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Technologies & Materials

Part 1: 3DPrinted Plastics

Toon Roels

What determines the Performance of a part?

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CONVENTIONAL TECHNOLOGIES

45 %

Material

10 %

Process

45 %

Design

3D Printing

20 %

20 %

60 %

Major Elements of this presentation

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- The **variety & differences** of the many **3DP Plastics technologies**
- The **Materials available**
- How the Technology/ process determines:
  - the Material/Part properties
  - The level of Freedom of Design

3D Printing Plastics: a huge family of technologies (and (trade)names)

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STEREOLITHOGRAPHY
bottom up><full vat
Laser><projection
#wavelengths

Continuous Liquid interface Polymerisation (CLIP/ Carbon)

Drop-on-Demand

POLYJET

Binderjetting

Laser Cladding

SELECTIVE LASER SINTERING (Sinter/ (S)LS)

MultiJetFusion (MJF)

Filament extrusion (FFF/ FDM)

Pellet/ syringe extrusion

The Technologies: Key aspects

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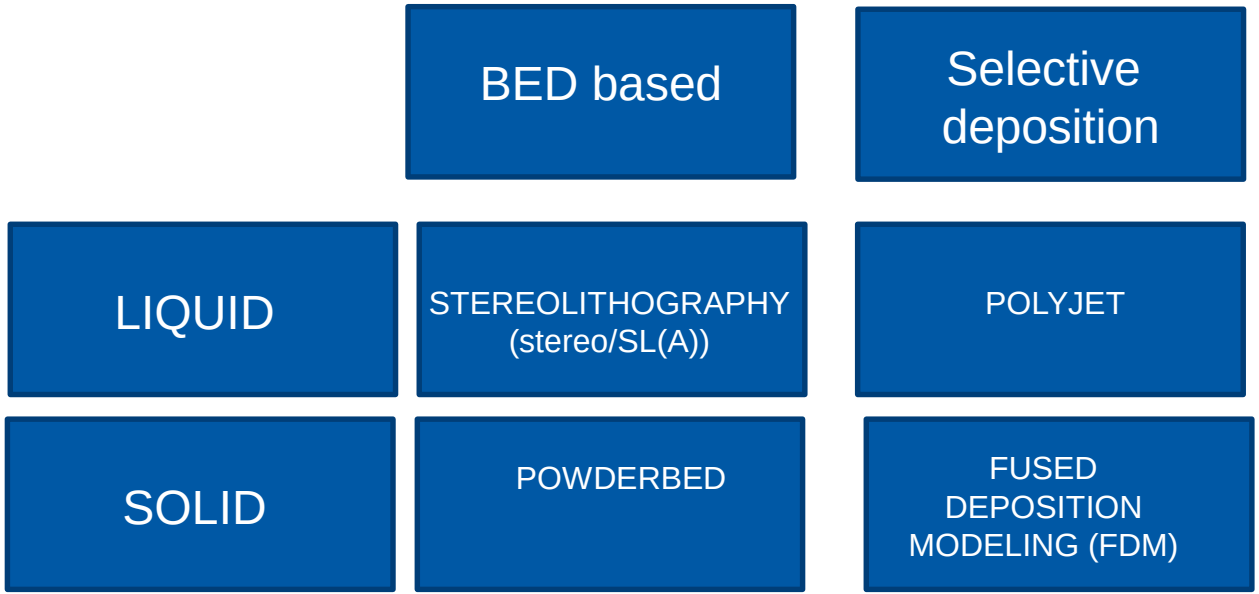

The Technologies: Key aspects

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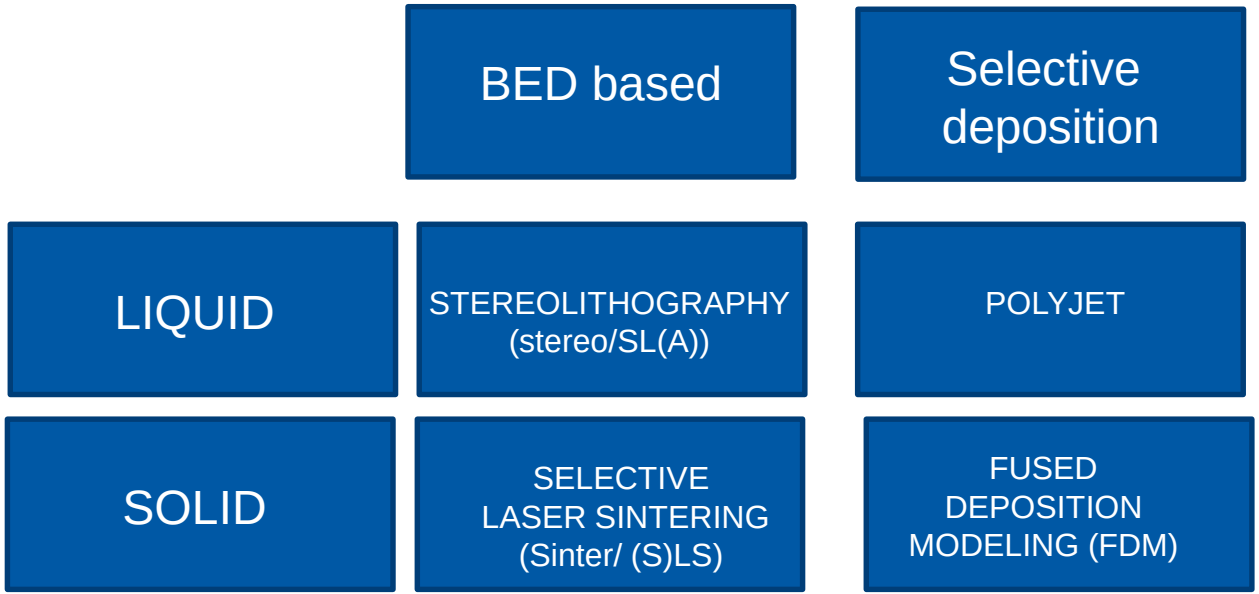

The Technologies: Key aspects

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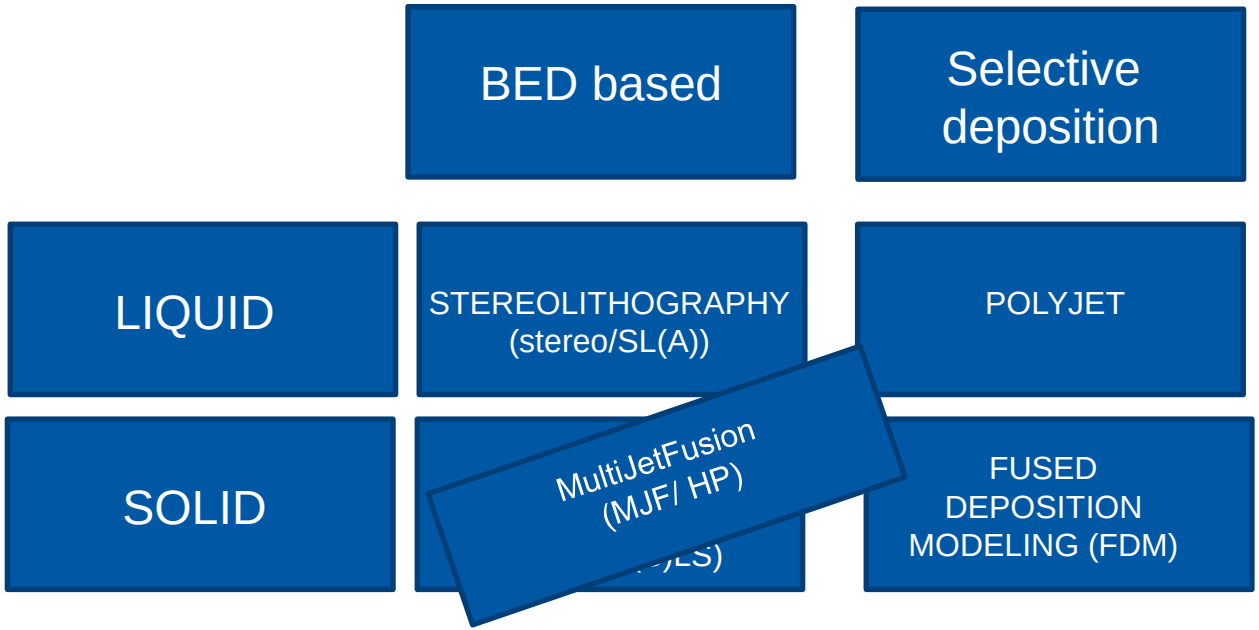
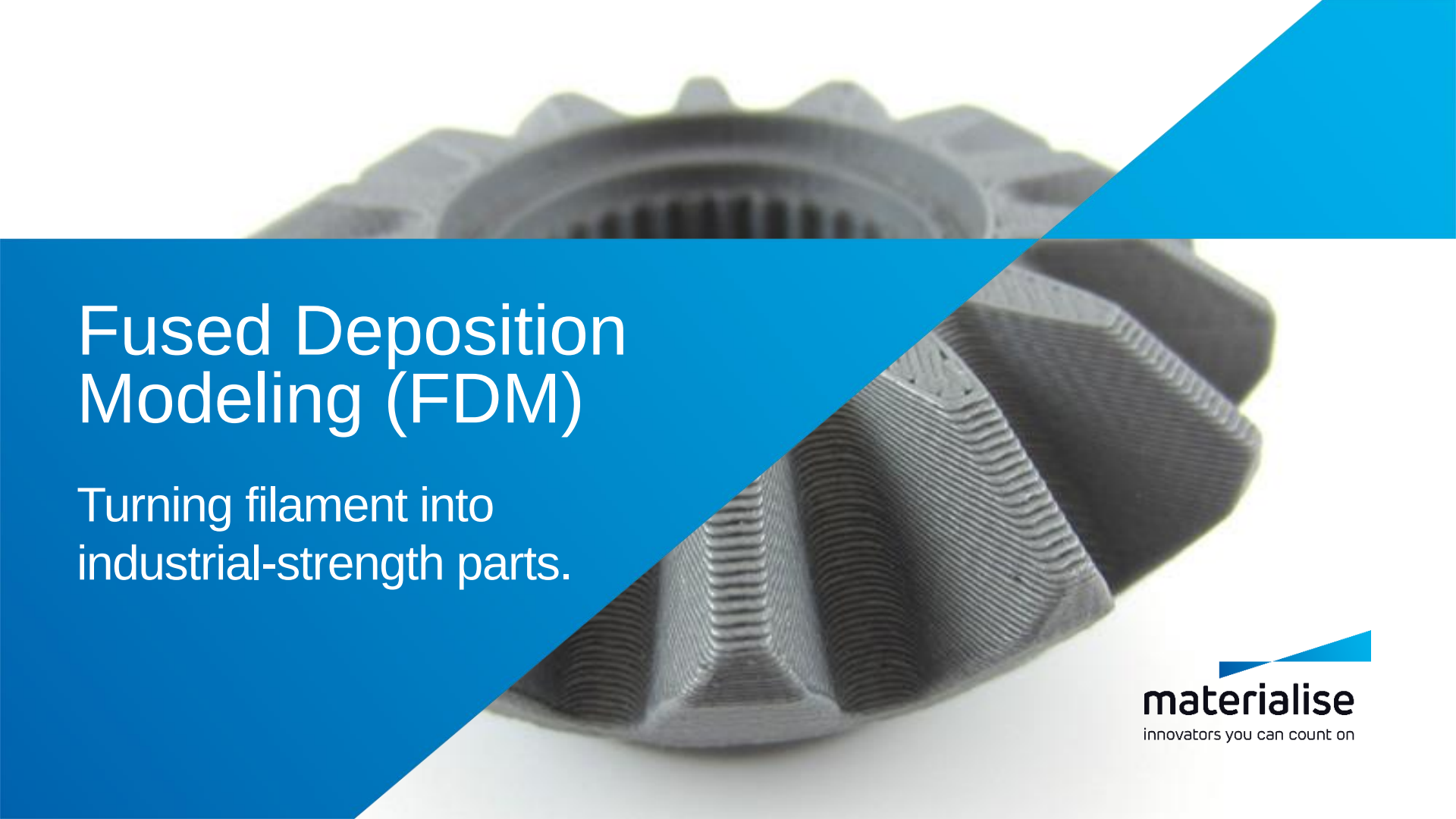


Fused Deposition Modeling (FDM)

Turning filament into industrial-strength parts.



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Fused Deposition Modeling/ Filament extrusion

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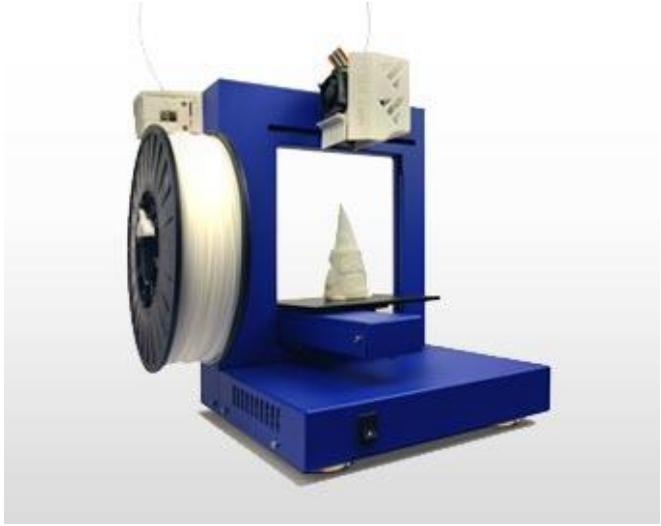
Professional FDM printer (Stratasys)



Low End Home Printer / Desktop

Mid- High End

FDM: How does it work?

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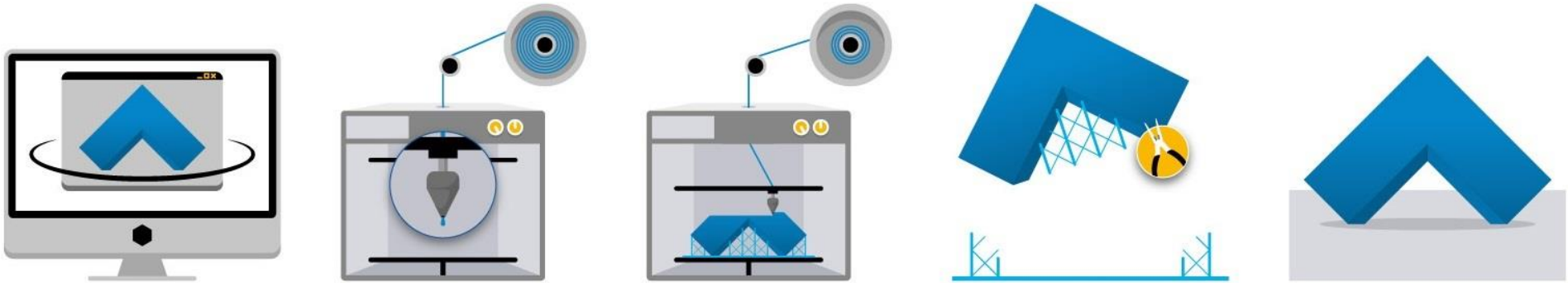

The 3D model

The thermoplastic modeling filament is heated to a semi-liquid state

The extrusion head ‘draws’ the part and its support, one layer at a time

The support is removed

The part is finished

Materials for FDM- Professional Printers

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- PPSU
- **Ultem 9085** & 1010 (PEI)
- PA12
- **Polycarbonate** (PC)
- **PC-ABS**
- ASA
- **ABS/** antistatic ABS (**ABS ESD7**)

Bold: @ Materialise

FDM: Modulus vs Heat Deflection Temperature (HDT)

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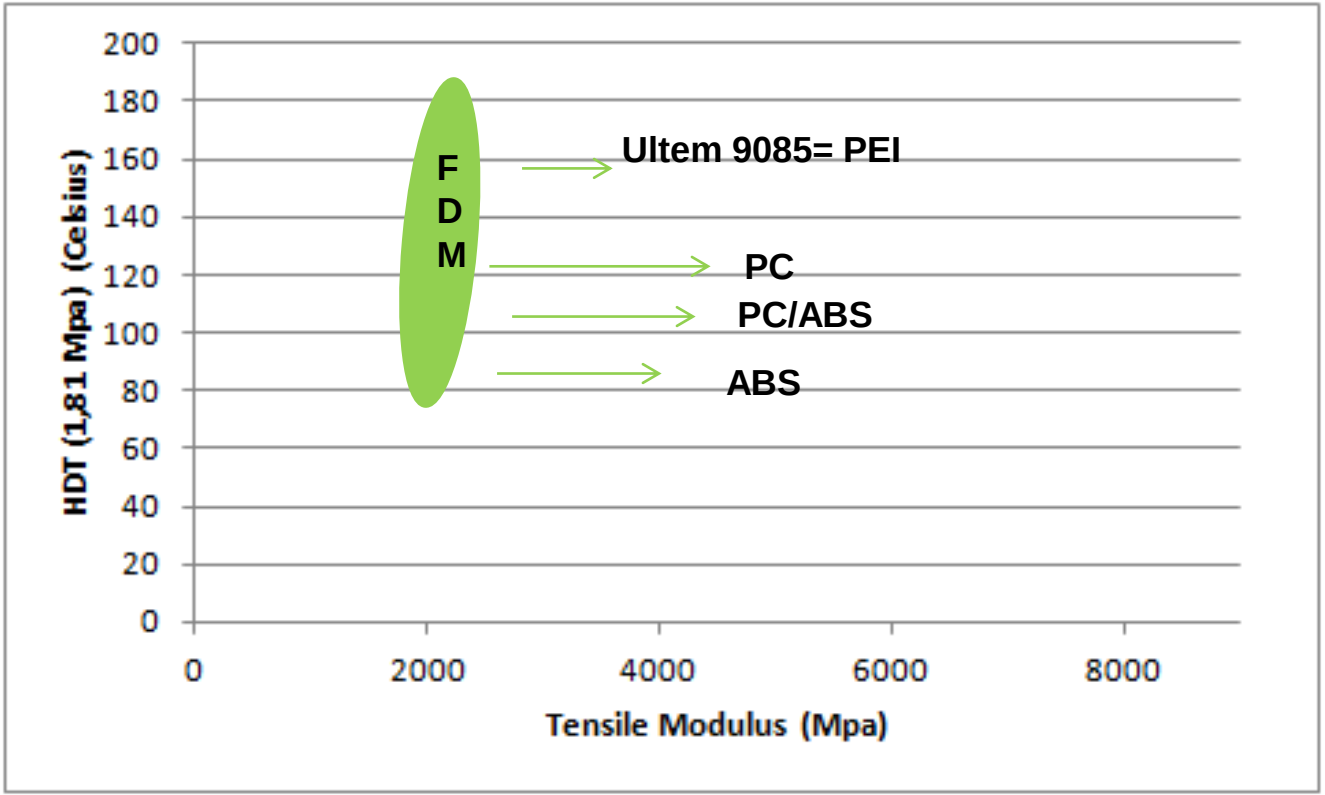

FDM

Fused Deposition Modeling:
open to many ‘conventional’ materials

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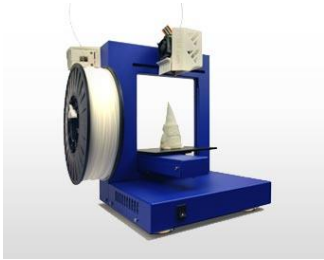
SSYS Professional FDM	Desktop open Material FDM
ABS	PLA
PC-ABS	ABS
PC	PC
ASA	PA12
PA12	PA- various
PEI	TPU
PPSU	PVA
	PCL
	coPA- various
	PES- various
	PSU
	PVC
	PS
	(HD)PE
	PEEK
	SEBS
	PVDF
	POM
	+ many more
	+ all kind of fillers



Filament extrusion 3DP: Modulus vs HDT

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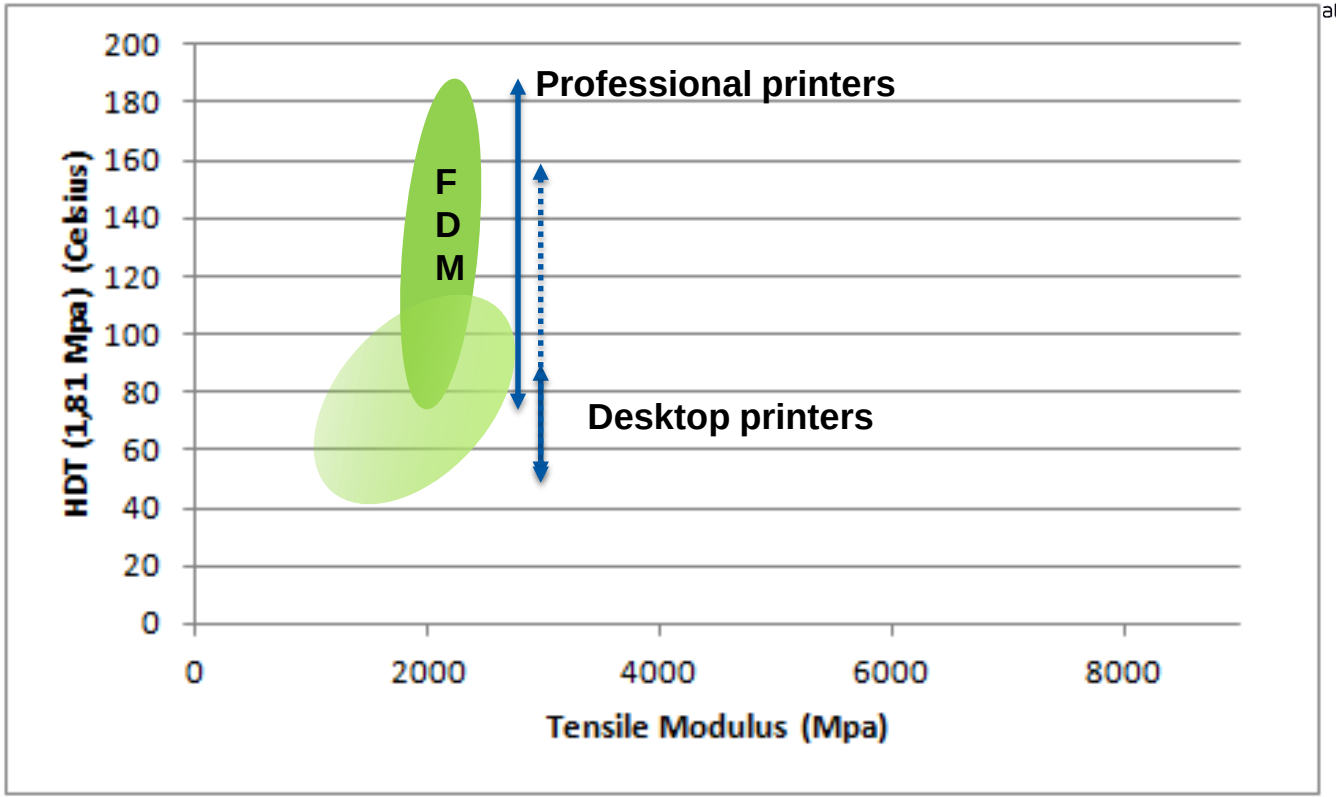
Process Temperature



3DP -FDM: Technology Effects affecting Material performance and Design Freedom

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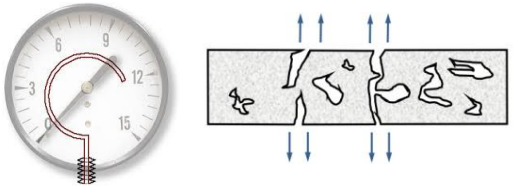
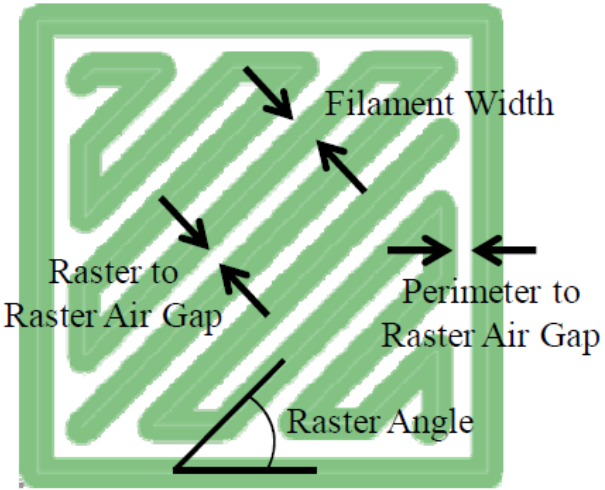
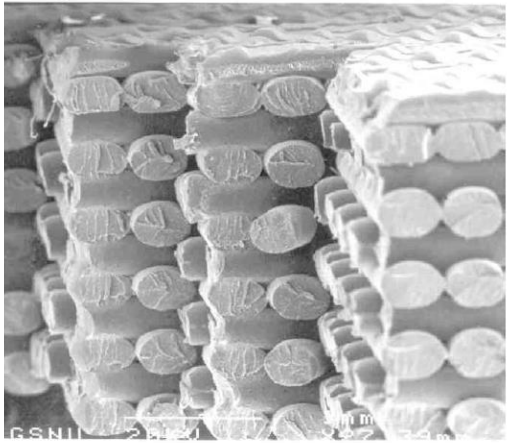


Pressureless → Risk of **porosity**

5-10%





(b) $[45^{o}/-45^{o}]_{6}$ specimen

3DP -FDM: Technology Effects affecting Material performance and Design Freedom

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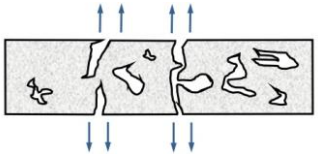
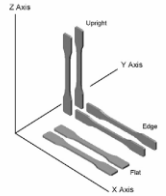


5-10%

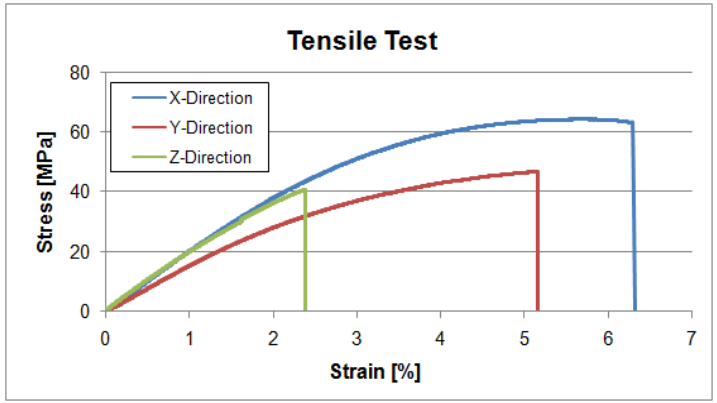
Pressureless → Risk of **porosity**



High Anisotropy

Layerwise → **Anisotropy**

FDM Part Quality Manufactured with Ultem*9085
A. Bagsik1,2, V. Schöppner1, E. Klemp2
1 Kunststofftechnik Paderborn (KTP),Universität Paderborn, D-33102 Paderborn, Germany
2 Direct Manufacturing Research Center (DMRC), Universität Paderborn, D-33102 Paderborn,
Germany



3DP -FDM: Technology Effects affecting Material performance and Design Freedom

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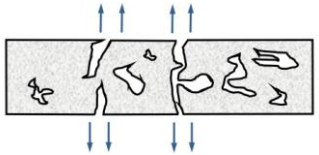
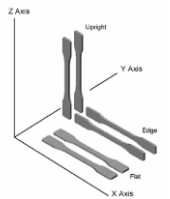


5-10%

Pressureless → Risk of **porosity**



High Anisotropy

Layerwise → **Anisotropy**

Need for **support structures**

Multicolour/Multimaterial?

FDM:
nozzles
typically max 2 materials:
Model + Support

Technical Specifications- FDM

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Standard lead time	Minimum of 4 working days (48 hours for Fast Lane orders) (depending on part size, number of components and required finishing)
Standard accuracy	**+/- 0.15%** (with lower limit on ± 0.2 mm)
Minimum wall thickness	1 mm
Layer thickness	**0.18 – 0.25 mm**
Maximum part dimensions	**914 x 610 x 914 mm**
Surface texture	Unfinished parts typically have a **rough surface** but all kinds of fine finishes are possible. FDM parts can be sandblasted, smoothed, painted and coated

Why choose FDM?

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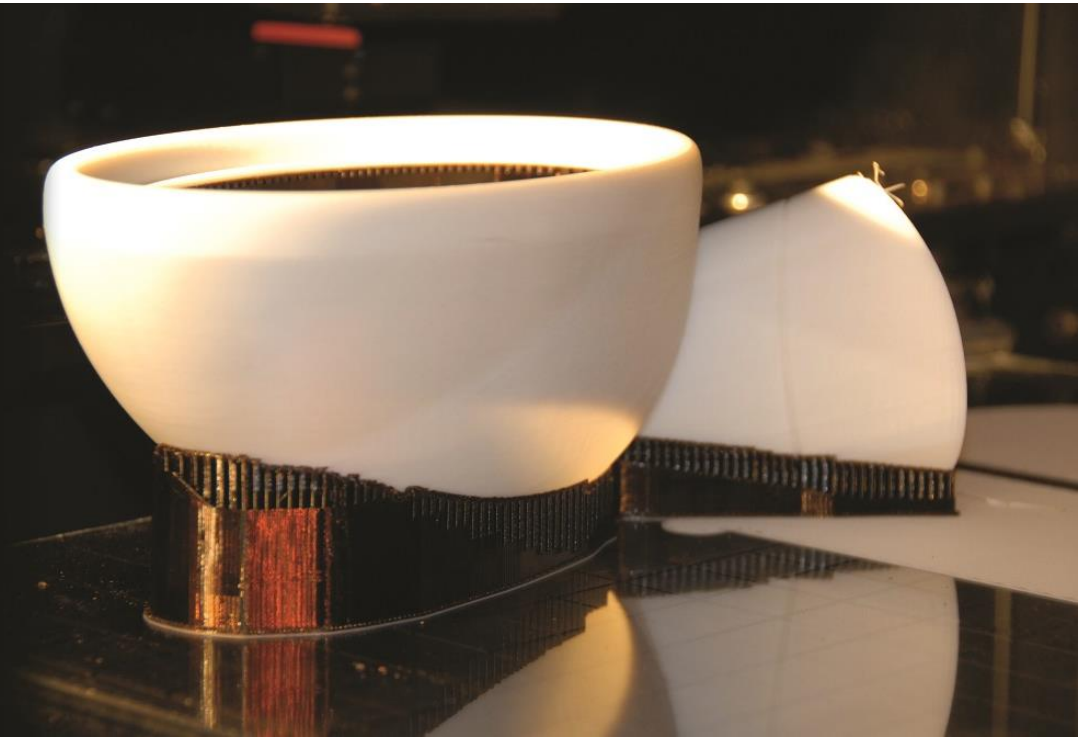
- High accuracy
- Functional parts
- Durable parts with high stability
- Production-grade materials
- Fast lead times



Trends in FDM technology (/research)

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- ‘Medium’ size/ Open Printers
- Broader Material palette: also high melting Polymers (PEEK etc)
- Short/Long fibre composites
- Printing on 3/5 axes
- Filament > Pellet based
- Size of printers

The Technologies: Key aspects

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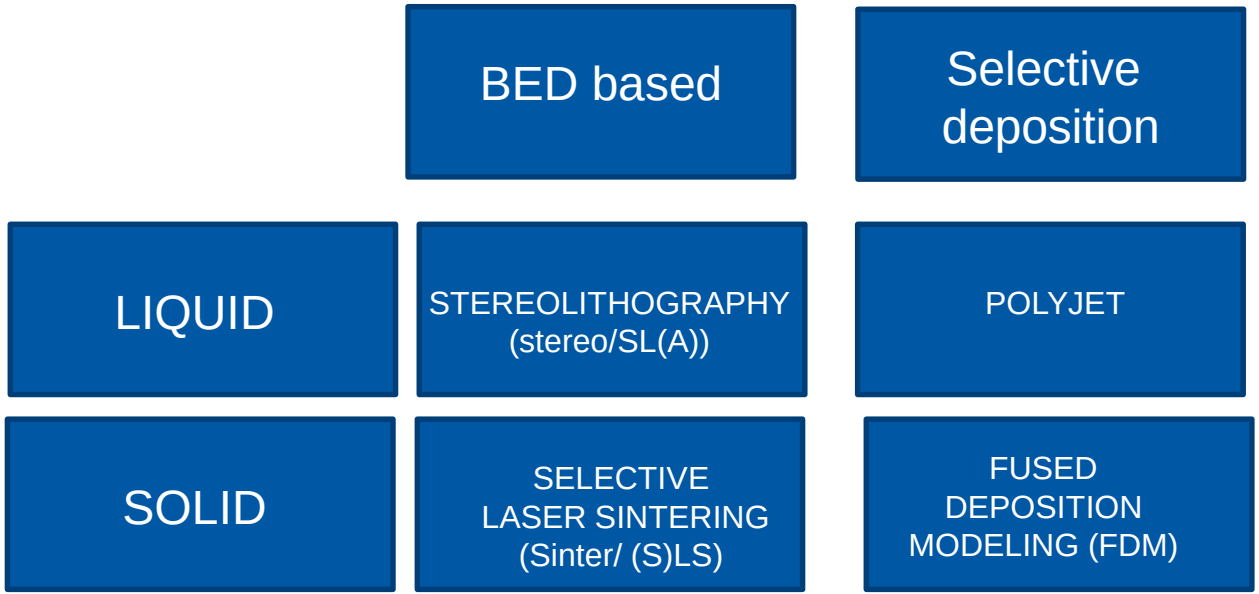

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Laser Sintering

Rethink ‘possible’.

Melonia shoe by Naim Josefi

Laser Sintering

Selective melting of powder

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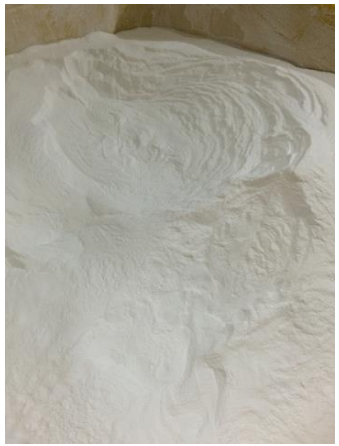
High Entry Barrier for Materials:

- Powder
- Specific process requirements



Laser Sintering: How does it work?

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The 3D model

A laser binds powder particles together

Successive powder layers are spread on top of each other, while a laser selectively binds particles to form the part and its support

The loose powder is removed

The part is finished

Materials for Laser Sintering

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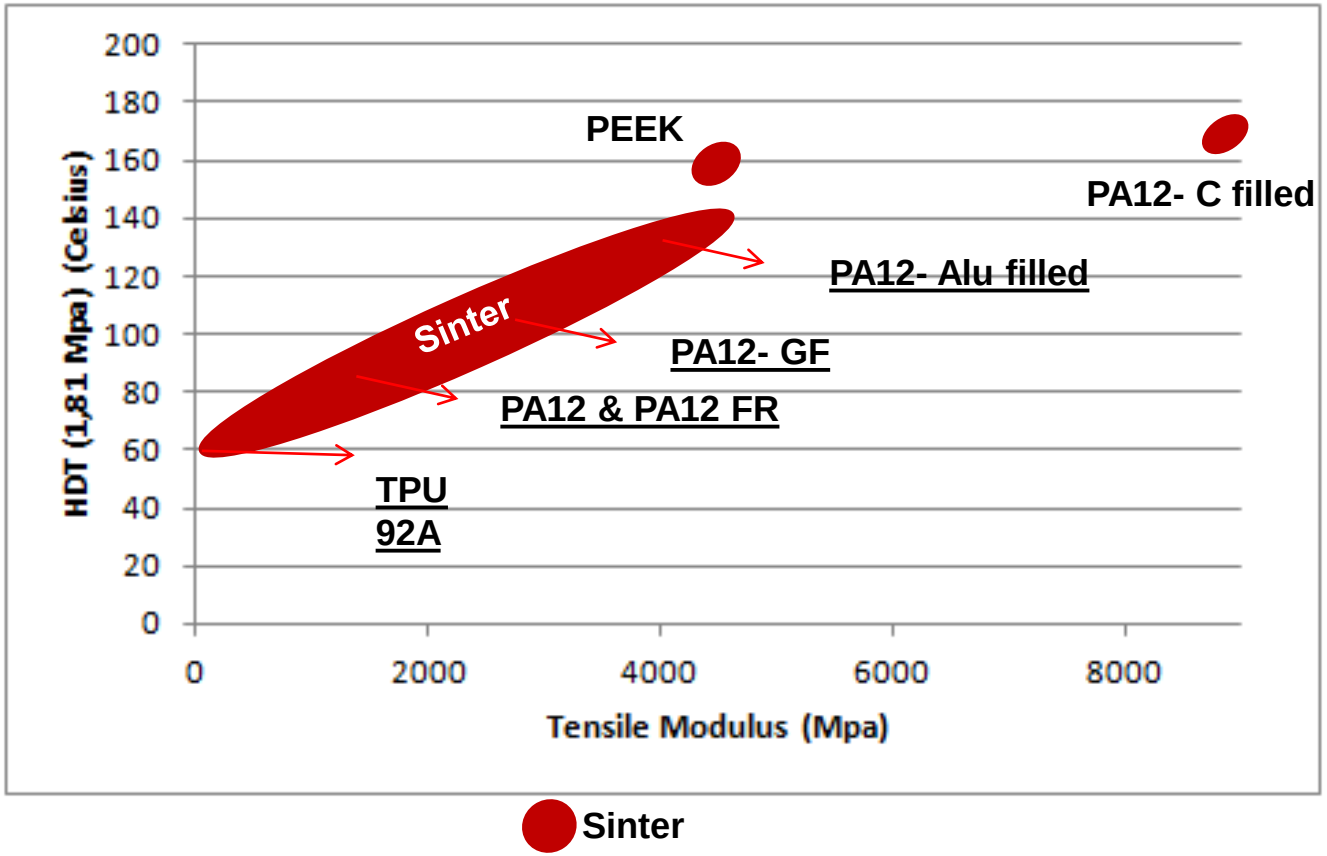
- **Polyamide 12 (PA12)**
- Polyamide 11
- PEBA(X)
- **Thermoplastic Polyurethane (TPU)**
- Polyamide 11
- **Polyamide 6***
- **PP**
- PAEK(PEEK/PEKK)

Materials for Laser Sintering

- **Polyamide 12 (PA12)**
  - **PA Aluminum-Filled**
  - **PA Glass-Filled (PA-GF)**
  - **PA Flame-Retardant (PA 2241 FR/ PA 2210 FR)**
  - Carbon Filled PA12
- Thermoplastic Polyurethane (**TPU 92A-1**)
- Polyamide 6
  - **PA6Mineral Filled black***
- **PP**

Bold: @Materialise
*: available soon

Laser Sintering/ MJF: Modulus vs HDT



3DP –Laser Sintering: Technology Effects affecting Material performance and Design Freedom

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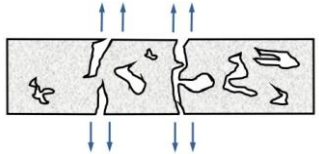
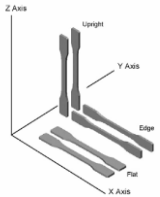


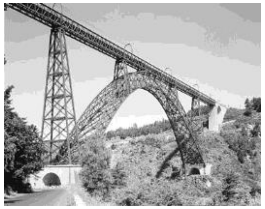
Pressureless → Risk of **porosity**

2-**5**-10%

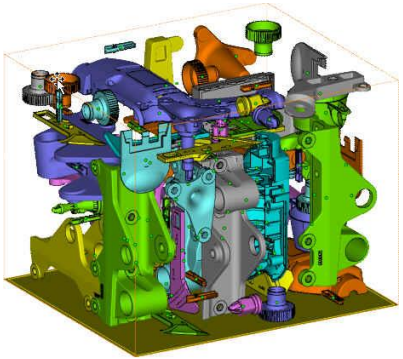


Layerwise → **Anisotropy**

Medium Anisotropy



NO Need for **support structures**
POWDER is support
Powder needs to be removed



3DP –Laser Sintering: Technology Effects affecting Material performance and Design Freedom

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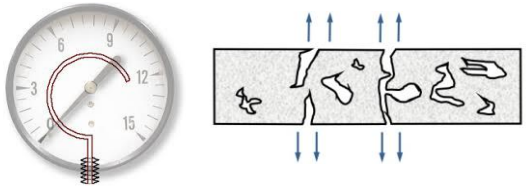
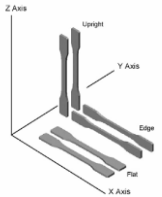


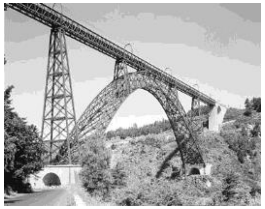
2-**5**-10%

Pressureless → Risk of **porosity**



Layerwise → **Anisotropy**

Medium Anisotropy



NO Need for **support structures**
POWDER is support
Powder needs to be removed

Multi-Colour/ Multi -material
NOT possible

Technical Specifications- Laser Sintering

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Standard lead time	Minimum of 4 working days (2 working days for Fast Lane orders) (depending on part size, number of components and required finishing)
Standard accuracy	+/- 0.3% (with lower limit on ± 0.3 mm)
Minimum wall thickness	1 mm (living hinges are possible at 0.3 mm)
Layer thickness	**0,1-0.12 mm**
Maximum part dimensions	650 x 330 x 560 mm
Surface texture	Unfinished parts typically have a **grainy surface** but all kinds of fine finishes are possible. Laser-sintered parts can be sandblasted, colored/impregnated, painted, covered and coated

Why choose Laser Sintering?

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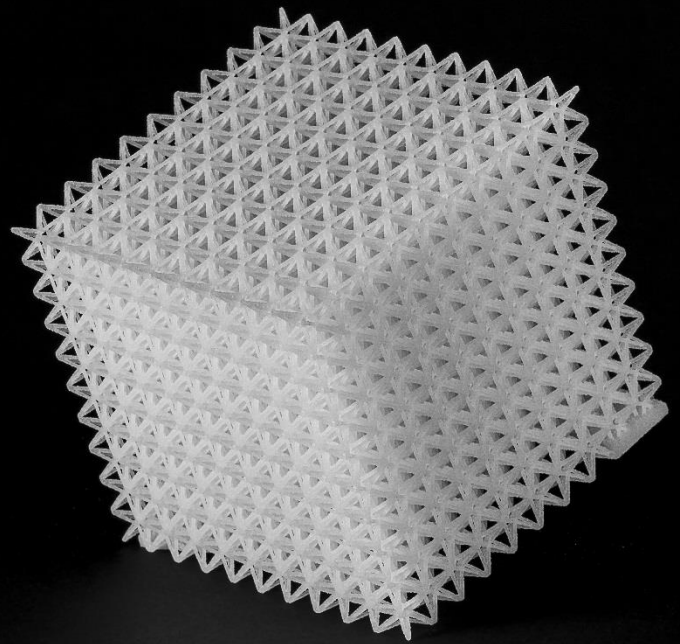
- Fast lead times and economical prices
- Durable and functional parts
- Large and complex parts
- Design freedom unhampered by support structure



Trends in Laser sintering/ Powder bed technologies

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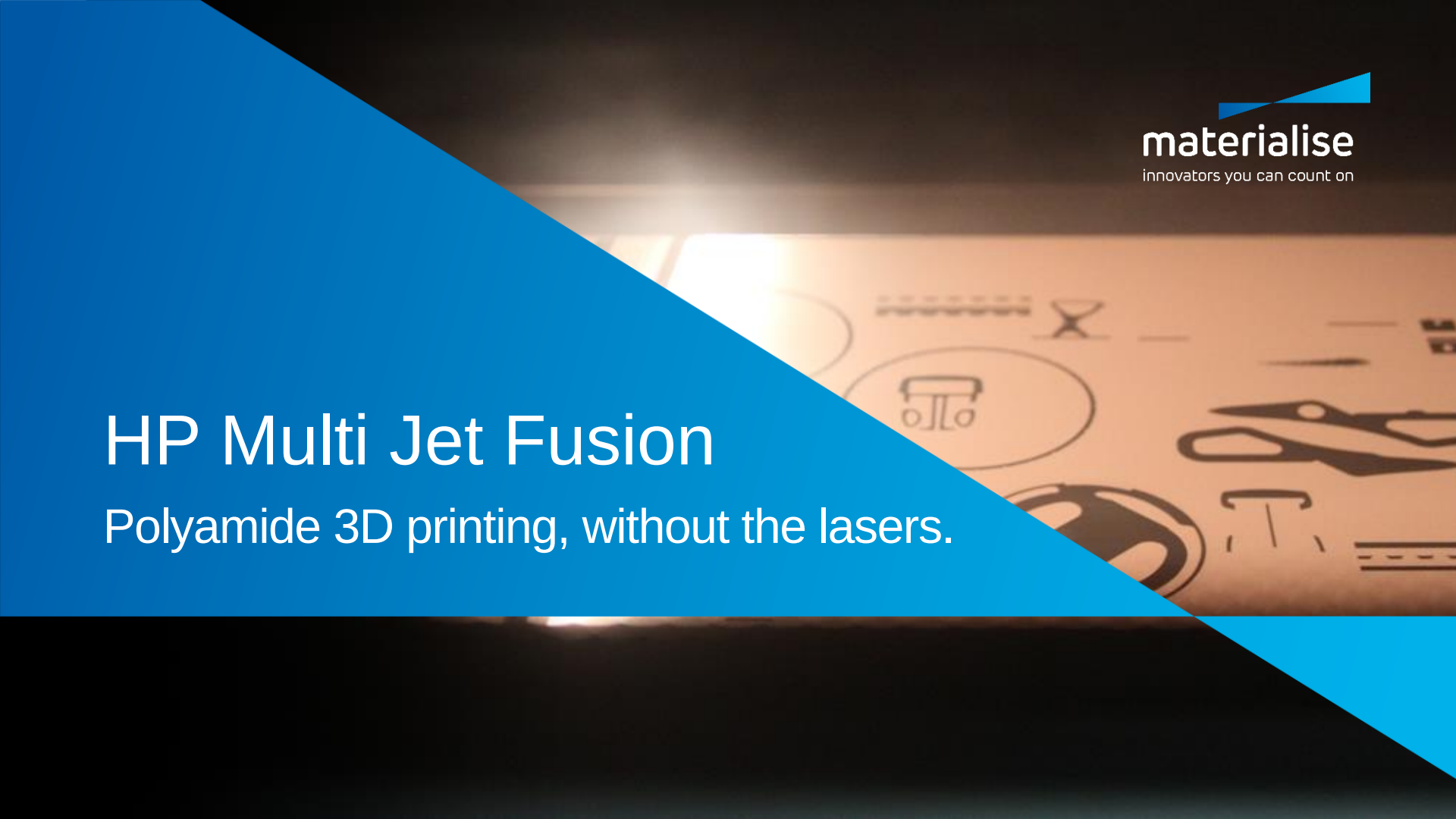
- Broader Material palette: PBT, PP, PA, PSU, FR
- Higher Reusability of Powder
- Speed



HP Multi Jet Fusion

Polyamide 3D printing, without the lasers.

HP MJF: How does it work?

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The 3D model

A fusing agent and a detailing agent are jetted to selectively melt powder particles and improve resolution

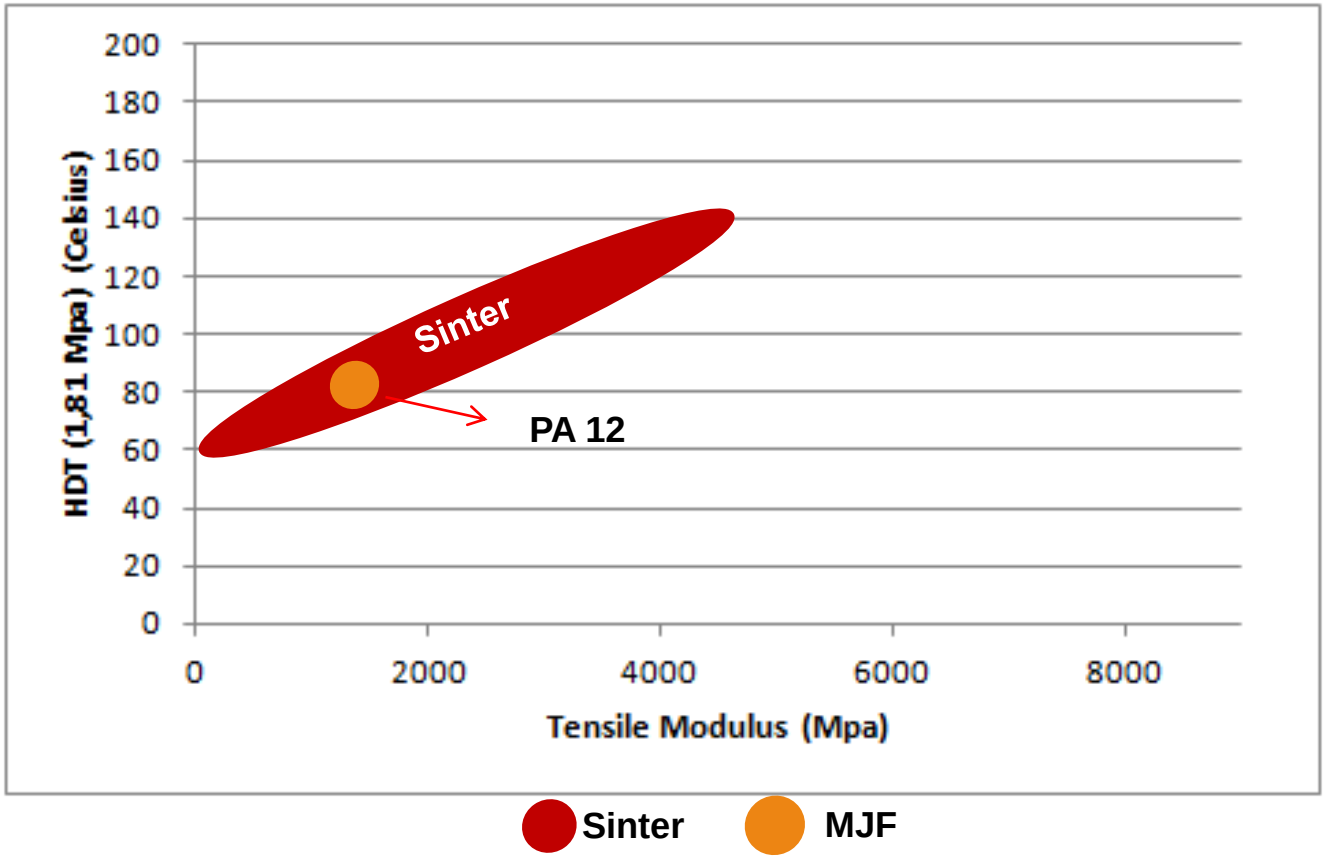
Lamps pass over the surface constantly, the jetted material captures and distributes the heat

The process continues, building up the part layer by layer

The loose powder is removed

The part is finished

Laser Sintering/ MJF: Modulus vs HDT



+ PA12GF
+ PA11
+ more to come

3DP -MJF: Technology Effects affecting Material performance and Design Freedom

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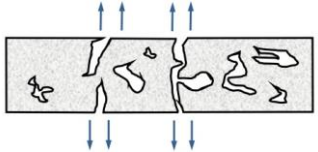
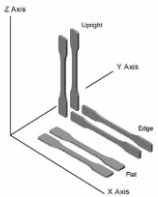


Pressureless → Risk of **porosity**

LS:2-**5**-10%
MJF: LOWER



Layerwise → **Anisotropy**

LS: Medium Anisotropy
MJF: more isotrope

3DP -MJF: Technology Effects affecting Material performance and Design Freedom

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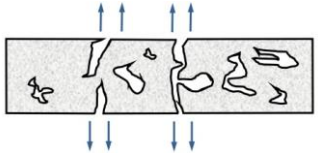

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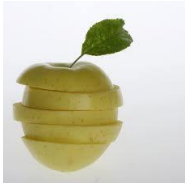
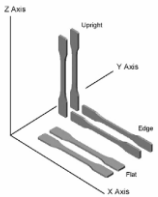
MJF: LOWER





Layerwise → **Anisotropy**

LS: Medium Anisotropy
MJF: more isotrope

NO Need for **support structures**
POWDER is support
Powder needs to be removed

Multi-colour
LS: not possible
MJF: possible in future

Technical Specifications-MJF

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Standard lead time	Minimum of 5 working days, depending on part size, number of components and finishing degrees
Standard accuracy	± 0.3% (with lower limit on ± 0.3 mm)
Minimum wall thickness	1 mm, but living hinges are possible at 0.5 mm
Layer thickness	**0.08 mm**
Maximum part dimensions	256 x 340 x 360 mm
Surface texture	Unfinished parts typically have a smooth surface, without visible layers, and a **stone-grey color**. Multi Jet Fusion parts can be sandblasted and colored/impregnated.

The Technologies: Key aspects

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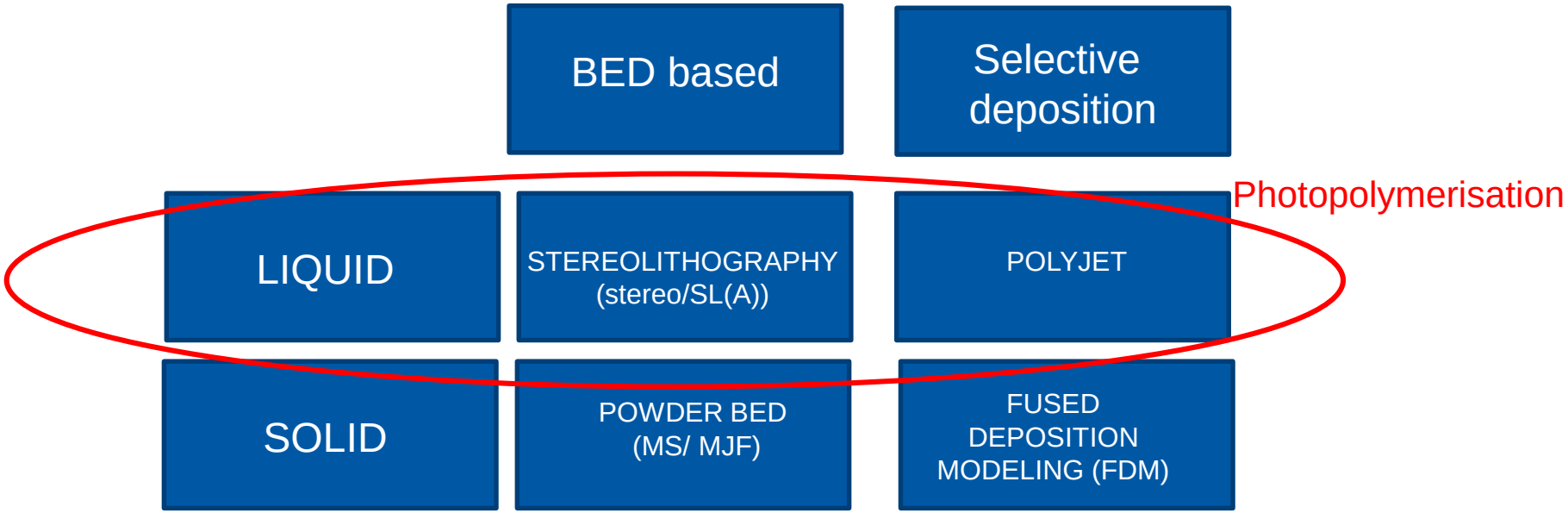

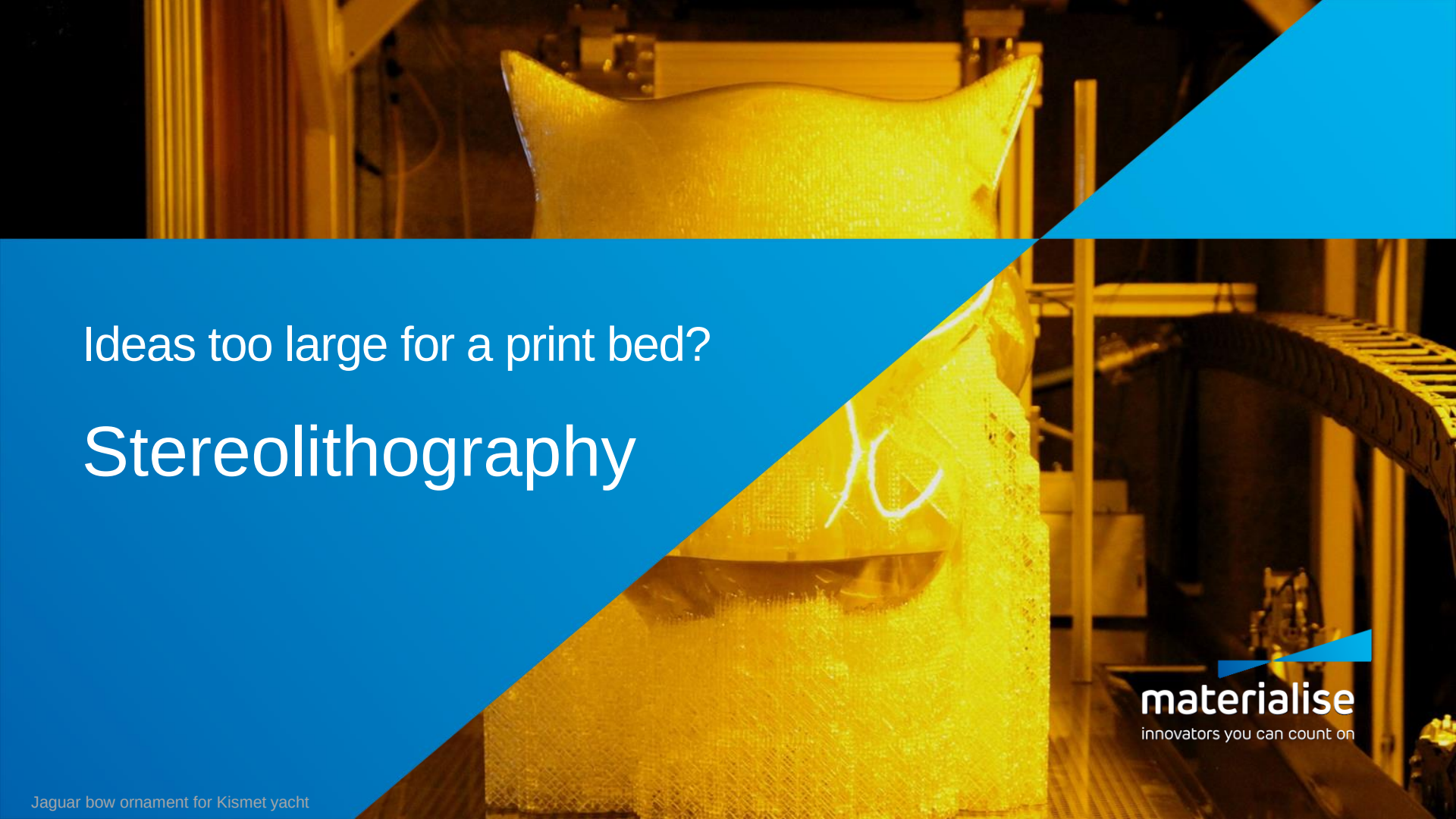

Ideas too large for a print bed?

Stereolithography

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Jaguar bow ornament for Kismet yacht

Stereolithography: How does it work?

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The 3D model

A laser hardens UV curable liquid

The platform is lowered gradually, while the laser selectively hardens the material to form the part and its support

The excess liquid is washed away and the support is removed

The part is finished

Materials for Stereolithography

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- Epoxy Acrylates

Materials for Stereolithography @Materialise

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- Poly1500
- TuskXC2700T / TuskXC2700W
- Tusk Somos SolidGrey3000
- NeXt
- ProtoGen White
- Xtreme
- Taurus
- PerFORM

Stereo: Modulus vs HDT

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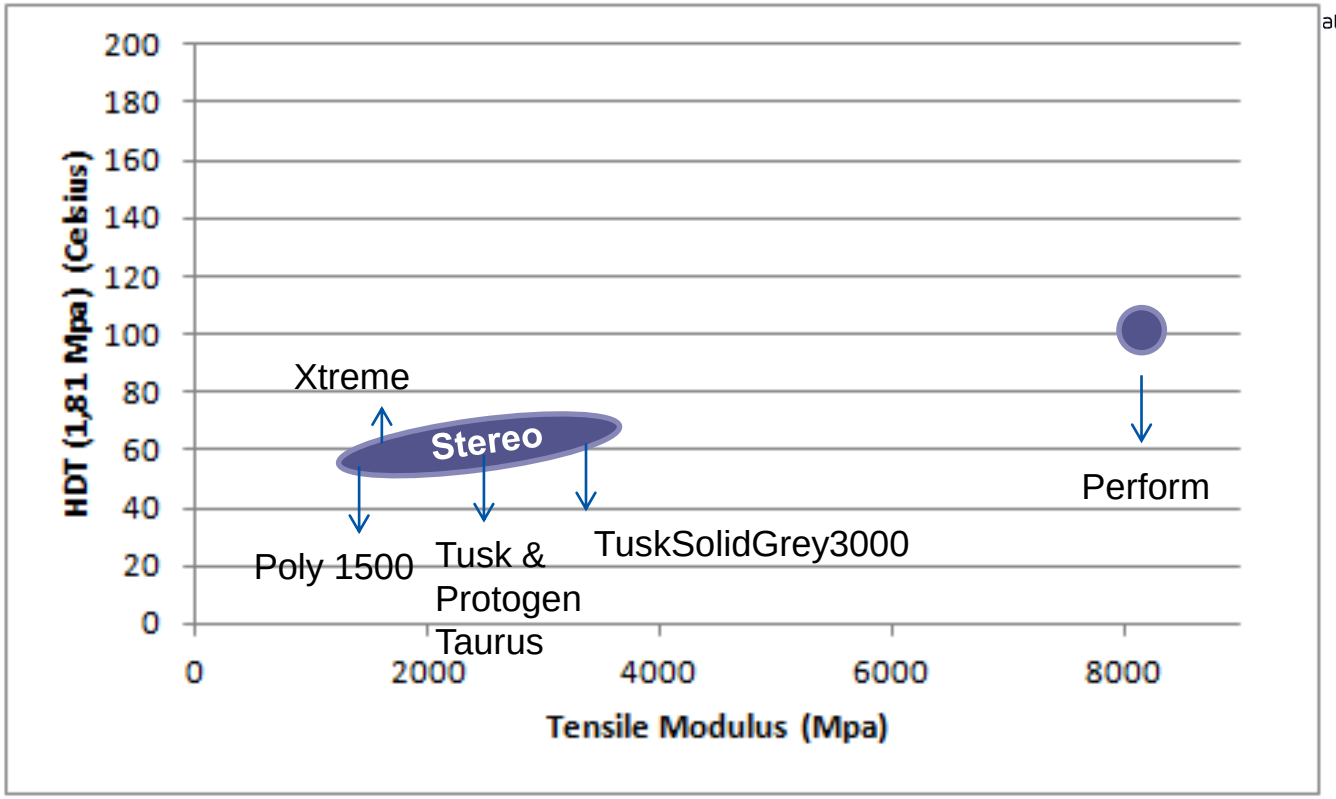

Stereo

3DP –Stereo: Technology Effects affecting Material performance and Design Freedom

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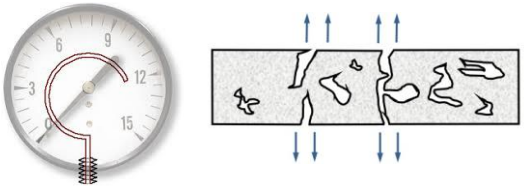

0%

Pressureless → Risk of **porosity**

3DP –Stereo: Technology Effects affecting Material performance and Design Freedom

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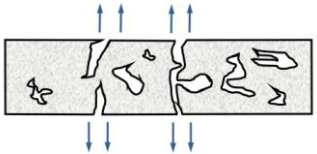
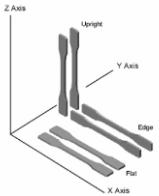


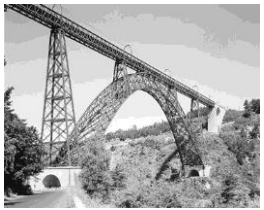
0%

Pressureless → Risk of **porosity**



Low Anisotropy

Layerwise → **Anisotropy**



Need for **support structures**

Multi-colour not obvious

Technical Specifications- stereolithography

Standard lead time	Minimum of 3 working days (or 12 hours for models using the NextDay service at Materialise OnSite), depending on part size, number of components and finishing degrees
Standard accuracy	+/- 0.2% (with lower limit on ± 0.2 mm)
Minimum wall thickness	1 – 3 mm (depending on part dimensions)
Layer thickness	Mammoth SL: 0.1 mm. Standard SL: 0.1 mm – 0.15 mm (varies by material). NextDay SL: 0.15 – 0.2 mm (varies by material)
Maximum part dimensions	**2100 x 700 x 800 mm** (offline orders) 1100x690x590 mm (online orders) 600x400x75 mm (NextDay orders)
Surface texture	Unfinished parts have visible building layers on the surface but post-production finishes can achieve different effects, from high glosses to coarse textures. Stereolithography parts can be sandblasted, colored, painted, varnished, coated

Why choose Stereolithography?

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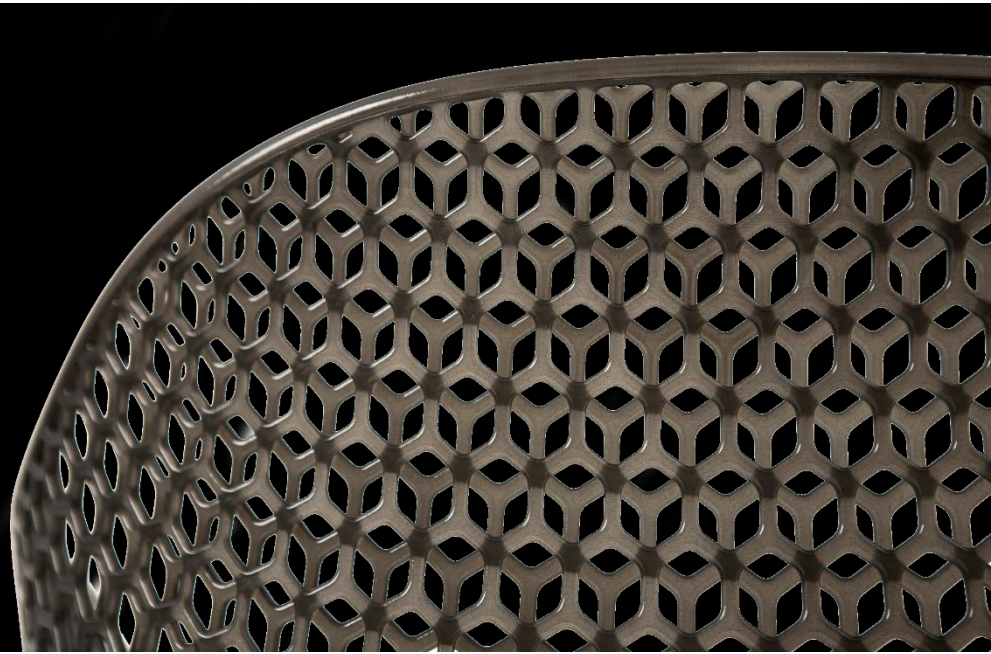
- High accuracy and surface quality
- Transparent parts
- Fast lead times
- Large single-build parts



GO wheelchair by Layer

Ideal Applications for Stereolithography

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Prototype of olive oil bottle

- **Prototypes**
- **Manufacturing/ End-use parts:** only for selective applications that can live with material limitations
- **Intermediates:**
  - Intermediate (Master) for copying techniques (Vacuum Casting)
  - Intermediate for Metal casting (Investment casting)

PolyJet

Sometimes, one material at a time just isn’t enough.

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PolyJet: How does it work?

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The 3D model

Print heads deposit photopolymer materials and support in ultra-thin layers

Each layer is cured by UV light immediately

The gel-like support material is washed away

The part is ready, without further finishing

Polyjet: Materials available

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Acrylates:

- **Veroclear**
- **Verowhite**
- **Agilus (rubber like)**

Stereo & Polyjet: Modulus vs HDT

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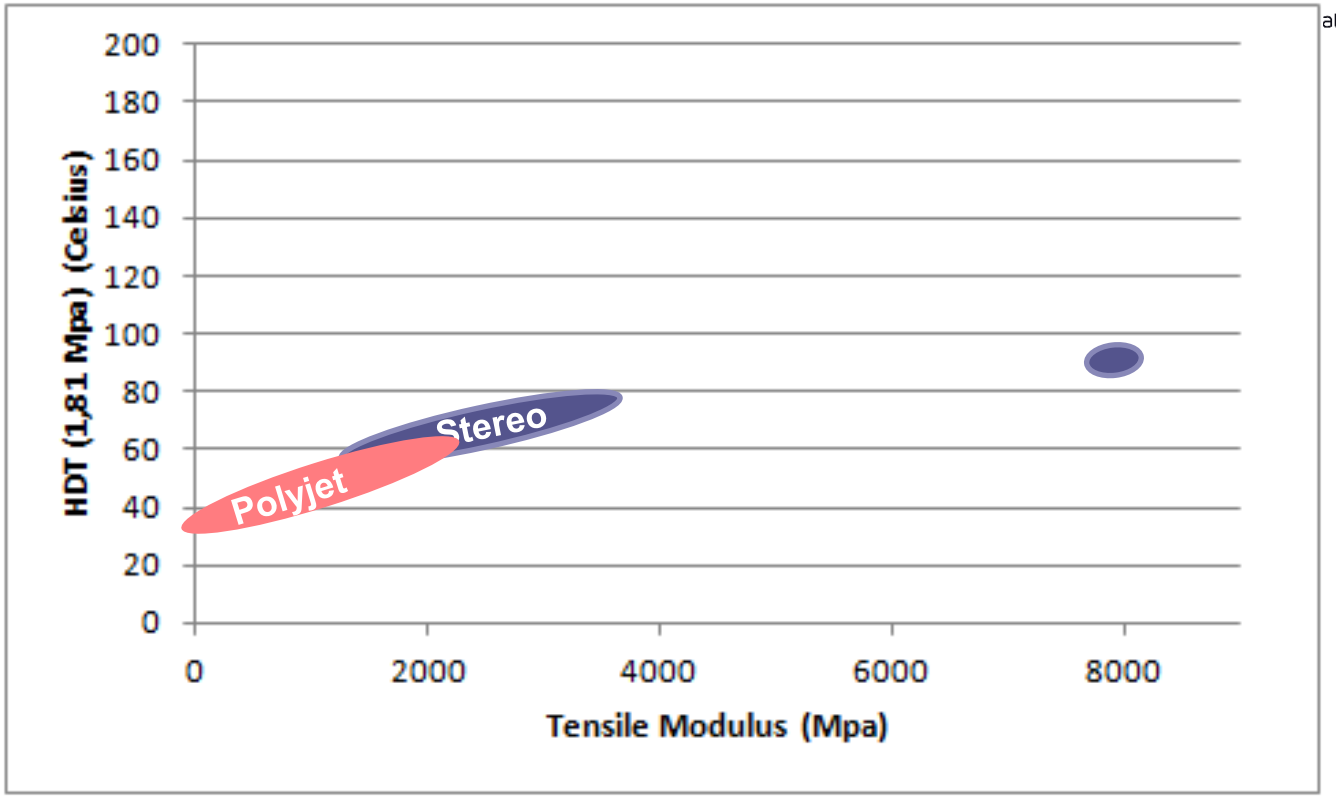

3DP –Polyjet: Technology Effects affecting Material performance and Design Freedom

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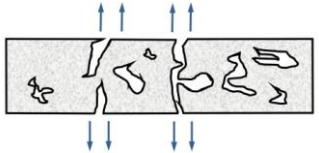
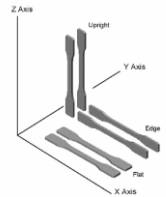


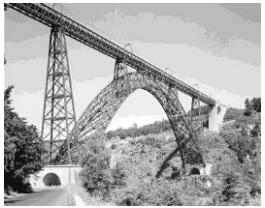
0%

Pressureless → Risk of **porosity**



Low Anisotropy

Layerwise → **Anisotropy**



Need for **support structures**

Multi-colour available
Multi-material available

Polyjet: Multi-material & Multi-Colour

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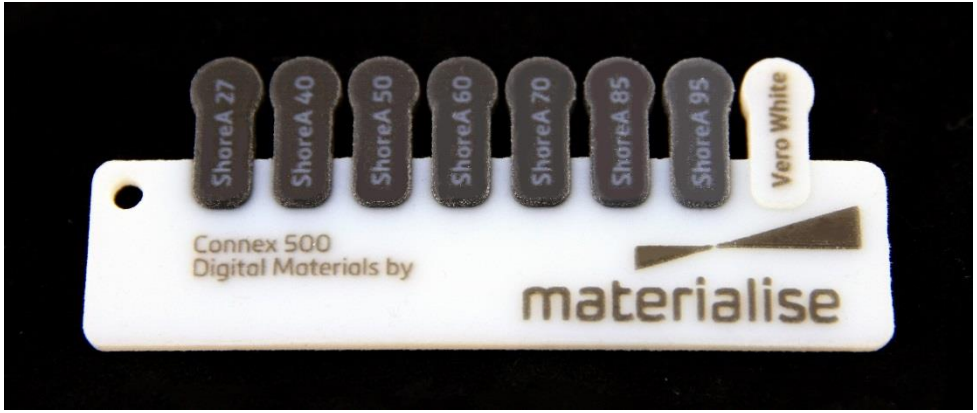

Concept of Digital Materials
Verowhite + Agilus
Lead to Shore A40 – Shore A 95

Technical Specifications

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Standard lead time	Minimum of 2 working days
Standard accuracy	0.1 – 0.3 mm
Minimum wall thickness	0.8 mm
Layer thickness	**0.016 mm**
Maximum part dimensions	500 x 400 x 200 mm
Surface texture	Unfinished PolyJet parts have a smooth surface, which can be further smoothed as desired through finishing processes

Why choose PolyJet?

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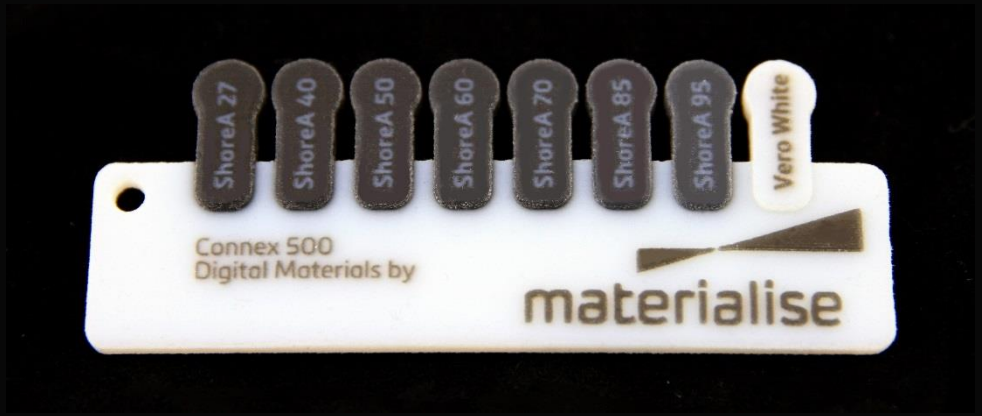
- High level of surface quality and detail
- Availability low Shore A
- Multi-color, multi-material parts
- High accuracy
- Fast lead times, from 48 hours



Trends in Photopolymerisation 3DP technologies

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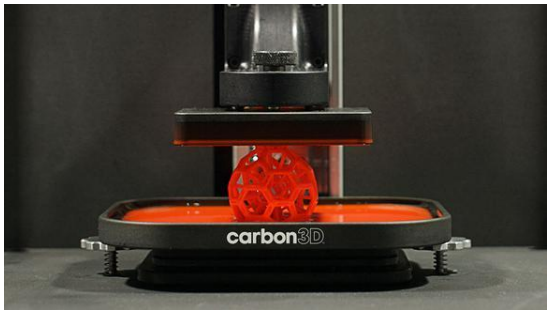
- Other Illumination sources
- Higher Performance Materials

Carbon: CLIP



Summary Material Functionality (HDT)

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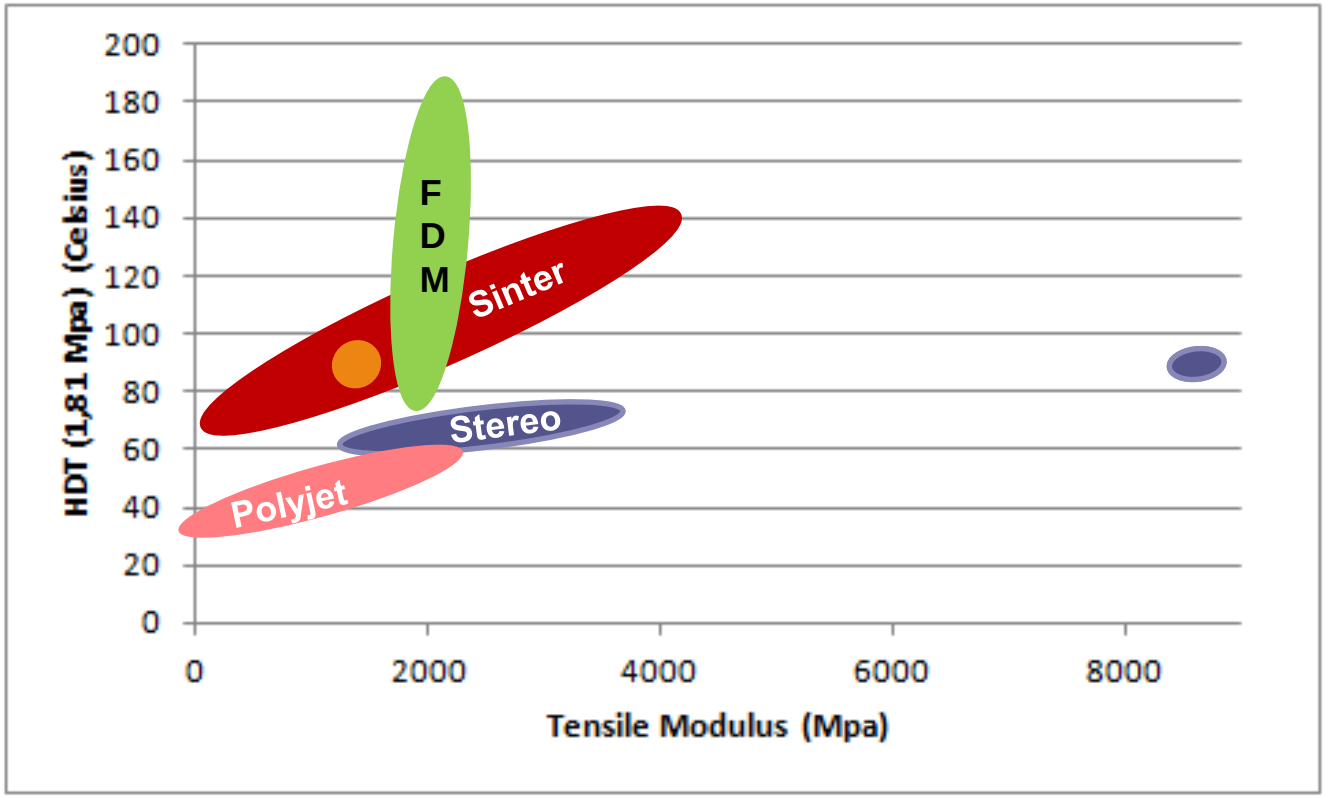

Technology Effects affecting Material performance and Design Freedom

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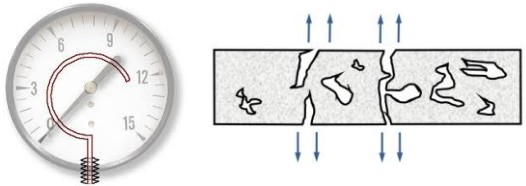
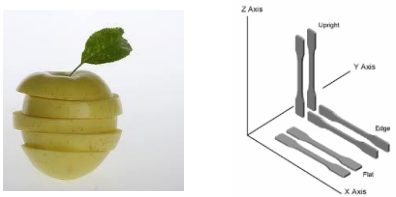
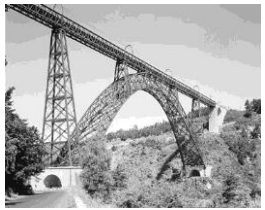


Pressureless → Risk of **porosity**



Layerwise → **Anisotropy**



Support structures

Multi-material/ Multi-colour

Final Balance: Suitability for Manufacturing

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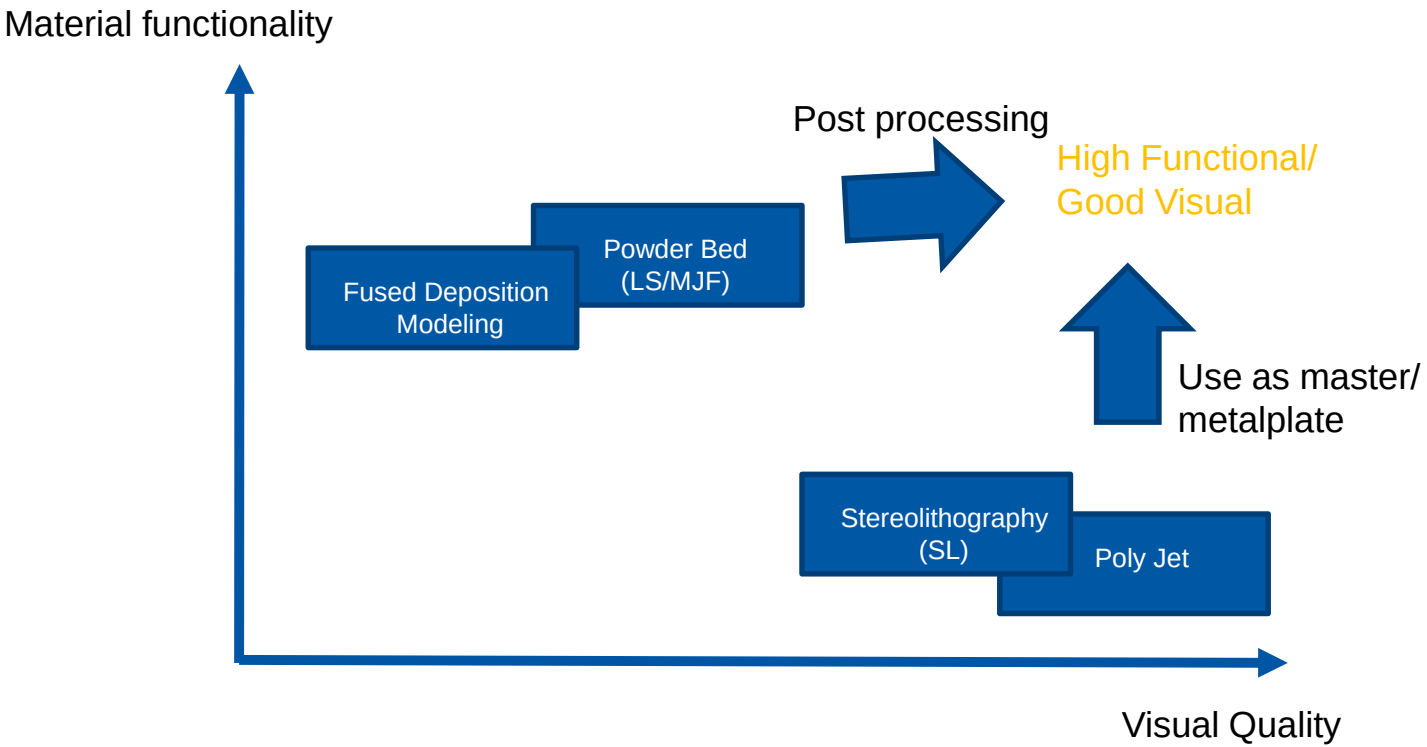

materialise
manufacturing

Thanks for your attention!