Create the unexpected.
With outstanding 3D-printing solutions from BASF.

“How can we achieve industrial applications quicker”
Alexander Cochrane, Marketing&Sales, BASF 3D Printing Solutions GmbH
BASF – The World’s Leading Chemical Company

- Our chemistry is used in almost all industries
- We combine economic success, social responsibility and environmental protection
- Sales 2016: €57,550 million
- EBIT 2016: €6,275 million
- Employees 2016: 113,830
- Global reach with >350 production sites
- R&D is major growth driver:
  - 10,000 employees worldwide in R&D
Classical BASF’s segments are very relevant for 3D-P

- Metals and ceramic powders
- Catamold
- Acrylates
- Solvents
- Resins
- Photo-reactive chemicals
- Dispersants
- Dyes & pigments
- Stabilizers
- Plastics
- UV-curing formulations
- Coatings
Materials know-how and cost reduction are key elements for the future of Additive Manufacturing (AM)

- **No compromise on PERFORMANCE** of functional parts according to specific target applications
- ... at acceptable COSTS

**Design prototypes**

1990 to 2010 to 2030

**Functional parts**
BASF is active in all major 3D-P technologies because there is no winning technology yet

**BASF products for 3D-Printing**

- **Thermoplastic materials and metals**
  - Powder Bed Fusion (SLS, HSS, MJF)
  - Filament & layer-by-layer extrusion (FFF)

- **Photopolymers**
  - Photo-curing (SLA/DLP & PPJ)
    - Stereolithography
    - Jetting
Enhancing performance and reducing costs accelerated by open business model in entire value chain

PERFORMANCE
• Materials’ versatility for specific applications
• Over-engineering of parts to comply with requirements

COSTS
• Low output versus invest
• Low degree of automation
• High material costs
• Reducing expectations in warranties
• Distribution channels

Open business models and competition in all elements of the value chain speeds up the industrialization of AM
### PERFORMANCE

- Materials’ versatility for specific applications
- Over-engineering of parts to comply with requirements

### COSTS

- Low output versus invest
- Low degree of automation
- High material costs
- Reducing expectations in specifications
- Certification challenges

Open business models and competition in all elements of the value chain speeds up the industrialization of AM
BASF offers services essential for development of parts beyond prototypes

- Simulation of 3D-printed part properties (Ultrasim3D) & topology optimization
- Fabricating and testing 3D-printed parts
  - Comparison of materials
  - Comparison of various 3D-printing technologies
- Optimizing part design for enhanced performance in function

Conventional injection-molding design

3D printing design

1st Failure
2nd Failure
Laser sintered parts using Ultrasint PA6 X028 show sufficient performance for functional prototypes

Ford observed lower gas leakage (passing 20 psi spec) of PA6 parts compared to PA12 powder

Daimler observed higher burst pressure and heat distortion stability (passing under the hood specs) of PA6 parts compared to PA12 powder
Applications for use-in-functions become accessible
Fire resistant parts fabricated by laser sintering

<table>
<thead>
<tr>
<th></th>
<th>Ultrasint PA6 FR X037</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>57 MPa</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>6000 MPa</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

All values dry "as printed", x-direction parts characterized

Plastic Powder Ultrasint PA6 FR X037

- Halogen-free flame retardant PA6 powder
- V-2 @ 0.8 - 2.0 mm UL94 V (flame 50 W)
# BASF Innofil3D® Plastics Filaments Portfolio for High Quality Parts

## Standard Filaments

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>Low warping, bio based, compostable, easy printing</td>
</tr>
<tr>
<td>ABS</td>
<td>Impact resistant, heat resistant, high toughness</td>
</tr>
<tr>
<td>PET</td>
<td>Low moisture absorption, dimensionally stable, good mechanical properties, easy printing</td>
</tr>
<tr>
<td>InnoFlex</td>
<td>Flexible TPC, available with Shore 45D/60D</td>
</tr>
</tbody>
</table>

## PRO Series

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro1</td>
<td>Engineering PLA, high strength, tough, versatile, fast and easy printing</td>
</tr>
<tr>
<td>ABS Fusion+</td>
<td>Engineering ABS filament optimized for 3D-printing with low warpage</td>
</tr>
<tr>
<td>ASA</td>
<td>UV resistant, outdoor use, anti-static properties</td>
</tr>
<tr>
<td>HIPS</td>
<td>Suitable for sanding and painting, solvable ABS support</td>
</tr>
<tr>
<td>PP</td>
<td>Low density, resistant to fatigue and chemicals, high impact strength</td>
</tr>
</tbody>
</table>

## Specials

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>InnoSolve</td>
<td>Water-soluble PVA</td>
</tr>
<tr>
<td>Inno-FR</td>
<td>Flame-retardant PLA</td>
</tr>
<tr>
<td>InnoCircle rPET</td>
<td>Filaments from recycled materials. Looks and prints as excellent as virgin material</td>
</tr>
</tbody>
</table>
Applications beyond design prototypes become accessible
High quality filaments for functional applications

- Carbon fiber filled polyethylene terephthalate (Innofil3D PET CF) for parts with low abrasion, high heat resistant, high dimensional stability
- Carbon fiber filled polyamide (Innofil3D PAHT CF) for parts with high stiffness and strength, low warping, low moisture absorption, high dimensional stability

Innofil3D ABS Fusion+ for easy printing, low warp, high repeatability and parts with high heat resistant, and good toughness

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile strength</th>
<th>Bending strength</th>
<th>Charpy impact strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET CF</td>
<td>80 MPa</td>
<td>130 MPa</td>
<td>40 kJ/m²</td>
</tr>
<tr>
<td>PAHT CF</td>
<td>170 MPa</td>
<td>n.a.</td>
<td>40 kJ/m²</td>
</tr>
</tbody>
</table>

Roboter gripper

Courtesy of Mass Portal
Ulrafuse Polysulfone filaments can be used for high performance applications like Ultem

3D-printed parts by Ulrafuse Polysulfones

- Intrinsically fire resistant (FAR 25 compliant)
- High long-term service temperatures (HDT/A >200°C)
- Fast printing (15-40 mm/s)
- Well fused layers (good z-strength) & water tight parts

<table>
<thead>
<tr>
<th></th>
<th>BASF Polysulfone</th>
<th>Ultem 9085 *</th>
</tr>
</thead>
<tbody>
<tr>
<td>xy-direction</td>
<td>z-direction</td>
<td>xy-direction</td>
</tr>
<tr>
<td>Tensile strength [MPa]</td>
<td>68</td>
<td>73</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>58</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>7%</td>
<td>7%</td>
</tr>
</tbody>
</table>

Why fabricate metal parts via FFF

Issues in metal powder laser sintering

- High investment costs for equipment
- Quality requirements of metal powder leads to high price
- Powder handling issues

New BASF offerings

**Ultrafuse 316LX**

- Low investment costs of FFF apparatus
- Batch oven-sintering with higher volume/time yield
- Easy handling of filament, and sintering in classical processes
Produce 100% metal parts via industrial-standard debinding & sintering process

15-17% shrinkage

Industrial-standard process of metal injection molding technology
Metal printing made easy

- Low investment costs for printing hardware
- Easy handling & reliable quality of filament
- Light weight designs: hollow / infill parts possible
- Fast printing process & batch- or continuous oven-sintering with higher volume/time yield
- Extensive BASF know-how on metal injection molding with broad metal portfolio
- Substantial cost advantage compared to SLM-printing on final part achievable
Enhancing performance and reducing costs accelerated by open business model in entire value chain

<table>
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</tr>
<tr>
<td></td>
<td>• Distribution channels</td>
</tr>
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</table>

Open business models and competition in all elements of the value chain speeds up the industrialization of AM
BASF materials can be used or are in the process of qualification on 3D-P equipment from various suppliers.

<table>
<thead>
<tr>
<th>SLS / MJF / HSS</th>
<th>Metal &amp; plastic filaments</th>
<th>SLA / DLP &amp; PPJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3D Systems</td>
<td>• Apium</td>
<td>• 3D Systems</td>
</tr>
<tr>
<td>• EOS</td>
<td>• Bigrep</td>
<td>• Miicraft</td>
</tr>
<tr>
<td>• Farsoon</td>
<td>• Drop</td>
<td>• Prodways</td>
</tr>
<tr>
<td>• HP (MJF)</td>
<td>• Essentium</td>
<td>• Totem</td>
</tr>
<tr>
<td>• Prodways</td>
<td>• Evo-tech</td>
<td>• Xaar (Photopolymer Jetting)</td>
</tr>
<tr>
<td>• Ricoh</td>
<td>• German RepRap</td>
<td>• XYZprinting</td>
</tr>
</tbody>
</table>

• Gewo
• Hage Sonder-maschinenbau
• Spiderbot
• Tiertime
• Ultimaker
• XYZprinting

Listed in alphabetical order, several additions are coming soon.

AM Dagen --- Dec. 7, 2017 --- 3D-Printing@basf.com
Plastic Powder Ultrasint PA6 X043 black

- Parts show good toughness and strength with higher heat distortion temperature (HDT) than PA12
- Considered for higher volumes

Affordable materials: Attractive pricing for higher volume tiers

Price versus volume

BASF reduces price with economy-of-scale
Affordable 3D-printed parts with faster printing

Who wants to develop a PPJ printer with BASF & Xaar?

- Xaar print-head operates with BASF developmental photopolymers with high productivity
  - High deposition rates of up to 10 l/h with addressability of 360 dpi with the Xaar 1003
    - Xaar 2001 in the 1-cycle high laydown technology could have deposition rates of up to 20 l/h with addressability of 720 dpi
  - Jetting of photopolymers with viscosity of >50mPa and particle-loaded fluids

<table>
<thead>
<tr>
<th>Print mode</th>
<th>3-cycle, 7 dpd (84 pl)</th>
<th>High Laydown, 4 dpd (80 pl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of printed layers</td>
<td>200 layers</td>
<td>38 layers</td>
</tr>
<tr>
<td>Print resolution</td>
<td>360 x 360 dpi</td>
<td>1826 x 360 dpi</td>
</tr>
<tr>
<td>Layer thickness</td>
<td>17 µm</td>
<td>90 µm</td>
</tr>
<tr>
<td>Time to print (incl. curing)</td>
<td>20-30 minutes</td>
<td>6 minutes</td>
</tr>
</tbody>
</table>
BASF portfolio of products for all main 3D-P technologies complemented with offering high quality services

**Powder Bed Fusion (SLS, HSS, MJF)**
- Plastic filaments for extrusion e.g. Innofil3D, Elastolan, Ultrason
- Plastics for direct layer-by-layer extrusion (BAAM) e.g. Ultramid products
- Ultrafuse 316LX for filament metal printing

**Filament & layer-by-layer extrusion (FFF)**
- Plastic filaments for extrusion e.g. Innofil3D, Elastolan, Ultrason

**Photo-curing (SLA & PPJ)**
- Raw Materials e.g. Laromer acrylates
- Photo-Resins for SLA/DLP systems
- Photo-Resins for PPJ

**Photo-curing (SLA & PPJ) Stereolithography Jetting**
- Photo-Resins for SLA/DLP systems
- Photo-Resins for PPJ

**Plastics for direct layer-by-layer extrusion (BAAM)**
- e.g. Ultramid products

**Ultrasint PA6 powders**
- Plastic filaments for extrusion e.g. Innofil3D, Elastolan, Ultrason
- Raw Materials e.g. Laromer acrylates

**Ultrasint PA6 mineral filled powder**
- Plastics for direct layer-by-layer extrusion (BAAM) e.g. Ultramid products

**Ultrasint PA6 glass beads filled powder**
- Raw Materials e.g. Laromer acrylates

**Ultrasint PA6 FR powder**
- Photo-Resins for SLA/DLP systems

**Ultrasint TPU powder (via EOS, and HP)**
- Raw Materials e.g. Laromer acrylates

**Raw Materials**
- e.g. Laromer acrylates

**Services**
- Ultrasim® for 3D-P
- Qualification of 3D-printed parts
- Design for function
- Sample & demonstrator parts by laser sintering

**BAAM: Big Area Additive Manufacturing;  DLP: Digital Light Processing**
Industrialization of 3D-Printing needs contributions from all elements in the value chain

BASF takes responsibility beyond materials
Create the unexpected.

With outstanding 3D-printing solutions from BASF.