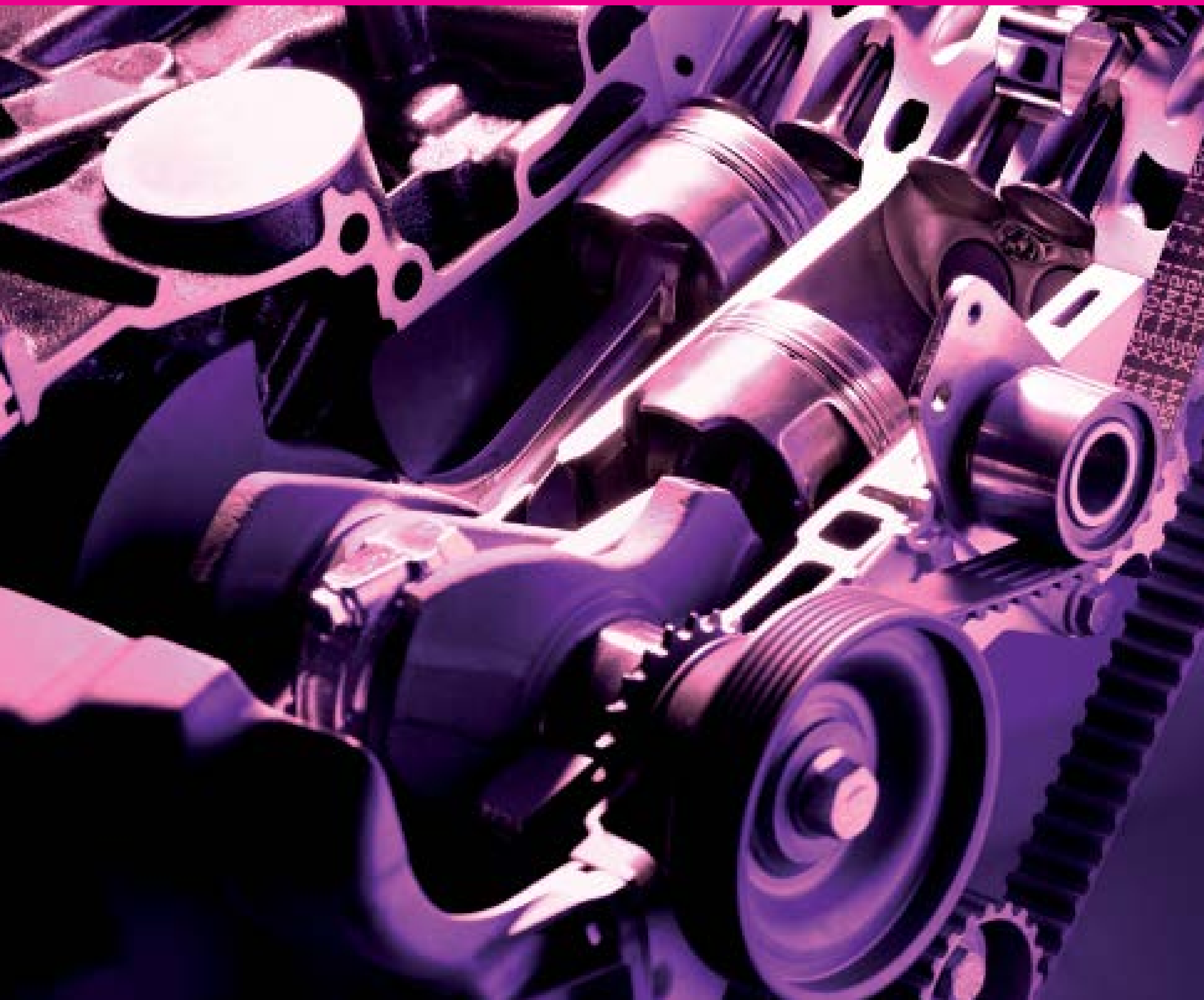
Fraunhofer

IST

FRAUNHOFER INSTITUTE FOR SURFACE ENGINEERING AND THIN FILMS IST

FUNCTIONAL COATINGS FOR THE AUTOMOTIVE INDUSTRY



Functional coatings for the automobile

Functional coatings for automotive engineering at the Fraunhofer IST

Thin-film technology is the core business of the Fraunhofer Institute for Surface Engineering and Thin Films IST. In our business fields of mechanical and automotive engineering, aerospace, tools, energy, glass and façade, optics, information and communication as well as life science and ecology, we, as an R&D service center close to industry, develop application-oriented and market-viable solutions for our partners.

To meet your challenges in the high-tech automotive sector, we combine our competences in the following fields:

- Tribology
- Micro and sensor technology
- Electrical and optical functional coatings
- Large area coating
- Vacuum and atmospheric pressure plasma processes
- Electroplating
- Simulation
- Analytics and characterization

We clean surfaces – Pretreatment

- Efficient water-based surface pretreatment including drying
- Special cleaning of glass
- Plasma pretreatment and plasma cleaning
- Plasma activation and plasma functionalization
- Pretreatment by wet-chemical etching
- Particle blast cleaning

We develop processes and coating systems – Coatings

- Coating development
- Process technology (including process diagnostics, modeling and control)
- Simulation of coating systems and processes

We secure quality – Testing/Characterization

- Test procedures and product-specific quality control, such as, for example, measurement of wear in components
- Testing film adhesion
- Mechanical, chemical, micromorphological and structural characterization
- Optical and electrical characterization
- Fast, confidential damage analysis

We transfer research results into practice – Application

- Economic calculations, development of economically efficient production scenarios
- Prototype development, low-volume production, coating sample components
- Installation concepts and production integration
- Advice and training courses
- Research and development in parallel with production

1 Functional coating on engine components.
2 Coated crank shaft.
3 Thrust bearing ring with sensor structure in the raceway.

Applications all around the automobile

Glazing
Ice-free windscreens, self-healing coatings, hydrophobic/hydrophilic and self-cleaning coatings, functional coatings for exterior applications, transparent anti-scratch and UV protection

Information display
Coatings for head-up displays, anti-reflective and anti-static films for the instrument cluster cover, anti-fogging films, free-form lens coatings

Drive
Coatings for friction reduction and wear protection

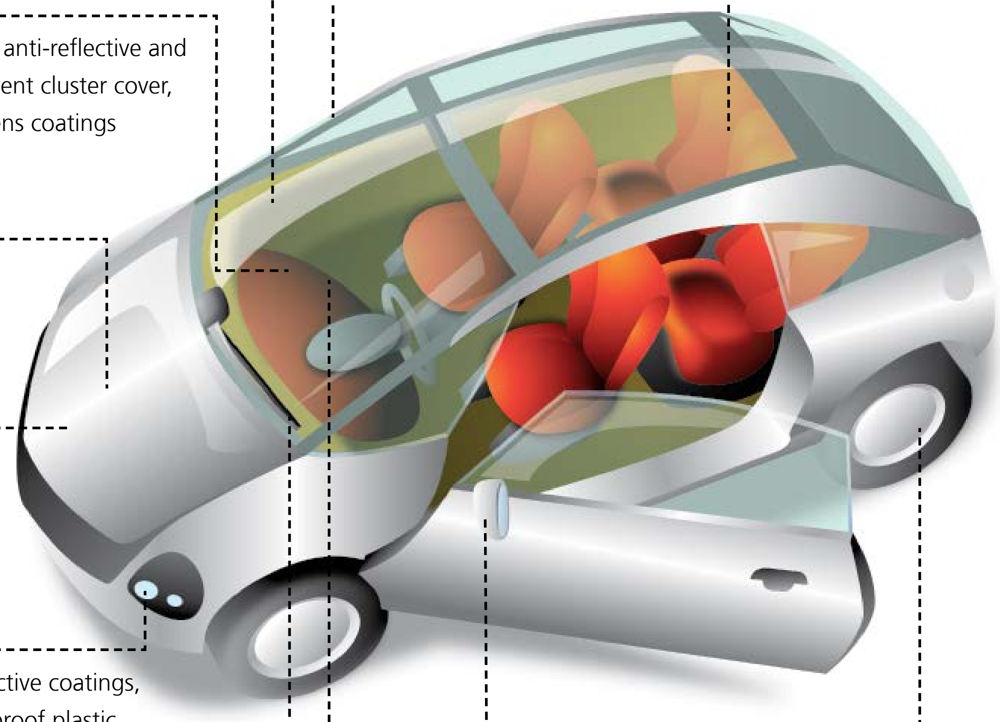
Engine
Camshaft, pistons, bucket tappets, crankshaft, gear-wheels, bearings

Headlights
Reflectors, photocatalytically active coatings, anti-fogging coatings, scratchproof plastic lenses

Windscreen wipers
Thin-film rain sensor for wiper control

Body
Active sound control, glazing with integrated lighting

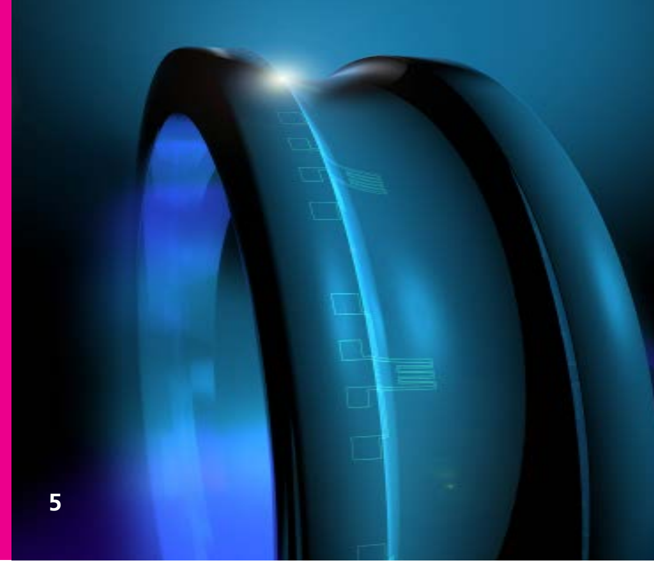
Switchable coatings
Sun control and privacy

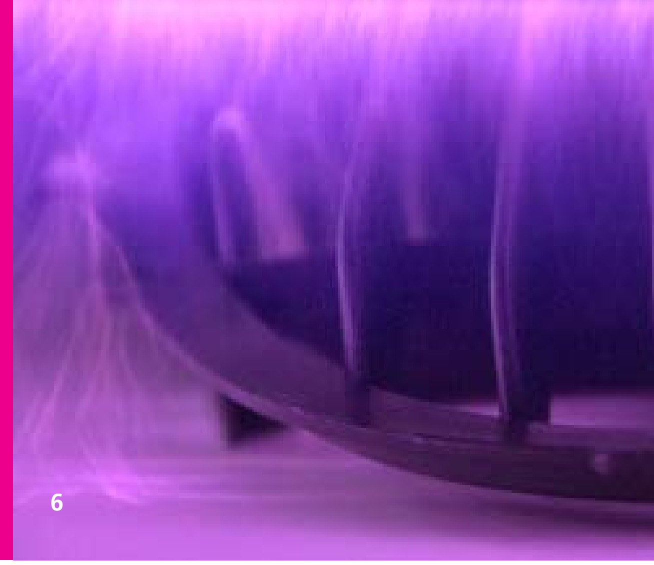


Switchable mirror
Electrochromic self cleaning mirror

Wheel rims
Corrosion protection, decoration

Optical sensors
Self-cleaning optical sensors, materials for imaging systems





Amorphous carbon coatings

Diamond-like carbon coatings (DLC)

Friction reduction and wear protection is one of the central concerns in automobile manufacturing. This is where amorphous diamond-like carbon (DLC) coatings come in. They extend service life and periods between maintenance, increase the load-bearing capacity of engine components, reduce losses due to friction, reduce the use of lubricants and in addition make the use of alternative materials possible. For example, application of a DLC coating to bucket tappets alone results in fuel consumption savings up to 1% and thus to a considerable reduction in CO_2 emissions. Diamond-like carbon coatings are deposited at temperatures below 200 °C by various chemical or physical techniques of thin-film technology (CVD, PVD) and exhibit excellent friction and wear characteristics in a variety of engineering applications. Depending on the actual process used and on chemical composition, properties such as hardness or surface energy can be specially tailored to the application's requirements. DLC coatings can thus be adapted to the load profiles of virtually any tribological system.

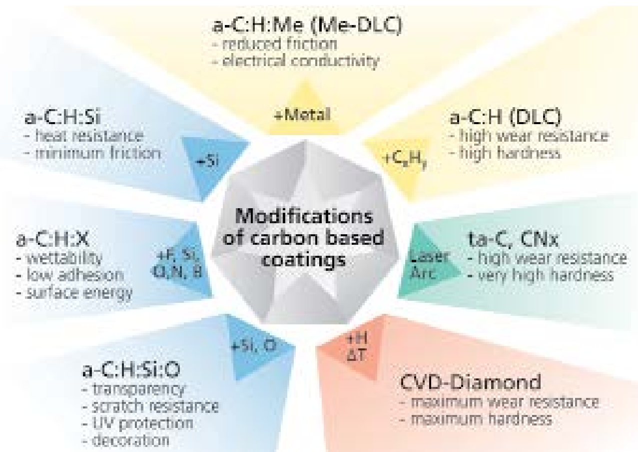
4 Coated engine components.
5 Intelligent bearings: with DiaForce® sensor system.
6 Atmospheric pressure plasma treatment of a plastic component.

Superhard a-C:H coatings (C-DLC)

A further development of DLC coatings are the superhard C-DLC (a-C:H) coatings. They offer greater hardnesses with lower surface roughness, improved adhesion and an expanded range of possible applications. C-DLC coatings are produced by magnetron sputtering in large-scale installations. Due to the reduced hydrogen content and a larger number of carbon-carbon bonds, coating hardnesses over 40 GPa are achieved. The considerable improvement in adhesion is to be attributed to the special design of the intermediate layer.

Advantages of DLC and superhard C-DLC coatings

- Energy efficiency due to friction reduction
- Extension of service intervals due to wear protection
- Cost efficiency due to dispensing with lubricants
- Low surface energy
- Extension of service life
- Decoration/decorative effects



Intelligent surfaces

In addition to tribological properties, diamond-like carbon coatings can also have sensorized properties. Modern plasma coating techniques make it possible to produce multifunctional surfaces which are tribologically optimized and at the same time have sensoric capabilities. The DiaForce® film which was developed at the Fraunhofer IST offers this combination of functions. It consists of amorphous hydrogenated carbon and has diamond-like tribological behavior. This is indicated by the syllable "Dia" while "Force" alludes to its principle use for force measurement in heavily loaded areas. This sensorized coating system is 6–9 µm thick and also has both piezo- and thermo-resistive properties. The coatings, which are deposited by the PACVD process, are structured by means of photolithography, wet-etching and direct laser writing. DiaForce® sensor systems can detect load, pressure, temperature and wear on smooth and curved surfaces.

Advantages of the DiaForce® sensor system

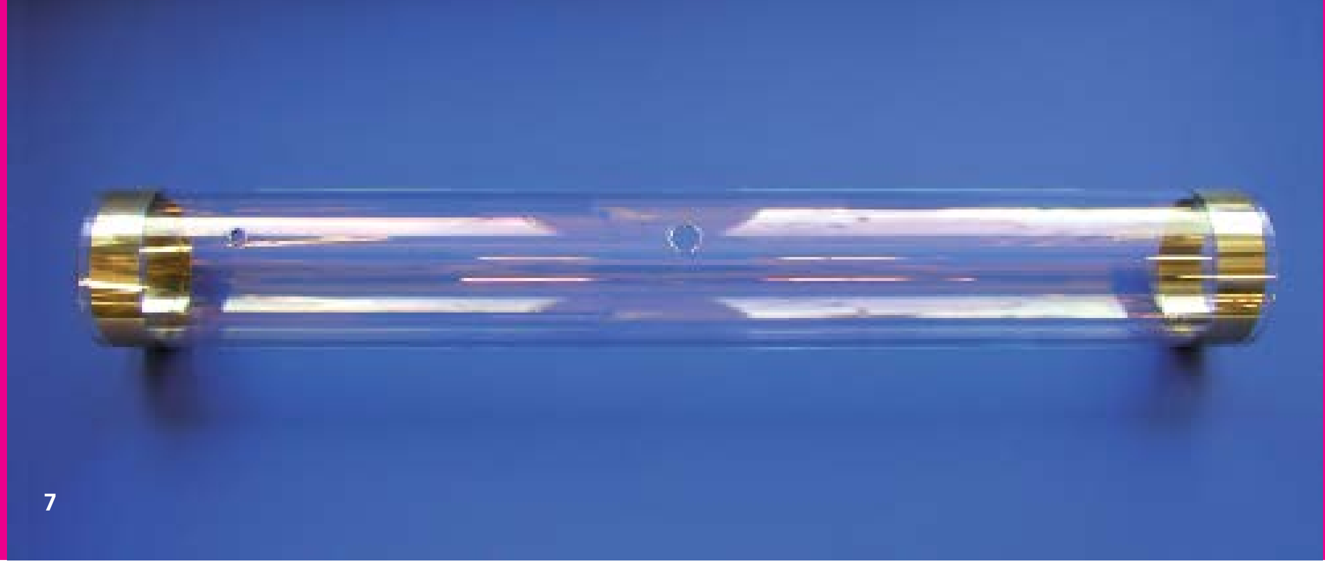
- Static and dynamic measurements in high load regions
- Increased product safety, e.g. by intelligent washers for wheel mounting
- Optimization of forming processes by integration of thin film sensor modules in deep drawing machines
- Online-monitoring of cutting processes with DiaForce® sensor systems in direct touch with the stamp

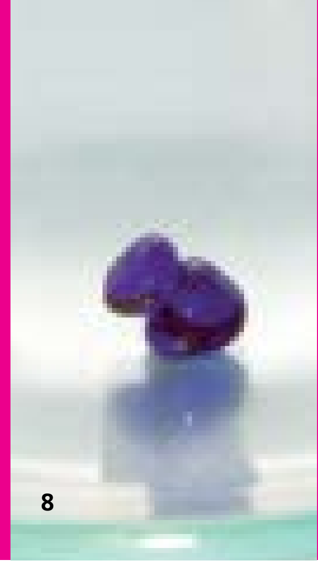
Modified surfaces

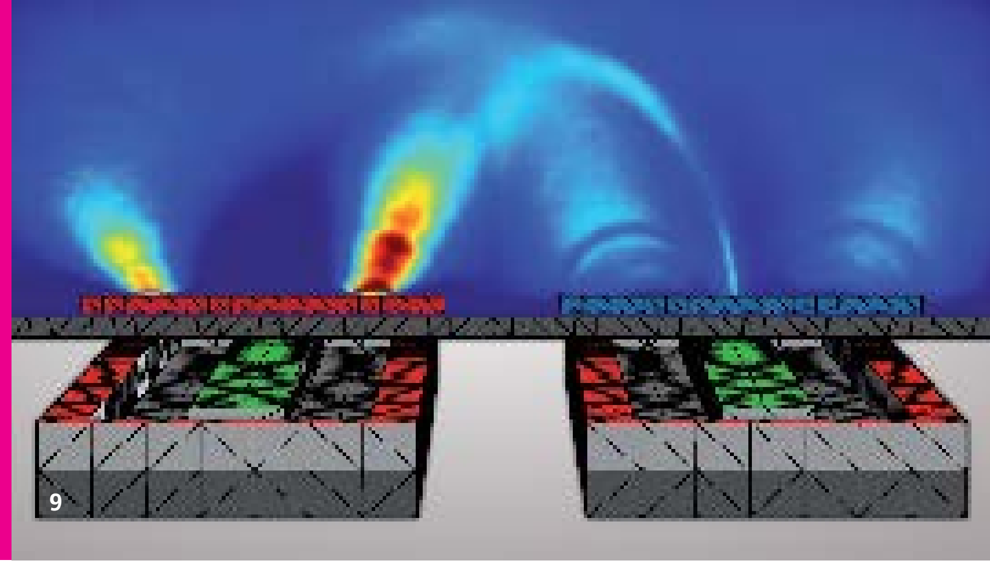
Modified surfaces with optimum adhesion properties for downstream processing such as gluing, painting or printing can be inexpensively produced to requirements by atmospheric-pressure plasma processes. In particular, alongside glass, silicon and metal, even plastics can be activated since treatment at atmospheric pressure only subjects the substrates to little thermal or mechanical stress. Generation of polar groups means that the surface energy and wettability of the substrates can be increased and, for example, the adhesion of organic coatings such as inks, paints or adhesives can be considerably improved. Furthermore, this method is suitable for the targeted functionalization of surfaces by the use of defined process gases and gas mixtures or by admixing precursors for coating deposition. The optimization of plasma parameters means that various chemically functional groups such as amino, hydroxy, carboxy or epoxy groups can be applied in high densities. These reactive groups can even form chemical bonds with whose help even hard-to-glue plastics can be securely attached to materials with low surface energies such as polypropylene or acrylonitrile butadiene styrene ABS/PC.

Advantages of modified surfaces

- Higher product quality by improved paint adhesion or more resistant bonding
- Defined setting of surface energy and a high density of functional groups
- Internal and external coating of components, e.g. tubes
- Greater flexibility for product design in the selection of materials
- Environmentally friendlier and more inexpensive process







Transparent conductive oxides (TCOs)

Transparent conductive oxides (TCOs) combine the properties of semiconductivity and transparency. At the Fraunhofer IST a broad range of high-grade TCO coating systems and processes are being developed for coating large-areas economically. Products such as ice-free windshields, transparent displays, optical-electronic components and low-emissivity applications require large-area coating systems with optical transparency and metallic conductivity. Transparent and conductive oxides based on oxidic semiconductors with a wide band gap such as ZnO, SnO_2 and In_2O_3 offer a solution here, making it possible to realize spectrally selective properties or large-area transparent electrodes.

Advantages of TCOs

- Tailored layer properties (thickness, charge carrier density, transparency, color impression)
- Gentle growing techniques for sensitive substrates (e.g. organic electronics, OLEDs and web coating)
- High-quality products due to state-of-the-art impulse sputtering processes and model-supported process development with high lateral homogeneity
- Cost savings due to processes with a high throughput and using inexpensive materials (for example, ITO replaced by ZnO:Al)
- Cost efficiency and process reliability due to simulation of coatings and deposition processes

7 *Glass tube with transparent ITO heating conductor coating. Application: heating distillation columns of the BASF group.*

Interference optics

Antireflection coatings (AR) reduce reflection in glass and polymer surfaces. Multiple-layer designs deliver broadband antireflective properties which satisfy the strictest requirements regarding process control and homogeneous coating. Furthermore, the Fraunhofer IST is developing special interference coatings for use in head-up displays, for example, which reflect laser light perfectly at special wavelengths. Alternative precision coating methods and new materials are opening up new possibilities for coating highly elastic free-form lenses made of polymer materials.

Advantages of antireflection coatings

- Safe, glare-free vision, for example, due to anti-reflective windshields, polymer lenses in optical instruments
- Design freedom in selecting interior material colors, for example, prevention of reflections on white
- Additional benefits due to anti-static properties (ARAS) and transparent scratchproofing on plastic

Our Vision

The ice-free windshield for tomorrow's cars offers effective switchable sun protection, cleans itself and during cold winter nights stays ice-free. With an innovative coating process developed at the Fraunhofer IST a particularly hard and scratchproof indium tin oxide coating has been successfully created. This transparent coating is as conductive as a metal – this makes the glass a heat mirror, which prevents the glass cooling down to the point where it ices over. There is thus no need for the lengthy process of heating the windows until they are clear – something which in the case of electric vehicles consumes a great deal of energy.

Photocatalytic coatings

With photocatalytic coatings, virtually any organic material which touches the coated surface will decompose under ultraviolet illumination. They also make complete wetting with water possible (superhydrophilia). In agreement with the Fraunhofer Photocatalysis Alliance, R&D work at the Fraunhofer IST is concentrating on the development and characterization of highly active photocatalytic coatings on glass and plastics.

Advantages of photocatalytic active coatings

- Antibacterial surfaces (e. g. steering wheel, gear shift or hand gear)
- Improved air quality due to photocatalytic air cleaning
- Cost reductions for surface cleaning due to the easy-clean properties of superhydrophilic surfaces (automotive glazing, rearview mirrors, and so on) and the photocatalytic decomposition of organic materials
- Greater driving safety due to anti-fogging coatings (for example, improved sensor function)

Simulation

Automotive engineering makes high demands on coatings since components with complicated shapes have to be coated and these coatings are subject to high chemical or mechanical stress when the vehicle is in operation. The simulation tools developed at the Fraunhofer IST make possible an economically efficient development of coating methods, which are optimized with regard to precision and productivity. The coated components are investigated using a large number of analytical methods. Not only metrological methods are used but also adapted simulation procedures in order to enable quantitative conclusions to be drawn from the component properties. The following simulation methods are used for automotive engineering at the Fraunhofer IST:

- Particle-in-Cell Monte-Carlo-Simulation for plasma coating processes
- Simulation-aided evaluation of spectroscopic and ellipsometric measurements
- Simulation of mechanical coating properties for alignment with mechanical load tests
- Model-supported evaluation of light scattering behavior as a function of surface morphology

8 *Stained water drops on ultrahydrophobically coated glass.*

9 *PIC-MC simulation of a dual magnetron sputtering module in a 2-D cross-section with bipolar medium-frequency excitation.*

We are pleased to support you

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