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Additive Manufacturing

Barcode zu Ansprech-partner und Infomaterialien

Motivation

Additive Manufacturing (AM) allows for the fabrication of highly complex geometries and individualized products and is an important method for future innovations. No tools are required to create functionally integrated assemblies. For establishing and strengthen the method in serial production, reproducibility, process robustness and the range of available material systems for advanced part properties have to be enhanced. Fused layer modeling (FLM) and selective laser sintering (SLS), representing methods for creating technical parts, are research objects at the Institute of Polymer Technology (LKT) with the focus on material development, material characterization, process analysis and optimization, tailored part properties and functionalization.

Fused Layer Modeling

Hybrid processes combining additive and subtractive processes (Fig. 2) with inserting operations and the integration of continuous semifinished products (fibers, cables) are of huge interest to enable individualized and functionalized products . In FLM, which is extrusion-based additive manufacturing, thermoplastic material is plasticized and deposited along a specified path through a nozzle on a heated build platform. Layers that have already been deposited are bonded to the newly deposited strands due to the local and temporary heat input. Hybrid additive manufacturing represents one of the focuses at the LKT, enabling the production of multi-material components.

Due to the material-specific properties of semi-crystalline thermoplastics, the fundamental process analysis is an important area of LKT research. The understanding of bond formation and crystalline structures across the interlayer surfaces provides the basis for new process strategies and material modifications. Therefore, the temperature development (Fig. 3) is investigated and specifically adjusted during processing for the correlation with thermal and rheological behavior of the raw materials and the resulting part properties (Fig. 4). Based on the specific require-ments, the raw materials for melt extrusion manufacturing can be tailored by compounding via twin-screw extrusion, rendering the process suitable for a wide range of applications.

Up to now, the material has mostly been supplied as filament, which is then plasticized in a heated nozzle. However, in the past few years, the use of conventional screw extruders has been accelerated and not only the diversity of materials has increased, but also the boundaries have been pushed towards the production of big parts.

*Fig. 1: Parts prepared by different additive manufacturing technologies, available at the LKT
From left to right: fused deposition modeling, selective laser sintering with filled material, selective laser sintering, stereolithography*

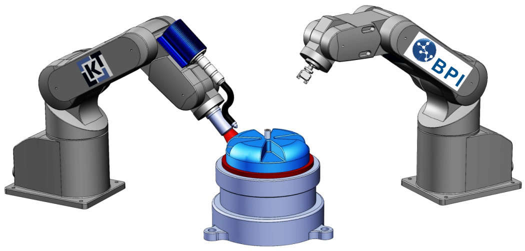

Fig. 2: Hybrid additive manufacturing cell for the fabrication of highly individualized and functionalized parts

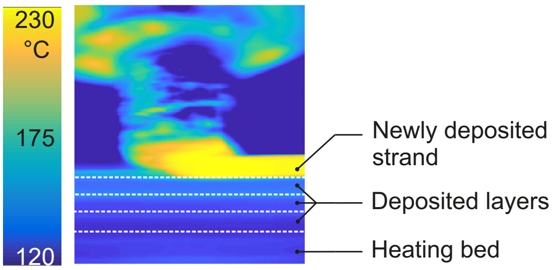

Fig. 3: Heat input through newly deposited strands

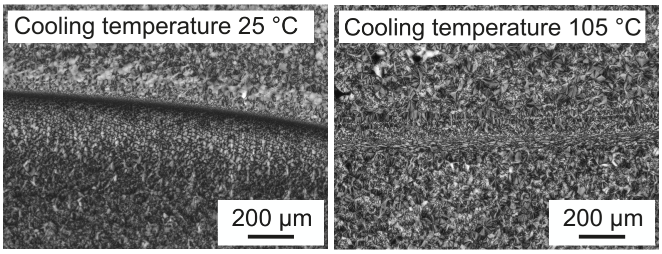

Fig. 4: Crystalline structures across the interlayer of polypropylene with different processing settings

Selective Laser Sintering – Materials

SLS is one of the most promising AM technologies, as comparatively high contour accuracy and mechanical properties can be achieved. Thin powder layers are applied by a coating mechanism and 3D structures are created by melting polymer powder selectively by a laser (Fig. 5). To boost this technology from mere prototype to series production, the fundamental analysis of the complete processing route ranging from material development over process analysis to part characterization and functionalization is in the scope of the LKT.

For the qualification of new materials, like multiphase systems, potential polymers need to exhibit certain time- and temperature-dependent properties. Conventional standardized analysis methods do not fulfil the requirements to characterize the materials' performance, as during laser exposure the material undergoes rapid and high temperature changes. Therefore, e. g. a Laser-High-Speed-DSC has been implemented to analyze the impact of high heating rates during laser energy input and to predict process parameters. To increase the selection of processible powder materials, filled systems and polymer blends are an important research topic at the LKT. The main focus lies on investigating the effect of filler materials and different blend component contents on the processing behavior (Fig. 6a). Besides the conventional route to use physical dry-blend mixtures new mixing strategies for filled systems, where fillers are integrated into the polymer particles (Fig. 6b), lead to a higher process robustness. Prior to their fabrication, the polymer powders are characterized in relation to process-relevant properties like thermal, rheological or optical behavior.

Selective Laser Sintering – Process and Parts

Process analysis and optimization is necessary to enhance the understanding of the part generation mechanisms and reach defined part properties. Especially with regard to innovative, modified and functionalized materials, new processing strategies, such as new exposure strategies (Fig. 7), need to be established. A main focus of the work at the LKT is to correlate powder properties and processing parameters to resulting component characteristics with the goal of generating parts with the highest level of reproducibility for serial production. Therefore, a fully parameterizable SLS system is decisive to generate a basic understanding of the complex interrelations between the subprocesses of powder coating, laser exposure and material consolidation. For guaranteeing powder reusability and optimum process settings, a powder quality management system is established. Material aging (Fig. 8) has to be taken into account, as it significantly alters the resulting part properties. The reproducibility of part properties when reusing powder can be enhanced by an empirical aging model based on aging mechanisms and powder properties, such as rheological and thermal properties.

As the last link in the process chain, functionally integrated parts are object of research for enhancing part properties. By the integration of filler materials or additives, increased thermal conductivity, mechanical stiffness or additional functionality, such as metallization or flame protection can be achieved. Part properties, such as crystallinity, porosity, surface roughness and the mechanical properties vary compared to standard polymer processing techniques. Fundamental findings concerning long term properties allow for the penetration of new application fields such as tribology or medical technology.

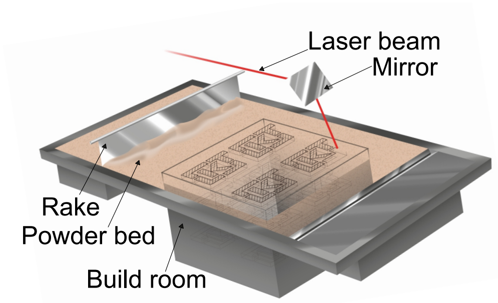

Fig. 5: Schematic depiction of the selective laser sintering process

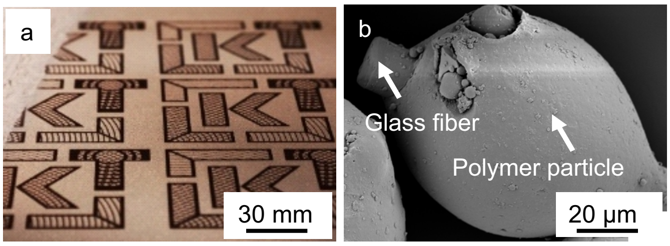

Fig. 6: a) Part fabrication of Polyamide 12 filled with 15 vol.- % copper
b) Particle-filled system

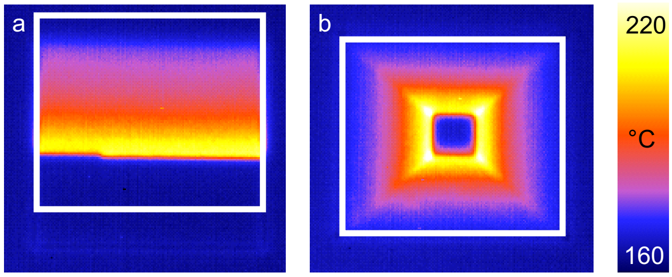

Fig. 7: Thermographic mappings of different exposure strategies
a) Meander strategy,
b) Spiral strategy

Fig. 8: Photography of PA 12 tensile bars at different aging stages for the determination of longterm properties; storage temperature: T = 140 °C, from left to right: 72 h, 168 h, 336 h and 672 h

Research Objects and Service for Industry

- Liquid, Filament, Powder-based Additive Manufacturing
- Development of New Powders and Photopolymer Formulations
- New Processing Strategies
- Process-Adapted Material Characterization
- Processing Trials on Open Manufacturing Plattforms
- Failure Analysis of Additive Manufactured Parts

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