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Emerging trends in 3D printing of plastic materials

Niklas Kretzschmar

Outline

1. **Additive Manufacturing (AM) research group**
2. **AM basics**
3. **Current state of AM plastics**
4. **Emerging trends of AM plastics**

   New AM processes

   New AM materials

   New AM applications

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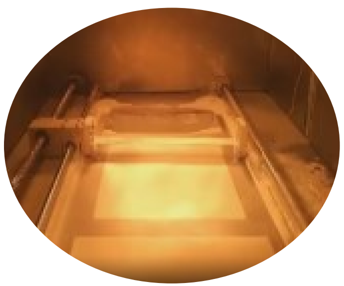
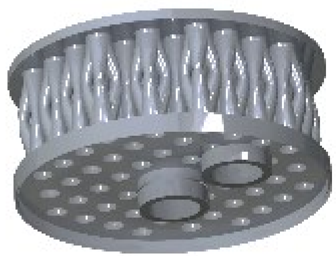
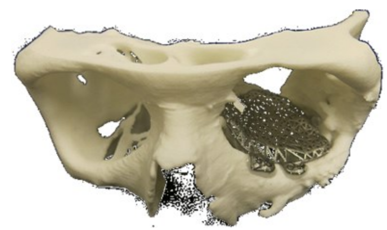
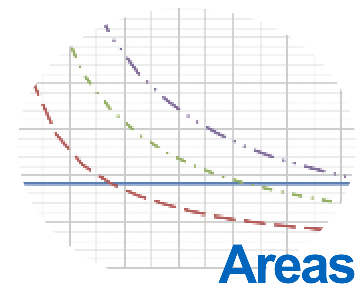
Additive Manufacturing (AM) research group

Research focus

Additive manufacturing technologies

Niklas Kretzschmar: Doctoral student

Jouni Partanen: Professor

AM process development & material testing	Industrial & Consumer applications	Medical applications	AM economic validations
			

National (Academy of Finland, Business Finland) and international projects (EIT)

Personal projects: 3D printing of „bio“materials, digital spare parts, EIT automation support

ADDLab

AM machine room for prototypes
Access for students and researchers
Closely tied to group research

AM processes

- (Micro) Stereolithography
- Fused Deposition Modeling & Paste extrusion
- Selective Laser Sintering
- Sheet Lamination
- Binder Jetting
- Material Jetting
- Selective Laser Melting

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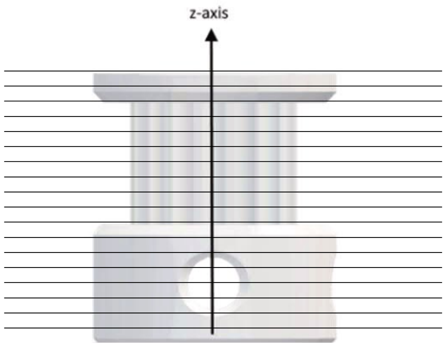
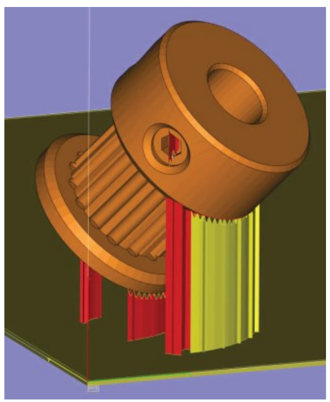
AM basics

AM Categories

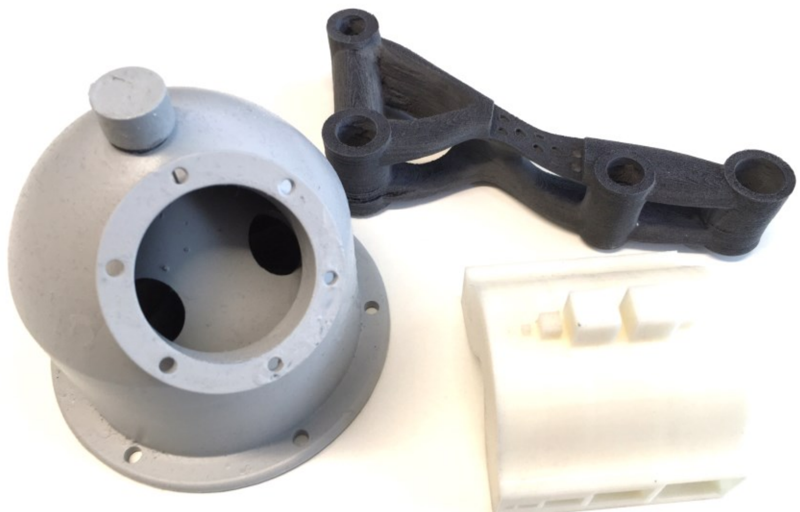




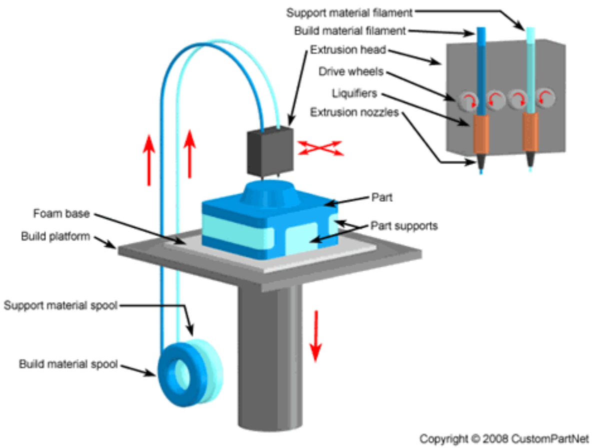
Technology	Commonly used materials
Vat Photopolymerization	**Plastics**
Material extrusion	**Plastics**
Powder bed fusion	**Plastics and metals**
Directed energy deposition	Metals
Sheet lamination	Paper
Material Jetting	Plastics
Binder Jetting	Gypsum and sand

Commonly used AM categories

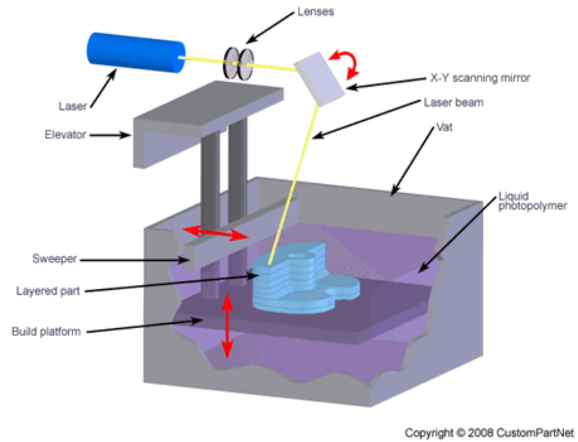
Technology group	Technology	Typical applications
Vat Photopolymerization	Stereolithography Digital light processing	Prototypes and medical parts
Material extrusion	Fused deposition modeling	Prototypes and special applications
Powder bed fusion	Selective laser sintering Selective laser melting	Leading technology for industrial applications



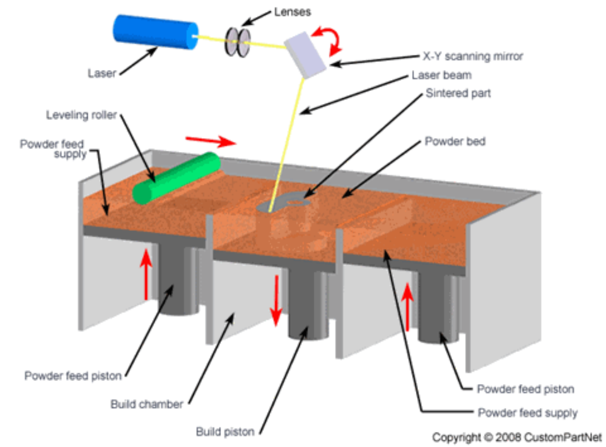
Work principles



Fused deposition modeling



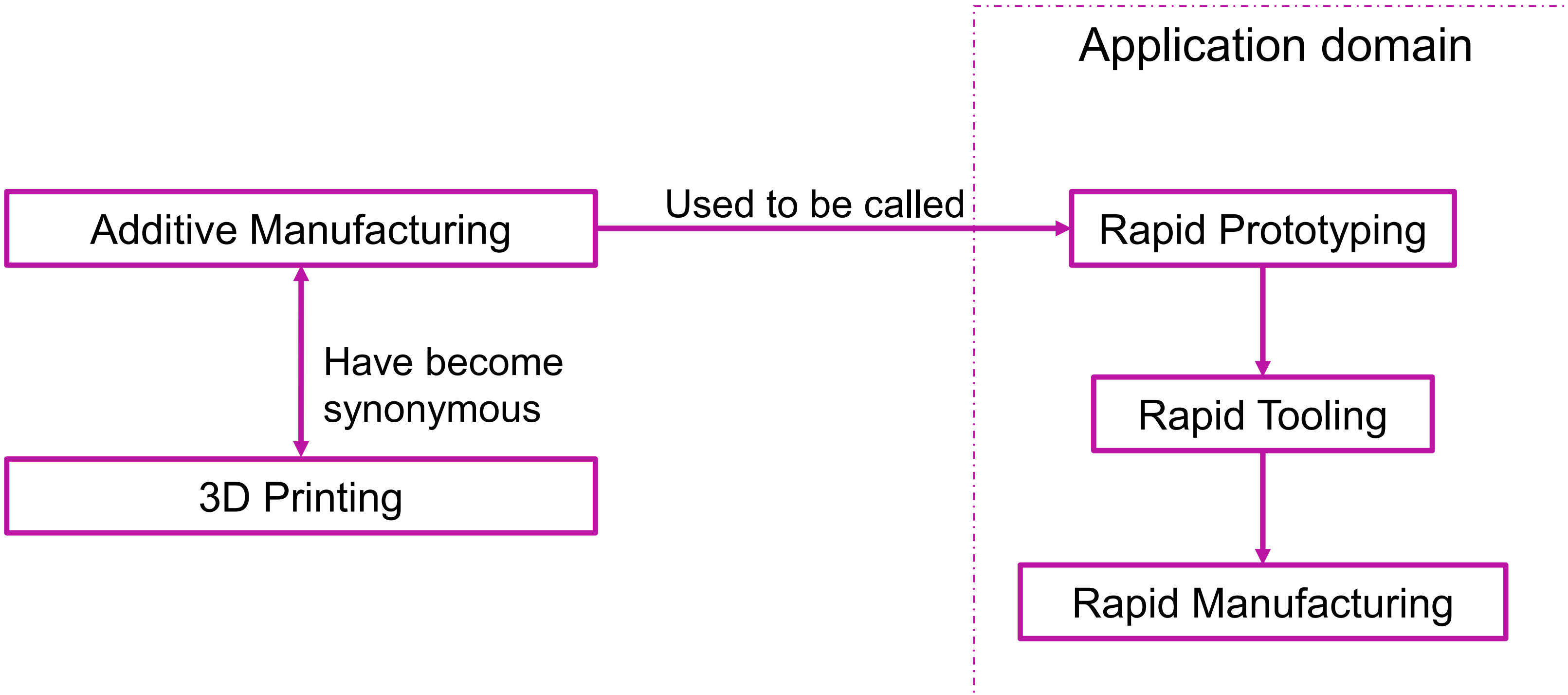
Stereolithography



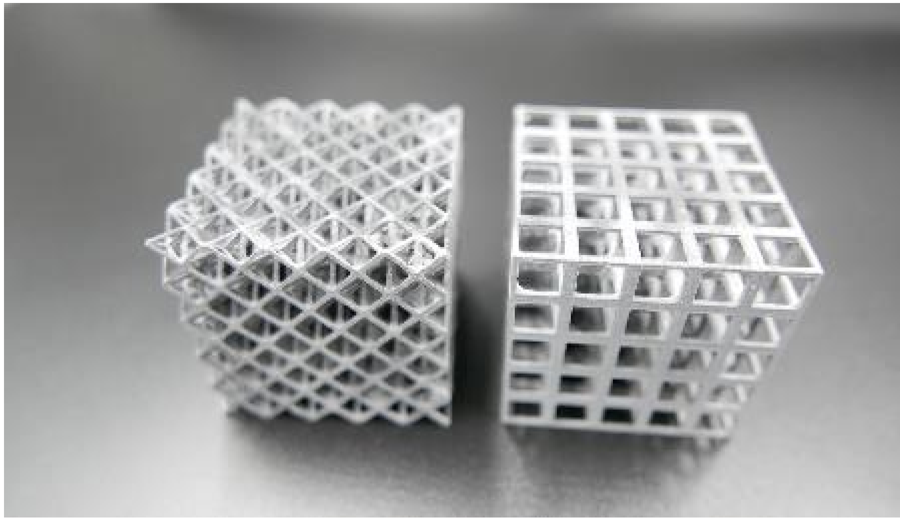
Selective laser sintering

Source: Custompartnet

Terms of the field



Rapid Prototyping



Lattice structures (PA12, Selective Laser Sintering)

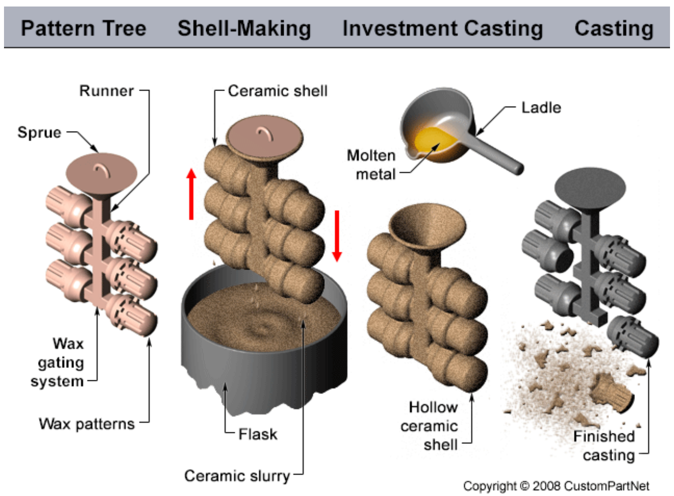
Source: Engadget

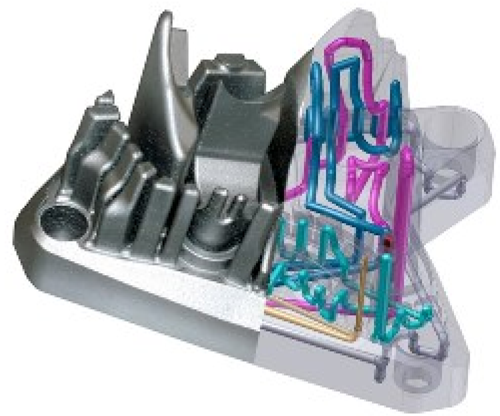
Iterative design

“application of additive manufacturing intended for reducing the time needed for producing prototypes”

Rapid Tooling

"application of additive manufacturing intended for the production of tools and tooling components with reduced lead times"





Investment casting / sand casting

Source: Fibrox3D, Custompartnet, ICOMold, Renishaw, Voxeljet

Rapid Manufacturing

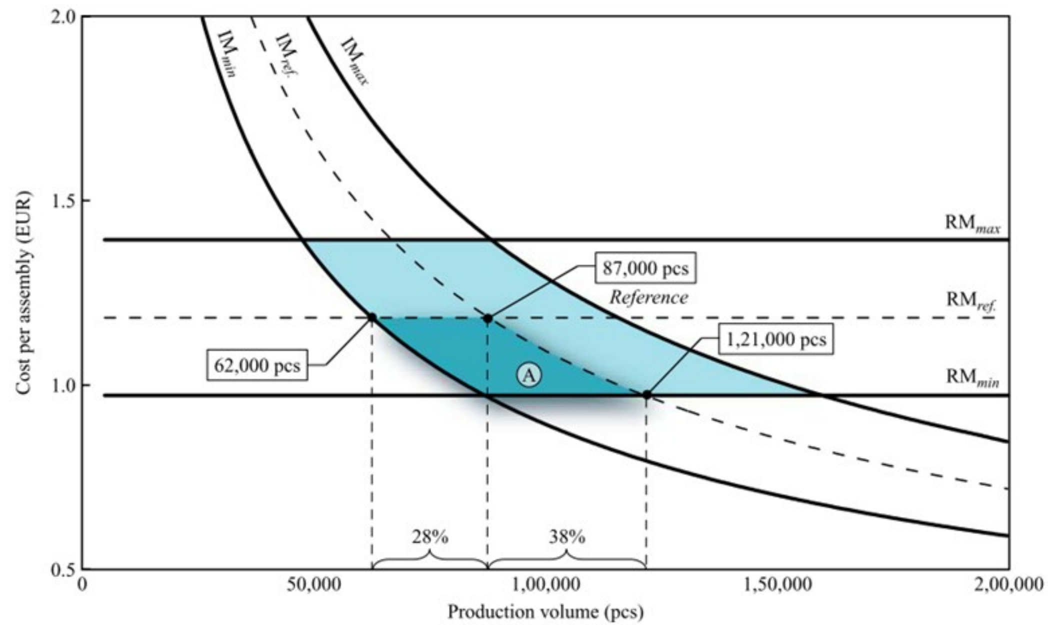
"the use of a computer aided design (CAD)-based automated additive manufacturing process to construct parts that are used directly as finished products or components"

Source: Renishaw, MetalAM, Fabbaloo

RM business opportunities

Advantages:

- No tooling costs
- Reduction of warehousing
- Improved lead times
- Distributed manufacturing
- More variants in less time
- Increasing manufacturing rates

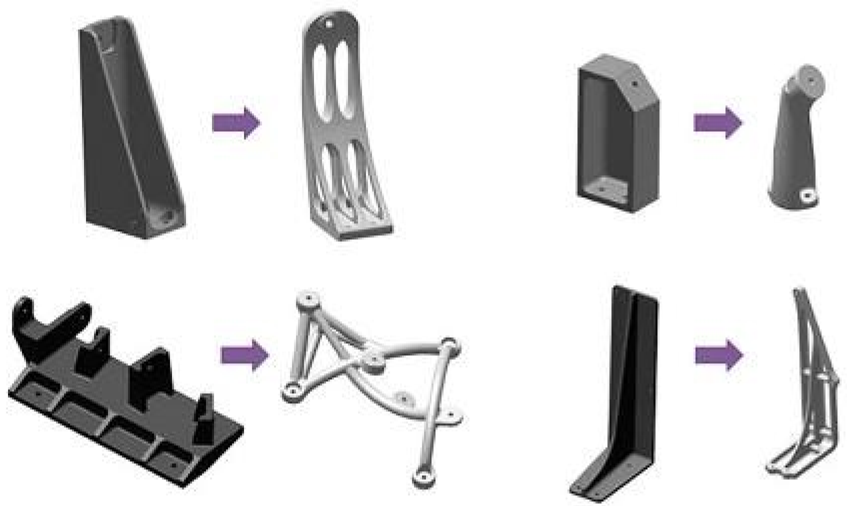


Design approach of redesign

Identify interfaces, the design space, and the functional requirements

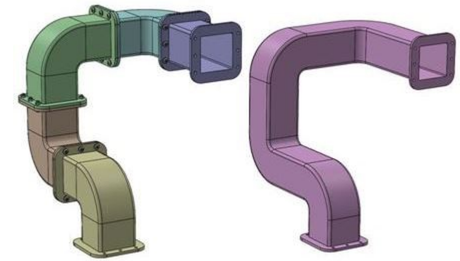
Add only the material needed to connect the interfaces while maintaining functionality requirements

Modify the part to be easily additively manufactured

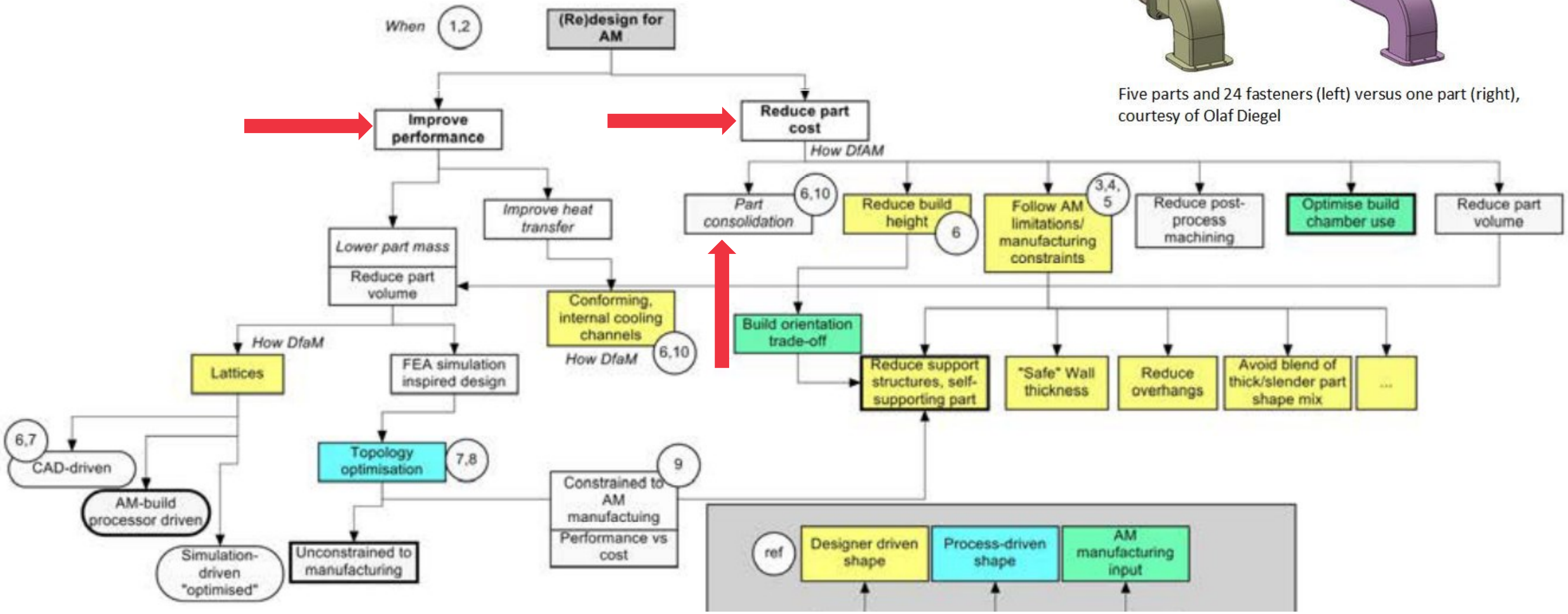


Images from Boeing

(Re)design for AM: Classification



Five parts and 24 fasteners (left) versus one part (right), courtesy of Olaf Diegel



Source: Hällgren et al. "(Re)Design for Additive Manufacturing"

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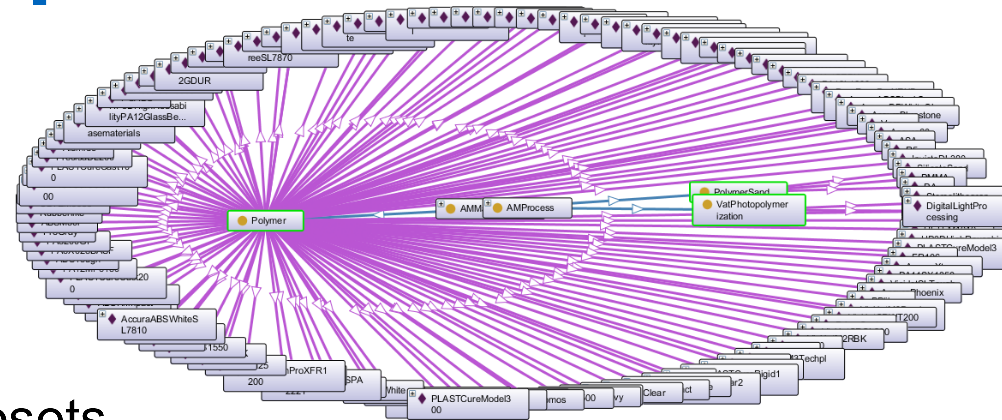
Current state of AM plastics

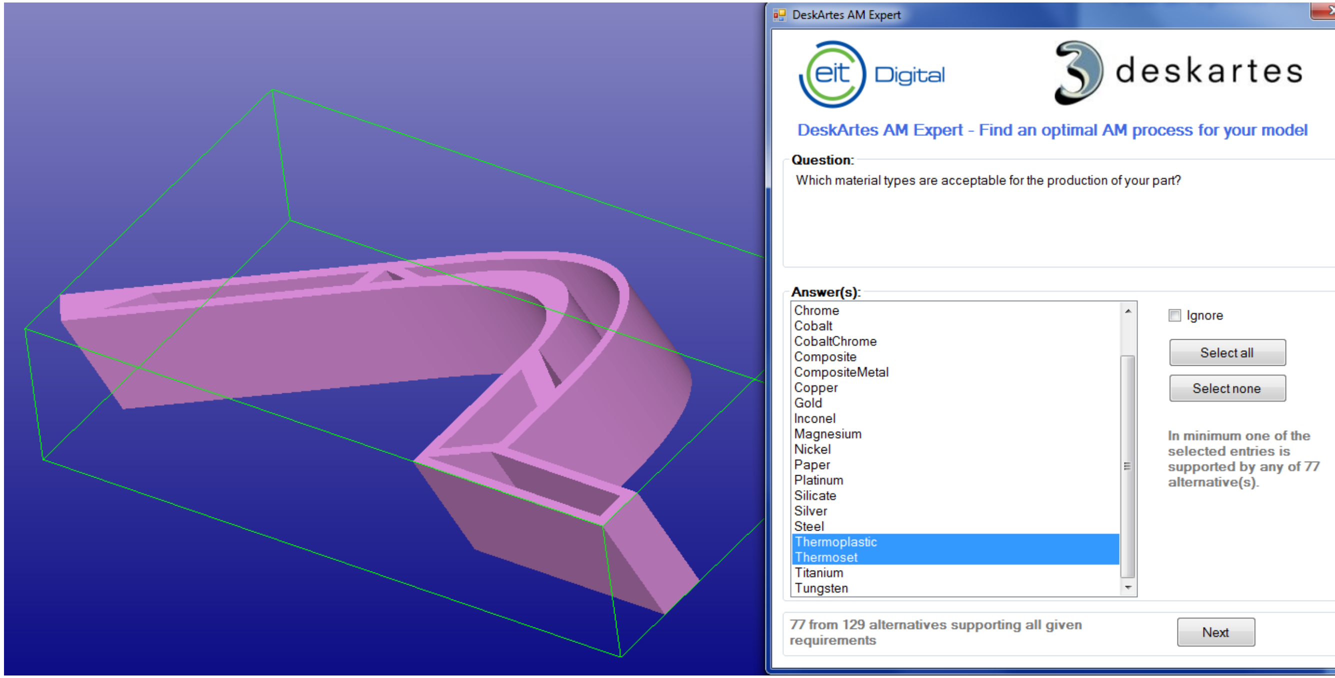
AM knowledge graphs



Polymers
- Thermoplastics
  - Filament → FFF/FDM
  - Powder → SLS/MJF
- Thermosets
  - Resin → SLA/DLP/CLIP/ Material Jetting

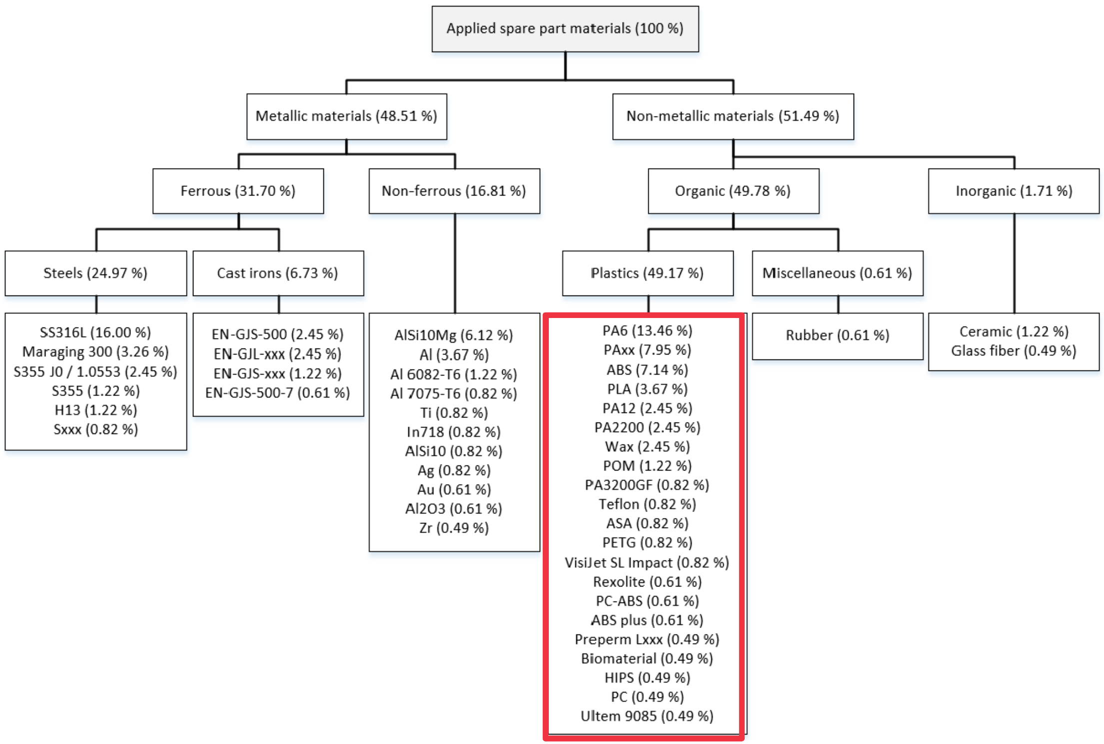
Specifications:
- Layer thickness
- AM system
- Mechanical performance
- Heat, Hygroscopicity, etc.

AM expert system



Which exact material types, systems, AM processes fulfill my requests?

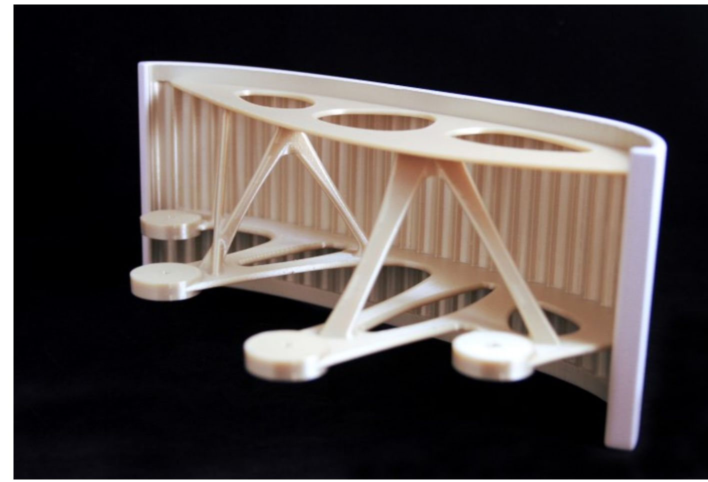
Requested materials from industry



- In particular plastic materials available as commercial AM materials for most commonly used spare part materials
- Not valid for special plastics

AM industrial example

Company:	Finnair via Airbus via Materialise
Component:	Cabin feature
Process:	Fused Deposition Modeling
Material:	Ultem (Polyetherimide, high-temp resistant)
Classification:	Redesigned for AM
Advantage:	Topology optimization (lighter)



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Emerging trends of AM plastics

Multi-head FDM

VIDEO

AM Bioplastics

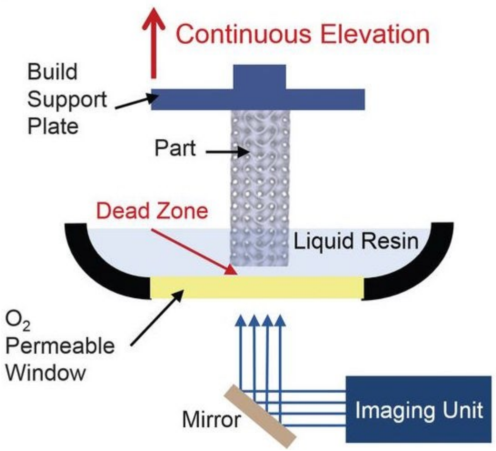
- Most commonly used AM bio-plastics: PLA, ABS
- Differentiation between (Bio-based & bio-degradable (often only in the lab) & bio-compatible (e.g. PMMA))
- Huge potential for improvements, especially for SLS powders → research
- Wood fiber filled, ideally oriented wood fibers would lead to enhanced mechanical properties
- FFF: spinned wood-fiber reinforced bio-plastics

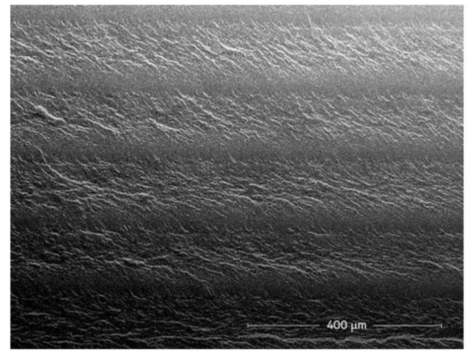
UPM Formi 3D
Wood-fiber filled

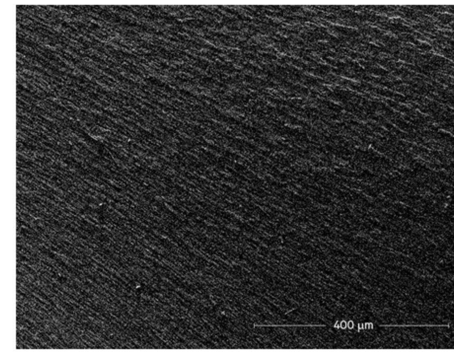
Carbon fiber plastic 3D printing

- FFF process
- Chopped or continuous carbon fiber plastic printer
- Enhanced mechanical strength (“beyond” plastics)
- Targeted behavior

Continous Liquid Interface Prodcution (CLIP)





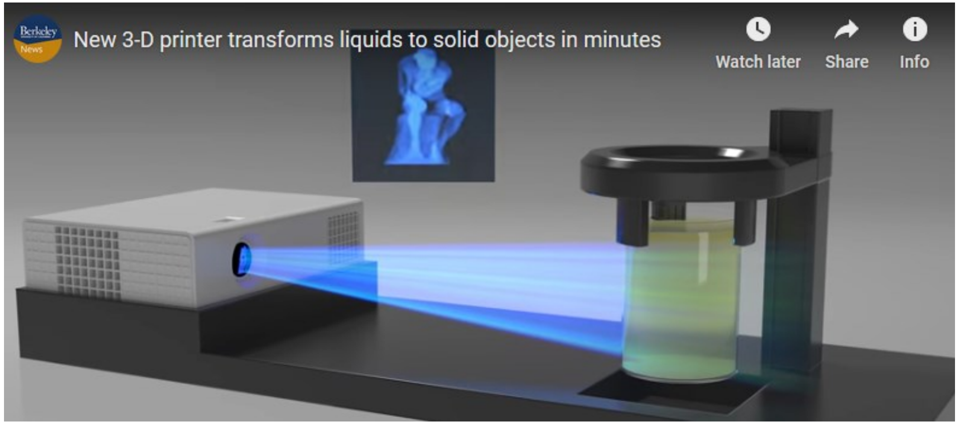


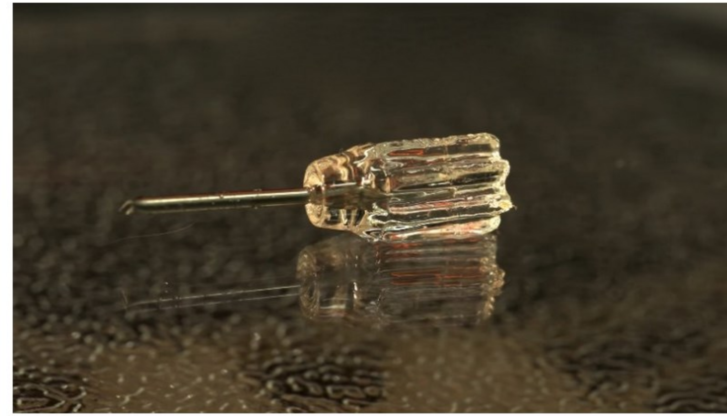
- Higher part production rates
- Isotropy (?!)
- Machine and material price

Continuous Liquid Interface Production (CLIP)

VIDEO

Future CLIP





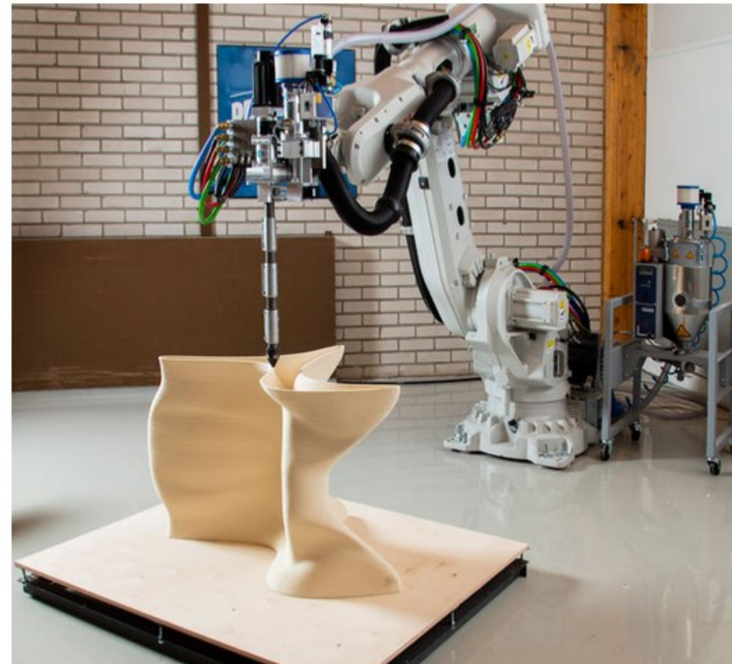
The technology makes it possible to add 3D-printed parts to existing solid objects, such as the handle on a screwdriver

Resin cures at pre-defined exposure levels
Rotating multi-projection without rotating the resin?

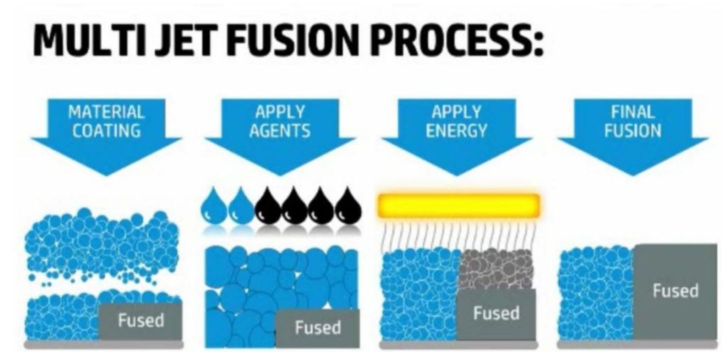
One great advantage: support free, object “floats”

Granule-based AM

- e.g. PRENTA Oy
- Large format printing one suitable application
- Material feeding of a wider range of materials possible (as compared to FFF)



Multi Jet Fusion



Color printing introduced

- Powder Bed Fusion process
- HP (e.g. PA11, PA12, TPU)
- Voxeljet “High Speed Sintering” (e.g. PA12, TPU)
- Can be faster and cheaper than SLS, similar mech. behavior

Multi-laser SLS systems

- EOS P 770
- Two laser system (2x70 W)
- Area division of the powder bed
- Alumide, PA 1101, PA 1102 black, PA 2200, PA 2201, PA 3200 GF, PrimeCast 101, PrimePart FR (PA 2241 FR), PrimePart PLUS (PA 2221)

Low-cost FFF/DLP printers

- Suitable for “hobby” 3D printing or for education
- Under 300 €… making it accessible for the majority of people
- Applicable with cheap “no-name” filaments/resins

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Thanks! Any questions?