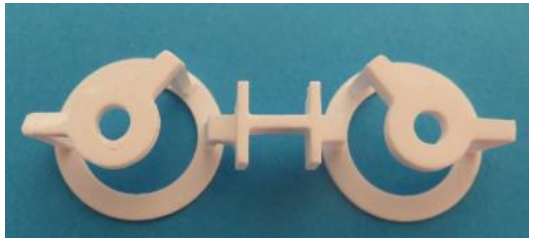
SPCTS, Limoges, France

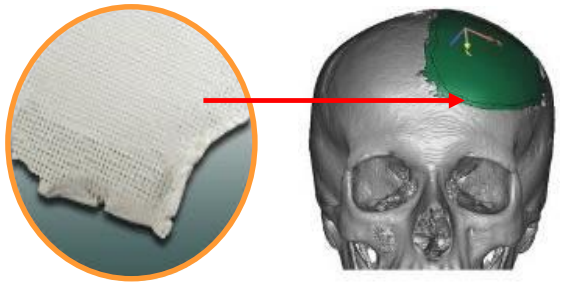
Ceradrop, Limoges, France

3D PRINTING TECHNOLOGIES

- **Photopolymerization (stereolithography):** reactive system is selectively cured by light-activated polymerization







SLA PROCESS: 2 STEPS

- Preprocess:
  - Creation of the CAD
  - Export to STL file and slicing

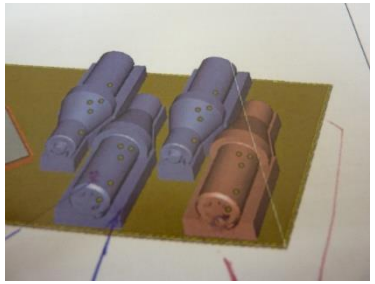
STEP 1

- Printing layer by layer.
- Post process
  - Debinding and sintering (shrinkage)
  - Final process

STEP 2

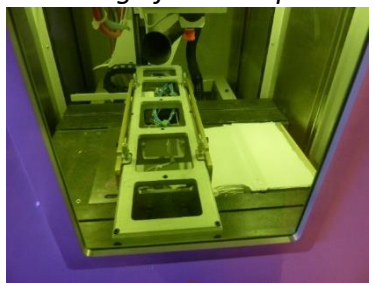
1 PREPROCESSING

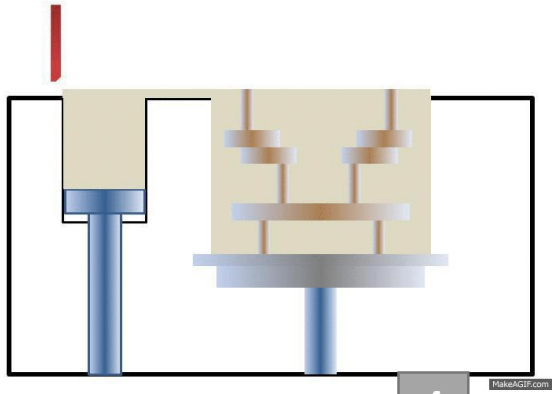
CAD file preparation



2 3DPRINT

Printing of a batch parts



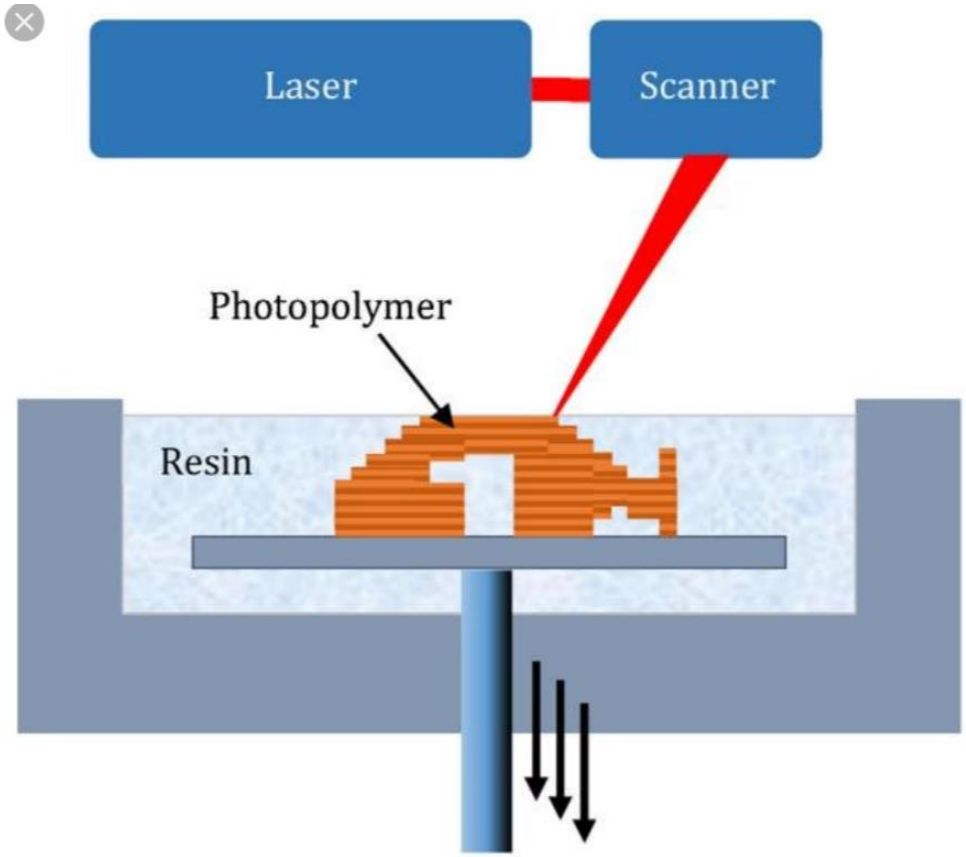


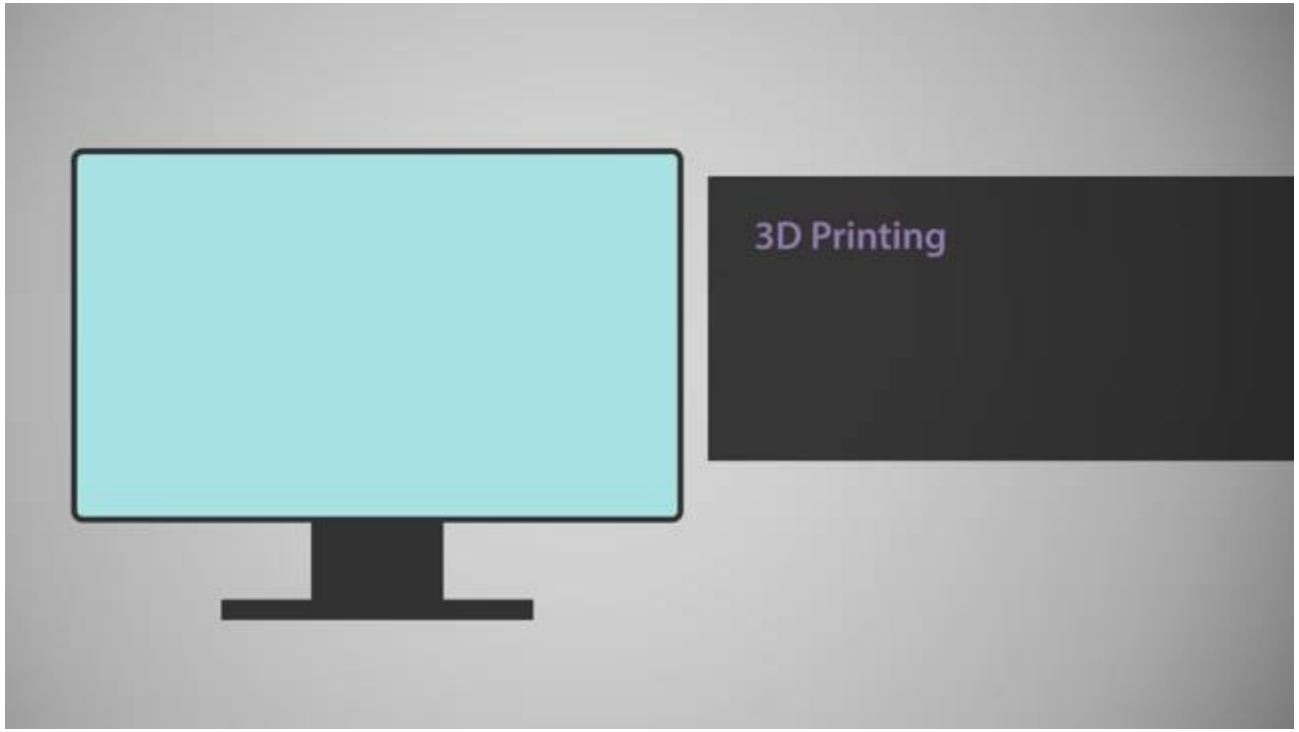
3 CLEANING

Work under hood

4 FIRING

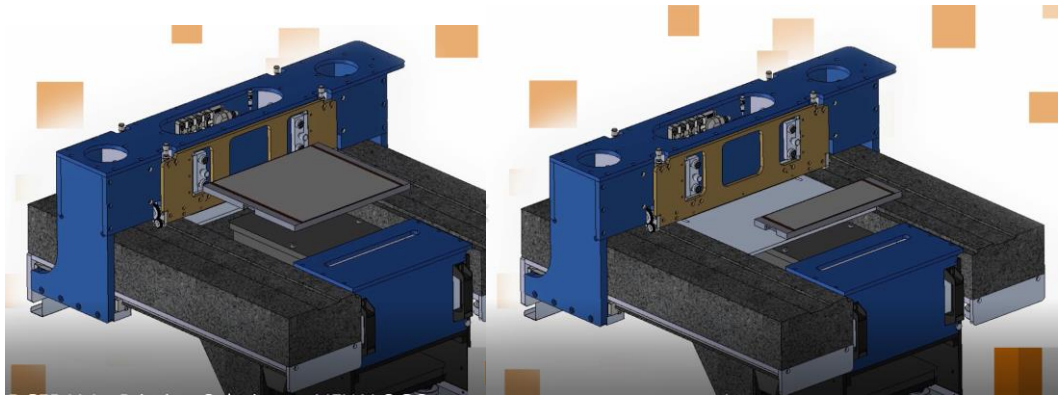
Debinding & sintering on kilns

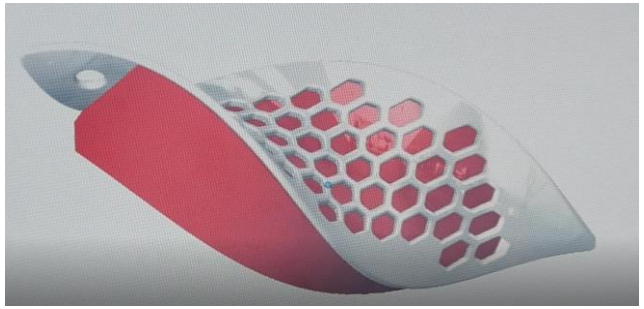

Laser
Scanner
Photopolymer
Resin

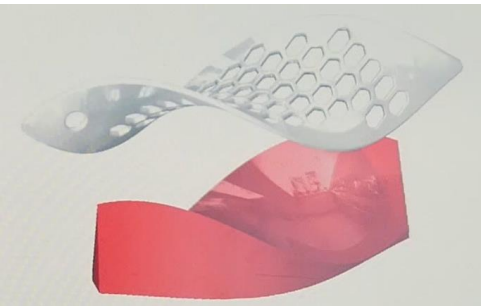

3D Printing

3DCERAM ADVANTAGES

1. **Print surface** from 100*100 to 600*600
2. **High Resolution** of 35µm
3. Same UV power EVERYWHERE on the print surface →same shrinkage
4. **Freek link** support
5. High surface quality
6. High loading content and **low shrinkage** during firing (15 to 20%)
7. Open system







SO WHY CHOOSE AM?

- Traditional Methods
  - Long lead times
  - Additional machining or processing may be required
  - Investment in equipment may be too much for immature designs
  - May limit part designs
- Additive Manufacturing
  - Easily fabricate complex geometries
  - Faster lead times
  - Tool free
  - Many parts can be made simultaneously (small)
  - Unattended operation

BUT!

- Traditional Methods
  - Scalability
  - High volume costs more economical
  - Better for simple designs
  - Technology is well understood
- Additive Manufacturing
  - Need for support structures
  - Still involves some manual labor (cleaning, etc.)
  - Material can be (very) expensive
  - Technology is in its infancy

QCM

1. One technology?
2. Advantages per technologies?
3. Are the different technologies in competition?

3D PRINTING CERAMIC OVERVIEW

Additive manufacturing offers a variety of technologies and process

PHOTOPOLYMERISATION

SLA TECHNOLOGY

3DCERAM

DLP TECHNOLOGY

LITHOZ PRODWAYS GROUP ADMATEC Additive Manufacturing Technologies DDM SYSTEMS

More than 150 machines in operation

BINDER JETTING / POWDER BED

ExOne voxeljet

SLS

3D SYSTEMS

MATERIAL JETTING

XJET

Ceradrop MGI Group

FDM

Lynxter CRYPT 3d-figo® WASP

Markets

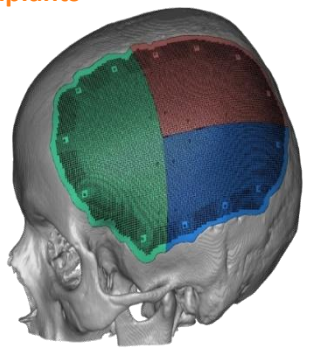
Stereolithography
applied to advanced ceramic

Aerospace

Energy

Biomedical

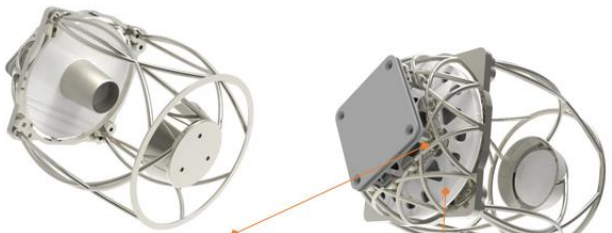
Bone substitute and implants



Luxury

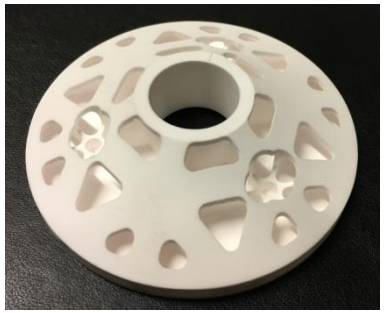
Bone substitute and implants

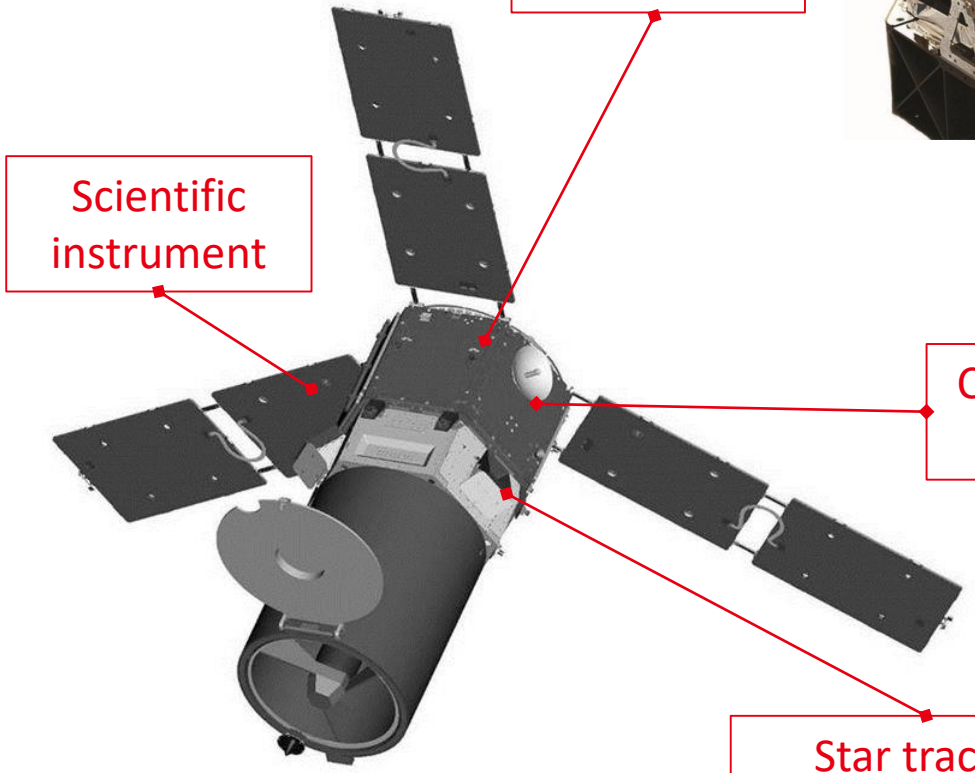
CERAMIC AM – FOCUS ON PRODUCTS (FUNCTION)

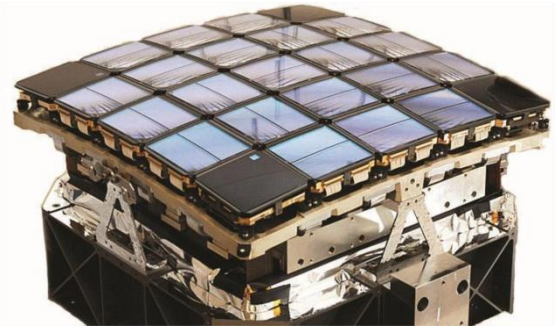


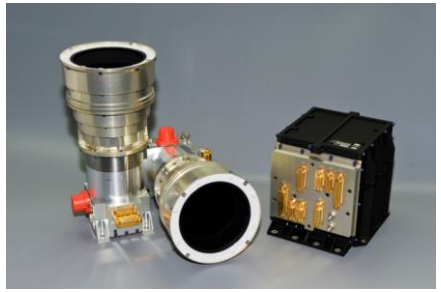
Integrated bipod:
- ✓ Easier assembly operation
- ✓ High compactness

Multi-material integration:
- ✓ Combining high performance ceramic mirror and lightweight metal structure
- ✓ Ultra-stable: low thermal expansion (very close CTE)



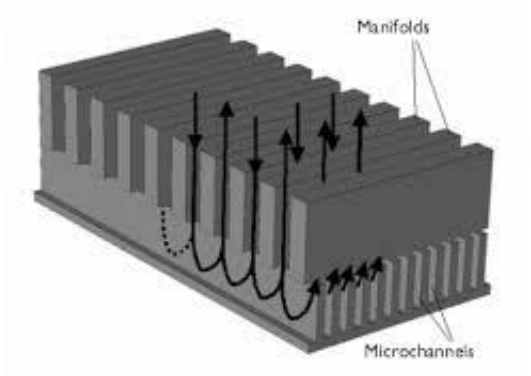






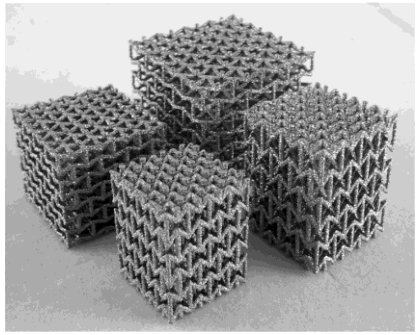
MANY OTHER APPLICATION

Heat exchange applications



Products – Conformal heat exchanger include micro channel, double wall design and conformal cooling.
AM ceramic materials - Alumina, Silicon Nitride, Zirconia.
CeraMaker benefits – Monolithic design to reduce thermal resistance and increase the compactness of the thermal solution.

Military applications

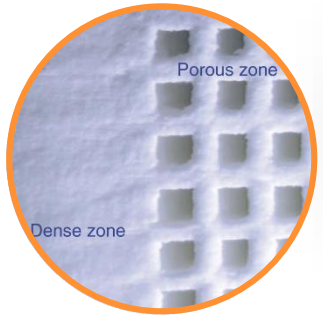


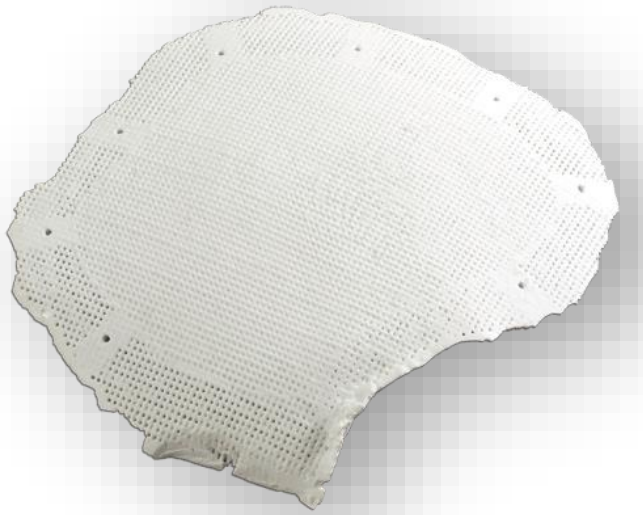
Products – Auxetic* structure base on lattice design optimization for new type of shield.
AM ceramic materials - Alumina, Silicon Nitride.
CeraMaker benefits – Disruptive and innovative design of shield.
**an auxetic strucrure has a negative Poisson ratio, It's better for the penetration resistance (ballistic).*

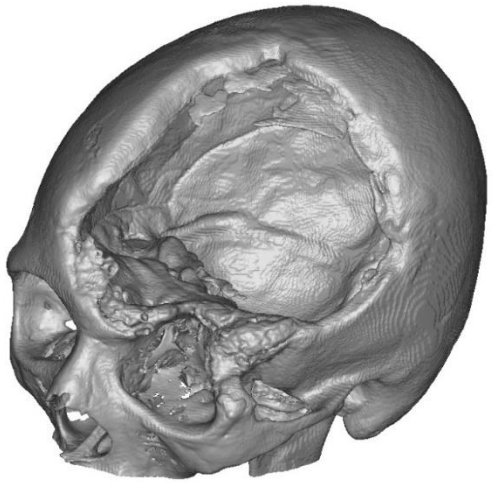
STUDY CASE TURBINE BLADES

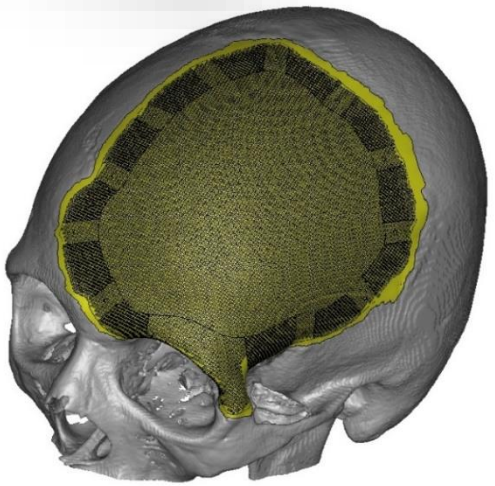
BIOMEDICAL IMPLANTS

- **Customized** implant
- No fragile structure but a 3D one
- **Porous and dense** areas **combined** on the same implant
  - Perfect Ostheo integration
  - Sturdiness wherever it is needed
- Holes in the design for temporary fixation
  - Surgeon goes faster,
  - **less down time**,
- Rugosity on the outside to “fix the skin”

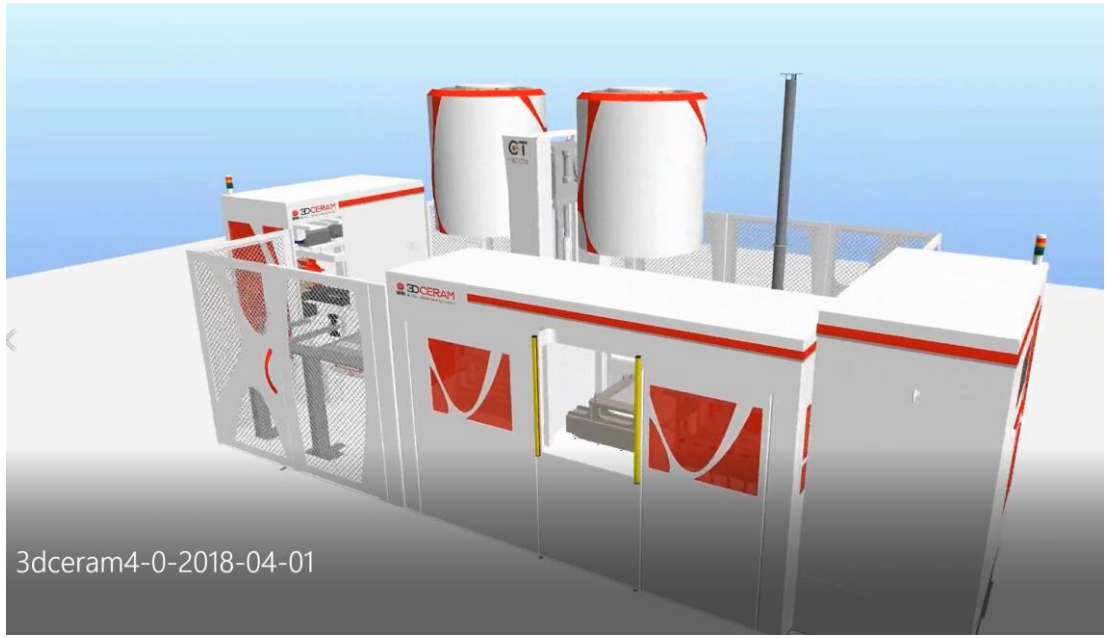








3DCERAM 4.0: AUTOMATED 3D PRINTING LINE



MORE CAPABLE.
MORE PROFITABLE.
MORE USER-FRIENDLY.

We develop technology to enable companies to succeed.

QUESTIONS

1. Opportunity or threat? An alternative technology or breakthrough technology?
2. Level of maturity of the AM technology?
3. Norms? Health, Environment, Safety,
4. Choice of material (various kind of ceramic)
5. ROI
6. Impact on current company organisation?

LEVEL OF MATURITY

1. Same quality of products as traditionnal technologies
2. Machines are robust (process is qualified by premium player, GE, Bosch, Morgan…)
3. Design to performance, design to technology is still an issue: necessity of an AM application engineer
4. The maturity is highly depending on the application,
5. Still a niche market due to price level

NORMS? HEALTH, ENVIRONMENT, SAFETY,

1. Norms: still under discusion. Several technologies, different norms
2. HSE:
   - Powder process, there is a risk already taken into consideration by national regulation
   - SLA, FDM, Extrusion: no issue for the health, but more complicated for the waste treatment (same as CIM)

CHOICE OF MATERIAL (VARIOUS KIND OF CERAMIC)

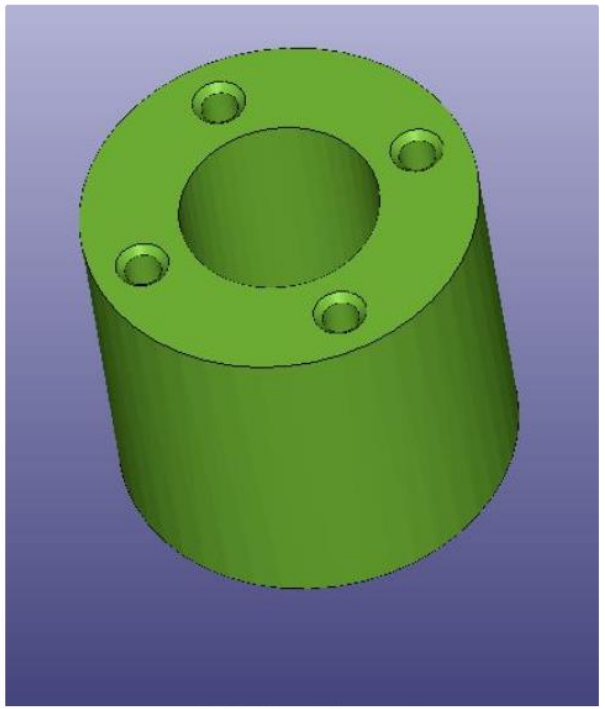
1. It depends…
   - Most of machine supplier does not allow technical ceramic supplier do do their feedstock:
     - Inkjetting: machine exclusive proprietary solution
     - Powder bed
   - Some exceptions:
     - Schunk has developped its own powder (powder bed)
     - Extrusion and FDM machine suppliers and feedstock suppliers are not the same companies
     - SLA: 3 solutions:
       - Machine suppliers supply the feedstock
       - Machine suppliers developp the feedstock and printing parameters with customer ceramic
       - Customer is developping its own feedstock

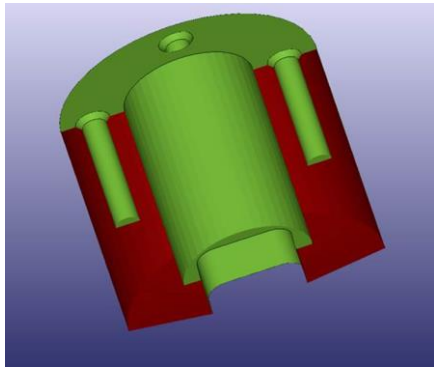
ROI

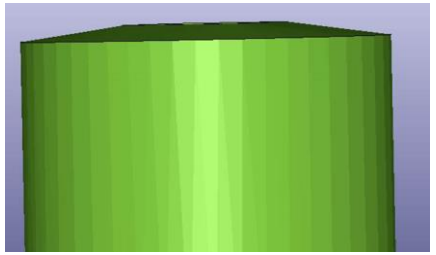
Estimation report construction

Part: On Semi ceramic sample

Material and aspect: Alumina, As Fired (without any post treatment)







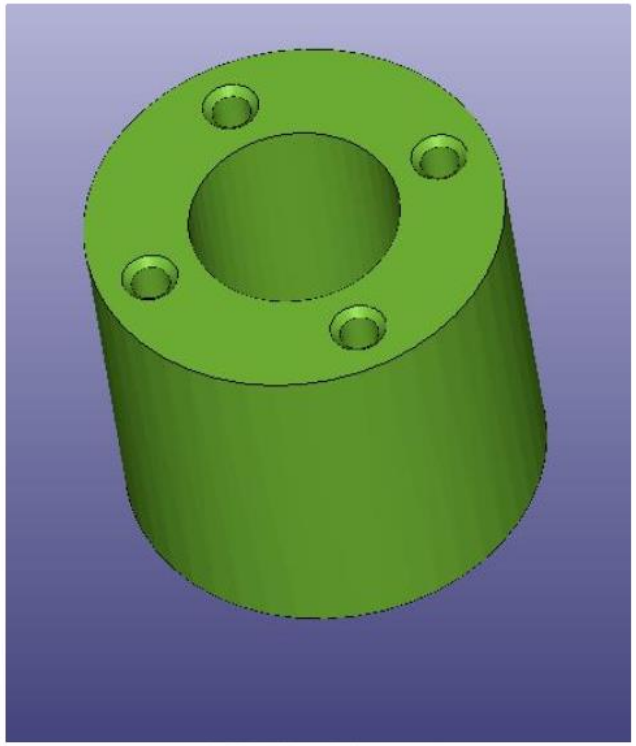
CAD File of the part

ROI

Estimation report construction

Part: On Semi ceramic sample

Material and aspect: Alumina, As Fired (without any post treatment)



CAD File of the part

1. 600 parts per month
2. Currently done by maschining: 50$
3. With the C900 : 30$ each
4. With the C3600: 17$ each

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3D IMPACT ON THE ORGANISATION OF YOUR COMPANY

1. It is a global project. It means a decision from the board as it changes many aspect of the organisation
2. The competencies (production, sales, R&D…)
3. The Supply chain,
4. Stock level,
5. Decision makers,

Merci!

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