FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

MATERIAL DEVELOPMENT FOR ADDITIVE MANUFACTURING

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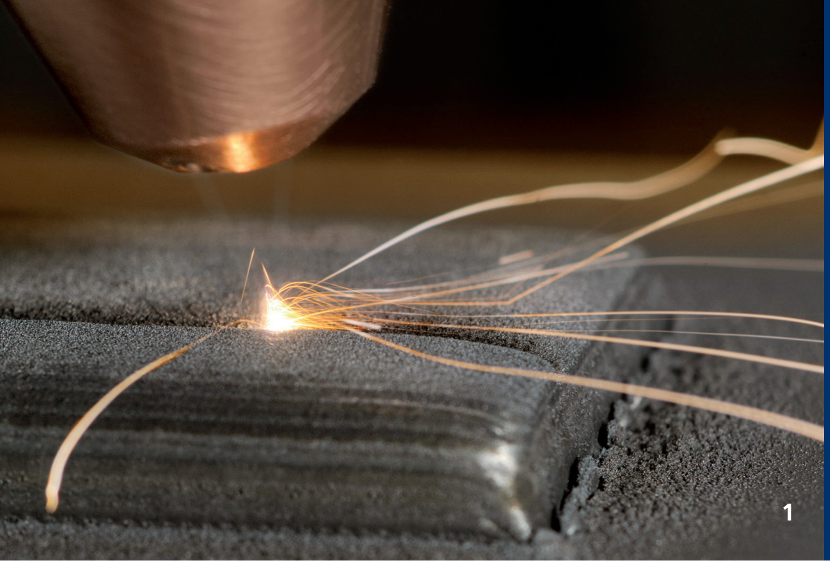
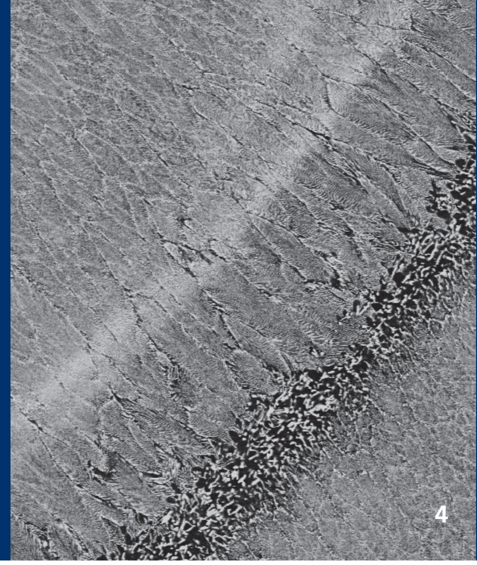
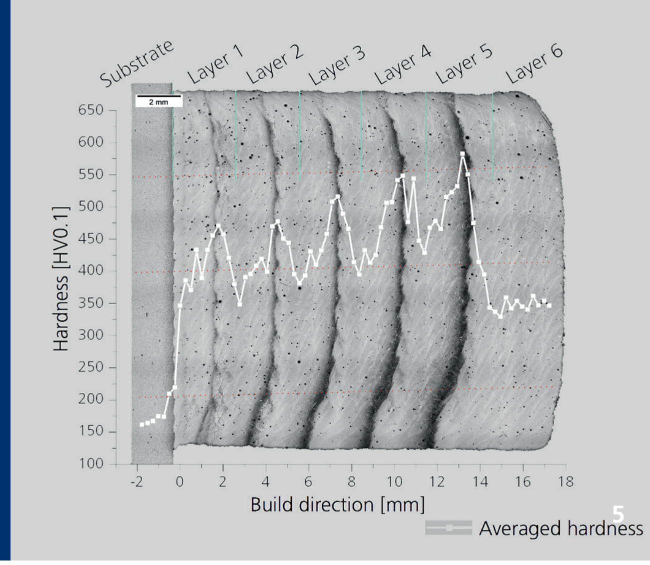
Fraunhofer Institute for Laser Technology ILT

The Fraunhofer Institute for Laser Technology ILT is one of the most important development and contract research institutes in laser development and application worldwide. Its activities encompass a wide range of areas such as developing new laser beam sources and components, laser-based metrology, testing technology and industrial laser processes. This includes laser cutting, ablation, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, Fraunhofer ILT develops photonic components and beam sources for quantum technology.

Overall, Fraunhofer ILT is active in the fields of laser plant technology, digitalization, process monitoring and control, simulation and modeling, AI in laser technology and in the entire system technology. We offer feasibility studies, process qualification and laser integration in customized manufacturing lines. The institute focuses on research and development for industrial and societal challenges in the areas of health, safety, communication, production, mobility, energy and environment. Fraunhofer ILT is integrated into the Fraunhofer-Gesellschaft.







MATERIAL DEVELOPMENT FOR ADDITIVE MANUFACTURING

The Fraunhofer Institute for Laser Technology ILT develops novel materials for laser-based additive manufacturing as commercially available alloys have not been developed for this process. Therefore, they cannot exploit the potential of additive manufacturing processes or are completely unsuitable for it. By improving their mechanical or physical properties, we have developed materials that offer added value and, thus, a competitive advantage for our project partners.

Laser-based Additive Manufacturing

In laser-based additive manufacturing, the laser beam melts the material locally and after exposure, the material solidifies instantly. Since the laser beam moves in a meandering manner, layers are generated, and as the layers are superimposed upon each other, a component is created. The manufacturing process basically has three characteristics: 1. highly dynamic melt flow conditions in the melt pool due to its small size, 2. the rapid solidification of the material, and 3. the cyclic reheating of the previously deposited volume. These characteristics can be used specifically to set material structures and properties that cannot or can only partially be generated with other manufacturing processes.

Fraunhofer ILT develops novel materials that are specially tailored for laser-based additive manufacturing.

1 Laser metal deposition.
2 Homogeneously distributed, nanoscale dispersoids, source: Access e.V..
3 Detailed view of a eutectic Al-Ni solidification morphology, source: Access e.V..

ODS Materials

Oxide dispersion-strengthened (ODS) materials are characterized by their outstanding high-temperature mechanical properties and good corrosion resistance. These properties are based on oxide dispersoids, which are homogeneously distributed in a corrosion-resistant metal matrix and typically only a few nanometers in size.

Conventionally, ODS materials are manufactured with powder metallurgical processes including mechanical alloying, consolidation by hot isostatic pressing or hot extrusion and subtractive shaping of final parts – and makes only a limited geometry of the components possible. Conventional casting can be eliminated as a manufacturing process for ODS materials since the solidification rate for a homogeneous distribution of extremely fine dispersoids in the matrix is often insufficient, resulting in agglomeration or flotation processes of oxide dispersoids.

Since the small melt pools rapidly solidify in laser-based additive manufacturing, the dispersoids are homogeneously incorporated in the metallic matrix. This process can significantly shorten the production chain. The production also occurs with near net shape and allows engineers a high degree of freedom when designing the component.

Eutectic Alloys

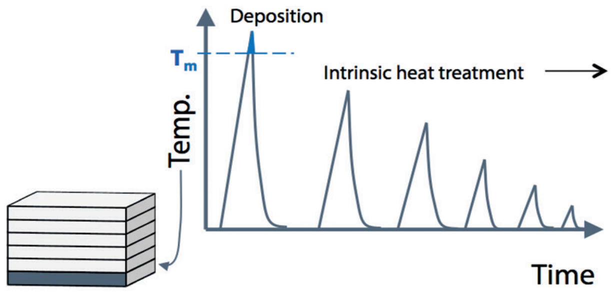
Eutectic cast alloys are characterized by a combination of a solid-solution crystal phase and a, secondary hard phase. As the two phases solidify simultaneously, a characteristic, often lamellar, solidification morphology is produced. In additive manufacturing, the lamellar spacing can be precisely adjusted since the microstructure can be refined by several orders of magnitude, up to nanoscale dimensions, which cannot be achieved by conventional casting. Due to the layered construction, the grain size of the structure is largely independent of component geometry. Since the microstructure is refined, the material's strength increases and the ductility decreases only moderately. With nanoscale solidification both strength and ductility can be increased.

Today, the eutectics systems Fe-C and Al-Si are used almost exclusively for technical purposes. However, there are many more eutectics that have not yet been used due to casting difficulties. These include special Al- and Ti-based eutectics that are of interest as lightweight materials.

Intrinsic Heat Treatment of Maraging Steels

Conventional materials manufactured with laser-based additive manufacturing often need to be subjected to subsequent heat treatment: by aging or a combination of solution annealing, quenching and aging, the desired properties can thus be adjusted.

The cyclic reheating of applied layers can be used to induce precipitation hardening already in the manufacturing process, which is referred to as intrinsic heat treatment. So that this intrinsic precipitation can be initiated, the alloy system must be sensitive to short-term heating and cooling cycles.



Schematic diagram of the thermal history of a layer manufactured with laser metal deposition.

Maraging steels (Fe-Ni alloys with additions of Al or Ti) are a suitable alloy system for such cycles. These are low-carbon steels which undergo martensitic transformation upon cooling and retain their strength through fine intermetallic precipitations produced during the heat treatment. The level of hardness can be controlled by the process conditions and also adapted locally in the component. A time-consuming and costly, subsequent heat treatment is thus unnecessary.

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4 Additively manufactured eutectic alloy, source: Access e.V..
5 Hardness profile of an intrinsically heat-treated specimen manufactured with laser metal deposition.