New Frontiers in Materials Design for Laser Additive Manufacturing

May 12-15, 2025, Designhotel + Congresscentrum Wienecke XI., Hannover, Germany

https://udue.de/matframeconf2025

Monday, May 12, 2025

16:00–18:00 Arrival and Registration

18:00–20:00 Dinner

20:00–22:00 Welcome Reception

Tuesday, May 13, 2025

08:00–09:00 Breakfast

09:00–09:15 Welcome by Prof. habil. Dr.-Ing. Stephan Barcikowski on behalf of the program committee

09:15–10:45 Session I: Fundamentals and new materials for additive manufacturing

(Chair: Prof. Dr. Bilal Gökce)

- **Dr. Yunhui Chen**, RMIT, Australia, *New Frontiers in Materials Design for Laser Additive Manufacturing*
- **Prof. Dr.-Ing. Ludger Overmeyer**, Laserzentrum Hannover, Germany, *New Process Parameter Spaces in Laser-Assisted Manufacturing Using the Example of Gravitation*

10:45–11:15 Coffee Break

11:15–12:45 Session II: Process development and simulation

(Chair: Prof. Bai-Xiang Xu)

- **Dr. Claas Bierwisch**, Fraunhofer IWM, Germany, *Polymer-specific Process Parameters for Laser Powder Bed Fusion: Insights from Experimentally Validated Simulations and Dimensional Analyses*
- **Prof. Dr. Stefan Nolte**, Friedrich-Schiller-Universität Jena, Germany, *LPBF with Ultrashort Laser Pulses – Additive Manufacturing Beyond Current Limits*

12:45–13:00 **Dr. Christiane Richter**, International Funding Opportunities DFG

13:00–13:15 **Dr. Tobias Böttcher**, Funding Opportunities Humboldt Foundation

13:15–14:00 Lunch

14:00–16:30 Excursion Guided Tour Royal Gardens of Herrenhausen (optional, free of charge)

16:30–18:00 Poster Session I

18:00–19:30 Dinner

19:30–21:00 Session III: Metallic materials and alloys

(Chair: Professor Dr.-Ing. Sebastian Weber)

- **Prof. Dr.-Ing. Ulrich Krupp**, RWTH Aachen University, Germany, *Dispersoid-Strengthened Cu Alloys for Additive Manufacturing of High-Temperature Components*
- **Dr.-Ing. Anastasiya Tönjes**, Leibniz-IWT Bremen, Germany, *Liquid In-situ Re-alloying in Additive Manufacturing*

Wednesday, May 14, 2025

08:00–09:00 Breakfast

09:00–11:15 Session IV: Process monitoring and characterization

(Chair: Dr. Anna Ziefuß)

- **Prof. Edward Kinzel**, University Notre Dame, USA, *In-situ Characterization of LPBF Using SWIR Imaging and OES*
- **Prof. Dr. Lutz Mädler**, University Bremen, Germany, *Droplets and Particles are Key Ingredients in Any Cake*
- **Prof. Mark Dadmun**, University Tenessee, USA, *Tailor Made Polymeric Feedstocks for Powder Bed Fusion Using Polymer Science Principles*

11:15–11:45 Coffee Break

11:45–13:15 Session V: Polymers and their processing

(Chair: **Dr. Claas Bierwisch**)

- **Prof. Dr. Andreas Ostendorf**, Ruhr University Bochum, Germany, *DED Process Development for Polymer Materials*
- **Prof. Dr. Michael Schmidt**, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, *Understanding the effects and potentials of nano-additives in NIR diode-based PBF-LB/P*

13:15–14:00 Lunch

14:00–16:30 Excursion Guided Tour Laserzentrum Hannover (optional, free of charge)

16:30–18:00 Poster Session II

18:00–19:30 Dinner

19:30–21:00 Session VI: Innovative applications and future prospects

(Chair: Dr. Silja-Katharina Rittinghaus)

- **Dr. Maria Teresa Perez**, IMDEA Materials Institute, Madrid, Spain, *Laser Additive Manufacturing of Soft Magnetic Fe-based Metallic Glasses*
- **Dr. Elain Lee**, Lawrence Livermore National Laboratory, USA, *Dynamically Responsive Shape Morphing of Printed Liquid Crystal Elastomers*

21:00 Reception with Instrumental Band Wildes Holz

Thursday, May 15, 2025

08:00–09:00	Breakfast
09:00–10:30	Session VII: Nanoparticles in additive manufacturing

(Chair: Prof. Dr. Stefan Nolte)

- **Dr. Anna Rosa Ziefuß**, University of Duisburg-Essen, Germany, *Boosting Coercivity of 3D Printed Hard Magnets Through Nano-Modification of the Powder Feedstock*
- **Prof. Dr.-Ing. habil. Olaf Keßler**, University of Rostock, Germany, *Heat Treatability after Laser Powder Bed Fusion of Alloy Al10Si0.3Mg Without and With Nanoparticles*

10:30–11:00	Coffee Break
11:00–11:30	Session VIII: Conclusion and prospects

(Chair: Prof. Dr. Stefan Nolte)

- **Prof. habil. Dr.-Ing. Stephan Barcikowski**, University of Duisburg-Essen, Germany, *Large-Scale Interlaboratory Study along the Entire Process Chain of Laser Powder Bed Fusion: Bridging Variability, Standards, and Optimization Across Metals and Polymers*

11:30–12:00	Closing
12:00–13:00	Lunch
13:00–14:00	Departure

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2	Becker, Louis	Broeckmann, Christoph; Lentz, Jonathan; Radtke, Felix; Webe	A Novel Route for Additive Manufacturing of High-Nitrogen Steels: PBF-LB/M Processing and Microstructure Formation
3	Bharech, Somnath	Goßling, Mareen; Gökce, Bilal; Xu, Bai-Xiang; Yang, Yangyiwei	Comparing Powder Bed Fusion and Direct Energy Deposition for Oxide-dispersion Strengthened Steels: A Simulation Study
4	Bierwisch, Claas	Dietemann, Bastien; Rudloff, Johannes	A One-Dimensional Multilayer Simulation Approach for PBF-LB/P
5	Boussinot, Guillaume	Apel, Markus; Cazic, Ivan; Döring, Markus; Schmidt, Michael	Ternary Eutectic Growth in Additively Manufactured Al-Ni-Ce Alloys
6	Breitbach, Elmar		Tailor made magnesium alloys for selective laser melting: Material development and process modelling
7	Burchard, Benedikt	Hofmann, Joseph; Wudy, Katrin	Evaluating Dielectric Analysis for Semi-Crystalline Thermoplastics to Analyze the Thermal and Rheological Properties in PBF-LB/P
8	Bürgi, Oliver		Carbide additivation to hot working tool steel by an optimized satelliting process with pectin binder
9	Dumbre, Jayshri	Zherui Tong; Yunhui Chen; Alexander Rack; Nathalie Isac; Manas V. Upadhyay; Mark Easton; Dong Qiu	Microstructural Evolution in Laser Directed Energy Deposited Ti-8.5Cu Alloy: Insights from In Situ Synchrotron X-ray Imaging
10	Gabriel, Philipp	Barcikowski, Stephan; Eibl, Florian; Jülich, Bastian; Ziefuss, Anna Rosa	3D Reconstruction of Local Chemical Composition in Additively Manufactured Parts Using In-Situ Optical Emission Spectroscopy
11	Ghasemi Kalash, Somayeh		Metallic Materials for DED Coatings to Enhance the Antibacterial Properties of Ti6Al4V Medical Implants
12	Hantke, Nick	Kwade, Arno; Lüddecke, Arne; Sehrt, Jan T.	Processability of Nanoparticle-Coated Powder by Powder Bed Fusion of Metals Using a Laser Beam
13	Olaf Kessler	Rabea Steuer, Benjamin Milkereit, Sigurd Wenner, Jette Broer, Florian Huber, Mirko Schaper, Olaf Kessler	Direct Natural and Artificial Aging of Aluminium Alloy AlSi10Mg after Laser Powder-Bed Fusion
14	Kollwitz, Marvin		Developing 3D-printable Materials based on dynamic covalent bonds - Towards recyclable and self-healing materials
15	Kricke, Jan Lino	Doñate-Buendía, Carlos; Fu, Zongwen; Gökce, Bilal; Kopp, Sebastian-Paul; Schmidt, Michael	Bactericidal surface functionalization of PBF-LB/P-printed parts by electrophotographic powder application
16	Kümmel, Simon	Anwar Siddiqui, Aamir; Roth, Johannes	Molecular dynamics simulations of laser-based powder bed fusion
17	Leupold, Simon	Barcikowski, Stephan; Kopp, Sebastian-Paul; Schmidt, Michael; Sommereyns, Alexander; Stratmann, Nadine; Willeke, Michael; Ziefuss, Anna Rosa	Challenges and possible solutions for using NIR laser radiation in polymer powder bed fusion
18	Lippmann, Stephanie	Dreyer, Malte; Hoyer, Kay-Peter; Liu, Dongmei; Matthäus, Lisa; Nolte, Stefan; Schrop, Mirko	Laser powder bed fusion process for AA8090 Al-Li alloy: generation and characterization of powders and single-track melt pools for process optimization
19	Lüddecke, Arne	Hantke, Nick; Kwade, Arno; Sehrt, Jan T.; Zetzener, Harald	Development of surface tailored metal powders for increased production efficiency at the laser powder-bed fusion additive manufacturing process
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21	Meyer, Fabian	Pich, Andrij	Binder-Assisted Additivation for Satelliting Carbides to H13 Tool Steel for PBF-LB Processing
22	Oster, Simon	Altenburg, Simon J.; Breese, Philipp P.	Short-wave infrared thermography as a quality assurance tool for laser powder bed fusion of metals
23	Radtke, Felix	Becker, Louis; Broeckmann, Christoph; Kaletsch, Anke; Lentz,Jonathan; Weber, Sebastian	A Novel Route for Additive Manufacturing of High-Nitrogen Steels: Static and Dynamic Mechanical Properties
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25	Roshanak, Mohammadi Siahboomi		Designing 3D Printed TiO2 Structures for Enhanced Acyclovir Degradation via TiO2/BiFeO3 Heterojunction
26	Sahoo, Priyatosh	Gutfleisch, Oliver; Liu, Jianing; Skokov, Konstantin; Schäfer, Lukas	Design and Qualification of Pr–Fe–Cu–B Alloys for the Additive Manufacturing of Permanent Magnets
27	Scheibel, Franziska		Functional properties of additively manufactured magneto- and multicaloric materials over the entire processing chain
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29	Shah, Abdul Wahid		A data-driven predictive framework for predicting tensile properties of Aluminium alloys for Laser powder bed fusion process
30	Stratmann, Nadine	Barcikowski, Stephan; Gabriel, Philipp; Gutfleisch, Oliver; Sahoo, Priyatosh; Skokov, Konstantin; Ziefuss, Anna Rosa	Optimizing rare-earth hard magnets: Enhancing Density and Coercivity through a Synergistic Application of Laser Powder-Bed Fusion and Nanoscale Tuning
31	Tisha, Layla Shams	Ellendt, Nils; Toenjes, Anastasiya	Impact of Iron Contamination on Liquid Properties and Microstructural Evolution in AlSi10 and AlSi20
32	Tisha, Layla Shams	Ellendt, Nils; Knoop, Daniel; Toenjes, Anastasiya	Laser powder bed fusion of iron contaminated Al-Si alloys: Effects on processing, hardness and electrical conductivity
33	Vaghar, Adrian	Jegorenkov, Georgij	Preparation and Thermal Modification of Disentangled UHMWPE particles for Powder based Additive Manufacturing
34	Ziefuss, Anna Rosa	Barcikowski, Stephan; Leupold, Simon; Schmidt, Michael; Stra	Impact of Sensitizer Distribution on Polymer Processing in Diode Laser Powder Bed Fusion
35	Ziefuss, Anna Rosa	Barcikowski, Stephan; Kusoglu, Murat	Large-Scale Interlaboratory Study along the Entire Process Chain of Laser Powder Bed Fusion: Bridging Variability, Standards, and Optimization Across Metals and Polymers
36	Ziefuss, Anna Rosa	Gabriel, Philipp; Stratmann, Nadine; Stephan Barcikowski	Boosting Coercivity of 3D Printed Hard Magnets Through Nano-Modification of the Powder Feedstock

Tailor-made Magnesium Alloys for Laser-Based Powder Bed Fusion

Arvid Abel[1], Elmar Breitbach[2], Michael Müller[1], Christian Klose[2], Nick Schwarz[1], Stefan Kaierle[1,3], Hans-Jürgen Maier[2], Ludger Overmeyer[3]

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Laser-based powder bed fusion (PBF-LB/M) of magnesium WE43 shows great potential for the fabrication of patient-specific bioresorbable implants and lightweight components. However, due to material related challenges, the processing window for manufacturing dense and accurate parts is narrow compared to other materials. Within this project, the exploration of PBF-LB/M conditions for processing tailored magnesium alloys is addressed.

Two major challenges arise in PBF-LB/M of magnesium alloys. On one hand, the low boiling point of magnesium of 1100 °C leads to a high degree of evaporation due to partial overheating during the melting process. On the other hand, the low absorption at an ytterbium laser wavelength of 1070 nm impedes the process efficiency and stability. In order to explore PBF-LB/M process conditions that enable the fabrication of parts with a high relative density, ductility, tensile strength as well as dimensional accuracy, three major process adaptations were investigated within this research project.

A Novel Route for Additive Manufacturing of High-Nitrogen Steels: PBF-LB/M Processing and Microstructure Formation

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Laser Powder Bed Fusion/Metal (PBF-LB/M) is a promising technology for industrial applications, but long processing times remain a challenge. The shell-core approach addresses this issue by forming a dense shell around a minimally exposed powder core, significantly reducing processing time while enabling full densification and property optimization through subsequent hot isostatic pressing (HIP). This study explores the fabrication of shell-core samples using a powder mixture of either austenitic stainless steel (X2CrNi18-9) or ferritic stainless steel (Fe20Cr) combined with Si_3N_4 to produce high- nitrogen steel PBF-LB/M components—otherwise challenging due to nitrogen's limited solubility in the melt. The goal for X2CrNi18-9 is to develop a nitrogen-enriched austenitic stainless steel, while for Fe- 20Cr, the aim is to achieve an austenitic microstructure solely based on the FeCr(Si)N system.
During PBF-LB/M, Si_3N_4 decomposes, leading to Si and N loss through laser-powder interaction. However, in the still-powdered core, the remaining Si_3N_4 particles act as a nitrogen source during HIP, utilizing nitrogen's higher solubility in the solid state to circumvent solubility constraints in the melt.
Post-HIP analysis using energy-dispersive spectrometry and electron backscatter diffraction reveals distinct microstructural differences between the two stainless steel variants. For X2CrNi18-9, a fully austenitic, nitrogen-enriched matrix forms, whereas for Fe20Cr, nitrogen loss induced by Si_3N_4 decomposition during laser exposure results in a martensitic–ferritic microstructure instead of the intended austenitic phase. This innovative approach highlights the feasibility of producing additively manufactured high-nitrogen steel components with enhanced properties by overcoming nitrogen solubility limitations in the steel melt during PBF-LB/M.

Comparing Powder Bed Fusion and Direct Energy Deposition for Oxide-dispersion Strengthened Steels: A Simulation Study

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During PBF-LB/M, Oxide-dispersion strengthened (ODS) steels, which contain oxide nanoparticles (NP) dispersed in a metallic matrix, demonstrate excellent high-temperature strength [1, 2]. The mechanical performance of these materials can be tailored by controlling the size and distribution of the dispersed NP [3, 4]. This study employs thermal-melt-microstructure— coupled phase-field simulations and subsequent nanoparticle tracing to analyze the thermo- microstructural evolution, melt flow characteristics, and in-process NP dispersion and agglomeration in Fe20Cr alloy system with 0.5 wt.-% ZrO_2 NP, processed using laser-based additive manufacturing (LAM) techniques such as powder bed fusion (PBF) and direct energy deposition (DED). The simulations offer insights into dispersoid characteristics, including size and interparticle distance, which are essential for determining strengthening through Orowan mechanism—information that is typically inaccessible via experimental methods.

The results reveal significant differences in the melt flow patterns and melt residence times between the two processes. Consequently, the NP dispersion is influenced by their position relative to the melt pool geometry. Regions closer to the beam spot center experience longer melt residence times and higher degree of dispersion resulting in larger interdispersoid distances, and lower estimated Orowan stress. At equivalent volumetric energy density, simulations indicate larger melt pool and more stable melt flow pattern in DED, resulting in better NP-dispersion, whereas the erratic melt dynamics in PBF lead to greater NP agglomeration. Subsequently higher Orowan stress is estimated for DED as compared to PBF. This study highlights the importance of process selection in optimizing ODS steel performance and lays the groundwork for further investigation into multi-layer effects during LAM.

References:
[1] V. Yakubov, J.J. Kruzic, X. Li, *Adv. Engg. Mat.* **24**, 7 2200159 (2022).
[2] M.S. El-Genk, J.-M. Tournier, *J. Nuclear. Mat.* **340**, 1 93 (2005).
[3] E. Arzt, *Acta Materialia* **46**, 16 5611 (1998).
[4] M.B. Wilms, S.-K. Rittinghaus, M. Goßling, B. Goekce, *Progress in Mat. Sci.* **133**, 101049 (2023)

A One-Dimensional Multilayer Simulation Approach for PBF-LB/P

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The laser-beam powder bed fusion process for polymers (PBF-LB/P), also known as selective laser sintering (SLS), involves multiple time scales from laser motion, thermal diffusion, viscous flow, crystallization kinetics, and powder layer application. The process is divided into distinct temporal regimes, exploited by implementing a one-dimensional process simulation solver that only considers the building direction. This dimensional reduction allows for rapid simulations, useful for investigating influences such as inter-layer time on the final part density.
The methodology in this work involves a transient numerical simulation approach for the PBF-LB/P process, discretized exclusively in the building direction. This model accurately predicts surface temperatures and facilitates the investigation of the effects of inter-layer time on part densification. The reduction of dimensionality of the system enables fast simulations which are used to investigate, e.g., the influence of the time between subsequent layers on the densification and crystallization kinetics during the PBF-LB/P process (cf. Figure 1). The validity of this model has been confirmed through comparisons with experimental data using polyamide 12 (PA 12), showing good agreement in terms of transient surface temperature and part density.

The results indicate that the one-dimensional numerical model is effective in quantitatively describing the densification of multiple powder layers. Additionally, the study elucidates the impact of inter-layer time on the densification process. The introduction of this innovative simulation method enables rapid process parameter adjustment for new polymer materials in the PBF-LB/P process, demonstrating its applicability and efficiency in optimizing polymer additive manufacturing.

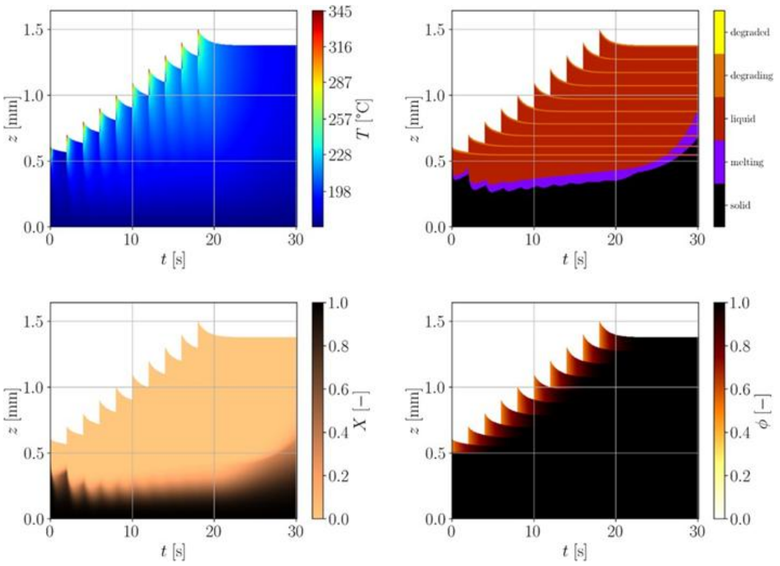

Figure 1: Simulation results for temperature, state of matter, volume fraction and crystallization as functions of time and building height (from top left in clockwise order) during PBF-LB/P of ten subsequent powder layers.

Ternary Eutectic Growth in Additively Manufactured Al-Ni-Ce alloys

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Coupled eutectic growth is known to favor enhanced materials' mechanical properties, owing to the small-scale composite microstructure that it produces upon solidification. Especially, in additive manufacturing, ultra-fine nanoscale eutectic structures associated to an efficient reduction of deformation mechanisms are expected. We evidence [1] the stabilization of ternary coupled growth of the three solid phases fcc-Al, Al3Ni, and Al11Ce3 in the Al-Ni-Ce ternary alloy, combining LPBF experiments and phase field simulations (see Figure). The results tend to confirm that ternary coupled growth occurs for nominal compositions of the alloy around the equiatomic Al-*x*Ni-*x*Ce. The value of *x* should then increase with the solidification velocity for ternary coupled growth to occur.

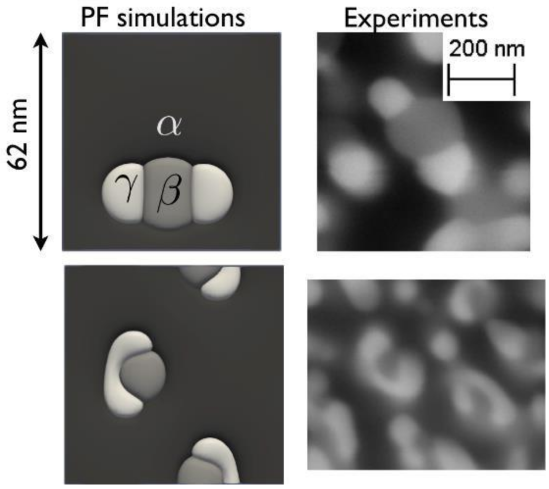

Figure 1: Phase field simulations and experimental results exhibiting the ternary coupled growth of the three α (fcc-Al), β (Al_3Ni) and γ($Al_{11}Ce_3$) solid phases (the growth velocity points towards the reader)

Tailor made magnesium alloys for selective laser melting: Material development and process modelling

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Additive manufacturing via laser powder bed fusion (PBF-LB) is a promising technique for processing magnesium (Mg) alloys, particularly for biomedical and lightweight structural applications. However, the high melting point of the oxide layer (≈ 2825 °C) compared to the boiling point of metallic Mg (≈ 1093 °C) poses challenges related to excessive evaporation and process instability [1]. To address these issues, this project develops novel ternary Mg alloys containing strontium (Sr), yttrium (Y), and neodymium (Nd) to increase both oxidation resistance for PBF-LB processing and mechanical properties of the final component.

Experimental investigations show that Sr reduces the oxide layer thickness, with a minimum observed at 0.5 wt.% Sr [2]. Since oxide formation contributes to process instability in PBF-LB, reducing the oxide layer thickness could lead to improved processing stability. While Nd enhances mechanical strength, it also increases oxidation, while Y maintains strength without significantly affecting oxidation behavior [3].

By incorporating zinc and calcium in addition to strontium, a biocompatible magnesium alloy with improved mechanical properties was developed using gravity die casting. Among the compositions tested, the alloy ZJX200 (2 wt.% Zn, 0.5 wt.% Sr, 0.5 wt.% Ca) exhibited the most favorable mechanical characteristics. This alloy could potentially be processed with reduced laser power in PBF-LB, minimizing evaporation and making it a promising candidate for the fabrication of complex three-dimensional structures such as patient-specific bone implants.

References:
[1] E.J. Breitbach, S. Julmi, S. Behrens, T. Blank, A. Abel, N. Emminghaus, L. Overmeyer, C. Klose, H.J. Maier, *Adv. Eng. Mater.*, 2401322 (2024).
[2] S. Julmi, A. Abel, N. Gerdes, C. Hoff, J. Hermsdorf, L. Overmeyer, C. Klose, H.J. Maier, Materials 14 (2021).
[3] A. Abel, Y. Wessarges, S. Julmi, C. Hoff, J. Hermsdorf, C. Klose, H.J. Maier, S. Kaierle, L. Overmeyer, Procedia CIRP **94,** (2020).

Evaluating Dielectric Analysis for Semi-Crystalline Thermoplastics to Analyze the Thermal and Rheological Properties in PBF-LB/P

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Understanding plastics' thermal and rheological properties in laser-based powder bed fusion (PBF-LB/P) is a prerequisite for industrial applicability. During PBF-LB/P, prolonged exposure to elevated temperatures causes the aging of semi-crystalline thermoplastics. Even though thermal aging can be revealed by material property changes, analyzed by melt-flow indexers (MVR) or differential scanning calorimetry (DSC), these techniques are limited to ex-situ analyses and do not provide insights into the plastics property changes during the PBF-LB/P process.

Dielectric analysis (DEA) is a potential in-situ measurement technique that can provide insights into the material changes during processing. However, DEA has so far been mainly used to analyze the curing behavior of thermosets, and the relation between the dielectric, thermal, and rheological properties of semi-crystalline thermoplastics has not yet been fully studied. Therefore, a new methodology is introduced to determine the characteristic melting and crystallization temperatures for semi-crystalline thermoplastics with DEA. The repeatability of the measurements and the influence of measurement frequency are investigated with the example of polyamide 12 (PA12).

Results show that DEA reliably characterizes melting and crystallization ranges while the measurement frequency influences the absolute temperatures. In addition, DEA can monitor plastic aging, even at lower temperatures, without melting it.

Carbide additivation to hot working tool steel by an optimized satelliting process with pectin binder

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Laser Powder Bed Fusion (PBF-LB/M) enables the production of individualized and complex components, making it particularly attractive for toolmaking. However, the range of well-processable materials remains limited. The addition of carbides can enhance both the processability and the resulting microstructure of tool steels. This project demonstrates these effects in AISI H13 tool steel by adding Cr_3C_2 and TiC carbides. Chromium carbides dissolve during processing and reprecipitate as eutectic M_7C_3, reducing solidification segregation and preventing solidification cracks. TiC carbides, in contrast, only partially dissolve, with the molten fraction forming primary carbides that act as nucleation sites, promoting an isotropic microstructure.

However, simple mixing of the carbides with steel powder leads to chemical gradients across the build platform. To mitigate this, a satelliting approach was employed, attaching fine carbide particles to larger steel particles using a polymer binder. Different binders and binder contents were evaluated, and two satelliting techniques – spray drying and the fluidized bed process - were compared. An optimized process ensured chemical homogeneity across the entire build plate. The use of the binder increases the carbon content in the component.
Future investigations will focus on optimizing the binder to reduce its content and, consequently, the introd uced carbon level.

Microstructural Evolution in Laser Directed Energy Deposited Ti-8.5Cu Alloy: Insights from In Situ Synchrotron X-ray Imaging

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Understanding how microstructures form and evolve in changing temperature fields during metal additive manufacturing is challenging, especially for alloys like Ti-Cu, which experience complex solid-state phase transformations. This study examines the impact of the build process on the microstructural evolution of Ti-8.5Cu alloy using Directed Energy Deposition – Laser Beam/Metals (DED-LB/M). By using in situ synchrotron X-ray radiography, we tracked changes in the melt pool for each layer. Our findings show that melt pool length, depth, and volume increase from the bottom to the top layers and with increasing laser power, due to rising residual temperatures. The pearlite phase fraction increases along the build direction. This data helps refine the Rosenthal model for accurate temperature profiling. Post-build electron microscopy reveals a V-shaped relationship between pearlite fraction and laser power, explained by the competition between nucleation and growth rate of pearlite which is dependent on the cooling rate. This study highlights ways to manipulate microstructures in Ti-8.5Cu alloys and showcases the effectiveness of in situ X-ray imaging in understanding complex manufacturing processes.

3D Reconstruction of Local Chemical Composition in Additively Manufactured Parts Using In-Situ Optical Emission Spectroscopy

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Laser powder bed fusion of metals (PBF-LB/M) is a well-established additive manufacturing technique that enables efficient net-shape fabrication with better resource utilization than traditional manufacturing methods.[1] Although in-situ quality monitoring and control systems offer significant advantages over post-processing inspections, current PBF-LB/M machine upgrades primarily rely on cameras or pyrometers, which do not provide chemical composition insights.[2,3] Addressing this limitation, our research focuses on tracking chemical composition during PBF-LB/M to establish correlations between compositional variations, processing behavior, and final part properties, ultimately aiming for enhanced quality control. In situ metal vapor plume analysis has been demonstrated for laser hybrid welding and PBF-LB/M [4-6], and optical emission spectroscopy (OES) has recently been demonstrated for composition analysis during PBF-LB/M.[6] Our investigations on a hard magnetic Nd-Fe-B-based alloy, highlight the potential to detect the local emission of Fe and Nd spectral lines, which act as reliable indicators for the elemental concentration and thereby magnet application relevance.[7] These x,y-positionally recorded emissions and their computed Nd/Fe-ratios are layer-wise reconstructed in 3D, representing chemical composition in additively manufactured parts (Figure 1). By integrating these reconstructions as digital twins in the future, our approach paves the way for transitioning from passive process monitoring to active process control, deepening the understanding of material behavior during processing, and aiming to improve the robustness, quality, and reliability of PBF-LB/M production.

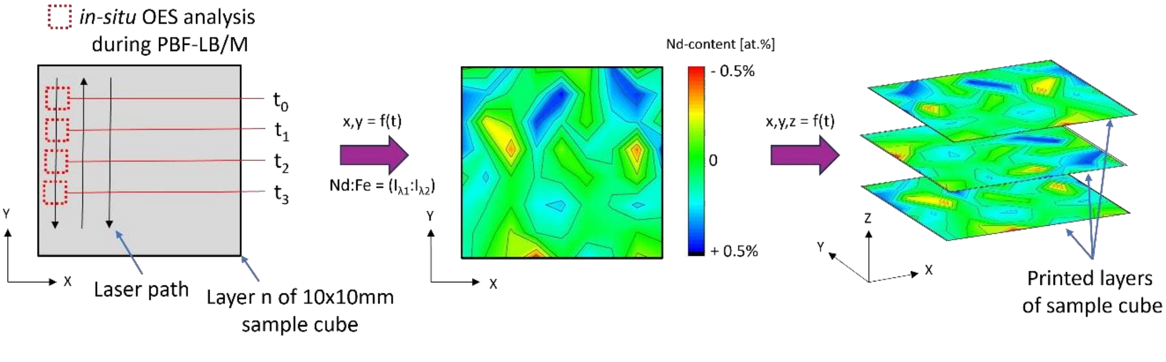

Figure 1: 3D reconstruction of local chemical composition in additively manufactured parts using in-situ optical emission spectroscopy for the exemplary hard magnetic Nd-Fe-B-based alloy.

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Metallic Materials for DED Coatings to Enhance the Antibacterial Properties of Ti6Al4V Medical Implants

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Ti6Al4V is widely used for manufacturing bone implants due to its mechanical properties, biological compatibility and favorable corrosion resistance in biological environments. Despite the desirable properties of Ti6Al4V alloy, implants produced through various additive manufacturing or traditional manufacturing processes face challenges such as the release of toxic Al and V ions, which have limited its application. An effective method to overcoming this limitation is surface modification using Directed Energy Deposition (DED) coatings which are particularly suited due to their high surface quality and repeatability. Ti-Cu alloys with compositions similar to that of the substrate are suitable options for improving the hardness as well as providing excellent antibacterial characteristics for the implants surface, which can be useful in preventing post-implantation infections [1-3]. In this regard, in the present study, copper was successfully incorporated into titanium in amounts of 2, 4.5, 7 and 9.5 wt% and demonstrated evenly distributed composition. Testing the bacterial adhesion of *S. capitis* and *E. coli* showed favorable results.

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Processability of Nanoparticle-Coated Powder by Powder Bed Fusion of Metals Using a Laser Beam

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Powder bed fusion of metals using a laser beam (PBF-LB/M) is a widely used additive manufacturing process for the direct production of metallic components from powder feedstock. Increasing the efficiency of the PBF-LB/M process and increasing the build rate are two important topics of current research. In this poster the influence of coating metal powder feedstock with silicon carbide (SiC), silicon (Si), and silicon nitride (Si3N4) nanoparticles in volume fractions of 0.25-1 vol% on the flowability, the laser reflectance and the processability by PBF-LB/M is presented.
The flowability is analyzed using Hall-Flow and a FT4 powder rheometer. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) is used to observe the influence of the coatings on the laser reflectance. The influence of nanoparticle coatings on the processability of the powder feedstock by PBF-LB/M is analyzed by means of consecutive experiments. In a first step, multilayer single tracks (MST) are produced and analyzed with regard to their continuity, the formation of keyhole porosity and their width. Based on the evaluation of the MST, dynamic hatch (DH) samples are produced. With these specimens, multiple hatch distances are produced in one specimen, which enables a time- and material-saving examination of the processability of a powder by PBF-LB/M.
Nanoparticle coatings of the powder feedstock show an improvement in flowability, a reduction in laser reflectance and thus an increased absorption of the supplied energy as well as an increase in the process window in the PBF-L.

Developing 3D-printable Materials based on dynamic covalent bonds – Towards recyclable and self-healing materials

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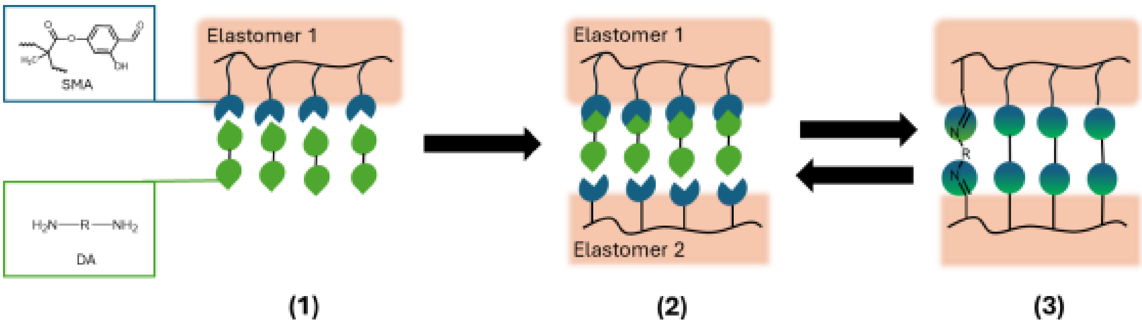
In today's world, sustainability and the efficient use of raw materials are becoming increasingly important. This is especially true in plastics production, because there is a strong emphasis on using materials as efficiently as possible, in the smallest quantities needed. [1] In this context, additive manufacturing (3D printing) proves to be highly effective, as material is typically applied only where it is required. This enables the rapid, simple, and cost-effective production of components. [2] In this study, we demonstrate a 3D-printed elastic material, featuring surface-active functional groups enabling the materials to form dynamic covalent imine bonds, which allows to post-functionalize the materials or provides the ability to self-healing. By employing resin-compatible amine acrylates the surface was amine functionalized. After photo-polymerisation in a commercially available SLA printer the materials properties could be subsequently functionalized by imine-condensation with salicylic aldehydes. The new materials can be varied in their emissive behaviour by chosing the corresponding salicyl aldehyde and may be employed as fluorescent sensors for metal ions in aqueous media. Using resin-compatible salicyl-aldehyde acrylates yielded after 3D-printing surfaces decorated with aldehyde functions. Variations in composition were explored to show tunability in mechanical and adhesive properties. The adhesion process was done in a two-step preparation. First, an aldehyde-containing polymer is activated with a bifunctional diamine (DA), which selectively reacts with the aldehyde groups to form imine bonds, as indicated by strong fluorescence (1). A second sample with aldehyde functionalized surface is then attached, creating a stable dynamic covalent bond bridging the two materials samples (2,3). Mechanical testing reveals that the crosslinked polymer exhibits high elasticity with adjustable stiffness. These material properties can be precisely controlled by varying the temperature. Moreover, the network is recyclable and reusable, thanks to the reversible nature of the dynamic covalent bonds.



Scheme 1: General strategy of adhesion between elastomer surfaces through dynamic covalent bonds

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Bactericidal surface functionalization of PBF-LB/P-printed parts by electrophotographic powder application

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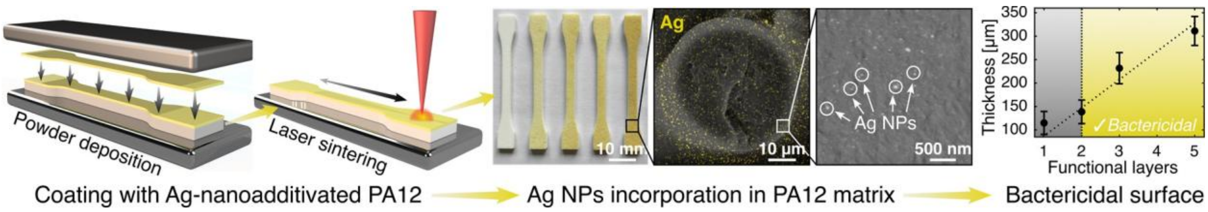
Incorporating minute amounts of nanoparticles (NPs) represents a promising method to tailor the physiochemical properties of polymer powders towards laser beam powder bed fusion (PBF-LB/P) of polymers with additional functionalities. However, strict requirements for powder flowability and size distribution limit the feedstock selection at compromised sustainability due to low nesting efficiencies and recycling rates [1]. To this end, electrophotographic powder application (EPA) is proposed to functionalize the surface of polymeric parts with 100 % powder utilization and targeted functional powder employment. In this study, polyamide 12 (PA12) microparticles are decorated with laser-synthesized silver NPs (0.1 wt%) and deposited in thin layers on bulk PBF-LB/P-printed PA12 parts via EPA, followed by laser sintering to coalesce the microparticles into porous layers.
Two layers corresponding to 140 µm coating thickness suffice to inhibit the growth of Gram-positive and Gram-negative bacteria while the printed parts' mechanical and calorimetric properties remain unaffected [2]. Remarkably, the targeted functional powder employment reduces the required Ag NP loading by more than one order of magnitude compared to recent studies on PBF-LB/P of bactericidal PA12 parts [3]. Moreover, the printed parts exhibit increased UV absorbance due to the preserved plasmonic resonance of the Ag NPs, which is associated with the gentle powder processing of EPA. Besides adding localized functionalities, EPA holds great potential to print multi-material and graded items, as virtually every powder layer could be composed of another material. [2]



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Molecular dynamics simulations of laser-based powder bed fusion

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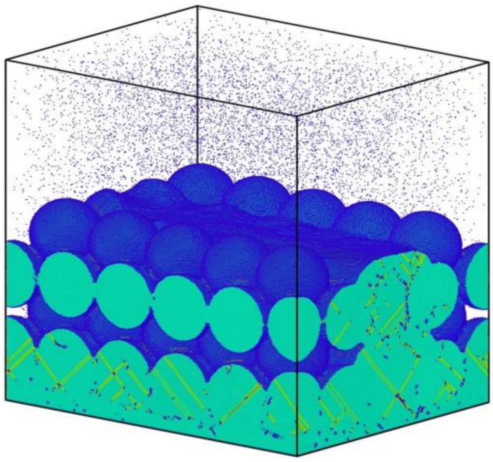
We have built up a framework for molecular dynamics simulations of laser-based powder bed fusion from sample creation, laser irradiation and cooling to testing the elastic properties upon deformation. This allows us to investigate the influence of several laser parameters, such as the laser power and scanning speed as well as the formation and dynamics of defects in the material.

We apply this framework to TiAl alloys in a protective gas atmosphere in different configurations to analyse how the strength of a printed piece made from this material can be improved. In particular, we focus on how structural defects form during and after quenching the sample after laser irradiation and what consequences they have for the structural integrity of a printed piece. Furthermore, we examine how the protective gas influences the strength of the sample due to the formation of inclusions in the material.



Challenges and possible solutions for using NIR laser radiation in polymer powder bed fusion

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The utilization of NIR diode lasers in powder bed fusion of polymers (PBF-LB/P) is accompanied by numerous challenges. The necessity for supplementary absorbers is often emphasized, as pure polymers generally exhibit insufficient absorption of NIR laser radiation. Even at low concentrations, these absorbers can have further unforeseen effects on the manufacturing quality of the produced parts. Furthermore, it is imperative to acknowledge the overarching issues that are prevalent in all powder bed fusion processes, specifically the identification of optimized scan strategies. To study the optical and thermal effects of the absorber on the PBF-LB/P process, polyamide 12 was modified with either CuS or LaB6 nanoparticles. The two nanoparticles were chosen as both have been shown to prevent oxidation of the polymer and thus improve reusability. It was possible to reliably manufacture a range of geometries using PBF-LB/P at 808 nm with these polymer-absorber-mixtures. In addition, our findings indicate that the properties of the nanoparticles have a substantial influence on not only the absorption process but also the resulting crystallinity and geometric accuracy, even when utilizing only a minimal amount of nanoparticles. Furthermore, the research proposes a promising approach for rapidly evaluating different scan strategies to facilitate the search for scan strategies that are optimized for precision, uniform melting and reduced print defects. To achieve this objective, a path length difference between adjacent scan curve points and path density is calculated. It has been demonstrated that this constitutes a useful tool for the prediction of defect positions and localized energy density.

Laser powder bed fusion process for AA8090 Al-Li alloy: generation and characterization of powders and single-track melt pools for process optimization

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Laser assisted powder bed fusion (LPBF) technology exhibits huge potentials not only on the manufacturing of complex structures aiming for light-weight design but also on the development of new materials of novel microstructures for excellent combination of mechanical properties. However, the adoption of LPBF process to Al-based alloys is still challenging and developes relatively slow in comparison with Ti-based alloys and steels. This is closely related to the inherent properties of the Al-alloy powders such as the formation of the surface oxide layer and the poor weldability of some high-strength Al alloys. In the present work, LPBF process using the ultrashort lasers has been for the first time performed on a high- strength Al-Li alloy, AA8090. This includes the generation of powders by the ultrasonic atomisation process, the characterization of the surface oxide(s) by the transmission electron microscope, the single-track LPBF processes with scanning speed covering from 100 to 900 mm/s and laser powers up to 130 W, and the postmortem microstructure analysis of the melt pools. Instead of a homogeneous single Al2O3 layer, formation of multiple alternative Al/Li rich and Mg rich oxide layers on the surface of the powders with thickness up to 60 nm has been observed, in which the Cu-rich precipitates in the matrix of the powder plays a critical role. During the LPBF process, high laser powers above 78W and low scanning speeds contribute to the building of steady single walls. For example, with the laser power of 130 W, steady walls are built with scanning speed up to 800 mm/s; however with a reduced laser power of 78 W, the highest scanning speed for building a steady wall drops to 400 mm/s. The melt pool size varies from 100 µm (78W, 400 mm/s) to 240 µm (104W, 100 mm/s). Restricted by the relative large powder size which is mainly above 100 µm, there are difficulties for building steady structures by the multi-track LPBF process. Further optimization for reduced powder size below 20 µm is undergoing, aiming for improved processibility during the LPBF process.

Development of surface tailored metal powders for increased production efficiency at the laser powder-bed fusion additive manufacturing process

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Additive manufacturing (AM) of metals is primarily used in lightweight construction and prototyping in various industries (automotive, aerospace and medical industries). A frequently used process in the additive manufacturing of metals is the powder bed fusion with a laser beam (PBF-LB/M). In PBF-LB/M, a layer of particles is spread evenly and afterwards selectively melted with a laser. This step is repeated several times, building up the final part layer by layer. Currently, investigations take place to increase productivity using higher laser intensities or the use of multiple lasers, i.e. this leads to a simultaneous increase in investment and operating costs. The approach of this work is to improve the efficiency of the process on the powder side by modifying the metal particle surface with nanoparticles. Previously published results show increased absorption values of the laser beam, better powder flow properties and improved component properties for silicon carbide, silicon and silicon nitride coated stainless steel (1.4404) applied in a fluidized bed [1-4] and graphene applied in a high intensity mixer [5]. An overview of possible coating processes is provided with a focus on wet coating in a fluidized bed and dry coating in a high-intensity mixer. Surface phenomena such as agglomeration, distribution and interparticle distances of nanoparticles on the surface are detected with scanning electron microscope, energy dispersive X-ray spectroscopy (EDX) which are compared with specific surface area (BET) measurements. In addition, conclusions of the coating-induced surface roughness towards a better flowability are provided. Not only conventional flowability measurements but also self-developed measurements at low consolidation stresses, for instance in an insitu-spreadability test rig integrated in a µCT, are presented.

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Laser-based Powder Bed Fusion of highly alloyed Al-Li

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Al-Li alloys have received increasing attention for light-weight applications due to their low density accompanied by a high stiffness. The additive manufacturing of Al-Li is a promising approach regarding the production of high stiffness light-weight components. The conventional processing of Al-Li alloys is still limited to Lithium concentrations below 9 at.%. The fabrication beyond this limit is desirable, because higher Lithium concentrations result in an increased mechanical performance.
Here we present laser-assisted additive manufacturing of binary Al-Li alloy powder with an increased Lithium content of 14 at.%. In contrast to common approaches, an ultrashort pulse laser with a pulse duration of 250 fs at 1030 nm wavelength is used for the powder bed fusion process. By using an average power 150 W at a repetition rate of 32 MHz the fabrication of highly dense Al-Li alloy specimens is demonstrated. However, during laser melting, there is an increased risk in a substantial loss of Lithium due to its low boiling point of 1342°C and the associated Lithium evaporation. Thus, ex situ laser-induced breakdown spectroscopy is performed in order to confirm the high Lithium content of the additively manufactured specimens. Investigations of the mechanical properties and the microstructure are carried out.

Binder-Assisted Additivation for Satelliting Carbides to H13 Tool Steel for PBF-LB Processing

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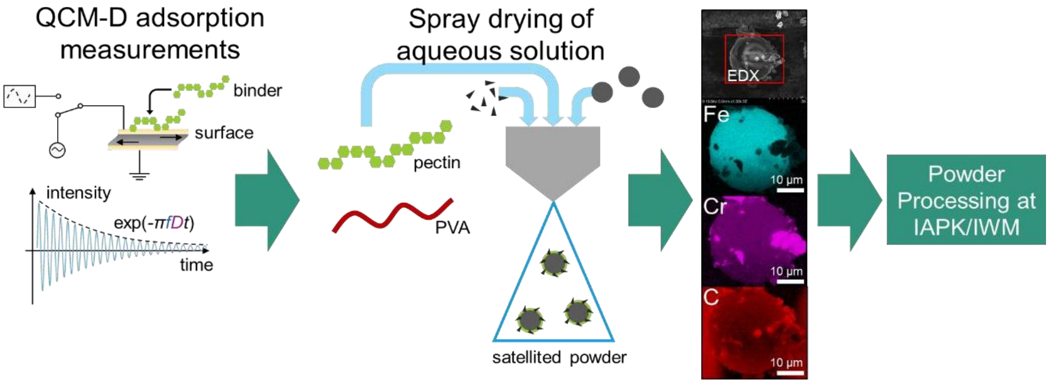
To extend the range of processable alloys for the application in PBF-LB reinforcing the alloys with additives has been proven successful.[1] One possible approach that reduces inhomogeneities based on local demixing effects is called satelliting.[2] This method is used to attach finer particles to the surface of larger parent particles via a suitable bonding agent. In this study, Cr3C2 has been successfully attached to AISI H13 tool steel using this approach with pectin as a functional binder. Pectin itself is a naturally occurring polysaccharide with suitable properties like bio-compatibility, degradability while still being cost-efficient. It offers numerous chemical binding sites that are known to adhere to surfaces such as steel.[3] The work focused on the adsorption of the binder onto the steel and chromium carbide surface characterized via quartz-crystal microbalance with dissipation monitoring (QCM-D), the thermal decomposition analysis (TGA) of the binder. Lastly, the satellited powder feedstock was prepared via spray-drying of the three components: base powder, additive and binder. The findings demonstrate that pectin proves as an effective binder for this method and performed better than a polymer of synthetic origin (PVA). Nevertheless, the alloy exhibited a carbon enrichment, leading to retained austenite. Future work will focus on the improvement of the binder allowing for a reduction of binder to mitigate these negative effects.



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Short-wave infrared thermography as a quality assurance tool for laser powder bed fusion of metals

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The quality assurance of parts manufactured by metal Additive Manufacturing (AM) becomes increasingly vital, especially in safety-critical areas such as the aerospace industry [1]. Powder Bed Fusion with Laser Beam of Metals (PBF-LB/M) is a widely adopted AM process which is strongly characterized by its thermal history. The information contained therein is closely connected to the part quality in terms of flaws and microstructure [2]. Short-wave infrared (SWIR) thermography can capture this thermal history in high spatial and temporal resolution over the entire build process. Although it is a promising tool for quality assurance and material characterization, it is rarely adopted in the scientific and industrial context. Therefore, this study aims to showcase the potential of SWIR thermography by presenting recent results from different use cases that are currently studied at BAM.

In a first use case, hyperspectral SWIR thermography aims to measure real temperatures in PBF-LB/M to quantitatively compare process conditions. The melt pool travels perpendicularly through the 1D measurement line of a SWIR camera equipped with a spectrograph. Through the high framerate (approx. 20 kHz), an effective melt pool is reconstructed. Its spectral exitance is locally measured, using a prior radiometric calibration. From this hyperspectrally resolved exitance, real temperature and emissivity maps are reconstructed using methods of temperature emissivity separation. Secondly, a SWIR thermography approach is presented which utilizes Machine Learning (ML) to predict local porosity within the bulk of manufactured parts. The developed ML method inherits algorithms for feature extraction and the inclusion of flaw formation physics during sample preparation. The porosity level of small, discrete subvolumes is predicted with high accuracy for process-induced and random flaw types. In a third use case, on-axis high speed SWIR thermography is studied for melt pool monitoring and precise measurement of the melt pool dimensions. Compared to the visual spectrum, SWIR cameras capture enhanced thermal information concerning the phase transformation and melt pool shape. The data obtained is therefore particularly suitable for the validation of numerical melt pool simulations, which is shown in an initial study. The presented results demonstrate that SWIR thermography can provide critical information for assuring the quality of printed parts and obtaining important insights into the process physics.

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A Novel Route for Additive Manufacturing of High-Nitrogen Steels: Static and Dynamic Mechanical Properties

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Additive manufacturing is gaining increasing importance in various industrial sectors like aerospace, medical, or chemical industries , with laser-based processes achieving significant market growth. This is primarily due to an one-step process, near-net-shape production of components, and favorable mechanical properties of the fabricated parts. However, a current limitation of this process lies in the restricted selection of materials and material systems that have been comprehensively investigated.
This study explores the combination of powder bed fusion-laser beam melting (PBF-LB/M) with a subsequent pressure-assisted heat treatment (HIP) to produce highly nitrogen-alloyed austenitic steels from powder mixtures. The mechanical properties of the resulting materials were characterized with respect to both static and dynamic parameters. As reference materials, conventionally manufactured solid material and HIP samples from the same powder mixture were analyzed. The results demonstrate a positive influence of nitrogen content on hardness, tensile strength, and long-life fatigue of the additively manufactured steels. Furthermore, it was shown that the particle size distribution of the powder affects both the resulting grain size and defect structure. While finer powders lead to smaller inclusions, they simultaneously result in a coarser grain structure.

Designing 3D Printed TiO2 Structures for Enhanced Acyclovir Degradation via TiO2/BiFeO3 Heterojunction

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Heterogeneous photocatalysis (HPC) with TiO2 nanoparticles is a promising method to degrade pollutants from wastewater [1]. However, nanopowder recovery in wastewater treatment requires costly sedimentation or filtration technologies. An emerging, economical solution to this is the 3D printing of TiO2 structures [2]. Nevertheless, TiO2's large band gap restricts its application to UV light. In contrast, the combination of TiO2 with BiFeO3 enables activity under sunlight, which makes the catalytic degradation more cost-efficient and more applicable [3].
In this study, novel 3D-printed porous nanocomposites of TiO2 and BiFeO3 with relatively high surface area have been synthesized using two distinct methods. One method involved creating a combined ink of TiO2 and BiFeO3 nanoparticles for the direct ink writing (DIW) technique, while the other method coated BiFeO3 nanoparticles onto a 3D-printed TiO2 surface. The photocatalytic performance of all samples besides the 3D-printed pure TiO2 was evaluated for the degradation of Acyclovir as a pharmaceutical pollutant model. The degradation was investigated under two different light sources: a medium-pressure Lamp (150W), which is more active in the UV region, and a blue (420 nm) LED lamp (6W). The photocatalytic efficiency of the samples was compared based on their electric energy consumption. The BiFeO3-embedded TiO2 sample achieved the highest performance, with 98.4% degradation in 3 hours under a Hg lamp and 55.3% in 6 hours under a blue LED lamp. The reusability test for the degradation of Acyclovir over four cycles under both lamps showed good stability demonstrating significant potential for practical applications.

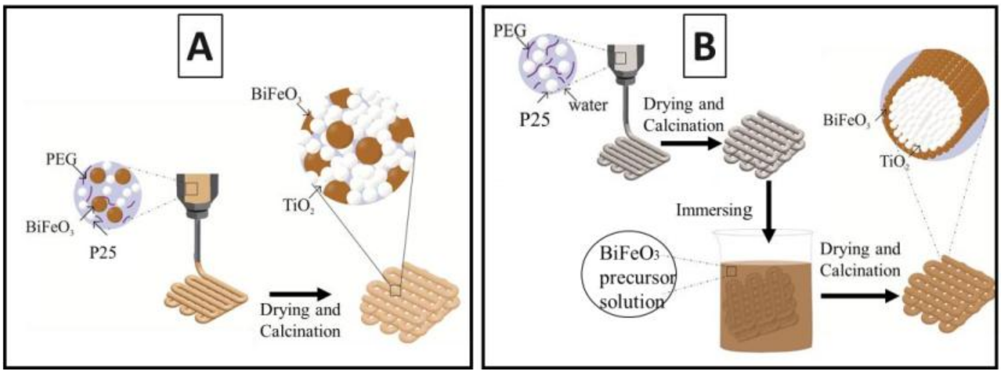

Figure 1: Schematic Illustration of the synthesis processes by employing two distinct methods for obtaining 3D printed nanocomposite of TiO2-BiFeO3 A) Embedding synthesized BiFeO3 nanoparticles into a TiO2 ink mixture for direct 3D printing, B) Coating a 3D-printed TiO2 structure with BiFeO3 layers after calcination

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Impact of Zirconium Oxide Nanoparticle Synthesis Method and Dispersion on the Microstructural and Mechanical Properties of Additively Manufactured Fe20Cr ODS Alloys

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As the demand for high-performance materials for advanced propulsion systems and energy generation technologies, such as nuclear fusion, grows, the development of metal-ceramic composites becomes increasingly important. Oxide Dispersion Strengthened (ODS) steels, which contain nano-scaled oxide particles dispersed in a corrosion-resistant steel matrix, show considerable potential due to their high-temperature strength and outstanding mechanical properties.[1] This study focuses on the role of ZrO2 nanoparticles (ONPs) in ODS Fe20Cr alloys produced by Powder Bed Fusion-Laser Beam (PBF-LB) [2]. It compares laser-generated ONPs, produced by laser ablation in liquids (LAL), with those synthesized through a chemical process in terms of size, morphology, and distribution [3]. The central hypothesis is that smaller, uniformly distributed ONPs will significantly improve the mechanical performance of ODS steels, especially at elevated temperatures. Additionally, various methods of powder preparation are explored to assess their impact on the dispersion of ONPs and their integration into the metallic matrix [4]. The synthesis of ONPs using LAL is studied in detail to understand better how NP characteristics—such as crystal structure and size—affect the final microstructure and mechanical properties. The research shows that ONPs contribute to grain refinement, hardness enhancement, and overall material strength, but excessive loading can cause agglomeration and porosity, which reduces material performance. Multiple analytical techniques, such as electron microscopy and X-ray fluorescence, are used to address challenges related to ONP incorporation and distribution during the AM process. This work enhances the understanding of NP behavior in AM-processed ODS alloys and provides critical insights into optimizing NP size, distribution, and synthesis to maximize their strengthening effects via mechanisms such as grain boundary pinning and the Orowan effect, ultimately aiding the development of high-performance materials for extreme applications.

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Design and Qualification of Pr–Fe–Cu–B Alloys for the Additive Manufacturing of Permanent Magnets

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Rare earth-based permanent magnets are essential in propelling the transition towards e-mobility, serving as a critical component in electric motors. However, the complex geometries often required for these magnets lead to substantial material waste when produced using conventional methods, as they necessitate machining to achieve the desired shape. In contrast, Additive Manufacturing (AM) presents a promising alternative, allowing for the creation of complex, fully dense, and functionally graded magnet geometries with minimal material loss [1].
The application of the Laser Powder Bed Fusion (PBF-LB/M) technique for the fabrication of Nd-Fe-B magnets is still in its early stages, encountering challenges in achieving fully dense magnets with high coercivity. This process often results in the re-melting of powder, which can form undesirable microstructural features that compromise coercivity. In this study, we demonstrate the development of an optimal microstructure that enhances coercivity in Pr21Fe73.5Cu2B3.5 and Nd21Fe73.5Cu2B3.5 alloys, exploring a potential method for fabricating fully dense permanent magnets via the PBF-LB/M process [2,3]. Our approach includes: (i) a suction casting technique that achieves a cooling rate similar to PBF-LB/M while requiring minimal powder for adjusting composition and microstructure prior to large-scale experiments;
(ii) conventional PBF-LB/M processing using kilograms of powder; and (iii) a subsequent annealing treatment analogous to conventional sintering. The heat treatment is crucial for achieving high coercivity by forming an optimal microstructure: hard magnetic (Nd,Pr)2Fe14B grains within a matrix of intermetallic (Nd,Pr)6Fe13Cu phase [3]. The final PBF-LB/M printed Pr21Fe73.5Cu2B3.5 samples exhibit a coercivity of 0.75 T.

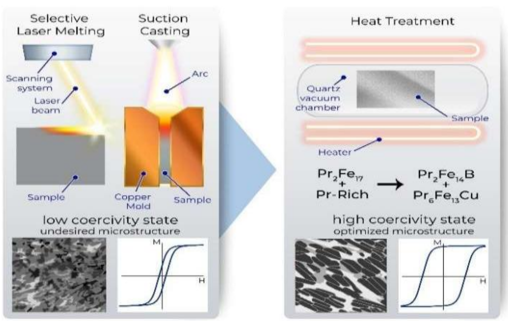

Figure 1: Schematic Representation of the scientific idea.

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Functional Properties of Additively Manufactured Magneto- and Multicaloric Materials over the Entire Processing Chain

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Cooling and refrigeration consume 20% of global electricity and 8% of emissions, necessitating eco-friendly alternatives to inefficient vapor compression technology. Magneto- and multicaloric materials like Gd and Ni-Mn-based Heusler alloys are potential materials for alternative solid-state cooling technology [1]. However, their use for application is often limited by their brittleness and the challenges in shaping and scaling. Additive manufacturing (AM) solves these problems by allowing the creation of complex structures that optimize thermal exchange and magnetic responsiveness, overcoming significant challenges in developing high-performance magneto- and multicaloric regenerators. Furthermore, laser powder bed fusion (PBF-LB) and direct energy deposition (DED), facilitate the development of textured or columnar grain structures, which can significantly enhance the mechanical stability of Heusler alloys [2].

This study explores the functional properties of Ni-Mn-Sn across the entire processing chain, from initial powder to fully processed components. We use AM techniques such as laser powder bed fusion (PBF-LB), direct energy deposition (DED), spark plasma sintering (SPS), and hot compaction for precise microstructure and intricate geometric structure design. By controlling particle size, process parameters, and microstructure, we can tailor the first-order magneto-structural transition (FOMST) characteristics.
We also used Gd as a magnetocaloric benchmark material to investigate the use of geometrically optimized thermal heat exchangers in a magnetocaloric device.
The work is funded by ERC (Adv. Grant "CoolInnov"), the Deutsche Forschungsgemeinschaft (DFG) CRC/TRR 270 "HoMMage" and 52721505, and LOEWE 3 Project „OptiKal“.

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Dimensionless Investigations on Energy Conversion and Analysis of Inter-Layer Time in Laser-Based Powder Bed Fusion of Polymers for Polypropylene

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Additive manufacturing (AM) offers design freedom and cost-effective production of complex parts. Powder bed fusion of polymers using laser beam (PBF-LB/P) is one of the most industrially relevant plastic AM techniques. Although the industrial importance of PBF-LB/P is steadily increasing, the range of materials available is very limited. This study combines material and process data to determine the energy conversion using dimensionless parameters. Further expanding previous investigations [1] on PA12 and PP, PP monolayers with different energy inputs are printed and their thickness is measured. The process is described by a dimensionless energy input value and an energy demand value to characterize the energy conversion during processing, considering important material and process parameters. Based on these printing trials and considerations, suitable process parameters are predicted. Tensile tests are performed to verify the finding of suitable printing parameters. Furthermore, multilayer experiments are carried out to replicate the printing process in an application-oriented experiment. The influence of the inter-layer time (ILT) on the resulting part properties is analyzed. Experiments and numerical models were developed to study the stepwise thickness increase of the first ten layers and density of multilayer samples. The results demonstrate increasing density with higher ILTs, which is in accordance with the simulation predictions.

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A data-driven predictive framework for predicting tensile properties of aluminum alloys for laser powder bed fusion process

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The rapid solidification and unique thermal gradients inherent to the laser powder bed fusion (LPBF) process limit the suitability of conventional aluminum (Al) alloys, necessitating the optimization of existing alloys or the development of new compositions to achieve the desired tensile properties while ensuring good processability. Experimental exploration of alloy compositions is labor-intensive, costly, and time-consuming. Machine learning (ML) offers a cost- effective, flexible approach to streamline alloy design and accelerate advancements in AM technologies. This study introduces a data-driven predictive framework for predicting tensile properties of Al alloys for LPBF. To address the limited data on LPBF of Al alloys and the restricted range of alloy systems investigated, data of conventional Al alloys (including cast and wrought alloys) and laser-directed energy deposition (LDED) built Al alloys were also included, alongside LPBF data. The dataset incorporates a comprehensive pool of features such as alloy composition, processing parameters, grain size, and elemental properties. The Pearson correlation coefficient (PCC) with feature importance-based feature selection was implemented to balance model complexity and accuracy via reducing the dimensionality and overfitting. The resulting ML framework demonstrates excellent predictive accuracy and generalizability, successfully extending its applicability to unseen alloy systems. This framework offers a reliable tool for optimizing Al alloy designs, significantly reducing reliance on costly experimental trials. The inclusion of Explainable AI provided detailed interpretability, elucidating the influence of individual features on model predictions, ensuring the predictions were scientifically grounded.

Optimizing rare-earth hard magnets: Enhancing Density and Coercivity through a Synergistic Application of Laser Powder-Bed Fusion and Nanoscale Tuning

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Permanent magnets are essential for several applications, including power generation, electromobility, and robotics. However, their dependence on rare-earth (RE) elements poses significant challenges due to their high cost and limited availability. Laser powder bed fusion (PBF-LB) has emerged as a promising approach for the additive manufacturing of complex-shaped permanent magnets by offering high geometrical flexibility and material efficiency. Unlike conventional manufacturing techniques, PBF-LB allows near-net-shape production, minimizing RE material consumption by reducing material waste and enabling precise control over microstructure, which is crucial for optimizing magnetic properties. However, achieving high part density remains challenging due to the inherent rapid solidification in PBF-LB. High cooling rates can lead to crack formation, insufficient densification, and microstructural defects such as grain coarsening and inhomogeneous phase distribution, ultimately reducing both the mechanical strength and coercivity of as-built parts.To resolve these challenges, this study systematically investigates process parameters to optimize part density and coercivity. In addition, the surface of the Nd-Fe-B-based feedstock was modified with nanoparticles (NPs) [1,2]. The contribution of, e.g., Ag-NPs can improve thermal conductivity during laser exposure, promoting more uniform melting and densification of the powder bed [1]. Additionally, their presence at grain boundaries can refine grain growth and, thus, the microstructure development (Fig. 1a, b), which can contribute to an increase in coercivity (Fig. 1c). A finer grain structure is known to enhance coercivity, further improving the magnetic performance of the printed parts [1,2].This study covers the entire process chain, from NP-synthesis via pulsed laser fragmentation in liquids [3] to nano-modified magnetic powder and the characterization of printed magnets. The findings demonstrate how targeted nanomodification can enhance both mechanical and magnetic properties, enabling more efficient processing of RE-based feedstocks in PBF-LB. By simultaneously improving material strength and coercivity, NP modification offers a pathway to high-performance permanent magnets with reduced RE content.

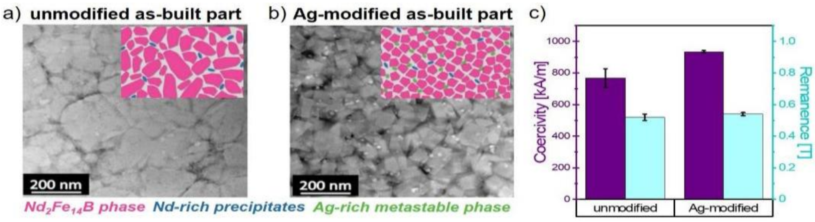

Figure 1: Schematic Representation of the scientific idea.

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Laser powder bed fusion of iron contaminated Al-Si alloys: Effects on processing, hardness and electrical conductivity

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Aluminum-Silicon alloys are widely popular for their lightweight and thermal conductivity. However, the presence of iron contamination is a hindrance towards recycling these alloys, as the formation of brittle Al-Si-Fe intermetallic phases. Laser Powder Bed Fusion (PBF-LB), a high-cooling-rate process, offers a potential solution by mitigating the formation of these detrimental phases. In this study, AlSi10 and AlSi20 alloys with iron concentrations varying from 0% to 7%wt were successfully processed using the PBF-LB process. The results demonstrate that varying iron content significantly influences the process window without crack formation within the alloys. Even at iron concentrations up to 7%, which clearly exceed the definition of contamination, only small Fe-rich phases were observed. Additionally, the presence of iron leads to an increase in hardness and a reduction in electrical conductivity.

Impact of Iron Contamination on Liquid Properties and Microstructural Evolution in AlSi10 and AlSi20

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Additive manufacturing processes enable highly flexible and scalable shaping while maintaining rapid solidification processing conditions. This combination makes additive manufacturing particularly attractive for recycling contaminated alloys, as it allows critical brittle phases to be refined and utilized as alloying elements. However, little is known about the impact of contaminants on the fluid properties of liquid metals. Herein, thermodynamic modeling and experimental methods are combined to investigate the properties of AlSi10 and AlSi20 and their contaminated variants with different degrees of Fe. The oscillating droplet method is used to experimentally determine surface tension and analyze solidified droplets to evaluate microstructure for different cooling rates. The findings indicate that while contaminants have a minor effect on fluid properties, they significantly influence microstructural properties.

Preparation and Thermal Modification of Disentangled UHMWPE particles for Powder based Additive Manufacturing

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Polymerization of ethylene at 5 bar pressure by a supported bisimine pyridine iron dichloridecatalyst yields round particles with a broad distribution but good flowability of disentangled ultrahigh molecular weight polyethylene (dUHMWPE). The catalytic support was obtained by treating spray dried silica particles with trimethyl aluminum and subsequently with the iron complex. High activity was generated by heating the loaded support to 50 °C. The prepared dUHMWPE powder had a bulk density of 0.26 g/mL. Thermal analysis, comprising fast and slow heating, holding and cooling procedures showed that the initial high state of disentanglement is not lost on melting and that crystallization from the melt basically reestablishes this state. Thermal treatment at 110 °C of the powder was possible without loss of the low viscosity to yield more compact particles (0.30 g/mL). Injection molding of dUHMWPE and thermally treated dUHMWPE was readily achieved. The ultimate tensile strength of the dUHMWPE was 30 MPa at 225 % strain; the treated dUHMWPE exhibited an ultimate tensile strength of 30 MPa at 100 % strain. Laser sintering experiments of the dUHWMPE powder along the directed energy deposition technique gave a dense cohesive surface: small hatch distances and longer pulse durations are favorable parameter.

Impact of Sensitizer Distribution on Polymer Processing in Diode Laser Powder Bed Fusion

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Laser powder bed fusion of polymers (PBF-LB/P) has conventionally relied on CO_2 lasers due to their strong absorption by standard polymer powders at 10.6 µm. However, diode lasers operating in the near-infrared (NIR) range present significant advantages, including higher energy efficiency, compact machine designs, and advanced beam shaping. Despite these benefits, most commercial polymer powders exhibit low NIR absorption, necessitating modification with sensitizers to enable efficient laser energy deposition and reliable layer bonding. This study systematically investigates how the distribution of NIR sensitizers—either embedded within the polymer volume or deposited on the particle surface—affects processability and part properties in PBF-LB/P.[1] By integrating feedstock preparation, laser processing, and part characterization, we assess key parameters influencing material behavior. Dark-field microscopy and mechanical testing reveal how the localization of sensitizers impacts layer bonding, powder aging, and mechanical performance. Additionally, differences in thermal management between volume- and surface-modified powders areevaluated to elucidate the effect of energy deposition patternson sintering dynamics. A key aspect of our approach is the absorption-normalized comparison, ensuring that differences in processing and material behavior are directly attributed to sensitizer distribution rather than variations in overall absorption. The findings highlight the advantages and trade-offs of each modification strategy, providing insights into rational powder design for NIR-based PBF-LB/P. The results demonstrate that surface modification offers enhanced energy control and reduced powder aging, while volume modification ensures homogeneous absorption but may introduce overheating challenges. These insights are essential for optimizing polymer powders for diode laser PBF-LB/P, paving the way for more energy-efficient and precise additive manufacturing.

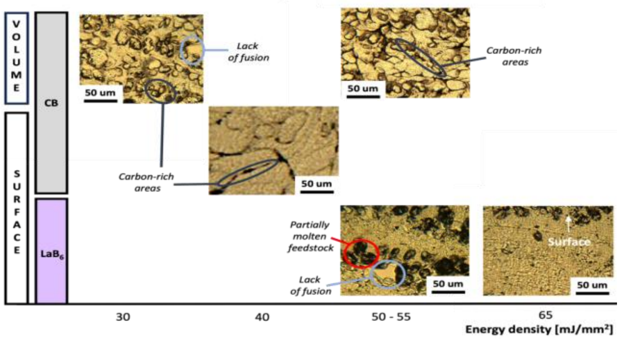

Figure 1: Dark field microscopy images of thin cross-sections from PA12 samples modified with carbon black (CB), lanthanum hexaboride (LaB6), and commercially available black PA12. These images showcase the variations in morphology and NP distribution within the polymer matrix.

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Large-Scale Interlaboratory Study along the Entire Process Chain of Laser Powder Bed Fusion: Bridging Variability, Standards, and Optimization Across Metals and Polymers

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Laser Powder Bed Fusion (PBF-LB) is a key additive manufacturing technology for metals and polymers, yet achieving reliable process robustness remains a challenge. A fundamental understanding of the interactions between feedstock properties, process conditions, and final part characteristics is essential for optimizing material performance and manufacturing outcomes. This study presents the results of a large-scale interlaboratory investigation, conducted by 32 research institutions using 20 PBF-LB machines, evaluating six distinct feedstocks, including nanoparticle-modified aluminum alloys and polyamide powders, under standardized protocols.
A structured analysis of 69 powder properties, 15 process parameters per print job, and 78 part characteristics resulted in a dataset of over 1.2 million correlations. Applying advanced statistical methods and machine learning, we identified key drivers of process variability, including the influence of nanoparticle modifications on powder flowability, thermal conductivity, and melt behavior, as well as the impact of processing conditions on part integrity. Furthermore, newly introduced dimensionless figures of merit provide universal metrics for evaluating thermal and mechanical interactions, enabling predictive modeling of PBF-LB process stability and material compatibility.
This study delivers critical insights into nanoparticle-modified feedstocks and their role in enhancing powder-process compatibility. The findings, supported by an open-access FAIR dataset, contribute to a deeper understanding of material-process-structure-property relationships and set a benchmark for future research. By systematically linking feedstock engineering to process robustness, this work paves the way for optimized and tailored materials materials in additive manufacturing.

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Boosting Coercivity of 3D Printed Hard Magnets Through Nano-Modification of the Powder Feedstock

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Laser Powder Bed Fusion (PBF-LB) has gained significant attention for manufacturing complex metallic components with high precision. However, applying PBF-LB to functional materials such as permanent magnets introduces additional challenges: the rapid solidification leads to grain coarsening, and phase inhomogeneities, all of which negatively impact magnetic performance.[1] Unlike structural materials, where densification is the primary objective, in magnet manufacturing, microstructural control at the nanoscale is key to optimizing coercivity. To address these challenges, we investigate the nanoparticle modification of Nd-Fe-B feedstocks as a strategy to influence the laser-material interaction during printing. Specifically, Ag nanoparticles (Ag NPs) are introduced to the powder surface (Fig. 1a), which has been reported to improve the intergranular Nd-rich phase, leading to an enhanced magnetic decoupling of hard magnetic grains and increased coercivity.[2] Ag additions have also been shown to improve the fracture toughness of Nd-Fe-B magnets and contribute to a higher packing density in the powder bed, which can positively influence the final part density and magnetic performance.[3] In our study, we achieve a coercivity increase of up to 17% (935 ± 6 kA/m), attributed to refined grain structures and improved intergranular phase formation (Fig.1b,c).[4] A systematic parameter study explores the interplay between laser processing parameters— including energy density, scan speed, and hatch spacing—and the nanoparticle-induced modifications. Our results establish nano-modification as a powerful approach to tailor feedstock properties for functional materials in PBF-LB. By demonstrating how material engineering and laser process optimization can be combined, we provide a pathway to enhance the applicability of PBF-LB for high-performance permanent magnets and other functional materials beyond conventional structural applications.

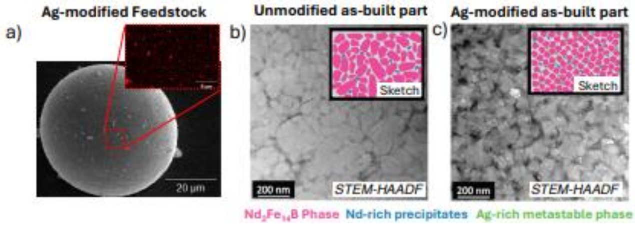

Figure 1: Figure 1 a) SEM image of a commercially available Nd-Fe-B microparticle, surface modified with laser-generated, surfactant-free Ag NPs. STEM-HAADF image and schematic representation of the microstructure of printed parts (VED: 71.5 J/mm³), b) unmodified, and c) Ag-modified. (All Taken from REF 4)

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