Workshop MERO

Introduction: Additive manufacturing

Workshop Mechatronics Ⅱ MERO

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Schmalkalden, 27.04.2023

Agenda

1. • Additive Manufacturing (AM) in general
2. • Stereolithography (SLA)
3. • Selective Laser Sintering (SLS)
4. • Fused Deposition Modeling (FDM)
5. • Atomic Diffusion Additive Manufacturing (ADAM)
6. • Conclusion

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Additive Manufacturing (AM) in general

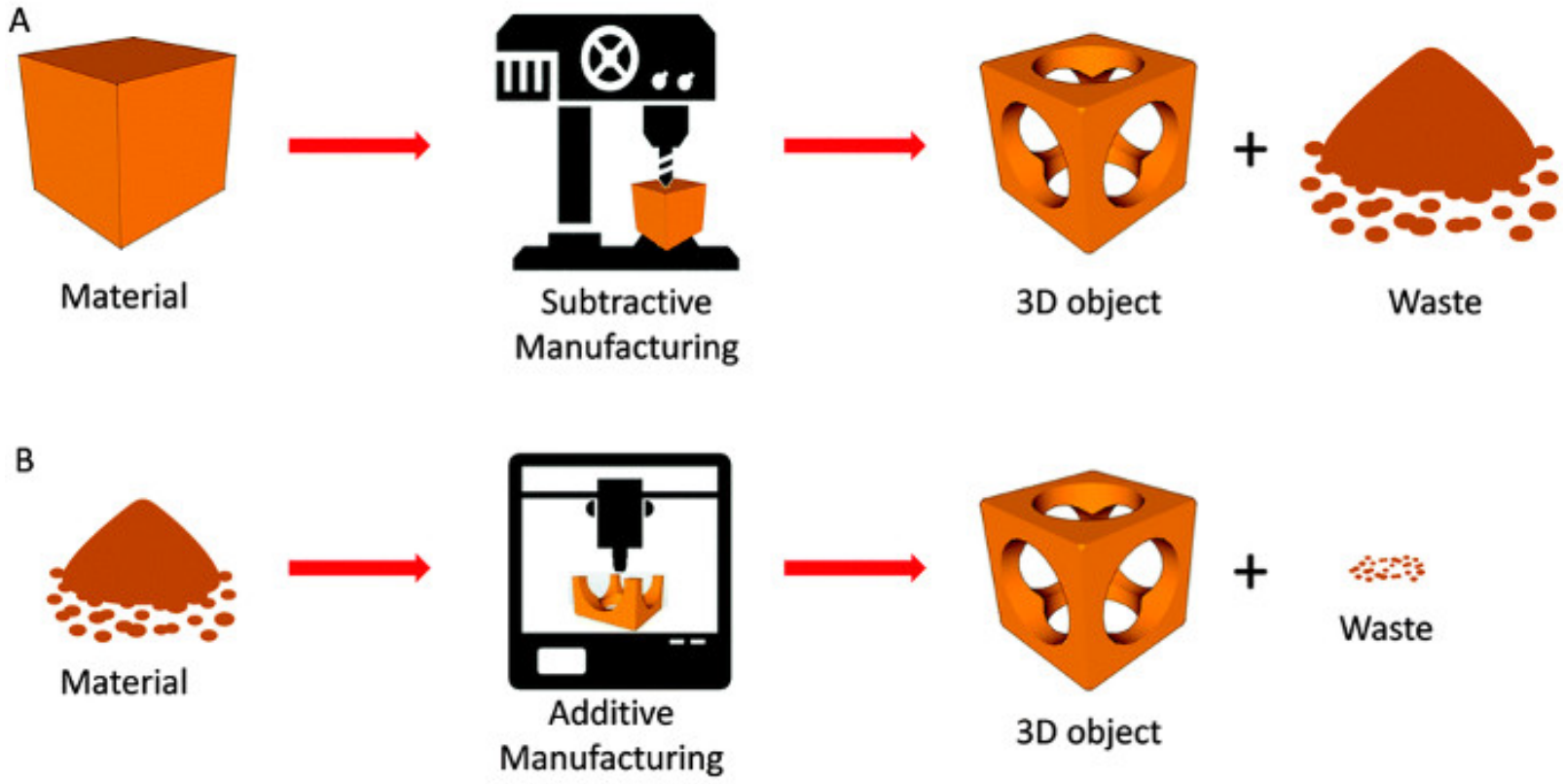
Difference between additive and subtractive manufacturing

Subtractive manufacturing

- Material is removed
- A lot of waste
- Drilling, milling…

Additive manufacturing

- Material is added
- Less waste
- SLA, FDM…



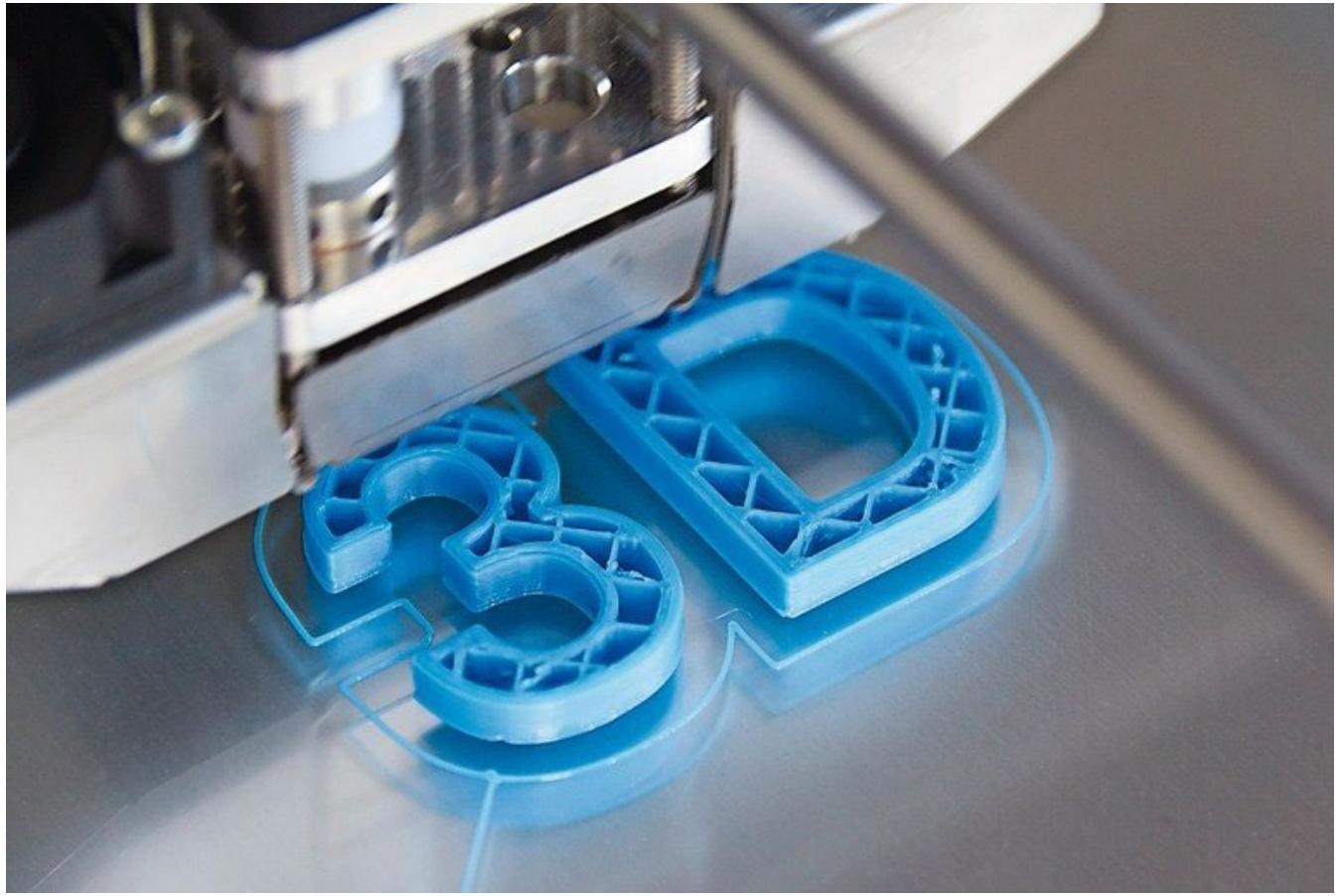
Source: 3Dnatives

Additive Manufacturing (AM) in general

Characteristics of additive manufacturing

Characteristics

- The parts are manufactured on the basis of digital 3D-CAD-data
- The objects are built up in layers
- Manufacture without the use of shaping tools
- Able to manufacture undercuts



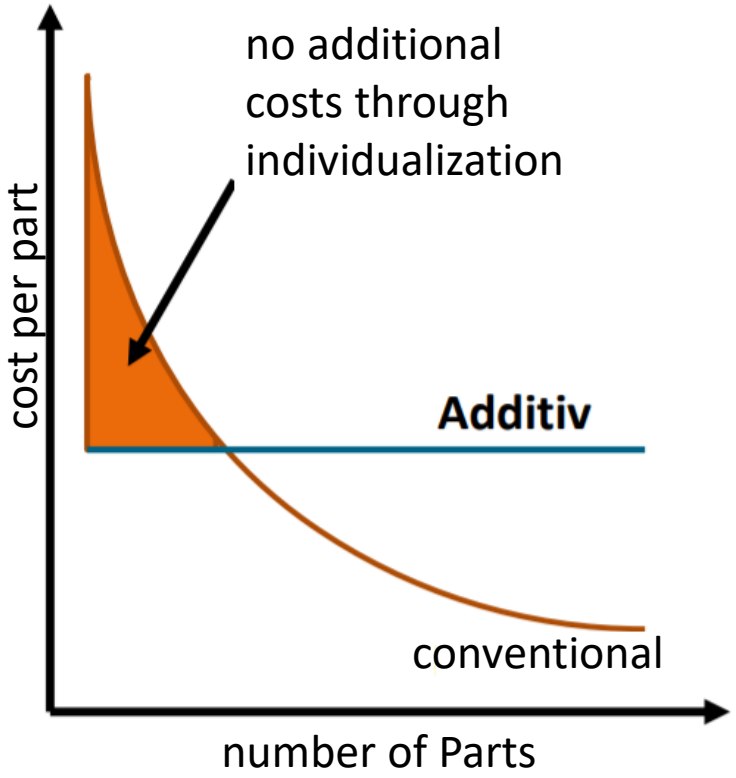
Source: industrie.de

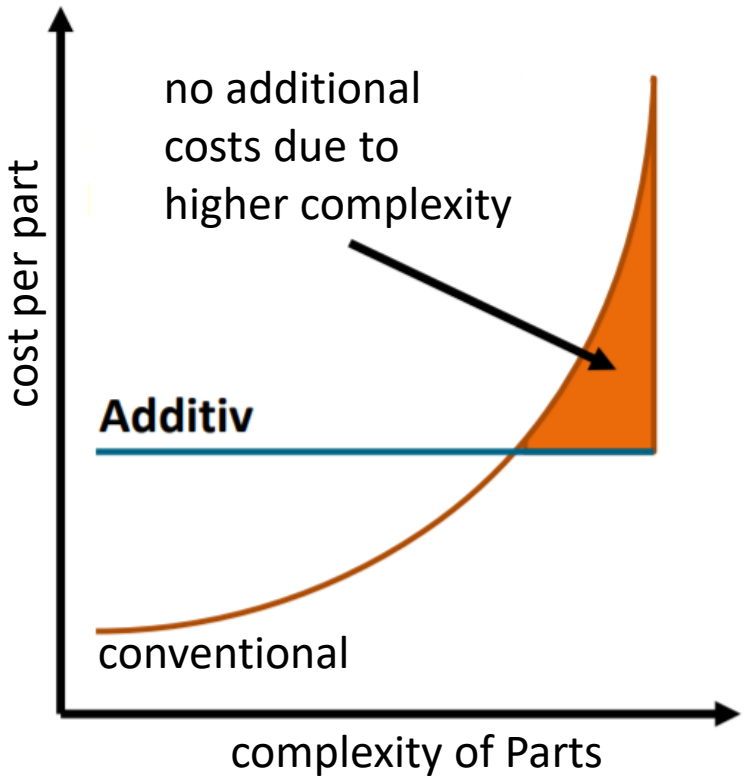
Additive Manufacturing (AM) in general

Additive vs. conventional manufacturing

Characteristics

- Additive manufacturing is economical with small quantities
- Additive manufacturing is economical for complex components





Source: TU Darmstadt.de

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Additive Manufacturing (AM) in general

Strategies

Rapid Prototyping (RP):

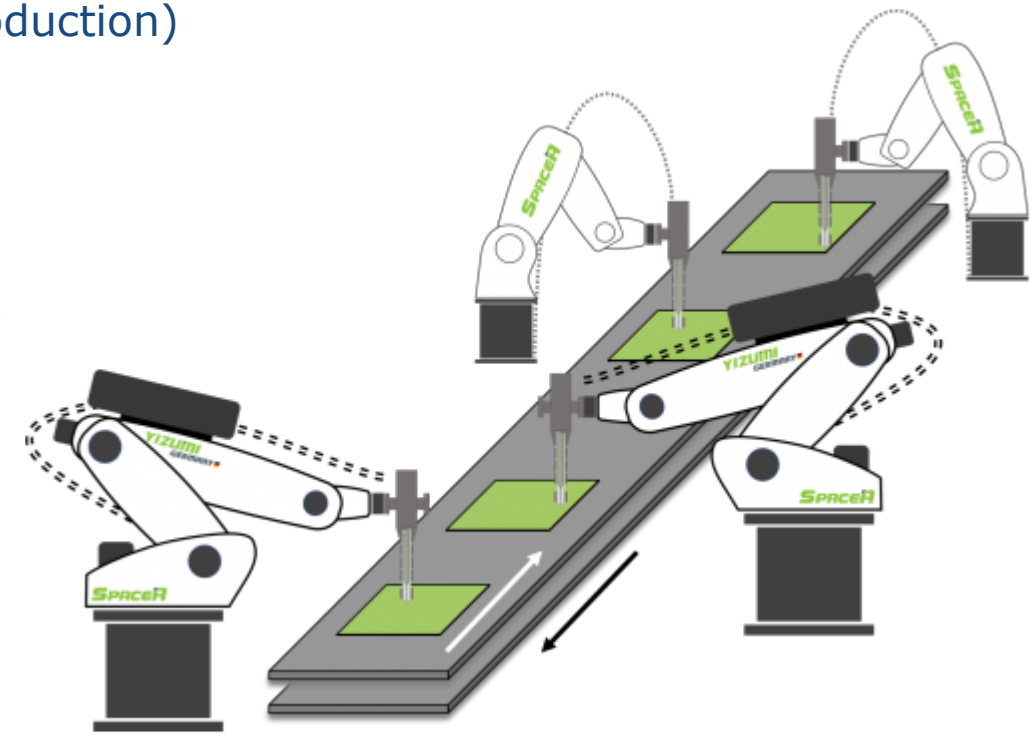
- is used for demonstration parts and prototypes (model production)
- Avoid production errors

Rapid Tooling (RT):

- production of prototypes and pre-series of tools and molds
- E.g. production of injection molds

Rapid Manufacturing (RM):

- Planning and manufacturing products in small series
- E.g. hearing aids, implants…



Source: yizumi.de

Additive Manufacturing (AM) in general

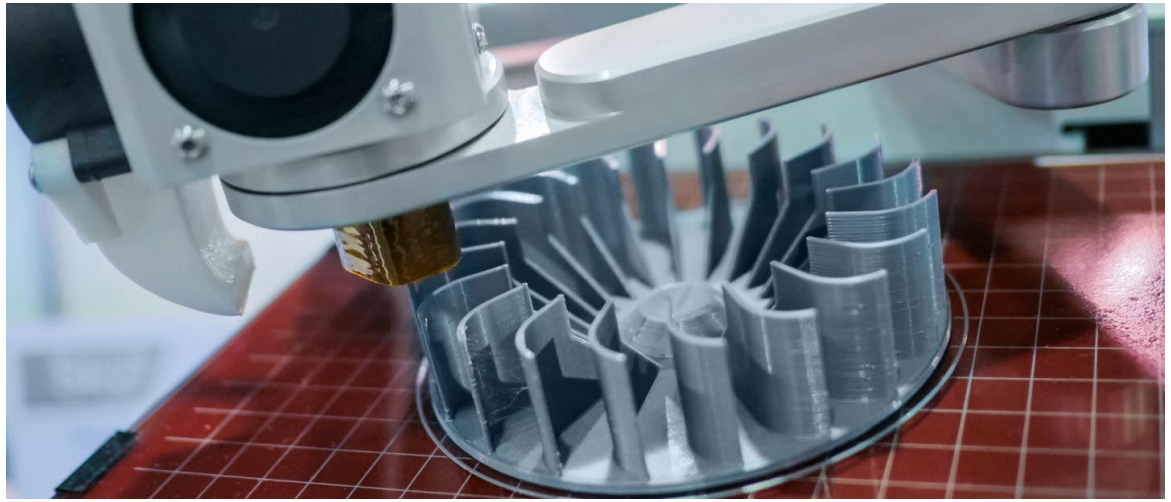
Industries and areas of applications

Industry sectors

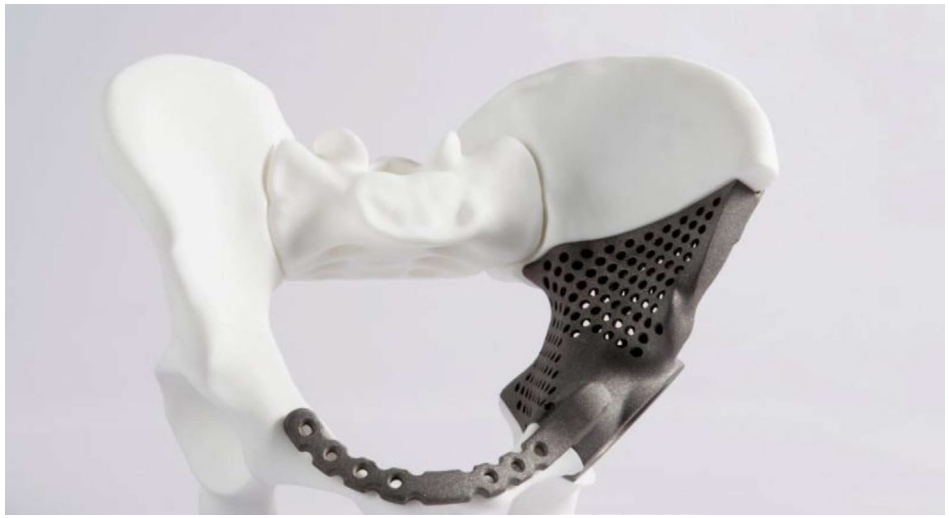
- Engineering
- Architecture
- Medicine
- Aerospace
- Art and design

Applications

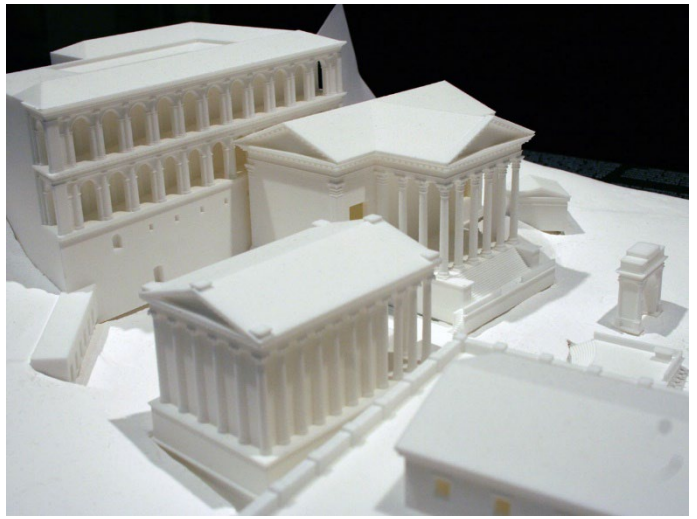
- Prototyping
- Small series
- Spare parts
- Etc.



Source: vodafone.de



Source: Münchner Merkur.de



Source: Rapidcobject.com

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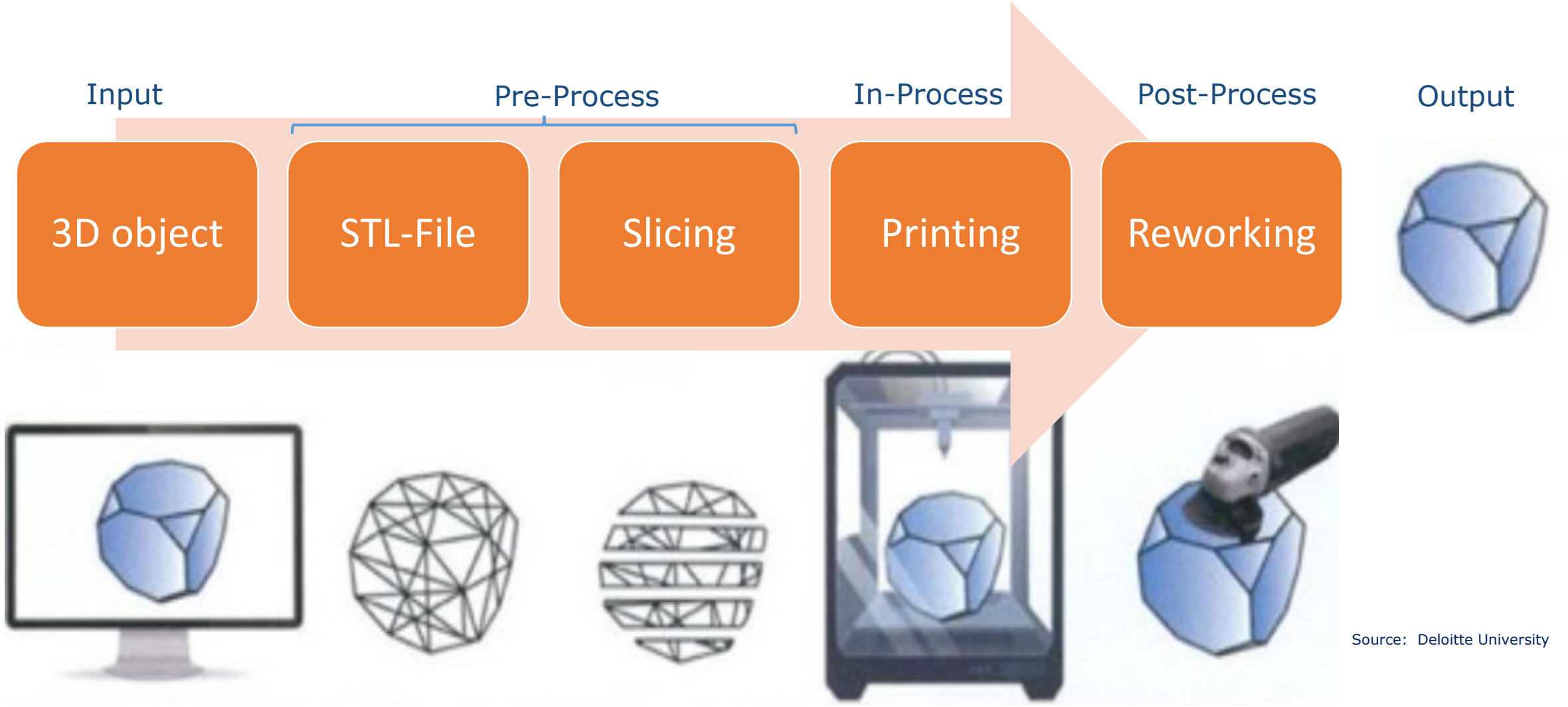
Additive Manufacturing (AM) in general

Additive manufacturing process



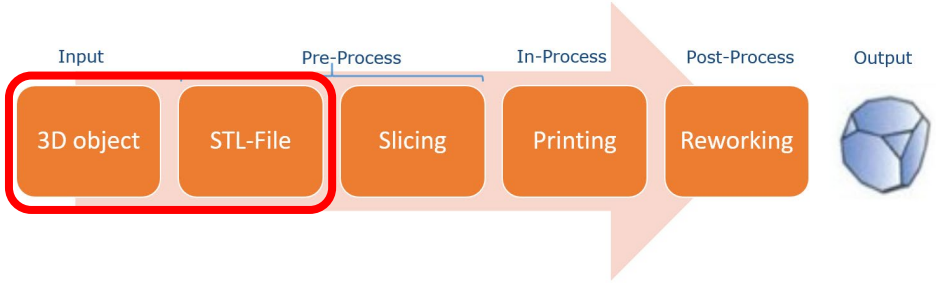
Source: Deloitte University

Additive Manufacturing (AM) in general

CAD-Systems

Siemens NX	Dassault SolidWorks	Autodesk Inventor	PTC Creo	Dassault CATIA
PLM Software SIEMENS NX	SOLIDWORKS	AUTODESK® INVENTOR®	creo™ parametric	CATIA

- many functions and modules are integrated
- Complex tools such as FE calculation, simulation, CAD, CAM and data management
- Recommended: Creo, SolidWorks



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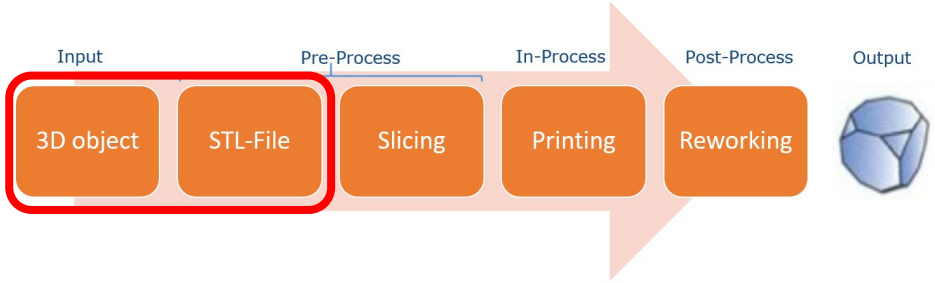
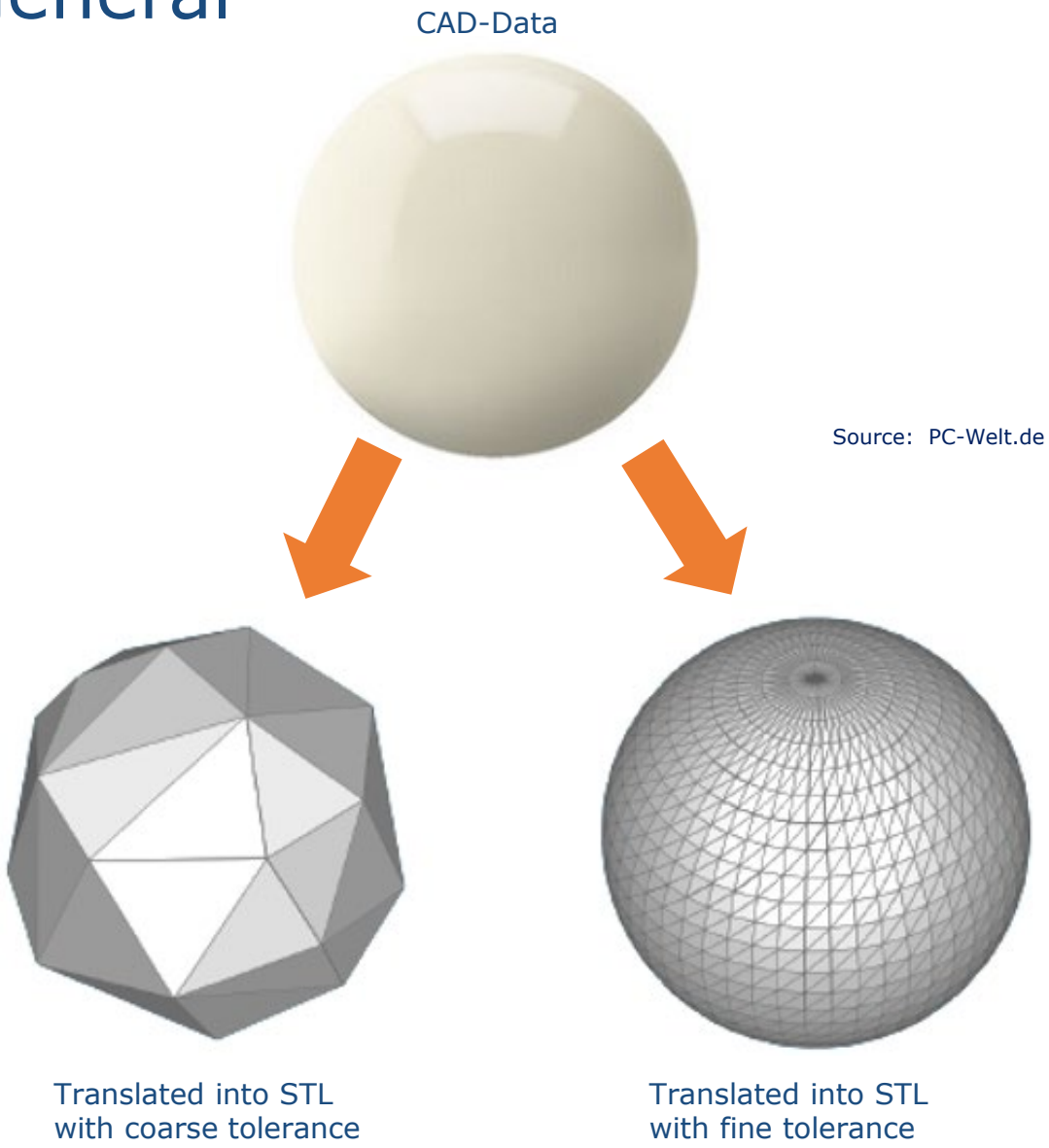
Additive Manufacturing (AM) in general

CAD-Systems → STL-File

- Export CAD-model into STL-File
  - Size of the triangles is influenced by the tolerance
- STL-File = triangulated shell model
  - Neutral data interface for AM
- Triangulated
  - The surface is modeled on triangles

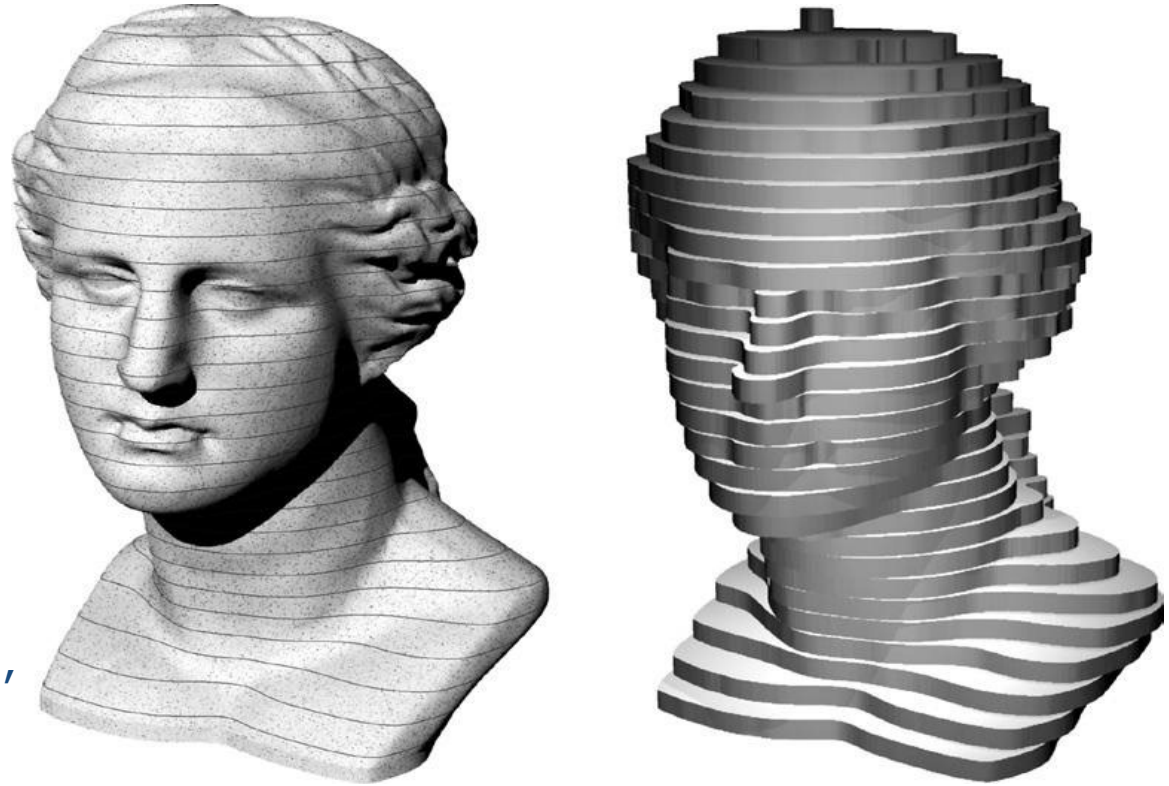




Additive Manufacturing (AM) in general

Slicing

Source: FH-Achen

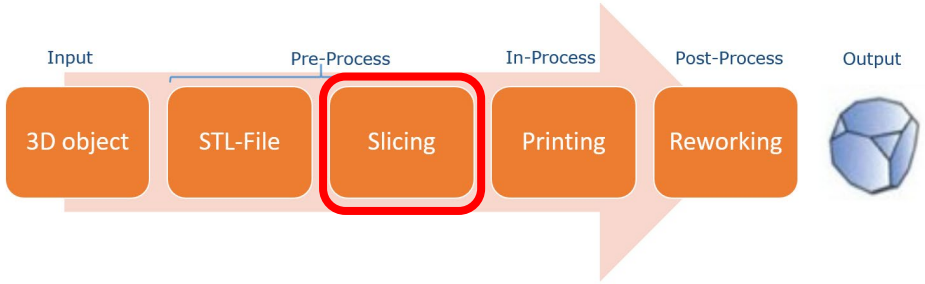


Slicing program

- Function 1: cut the CAD file into horizontal layers
- Function 2: Define parameters for part generation

Parameter

- layer height, nozzle temperature, printing speed, infill, support structure



The lower the layer height, the more precisely the geometry is printed.

Additive Manufacturing (AM) in general

Source: 3Dnatives

Slicing

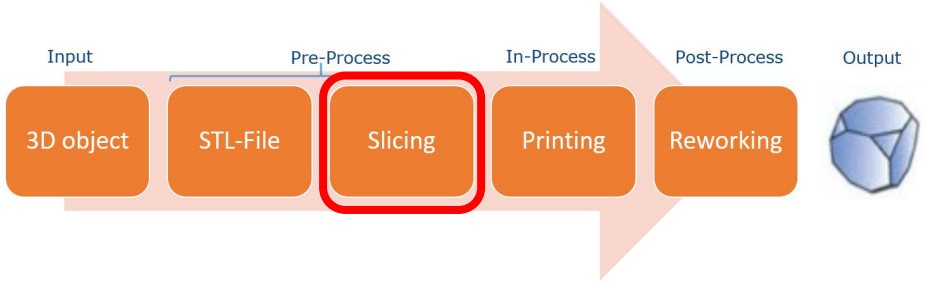
- common slicer

Cura	Eiger	Makerprint	XYZ-printing	Simplify3D

Cura → Open source, user-friendly

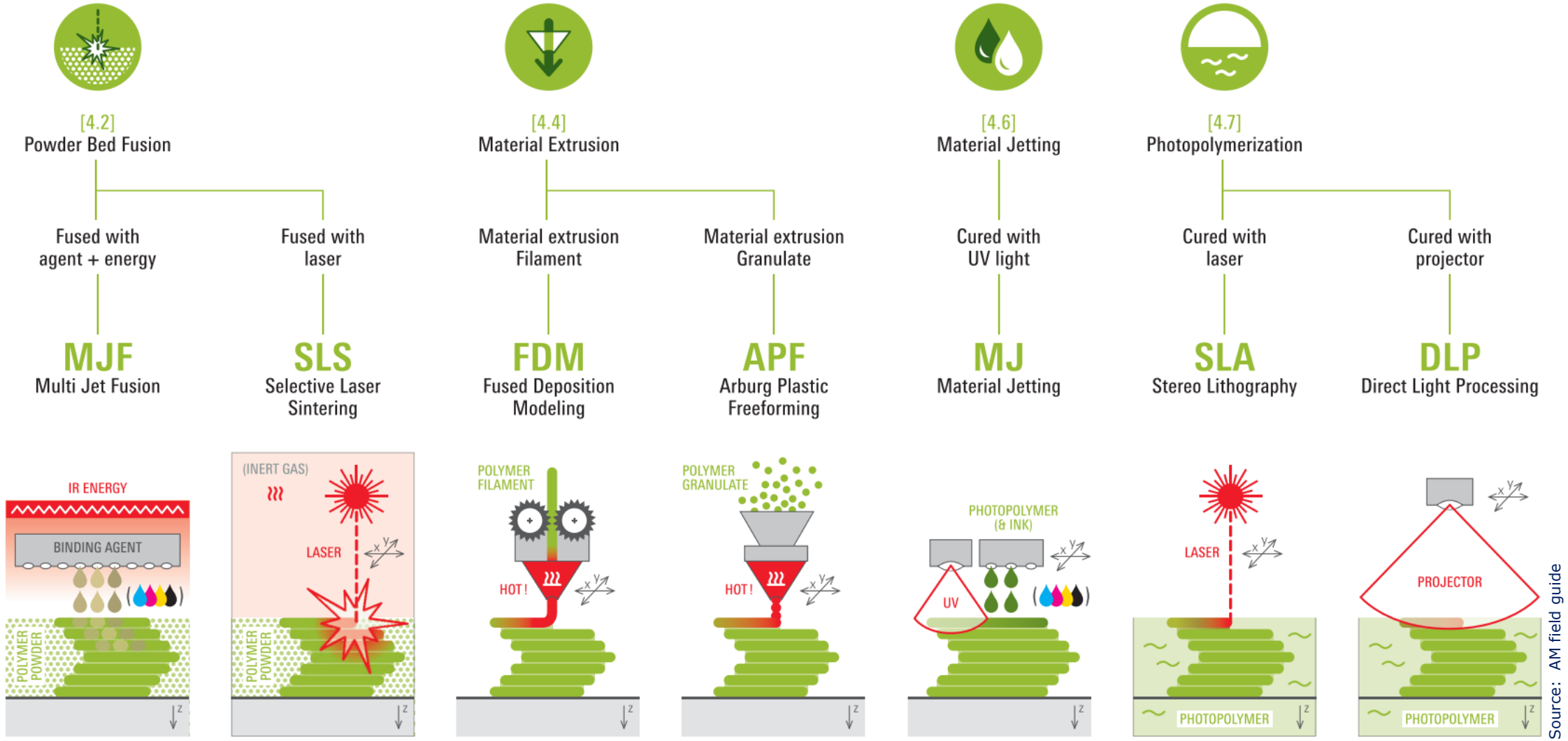
Eiger, Makerprint, XYZ-printing → printer specific, user-friendly

Simplify3D → extended parameter setting possible, expert knowledge required



Additive Manufacturing (AM) in general

Printing (plastic)



Source: AM field guide

Additive Manufacturing (AM) in general

Reworking

Remove the component from the building board

- Scraper, print sheet

Remove support structure by:

- Mechanically (pliers, scalpel…)
- Non mechanically (solvent, water, heat…)

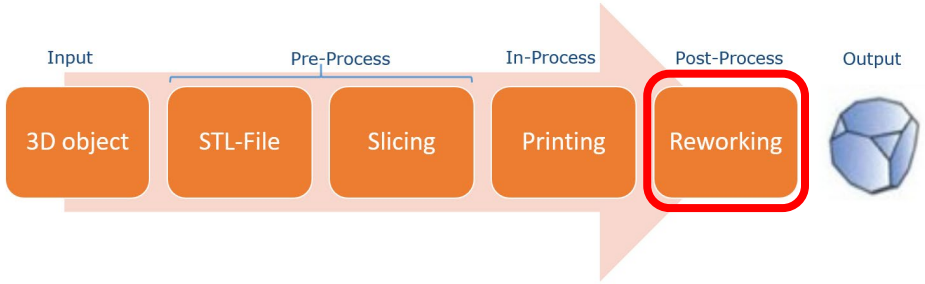
Rework

- Smooth surface by acetone
- Grinding, milling, drilling…

Source: filamentworld.de

Source: filament2print.com

Source: All3DP.com



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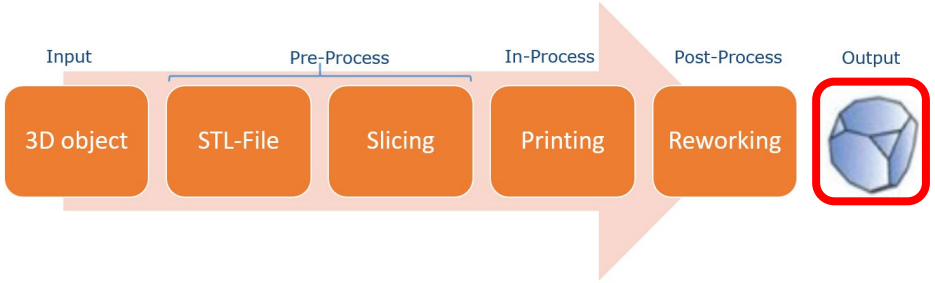
Additive Manufacturing (AM) in general

Output

Possible applications

- Medicine (hearing aids, orthotics,…)
- Tools (Injection molding, hand tools,…)
- Spare parts

Source: Kaleidoskop.com



Source: industrie.de

Agenda

1. Additive Manufacturing (AM) in general
2. **Stereolithography (SLA)**
3. Selective Laser Sintering (SLS)
4. Fused Deposition Modeling (FDM)
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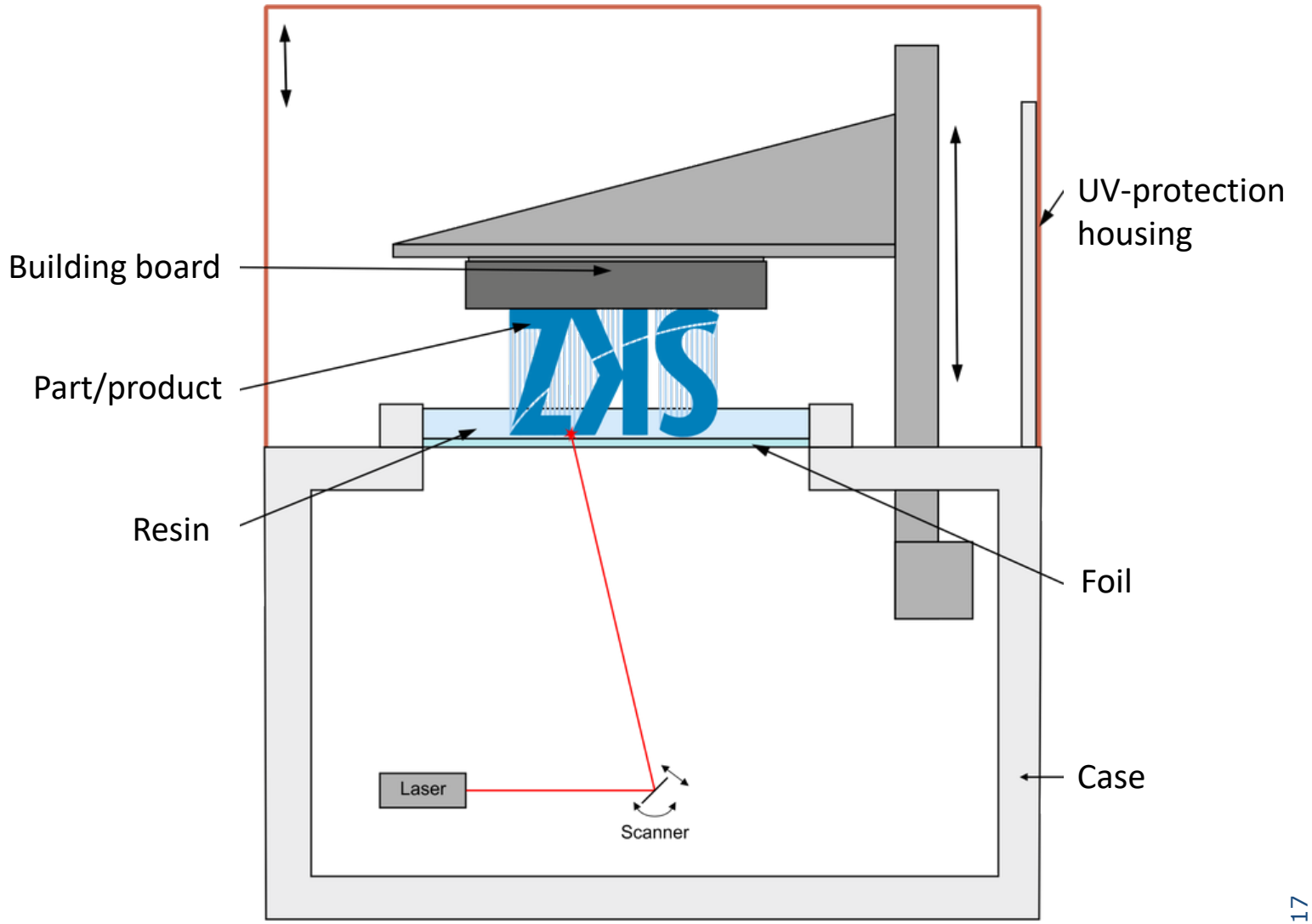
6. Conclusion

Stereolithography (SLA)

Method

https://www.youtube.com/watch?v=jeCHKDxQQh0



Source: SKZ.de

Process

- Material: Photosensitive liquid monomer (resin)
- 1. Local exposure (UV-light)
- 2. Solidification of the resin
- 3. Rising building board

Stereolithography (SLA)

Advantages, disadvantages and applications

Advantages

- High resolution
- Very low layer height (0,05 mm)
- Smooth surface
- Quite fast

Disadvantages

- Expensive material
- High purchase costs
- Difficult to clean
- Difficult material change
- Support necessary

Applications

- High precision components
- Transparent parts (optics)
- Examples: hearing aids, braces…

Source: rapidobject.com

Source: Additively.com

Source: 3daktur.com

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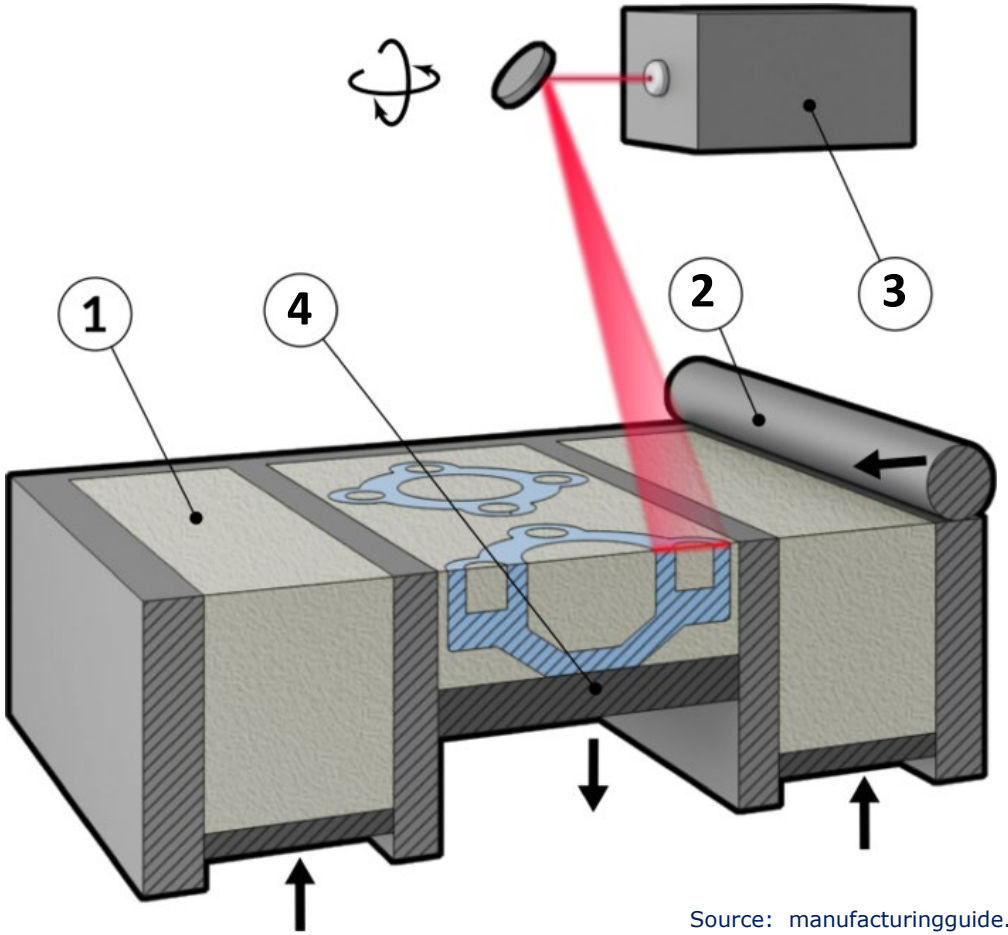
Selective Laser Sintering (SLS)

Method

https://www.youtube.com/watch?v=9E5MfBAV_tA

Process

- Material: Thermoplastics (PLA, ABS, PA…)
- 1. Heat powder material
- 2. Spread the powder in an even layer over the building board
- 3. The laser scans the contours of the part, which causes the powder particles to adhere to each other by sintering
- 4. Lowering the building board (layer height)



Source: manufacturingguide.com

Selective Laser Sintering (SLS)

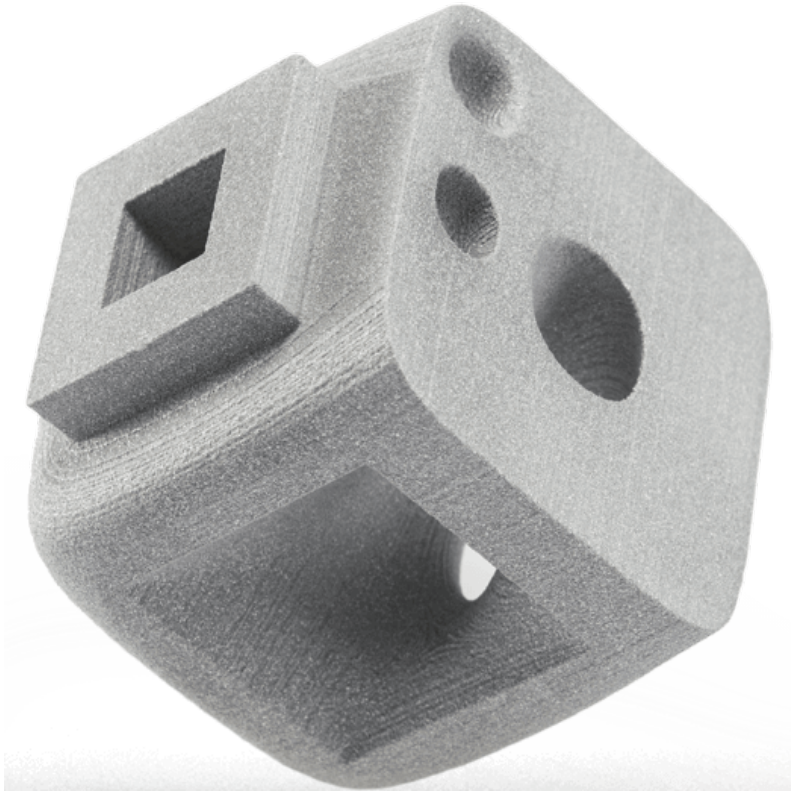
Advantages and disadvantages

Advantages

- Comparatively mechanically resilient
- No support structures are necessary
- High variety of materials
- Most complex design possible

Disadvantages

- Slightly rough surface
- Slow manufacturing process
- Only single-color models are possible



Source: visiotech-gmbh.de

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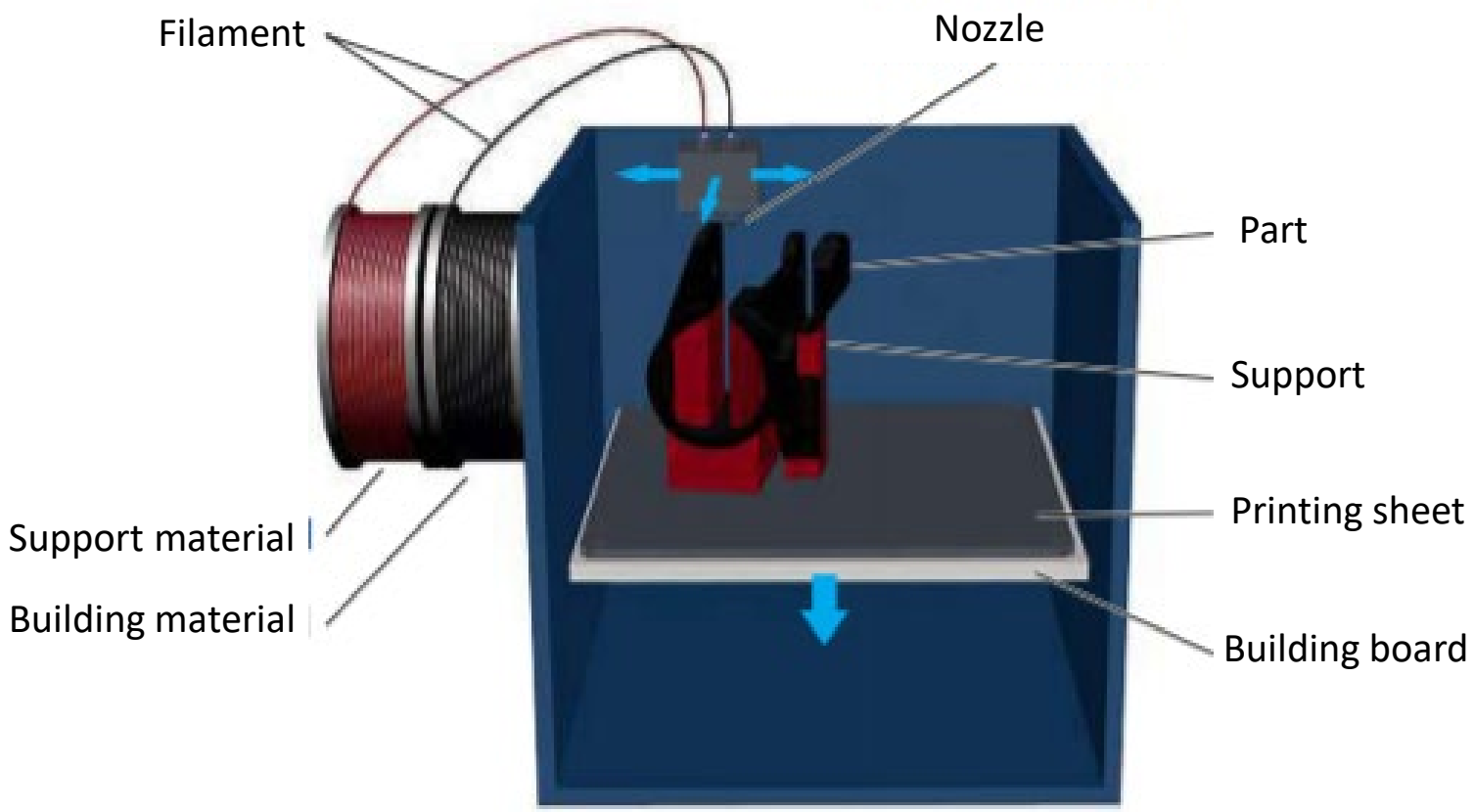
Fused Deposition Modeling (FDM)

Method

Process

- Material: Thermoplastics (PLA, ABS, PA…)
- 1. Melt the filament
- 2. Place the molt plastic on the printing sheet, according to the geometry that has been loaded
- 3. Lowering the building board (layer height)

https://www.youtube.com/watch?v=GxLjDNrQBgs



Source: Klahn, C (Hrsg.); Meboldt, M (Hrsg.): Entwicklung und Konstruktion für die Additve Fertigung. Würzburg: Vogel Business Media GmbH, 2018

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Fused Deposition Modeling (FDM)

Advantages and disadvantages

Advantages

- Various materials available
- Processing of different materials possible at the same time
- high volume throughputs possible

Disadvantages

- Resolution depends on nozzle width
- Nozzles tend to clog
- Support necessary
- Printed parts are comparative fragile

Source: deutsches-skoliose-netzwerk.de

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Atomic Diffusion Additive Manufacturing (ADAM)

Introduction

Atomic Diffusion Additive Manufacturing (ADAM)

- Additive process for the production of metal components with use of FDM-technology
- Developed: Markforged, presented in 2017
- Hardware: Metal-X (Sinter-1, printer, Wash-1)

Source: Mark3D.de

Atomic Diffusion Additive Manufacturing (ADAM)

Process

Printing

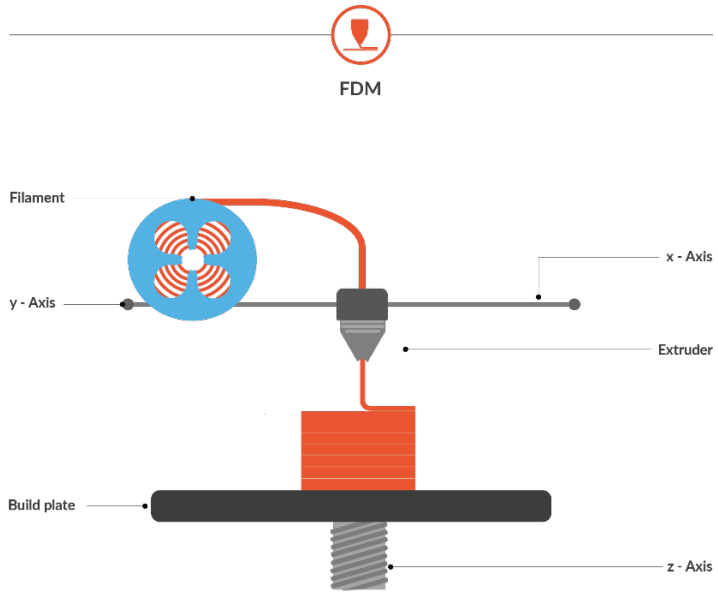
Washing

Sintering

Source: Mark3D.de

Atomic Diffusion Additive Manufacturing (ADAM)

Process



Bildquelle: Druckwege.de

Printing

- Additive manufacturing: FDM technology
- Filament: metal powder, plastic and wax (binder)
- Ceramic filament as an intermediate layer
- + 19.5% scaling

Atomic Diffusion Additive Manufacturing (ADAM)

Process

Washing

- Release the binder
- Novec 72DA / 73DE
- Washing temperature: 54 ° C
- Drying

Bildquelle: Mark3D.de

Atomic Diffusion Additive Manufacturing (ADAM)

Process

Sintering

- Burning out the plastic
- Sintering the metal powder
- Ceramic filament powdered
- Sintering time: depends on the material (~27h)

Bildquelle: Mark3D.de

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Atomic Diffusion Additive Manufacturing (ADAM)

Advantages, disadvantages and characteristics

Advantages

- low investment
- Process parameters fixed
- easy handling
- stable operation

Disadvantages

- high gas consumption
- Expensive: "Special gas" 2.9% H2
- Special cleaning liquid
- Component size limited by sintering furnace

Criteria	Characteristics
Layer height	0.05 mm / 0.125 mm
Installation space	235 x 68.3 x 65.5 [mm]
Material	Stainless steel Tool steel Nickel alloy Titanium alloy Copper

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Conclusion

Chances

- Exciting technology that is rapidly evolving
- Offers plenty of room for creativity (e.g. food printers, bio printers)
- Huge application area (e.g. customized medical devices)
- Unimagined design options

Problems

- Slow construction rate → no mass production
- Limited construction volume
- Often post-processing necessary
- Material diversity too low

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Thank you for your attention

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