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Laser Powder Bed Fusion of Polymers

Motivation

Additive Manufacturing (AM) techniques enable the production of highly complex and functional polymer parts, (Fig. 1). Laser powder bed fusion of polymers (LPBF-P) is one of the most promising AM techniques as comparatively high contour accuracy and mechanical properties can be achieved (Fig. 2). Due to the complex thermal process interactions, expanding the range of available materials and enhancing the reproducibility of functional part generation are the key challenges and therefore research topics of the Institute of Polymer Technology (LKT).

Application

Initially, LPBF-P was predominantly applied for prototyping applications. In recent years, technological developments enabled the manufacturing of components for a variety of economic sectors such as medicine, automotive, aviation and aerospace. In these disciplines, either a high degree of individualization or structural light-weight design are of particular importance. The latter can either be achieved by the generation of highly complex geometric structures such as anisotropic lattices or the use of functional fillers for tailoring the material properties according to the requirements of the desired applications. Material adaptions can be achieved by the use of additives, fillers or polymer blends. Different mixing strategies such as dry blending or in-particle filled systems (Fig. 3) are commonly applied.

Fig. 1: Parts prepared by different AM techniques: fused filament fabrication, LPBF-P and stereolithography

Fig. 2: Processing of polyamide 12 filled with 15 vol.-% copper beads via LPBF-P

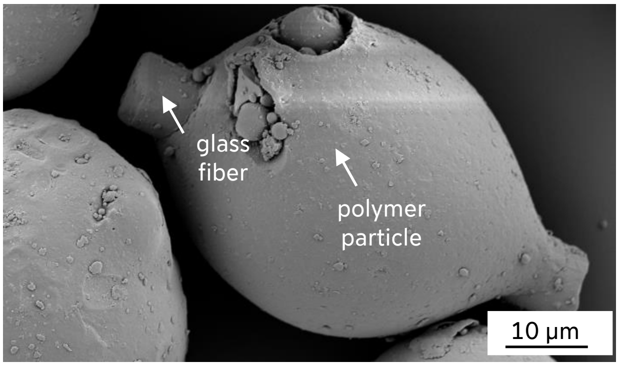

Fig. 3: Tailored powder system: Glass fiber filled polypropylene particles for LPBF-P

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Research focus

In LPBF-P, diverse research foci are pursued in multifaceted projects, starting from powder material through the manufacturing process to the functionalization of part properties. Method development for incoming powder inspection, process adapted material characterization and the implementation of new material systems represent research topics in the scope of the LKT. In-situ and ex-situ process analysis is performed for developing new process strategies that aim for process acceleration, enhanced sustainability in the use of powder materials or improved reproducibility of part properties.

Main research results

In recent years, a variety of insights have been gained at the LKT, including considerable advances in the resource-saving management of process powders, the fundamental understanding of part aging, the development of ground breaking processing strategies and novel monitoring approaches (Fig. 4). Analytical and machine learning-based process optimization is vital for understanding fundamental mechanisms of part generation.

With regard to innovative, modified and functionalized materials, the impact of exposure strategies (Fig. 5), part packing or part orientation becomes more relevant. Especially concerning thin walled parts, the thermal history is of significant importance.

Recent research focuses on a new low temperature LPBF-P process (Fig. 6), that allows for significantly reduced build chamber temperatures. For polyamide 12, a temperature decrease of more than 100 °C relative to the standard process is possible. This can greatly reduce material aging, enhancing the reusability of polyamide 12 powders. Furthermore, thermosensitive materials could be processed.

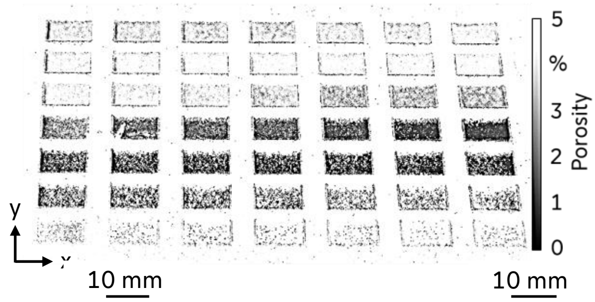

Fig. 4: Deep learning-based inline monitoring of the LPBF-P process

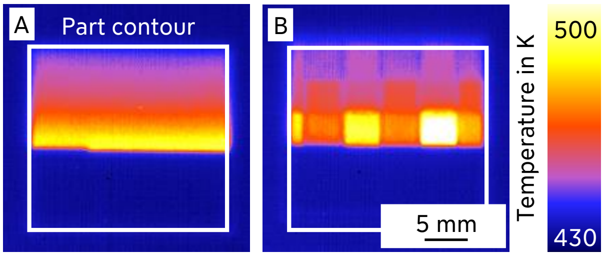

Fig. 5: Thermographic mappings of different exposure strategies:
A) meander strategy
B) segmented strategy

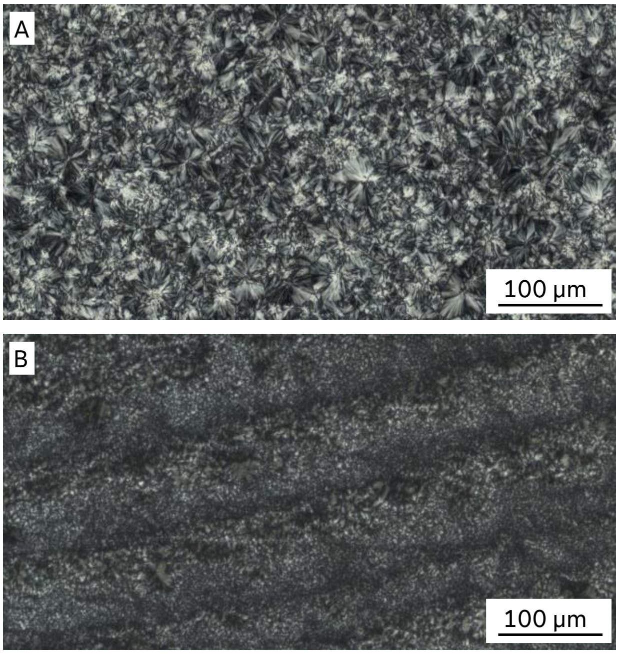

Fig. 6: *Morphology of LPBF-P parts under polarized light:*
A) standard process
B) low temperature LPBF-P

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