Press Release

Laser Material Deposition opens up new possibilities for tool, mold, and model making

Longer service life for molds and tools

Manufacturing and maintaining die-casting tools professionally is crucial to the foundry industry: As one of the most expensive assets, these tools play a decisive role in determining quality, efficiency, and cost-effectiveness. Easily costing hundreds of thousands of euros, complex molds and inserts must be able to function over many years without interruption. They must also withstand extreme stress: In die casting, for example, the mold materials are exposed to temperatures of up to 700 °C, while the tools to mechanical forces of several hundred kilonewtons. Added to this are abrasive stresses on the tool surface and chemical attack by alloying elements in the casting materials. Thermal stresses and material fatigue lead to cracking, erosion, and abrasive wear. Even when the molds are designed optimally and manufactured carefully, their wear is an unavoidable factor that eventually means tools have to be replaced. If this occurs unexpectedly, it results in significant downstream costs.

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The economic implications are significant: Every tool failure results in production downtime, additional setup times, and sometimes a manufacturer needs to produce new inserts or even entire tools. At the same time, manufacturers are under growing pressure to produce and operate molds both cost-effectively as well as sustainably. “In an industry where every minute of production time counts, we need processes that can extend tool lifecycles, reduce downtime, and optimize production processes from an environmental perspective,” explains Dr. Thomas Schopphoven, Head of the Laser Material Deposition Department at the Fraunhofer Institute for Laser Technology ILT in Aachen, Germany.

Traditional approaches, which commonly use high-alloy tool steels, are reaching their physical limits. Higher hardness and wear resistance often mean complex processing, long lead times, and high raw material costs. In addition to service life considerations, demands on flexibility in tool manufacturing are also increasing: Product modifications regularly require changes to mold inserts, gate systems, and cooling systems, which pose additional challenges for toolmakers.

The search for solutions must, therefore, go beyond existing strategies. Conventionally, tools are made of a single material, which limits their performance and makes them difficult to repair. Innovative manufacturing technologies such as Laser Material Deposition (LMD) enable users to repair tools, selectively coat areas subject to particularly high stress, and flexibly adapt geometries through hybrid additive manufacturing approaches. In this way, molds can be used for longer, adapted more quickly, and operated in a more resource-efficient manner. At a time when the circular economy is gaining increasing importance in industrial toolmaking, this technology offers enormous forward-looking potential.

Laser Material Deposition and EHLA

Laser Material Deposition (LMD), often called laser cladding, is an additive manufacturing process that has become widely used in industry across numerous sectors, such as for repairing turbomachinery components or coating rollers and cylinders. The principles are simple, but the possibilities remarkable. A laser beam creates a melt pool of a precisely adjustable size on the surface of a workpiece, while metal powder is simultaneously fed into this melt pool. Thanks to precise control of the travel paths, material is deposited locally, layer by layer, allowing not only worn areas to be rebuilt but also new, functional geometries to be created. The key feature lies in the high level of process control: Laser parameters, powder feed, and travel speed are precisely coordinated so that heat input remains minimal and thermal stresses are reduced.

A further development of this process is the multi-award-winning Extreme High-Speed Laser Material Deposition (EHLA), which Dr. Schopphoven developed several years ago at Fraunhofer ILT: “While conventional LMD is primarily used for thicker layers in the millimeter range, EHLA allows for the production of very thin, wear-resistant coatings with layer thicknesses starting at approximately 30 µm.” This is achieved at a speed that lives up to the process’s name: Several hundred meters per minute are possible. The technology is now established in numerous industries; several hundred EHLA systems are already in industrial use worldwide. The decisive advantage lies in precision and efficiency: EHLA makes it possible to process even difficult-to-weld material combinations, such as high-alloy tool steels or cemented carbides, improving process reliability and maintaining low energy consumption.

With EHLA3D, the process has raised the bar. Since it has been integrated into 5-axis CNC machines, the technology can be used for coatings and minor repairs, but also for additive manufacturing. Complex free-form geometries can be built up on semi-finished products at high precision. The technology combines capabilities from the fields of manufacturing, coating, and repair into a single process that can be used both for the production of new tools and for their regeneration. Of particular interest to toolmaking is the ability to selectively reinforce functional zones without having to remanufacture the entire tool. The low heat input allows users to process delicate geometries without distortion, while the high deposition rate enables them to produce on large surfaces cost-effectively.

Benefits for the foundry industry

The benefits of LMD and EHLA for the foundry industry are numerous and extend far beyond simply extending tool life. The process offers clear economic and technical advantages, particularly for die-casting molds exposed to extreme temperature fluctuations and abrasive wear. Current research shows that targeted coating of functional zones can significantly reduce wear.

In sliding friction wear tests, improvements of up to a factor of 40 were observed compared to conventional tool steel, depending on the alloy and the process parameters. Materials such as high-alloy carbide-forming materials achieve hardnesses of up to 930 HV while maintaining a metallurgical bond with the substrate. These results impressively demonstrate that tool life can be significantly increased, which has a direct impact on production reliability and cost-effectiveness.

In addition to extending tool life, LMD enables a more efficient use of materials. While conventional tools are often made entirely of expensive, high-alloy tool steel, LMD allows manufacturers to use lower-cost structural steel as a substrate. Only the areas that are actually exposed to high loads are coated with a hard alloy. This “material-on-demand” principle reduces costs and minimizes machining requirements. The near-net-shape deposition eliminates a large portion of the time-consuming milling operations, and molds can be put into operation more quickly.

Molds that previously had to be completely replaced after cracks or spalling occurred can now be remanufactured using LMD. Damaged areas are selectively welded and then machined so that the molds regain their original geometry. This approach can reduce costs and reduce reliance on long supply chains for new molds. This flexibility is a decisive factor, particularly for large and complex die-casting tools that require customized manufacturing processes.

AI-SLAM: Automated repair using artificial intelligence

A key step toward the widespread adoption of LMD in toolmaking is increasing automation. In the AI-SLAM (Artificial Intelligence Enhancement of Process Sensing for Adaptive Laser Additive Manufacturing) research project, experts at Fraunhofer ILT, in collaboration with international partners, have demonstrated that coating and repair processes can be automated using sensor technology and artificial intelligence.

In the AI-SLAM project, a line laser equipped with a camera scans the worn surface of a tool used in the mining industry and compares it with the original CAD geometry. Based on the difference, the software calculates the exact travel paths and the required layer thickness needed to restore the original contour. Path planning is performed automatically, and the AI monitors the process even while the job is in progress. Deviations in size or characteristics of the melt pool or in the geometry are immediately detected and corrected by adjusting the process parameters.

One distinctive feature is the wide range of parameters monitored. In addition to checking geometry, pyrometers measure temperature, cameras analyze the shape of the melt pool, and profilometers monitor the layer structure. These data streams are consolidated in real time and evaluated by AI. Operators no longer need to manually adjust complex parameters; they simply need to issue the start command, and the system takes over control of the process.

This reduces reliance on highly specialized personnel, who were previously indispensable for the successful use of LMD.

This also represents a significant advance for the foundry industry. Repairs to die-casting molds, which previously required extensive planning and a great deal of experience to carry out, can now be performed in a reproducible and standardized manner. Of particular interest is the ability to automatically regenerate even large and complex molds. Defects are not only detected, but also immediately corrected, drastically reducing downtime. In addition, the results can be documented and verified, which is essential for series production in an industrial setting.

The AI-SLAM project opens up a new perspective in which tools are no longer viewed as wear parts, but rather as long-term investments that can be optimized and improved throughout their entire lifecycle.

An innovative approach to the manufacture of tools

As part of the H2GO project (National Action Plan for Fuel Cell Production), Fraunhofer ILT has presented a novel approach to manufacturing tools for bipolar plates. Instead of the time- and material-intensive process of milling tools from solid stock, a wear-resistant functional layer is applied directly to low-cost structural steel using EHLA. This method produces tools faster, more cost-effectively, and with significantly less material usage.

Coating materials used include high-speed steel 1.3343 and Ferro55, which achieve hardness values of up to 865 HV0.5. A typical EHLA application produces a layer thickness of approximately 0.05 mm to 0.15 mm per layer; the required final contour can be precisely built up by applying multiple layers. This process not only saves milling time and reduces tooling as well as material costs, but also extends the service life of the molds produced.

A demonstrator clearly illustrated the entire process: from EHLA coating and finishing to the texturing of functional surfaces using ultrashort-pulse lasers. In collaboration with Fraunhofer IPT, the tools produced in this way are currently being tested under realistic conditions. The goal is to validate the service life of EHLA-coated tools under industrial stress scenarios.

One decisive advantage is already apparent: The process allows particularly hard, long-term stable alloys to be applied to the tool surface, alloys that are difficult or nearly impossible to machine using conventional methods. This significantly increases the service life of the tools, thereby lowering production costs significantly. In addition, EHLA enables localized application: Defective or worn areas can be repaired in a targeted manner, allowing tools to be reused multiple times. This possibility of reuse represents another promising lever for cost reduction and also opens up new prospects for toolmaking in other industries.

“Applying these approaches to the foundry industry could fundamentally change current toolmaking processes,” says Thomas Schopphoven. “Instead of procuring new molds on a fixed schedule, companies can use their existing tools longer and more efficiently.” At the same time, LMD opens up the possibility of continuously adapting tools to new product designs and manufacturing requirements. In an era where flexibility and speed, resilience, and independence from supply chains represent decisive competitive advantages, laser cladding is becoming a key technology for the future of toolmaking.

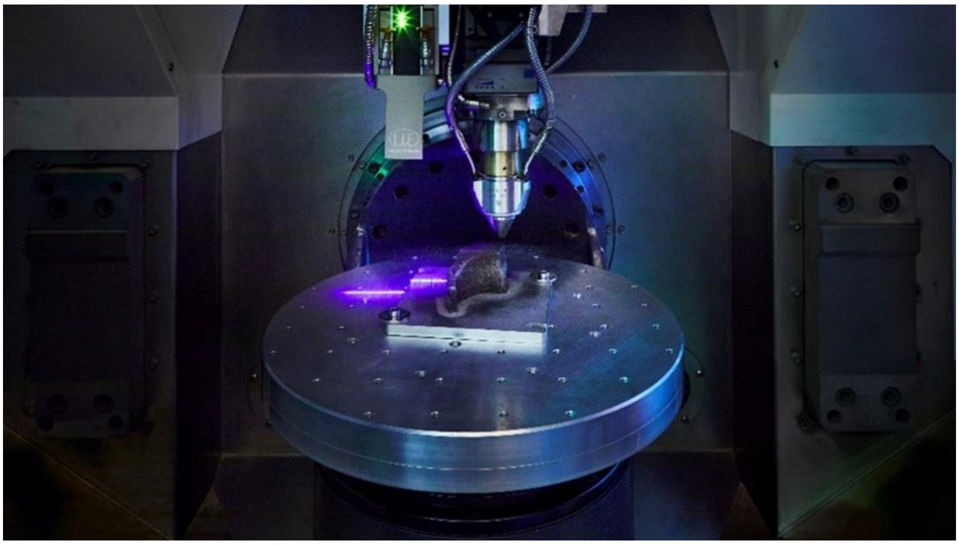
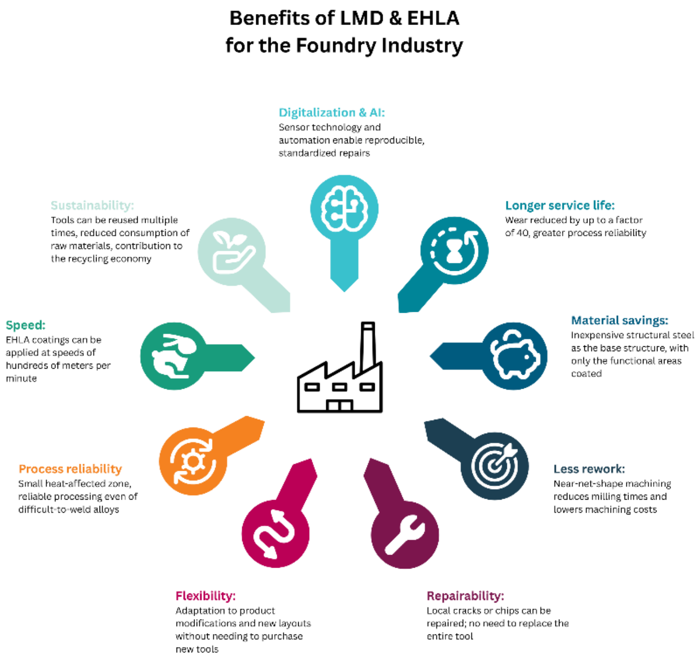


Image 1:
Extreme high-speed Laser Material Deposition (EHLA) enables the additive deposition of functional surfaces with high precision and speed. This allows components to be efficiently coated, repaired, or manufactured with close-to-final-contour precision.
© Fraunhofer ILT, Aachen, Germany.



Benefits of LMD & EHLA for the Foundry Industry

Digitalization & AI: Sensor technology and automation enable reproducible, standardized repairs

Longer service life: Wear reduced by up to a factor of 40, greater process reliability

Material savings: Inexpensive structural steel as the base structure, with only the functional areas coated

Less rework: Near-net-shape machining reduces milling times and lowers machining costs

Repairability: Local cracks or chips can be repaired; no need to replace the entire tool

Flexibility: Adaptation to product modifications and new layouts without needing to purchase new tools

Process reliability Small heat-affected zone, reliable processing even of difficult-to-weld alloys

Speed: EHLA coatings can be applied at speeds of hundreds of meters per minute

Sustainability: Tools can be reused multiple times, reduced consumption of raw materials, contribution to the recycling economy

Image 2:
Overview of the key benefits of LMD and EHLA for the foundry industry: longer service life, lower costs, greater flexibility, and a contribution to sustainable, resource-efficient production processes.
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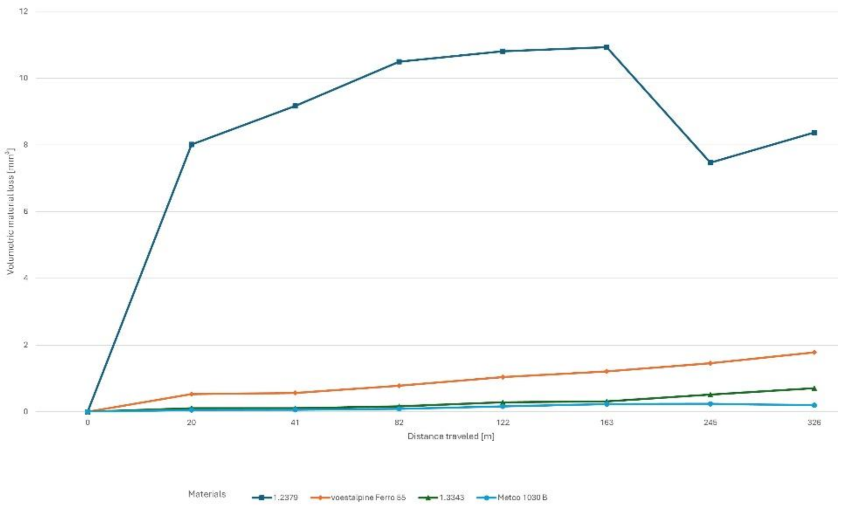

Image 3:
While the volumetric material loss of unhardened 1.2379 increases significantly, samples coated with Ferro55, 1.3343, and 1030B exhibit substantially higher resistance. 1.3343 is particularly interesting for industrial use, as it is less prone to cracking than material 1030B and yet exhibits excellent performance in the sliding friction wear test.
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Image 4:
In the AI-SLAM project, researchers at Fraunhofer ILT, in collaboration with international partners, are demonstrating that coating and repair processes can be automated using sensors and artificial intelligence.
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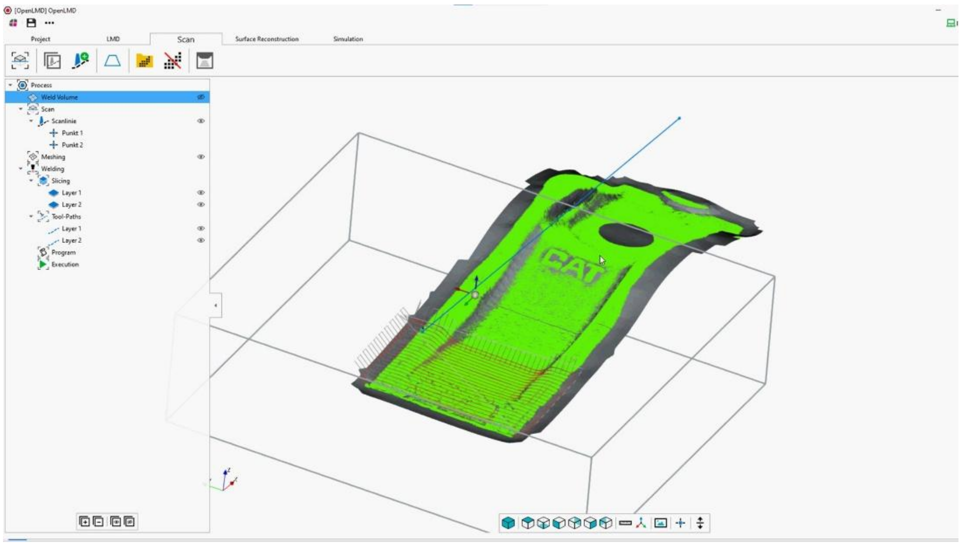

Image 5:
The AI-driven LMD process simplifies the operator's role in the coating of heavily loaded tools.
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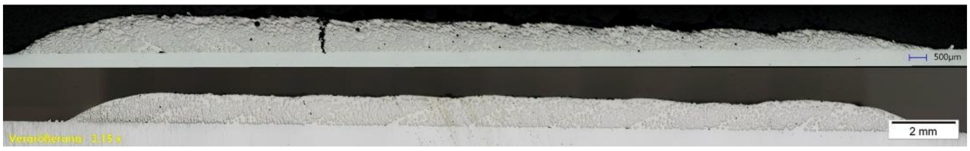

Image 6:
The AI-SLAM project demonstrates how AI can improve the quality of the additive LMD process. For comparison: the result before is shown above (without AI), and the result after is shown below (with AI support). The findings provide a solid foundation for further research and the expansion of the technology into various industrial applications.
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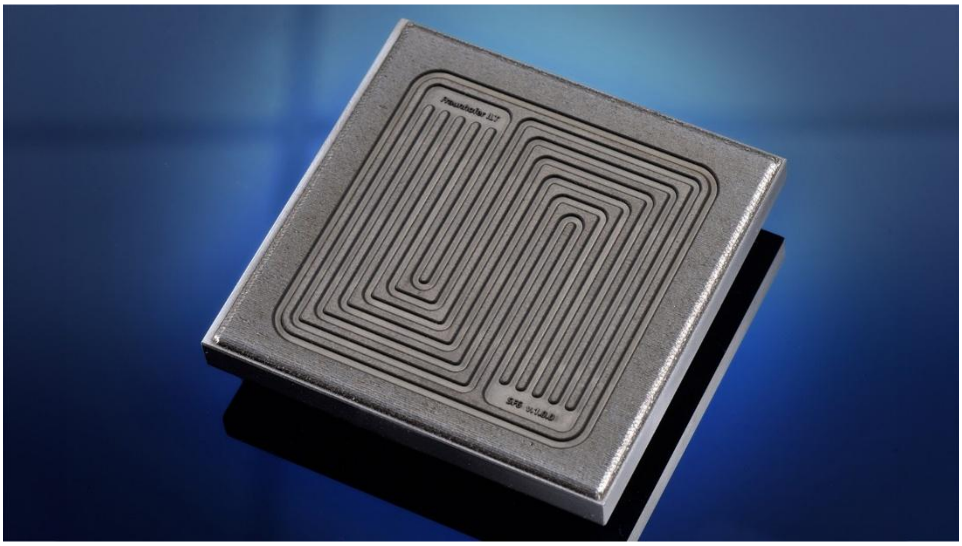

Image 7:
Researchers at Fraunhofer ILT have developed process chains for coating and repairing tools using the EHLA process. This enables coating and repair processes to be implemented in other industrial sectors as well, saving time and costs in toolmaking.
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Contact

Technical Contacts

Dr.-Ing. Thomas Schopphoven
Fraunhofer Institute for Laser Technology
Head of department Laser Material Deposition
Phone +49 241 8906-8107
thomas.schopphoven@ilt.fraunhofer.de

Max Gero Zimmermann M. Sc.
Fraunhofer Institute for Laser Technology
Group leader Additive Manufacturing and Repair LMD
Phone +49 241 8906-253
max.zimmermann@ilt.fraunhofer.de

Press Contact

Petra Nolis
Fraunhofer Institute for Laser Technology
Communications
Group Manager
Phone +49 1714115001
petra.nolis@ilt.fraunhofer.de

www.ilt.fraunhofer.de