Challenges and opportunities of metal 3D printing for medical applications

Wolfgang Waldhauser, Jelena Petrusa, Benjamin Meier, Vojislav Petrovic

EPIC Online Technology Meeting on Additive Manufacturing

15th May 2023

JOANNEUM RESEARCH MATERIALS

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

JOANNEUM RESEARCH Forschungsgesellschaft mbH

FACTS & FIGURES
As of: 2022

~500
Employees

6
Locations

Graz
Klagenfurt
Niklasdorf
Pinkafeld
Weiz
Vienna

3 Owners

State of Styria (80.75 %)

BABEG – Kärntner Betriebsansiedlungs- & Beteiligungsgesellschaft (14.25 %)

Wirtschaftsagentur Burgenland GmbH (5 %)

7
Research Units

Austria

Styria

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

JOANNEUM RESEARCH

JOANNEUM RESEARCH Forschungsgesellschaft mbH

Executive Board and Corporate Staff

Research Units

DIGITAL
Institute for Digital Technologies

- Remote Sensing and Geoinformation 01 05
- Intelligent Vision Applications 01 05
- Intelligent Acoustic Solutions 01
- Telecommunication, Navigation and Signal Processing 01 05
- Connected Computing 01
- Cyber Security and Defence 01
- Digital Twin Lab 05

MATERIALS
Institute for Sensors, Photonics and Manufacturing Technologies

- Hybrid Electronics and Patterning 02
- Light and Optical Technologies 02
- Laser and Plasma Processing 03
- Sensors and Functional Printing 02
- Smart Connected Lighting 06

ROBOTICS
Institut for Robotics and Flexible Production

- Industrial-Robotsystem-Technologies 05
- ROBOTICS Evaluation Lab 05
- ROBOTICS Training Center 05

COREMED
Centre for Regenerative and Precision Medicine

- Tissue Regeneration and Wound Healing 01

HEALTH
Institute for Biomedical Research and Technologies

- Biomedical Tissue Monitoring 01
- Bioanalysis and Metabolomics 01
- Data Management and Biostatistics 01
- Digital Healthcare Solutions 01

LIFE
Institute for Climate, Energy Systems and Society

- Weather and Climate Risk Management 01
- Climate-Neutral Energy Systems and Lifestyles 01 05
- International Climate Policy and Economics 01
- Urban Living Lab 01 05

POLICIES
Institute for Economic, Social and Innovation Research

- Technology, Innovation and Policy Consulting 01 04
- Data Analytics and Statistical Modelling 01 05
- Regional Economics and Structural Policy 01 05

Austria Styria

Locations: 01 Graz 02 Weiz 03 Niklasdorf 04 Vienna 05 Klagenfurt 06 Pinkafeld

Institute for Sensors, Photonics and Manufacturing Technologies

Head: Prof. Dr. Paul Hartmann

Staff: about 100

Main areas of expertise (research groups)**:**

- Hybrid Electronics and Patterning (Dr. Barbara Stadlober)
- Light and Optical Technologies (Dr. Christian Sommer)
- **Laser and Plasma Processing** (Dr. Wolfgang Waldhauser)
  - Laser Processing
  - Plasma Surface Engineering
- Sensors and Functional Printing (Dr. Jan Hesse)
- Smart Connected Lighting (Dr. Andreas Weiss)

Locations:
Weiz, Niklasdorf, Pinkafeld

Research Group: Laser- and Plasma-Processing

Laser Processing Methods with High-Power Lasers

- Laser welding
- **3D laser metal deposition** (LMD or L-DED)
- **3D selective laser melting** (SLM or L-PBF)
- Laser cladding and alloying
- Laser beam analysis
- Metallographic characterization

Plasma Surface Engineering

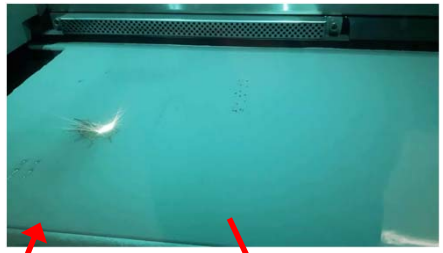
- PVD, PECVD
- Plasma polymerisation
- Hybrid processes
- Atmospheric pressure plasma coating (APPD)
- Film Characterization

Our Activities (Offers) in Additive Manufacturing

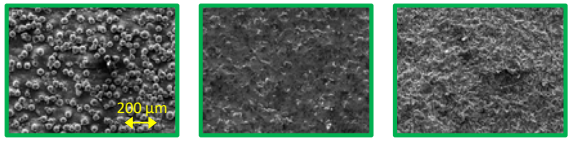
Applied Research in Selective Laser Melting (SLM) or Laser Powder Bed Fusion (L-PBF)

- Parameter studies and process development for metallic materials
  - Titanium alloys (Ti Gd 2, Ti6Al4V, Ti6Al7Nb)
  - Aluminium alloys
  - Nickel alloys (Inconel)
  - Metallic glasses (Zr based)
  - Composites with metallic matrix
  - Composite Materials (metal (L-PBF, polymer (FFF))
- Simulation of AM processes and part(ANSYS)
  - Temperatur distribtion, intrinsic stresses and distorsion
  - Microstructure (planned)
- Post Processing of AM parts
- Opening up new fields of application
  - Aviation, tool technology, medical technology

Materials characterisation with the scanning electron microscope



Printing process in EOSINT M280 at JOANNEUM RESEARCH



Surface finishing of AM parts:
as printed glass bead blasted sandblasted

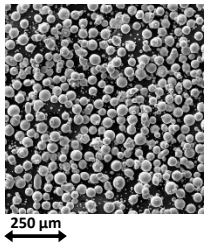
Additive manufacturing of personalized implants

EPIC EUROPEAN PHOTONICS INDUSTRY CONSORTIUM
CAMed Medizinische Universität Graz
Clinical additive manufacturing for medical applications
Financial Support by: FFG Forschung wirkt. SFG Bundesministerium Digitalisierung und Wirtschaftsstandort Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
JOANNEUM RESEARCH MATERIALS

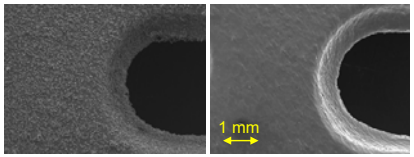
Personalised implants through additive manufacturing

Process chain (ongoing national project CAMed)

Material selection → Finding the optimal printing parameters → Finding suitable method for post-processing of printed parts → Cytotoxicity tests to check material compatibility → Biomechanical testing of the radius plate with sawbones → Biomechanical testing of the radius plate with cadavers → Clinical tests of the radius and humerus plate



- **Titanium alloys**
  - Ti grade 2 (Ref)
  - Ti6Al7Nb
- **Amorphous Alloys**
  - Zr-based – VIT 105
  - Cu-based – AMC4



- **Selective Laser Melting (SLM)**
  - Design of implants
  - Preparation of STL files
  - DOE for parameter finding
- **Characterisation**
  - Powder
  - Microstructure & porosity of printed samples
  - Mechanical Properties
- **Heat treatment**
  - Stress relief annealing
  - Heat treatment
  - Hot Isostatic Pressing
- **Surface finishing**
  - Corundum blasting
  - Glass bead blasting
  - Barrel finishing
  - Electro polishing
  - (Coating)

- **In Vitro Cytotoxicity**
  - ISO 10993-5
  - ISO 10993-12
- **Antibacterial behaviour**
  - Coated samples

- **Biomechanical tests**
  - In comparison to the INTEOS® Radius 2.5 from Hofer Medical
  - Cyclical loading tests
  - Load-to-failure tests

INTEOS® Radius 2.5:

https://www.hofer-medical.com/portfolio-item/inteos_radius_2_5/

- **Biomechanical tests**
  - Anatomical Institute of the Medical University of Graz
- **Final Goal**
  - Plates, which are tailored to the patient
  - Adjustment of the plate to the needs for optimal fracture treatment, as well as to the individual bone structure
  - AM of complex shaped plates like humerus plate

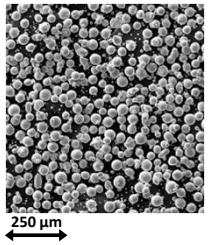
New Planned Horizon Europe Project

- **Project Goal:** To develop the scientific, technological and medical basis for the realisation of **load-bearing implants** made of **resorbable and non-resorbable metals** and composite materials with the help of additive manufacturing (AM) and to equip these implants with **suitable sensor technology.**
- **Project Approach:**
- Development of **composite implants**
- **3D printing** of **non-bioresorbable** and **bioresorbable metals**
- **Integration of sensors** based on Pyzoflex technology for
  - detection of deformations,
  - vibration behavior,
  - temperature
- Research whether the following information can be obtained
  - loading of the implant,
  - ingrowth behavior,
  - inflammatory processes,
  - degradation of bioresorbable implants
- Development of a **digital twin** of selected implants

We are looking for

Partners

- interested in the development of functionalised AM-manufactured implants
- with expertise in FEM calculations for the design of load-bearing implants
- with expertise in the production of metal powders from resorbable metals for medical applications
- interested in the Pyzoflex sensor technology
- with expertise in the realisation of miniaturised and implantable electronics
- with expertise in RFID and NFC technologies
- with expertise in programming evaluation software for sensor data
- with expertise in the creation of digital twins for medical technology



Metal powder for AM


X-ray of an implanted femoral plate

Research Group Laser and Plasma Processing

Employed since:

1998	1998	2021	1994	2003	2017	2019	2019
							
Rene Feldbaumer	Roswitha Elter	Eva Pycha	Barbara Wolfsberger	Jürgen Lackner	Benjamin Meier	Maximilian Trafella	Jelena Petrusa

2008	2011	1990	1999	2008	2008	2019	2019	2022
								
Richard Görgl	Reinhard Kaindl	Raimund Krenn	Wolfgang Waldhauser	Harald Parizek	Bettina Großschädl	Simon Chwatal	Voijslav Petrovic	Maximilian Kamencek

2022	2020	2001	2004	2008	2017	2020	1989	2023
								
Katharina Shickle	Dietmar Kopp	Thomas Prethaler	Gerfried Polding	Andrea Jantscher	Alexander Schwan	Carina Hendler	Elmar Brandstätter	Mirjam Spuler

Financial Support by: FFG Forschung wirkt. SFG Bundesministerium Digitalisierung und Wirtschaftsstandort Bundesministerium Verkehr, Innovation und Technologie Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie Das Land Steiermark

Thank you for your attention!

Wolfgang Waldhauser
wolfgang.waldhauser@joanneum.at

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MATERIALS – Institute for Sensors, Photonics and Manufacturing Technologies

Leobner Straße 94
A-8712 Niklasdorf (Austria)

Tel. +43 316 876-3304
materials@joanneum.at

www.joanneum.at/materials

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