»Vernetzung von Kompetenzen in der Additiven Fertigung – Werkstoffe, Charakterisierung, Recycling«


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Additive Manufacturing
What means »Additive Manufacturing«?

Techniques for the manufacturing of parts directly from the construction drawing by the successive build-up of materials, better known under the name »3-D Printing«

- A magnitude of technical variants exist on the base of
  
  Direct printing (ink jet or filament)
  
  Stereo lithography
  
  Selective melting of powders
  
  ...
Additive Manufacturing
What means »Additive Manufacturing«?

Techniques for the manufacturing of parts directly from the construction drawing by the successive build-up of materials, better known under the name »3-D Printing«

- Technology examples
  - »Printer« for under 1.000 Euro up to industrial production systems for more than 500.000 Euro

Renkforce RF500 3D Printer
Plastics filaments from PLA, ABS, Polyamid (PA) …
build space max. 210 mm x 135 mm x 170 mm

EOS M400 selective laser melting unit
for metals, 1 kW laser power
build space max. 400 mm x 400 mm x 400 mm

Source: Conrad electronic SE
Source: EOS GmbH
Additive Manufacturing
What means »Additive Manufacturing«?

Techniques for the manufacturing of parts directly from the construction drawing by the successive build-up of materials, better known under the name »3-D Printing«

- Technology examples
  - Industrial systems for metals mainly use powder bed based techniques

EOS M400 selective laser melting unit
for metals, 1 kW laser power
build space max. 400 mm x 400 mm x 400 mm

Source: EOS GmbH

Source: 3D Systems
Additive Manufacturing
What is specific for these technologies?

Extremely high degree in geometrical design

- AM parts examples
  - Complex shapes and inner geometries which cannot be produced via concurrent techniques
  - Individually designed single parts (medical, jewelry, ...) at lower costs (no tool manufacturing)
Additive Manufacturing
What is specific for these technologies?

Direct manufacturing is performed
- directly from the CAD data
- in a layer-by-layer parts building technique
- with unique and individual geometries (e.g. any desired inner structures or person-specific adopted medical parts)
- without the need of tool forms
- with (nominally) no waste

Ressource efficient/sustainable
Predestinated for industry 4.0
Additive Manufacturing
What is specific for these technologies?

Layer-by-layer manufacturing

Example: Powder bed based technique

Source: L.N. Carter et al., J. Alloys and Compounds 615, 2014
Additive Manufacturing
What are the challenges?

Industrial powder bed based techniques
- Size and quality restrictions
- Limited availability of materials
- Waste! Ressource efficient?

Source: L.N. Carter et al.,
J. Alloys and Compounds 615, 2014

Source: Buffalo Manufacturing Works/EWI
Additive Manufacturing – Selective Laser Beam Melting
Where do we locate our competencies?

Relevant measures in the AM process chain

Materials
- Laser energy absorption
- Heat conductivity
- Melt temperature
- Viscosity
- Surface tension

Powder
- Particle size distribution
- Particle shape
- Surface morphology and chemistry
- Microstructure

AM process/part
- Powder supply
- Apparent density
- Heating, melting and solidification behaviour
- Parts microstructure and surface quality

Parts quality and range of applications for industrial use
Additive Manufacturing – Selective Laser Beam Melting
Where do we locate our competencies?

Long-term experience and specific facilities for metal powder manufacturing, materials development and recycling techniques

- Powder manufacturing units with specific patented features
  - Gas and (reactive) hot gas atomization
  - Rotating disc atomization
- Innovative recycling technologies (e.g. iCycle®)

iCycle®
Intelligent composite recycling
iCycle process for mixed wastes
Rotating disk atomization
Coarse powder production
Gas atomization
Molten particle jet
Made-to-measure powders
Gas atomized metal powder
Gas and hot gas atomizers
Engineering of production processes
Institutes or divisions of institutes with specific competencies cooperate in Fraunhofer alliances in order to jointly work on, to promote and to market important technologies.
Additive Manufacturing – Networks
Fraunhofer Alliance »Generative Fertigung«

Main topics of Fraunhofer UMSICHT

- Additive manufacturing with thermoplastics (focus in Oberhausen)
  - (Bio-)plastics and thermoplastic powders for AM
  - Parts and process development for selective laser sintering processes (SLS)

- Additive manufacturing with metals (focus in Sulzbach-Rosenberg)
  - Materials and powder manufacturing (metal alloys, thermoplastics)
  - Recycling and re-use of aged powders and residues from powder bed based laser beam melting (LBM, SLS) processes

Source: Fraunhofer Alliance »Additive Manufacturing«

3-D printing technologies

Simulation based development

Light weight skateboard axis
Additive Manufacturing – Networks
AM network organized by OTH Amberg-Weiden

Regional network based on the initiative and under guidance of Prof. Blöchl (OTH Amberg)

- Actors are predominantly industrial companies from the Oberpfalz area
- SME and large size companies
- Knowledge sharing and qualification of processes and parts
- OTH initiative for the development of an universally usable test part
  - Fast and simple test method for measuring dimensional accuracy
  - Complete specification of position-dependent geometry parameters (drillings, bars, overhangs, …)
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – BTHA-FV9

BTHA-FV9 – »New Materials for additive manufacturing«

- Research cooperation with OTH Amberg (coordinator) and the universities of Pilsen and Ostrava

- Intention:
  - Materials related developments for AM parts
  - Investigations on the aging of powders during the AM process
  - Establishing new cross-border networks in the Bavarian-Czech border area
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – **BTHA-FV9**

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- **Role of Fraunhofer UMSICHT SuRo**
  - Materials and powder related issues
  - Aging and recycling/re-use investigations
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – »Optimized powders for 3D printing«

- Joint German-Belgian research cooperation
- Enabling the processing of critical materials by surface coating of powders
  - Copper
  - Aluminium alloys

http://www.fem-online.de/en/content/OpP3D

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Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – LBM of Copper parts

- Materials
  - Laser energy absorption, Heat conductivity, Melt temperature, Viscosity, Surface tension

- Powder
  - Particle size distribution, Particle shape, Surface morphology and chemistry, Microstructure

- AM process/part
  - Powder supply, Apparent density, Heating, melting and solidification behaviour, Parts microstructure and surface quality

Parts quality and range of applications for industrial use
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – **OpP3D**

**OpP3D** – LBM of **Copper** parts

- Low absorption of the laser light
- High heat conductivity
- Aggravating conditions for generating a stable melt bath and dense parts

>97 % laser light reflection

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Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – LBM of Copper parts

- Solution 1:
  - Alloying of the pure copper powder

http://www.fem-online.de/de/content/additive-fertigung

Pure copper (left) and CuNi3Si1 alloy from powder in the size range **10-45 µm** (right), porosity levels in %.

Parts built by fem, Forschungsinstitut für Edelmetalle und Metalchemie
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – **OpP3D**

**OpP3D** – LBM of **Copper** parts

- **Solution 1:**
  - Alloying of the pure copper powder

- **Solution 2:**
  - with adjusted particle size range:
    - 10-45 µm 5.5 %, 10-25 µm 1.3 % porosity

Pure copper (left) and CuNi3Si1 alloy from powder in the size range **10-25 µm** (right), porosity levels in %.
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – LBM of Copper parts

- Low absorption of the laser light
- High heat conductivity
- Aggravating conditions for generating a stable melt bath and dense parts
- Dramatic decrease of electrical conductivity already at low levels of alloying elements

(Download from Deutsches Kupferinstitut (accessed: 10-May-2018)
https://www.kupferinstitut.de/de/werkstoffe/eigenschaften/niedriglegierte-kupferwerkstoffe.html
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – LBM of Copper parts

Solution 3:
- Coating of the powder particles for enhanced laser energy absorption
  - Metallic (Materia Nova)
  - Non-metallic (UMSICHT)

Pure copper (left) and < 100 nm Ti coated Cu powder (right), porosity levels in %.
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – OpP3D

OpP3D – LBM of Copper parts

- Application:
  - Complexly shaped, miniature electrical induction coils (Unicorn Engineering GmbH: Intelligent solutions for electrical energy storage systems)
Additive Manufacturing – Selective Laser Beam Melting
Research Activities and Networks at UMSICHT SuRo – 3D Cover

3D Cover – »Metallic Materials in the process chain of additive manufacturing«

- Research cooperation with COMTES FHT a.s. Dobřany (coordinator) and OTH Amberg
- Intention: Improving AM process chain and parts by
  - materials and powder development for AM, focused on
    - Aluminium alloys
    - steels
  - AM process development for new materials and fine powders
  - application and investigation of specific micro-characterization methods (mechanical, structural)
  - process related simulation of microstructure and stress evolution
  - residual stress and corrosion investigations, specific surface treatments
  - enhanced mechanical properties, surface qualities and corrosion resistance
Additive Manufacturing – Selective Laser Beam Melting
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Further profile raising by using and extending the present expertise and equipment in the direction to AM

- **Priority topics**
  - Powder development
  - Recycling and re-use

- **Utilization of the present cooperations and networks and of the strategic developments within the UMSICHT sites and the Fraunhofer group**

- **Consequent continuation and marketing of successful developments with key customers**