Open Innovation Platform
University - Enterprise
Collaboration

Overview

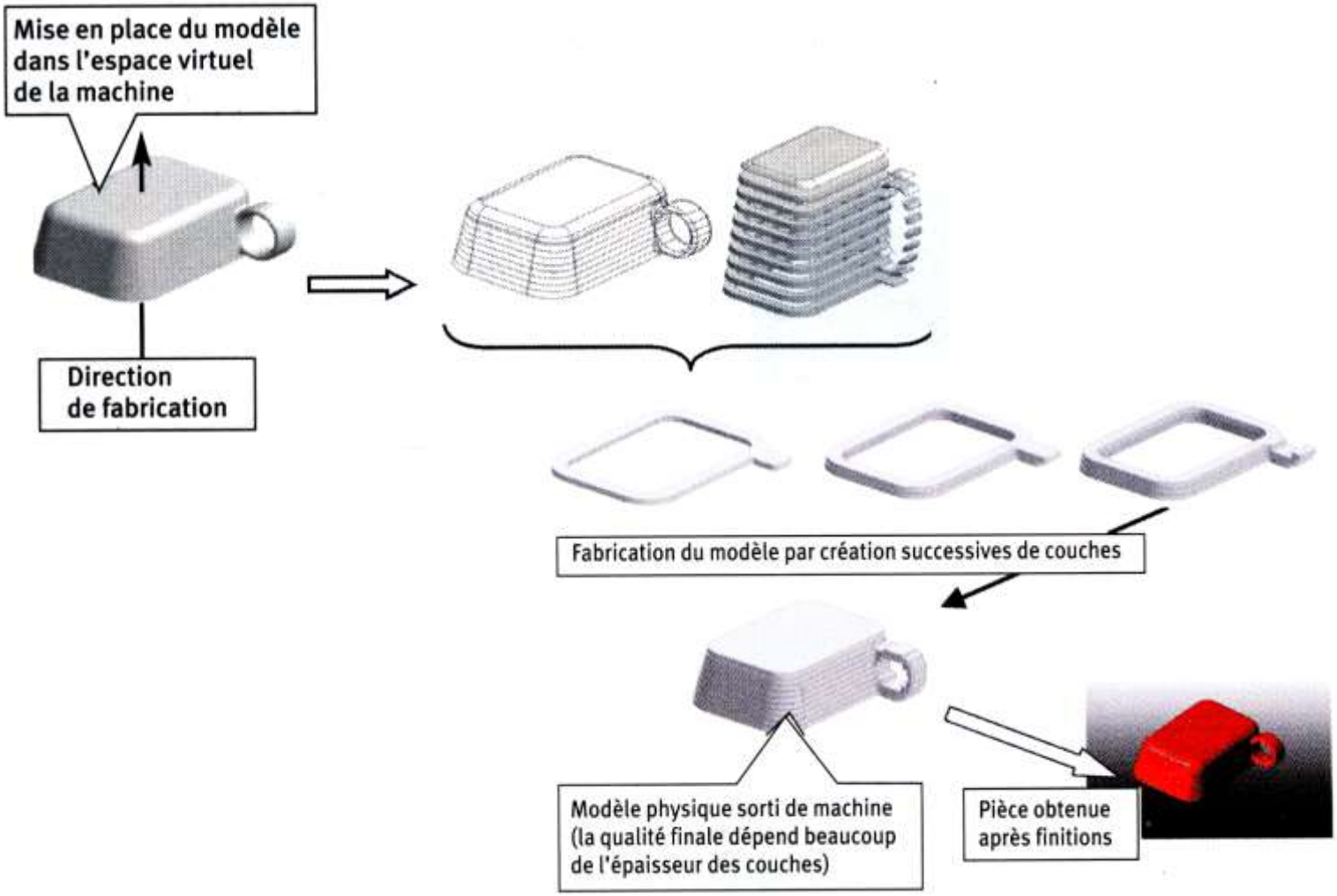
Additive Manufacturing and 3D Printing Technologies

Moscow – Vladimir Workshop
November 14-19, 2016

Jean-François BOUJUT
Grenoble INP

Co-funded by the
Erasmus+ Programme
of the European Union

Additive Technologies (Fabrication by layers)



AM vs 3D Printing

Main objectives of 3D printing: Obtain a physical model of a part from a CAD model without any shape limitation

- Rapidely
- Cheap
- With no specific tooling

Main objective of additive manufacturing: produce parts that cannot be manufactured with another technology

- Reduce waste
- Better performance
- New materials

Classifications

Raw Phase

- Liquid
- Poudre
- Filament
- Solid board
- Gell

Material

- Polymer resin
- Thermoplastic
- Ceramic
- Sand
- Wood
- Metal
- Bio / edibale
- Plaster
- Living mater

Physical Principal

- fusion
- bounding
- extrusion
- polymerisation
- cutting+bounding
- Culture

Energy

- UV
- Laser
- thermal
- chemical
- mecanical
- Electron beam

Layer generation

- Hatching
- contours
- surface
- Jetting

Materials	Technologies		
	Parts built through polymerization	Parts built through bonding agent	Parts built through melting
Ceramic		BJ	LM
Metal			EBM
Sand			
Plastic	SL, PJ		FDM, LS
Wax			MJ *

Lower	Durability	Higher
Smoother	Surface finish	Rougher
Higher	Detail	Lower
Prototypes | Indirect processes	Application	Functional parts

Source: https://www.additively.com

Binder Jetting

Poudre | Plaster | Bounding | Chemical | surface

Process sequences:

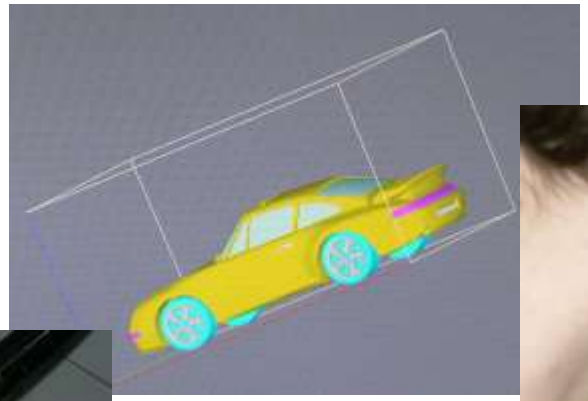
- Deposition of plaster and polymer layers
- Cleaning
- Post processing (reinforcment with additional impregnation)

Quality:

- Precision (0,1mm)
- Details (0,2mm)
- No support
- Good resistance depending on thickness
- Full Color
- Surface finish
- Pas de parois très minces (2 à 3mm)

(Sources Z-Corporation)

Binder Jetting



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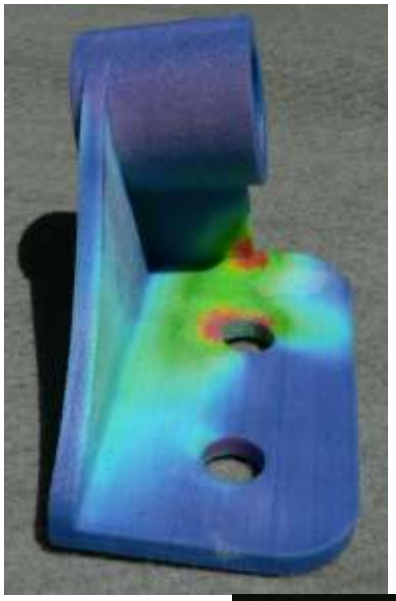
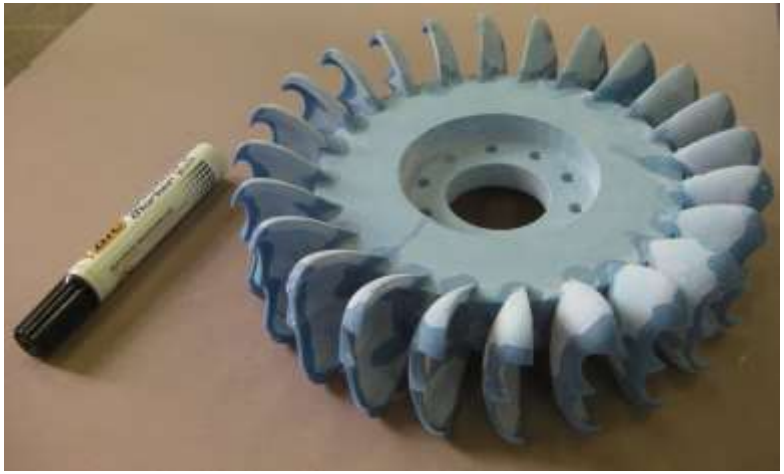
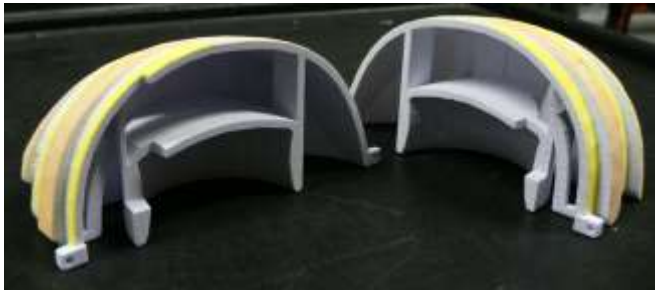
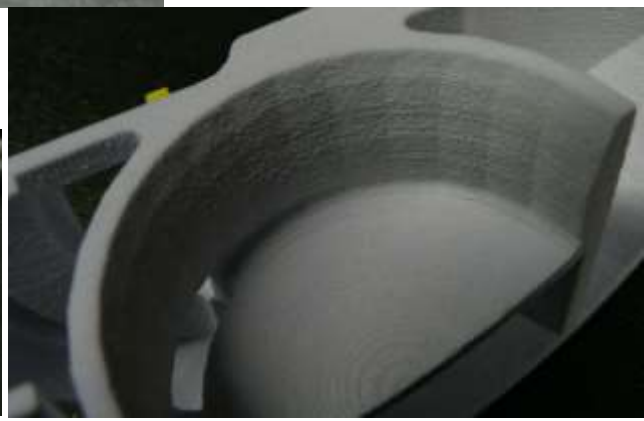


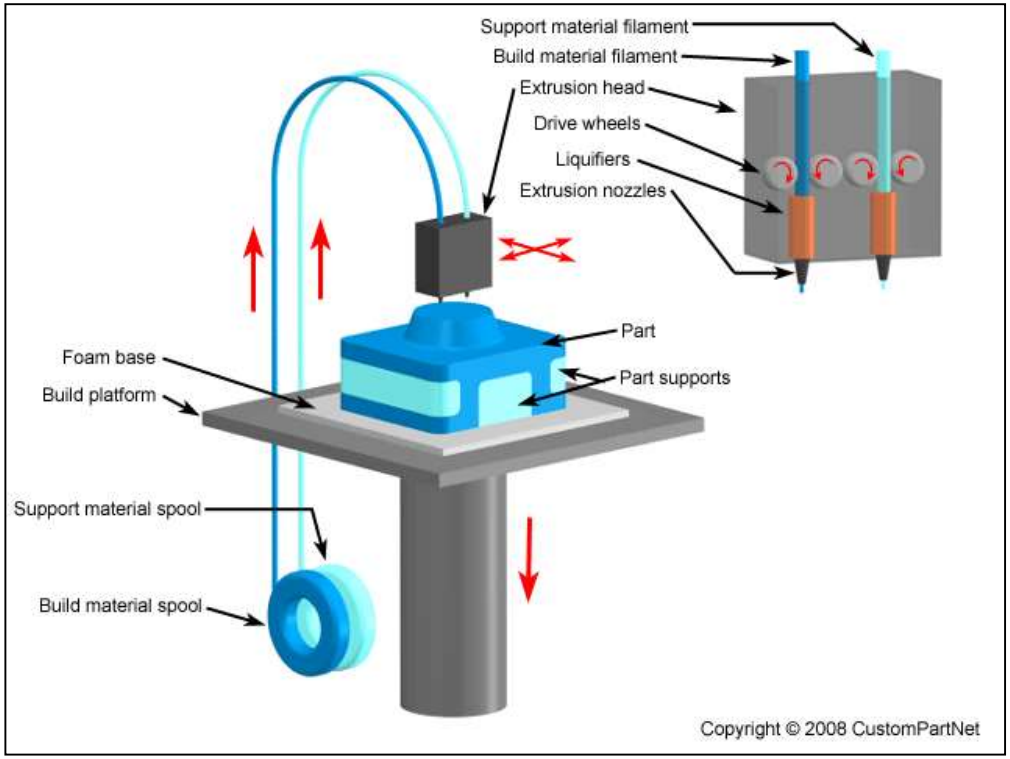






Fused deposition model: FDM

Filament | Thremoplastic | fusion | Thermal | Hatching



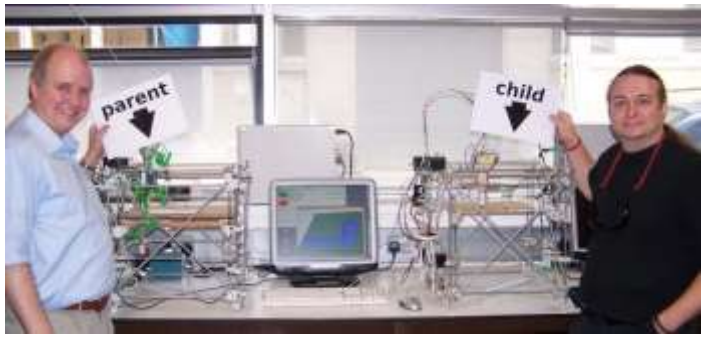
Process sequences:

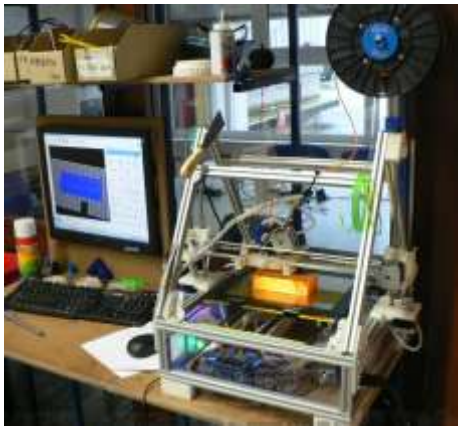
- Contour building
- Surface filling
- Support manufacturing
- Support removal

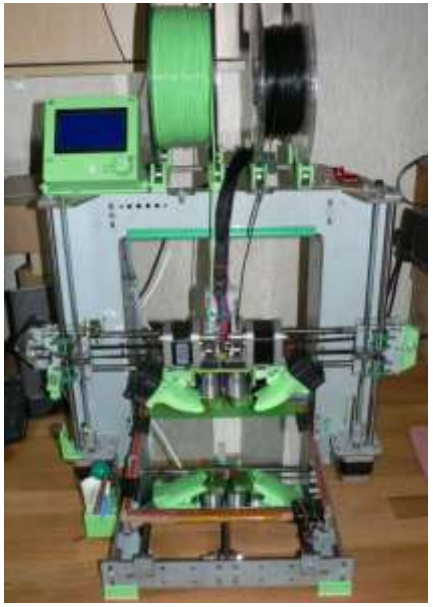
Quality:

- Precision (0,2mm)
- Detauls f(filament) (0,3mm)
- Good mecanical resistance
- Filling strategies
- Costless
- Poor surface finish

FDM open architecture: RepRap







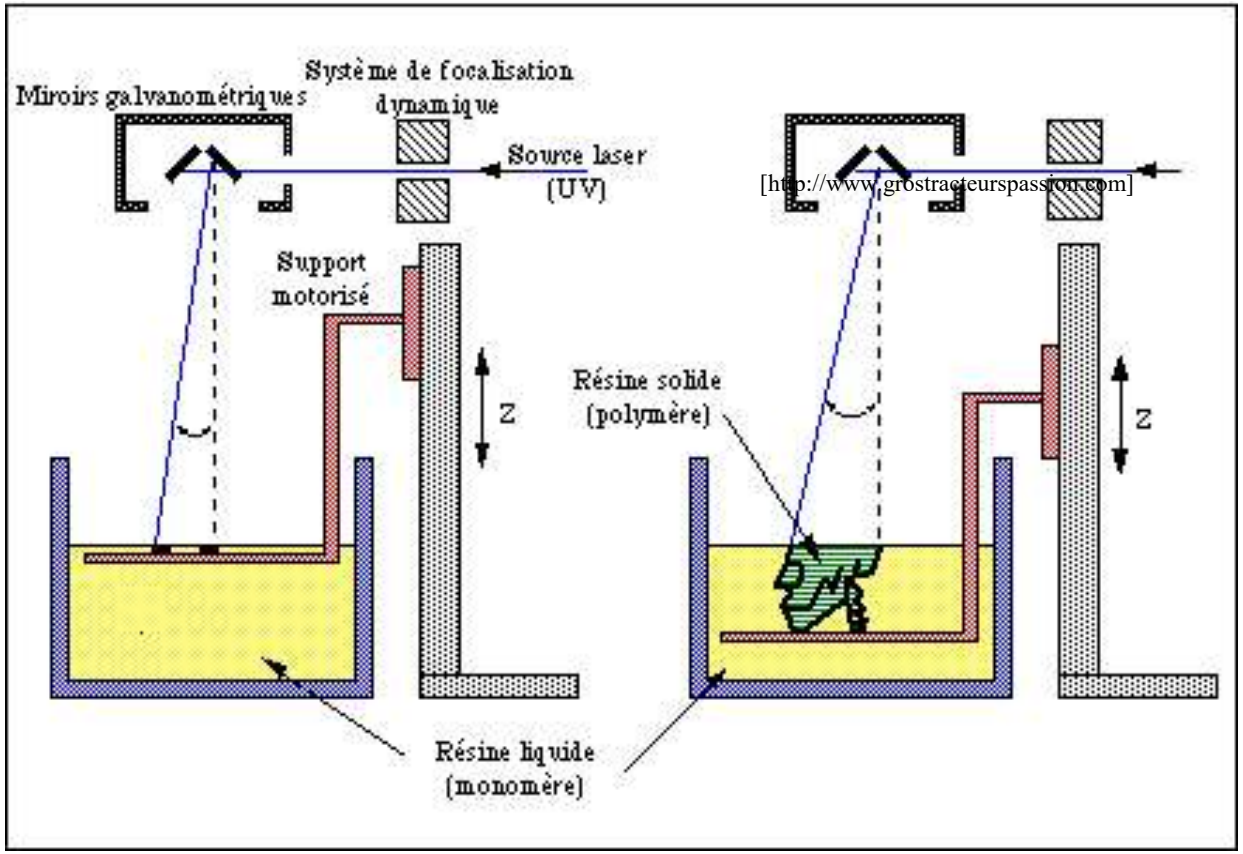
FDM : supports

Stereolithography

Liquide | Resin | polimerisation | Laser | hatching

Process sequences:

- Contour
- Surfaces hatching
- Support manufcturing
- Post curing

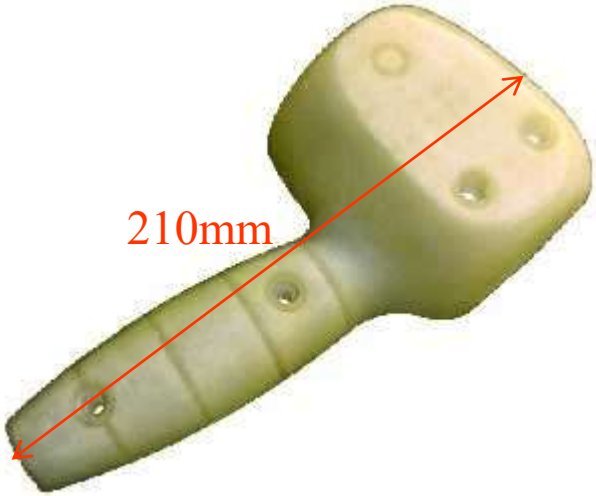


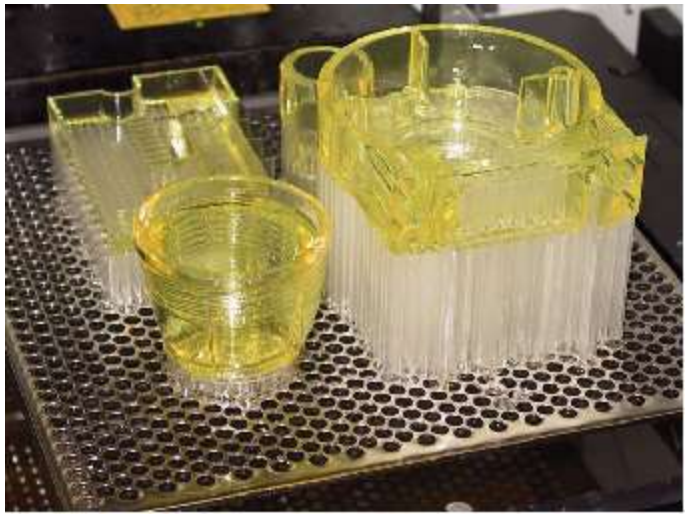
[http://www.grostracteurspassion.com]

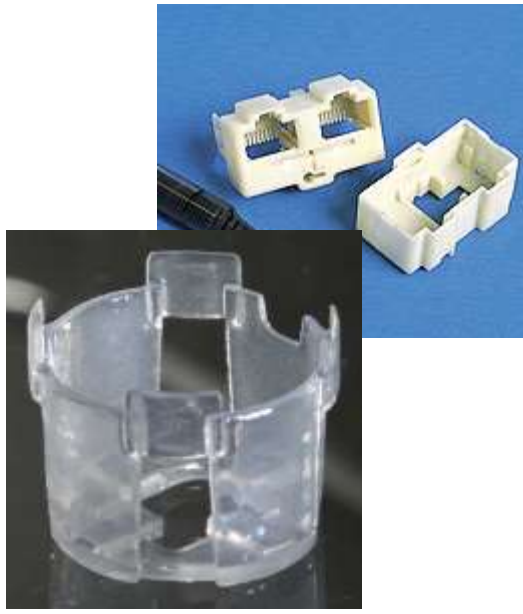
Quality:

- Precision (0,1mm)
- Small details (0,6mm)
- Thin walls
- Vieillissement à la lumière

Stereolithography







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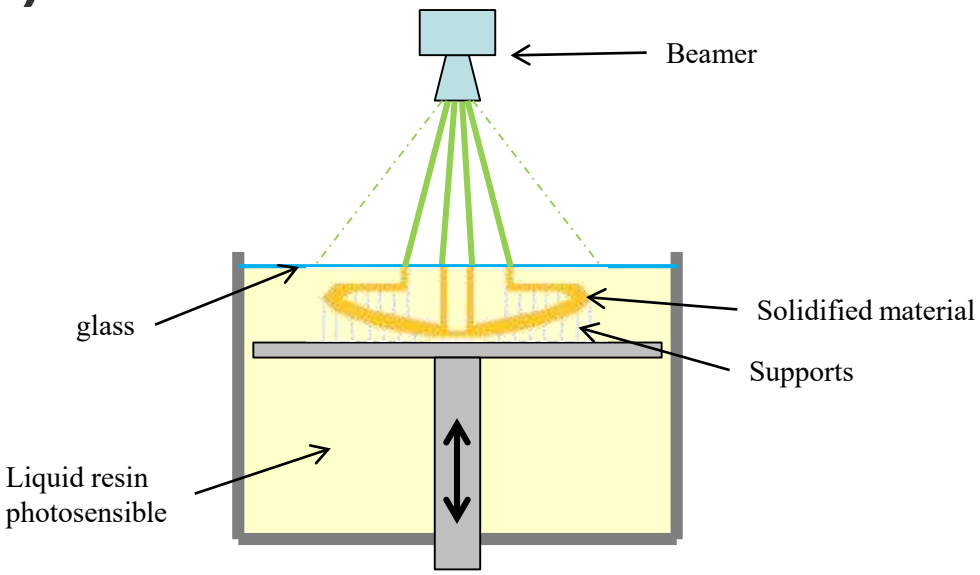
Digital Light Processing (DLP)

Liquid | polymer | polymerisation | UV | surface

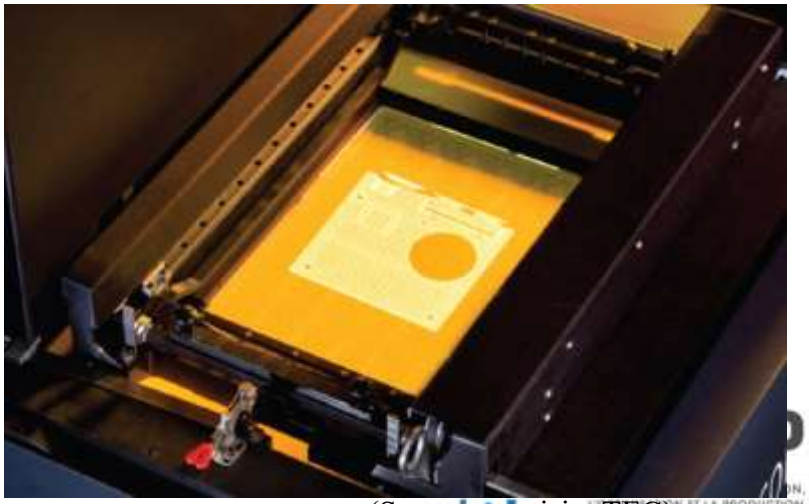


Opérations requises :

- Préparation des supports (logiciel)
- Flashage couche par couche
- Extraction des supports
- nettoyage

Qualités :

- Très bonne finition
- Précision (0,2mm)
- Détails très fins (0,05mm)
- Parois minces (1mm)
- Bonne résilience
- Durcissement progressif à la lumière
- Moins bon côté supports



(Source : envisionTEC)

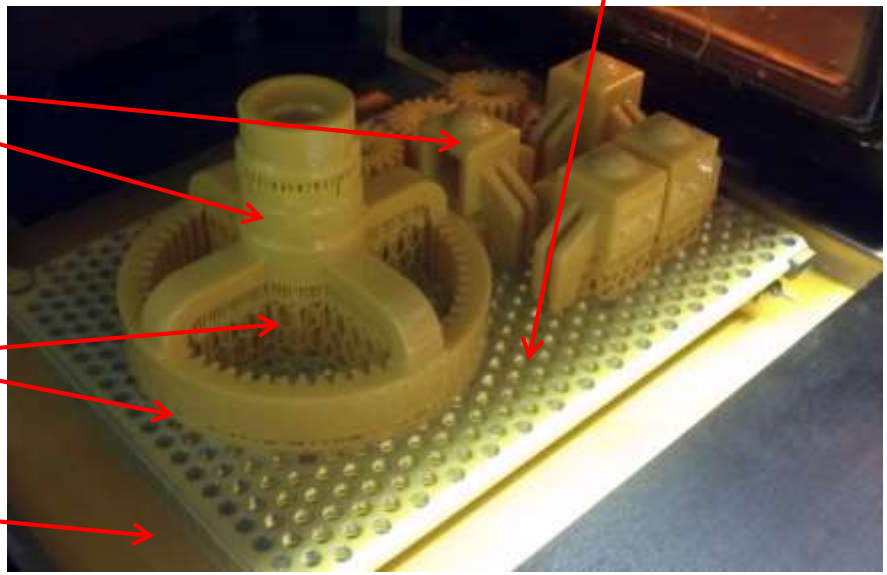
DLP

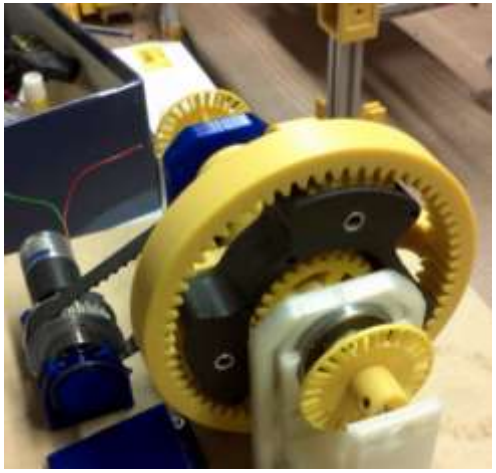
Plate

Parts

Supports

Resin



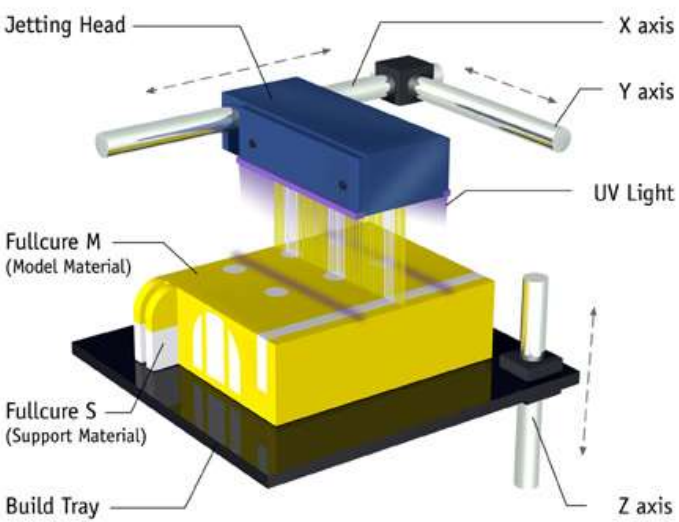


Polyjet

Liquide | Polymer Resin | polymerisation | UV | jetting

Process sequence:

- Preparation of supports (software)
- Photopolymer jetting
- Supports Extraction
- Cleaning



The Objet PolyJet Process

Quality:

- Very good surface finish
- Precision (0,1mm)
- Very thin details (0,05mm)
- Thin walls (1mm)
- Multi material multi-color
- Variable flexibility/color

http://www.stratasys.com

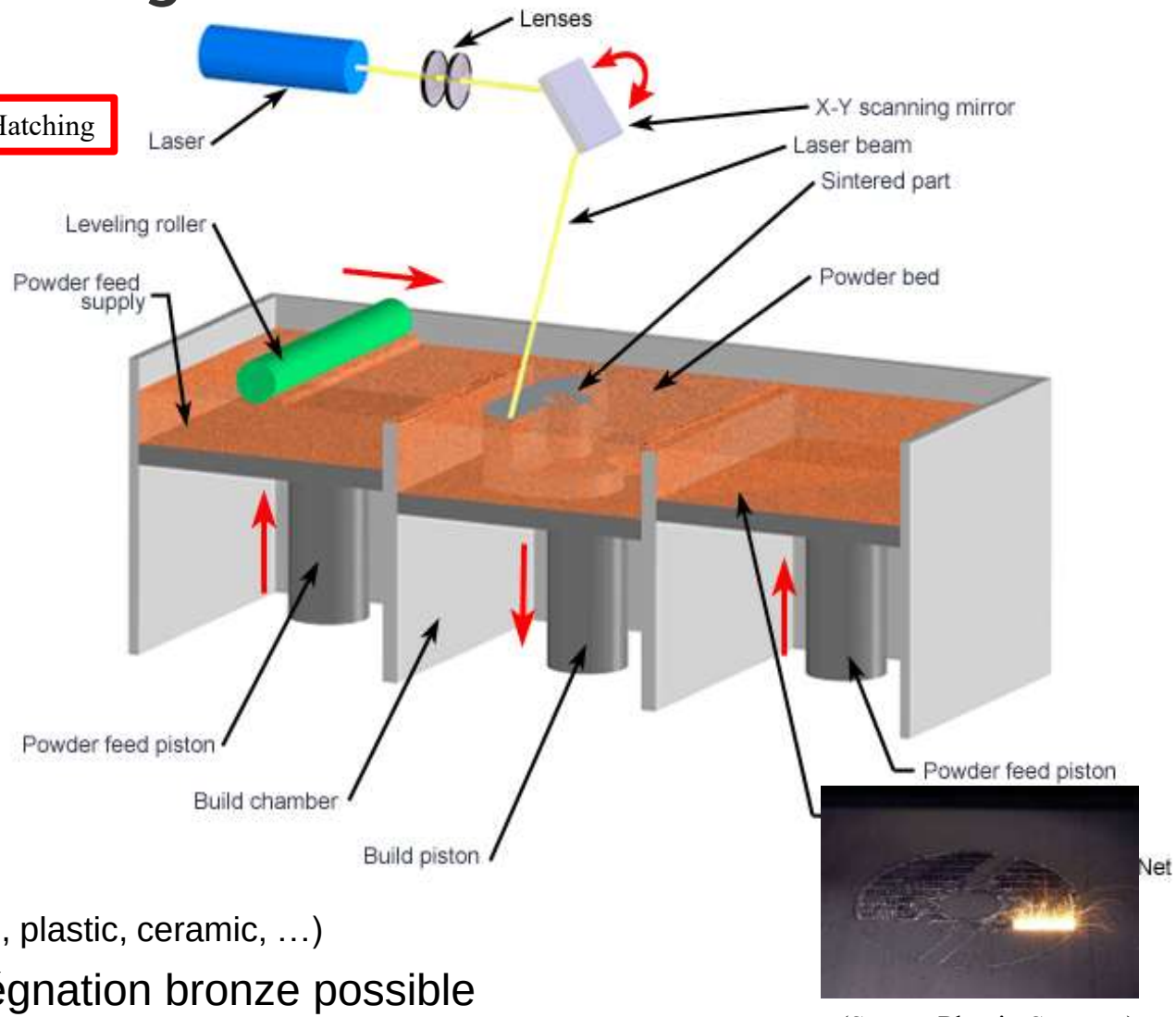
Selective Laser Sintering: SLS

Plastic

Poudre | Sand | fusion | Laser | Hatching

Métal

Bounding if req



(Source Phenix Systems)

Process sequence:

- Layer manufacturing
- Cleaning
- Surface finish

Quality :

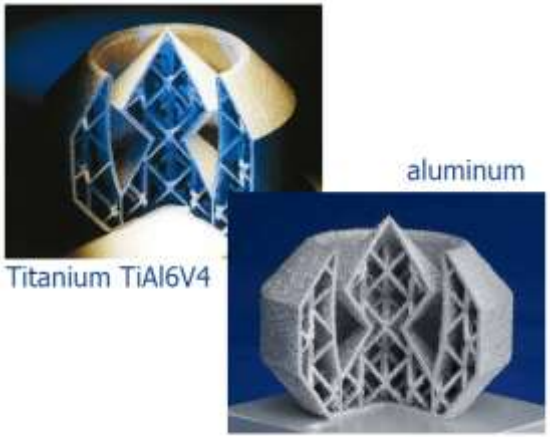
- Precision (0,2mm)
- Details (0,1mm)
- Thin walls
- Surface granularity
- Varied material (metal, plastic, ceramic, …)
- Poudre métal : imprégnation bronze possible

SLS

http://www.kinzoku.co.jp

http://www.axisproto.com : DMLS acier inox

http://vortexspace.org



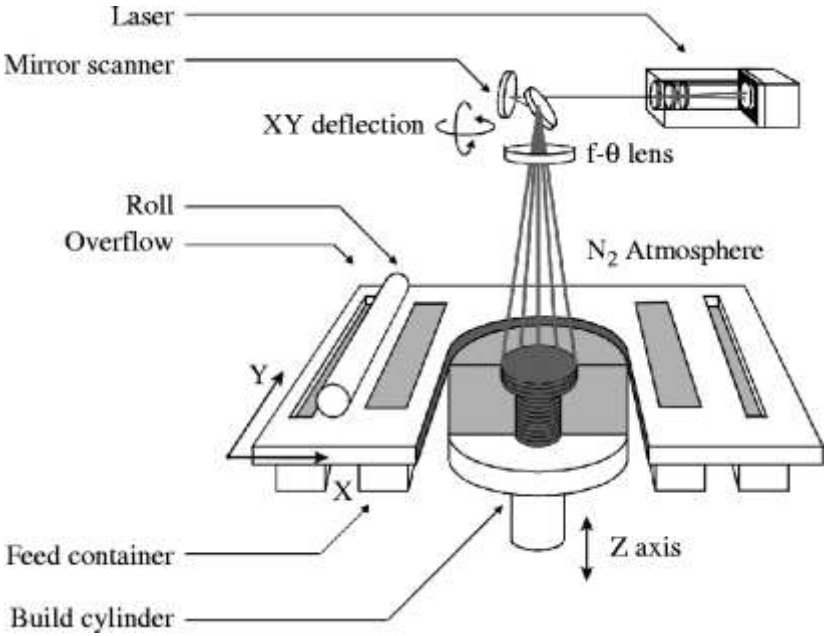
http://directmetallasersintering.blogspot.fr

(Source CLFA Fraunofer ILT)

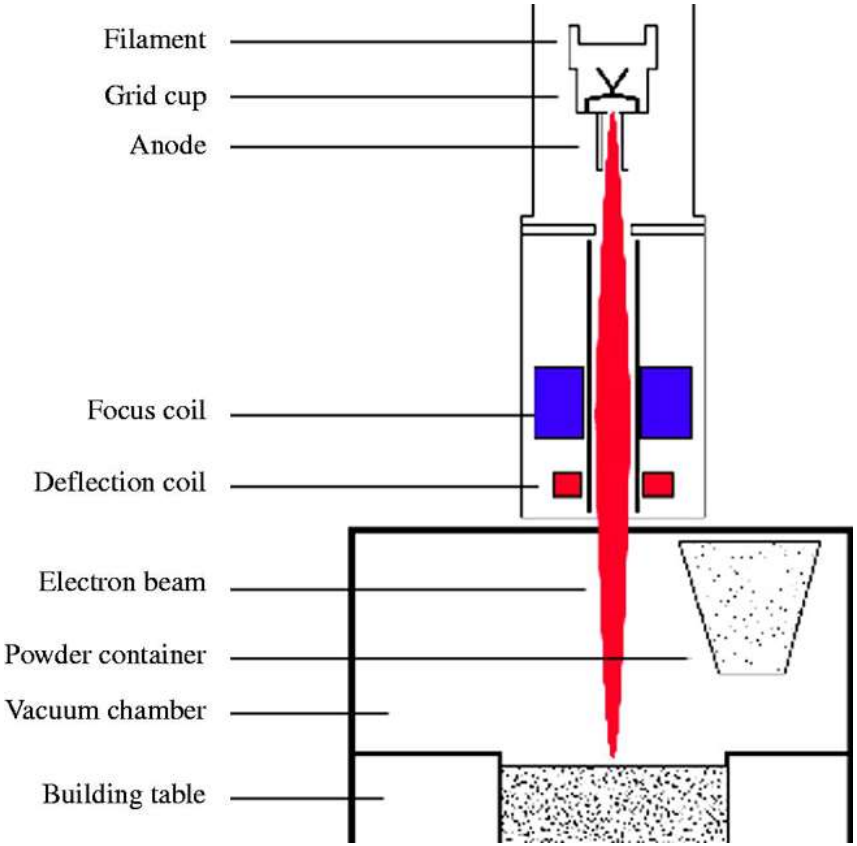
Fusion of metalic powder

Powder | Metal | fusion | Electron beam | Laser | hatching

- **Laser beam:**
  - Direct Metal Laser Sintering (DMLS)
  - Selective Laser Melting (SLM)



- **Electron Beam:**
  - Electron Beam Melting (EBM)

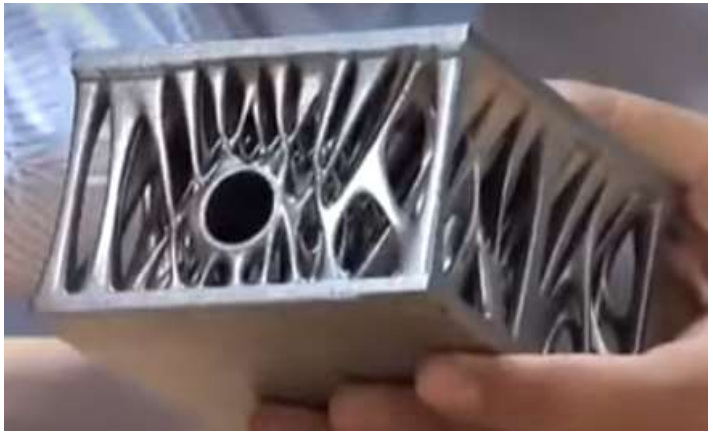


Selective Laser Melting: SLM

Powder | Metal | fusion | Laser beam | hachurage

Process sequence:

- Idem SLS
- Travail
- Supports

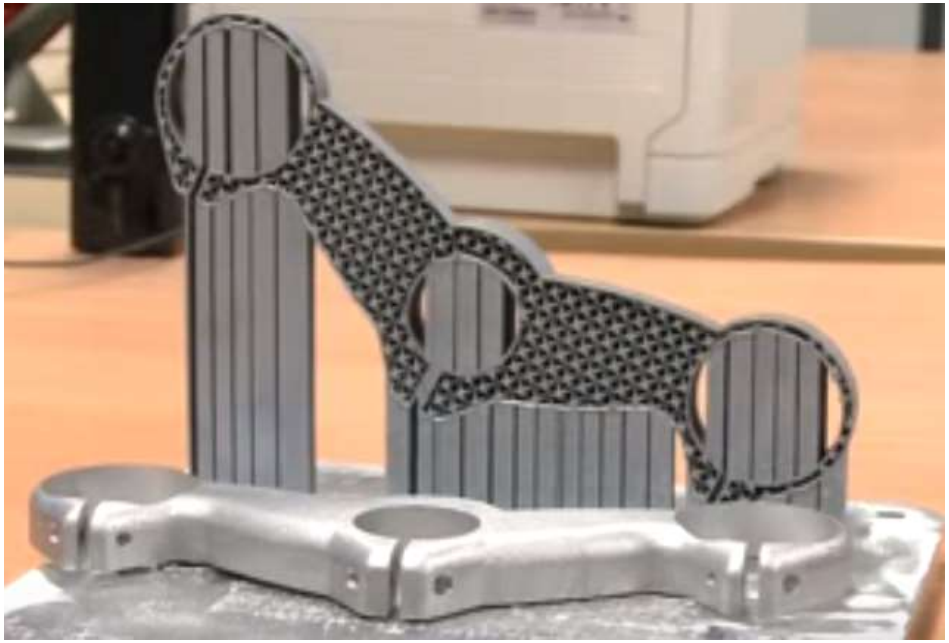


http://www.poly-shape.com/

Qualités :

- Matières acier, titane, aluminium
- Grande résistance

http://www.multistation.com/



Electron Beam Melting : EBM

Poudre | Metal | fusion | Electron beam | hatching

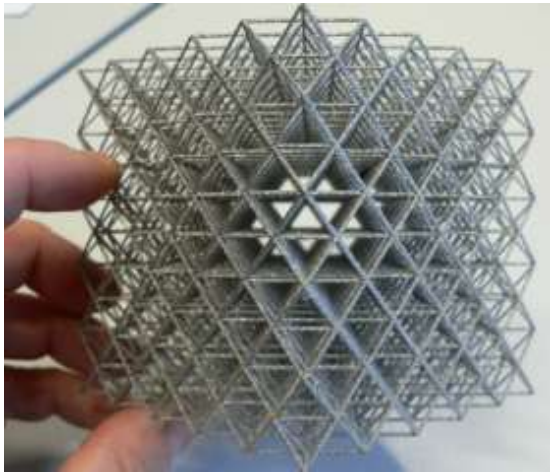
Process definition:

- Idem SLS
- Vaccum
- ~~No support needed~~ → thermal evacuation

Quality:

- TA6V
- cohesion, resistance

http://www.arcam.com



Laser Cladding

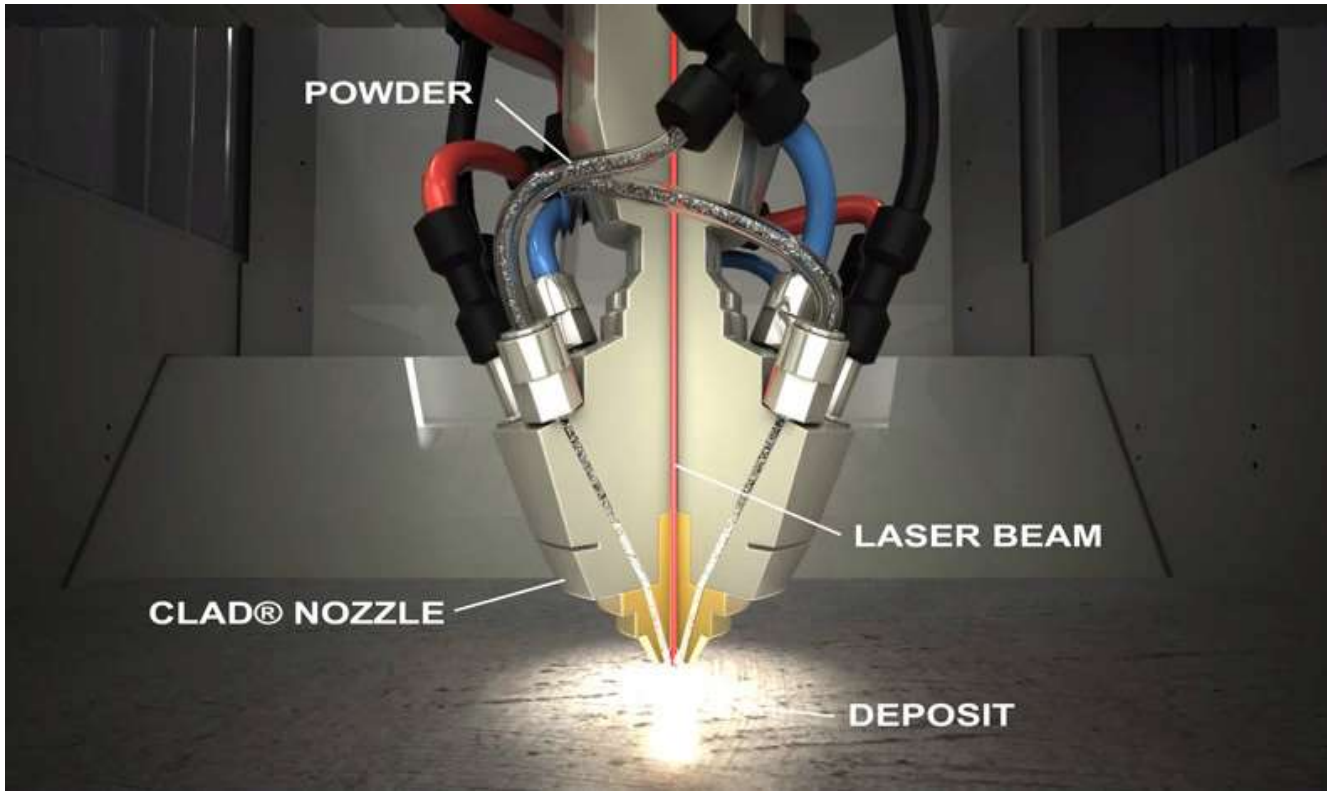
Poudre | Metal | fusion | laser | jetting

Process definition:

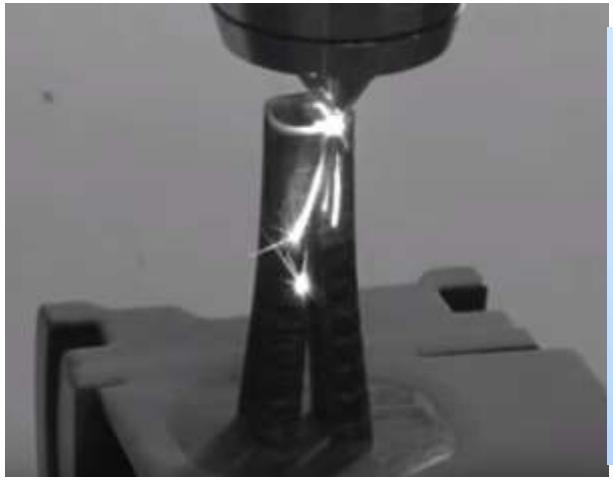
- Layer deposition
- Support
- Surface finish

Quality:

- Multi material
- recharging



Laser Cladding

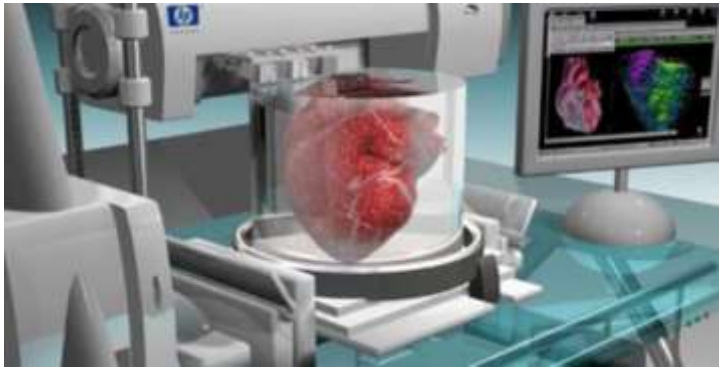


Source : https://www.3dnatives.com/beam-open-innovation-impression-3d-17062015/

Source : http://www.irepa-laser.com/

Bio-printing

http://www.homemedia.fr/guides/220-dossier-l-impression-3d-expliqu-1.html



[1] Auteur inconnu. Disponible sur http://blog.econocom.com/wp-content/uploads/2013/10/bio-printing3-500x261.jpg (consulté le 05/10/2014)
[2]Organovo compagny. Disponible sur http://www.organovo.com/company/about-organovo (consulté le 05/10/2014)
[3] H, Jalinières. Disponible sur http://www.sciencesetavenir.fr/galeries-photos/sante/20140708.OBS3058/la-bio-impression-3d.html (consulté le 05/10/2014)
[4] D.Sergent. Disponible sur http://www.la-croix.com/Actualite/France/Comment-fabriquer-de-la-peau-avec-une-imprimante-3D-2014-07-06-1175172 (consulté le 05/10/2014)

Other applications

- **LOM (feuilles « papier », découpe laser)**

- **CandyFab (http://wiki.candyfab.org)**

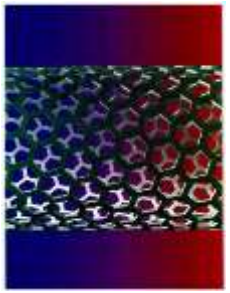
- **Bio-impression**

  http://etsinnovation.wordpress.com/2012/03/05/3d-bio-printing-imprimer-des-muscles-et-des-organes/

  http://www.youtube.com/watch?v=vAi3fUlMdHk&feature=endscreen&NR=1

http://www.wakehealth.edu/WFIRM/

http://www.organovo.com/science-technology/bioprinted-human-tissue



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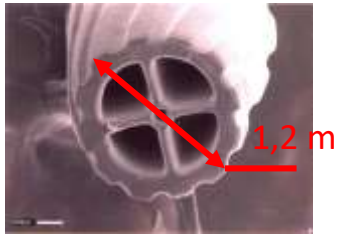
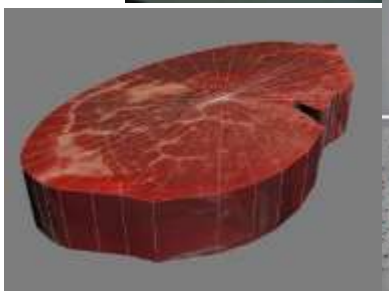


Micro-gear



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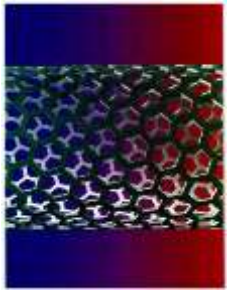

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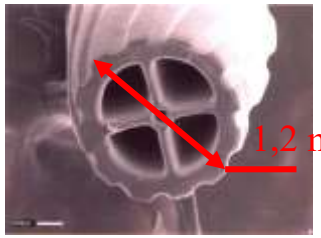
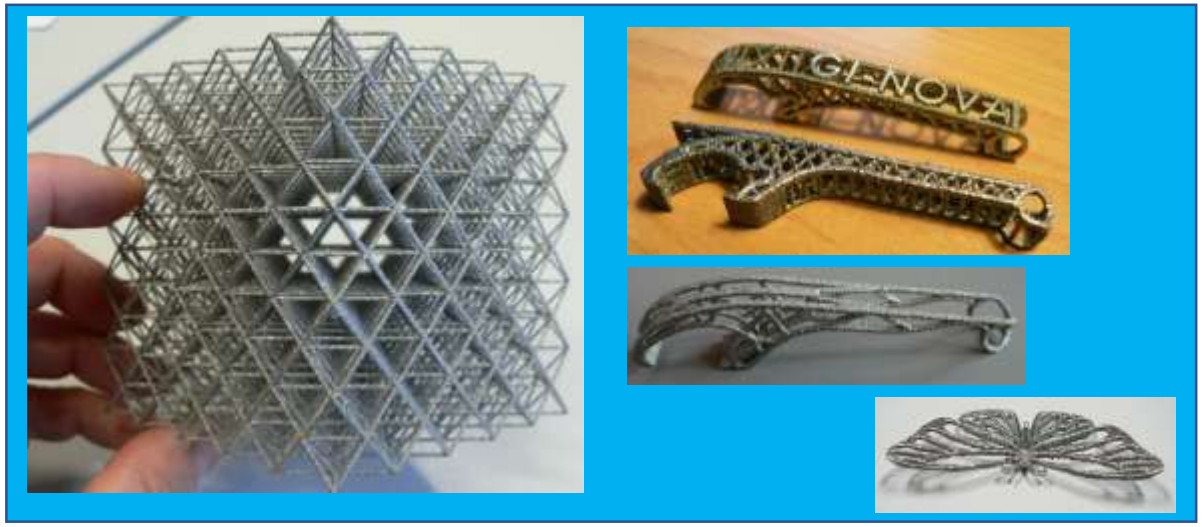
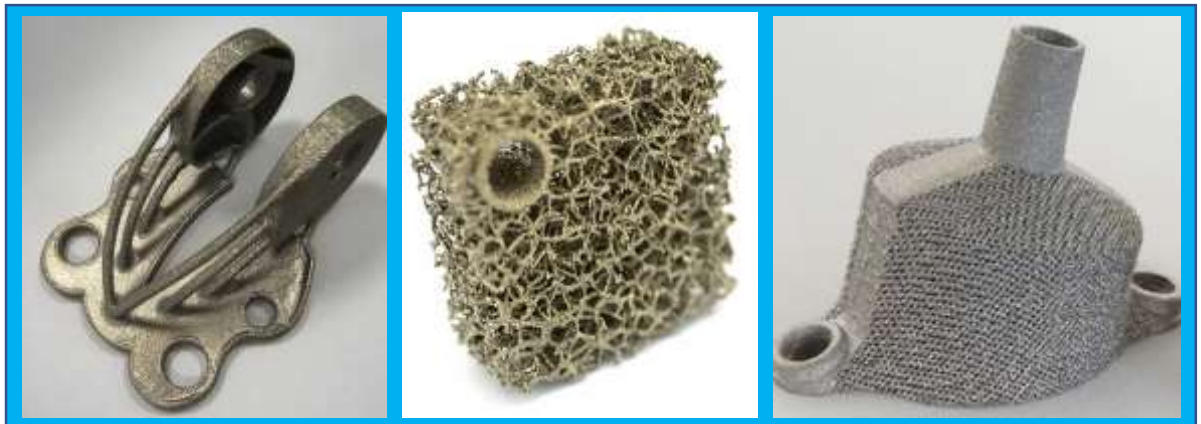


Micro-gear

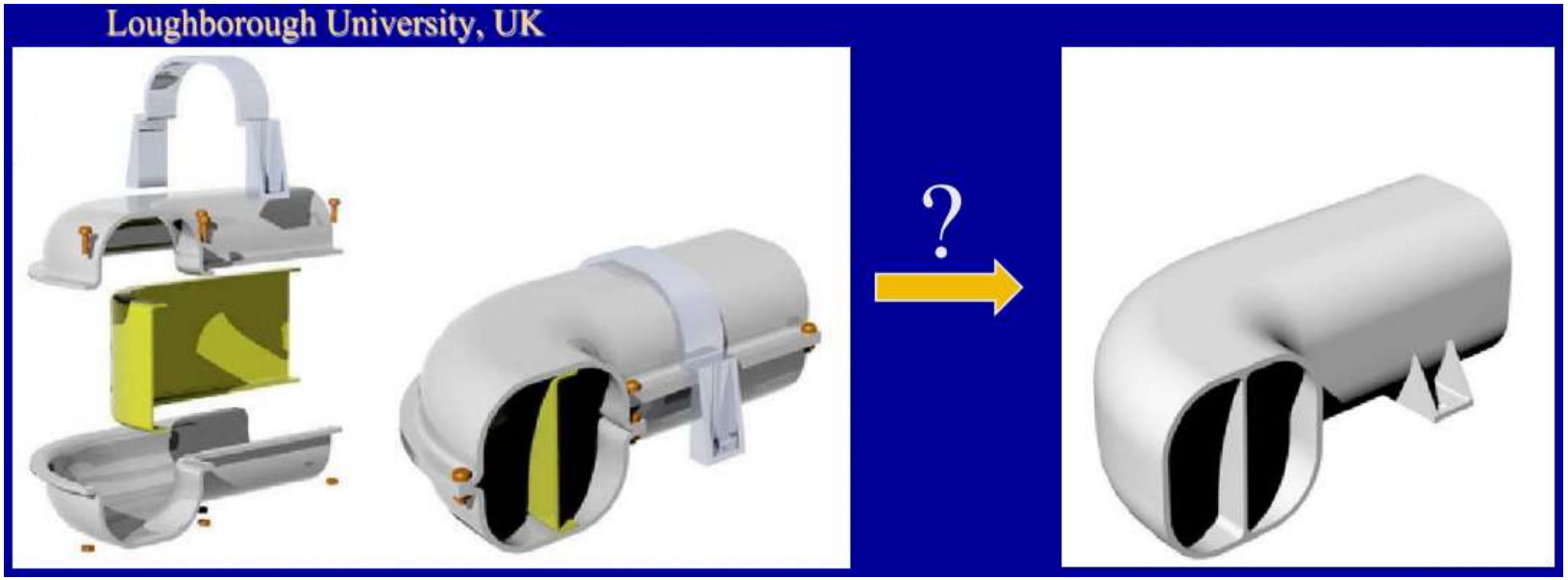
Complex Shapes

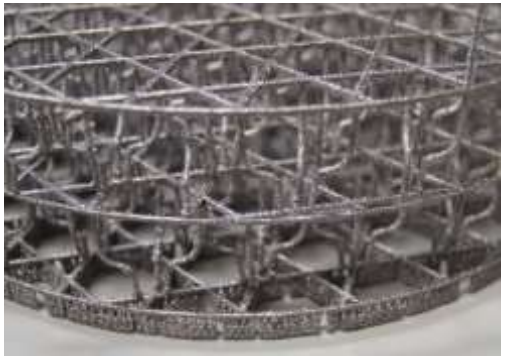




3A : http://www.rm4metal.com/

Complex Shapes





Complex Shapes

http://www.3ders.org/articles/20140915-futurist-christopher-barnatt-report-london-2014-3d-printshow.html

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Metal					EBM
Sand					
Plastic	SL	PJ		FDM	LS
Wax					MJ *

Lower	Durability	Higher
Smoother	Surface finish	Rougher
Higher	Detail	Lower
Prototypes | Indirect processes	Application	Functional parts

Source: https://www.additively.com

Additive Manufacturing and 3D printing technologies

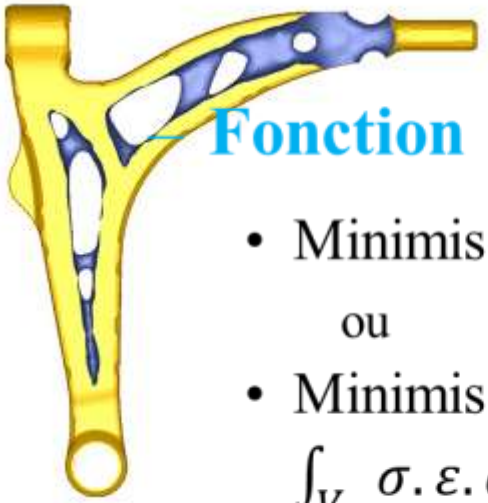
OVERVIEW

History

- 1980 : Professor Jean-Claude André from ENSIC Nancy invents Stereolithograpy
- 1984 : Charles Hull creates 3D-System to industrialise Stereolithography (SLA)
- 1985 : DTM Corporation (USA) puts a patent on Selective Laser Sintering (SLS)
- 1988 : 1rst SLA machine commercialised by 3D-System : SLA-2502
- 1988 : S. Scott Crump creates Stratasys in the USA and develops the Fused Deposition Molding process (FDM)
- 1993 : Developpement of binder jetting technology at MIT (USA)
- 1995 : Z Corporation (USA) buys a licence of the process
- 1996 : First mention of the term 3D Printing
- 1997 : Creation of ARCAM AB (Sweden) for commercialising Electron Beam Melting technology (EBM)
- 1999 : Objet Ltd (USA) patents the PolyJet process
- 2000 : Developpement of Direct Metal Laser Sintering (DMLS) et du Selective Laser Melting (SLM)
- 2000 : The Américain standardisation office adopts the term SLM
- 2002 : First EBM machine (model S12) in industry
- 2005 : Dissemination of the RepRap projet by Adrian Bowyer professor at the university of Bath (UK)
- 2011 à 2014 : 150 % of market growth in average each year
- 2014 : DMG MORI presents the first hybrid machine additive/soustractive

Topological Optimization

– **Variables** = densité de matière ρ au sein de chaque élément fini d'un maillage



– **Fonction objectif**

- Minimiser la masse = $\int_V \rho . dV$

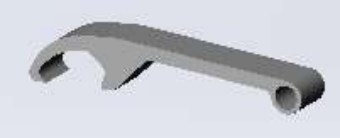
  ou

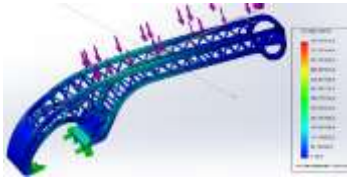
- Minimiser la compliance = énergie de déformation = $\int_V \sigma . \varepsilon . dV$

La compliance est exprimée en fonction de la densité.

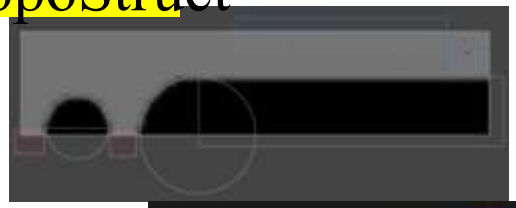
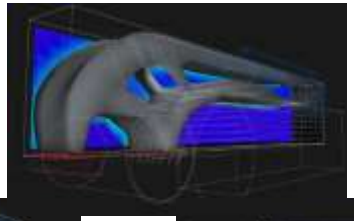
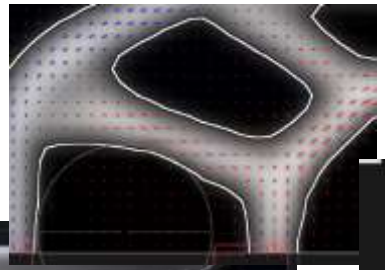
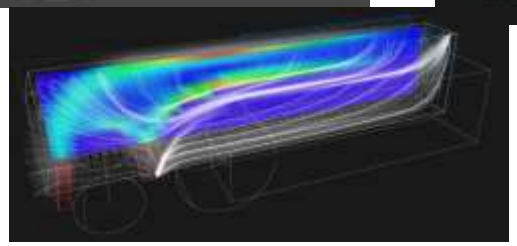
Par exemple : $E = E_0 + \rho^n E_1$

Topological Optimization

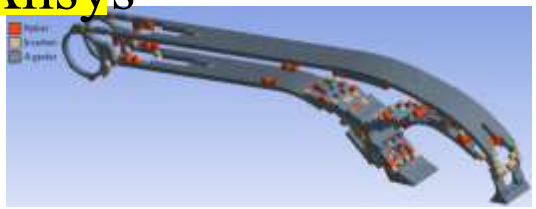




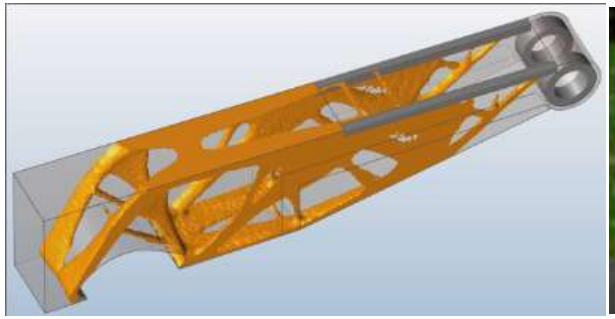
TopoStruct

Ansys



Inspire



Patte support d’airbus A380 (EOS)

Jean-François BOUJUT

Laboratoire G-SCOP/Université Grenoble Alpes- Grenoble INP

Laboratoire G-SCOP
46, av Félix Viallet
38031 Grenoble
Cedex
www.g-scop.inpg.fr

Thank you