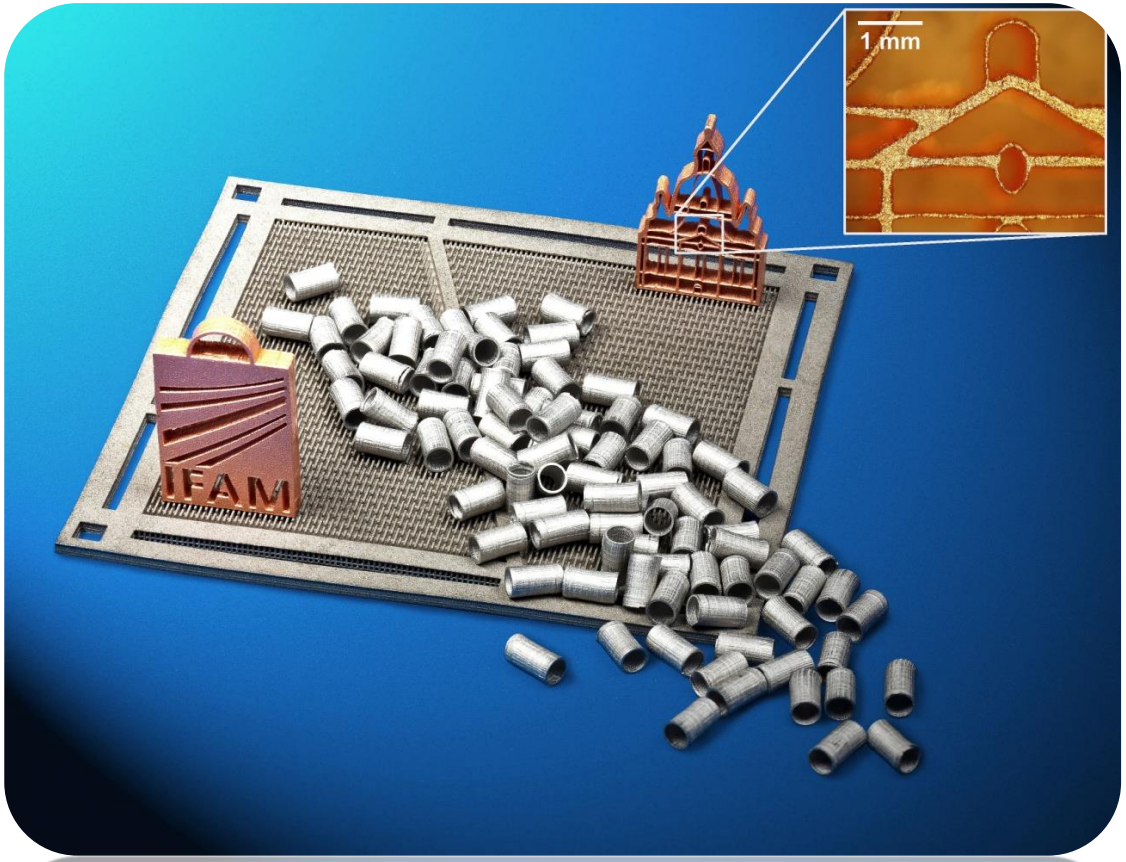
3D SCREEN AND STENCIL PRINTING
REAL MASS PRODUCTION FOR METALS, CERAMICS AND THEIR COMBINATIONS



Fraunhofer IFAM Branch Lab Dresden

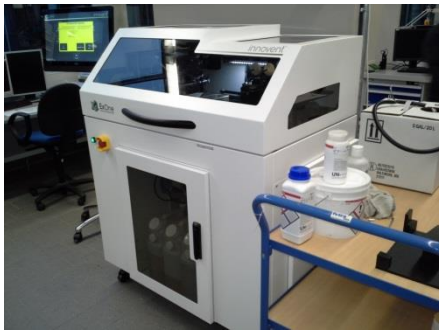
Metal Additive Manufacturing @ Fraunhofer IFAM

- Laser Beam Melting (LBM) [HB]

- Electron Beam Melting (EBM) [DD]

- 3D Screen Printing (3DMP) [DD]

- 3D Metal Printing - Binder Jetting approach (3DP) [HB]



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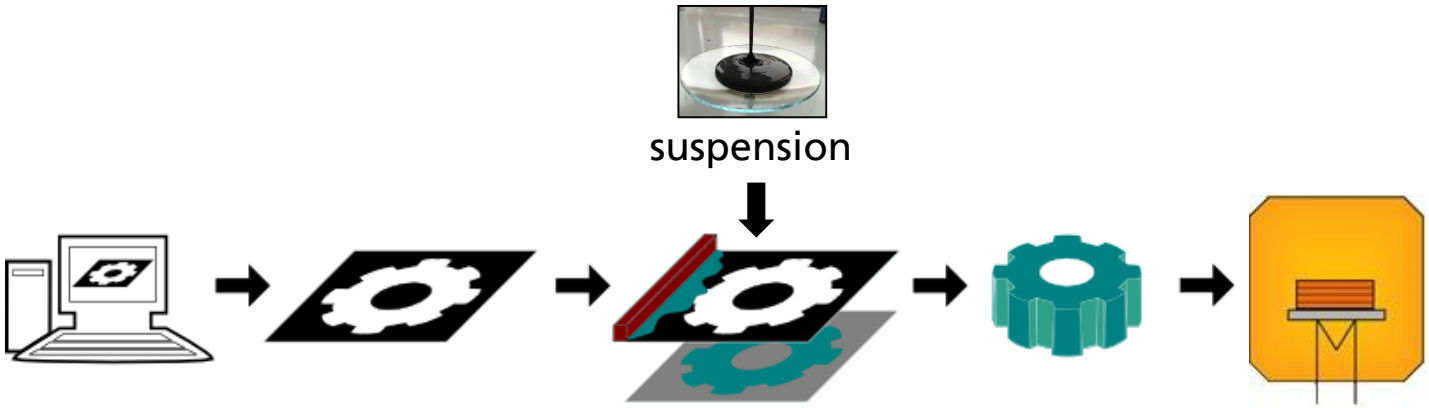
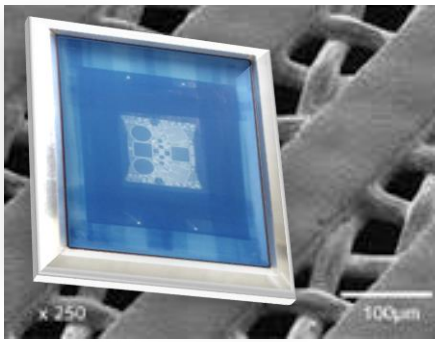
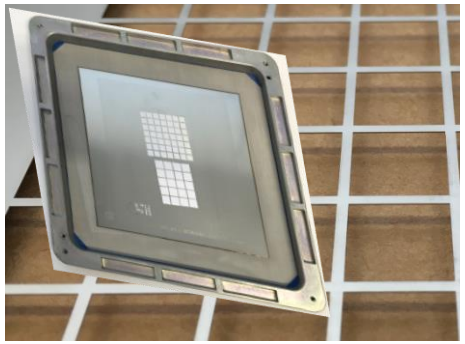
3D with screen printing?

- 2D-screen printing widely used in the industry in mass production
  - Photovoltaic
  - Sensors
  - Solder bumps
  - …
- 3D-screen printing patented in 1993
- First 3D-screen printing machine at Fraunhofer IFAM Dresden in 2008
- New machine installed 2014, most advanced machine worldwide

3D-screen printing – process outline



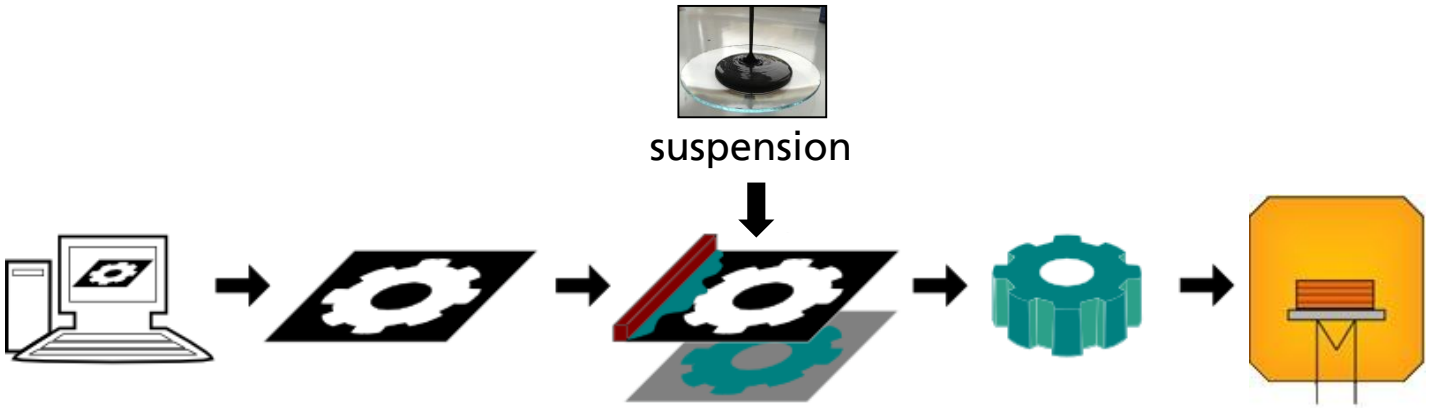


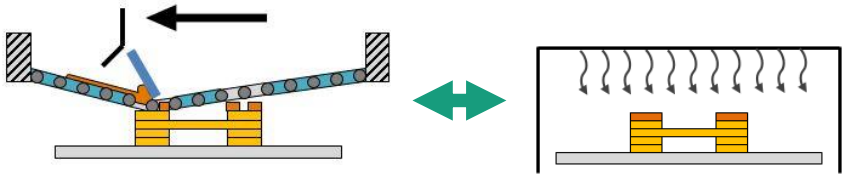


Sample screen (left) and close-up showing coating (right)

- Screen printing:
  Polymer coating defines layout
- Stencil printing:
  Cut openings define layout
- Fineline-printing: ~80 µm

3D-screen printing – process outline





- Repeated printing and curing
- Layer thickness 10-300 µm
- Printing time per layer ~3 s
- Drying time per layer 20-30 s

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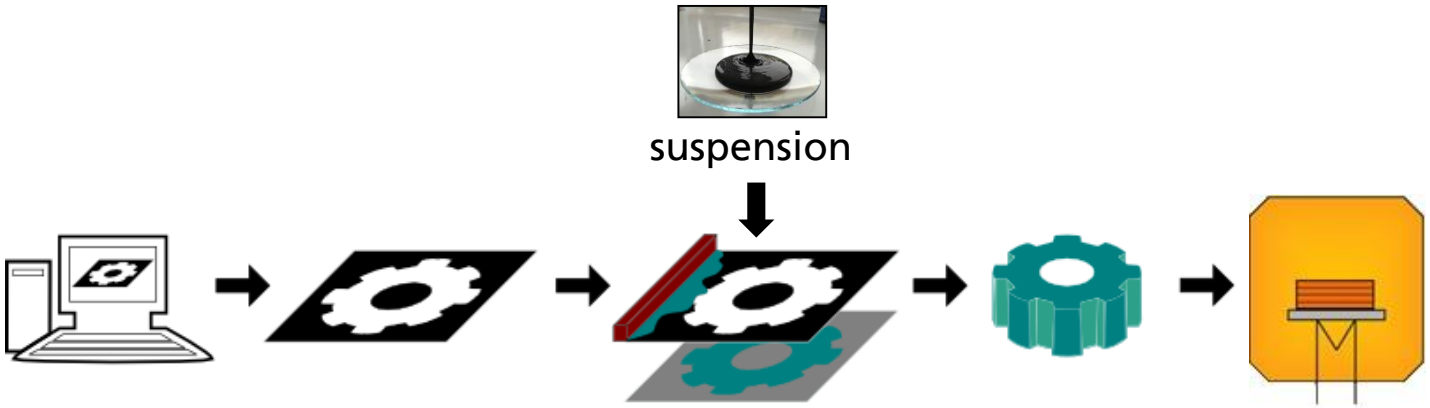
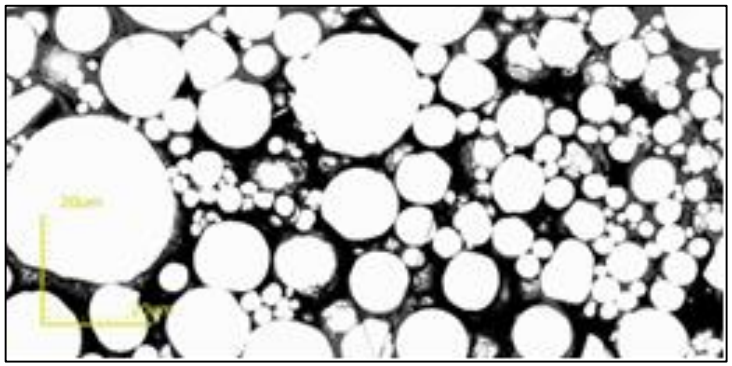


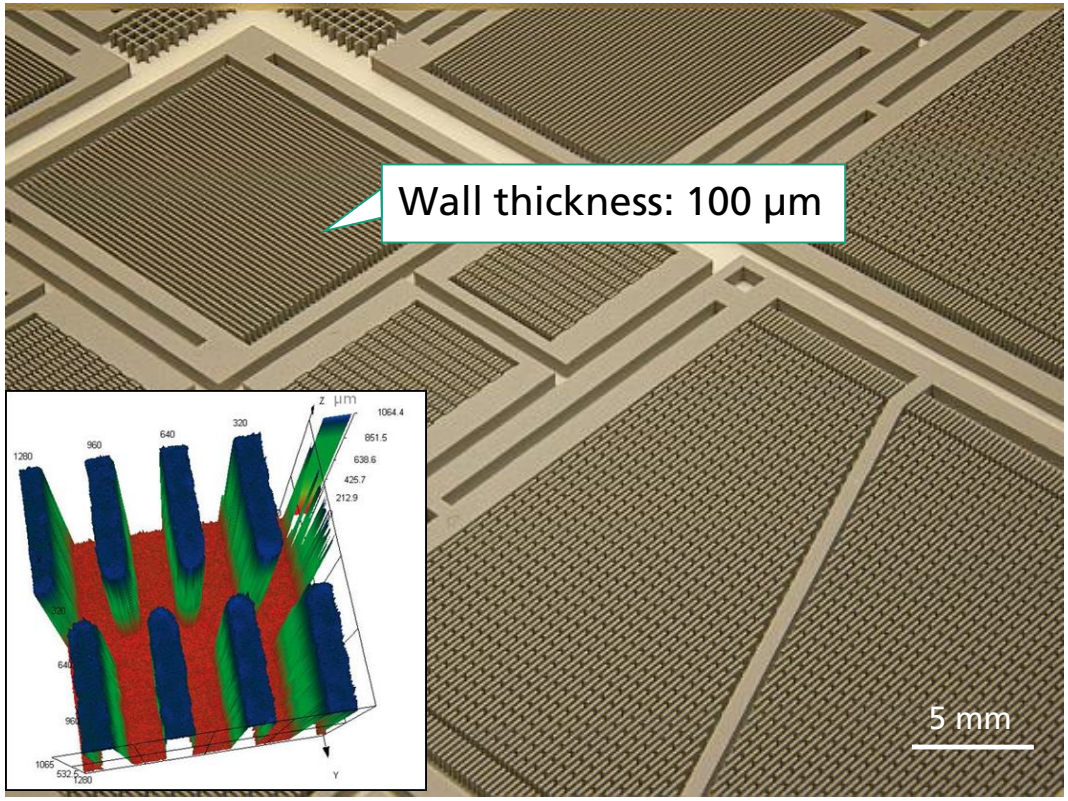


TiAl6V4 green part, green density 69.9%

- green part: powder particles glued together with binder
- Green density 55-70%
- Organics content ~1-5 wt%

3D-screen printing – sample structures

- thin walls (100 µm)
- openings (80 µm)
- cavities
- brittle, hard materials
- material combinations



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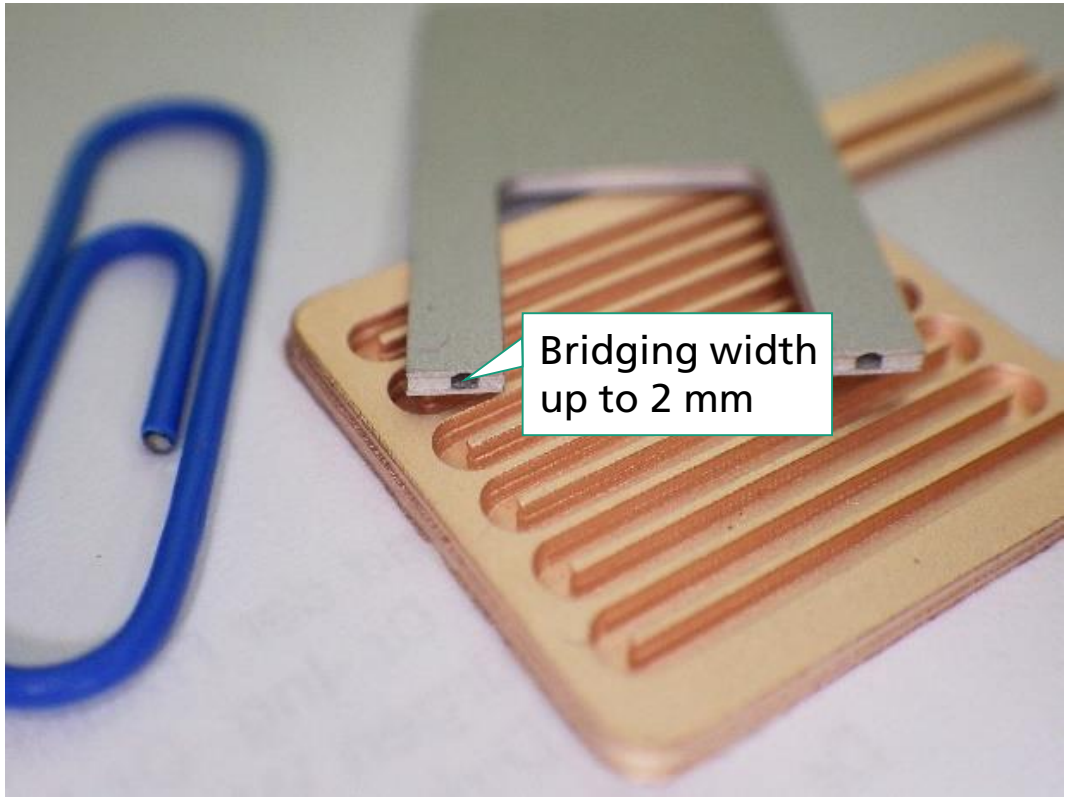

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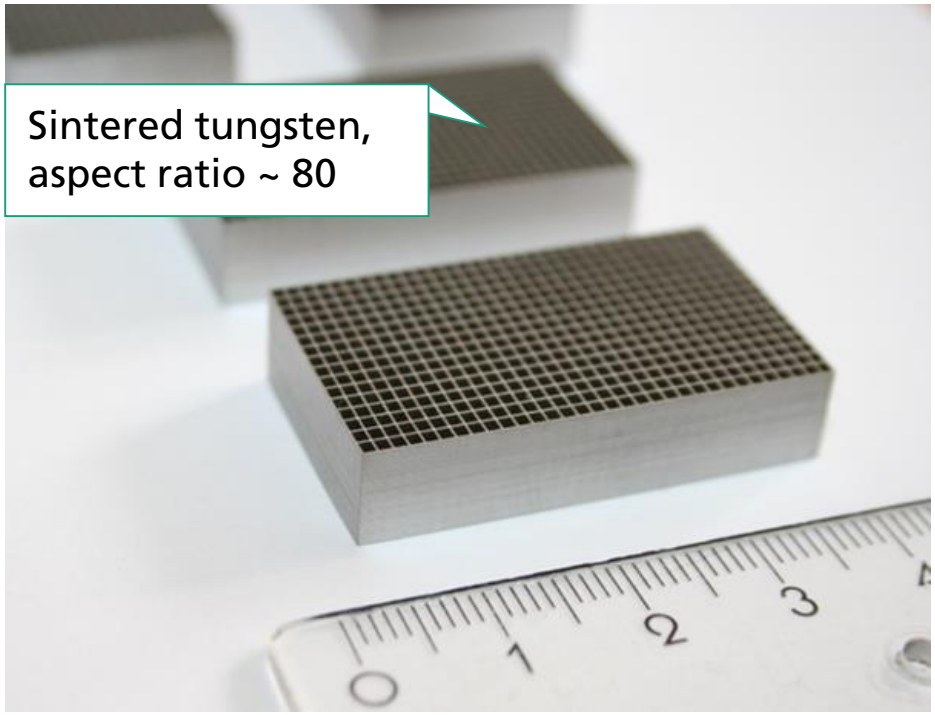

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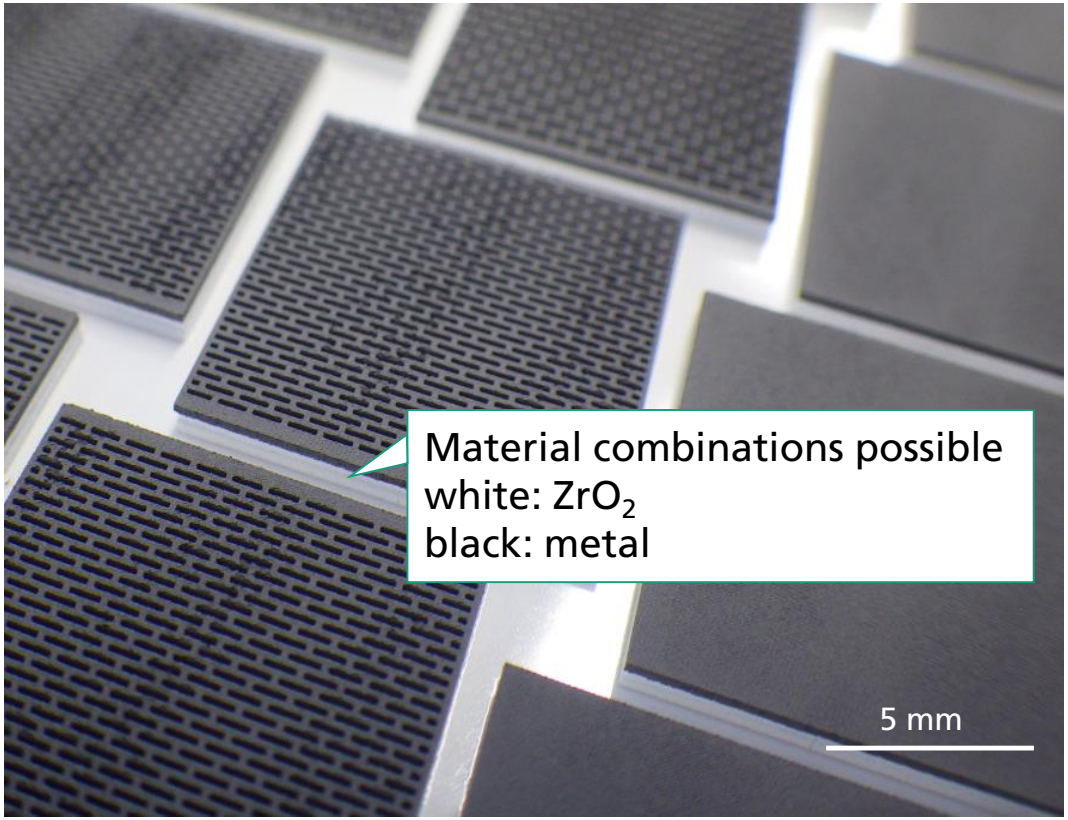

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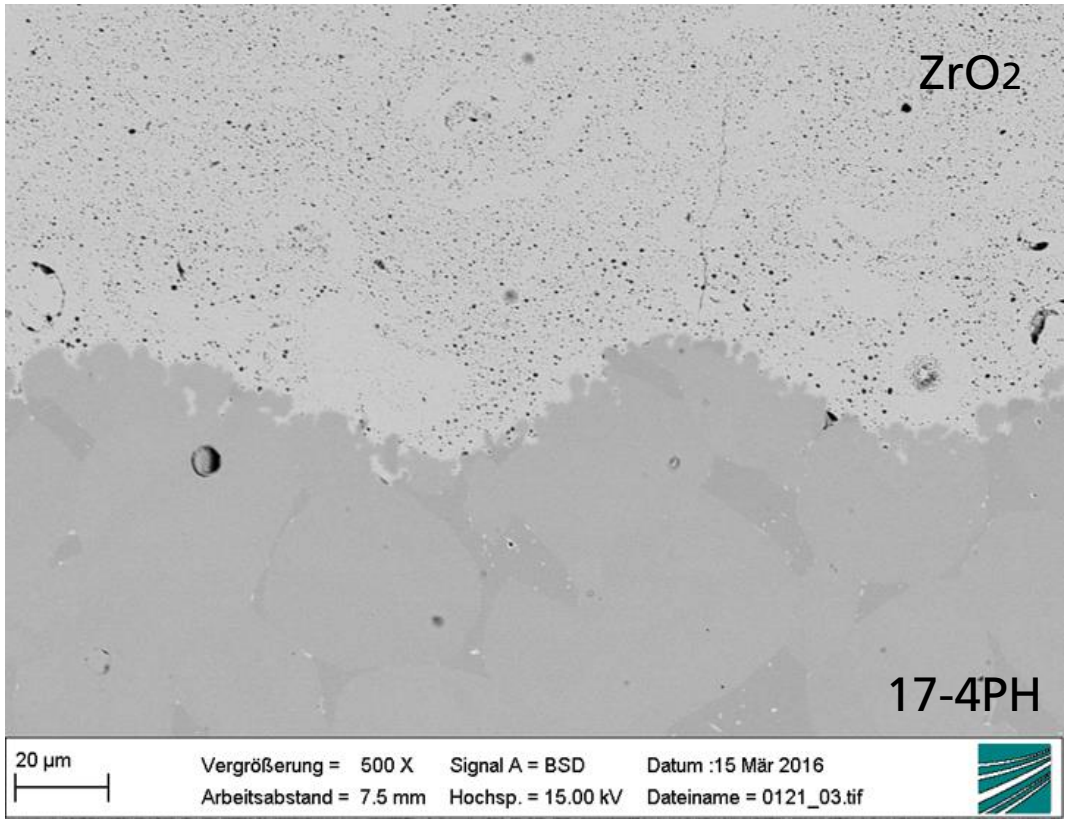
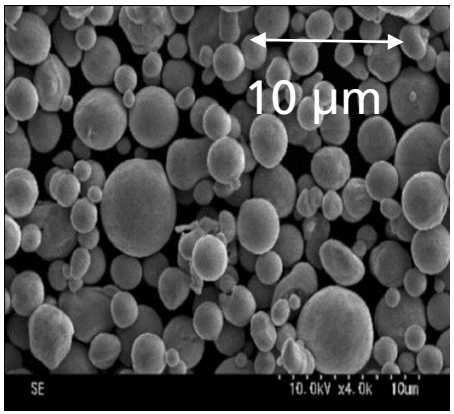
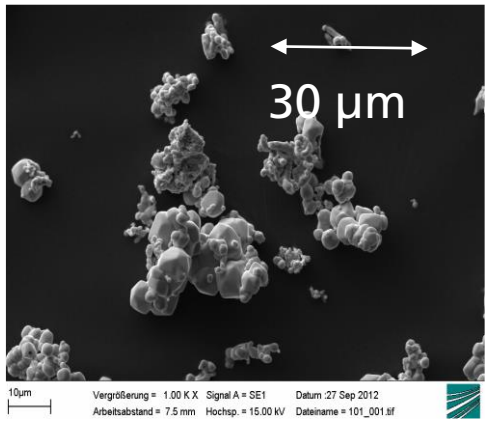


3D-screen printing – materials

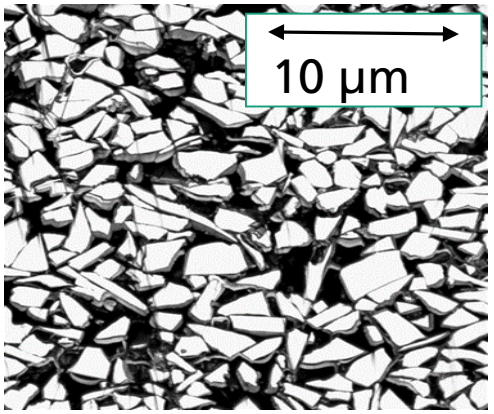
- Metals variety same as MIM
  - Fe, W, Ni, Ti, Al, La, Cu, Ag, Co, …
- Ceramics (in cooperation with Fraunhofer IKTS)
  - Al_2O_3, ZrO_2, SiC



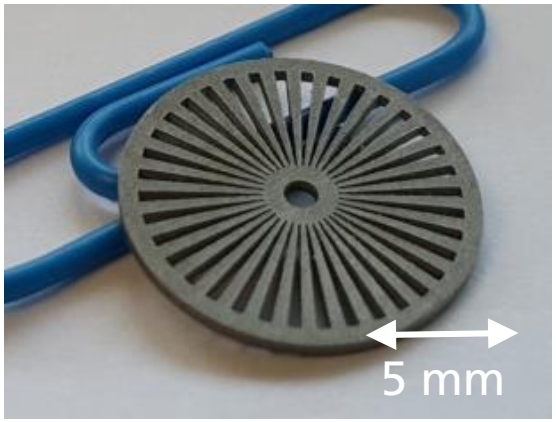
316L - spherical



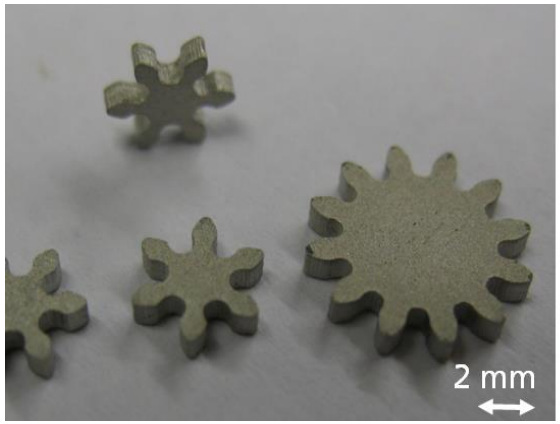
Mo - agglomerated



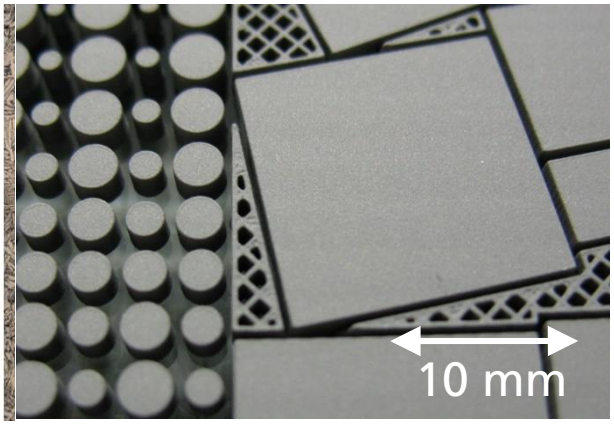
SiC- irregular



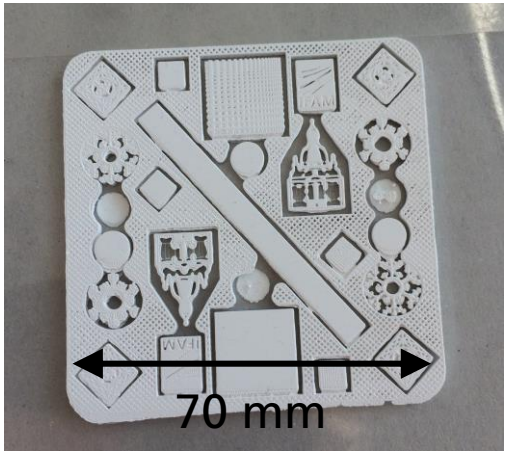
Tungsten / Nickel



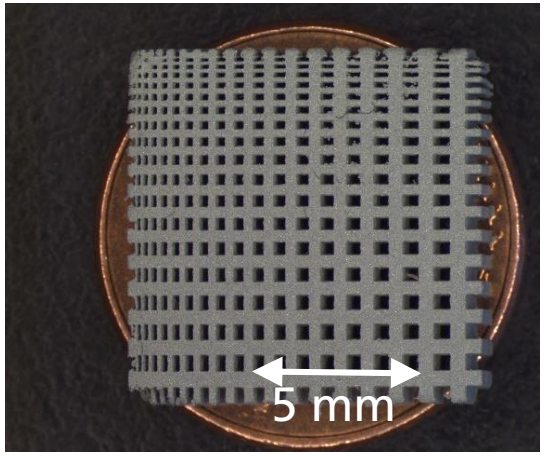
TiAl6V4



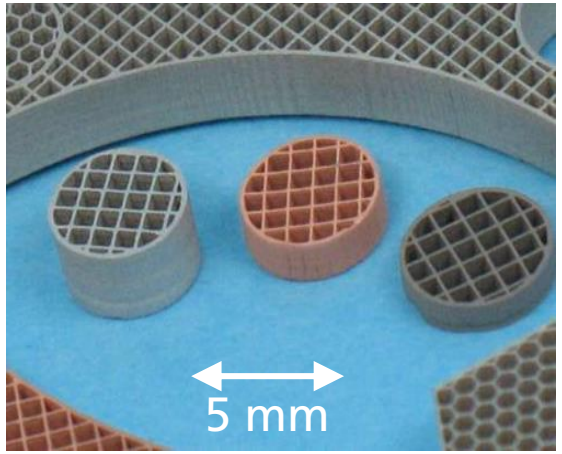
LaFeBMn



Al_2O_3



SiC



Copper, Steel, $MoSi_2$

3D-screen printing – impurities (TiAl6V4)

Processing step	Impurities [wt.%]	
	O	C
As-received powder	0,206	0,011
Green structures	0,203	0,028
Brown structures	0,392	0,103
Sintered structures	0,411	0,114
After electrolytic reduction	0,18	0,07

- Heat treatment critical step
- Parts can be reduced in additional step
- → *Session 49 (AM-Special aspects) "3D screen printing – additive manufacturing of finely structured titanium based parts"*

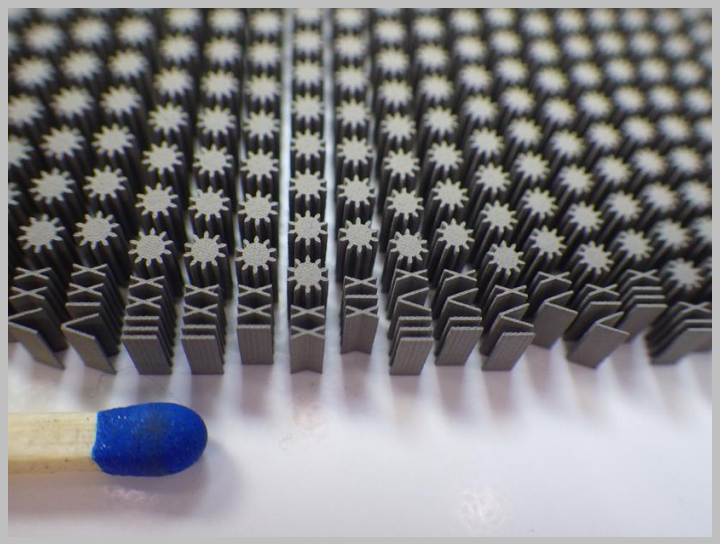
3D-screen printing – applications

- micro parts
- heat exchanger
- fuel cells
- electronics
- implants
- filter
- automotive
- jewelry and branding

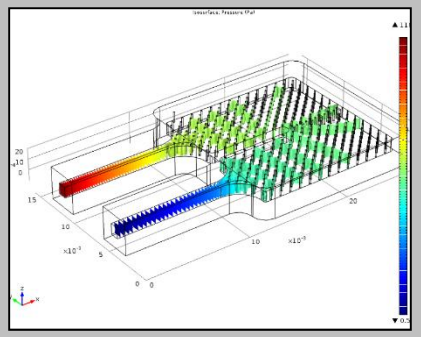
Example: Microparts

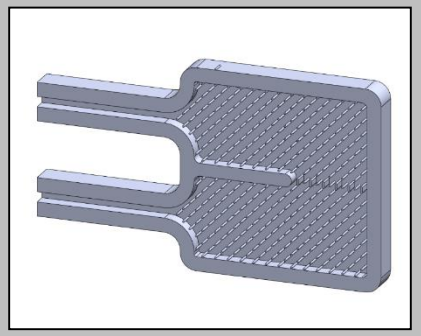
26
Fe
Iron
55.847

- Complex parts up to printed with five screens
- ~ 1.5 Million parts per year possible on lab machine
- Roughness Ra ~ 2 µm without postprocessing
- → *Session 23 (Shaping), "Microparts Manufacturing by Powder Metallurgy (Micro PM)"*

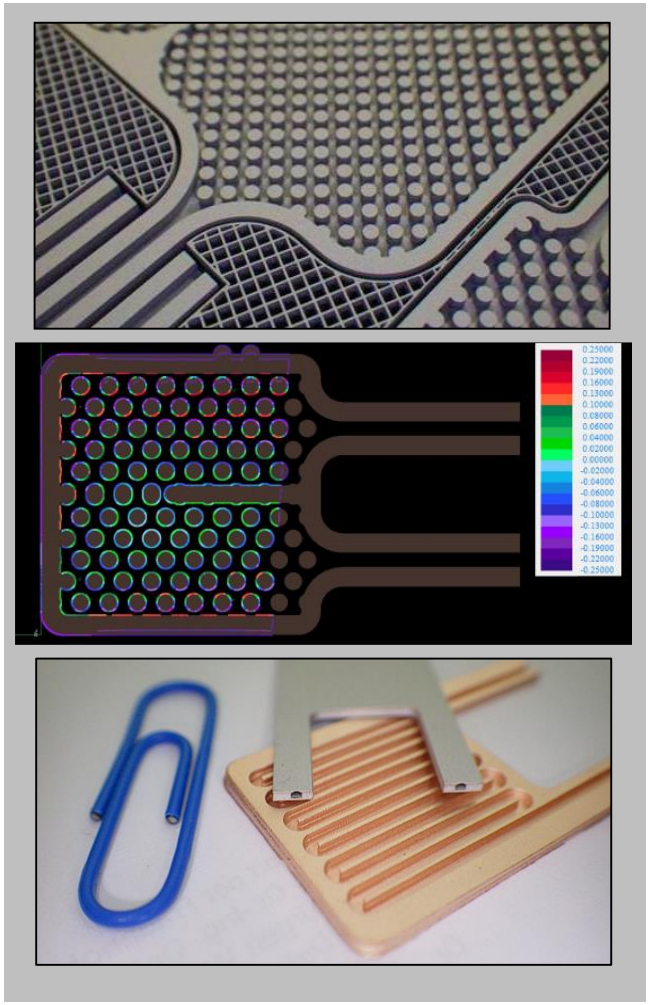


Example: Micro cooling systems





- Design of optimized structures (COMSOL)
- Different CAD models transferred onto one screen



26
Fe
Iron
55.847

29
Cu
Copper
63.546

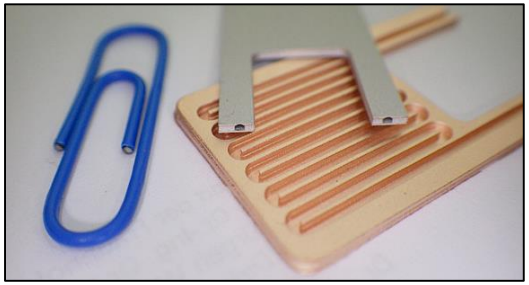
Economic Aspects

3D-screen printing – equipment

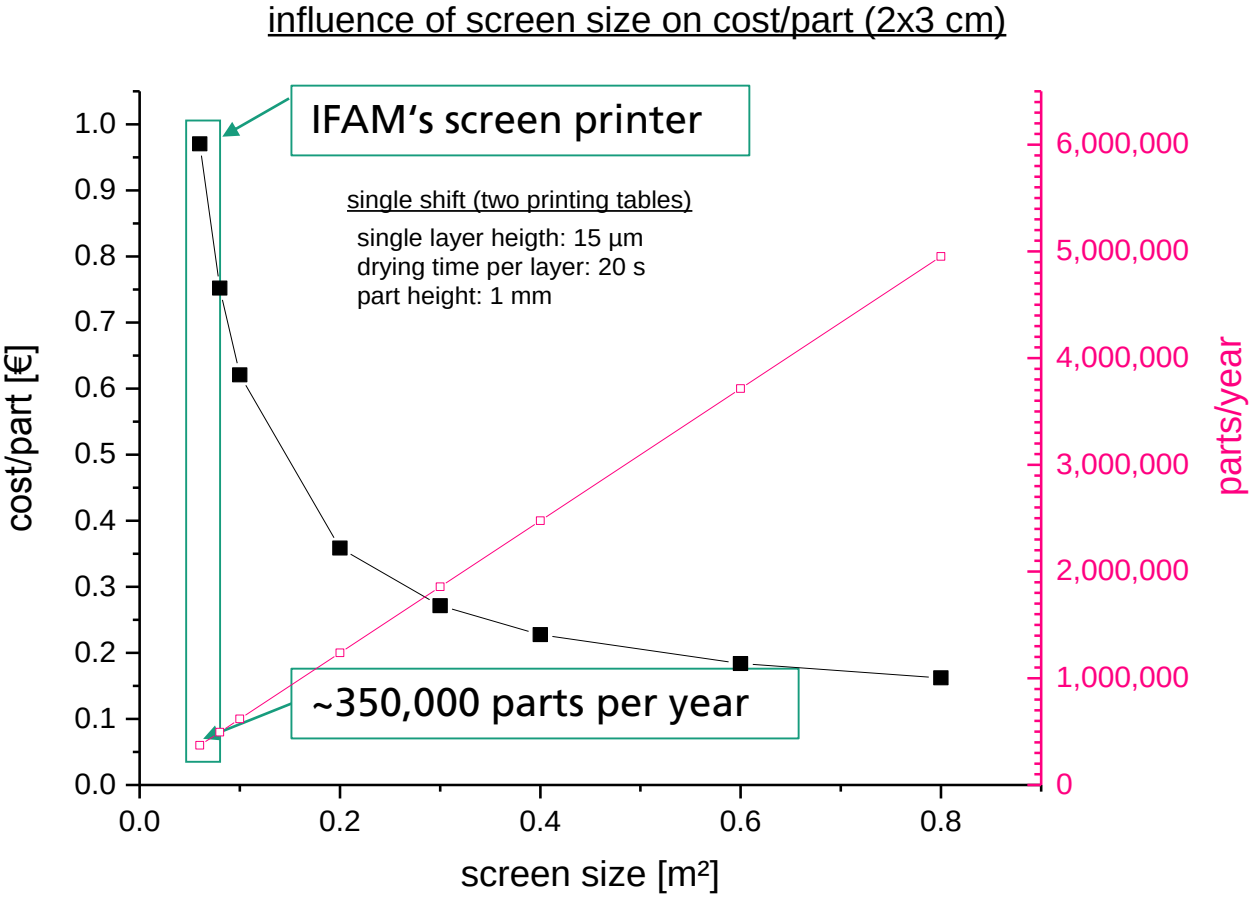
- printing area 200 x 300 mm²
- air-conditioned printing chamber
- 2 printing tables
- net-buildrate 30- 200 cm³/h (sintered)

3D-screen printing – case study – heat exchanger

Sample heat exchanger



- Further improvements
  - More Printing tables
  - thicker layers
  - 24 / 7



- Productivity / Costs comparable to MIM parts

Economical aspects

Technique	Built rate [cm³ / h]	Wall thickness [µm]	Powder size [µm]	Tools?
3D-Screen Printing (Lab machine IFAM)	30 - 100	80	< 25	Screen / Stencil
Screen Printing (potential Mass Production)	> 1000	80	< 25	Screen / Stencil
SLM / EBM	100	250	> 45	--
FDM	50	400	--	--

3D-screen printing – summary

- High resolution < 100 µm
- High aspect ratios > 100
- Metals, ceramics, powder mixtures, multimaterial systems
- Real mass production possible
- Small parts preferred
- Limited freeform capabilities

- 3D screen printing offers new possibilities in part production

IFAM booth: 197