CHALLENGES REGARDING ADDITIVE MANUFACTURING WITH SPECIAL METALS
Heraeus

› A family owned technology group founded in 1851
› Focus on metals and functional materials
› Globally active with >100 sites in 38 countries and >12,500 employees
› Revenues ~13 bn € in 2015

Tobias Caspari

› Responsible for Additive Manufacturing
› Based in Hanau, Germany
160 YEARS OF COMPETENCE IN METALS AND POWDER TECHNOLOGY

1856 - 1900
- Platinum Melting
- Semifinished Jewelry
- Ultra Pure Platinum
- Platinum Crucibles
- Ceramic Colors

1900 - 1950
- Platinum Gauzes
- Dental Alloys
- Catalysts

1950 - 2010
- Sputtering Targets
- Steel Sensor
- Special Metals
- Thick Film Pastes
- Medical Components

2010 - now
- Solar Cell Pastes
- Porous Carbons
- Special metals for Additive Manufacturing
We cover the entire value chain for “special metals”

“Standard metals” include:
- 316L
- CoCr
- Ti6Al4V
- AlSi10Mg
- IN718

“Special metals“

Alloy development and melting

Process development and printing

Recycling of metal powders
BROAD RANGE OF CHALLENGES REGARDING (SPECIAL) METALS
POWDER – CHALLENGE 1: SUITABLE QUALITY

Atomization methods

› **Gas atomization** (vs. water atomization)
  - Spherical particles
  - Low oxygen content
  - High packaging density
  - Small size (10-45µm) and small size distribution

› Own EIGA and VIGA equipment
  - EIGA = Electrode Induction Melting Inert Gas Atomization
  - VIGA = Vacuum Induction Melting Inert Gas Atomization
  - EIGA for crucible free processing
  - EIGA for **temperature range up to 3,000°C**
**POWDER – CHALLENGE 2: STABLE QUALITY**

**Powder quality**

- Batch-to-batch consistency is critical
- Otherwise it is **impossible to be repeat and/or qualify** additive manufacturing processes
- Multi-modal PSD to achieve a high powder density

![Image of powder samples](image)
POWDER – CHALLENGE 3: SUITABLE SPECS

Powder specs

› Example: Reported **printing issue** (AlSi10Mg, 10-45 µm), 2\textsuperscript{nd} print with improved result

› SEM indicates **similar powder appearance**:

Reference material

Heraeus material
PROCESS – CHALLENGE: SUITABLE PROCESSES FOR SPECIAL METALS

Printing parameters

› Only “standard” processes for “standard” metals available

› High development effort with partly invisible parameters – limited scalability across equipment and/or parts

› Simulation used to determine process window before running SLM/EBM experiments

› Example: simulation of ...

... porosity and roughness:

… selective evaporation and material composition:
PRINTER – EXISTING LAB

Printing lab
› Own SLM and EBM equipment
› Established quality as well as security procedures

Engineering and post-processing
› Powder, metallurgical and chemical labs
› Engineering and scanning expertise
› Own post-processing equipment, e.g. HIP, machining, milling, drilling etc.
COMPONENT – CASE STUDY: PRECIOUS METALS

1st ever 3D printed thruster chamber out of PtRh20 (with SLM)

› Context: Conventional production ongoing at Heraeus
› Key challenge: Optimization of fit between powder and printing process
› Result: Passed hot-fire test at ESA with >600 ignitions at >1250°C and no signs of wear or fatigue
› Potential applications: Components / tools with high heat exposure
COMPONENT – CASE STUDY: PRECIOUS METALS

Printing of Iridium and PtIr50 (with SLM)

› Context: Iridium is difficult to machine and needs complex deformation processes
› Key challenge: High melting temperature (Tm= 2.500°C) and high reflectivity
› Result: Achieved porosity of <1%
› Potential applications: components for semi-conductor industry, chemical and catalytic applications
COMPONENT – CASE STUDY: AMORPHOUS METALS

Context: Amorphous metals / metallic glasses

› Periodic lattice structures (crystalline) vs. frozen liquids (amorphous)

![Periodic lattice structures](image1)

![Frozen liquids (amorphous)](image2)

› Achieved via rapid cooling (“freeze in liquid state”)

› Current limitation: size – dimensions achieved via casting <10 mm

› Properties:

  › Mechanical: high strength, high hardness / wear resistance, high elasticity, low damping, high resilience

  › Aesthetic: high surface finish, smooth and wear-resistant surfaces

  › Corrosion: increased corrosion resistance

  › Magnetic: excellent soft magnetic behavior
COMPONENT – CASE STUDY: AMORPHOUS METALS

Printing of Zirconium-based amorphous metal Zr_{59.3}Cu_{28.8}Al_{10.4}Nb_{1.5} = AMZ4 (with SLM)

› Context: Proprietary alloy
› Key challenge: Development of printing parameters
› Result: Parts 30 mm x 12+ mm (diameter x height) – confirmed as fully amorphous by X-ray analysis

Bouncing on 316L vs. on AMZ4
COMPONENT – CASE STUDY: AMORPHOUS METALS

Potential applications:

- **CONSUMER ELECTRONICS**: Shock-absorbent, scratch- and wear-resistant – Shatterproof and lighter casings for smartphones
- **AUTOMOTIVE INDUSTRY**: Extremely strong, thermoplastic – Stable suspension systems, wear-resistant gears and drive components
- **MEDICAL TECHNOLOGY**: Harder and more corrosion-resistant than conventional metals – Sharp, durable scalpels and minimally invasive instruments
- **WATCHMAKING AND JEWELRY INDUSTRY**: High surface quality – Jewelry and abrasion-resistant clockwork components
- **SPORTS AND LEISURE**: High storage capacity of elastic energy – Golf clubs, skis and snowboards

Amorphous metals...
SPECIAL METALS can be used for additive manufacturing.

IF the “magic triangle” (printer – process – powder) is controlled AND by offering will new material options and new functionalities, they will help *unlocking the value of this technology*!