Fraunhofer Institute for Laser Technology ILT

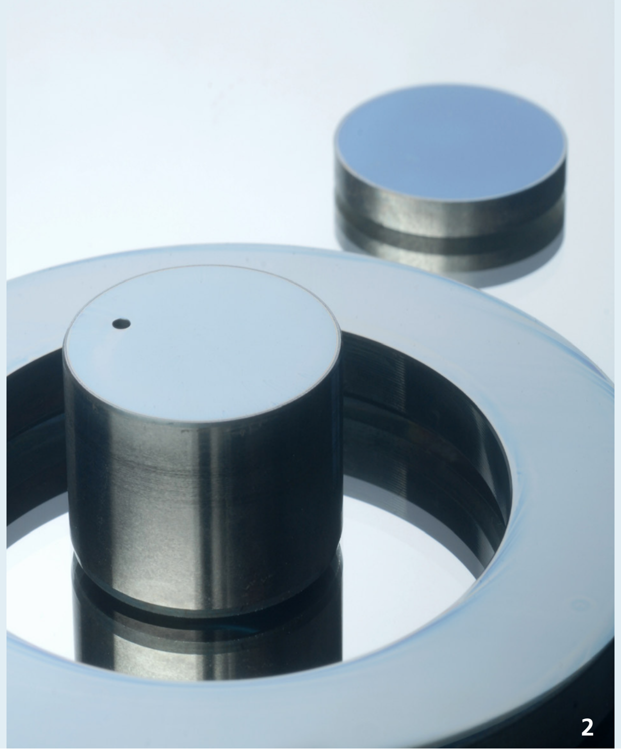
Laser Processes for tribological Coatings and Corrosion Protection

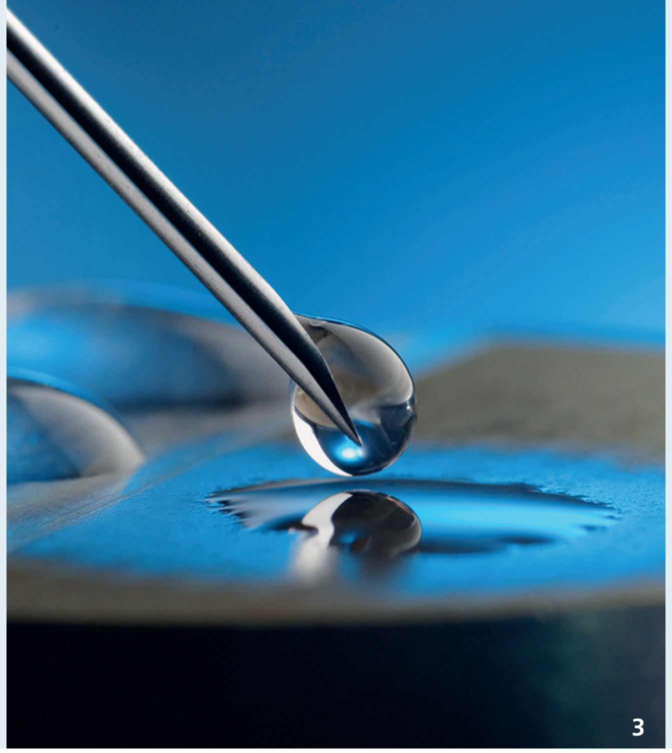
The Fraunhofer Institute for Laser Technology ILT develops energy-efficient, site-selective and sustainable laser processes for producing coatings that increase the temperature resistance of components, reduce friction or protect against wear and corrosion. Such tribological coatings are mainly used in applications in which the functional requirements of components exceed the performance of the base materials. As the cross-industry trend towards functional integration continues to develop, the requirements are becoming increasingly complex. Laser technology can provide economical solutions for innovative and sustainable coating concepts.

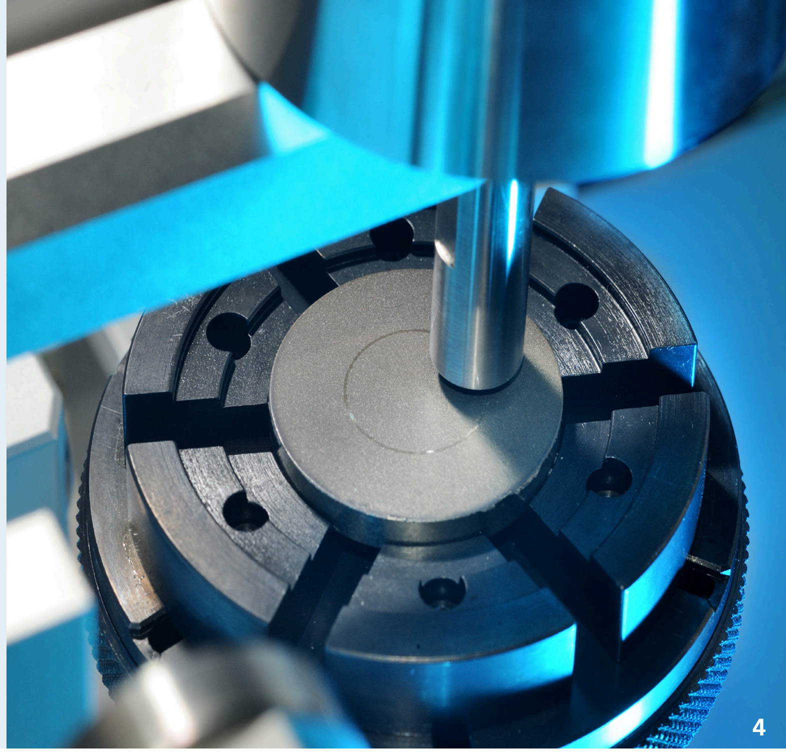
Laser-based Production of Functional Coatings

Producing tribological coatings often involves a process step with which the previously wet-chemically applied coating materials are thermally functionalized (e.g. curing, sintering, melting, compacting). Conventionally, this step takes place by means of oven-based methods, but has the significant disadvantage that the entire component must be heated to the functionalization temperature of the coating. On the one hand, this results in low energy efficiency and, on the other, a significant limitation of the material spectrum: Temperature-sensitive materials, such as industrially relevant roller bearing steels and aluminum alloys, can thus only be used in very few cases or not at all.

Processing step for the production of polymeric protective layers.







Laser processes for tribological coatings and corrosion protection

One promising alternative is a laser-based coating process with which the thermal energy is introduced directly into the coating and not into the entire component. The spectral, temporal and spatial controllability of the laser radiation allows an application-adapted modulation of the temperature profiles in the component. Since large heating and cooling rates can be achieved in defined small volumes, the energy input into the component can be reduced and the thermal load thus minimized.

Compared to conventional methods, this laser process has, for example, ecological and economical advantages: The laser, as a non-contact and wear-free tool, processes the coatings quickly and efficiently. The process developed has been designed for the industrial changes triggered by Industry 4.0 (i.e. for machine networking and integrated data management).

Polymer-based coatings for tribological applications and corrosion protection

High-performance polymers are predestined for use as coating materials for applications in which there are additional requirements for temperature and corrosion resistance, in addition to tribological loads. Furthermore, this class of materials allows an application-specific additivation, for example, to selectively modify the friction behavior. Previous work in this area includes, in particular, polyether ether ketone (PEEK) based coatings on metallic components.

The polymer layer thickness typically ranges from 10–100 µm. For steel substrates, the interaction time needed to fully functionalize the polymer can be reduced to a hundredth compared to furnace-based processes.

Polymer-based multilayers with layer thicknesses exceeding 100 µm can be produced by iteratively repeating layer application and laser-based functionalization. In this process, tribologically optimized individual layers can also be combined to form multi-layer systems without the individual layers mixing during the melting process.

Sol-gel based wear and non-stick coatings

Since they have enormous potential, wear protection coatings are used, among other things, in the automotive industry to optimize the tribomechanical properties of highly stressed engine and transmission components. In particular, energy- and resource-saving processes of pressure and spraying can be used to selectively apply nanoparticulate materials, e.g. in the form of sol-gel systems, to highly stressed areas of the components needing protection with little technological effort. On hardened steel, coatings can be produced with layer thicknesses of 0.1–1 µm and a microhardness of over 1000 HV.

In addition to wear-resistant coatings, sol-gel-based non-stick coatings can also be functionalized using laser radiation. With lasers, the necessary temperature can be generated in the coating without placing great thermal load on the component, an advantage that makes it possible to coat even temperature-sensitive substrates quickly and efficiently. Sol-gel-based anti-adhesion coatings have been successfully produced on metal, polymer and CFRP with laser radiation.

Friction-reducing paint coatings

Thermosetting lacquers (e.g. MoS_2-based materials) have great potential for wide industrial application in the area of friction reduction at medium to high temperatures. The lacquers are used primarily for coating steel materials, e.g. for aerospace applications. When Vertical Cavity Surface Emitting Laser Beam Sources (VCSEL) are used, the process time of up to 30 minutes in furnace processes can be reduced to just a few seconds. In addition, the wear coefficient measured by calotte grinding decreases by a factor of six.

Pretreatment and cleaning

Fraunhofer ILT has many years of experience in the field of laser-based cleaning as well as the pre-treatment and structuring of component surfaces. On the basis of these competencies, Fraunhofer ILT develops processes for the pretreatment of components to be coated; such processes can improve, for example, the wetting behavior of the wet-chemical deposited layers. In addition, the bond strength of coating and com-ponent can generally be significantly increased by a targeted oxidation of the surface or a modification of the surface topography.

1 Engine piston coated with PEEK.
2 Bearing components with ceramic wear protection coatings.
3 Metal surface before (left) and after (right) laser pretreatment.
4 Tribological analysis of a coated test specimen.

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.

DQS certified by
DIN EN ISO 9001:2015
Reg. No. 069572 QM15

Fraunhofer Institute
for Laser Technology ILT
Director
Prof. Constantin Häfner

Steinbachstraße 15
52074 Aachen, Germany
Phone +49 241 8906-0
Fax +49 241 8906-121
info@ilt.fraunhofer.de
www.ilt.fraunhofer.de

Contact

Samuel Fink M. Sc.
Phone +49 241 8906-624
samuel.fink@ilt.fraunhofer.de

Dr. Christian Vedder
Phone +49 241 8906-378
christian.vedder@ilt.fraunhofer.de