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Block F: Materials for AM

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- Metals
- Polymers
- Ceramics
Innovation in material and process enable new products

- Material- and process development depend on each other

Product innovation

Material innovation

Process innovation
## AM – Processes for Polymers

<table>
<thead>
<tr>
<th>Domain</th>
<th>Processes</th>
<th>Materials</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymers</td>
<td>Selective Laser Sintering (SLS)</td>
<td>Pulver - PA12, (PA6, PA11), PP - Z.T. gefüllte / modifzierte Varianten</td>
<td></td>
</tr>
<tr>
<td>Polymers</td>
<td>Fused Deposition Modeling (FDM)</td>
<td>Filaments - ABS, PC, PA, PLA, PEEK - Generally thermoplasts</td>
<td></td>
</tr>
<tr>
<td>Polymers</td>
<td>Binder jetting (BJT)</td>
<td>Powder - Thermoplastic materials PA, PMMA,</td>
<td></td>
</tr>
<tr>
<td>Polymers</td>
<td>HP Multijet fusion Printing of absorber ink and heating by light source</td>
<td>- Thermoplastic materials</td>
<td></td>
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</tbody>
</table>
The market volume of polymer powders for SLS is tiny in comparison to the total polymer market. ➔ high price for limited material spectrum.
SLS new material icoPP

**icoPP™ Polypropylene**

- First coPP introduced in the Swiss/German market by Inspire
- High impact & chemical resistance
- Outstanding Elongation at Break > 200%
- Great detail resolution
- Seal-ability with other PP-parts
- Serializable (medical)

### Thermische Eigenschaften

<table>
<thead>
<tr>
<th>Eigenschaft</th>
<th>Methode</th>
<th>Wert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schmelzpunkt</td>
<td>DSC - DIN 53675</td>
<td>≥ 120°C</td>
</tr>
<tr>
<td>Kristallisationspunkt</td>
<td>DSC - DIN 53675</td>
<td>≤ 90°C</td>
</tr>
<tr>
<td>Wärmeformbeständigkeit HDT-A</td>
<td>ISO 75-1 (1.82 MPa)</td>
<td>ca. 50°C</td>
</tr>
</tbody>
</table>

### Mechanische Eigenschaften

<table>
<thead>
<tr>
<th>Eigenschaft</th>
<th>Methode</th>
<th>Wert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dichte (Bauteil)</td>
<td>intern</td>
<td>≥ 0.9 g/cm³</td>
</tr>
<tr>
<td>E-Modul (Zugversuch)</td>
<td>ISO 527-1</td>
<td>≥ 800 MPa</td>
</tr>
<tr>
<td>Zugfestigkeit</td>
<td>ISO 527-1</td>
<td>≥ 18 MPa</td>
</tr>
<tr>
<td>Reissdehnung</td>
<td>ISO 527-1</td>
<td>≥ 200 %</td>
</tr>
<tr>
<td>Schlagzähigkeit - Charpy</td>
<td>ISO 179-1/1eU</td>
<td>≥ 40 kJ/m²</td>
</tr>
<tr>
<td>Kerbschlagzähigkeit - Charpy</td>
<td>ISO 179-1/1eA</td>
<td>≥ 5 kJ/m²</td>
</tr>
</tbody>
</table>
## AM – Processes for Metals

<table>
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<tr>
<th>Domain</th>
<th>Processes</th>
<th>Materials</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>Selective Laser Melting (SLM)</td>
<td>Powder - Stainless steel, tool steel - Ni-base alloys - Aluminum, Titanium - Copper, bronze, ...</td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>Direct Metal Deposition (DMD)</td>
<td>Powder or wire - Metals (see above)</td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>Electron Beam Melting (EBM)</td>
<td>Powder - Metals (see above) problem: ferromagnetic material</td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>Binder jetting (BJT)</td>
<td>Powder - All metals, including WC and other hard metals - Sintering step</td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>MIG based direct metal deposition (WAAM, Arc-DMD)</td>
<td>Pulver - Metals, (weldable)</td>
<td></td>
</tr>
</tbody>
</table>
SLM of different IN738LC batches
AM-specific material required
- Engineering the material
- AM as material generator
- Alloying by mixing, i.e., Diamond dispersions in metal
- Grading of materials
Structural aluminum

- **Micro structure**

- Scandium-alloyed Aluminum
- Duplex structure consisting of fine and columnar grains
- Quasi isotropic
- Principle of SLM specific materials with low texture

**Source:** inspire-icams

**Build direction:**

Heat treated 350°C/4h

Spierings 2015
Contents of quality in additive manufacturing
- Material and Geometry are made in the same process step
- Process monitoring and qualification instead of part inspection
AM part of the total process chain ➔ functionalization

- Powder generation
  - Alloying
  - Atomization
  - Sieving
- Powder mixing
- AM-Machine
  - Coating
  - Melting, Solidification
  - Unpacking cleaning
- Cutting
- Heat treatment
- Detaching build plate
- Surface treatment
- Coating
Thank you very much for your kind attention

www.iwf.mavt.ethz.ch
www.inspire.ethz.ch