Fraunhofer IFAM

Fraunhofer-Institut für Fertigungs-
technik und Angewandte
Materialforschung IFAM

Additive Manufacturing

Sinter-based AM Technologies

Content

- Sinter-based AM @ Fraunhofer IFAM
- Sinter-based AM - Introduction
- Metal Binder Jetting (MBJ)
- Fused Filament Fabrication (FFF)
- 3D screen printing
- Mold Jetting
- Gelcasting
- Summary and Conclusions

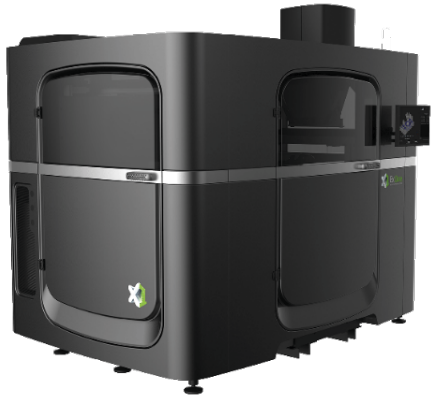
INTRODUCING FRAUNHOFER IFAM

Creating added value by material innovations –
from material development to pilot series production

Metal Additive Manufacturing @ Fraunhofer IFAM

Powderbed Fusion
Laser Beam (PBF-LB)

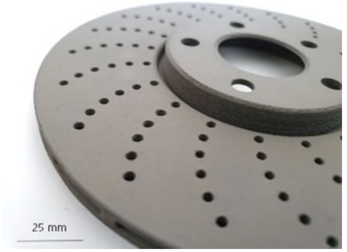
Powderbed Fusion
Electron Beam (PBF-EB)



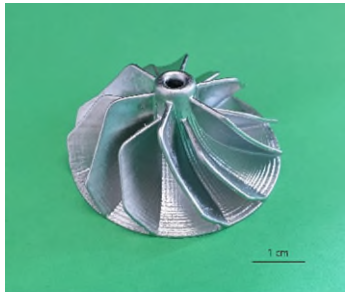
Metal Binder Jetting (MBJ)

3D Screen Printing

Fused Filament Fabrication (FFF)



MoldJetting

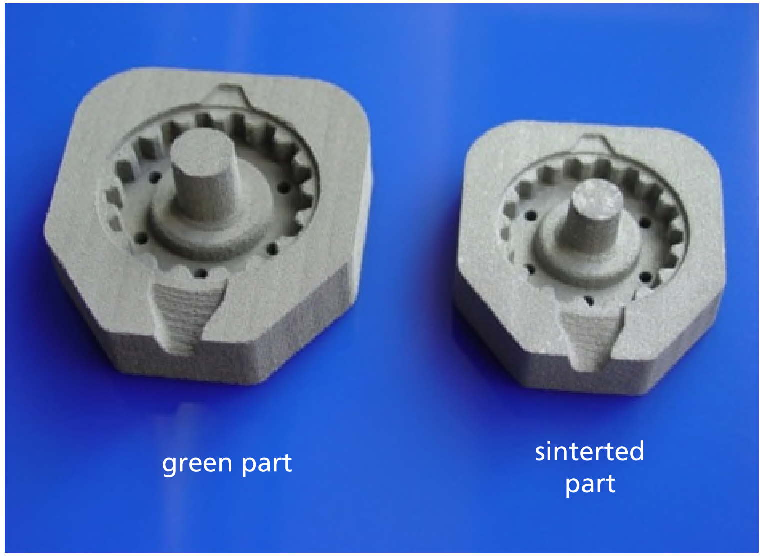


Gelcasting

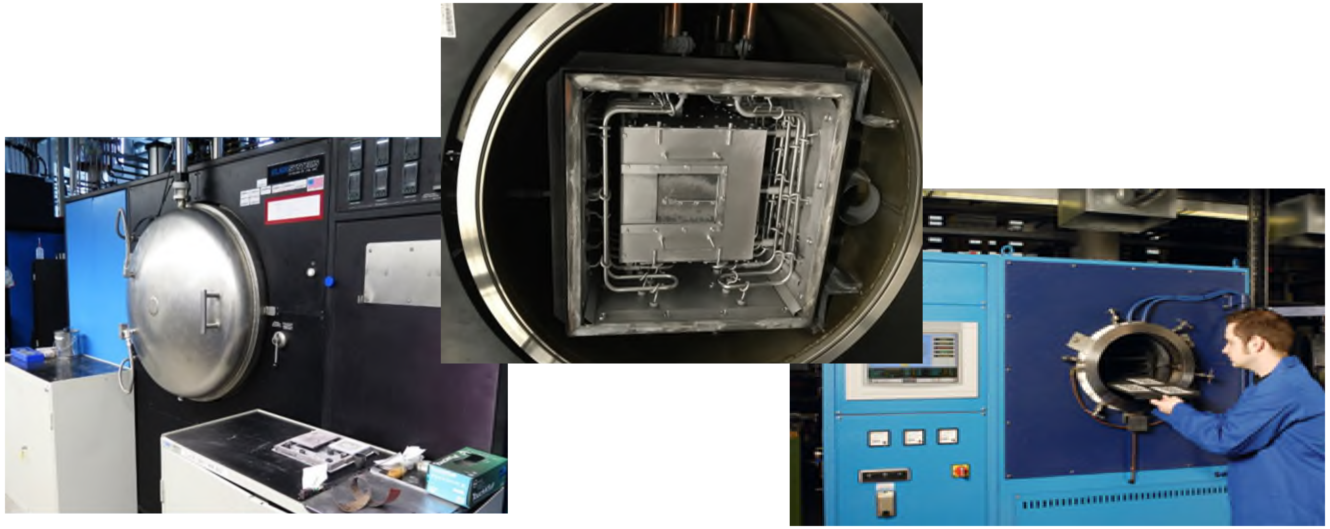
Powder Quality Testing

Fraunhofer IFAM

Sinter-based AM – Introduction



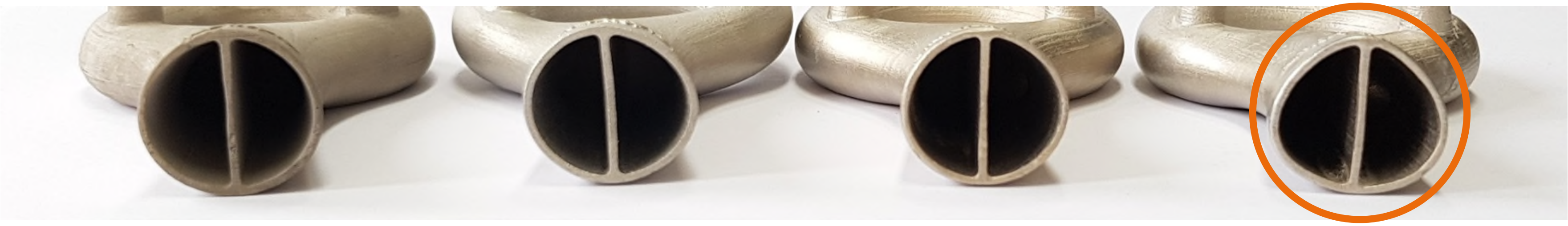
- Two-step process for metal powders plus bonding „phase“
  1. Build-up of so called green parts
  2. Thermal treatment –
     generally debinding and sintering



Sintering – Temperature considerations

Alloy:
Inconel 718

1260 °C | 1270 °C | 1280 °C | 1290 °C



Fraunhofer
IFAM

Sintering – Supports for complex parts

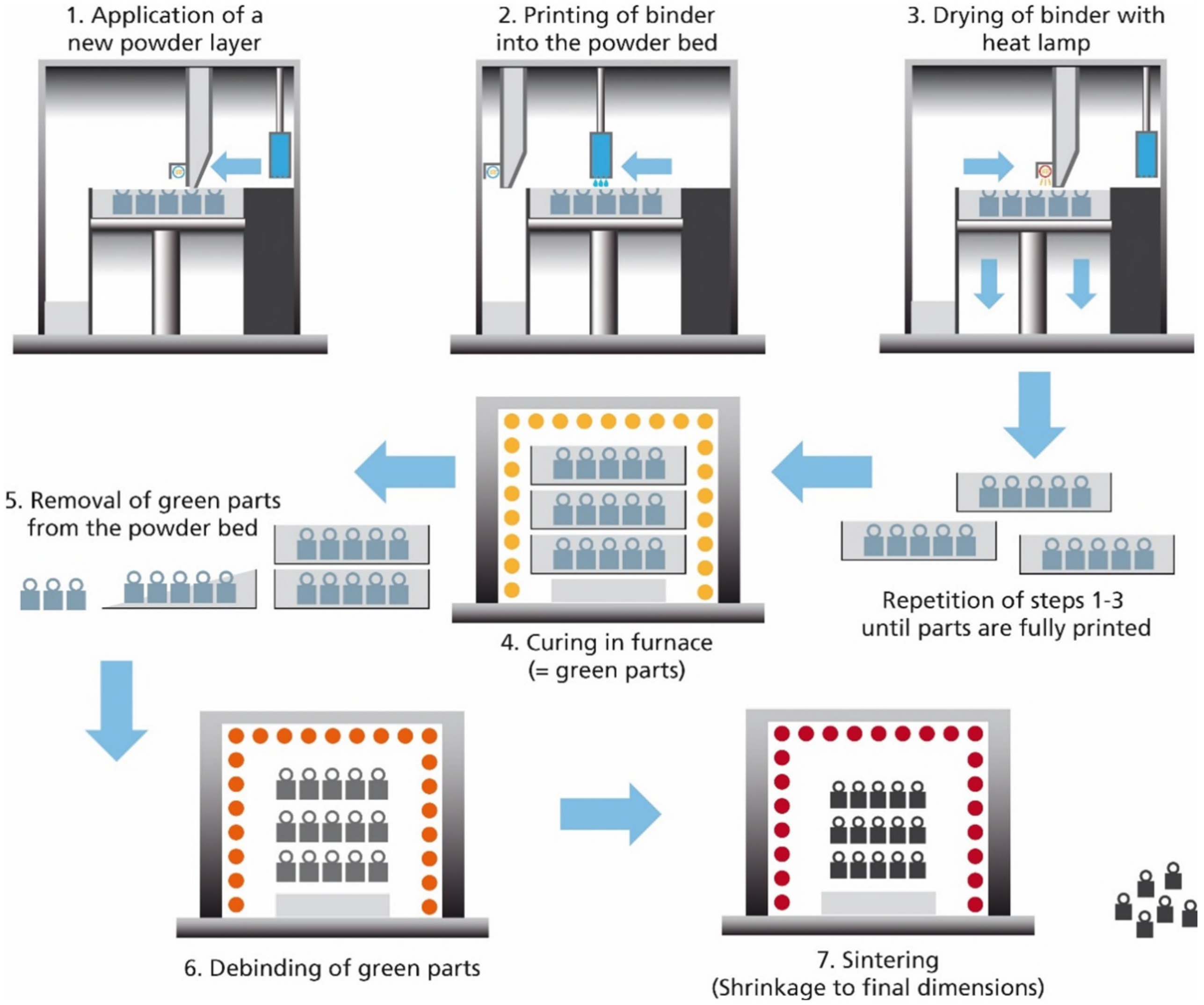
First Approach

Optimization

- Solid connection between setter and part
- Distortion in the upper section

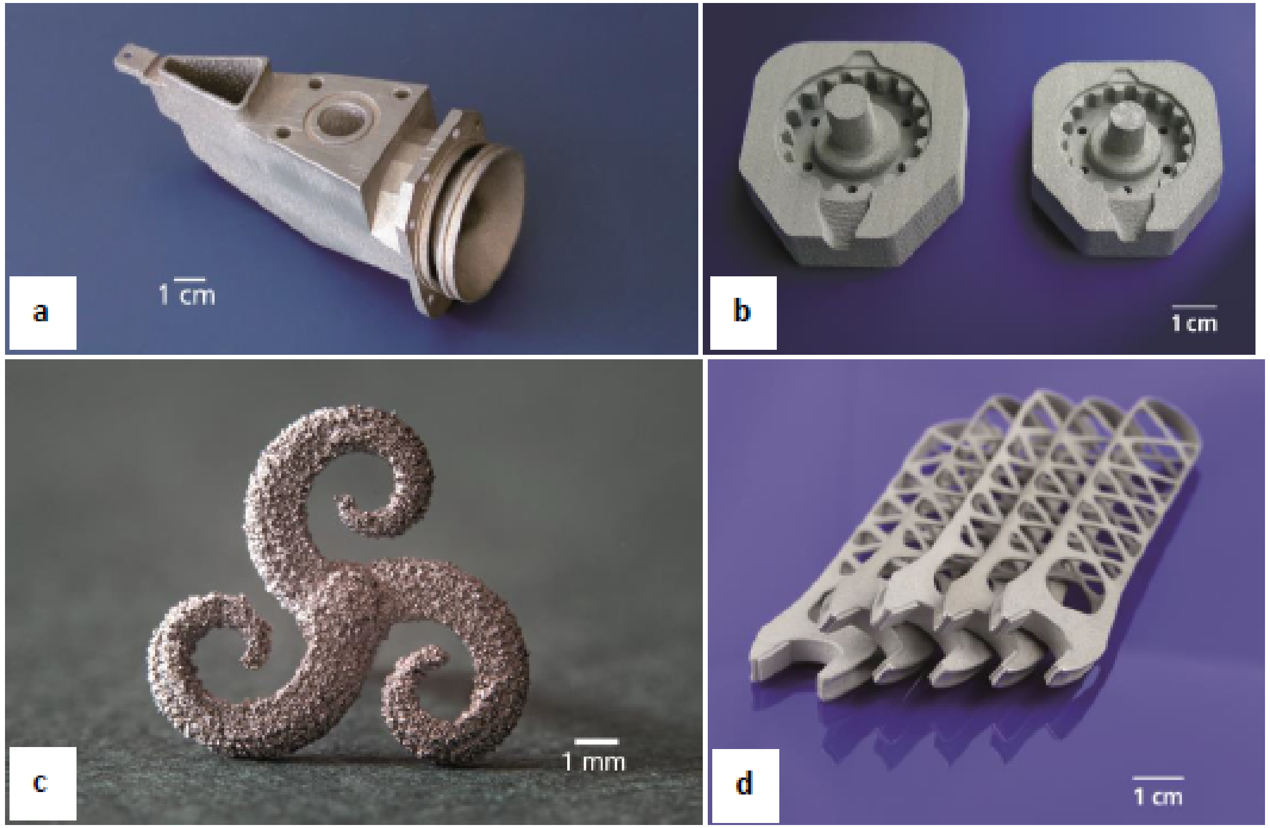
- Easy separation of setter and part
- Dimensional stability in the upper section

Metal Binder Jetting – Process outline



Metal Binder Jetting – Processible materials

- In principal
  all sinterable materials can be processed
- IFAM has successfully processed (e.g.):
  - Stainless steels (420, 316L, 17-4 PH,…)
  - Nickel-Superalloys
  - HSS Steel M2



a) Stainless steel bronze infiltrated
b) Tool steel X190CrVMo20

c) SS 316L
d) SS 420

Fraunhofer
IFAM

Metal Binder Jetting – Comparison of support structures

www.cetim.fr

Binder Jetting – no overhangs to be supported

Beam Melting (here LBM) – overhangs have to be supported

www.cetim.fr

Metal Binder Jetting – Equipment Manufacturers

US

ExOne
DIGITAL PART MATERIALIZATION

GE Additive

Desktop Metal

hp

DIGITAL METAL®

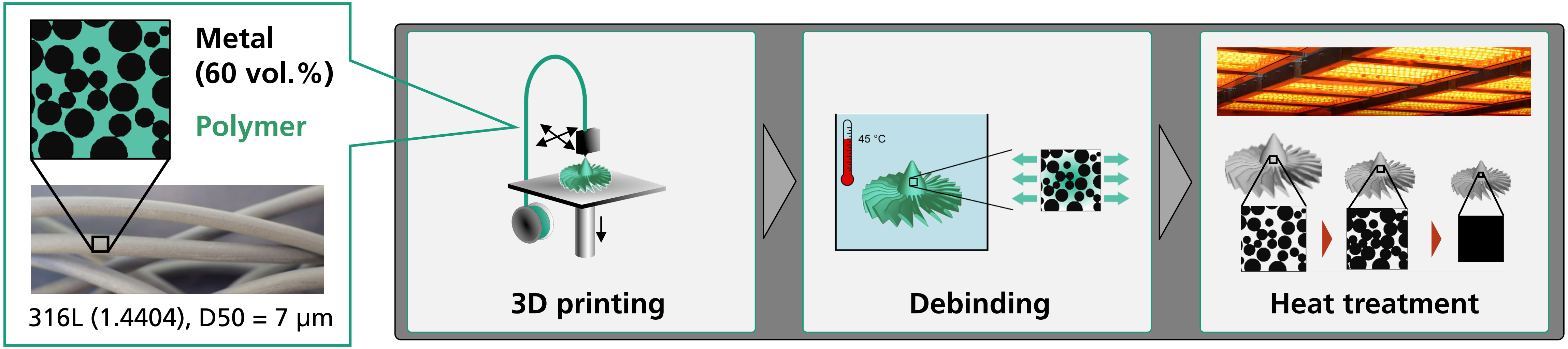
Metal Binder Jetting – Summary

- High number of activities in the market
- High interest from industry
- Cold print process & densification by sintering without thermal gradients
  -> Low residual stresses
- Parts are not connected to the build plate &
  do not require support structures during printing
  -> Reduced post-processing effort
- Surrounding powder does not stick to the part
  -> Lower roughness and roughness almost independent of the build angle
- Print head bar instead of a single laser spot that provides adhesion/ densification
  -> Higher building speed

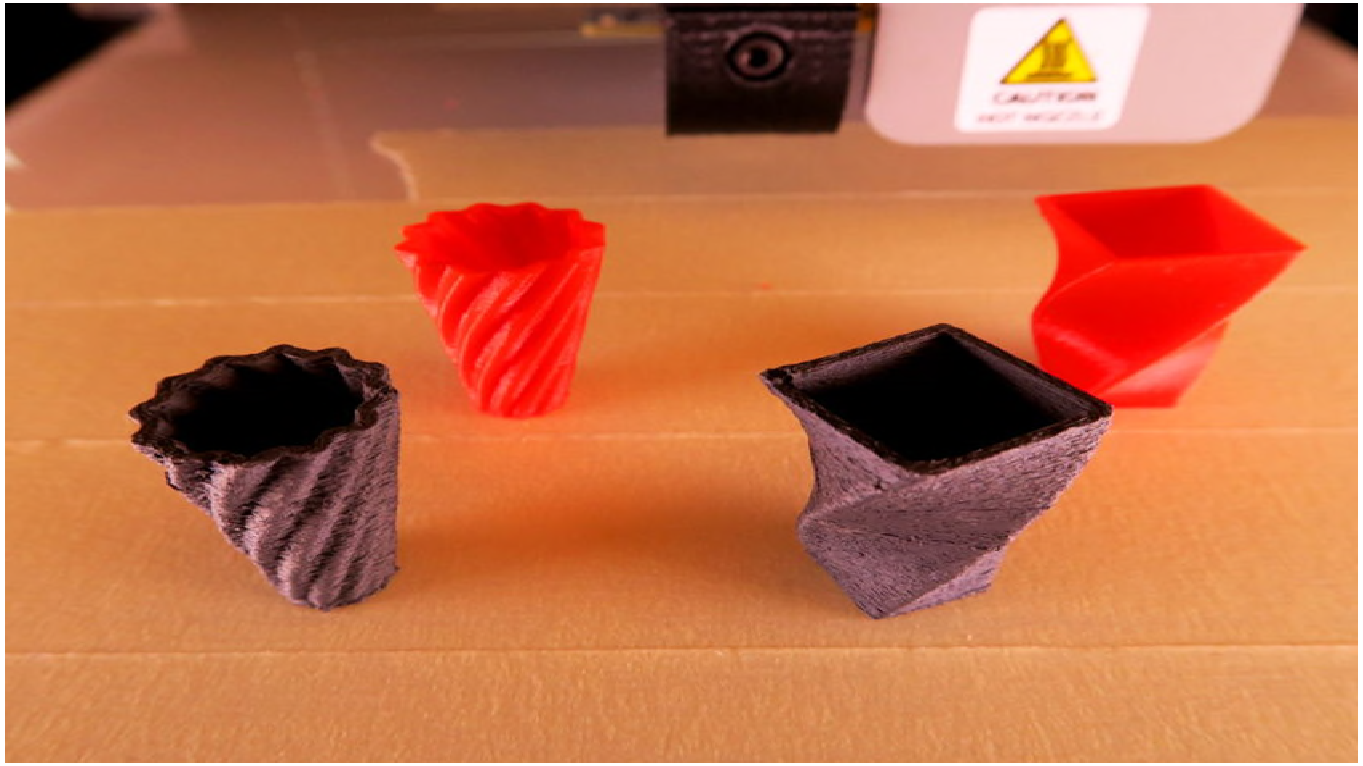
Fused Filament Fabrication – Process details

Process steps

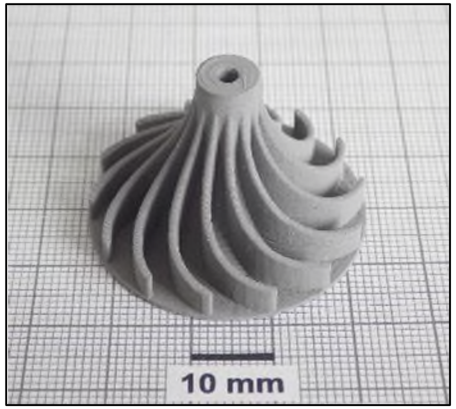
- Use of a highly filled metallic filament for the production of the green part
- Chemical/catalytic debinding of the green part
- Thermal debinding and sintering of the component

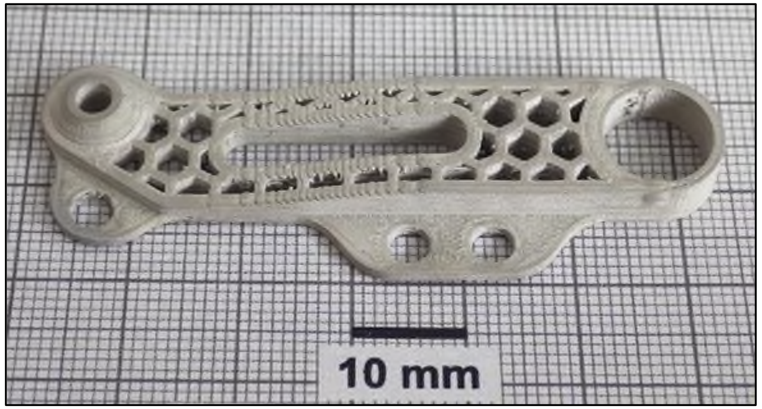


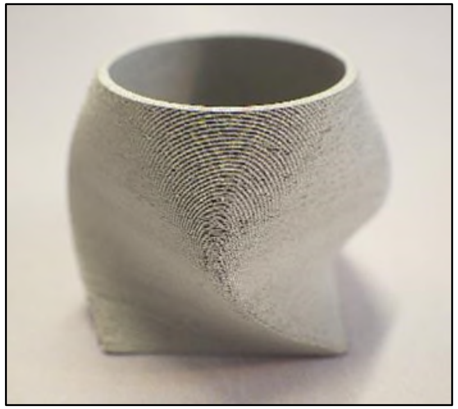
Fused Filament Fabrication – First steps with simple systems

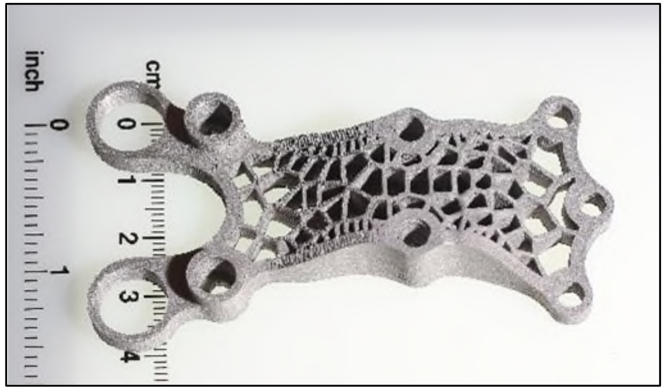


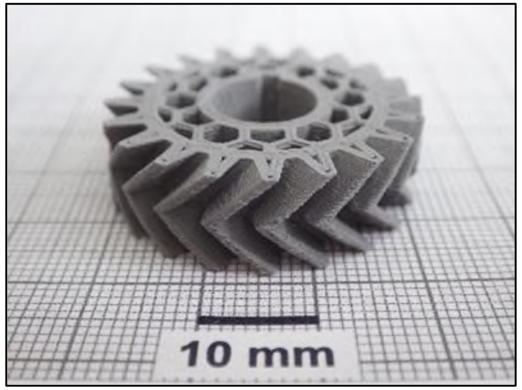
Fused Filament Fabrication – Sample parts

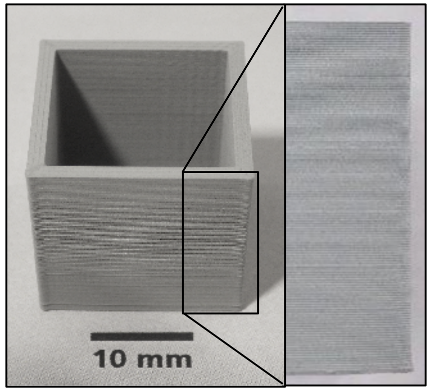




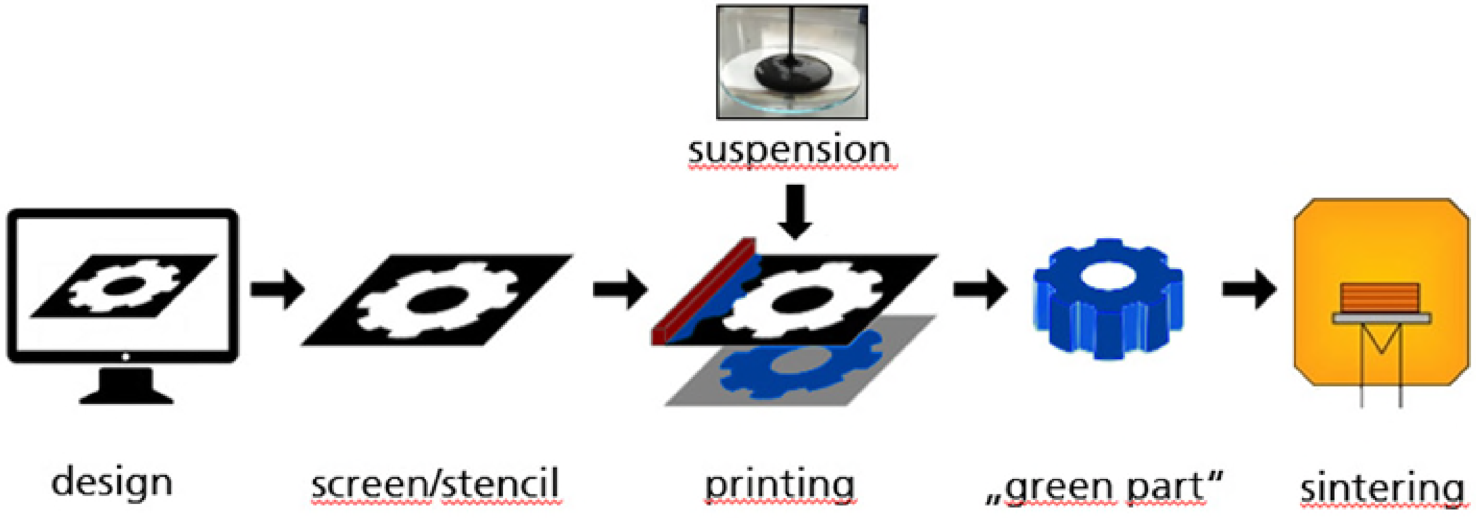


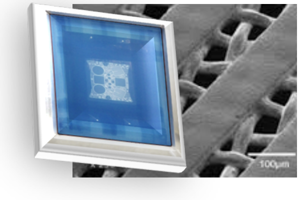


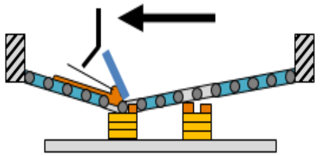


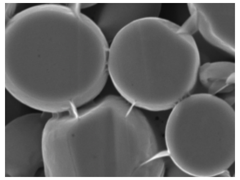


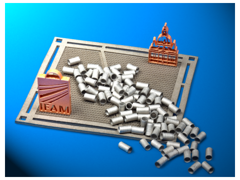
3D screen printing – Process outline



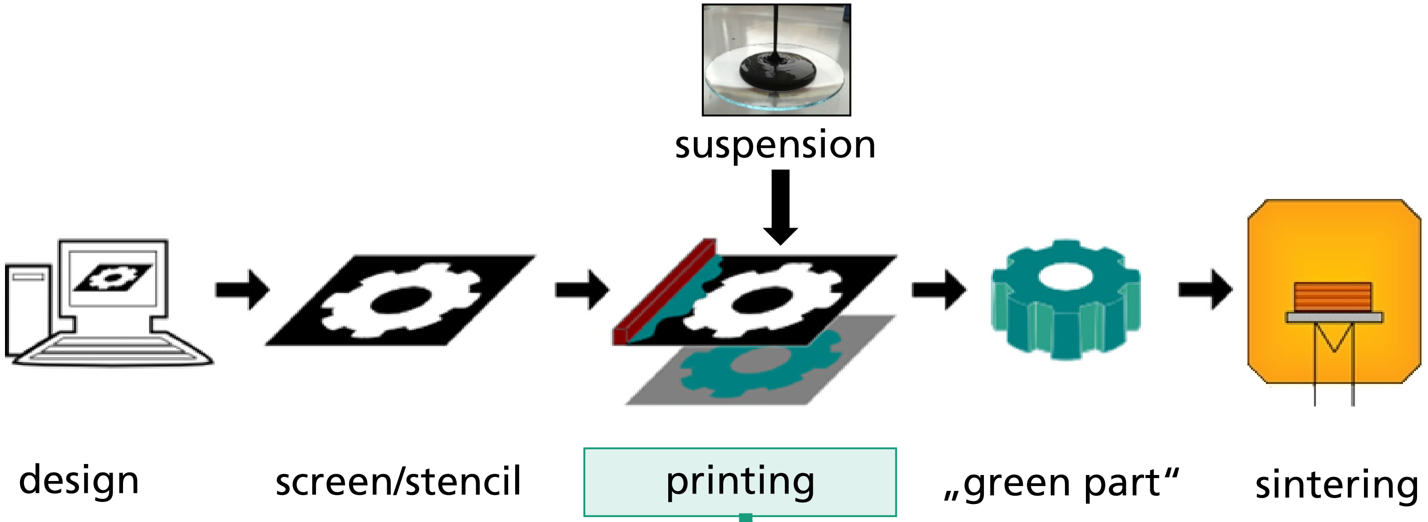


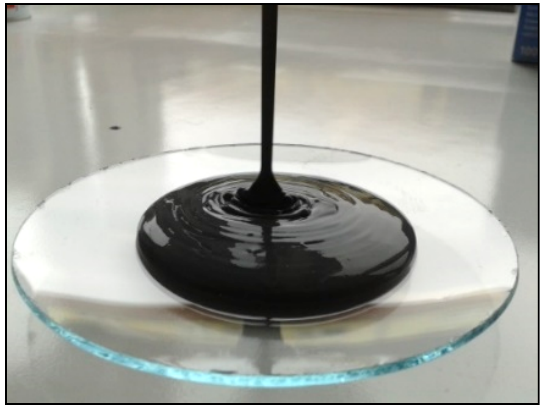






3D screen printing – Process details





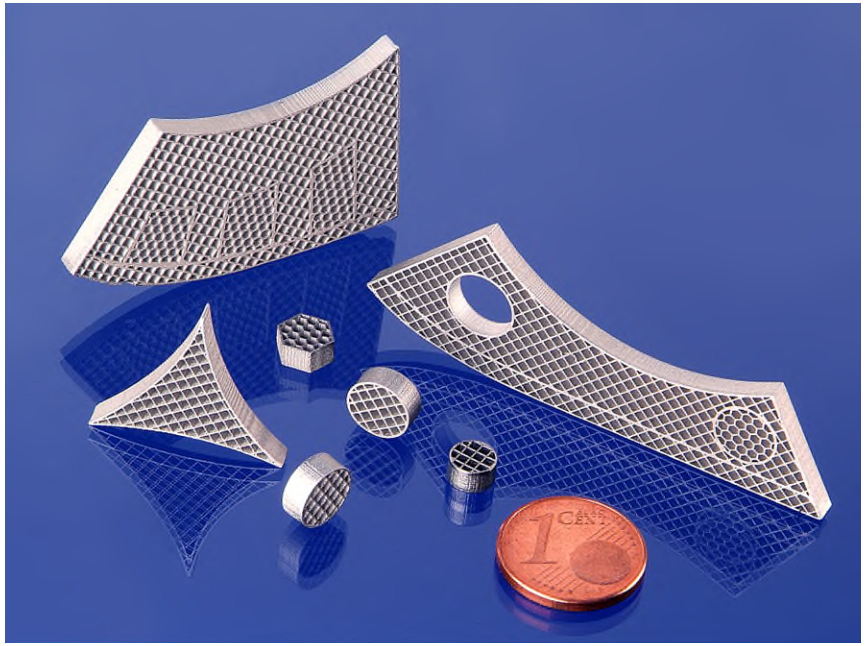
- Paste: powder, additives, binder, carrier
- Solid loading 20-45 vol%
- Adjusting viscosity right is crucial
- Layer height 5-50 µm (screen)
- Layer height 300 µm (stencil)

Fraunhofer IFAM

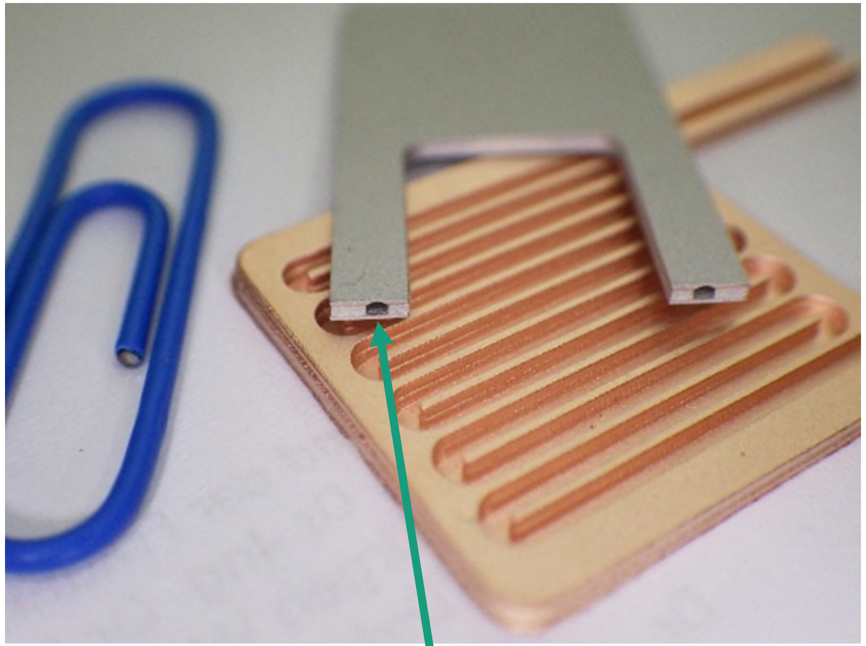
3D screen printing – Summary

- High resolution < 100 µm
- High aspect ratio > 1/100
- Small-sized parts preferred (height < 1 cm)
- Intricate internal structures, cavities printable
- Functionalization of pre-machined structures
- Metals, ceramics, powder mixtures, multi-material systems
- Mass production capable

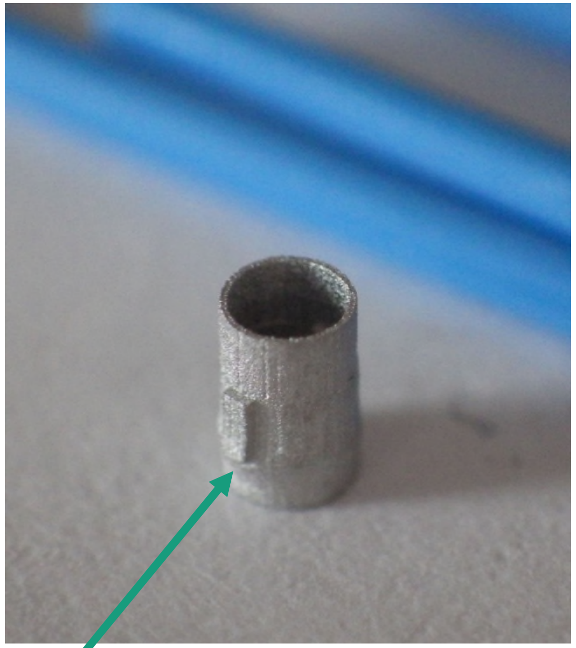
3D screen printing – Sample parts



Thin walls

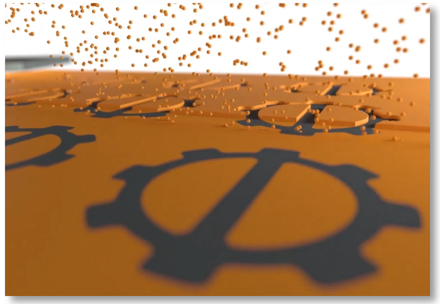


Hollow parts can be produced



overhangs

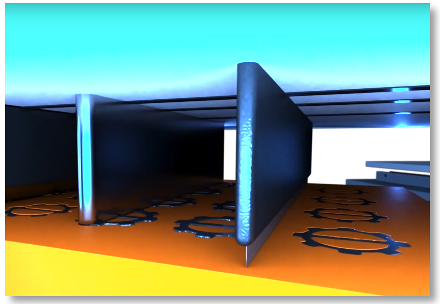
MoldJetting – Process outline



Printing the mould

(layer-by-layer)

1



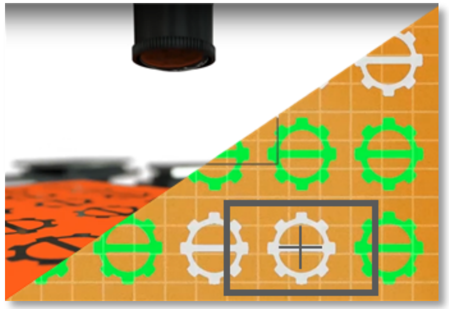
Filling the mold with metal paste

(layer-by-layer)

2

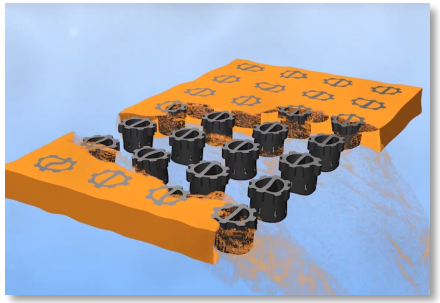
Dying/curing of filled final layer

3



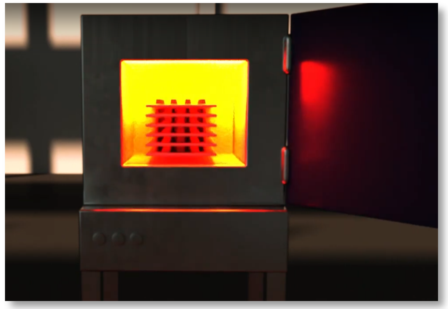
Camera supported analysis of the final layer

4*



Demoulding of parts after printing

5



Thermal debinding & Sintering

(outside the printer)

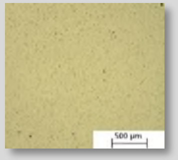
6

***mechanical Post-processing** of incorrect layers based on analytical data

https://tritoneam.com/technology/systems/

MoldJetting – Performance

Material

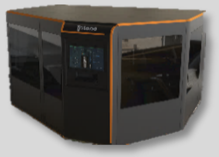


- 100 % material utilization
- Printability of difficult to machine materials
- multi-material design
- Metal powder is bound in the paste

Part

- Very high geometry variety (internal channels, overhangs, undercuts)
- Large-volume components can be produced
- Scalability of the number of pieces (material consumption according to the required components, does not always require a necessary basic amount of material)

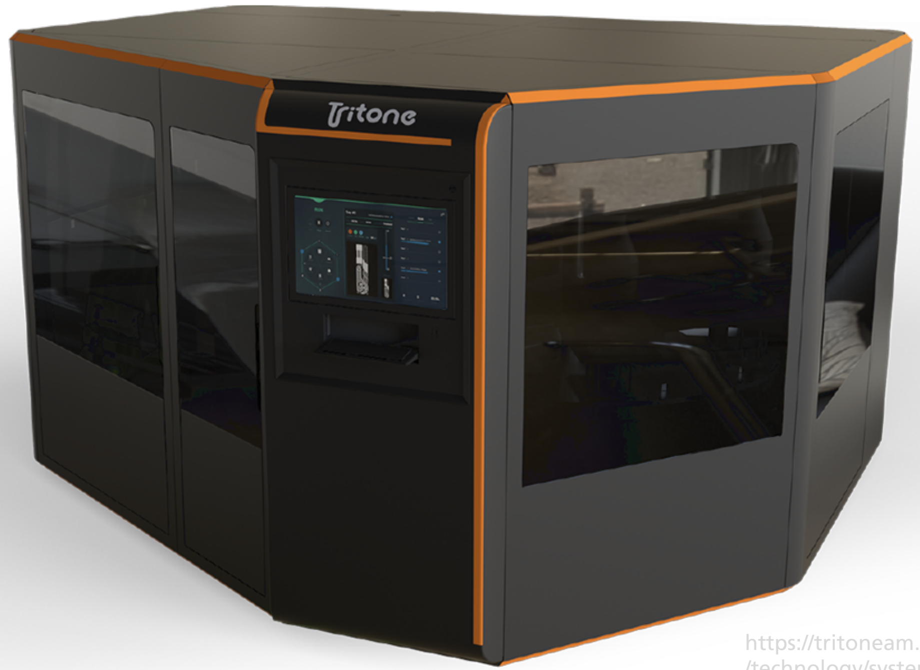
Process



- Very high buildvrate
- High degree of automation (clocking, process runs operator-free)
- Cost-effective production of components even in the low-volume range
- Wear-free moulding process

MoldJetting – Printer details

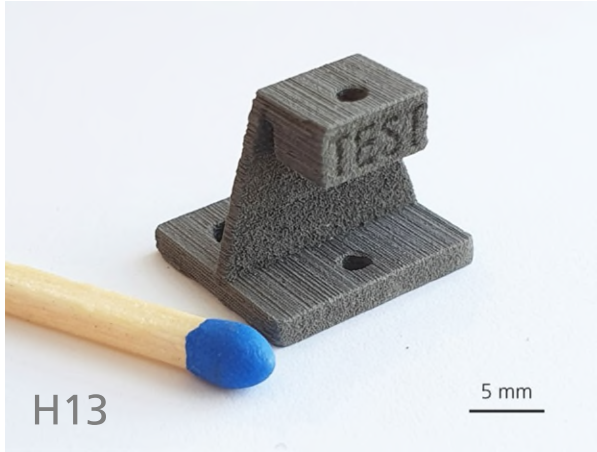
System	Tritone DOMINANT industrial
Printing principle	MoldJet – digital mold fabrication
Build dimensions (per tray)	400 x 240 x 120 mm (L x W x H)
Build rate	1000 – 1600 cm³/h
Resolution	250 µm
nominal layer thickness	40 – 200 µm
System footprint	3200 x 2200 x 1900 (L x W x H)



https://tritoneam.com/technology/systems/

MoldJetting – Sample parts

green

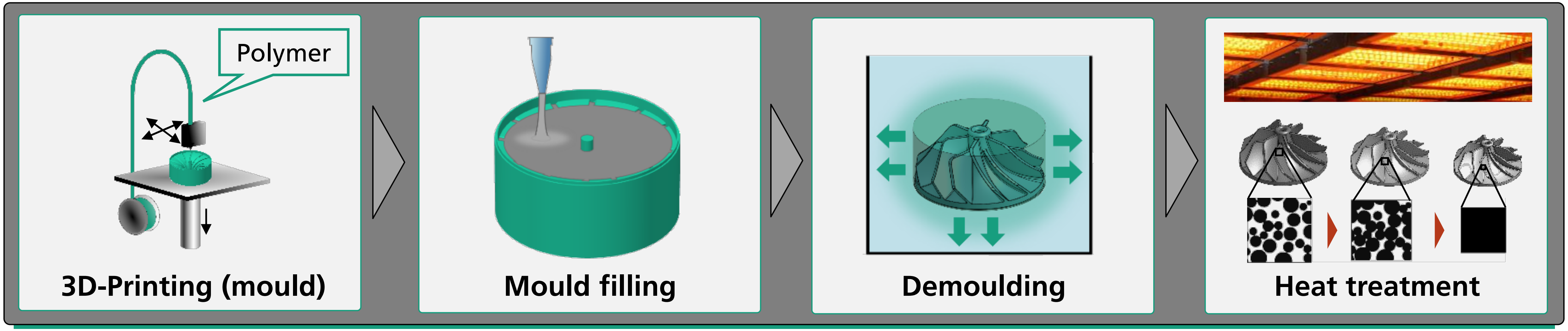


sintered

Inconel 718

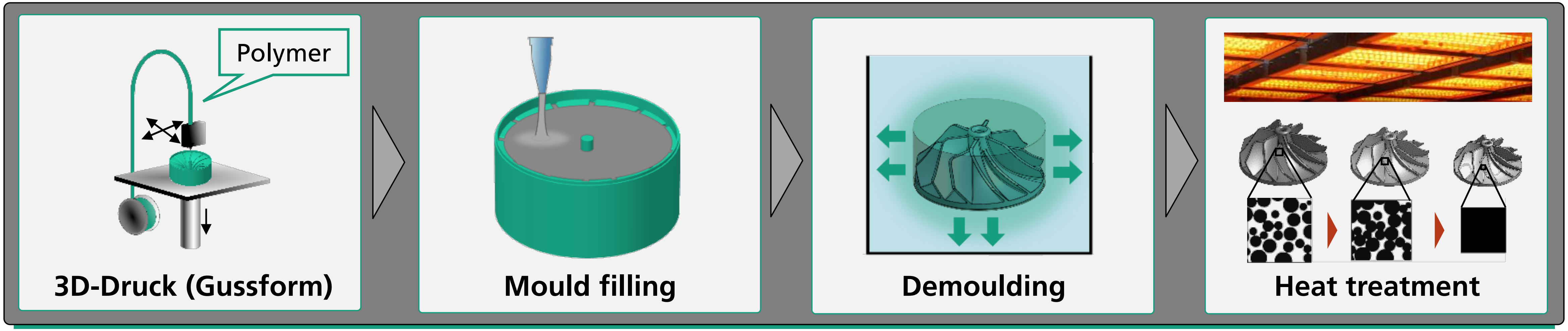
Metal Gelcasting – Process outline

1. Use of a polymer filament for the printing of (lost) moulds
2. Filling the mould with a metal powder suspension, curing/gelling
3. Demoulding in solvent bath or directly (if possible)
4. Thermal debinding and sintering of the component

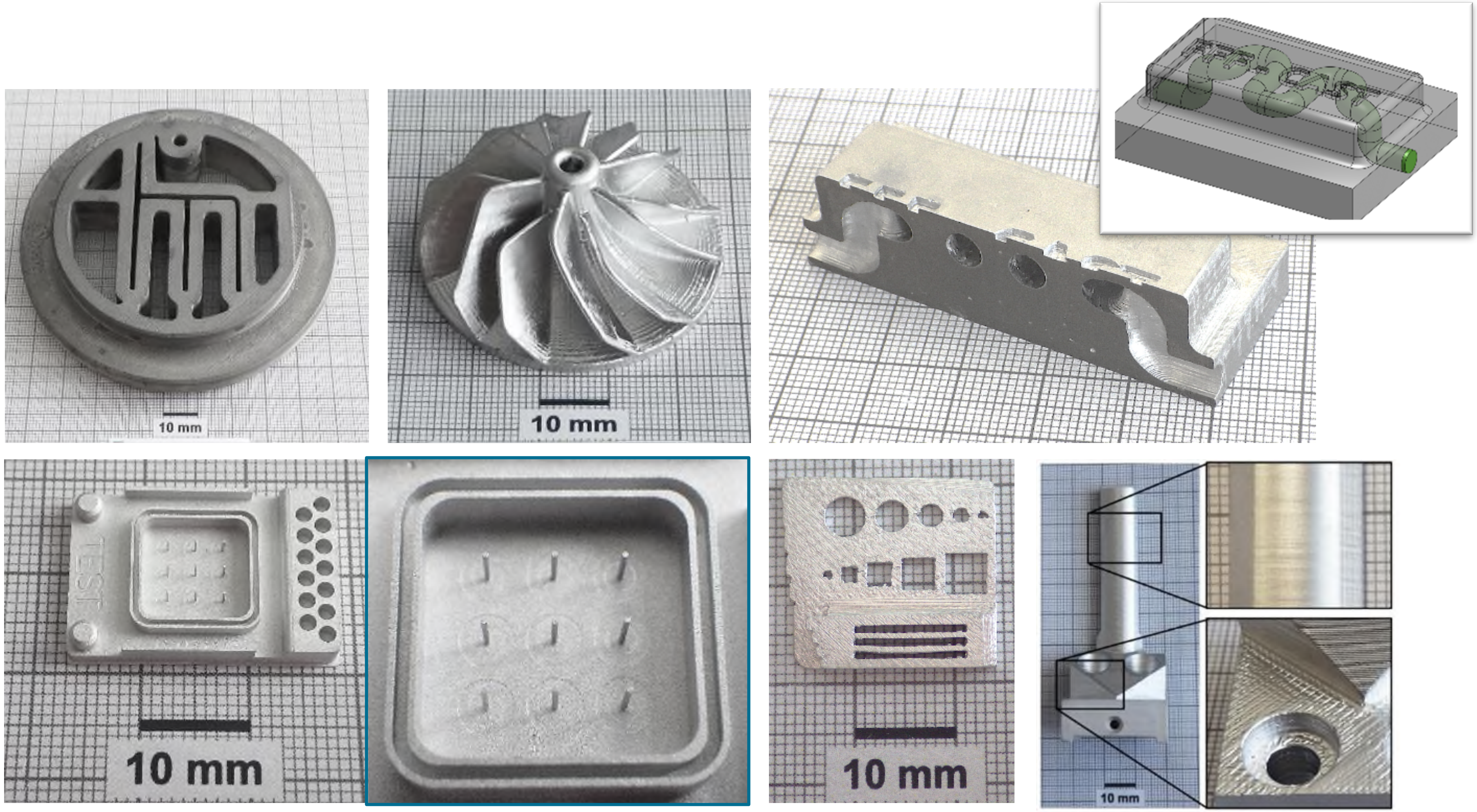


Metal Gelcasting – Process advantages

- Very fast process with reusable and large moulds (only the shell is printed).
- No thermal stresses in the component
- Thick-walled components possible due to low organic content (< 1 wt.%)
- Isotropic, homogeneous green body



Metal Gelcasting – Sample parts



Conclusion (1) – Comparison of Sinter-based AM technologies

Sinter-based AM Technology	Small series	Part Complexitiy	Productivity	Surface finish	Resolution	Small Parts [1]	Big Parts
Metal Binder Jetting (MBJ)	+	+	++	+	+	+	+
Metal Fused Filament Fabrication (MFFF)	++	0	-	0	-	0	+
3D screen printing	++	-	++ [2]	++	++	++	-
Mold Jetting	+	+	+	+	+	+	+
Gelcasting	+	0	-	+	+	+	-
Metal Injection Moulding (MIM)	- -	0	++	++	++	+	+
Laser Beam Melting (LBM)	++	++	+	0	+	+	+
Electron Beam Melting (EBM)	++	++	+	-	0	+	+
Direct Energy Deposition (DED)	++	+	++	- -	- -	-	++

[1] small parts: < 40 x 40 x 40 mm^3; [2] for small parts

Fraunhofer IFAM

Conclusion (2) – General Remarks on Sinter-based AM

Market specific

- High number of activities in the market – ExOne/Destop Metal – HP – GE – DIGITAL METAL
- High interest from industry
- Still a niche, sinter-based AM will find its way into special areas of industrial production
- Ideal for users who are familiar with Debinding & Sintering
  -> those who are experienced in classical powder metallurgy
  -> who already have the right hardware available

Process specific

- All AM techniques have their pros and cons
- Cold print process & densification by sintering without thermal gradients
  -> Low residual stresses
- Binder as an additional degree of freedom for material adaptation and customization
- New green part printing approaches emerging - Metal SLS (HEADMADE MATERIALS), Metal Lithography (INCUS/METSHAPE), Layered Powder Metallurgy (STRATASYS), Pellet FDM (AIM3D)

Fraunhofer
IFAM

AM Events 2024 to meet Fraunhofer IFAM

March 20-21st	AM-Forum, Berlin
September 4-5th	Sinter-Based AM Workshop, Fraunhofer IFAM, Bremen
September 29th - October 2nd	EuroPM, Malmö
November 19th-22nd	Formnext, Frankfurt

Fraunhofer IFAM

Fraunhofer Institute for
Manufacturing Technology and
Advanced Materials IFAM

Thank you for your attention

Contact

Claus Aumund-Kopp
Powder Technology
Phone +49 421 2246 226
claus.aumund-kopp@ifam.fraunhofer.de

Fraunhofer Institute for Manufacturing Technology
and Advanced Materials IFAM
Wiener Strasse 12
28359 Bremen, Germany

www.ifam.fraunhofer.de

Fraunhofer
IFAM

Fraunhofer Institute for
Manufacturing Technology and
Advanced Materials IFAM