3D SCREEN AND STENCIL PRINTING
REAL MASS PRODUCTION FOR METALS, CERAMICS AND THEIR COMBINATIONS
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]
- 3D Metal Printing - Binder Jetting approach (3DP) [HB]
Metal Additive Manufacturing @ Fraunhofer IFAM

- Laser Beam Melting (LBM) [HB]
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- 3D Screen Printing (3DSP) [DD]
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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

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

Sample screen (left) and close-up showing coating (right)
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
3D-screen printing – process outline

- **Suspension**

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

TiAl6V4 green part, green density 69.9%
3D-screen printing – sample structures

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

Wall thickness: 100 µm
3D-screen printing – sample structures

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

Bridging width up to 2 mm
3D-screen printing – sample structures

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

Sintered tungsten, aspect ratio ~ 80
3D-screen printing – sample structures

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

Material combinations possible:
white: ZrO₂
black: metal

5 mm
3D-screen printing – sample structures

- thin walls (100 µm)
- openings (80 µm)
- cavities
- brittle, hard materials
- material combinations
3D-screen printing – materials

- **Metals variety same as MIM**
  - Fe, W, Ni, Ti, Al, La, Cu, Ag, Co, …

- **Ceramics (in cooperation with Fraunhofer IKTS)**
  - Al₂O₃, ZrO₂, SiC

316L - spherical  Mo - agglomerated  SiC- irregular
Tungsten / Nickel

SiC

Al₂O₃

TiAl₆V₄

LaFeBMn

Copper, Steel, MoSi₂
3D-screen printing – impurities (TiAl6V4)

<table>
<thead>
<tr>
<th>Processing step</th>
<th>Impurities [wt. %]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>As-received powder</td>
<td>0,206</td>
</tr>
<tr>
<td>Green structures</td>
<td>0,203</td>
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<tr>
<td>Brown structures</td>
<td>0,392</td>
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<tr>
<td>Sintered structures</td>
<td>0,411</td>
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<tr>
<td>After electrolytic reduction</td>
<td>0,18</td>
</tr>
</tbody>
</table>

- 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

- 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
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

IFAM’s screen printer

- Single shift (two printing tables)
- Single layer height: 15 µm
- Drying time per layer: 20 s
- Part height: 1 mm

~350,000 parts per year

Influence of screen size on cost/part (2x3 cm)
## Economical aspects

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