Evonik.
Power to create.

“Materialien für den industriellen 3D-Druck”

Additive Fertigung: Chancen und Herausforderungen durch 3D Druck
Transferinitiative Rheinland-Pfalz

Sayama Kazi/Sylvia Monsheimer
Agenda

1. The Evonik Industries Group
2. The High Performance Polymers Business Line
3. What is 3D printing?
4. Material Development for 3D Printing
5. Quality – very important
6. Hurdles and new opportunities
Our positioning

Evonik is the creative industrial group from Germany and one of the world’s leading specialty chemicals companies.
A modern structure

<table>
<thead>
<tr>
<th>Nutrition &amp; Care</th>
<th>Resource Efficiency</th>
<th>Performance Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales*: €4.9 bn</td>
<td>Sales*: €4.3 bn</td>
<td>Sales*: €3.4 bn</td>
</tr>
</tbody>
</table>

- **Business Lines**:  
  - Personal Care  
  - Household Care  
  - Comfort & Insulation  
  - Interface & Performance  
  - Baby Care  
  - Health Care  
  - Animal Nutrition

- **Business Lines**:  
  - Active Oxygens  
  - Catalysts  
  - Coating & Additives  
  - Coating & Adhesive Resins  
  - Crosslinkers  
  - **High Performance Polymers**  
  - Oil Additives  
  - Silanes  
  - Silica

- **Business Lines**:  
  - Performance Intermediates  
  - Agrochemicals & Polymer Additives  
  - Functional Solutions  
  - Acrylic Monomers  
  - Acrylic Polymers  
  - CyPlus Technologies

**Services**  
- Administrative Services  
- Technology & Infrastructure

**Corporate / Other**  
- Corporate Center  
- Strategic R&D

<table>
<thead>
<tr>
<th>Specialty chemicals segments</th>
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</thead>
</table>

* Fiscal 2015
2015: Evonik in figures

Employees December 31, 2015
33,576

Profitability (adjusted EBITDA margin)
18.2 %

€2.465 billion Adjusted EBITDA

€13.5 billion sales

Return on capital Employed (ROCE)
16.6 %
High Performance Polymers

Key facts

- About 1330 employees
- R&D ratio about 5 %
- 7 research facilities
- Specialist for customized solutions
- Facilities all over the world

[Map showing locations such as Mobile, USA, Tippecanoe, USA, Darmstadt, Germany, London, UK, Lenzing/Schörfling, Austria, Marl, Germany Headquarters, Witten, Germany, Wörth, Germany, Changchun, China, Shanghai, China, Aboshi, Japan]
Evonik Resource Efficiency GmbH
BL High Performance Polymers
3DP – some words about the HYPE…
Additive Manufacturing

Important features of the powder based processes:

- good mechanical properties
- no support structures necessary
- arbitrary complexity of the parts possible
- big volume usable

⇒ High potential for real (small) series production
Motivation for the use of toolless fabrication processes

1. Price issue for injection moulding of small series (dependent on the part itself)
2. Individual parts (needs software and handling etc)
3. Impossible to produce by injection moulding (undercuts etc)
4. Integration of several parts to one part (difficult to show)(whole production process)
Motivation - Economic Aspects

„Rapid“ is no longer important in the sense of Rapid Prototyping

The whole production process has to be economically

Competition against injection moulding

![Graph showing cost per unit vs. number of units]

Principle only

Dependent on the specific part

Small parts have higher break even values

Comparison 1:1, without using advantages like integrating functionality, or more freedom of design
Motivation - Freedom of Design

Application example: Special Gripper

• Made from Polyamide powder, layer thickness 0.1 mm
• Light, flexible, adaptable
• Adjusts itself to the shape of the object to be gripped
• Unique solution for pressure sensitive goods (fruit, bulbs, eggs)
• German Future Prize December 2010

Photo: Festo AG&Co KG
BL High Performance Polymers - Development of Materials for AM

Mechanical properties

Surface quality

Processability
BL High Performance Polymers - Development of Materials for AM

The polymer powders have a characteristic shape

- Mainly spherical particles
- Narrow grain size distribution
- Special (high) crystallinity
- Good melt flow without shear
- Tailor made surface properties

Properties required to be adjusted by the material producer
Materials Development – The Toolbox and Examples

Analytics
Standards Committee
Polymer Testing
Application Tests
Reactive Systems
Ink Formulation
Modification and Fractionation
Powder
Polymer
Monomer
BL High Performance Polymers - New Materials for AM

<table>
<thead>
<tr>
<th>VESTAKEEP AM 9000</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E modulus</td>
<td>3720 MPa</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>2,2 %</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>72 MPa</td>
</tr>
<tr>
<td>Melting point</td>
<td>340 °C</td>
</tr>
<tr>
<td>Continuous operating temperature</td>
<td>280 °C</td>
</tr>
</tbody>
</table>

Easy to process
Sharp edges
Rough surface

- Inherent flame retardant; UL94 V-0
- Low smoke density and no toxic gases
- High heat temperature resistance, excellent chemical resistance
- Resistance against X-ray, beta, and gamma radiation
- High strength and flexibility
Comparison of material properties

<table>
<thead>
<tr>
<th></th>
<th>standard grade</th>
<th>new rubberlike material VESTOSINT Z2611</th>
</tr>
</thead>
<tbody>
<tr>
<td>E modulus</td>
<td>1700 MPa (246.500 psi)</td>
<td>100 - 250 MPa (14.500 – 36.200 psi)</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>15 %</td>
<td>&gt;100 %</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>45 MPa (6.250 psi)</td>
<td>8 MPa (1.160 psi)</td>
</tr>
<tr>
<td>Notched impact strength</td>
<td>3,5 kJ/m²</td>
<td>No break</td>
</tr>
<tr>
<td>Melting point</td>
<td>186 °C (366 F)</td>
<td>150 °C (302 F)</td>
</tr>
<tr>
<td>Common refreshing rate</td>
<td>50 %</td>
<td>50 %</td>
</tr>
</tbody>
</table>

Shore A 90
Shore D 40
Air Duct

With some integrated functionality (heat shield, injection nozzle)

New Material Grade

• Temperature Resistance
• High Impact Strength
• Improved Stiffness
Quality

Where quality control of the AM powders takes place:
General Electric (GE) is expanding the uses of 3D printing and expects the technology to be involved in more than half of its manufacturing in 20 years.

GE uses less than 10% of 3D printing in its manufacturing processes today, but that share should rise to 20% to 25% in 10 years and 50% or more in 20 years, says Christine Furstoss, GE's technical director of manufacturing and materials technologies in an interview with IBD.

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Large steps forward need their time!!!

New upcoming applications in different branches
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