UNIVERSITÀ DEGLI STUDI DI PADOVA

TTA
Technology Turn Around

Additive Manufacturing - a Revolutionary Enabling Innovation-Space Past Present and Future

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Additive Manufacturing and
Electro Physical & Chemical Processes
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AM is the enabling space for future innovation

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1. Introduction
2. Process
   - Laser vs Non-Laser
   - Voxelization
   - Size and Productivity
3. Material for Processes
4. AM work flow
   - Dataflow Design Simulation
   - In situ control
   - Automation
5. Economical and Functional justifications
6. Already in Manufacturing
7. Complexity challenges ahead
   - Standards
   - IP
8. Conclusions

- We can identify the following AM period's time-line:
- 1980 – 1995 Pioneers
  1995 – 2000 Rapid Prototyping & rapid Tooling
  2012 - ASTM Terminology: Additive Manufacturing
  2000 – 2010 Early Adaptors
  2011 – 2015 Euphoric explosion DIY extrusion printers
- 2015 - 3D Printing as synonym

- **2016/17 can be recognized as a breakthrough game-changing milestone in the AM on the way to wide industrialization.**
- Large companies and 2D printers enter the challenges

Almost 35 years ago

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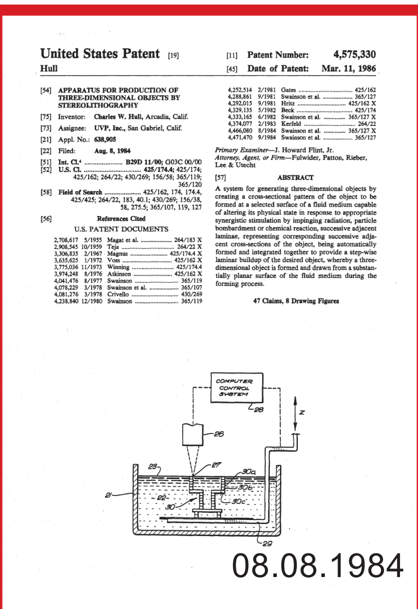

United States Patent [19] — Hull
[11] Patent Number: 4,575,330
[45] Date of Patent: Mar. 11, 1986

[54] APPARATUS FOR PRODUCTION OF THREE-DIMENSIONAL OBJECTS BY STEREOLITHOGRAPHY
[75] Inventor: Charles W. Hull, Arcadia, Calif.
[73] Assignee: UVP, Inc., San Gabriel, Calif.
[21] Appl. No.: 638,905
[22] Filed: Aug. 8, 1984
[51] Int. Cl.⁴ B29D 11/00; G03C 00/00
[52] U.S. Cl. 425/174.4; 425/174; 425/162; 264/22; 430/269; 156/58; 365/119; 365/120
[58] Field of Search 425/162, 174, 174.4, 425/425; 264/22, 183, 40.1; 430/269; 156/38, 58, 275.5; 365/107, 119, 127

[56] References Cited
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3,775,036	11/1973	Winning	425/174.4
3,974,248	8/1976	Atkinson	425/162 X
4,041,476	8/1977	Swainson	365/119
4,078,229	3/1978	Swainson et al.	365/107
4,081,276	3/1978	Crivello	430/269
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4,374,077	2/1983	Kerfeld	264/22
4,466,080	8/1984	Swainson et al.	365/127 X
4,471,470	9/1984	Swainson et al.	365/127

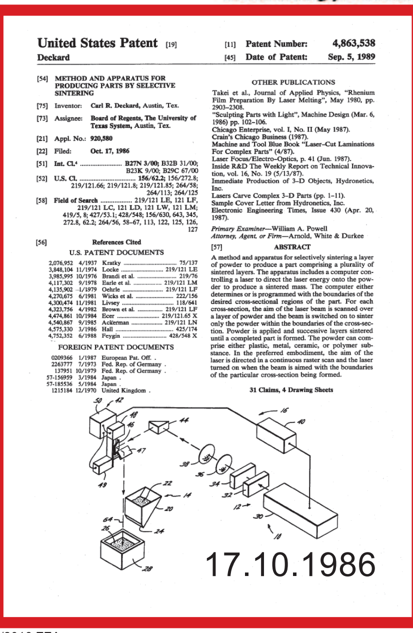
Primary Examiner—J. Howard Flint, Jr.
Attorney, Agent, or Firm—Fulwider, Patton, Rieber, Lee & Utecht

[57] ABSTRACT

A system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed at a selected surface of a fluid medium capable of altering its physical state in response to appropriate synergistic stimulation by impinging radiation, particle bombardment or chemical reaction, successive adjacent laminae, representing corresponding successive adjacent cross-sections of the object, being automatically formed and integrated together to provide a step-wise laminar buildup of the desired object, whereby a three-dimensional object is formed and drawn from a substantially planar surface of the fluid medium during the forming process.

47 Claims, 8 Drawing Figures

08.08.1984



United States Patent [19] — Deckard
[11] Patent Number: 4,863,538
[45] Date of Patent: Sep. 5, 1989

[54] METHOD AND APPARATUS FOR PRODUCING PARTS BY SELECTIVE SINTERING
[75] Inventor: Carl R. Deckard, Austin, Tex.
[73] Assignee: Board of Regents, The University of Texas System, Austin, Tex.
[21] Appl. No.: 920,580
[22] Filed: Oct. 17, 1986
[51] Int. Cl.⁴ B27N 3/00; B32B 31/00; B23K 9/00; B29C 67/00
[52] U.S. Cl. 156/62.2; 156/272.8; 219/121.66; 219/121.8; 219/121.85; 264/58; 264/113; 264/125
[58] Field of Search ..... 219/121 LE, 121 LF, 219/121 LC, 121 LD, 121 LW, 121 LM; 419/5, 8; 427/53.1; 428/548; 156/630, 643, 345, 272.8, 62.2; 264/56, 58–67, 113, 122, 125, 126, 127

[56] References Cited
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3,848,104	11/1974	Locke	219/121 LE
3,985,995	10/1976	Brandi et al.	219/76
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4,270,675	6/1981	Wicks et al.	222/156
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4,323,756	4/1982	Brown et al.	219/121 LF
4,474,861	10/1984	Ecer	219/121.65 X
4,540,867	9/1985	Ackerman	219/121 LN
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4,752,352	6/1988	Feygin	428/548 X

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2263777	7/1973	Fed. Rep. of Germany
137951	10/1979	Fed. Rep. of Germany
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1215184	12/1970	United Kingdom

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"Sculpting Parts with Light", Machine Design (Mar. 6, 1986) pp. 102–106.
Chicago Enterprise, vol. I, No. II (May 1987).
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Machine and Tool Blue Book "Laser-Cut Laminations For Complex Parts" (4/87).
Laser Focus/Electro-Optics, p. 41 (Jun. 1987).
Inside R&D The Weekly Report on Technical Innovation, vol. 16, No. 19 (5/13/87).
Immediate Production of 3-D Objects, Hydronetics, Inc.
Lasers Carve Complex 3-D Parts (pp. 1–11).
Sample Cover Letter from Hydronetics, Inc.
Electronic Engineering Times, Issue 430 (Apr. 20, 1987).

Primary Examiner—William A. Powell
Attorney, Agent, or Firm—Arnold, White & Durkee

[57] ABSTRACT

A method and apparatus for selectively sintering a layer of powder to produce a part comprising a plurality of sintered layers. The apparatus includes a computer controlling a laser to direct the laser energy onto the powder to produce a sintered mass. The computer either determines or is programmed with the boundaries of the desired cross-sectional regions of the part. For each cross-section, the aim of the laser beam is scanned over a layer of powder and the beam is switched on to sinter only the powder within the boundaries of the cross-section. Powder is applied and successive layers sintered until a completed part is formed. The powder can comprise either plastic, metal, ceramic, or polymer substance. In the preferred embodiment, the aim of the laser is directed in a continuous raster scan and the laser turned on when the beam is aimed with the boundaries of the particular cross-section being formed.

31 Claims, 4 Drawing Sheets

17.10.1986

Patent FDM and EBM

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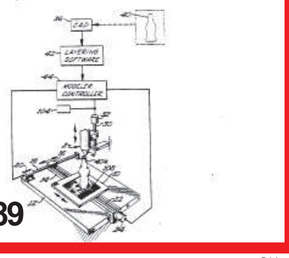
United States Patent [19]
Crump
[11] Patent Number: 5,121,329
[45] Date of Patent: Jun. 9, 1992

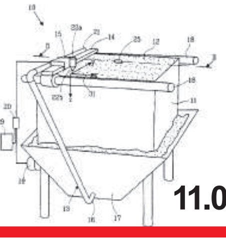
[54] APPARATUS AND METHOD FOR CREATING THREE-DIMENSIONAL OBJECTS



30.10.1989

United States Patent [19]
Larson
[11] Patent Number: 5,786,562
[45] Date of Patent: Jul. 28, 1998

[54] METHOD AND DEVICE FOR PRODUCING THREE-DIMENSIONAL BODIES



11.05.1994

Patents of SLM and 3DP

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(12) United States Patent
Meiners et al.
(10) Patent No.: US 6,215,093 B1
(45) Date of Patent: Apr. 10, 2001

(54) SELECTIVE LASER SINTERING AT MELTING TEMPERATURE

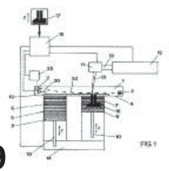
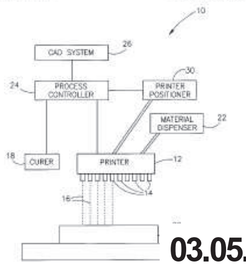


FIG 1

12.07.1999

(12) United States Patent
Gothait
(10) Patent No.: US 6,259,962 B1
(45) Date of Patent: Jul. 10, 2001

(54) APPARATUS AND METHOD FOR THREE DIMENSIONAL MODEL PRINTING



03.05.1999

(layer by layer)

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Sir Edmund Hilary first EVEREST conquest 29.05.1953

NAMII ADDITIVE MANUFACTURING INNOVATION INSTITUTE

AM is Hot …published 13.02.2013

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America Makes
National Additive Manufacturing Innovation Institute

"3D printing that has the potential to revolutionize the way we make almost everything" President Obama

Trends and Slogans in Advanced Manufacturing

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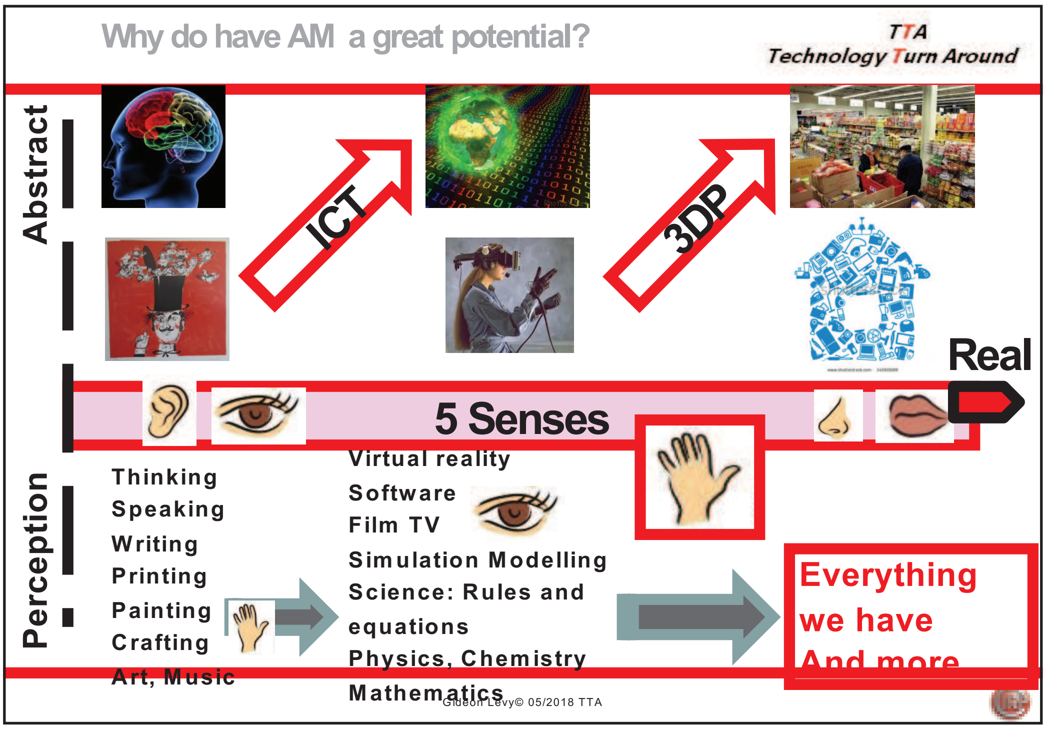
- **Digitalization**
- **Industry 4.0**
- **Sustainability**
- **E- Mobility**
- **Natural resources**
- **Biomimetic**
- **Bio Manufacturing**
- **BIOLOGICAL TRANSFORMATION OF MANUFACTURING**
- **Biologization**
- **Biological Materials**
- **Bio Economics**



Future manufacturing space

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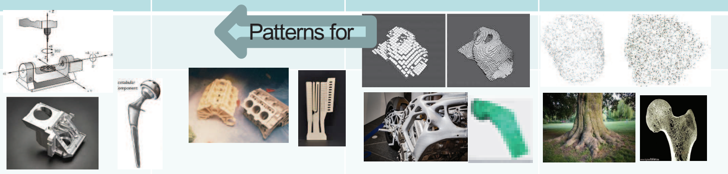
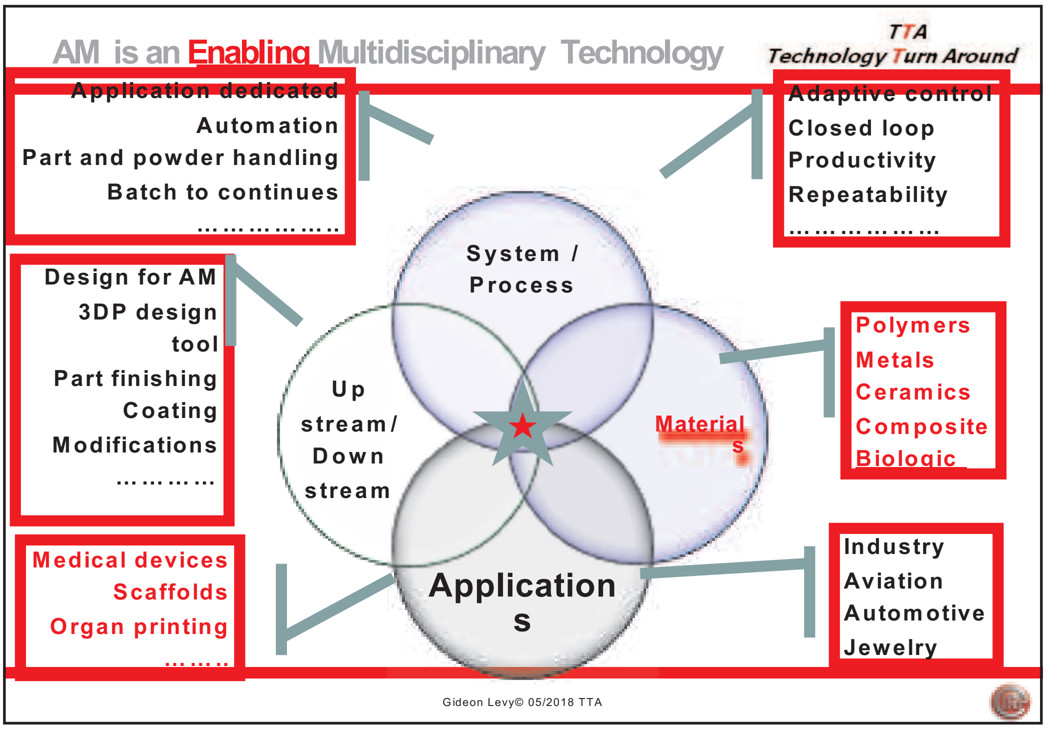


	SM	FM	AM	Nature
Geometry coordinates				
Geometry				
Metals	+++++	+++++	++++	☺
Polymers	++++	+++++	++++	X
Technical Ceramics	++	++++	+++	X
Natural Ceramics	+	+	+ ← R&D	+++++
Composite	++	+++	++	X
Natural Materials	+++	X	+ ← R&D	+++++
Bio Materials (cells)	X	X	++ ← R&D	+++++


AM is an Enabling Multidisciplinary Technology
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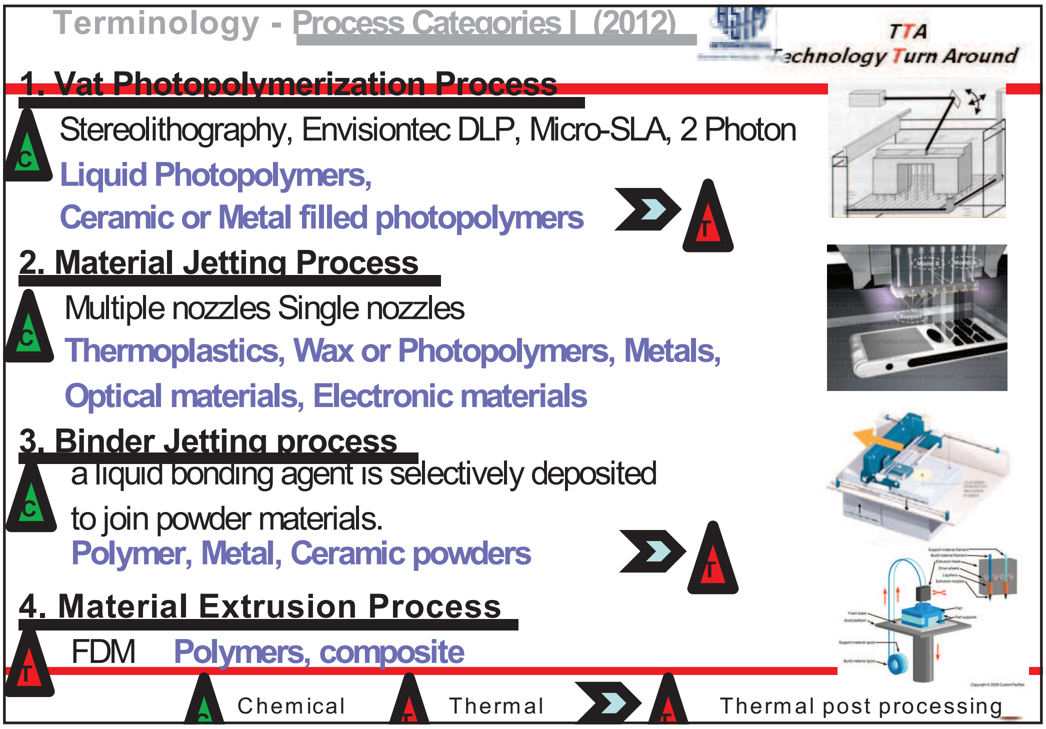
Application dedicated
Automation
Part and powder handling
Batch to continues
……………….
Adaptive control
Closed loop
Productivity
Repeatability
………………
Design for AM
3DP design
tool
Part finishing
Coating
Modifications
…………
System /
Process
Up
stream/
Down
stream
Material
s
Application
s
Polymers
Metals
Ceramics
Composite
Biologic
Medical devices
Scaffolds
Organ printing
……..
Industry
Aviation
Automotive
Jewelry
Gideon Levy© 05/2018 TTA


Terminology - Process Categories I (2012)
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1. Vat Photopolymerization Process
Stereolithography, Envisiontec DLP, Micro-SLA, 2 Photon
Liquid Photopolymers,
Ceramic or Metal filled photopolymers
2. Material Jetting Process
Multiple nozzles Single nozzles
Thermoplastics, Wax or Photopolymers, Metals,
Optical materials, Electronic materials
3. Binder Jetting process
a liquid bonding agent is selectively deposited
to join powder materials.
Polymer, Metal, Ceramic powders
4. Material Extrusion Process
FDM Polymers, composite
Chemical
Thermal
Thermal post processing

Terminology - Process Categories II (2012)

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5. Powder Bed Fusion Process

SLS, SLM, EBM

Polymers, metals & ceramics powder

6. Sheet Lamination Process

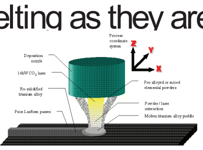
Bonding, hot melt, glue, US welding

Paper, Metal, Polymers

7. Directed Energy Deposition Process

focused thermal energy is used to fuse materials by melting as they are being deposited

Metal, polymers, powder, wire



Chemical   Thermal   Thermal post processing

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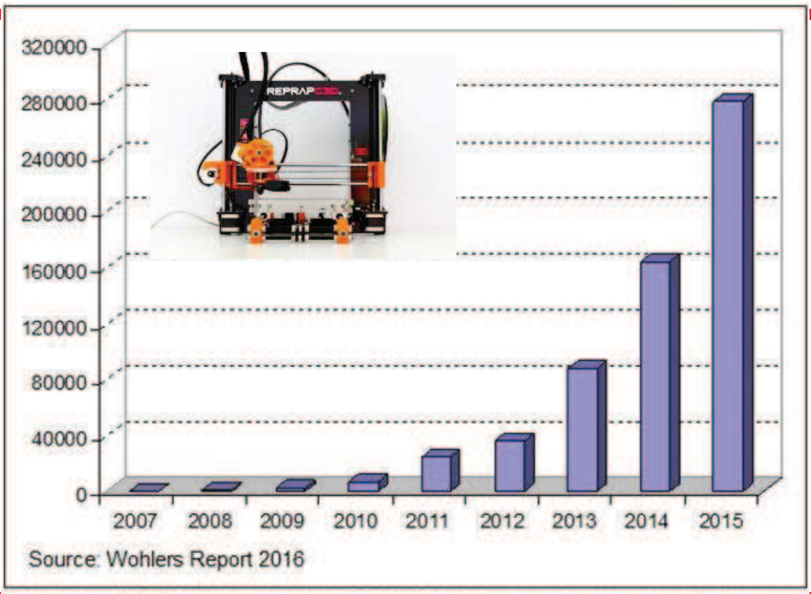

More than 278,000 desktop (under $5,000) 3D printers were sold worldwide last year

Economy SLS Systems (June 2018)

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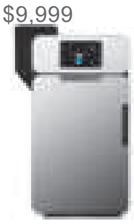
Sinterit Lisa
- **Country**: Poland
- **Build volume**: 150 x 200 x 150 mm
- **Price**: $6,990

Sintratec Kit
- **Country**: Switzerland
- **Build volume**: 130 x 130 x 130 mm
- **Price**: $5,350

Formlabs Fuse 1
- **Country**: United States
- **Build volume**: 165 x 165 x 320 mm
- **Price**: $9,999



RED ROCK 3D RED ROCK
- **Country**: Russia
- **Build volume**: 180 x 180 x 180 mm

RED ROCK 3D RED ROCK
- **Country**: Russia
- **Build volume**: 180 x 180 x 180 mm

Metal AM systems sales

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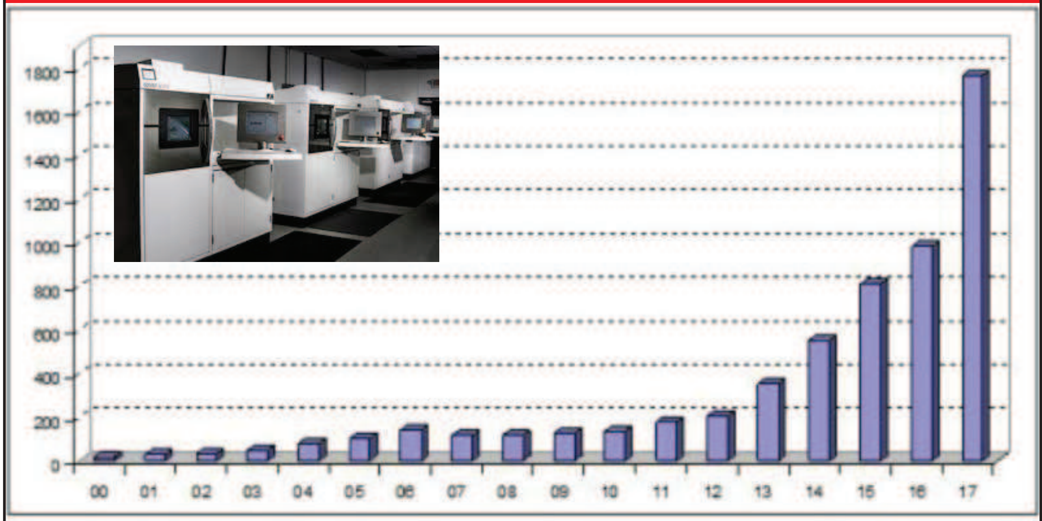

Dramatic rise in metal AM system sales

Source: Wohlers Report 2018

Application specific 3DP Evolution

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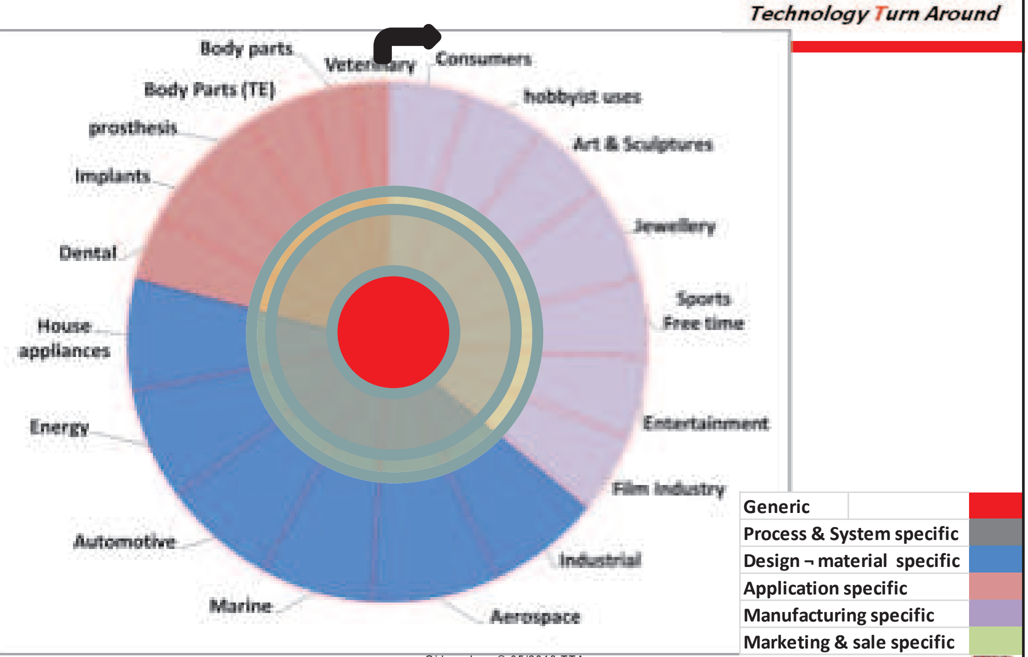

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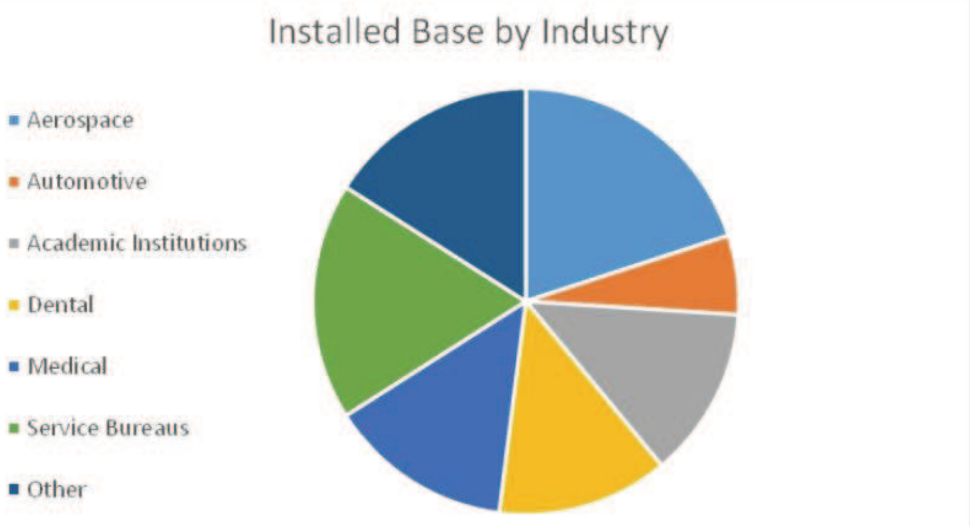
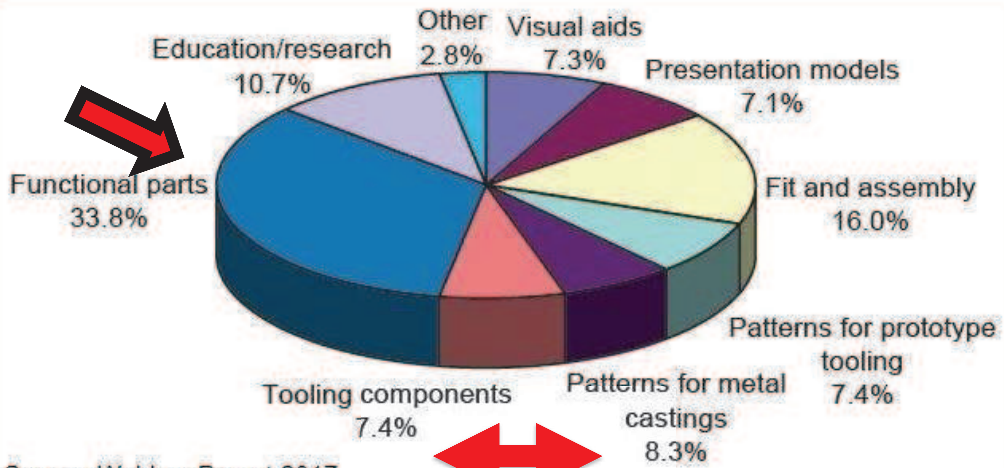
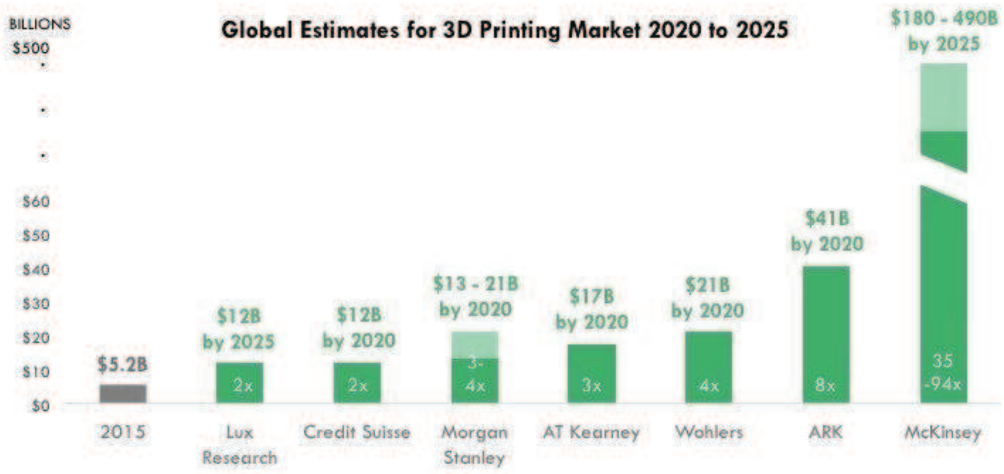


AM Systems are used for:



Source: Wohlers Report 2017



Source: ARK Investment Management LLC

Biomedical engineering (BME) advanced complexity

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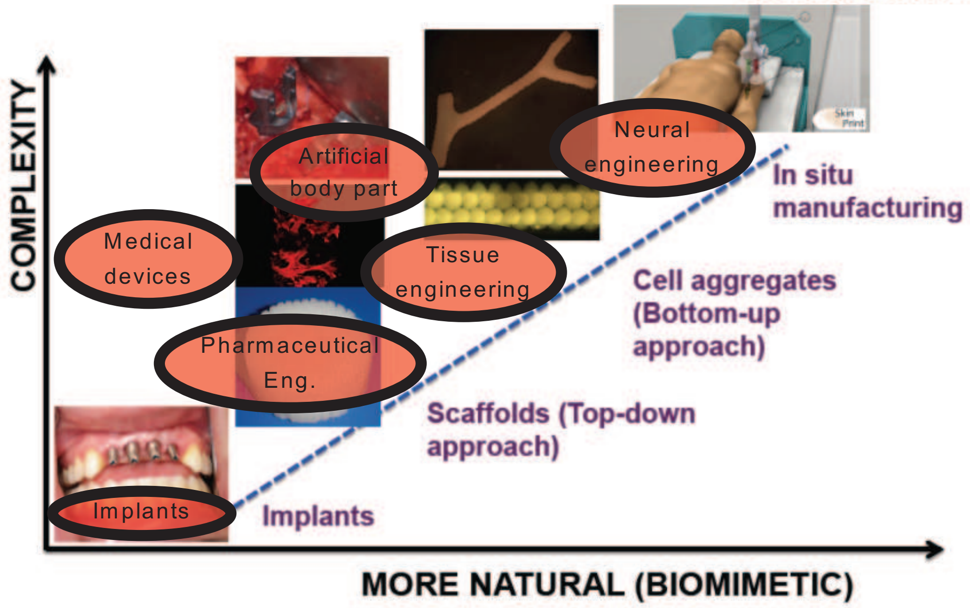

Medical and Life Science models a promising future

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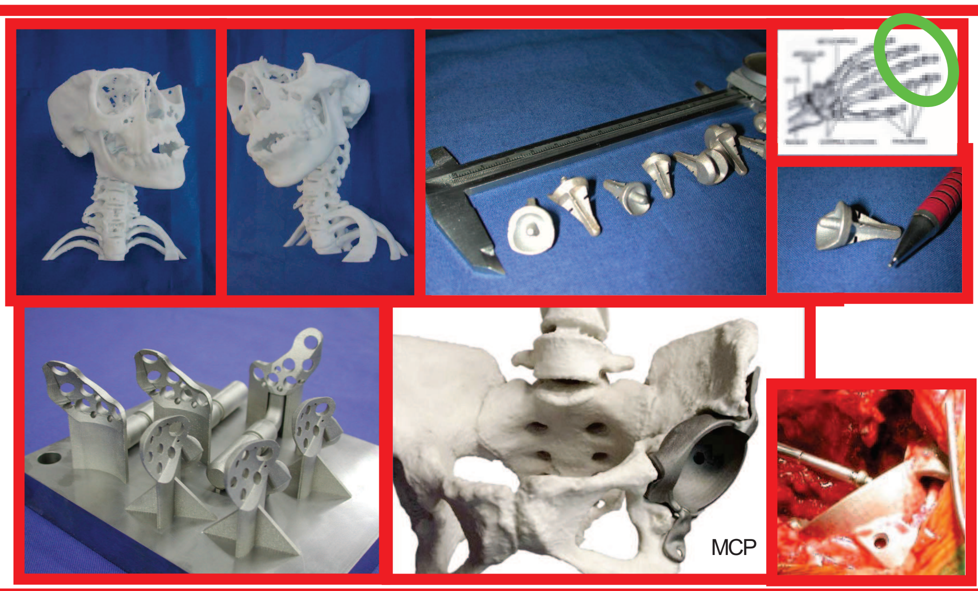

EMMA

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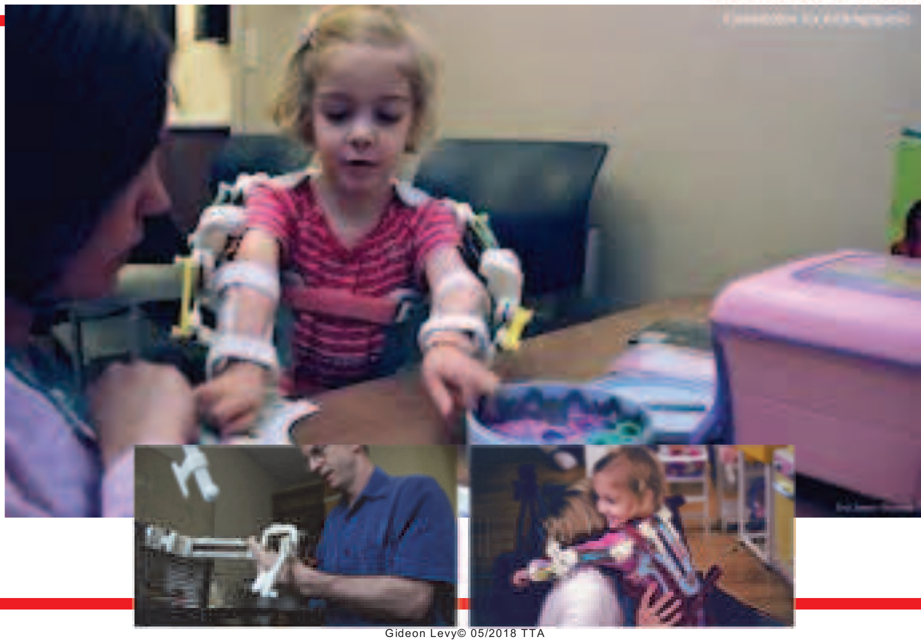

Healthcare applications

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BioNEEK

PEEK Bionic Knee Brace

INTAMSYS
infinite possibilities

PolyJet Precision Pre Operative Planning

TTA
Techn

Stratasys FOR A 3D WORLD

The Challenge

Co-joined twins to undergo surgery

require separation of blood vessels – impossible to plan using 2D X-Rays

The Solution

3D printed model reduced procedure to

22hrs instead of 97hrs

"No matter how good our 3-D graphics are,

there is nothing like a model in your hands"

Henry K. Kawamoto, M.D., D.D.S. UCLA Medical Center

Dr. Anthony Atala (USA) : 3D Printing of Body Parts

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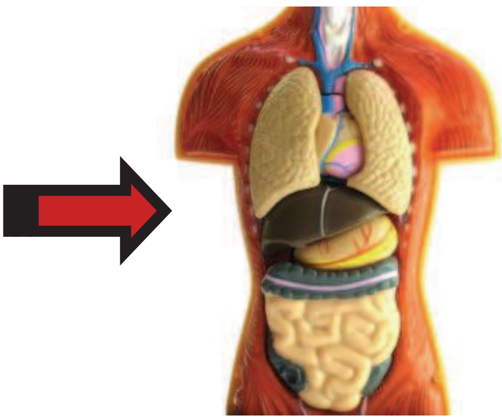

Institute for Regenerative Medicine in North Carolina

Gartner 3DP Hype 2017

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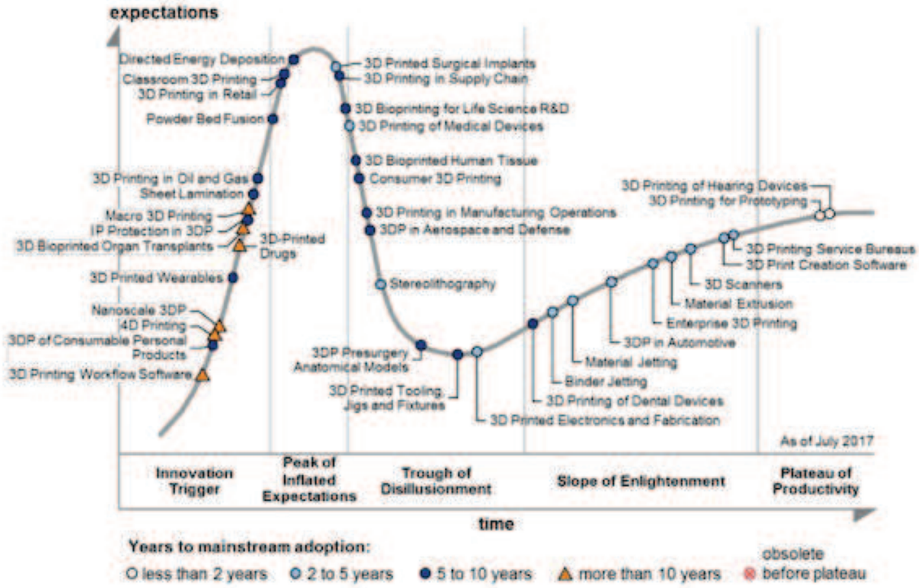

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The value chain in product creation

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CONCEPT MODELING

RAPID PROTOTYPING

Pre-SERIE / BRIDGING

CONFORMAL COOLING / TOOLING

REVERSE ENGINEERING

ADDITIVE MANUFACTURING

The Trend

LASER and no-LASER AM systems vs. materials

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	Polymer	Metals	Ceramics	Composite
Non - LASER Size: S M	HP CARBON	Desktop Metal	XJET	Impossible Objects EnvisionTec Marktforged ….
LASER Size: XS S M L				

SENVOL

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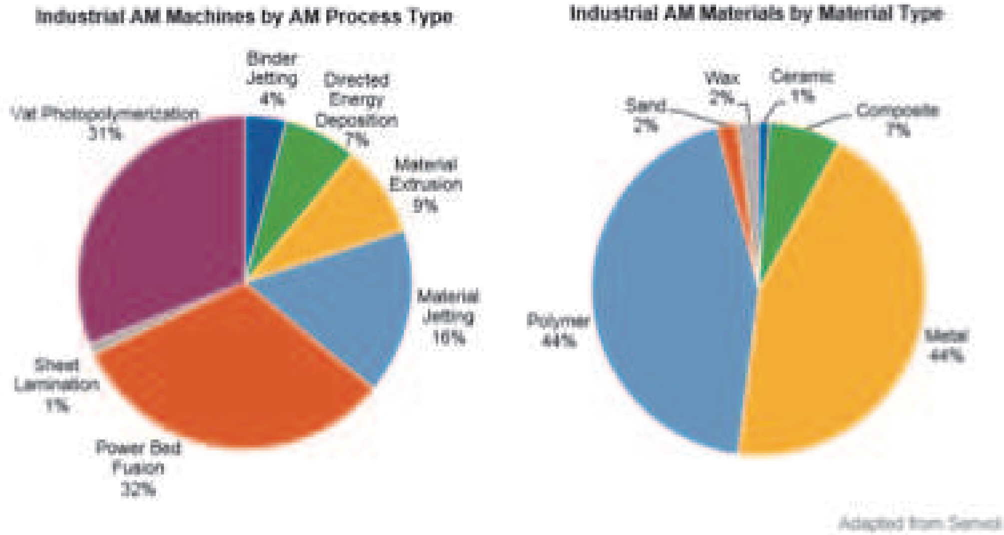

Source Senvol

HP Multi Jet Fusion Process§

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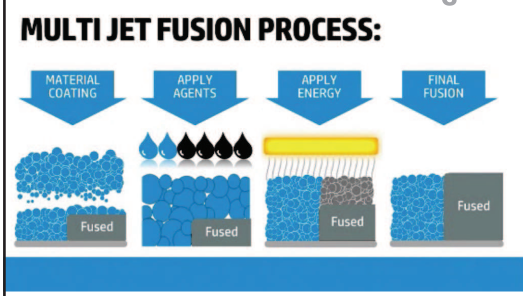

CLIP

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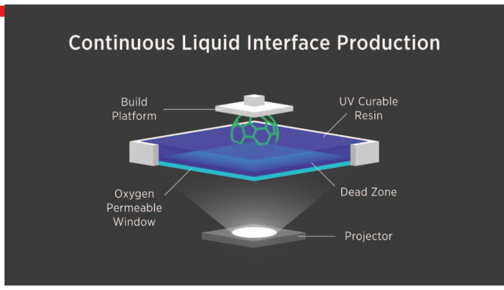

CARBON CLIP Process

carbon3D

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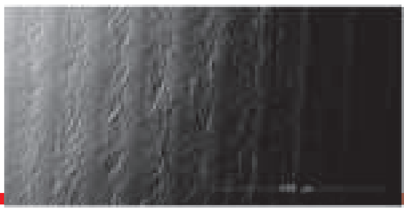
CLIP – Continuous Liquid Interface Production – is a photochemical process that makes it possible to produce parts with excellent mechanical properties, resolution, and surface finish.

Traditional

3D printed parts are notoriously inconsistent. Their mechanical properties vary depending on the direction the parts were printed due to the layer-by-layer approach

Clip

Parts printed with CLIP are much more like injection-molded parts. CLIP produces consistent and predictable mechanical properties, creating parts that are solid on the inside.



Positioning for plastic part AM manufacturing

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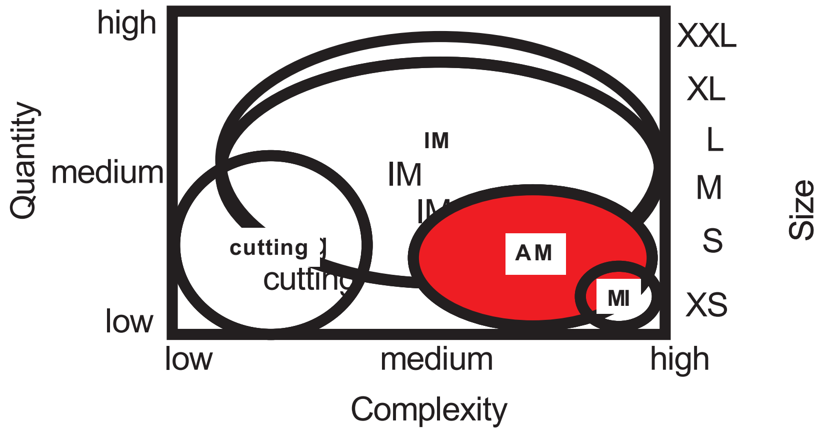

Positioning for plastic part manufacturing:
- AM - Addetive Manufacturing;
- MI - Micro Injection;
- IM - Injection Moulding

(Source: Levy G.N.iRPD)

metal jetting basics

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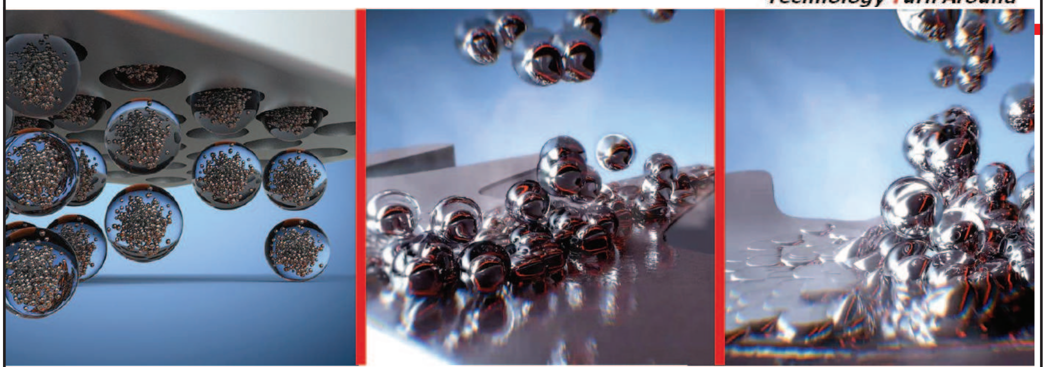

Print Head | Droplet touches Tray | Evaporation

XJET PROPRIETARY & CONFIDENTIAL 16

XJET

AUTODESK

XJET

- 24 (heads)
- 512 (nozzles)
- 18,000 (droplets/sec)

221 Million dps

The Xjet System and demonstrators

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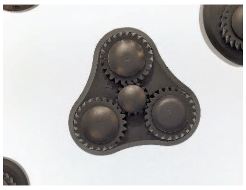

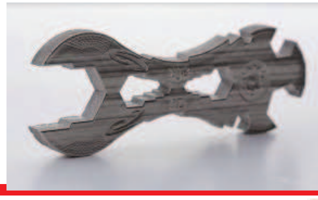

Composite IMPOSSIBLE OBJECTS

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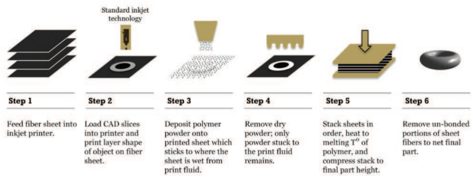

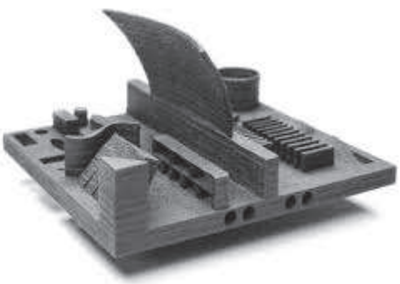

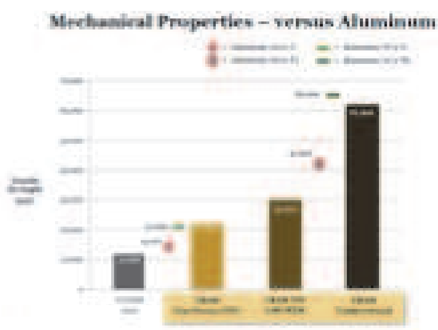

Composite part

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Metal parts Direct and Indirect parts with AM

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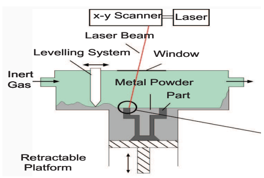
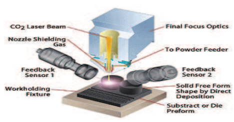
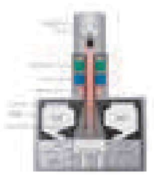
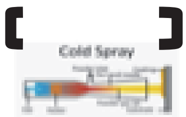
Metals	Material extrusion	Material jetting	Binder jetting	Vat Photopoly-merizasion	Sheet lamination	Powder bed fusion	Direct energy deposion
Direct					+	+++++	++++
2 stage (+ debinding/ sintering)	++	+	+++				
Indirect (casting: pattern cores etc)	++	+	++++	++++			





Directed Energy Deposition





Direct Ballistic Metal Deposition

AM direct metal components production relative to usual options

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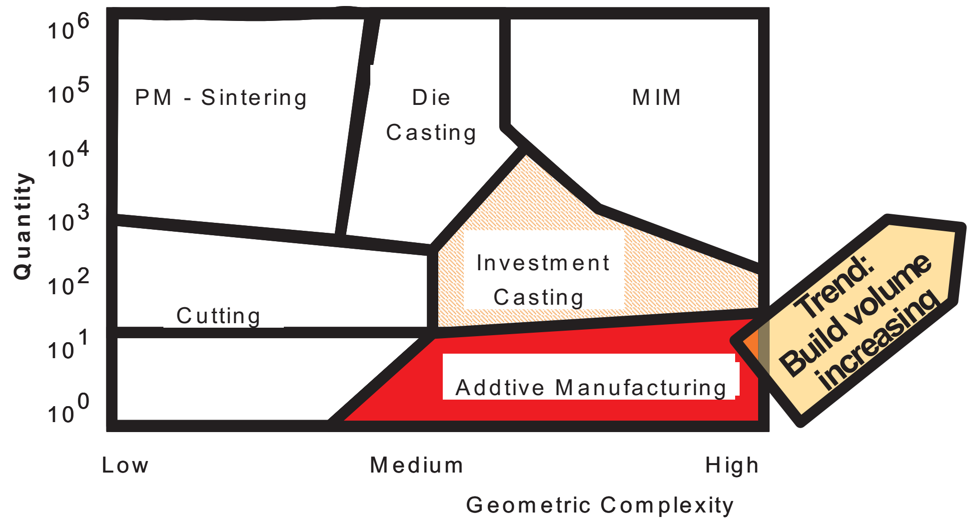

(Source: Meyer E.B., Levy G.N.)

Material (roods) extrusion process (2 stage)

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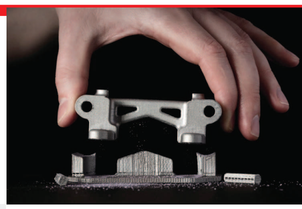
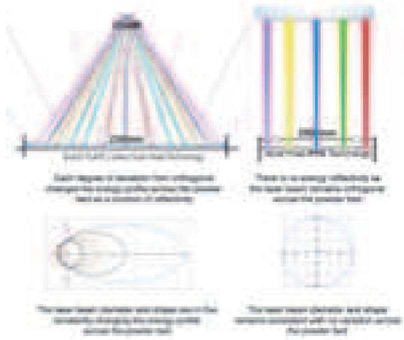
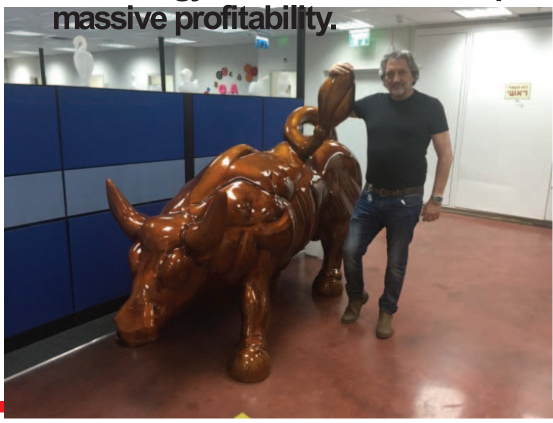
Desktop Metal™

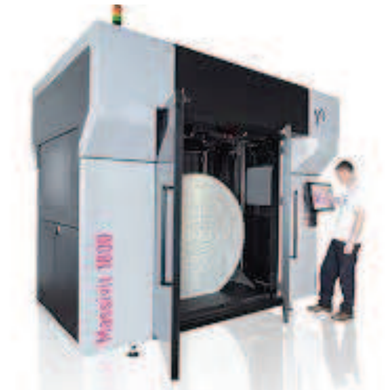


Fonon (http://www.fonon.us/)(USA)



- The Massivit 3D max. printing size
  HEIGHT 180 cm WIDTH 150 cm DEPTH 120 cm
- Massivit 1800 employs ground-breaking Gel Dispensing Printing technology to deliver incredible productivity, awesome results and massive profitability.





Size

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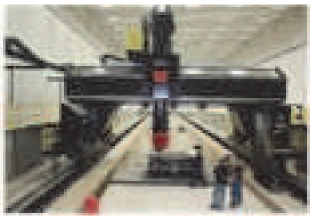
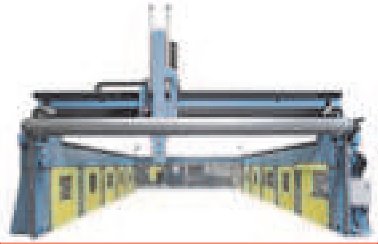
ORNL /Ingersoll

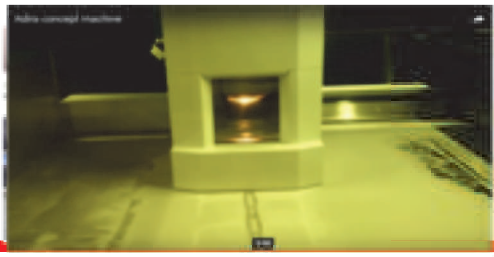


Thermwood LSAM

Multiax International



ADIRA / GE Additive



Common Goal

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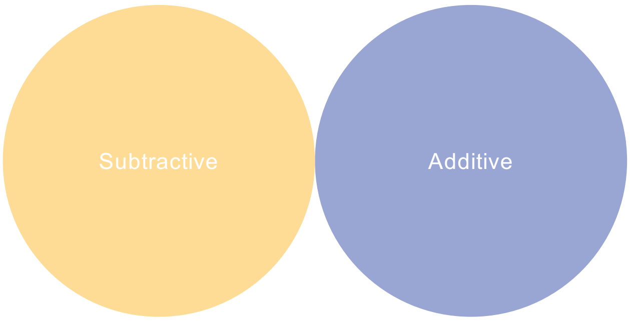
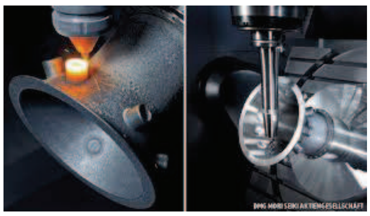


- Tight tolerances
- Surface finish control
- Threads
- Large parts
- Faster cycle times
- Balanced parts

- Internal features
- Bi metallic parts
- Difficult materials to cut



Production

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Justification
- Material
- Time
- Tooling
- Machining
- Rework

"Metal Laser Sintering Hybrid Manufacturing"

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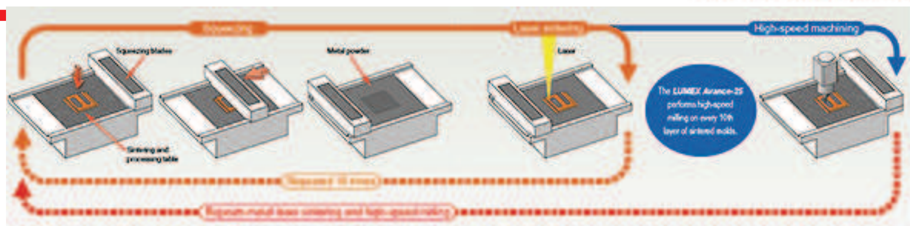

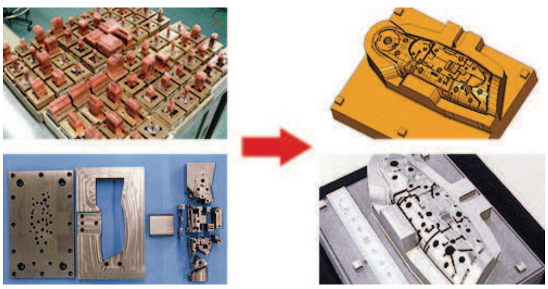

LUMEX Series
Innovation by Matsuura

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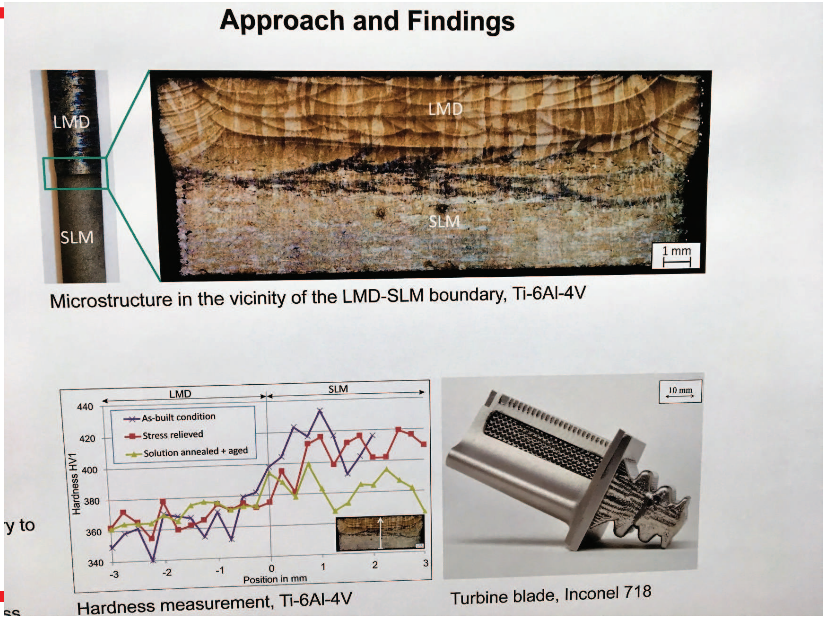

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1. Introduction
2. Process
   - Laser vs Non-Laser
   - Voxelization
   - Size and Productivity
3. Material for Processes
4. AM work flow
   - Dataflow Design Simulation
   - In situ control
   - Automation
5. Economical and Functional justifications
6. Already in Manufacturing
7. Complexity challenges ahead
   - Standards
   - IP
8. Conclusions

Materials relative importance over time

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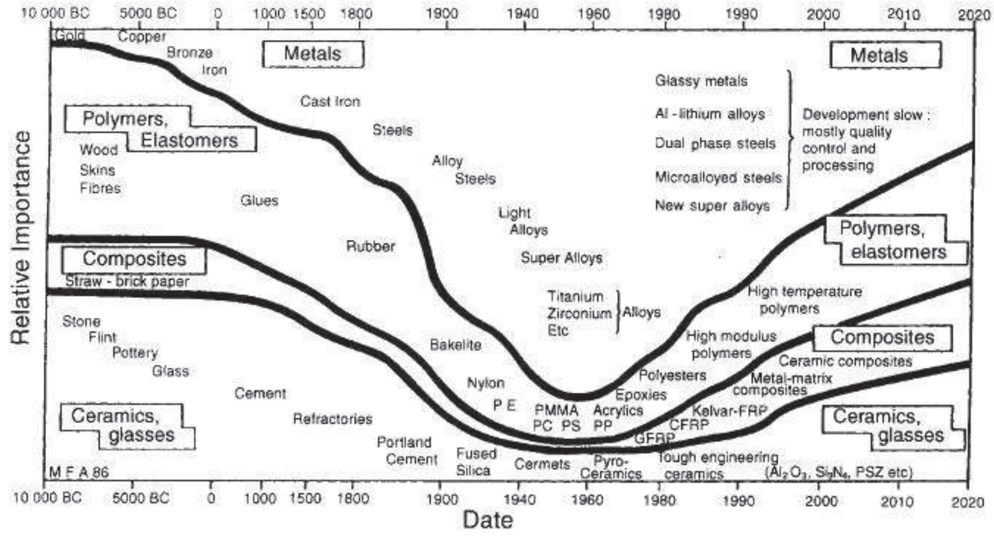

Source: M. F. Ashby

http://www.grantadesign.com/ and 3DP materials

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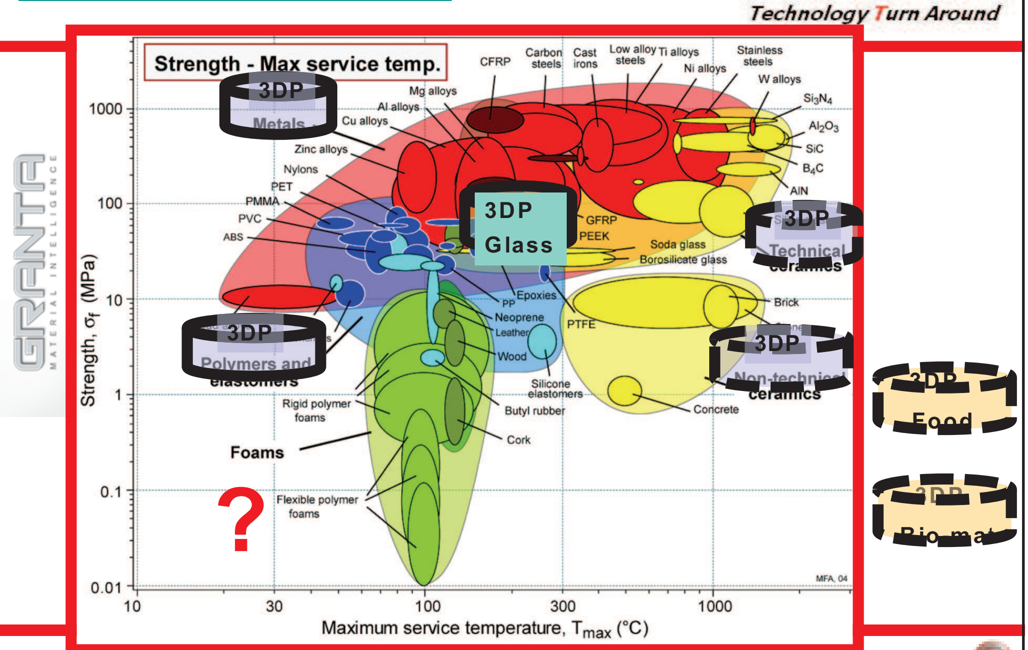

Process / material matrix

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Process/material matrix

The following table shows the intersections between the AM processes and the available material families and applications, such as investment and sanding casting. As can be seen, some processes are inherently linked to certain materials.

	Material extrusion	Material jetting	Binder jetting	Vat photopoly-merization	Sheet lamination	Powder bed fusion	Directed energy deposition
Polymers, polymer blends	x	x	x	x	x[1]	x	
Composites[2]		x	x	x		x	
Metals		x	x		x	x	x
Graded/hybrid metals[3]							
Ceramics			x	x		x	
Investment casting patterns		x	x	x		x	
Sand molds and cores						x	
Paper					x		

Source: Wohlers Associates, Inc

Footnotes:
1 The sheet lamination syste
2 Includes filled materials.
3 Hybrid materials are most t pically produced using ultrasonic additive manufacturing. Graded materials are produced with directed energy deposition systems.

For most process some bio-compatibles are available.

For few process bio-materials (cells) are available.

Crystallization model proposed during the build stage analyzed by DSC

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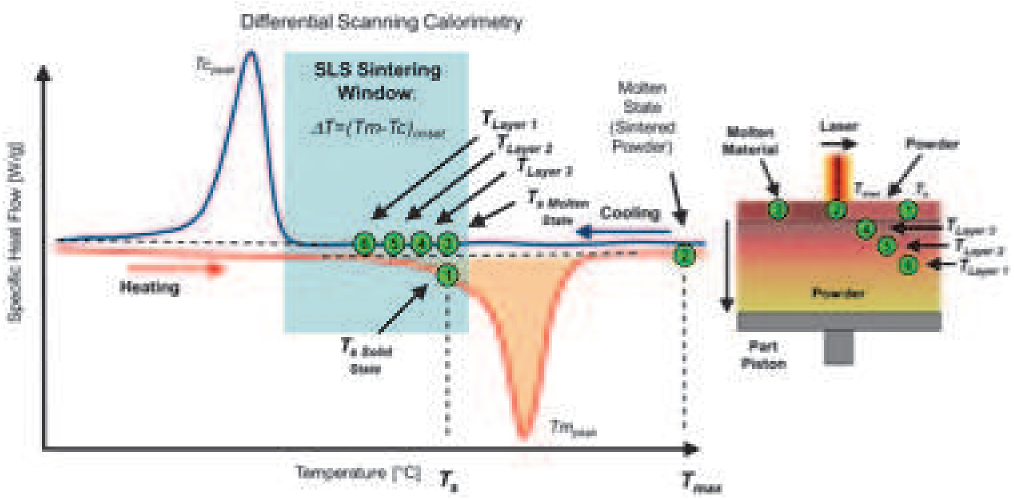

Dr. Antonio Felipe Amado Becker
Diss ETH Z 2016

PA11 SLS Powder

RILSAN FINE POWDERS BY ARKEMA

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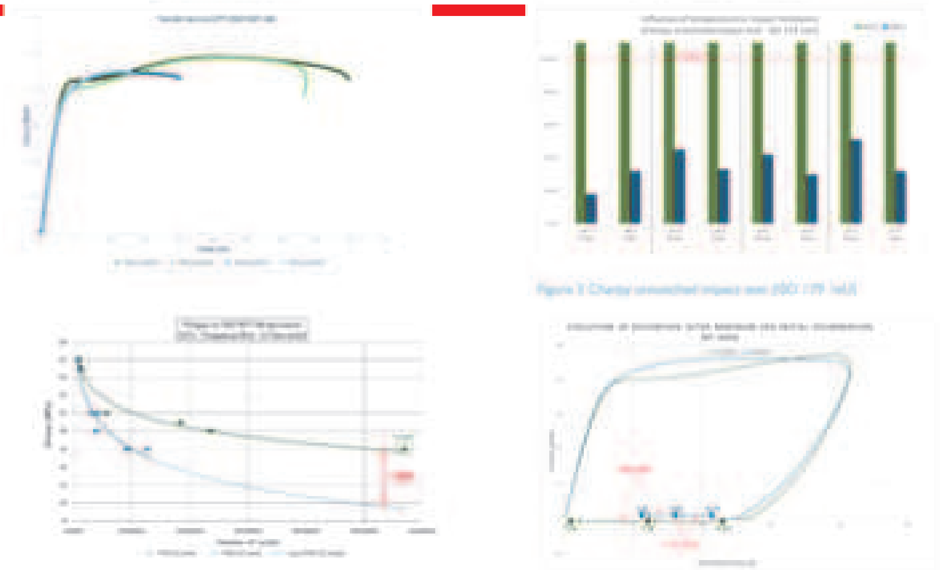

SLM physical effects and phenomena

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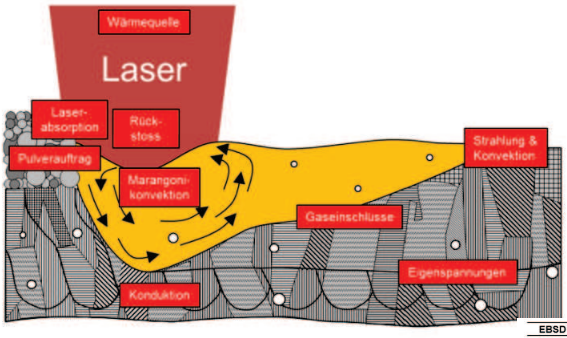

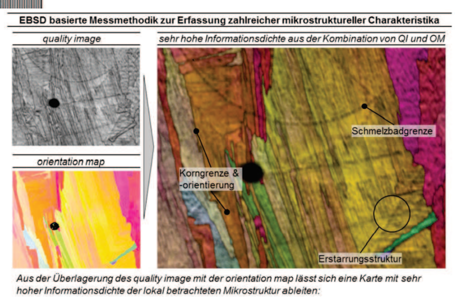

Dr. M. Cloots PhD Diss. ETHZ 2017

for porosity and cracking

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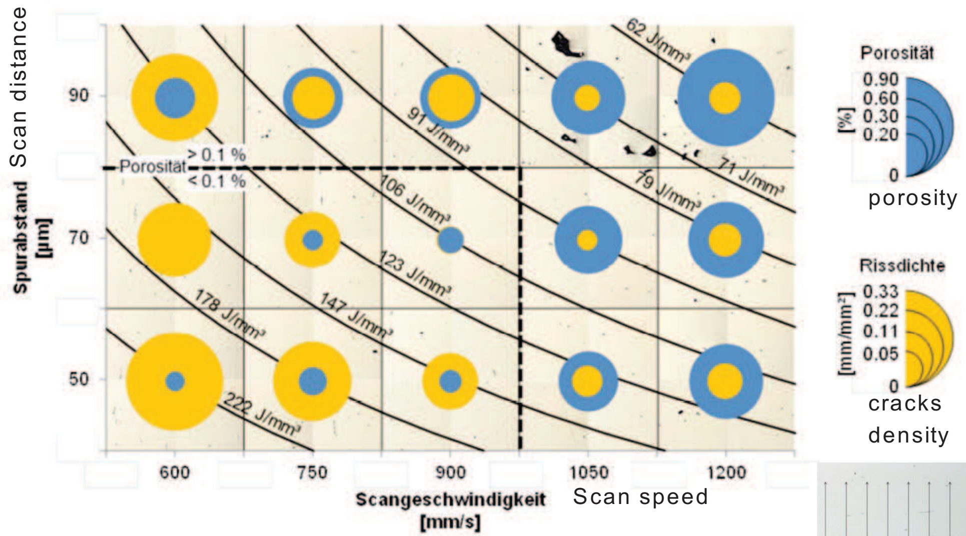

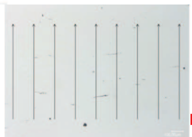

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CIRP Annals - Manufacturing Technology 65 (2016) 213–216

Contents lists available at ScienceDirect

CIRP Annals - Manufacturing Technology

journal homepage: http://ees.elsevier.com/cirp/default.asp

ELSEVIER

Microstructure and mechanical properties of as-processed scandium-modified aluminium using selective laser melting

CrossMark

Adriaan B. Spierings [a,*], Karl Dawson [b], Mark Voegtlin [a], Frank Palm [c], Peter J. Uggowitzer [d]

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Submitted by Prof. Dr. Gideon Levy (1), TTA Technology Turn Around, Switzerland

ARTICLE INFO

Keywords:
Selective laser meltin...
Aluminium
M...

ABST...

...owards optimized lightweight structures for ... aluminium alloys are of special interest to reach a ... presents the development of appropriate selective laser melting ... for a scandium modified aluminium alloy (Scalmalloy®), reaching densities ... mechanical properties of as-processed material are analyzed, pointing out a comparably low ...otropy with regard to the build orientation. A fine-grained microstructure is observed next to regions of coarser, elongated grains. The paper discusses the observed microstructure, and concludes with suggestions for innovative material design for AM.

Full understanding of the "working principle" of this alloy system might pave the way to the development of other AM-designed alloys.

Metal Powder for Process

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❑ (64% Fe powder + 36% Ni powder) * laser printed ~ Invar 36

Powder	D_m	D95	D90	D50	D10	D5
Fe	12.8	26.8	22.2	11.7	4.6	3.6
Ni	12.5	24.5	20.7	11.7	4.9	3.9
64Fe 36Ni mix	12.6	25.4	21.3	11.7	4.8	3.8

All size data in microns.

Powder	Flow	$\rho_{app, \% theo.}$	$\rho_{tap, \% theo.}$	$\rho_{theo.}$	Hausner ratio
Fe	No flow	3.2 (41%)	4.4 (56%)	7.87	1.38
Ni	No flow	3.6 (40%)	5.0 (56%)	8.91	1.39
64Fe 36Ni mix	No flow	3.3 (40%)	4.6 (56%)	8.24	1.39

❑ Mechanical properties of this mixture were comparable with Invar 36 specs.

❑ Thermomechanical properties of the printed parts had more scatter than Invar 36 but were generally within alloy specifications.

- [redacted]
- 100 micron spot size
- [redacted]
- Scan +/- 45 degrees, zero overlap
- Beam speed: 2500 mm/sec

Material	CTE 260 °C	CTE 371 °C
Invar 36	3.4-5.0	7.3-8.4
Invar 36 cold drawn	4.1	7.2
Invar 36 + HT	3.9	7.3
Invar 36 + Ann	4.0	7.3
75% power AP	4.5	7.5
75% power + HT	5.1	7.5
75% power + Ann	4.3	8.0
100% power AP	4.6	7.1
100% power + HT	4.9	7.3
100% power + Ann	4.1	6.8

Red: Ref: Cartech

HT: Heat Treated 1310 C
Ann: Annealed 815 C
AP: As-printed

CTE: ppm cm/cm/°C

All samples measured In "Z" direction. Average of two data points.

Outside of spec.

New Steel Alloys For Metal 3D Printing

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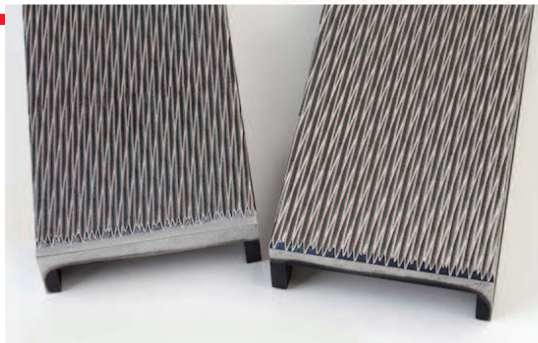

NanoSteel
a new class of steel powders that combine high hardness and toughness and are printable at room temperature using standard commercial equipment.
Applications: • Tools, dies and fixtures • Valves • Gears

BLDRmetal™ L-40 Key Features:
- ✓ Case Hardening: Up to 74 HRC
- ✓ High Core Properties: Hard: >50 HRC Ductile: >10% Elongation
- ✓ Tough: 65J (v-notch, as built)
- ✓ Easy to Print (RT to 200ºC)

NANOSTEEL
STEEL. REDEFINED.®

NANOSTEEL
STEEL. REDEFINED.

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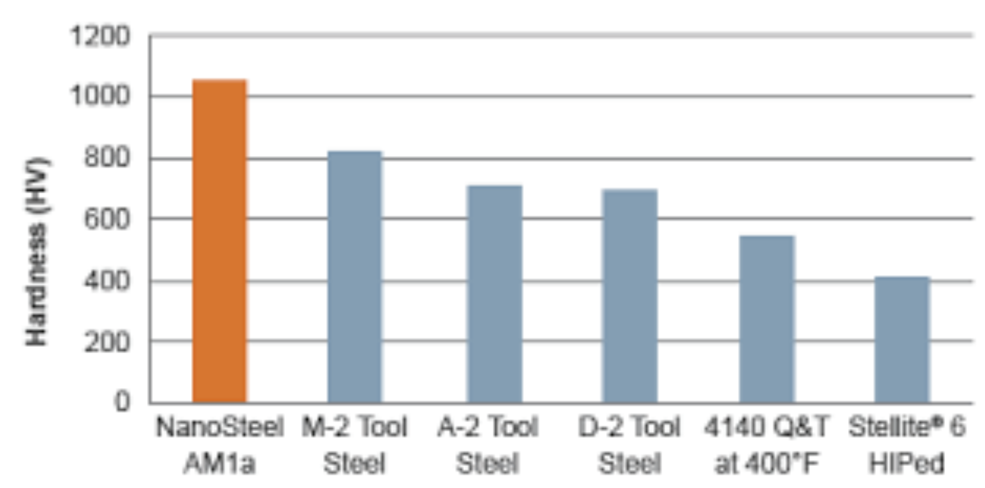

AAMS - ALLOYS FOR ADDITIVE MANUFACTURING SYMPOSIUM

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AAM Workshop 2016

AAMS2017

Alloys for Additive Manufacturing Symposium 2017

Beginning: Sep 11, 2017
End: Sep 12, 2017
Location: Empa AKADEMIE, Dübendorf, Überlandstrasse 129, Switzerland
Host: Empa-Swiss Federal

Additive Manufacturing is adoption. In some fields su aerospace industry, it is ra production of highly compl currently focussing on imp and productivity. At the sa the conclusion that a renev during the AM processes is application.

In this workshop, we will focu based composites for AM, i.e. and on materials by AM, i.e. effectively by AM. The entire to processing and post-proce well as industrial researchers to participate in the workshop.

As Additive Manufacturing tec more industries, the focus of materials in use. Additionally, academia and industry realise produce materials that were l manufacturing techniques or Additive Manufacturing Symp of these issues by researchers scientific issues pertaining to and composites including a m conference.

3RD – 4TH SEPTEMBER 2018
ALLOYS FOR ADDITIVE MANUFACTURING SYMPOSIUM 2018 (AAMS18)

SENVOL & GRANTA

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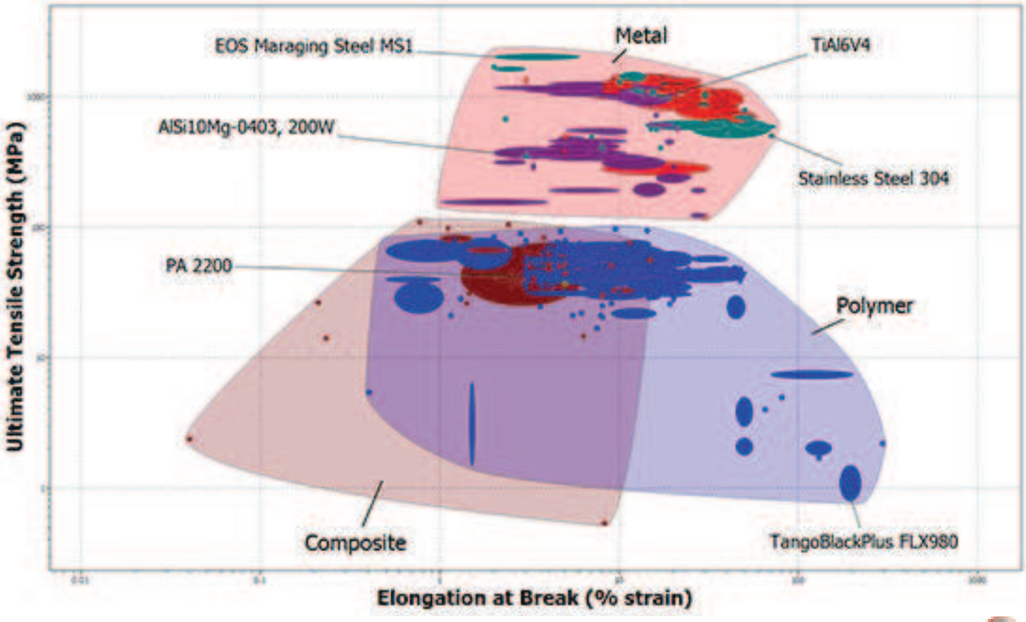

Light-weight "material" selection done by geometry

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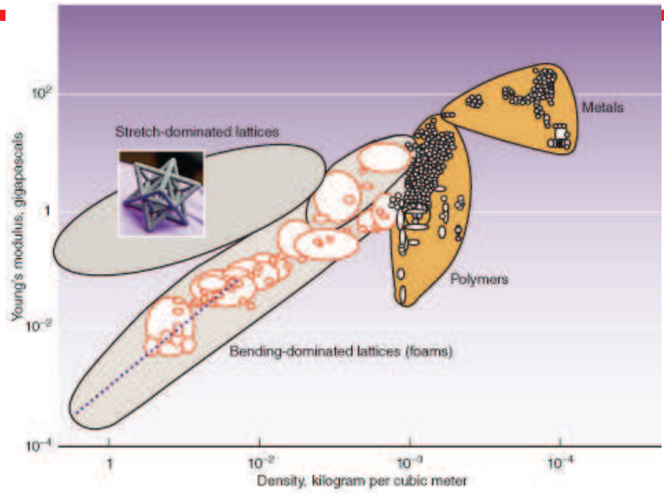
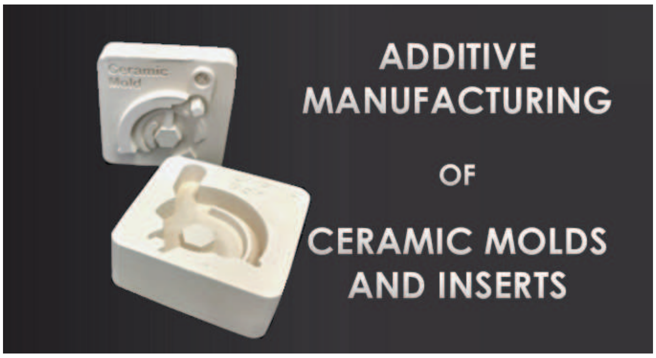
LAWRENCE LIVERMORE NATIONAL LABORATORY



Materials designed with new additive manufacturing techniques exhibit high stiffness and low density, occupying a previously **unsettled area of the Ashby material selection chart** for Young's modulus (stiffness) versus density. The octet truss structure recently fabricated by Livermore researchers is a stretch-dominated lattice.



Avi Cohen
Vice President,
Healthcare &
Education

WZR uses the powder bed based 3D printing of ceramics since 2008 as a production method to produce components for industrial use

The material is called CerPrint® Alox-01, it is sintered at 1600 ° C and then consists of a pure ceramic having an Al2O3 content of min. 99.5%. In addition, a special compound for the prin

https://wzr.cc/en/

Process Development

SLM of Net-shaped Ceramics

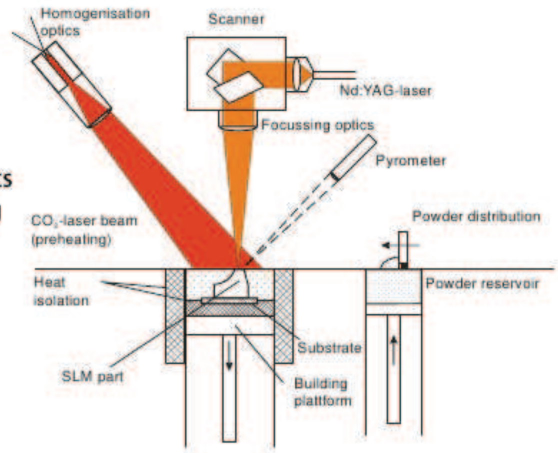
SLM for Ceramics

Experimental Setup I/II

- CO_2 laser-preheating

➡ Decrease of thermal gradients during selective laser melting

➡ Crack-free specimens



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Fraunhofer

3DCERAM Advanced Ceramics

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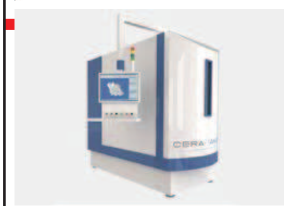

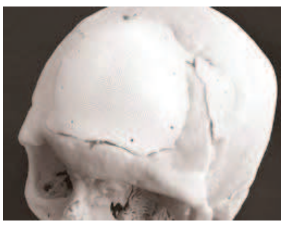

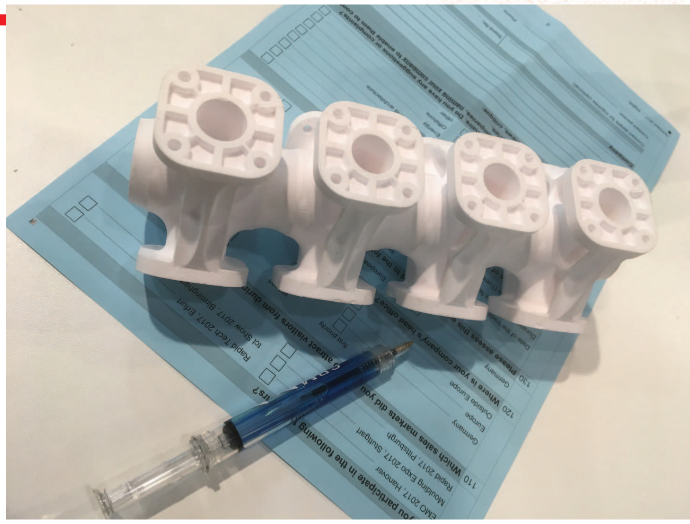

3DCERAM offers several types of ceramics formulated to be printed with the CERAMAKER printer: zirconia, alumina, hydroxyapatite/TCP, Si3N4, cordierite, zirconsilica, silica.

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Lithography-based ceramic manufacturing (or LCM) process

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THOZ
Manufacture the future.

Technical properties	CeraFab 7500	CeraFab 8500
Lateral resolution	40 µm (635 dpi)	60 µm (423 dpi)
Layer thickness	10 – 100 µm	10 – 100 µm
Number of pixels (X,Y)	1920 x 1080	1920 x 1080
Building envelope (X,Y,Z)	76 mm × 43 mm × 170 mm	115 mm × 64 mm × 200 mm
Data format	.stl (binary)	.stl (binary)
Light source	LED	LED
Building speed	up to 100 slices per hour	up to 100 slices per hour

http://www.lithoz.com/

Winsun 3D printed house (China)

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How a Chinese Company Built 10 Homes in 24 Hours

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Suzhou-based construction-materials firm **Winsun New Materials** says it has built 10 200-square-meter homes using a gigantic 3-D printer that it spent 20 million yuan ($3.2 million) and 12 years developing.

Winsun's 3-D printer is 6.6 meters (22 feet) tall, 10 meters wide and 150 meters long, the firm said, and the "ink" it uses is created from a combination of cement and glass fibers. In a nod to China's green agenda, Winsun said in the future it plans to use scrap material left over from construction and mining sites to make its 3-D buildings

Wasp - Massa Lombarda – 48024 Ravenna

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CSP (Centro Sviluppo Progetti) was founded in 2003 from a 10-year experience of founder Massimo Moretti gained in the world of electronics and mechanics. The company develops innovative projects: **continuous research and state of the art**

And that is how **WASP** (World's Advanced Saving Project) **was created in 2012**. A project focused on developing 3D printing and that finds its roots in the world of Open-source, trying to give and put into circulation know-how and tools. WASP manufactures solid professional printers with the aim to encourage sustainable development and **in-house production**.

Delta 60 100

Delta WASP 40100 Clay

Delta WASP 2040 Clay

Delta WASP 40100 Clay. - *Ceramic 3d printer*

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LDM TECHNOLOGY

Printing volume: Ø400mm x H1000mm

Layer resolution: max 0.5mm

Nozzle: Ø1.2mm (as series)

Maximum printing speed: 150 mm/s

Maximum travel speed: 150 mm/s

Acceleration: 500mm/s

MATERIALS

Ceramic materials: porcelain, erthenware, gres, refractory, clay

LDM WASP Extruder

€250,00 (IVA esclusa / VAT excluded)

LDM (Liquid Deposit Modeling) WASP Extrude

Material – System – Part Interactions

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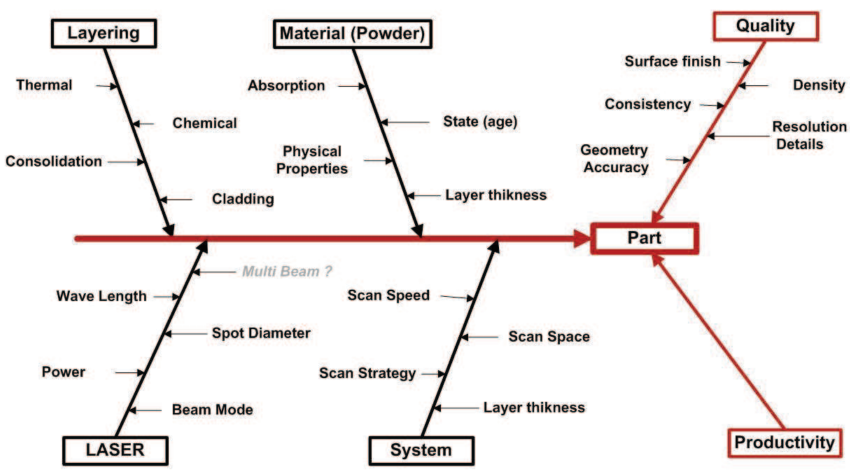

Anisotropy Internal tensions

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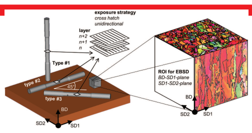
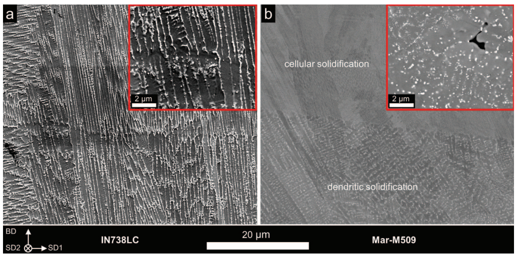
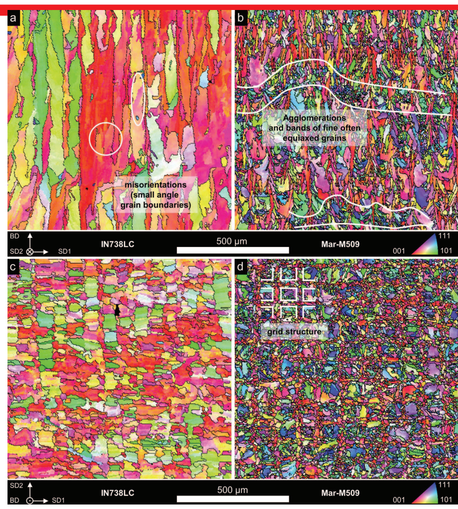
- Material
- Geometry
- Orientation
- Heat Source
- Scan Strategy
- Cooling Solidification
- Thermal history







Microstructural characteristics of the nickel-based alloy IN738LC and the cobalt-based alloy Mar-M509 produced by selective laser melting

Michael Cloots, Karsten Kunze, Peter J. Uggowitzer, Konrad Wegener (Materials Science & Engineering A 658 (2016) 68–76)

Laser scan patterns (outline and hutch-fill)

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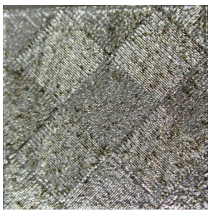

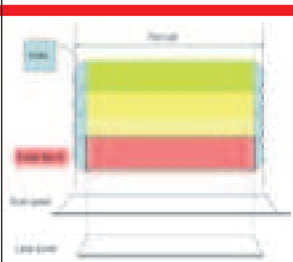

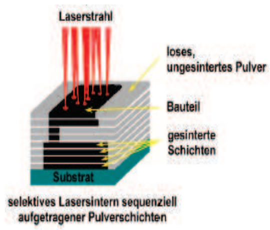

Islands scan strategy (courtesy iRPD)	"End of Vector"	Stochastic fill shooting [15]

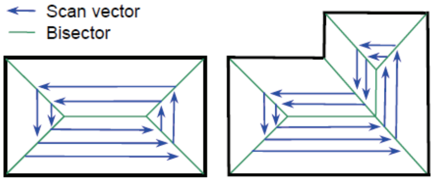

Figure 1: Principles of Bisector scanning pattern.

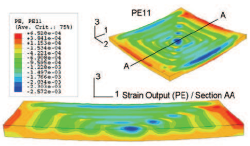

Figure 10: Model output for the Bisector scanning pattern showing the plastic strain in the 1 or x direction after processing.

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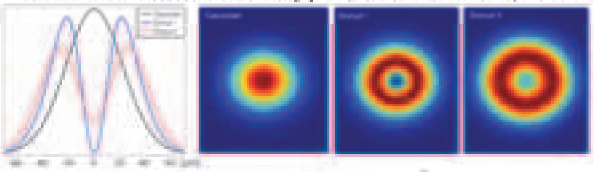
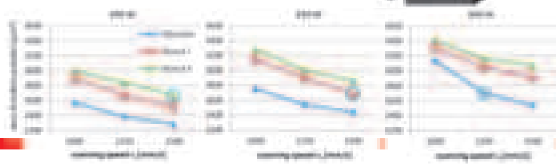
Simulation of the effect of different laser beam intensity profiles on heat distribution in selective laser melting

Tim Marten Wischeropp[1]*, Raul Salazar[1], Dirk Herzog[2], Claus Emmelmann[2]





Study of an annular laser beam based axially-fed powder cladding process (CIRP Annals 2018)

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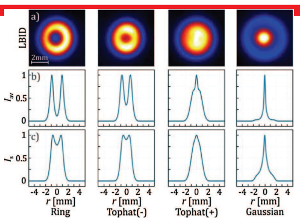

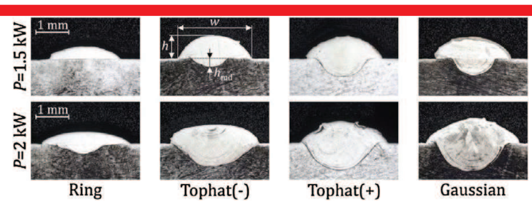

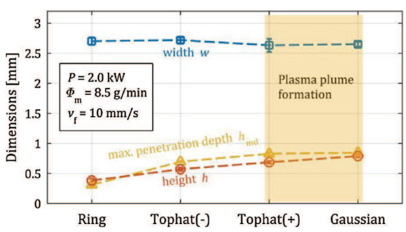

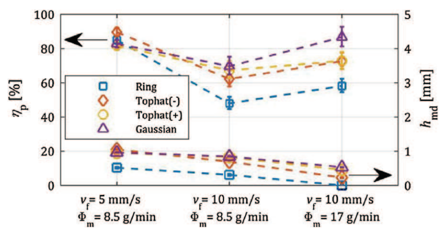

Based on the experimental results it can be concluded that axial powder feeding is very beneficial from the point of view of high powder catchment efficiency. In a combination with a proper LBID a low dilution with good bonding at the clad edges, and low porosity of clads can be achieved.

Edvard Govekar (1), Andrej Jeromen, Alexander Kuznetsov, Gideon Levy (1)