FRAUNHOFER INSTITUTE FOR SURFACE ENGINEERING AND THIN FILMS IST

ANNUAL REPORT 2014

COVER *Inline coating plant with dual magnetron for reactive Al_2O_3 deposition.*

FOREWORD

Ladies and gentlemen,

in the annual report 2014 at hand we provide you with a selection of the most important developments of the Fraunhofer Institute for Surface Engineeing and Thin Films IST. For our institute the year 2014 was another very successful year with many highlights and exciting projects. You can find out more on the following pages.

We woud like to take this opportunity to express our thanks to all people whose hard work and commitment made our success possible in the first place: above all the employees of the Fraunhofer IST, our partners from research and development, our customers from industry, our sponsors, colleagues and friends. Thank you for a trusting cooperation.

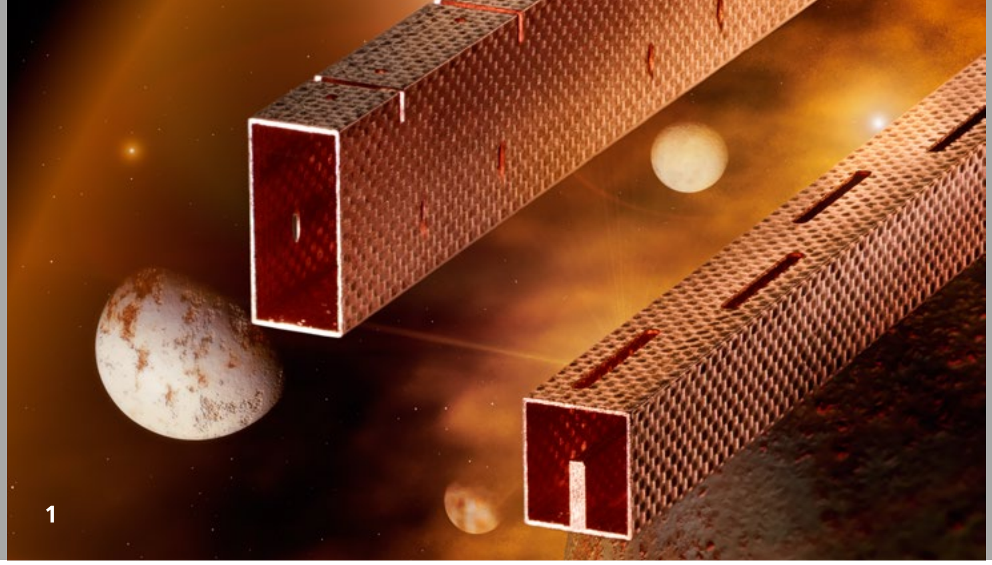
Dear reader, we wish you a great joy in reading and are looking forward to your ideas for cooperation in future.

1 *On the left: deputy director Prof. Wolfgang Diehl. On the right: director Prof. Dr. Günter Bräuer.*

Prof. Dr. Günter Bräuer

Prof. Wolfgang Diehl

CONTENT



HIGHLIGHTS 2014

"Cold plasma – a miracle solution?" Under this headline a current issue of the German periodical "Bild der Wissenschaft" reported on the prospects for low-temperature plasmas. One of the main themes of the article was the application of atmospheric-pressure plasmas in medical technology. On 26th November 2014 the young company Cinogy GmbH was awarded the Innovation Prize of the District of Göttingen together with researchers and developers from our Application Center for Plasma and Photonics, the Göttingen University of Applied Science and Art as well as the Clinic for Dermatology, Venereology and Allergology of the University of Göttingen Medical School. The team received this award for a CE-certified method of to accelerate the healing of wounds with plasma. This honor is a further milestone on our way to utilizing atmospheric-pressure plasmas in the life sciences. On June 3, 2014 the application center's new building in Göttingen was officially opened, where twenty to thirty researchers are pushing forwards developments in this field.

Atmospheric-pressure plasmas are also especially suitable for the structured treatment of polymer films. Very diverse patterns and dimensions up to structure widths and spacings of 25 µm can be realized. With the plasma printing technique, which was developed at the Fraunhofer IST, for example the wettability of the treated surfaces can be selectively adjusted. The structures in question can then be wet-chemically metallized in order to produce, for example, biosensors, printed circuit boards or RFID antennas cost-efficiently. In collaboration with its partners the Fraunhofer IST built a first industrial reel-to-reel system which was successfully commissioned early in the year.

Under the headline "Braunschweig technology transmitting in space" the media reported early in 2014 about an event which our employees were also feverishly awaiting: on the evening of April 3, 2014 the European Space Agency launched its observation satellite "Sentinel 1A" into space. Shortly afterwards the large antenna (12.30 m x 0.90 m) of the new radar instrument developed by Airbus Defense and Space successfully deployed and locked in place. Braunschweig is the origin: the waveguides made of carbon-fiber-reinforced plastic (CFRP) were supplied by the Braunschweig company Invent and the subsequent metallization of components was carried out in our electroplating facility.

Atomic layer deposition is a coating process whose basic principles we have successfully developed over the last five years. In order to demonstrate the potential of this method, for applying precise coatings to three-dimensional objects, our experts applied an antireflective coating on the surface of a glass sphere. The result is impressive.

On the occasion of the Technical Conference of the American Society of Vacuum Coatings (SVC) our deputy director, Prof. Wolfgang Diehl, took office as the SVC's president on the evening of the May 4, 2014 in Chicago. He is the first non-American to hold this responsible post of this renowned society. On the same day our employee Dr. Ralf Bandorf was honored with the "Mentor Award" of the SVC. He received this award for his extraordinary contributions to the development of high-power impulse magnetron sputtering on the industrial scale.

Discover much more about our activities in 2014 on the following pages. I hope that you will enjoy reading it.

Günter Bräuer

1 *The Fraunhofer IST metallizes the fiber composite antennas for the ESA's Sentinel mission.*

2 *Prof. Wolfgang Diehl (right) decorates Dr. Ralf Bandorf with the SVC Mentor Award.*

BOARD OF TRUSTEES

RESEARCH AND APPLICATION

The Fraunhofer Society is one of the most important pillars of the German research world. Every day, it strives to go beyond purely scientific research and find its practical applications – entirely following the example set by Joseph von Fraunhofer of living a symbiosis of research and entrepreneurialism and putting this into practice in its daily work.

As head of development for a medium-sized company I value the scientific competence of the institutes in opening up new territories, tackling challenging areas and coming up with innovations. Our company can look back on years of very rewarding collaboration with the Fraunhofer IST in various central topics. One current example is our collaboration in the field of plasma printing. Together with further partners a technology has been developed which opens up new applications for GRT in the field of plasma. We will continue also in future to collaborate with the Fraunhofer IST in going into this area in greater depth in order to find innovative approaches in, for instance, printed electronics.

From my own work in our company I know very well the balancing act between research and application – "two souls are housed in my bosom" (Goethe) – which many people in the institute also have to master. The board of trustees has supported to instal a new division between the scientific level and the business fields of the application. This change has been positively implemented by the institute. It gives every employee the opportunity of development. We on the board of trustees see this restructuring as an opportunity for injecting the excellent scientific results of the institute with even more success into new markets in the future as well.

I wish every employee of the institute and also institute management every success in 2015 as well.

Dr. Ernst-Rudolf Weidlich
GRT GmbH & Co. KG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OUTSTANDING COLLABORATION

IHI Hauzer Techno Coating B.V. is part of the large Japanese IHI Group with worldwide more than 28,000 employees. Headquartered in the Netherlands the company specializes in the manufacture of PVD/PECVD systems. Hauzer is a global leader in the field of coatings on automotive components.

In the development of engines major breakthroughs have been achieved in recent years with the aid of PVD/PECVD technology. Without this technology it would not have been possible, for example, to produce the high-pressure diesel injection pump. Hauzer supplied the PVD systems and thus made large-scale production of these components possible. The Fraunhofer Institute for Surface Engineering and Thin Films IST made an important contribution to these developments. Back in 1993 it demonstrated the potential of Hauzer's system technology by developing innovative coatings and processes. This was the starting point of a long-term collaboration.

Hauzer's strengths lie in application-oriented coating development in which they work together intensively with end users and material designers. Here the end user lists the problems which are to be solved by means of a coating while the material designer supplies possible solutions in the form of innovative coatings. The Fraunhofer IST can draw on years of experience in the field of tribological coatings. A few years ago this finally resulted in starting a development project in collaboration with the Fraunhofer IST which aimed at developing heat-resistant coating systems with a low coefficient of friction.

The continuous increase in injection pressures and the associated rise in the power densities of the engine components have resulted in a greater demand for improved wear protection. However, reduction of CO_2 emissions has also played an important role, especially in recent years. Both objectives can be achieved with the aid of DLC coatings on the engine components, which is why the demand for these coatings has enormously increased. They secure the lowest coefficients of friction while simultaneously offering good compatibility with the lubricants used.

A reduction in CO_2 emissions also means that injection pressure will keep on rising – even up to 2500 bar. This in turn means that the coatings will also be subjected to even higher thermal stresses. At the present time the coatings must withstand temperatures between 400 °C and 500 °C and still guarantee low coefficients of friction and also a high level of wear protection. These requirements could no longer be satisfied by the hydrogenated and non-hydrogenated DLC coatings available. In an intensive collaboration between Hauzer and the Fraunhofer IST, various doped DLC coatings have been developed, some of which have already proved superior in comparative tests to existing DLC systems.

At this point I would like to express my thanks to the Fraunhofer IST for many years of trustful collaboration we have enjoyed together.

Roel Tietema
IHI Hauzer Techno Coating B.V.

1 *Hauzer systems are used worldwide in the automotive sector in large-scale production (approx. 400 – 500 million components per year).*

2 *Roel Tietema, IHI Hauzer Techno Coating B.V.*

3 *High-temperature tribometer at the Fraunhofer IST, used for measuring wear at 450 °C.*

INSTITUTE PROFILE

As an industry oriented R&D service center, the Fraunhofer Institute for Surface Engineering and Thin Films IST is pooling competencies in the areas surface treatment and modification, film deposition, coating production and application, film characterization, and surface analysis. A large number of scientists, engineers, and technicians are busily working to provide various types of surfaces with new or improved functions and, as a result, help create innovative marketable products. At present, the institute's business segments are:

- Mechanical and Automotive Engineering
- Aerospace
- Tools
- Energy, Glass and Facade
- Optics and Electronics
- Life Sciences and Ecology

In pursuing these business segments the institute utilizes its competencies in the following fields:

- Friction Reduction and Wear Protection
- Super hard Coatings
- Electrical and Optical Coatings
- Micro and Nano Technology
- Low Pressure Processes
- Atmospheric Pressure Processes
- Simulation
- Analysis and Testing

In line with the cross-sectional character of coatings and surface technologies the institute cooperates with a large number of coating service providers, equipment manufacturers, and coating users from diverse industries like machinery, transportation, production technology, electronics, optics, information technology, energy, medical devices, and biotechnology to name just the most important ones.

At the site in Braunschweig on an office and laboratory area of more than 4000 square meters 112 tenured employees are addressing a variety of research projects. In addition the new building of the Application Center for Plasma and Photonics provides 1500 square meters of office and laboratory area on three storeys for the 18 tenured employees in Göttingen. The service offers of the Fraunhofer IST are supplemented by the competencies of other institutes from the Fraunhofer Group "Light & Surfaces" as well as by the Institute for Surface Technology of the Technical Universitiy of Braunschweig which ist also managed by the IST director Prof. Dr. Günter Bräuer. Many projects are supported by funding through the state (Land) Niedersachsen (Lower Saxony) the federal government, the European Union, and other institutions.

Important goals of the Fraunhofer IST are:

- the rapid transfer of innovative solutions from application oriented research and development to the industrial praxis
- the establishment of new future oriented technologies in the market place and
- the transfer of these innovative technologies to small and medium sized companies.

THE INSTITUTE IN FIGURES

Talent management

In 2013, the period under review, the Fraunhofer IST had 130 employees. Around 60 % are scientific personnel, doctoral candidates and engineers. Research activities were supported by technical and commercial staff as well as a large number of graduands and student assistants. Training opportunities in the vocational fields of galvanics, physics and information technology were taken up by seven employees in all.

Operating budget

In the period under review the operating budget experienced growth of € 600 000 compared to the previous year. Thus it resulted in a total operating budget of € 12.2 million. The personal costs contribute 63 % to the total operating budget. According to that at Fraunhofer IST exists an almost ideal 60 : 40 ratio of personnel and material-related cost.

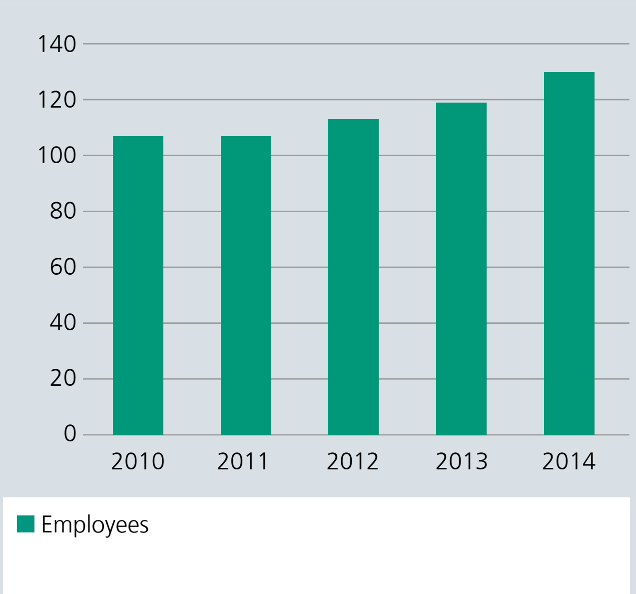
Earning structure

The relative increase was 42.9 % in the period under review. In total, the institute achieve external revenue amounting up € 8.0 million, of which about € 5.2 million can be attributed to industry. An additional € 2.5 million were realized through public sector (inclusive EU revenue), about € 200 000 through other revenues.

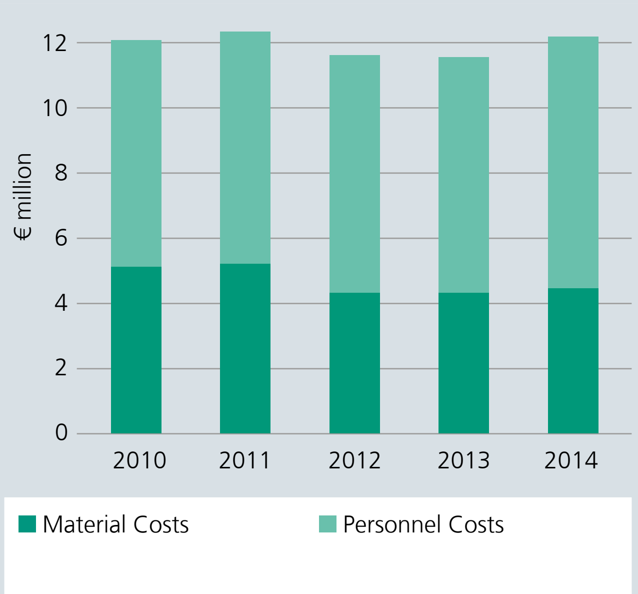
Investments

All in all the Fraunhofer IST dispensed on normal investment some € 900 000. € 90 000 could be invested through external project funds. € 335 000 can be attributed to normal investments, € 475 000 to strategic investments. This means for the Fraunhofer IST an overall budget (B + I) totaling € 13.1 million.

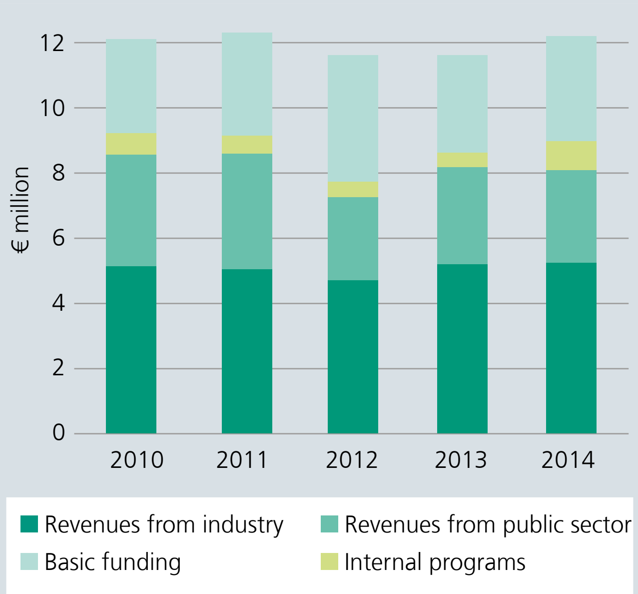
Number of employees.



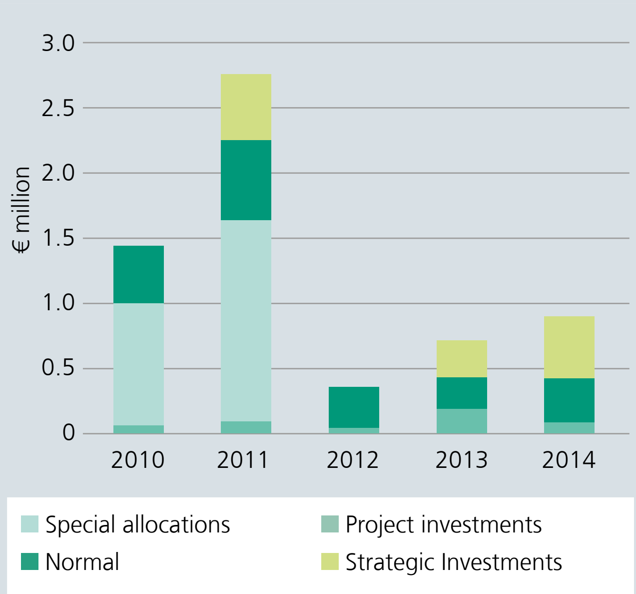
Personnel and material costs.



Earning structure.



Investments.



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Simulation
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Analysis and Quality Assurance
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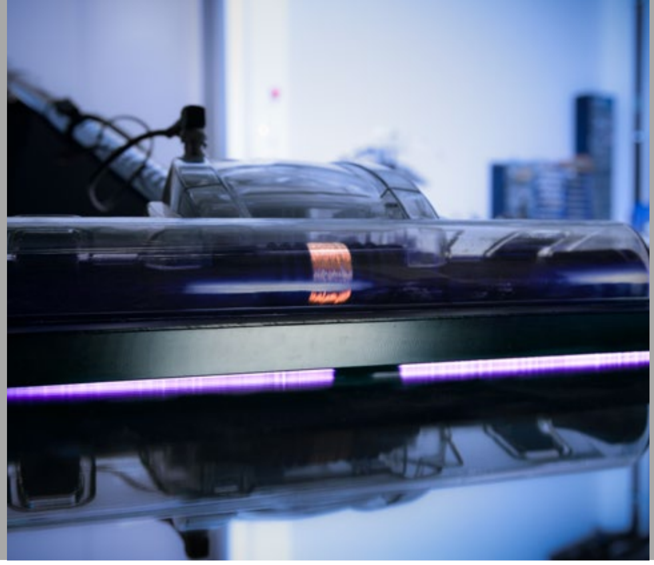
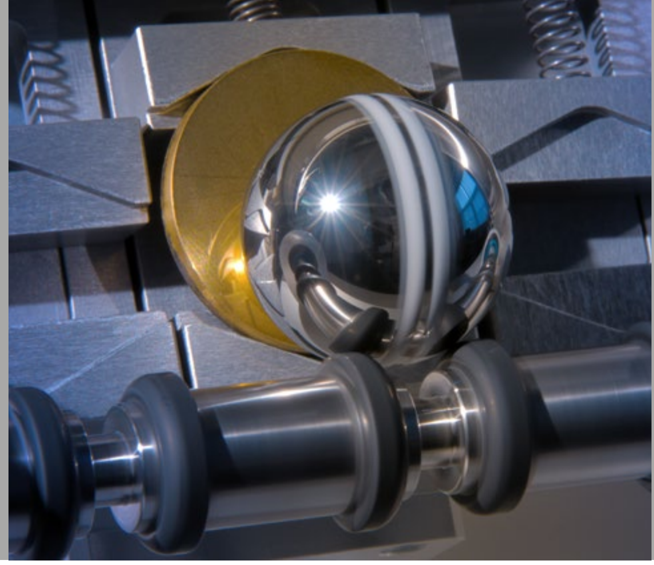
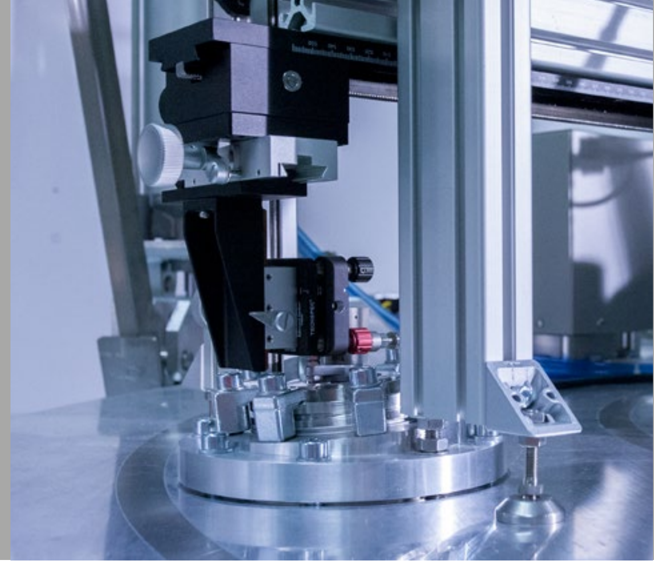




THE SCOPE OF RESEARCH AND SERVICES

Pretreatment – We clean surfaces

Successful coating processes imply a proper surface pretreatment. Therefore we offer:

- Effective aqueous surface cleaning including drying
- Special glass cleaning
- Plasma pretreatment and Plasma cleaning
- Plasma activation and Plasma functionalization
- Wet-chemical etching pretreatment
- Particle beam

Modification and Coating – We develop processes and coating systems

Thin films and specifically modified surfaces are the core business of the Fraunhofer IST. The institute utilizes a wide range of coating technologies and surface treatments, ranging from plasma coating and treatment in vacuum and at atmospheric pressure over hot-filament CVD processes to electroplating. Our services are:

- Surface modification
- Development of coatings
- Process technology (including process diagnostics, modeling and control)
- Simulation of optical layer systems
- Development of system components and processes
- Toolbuilding and plant engineering

Testing and Characterization – We ensure quality

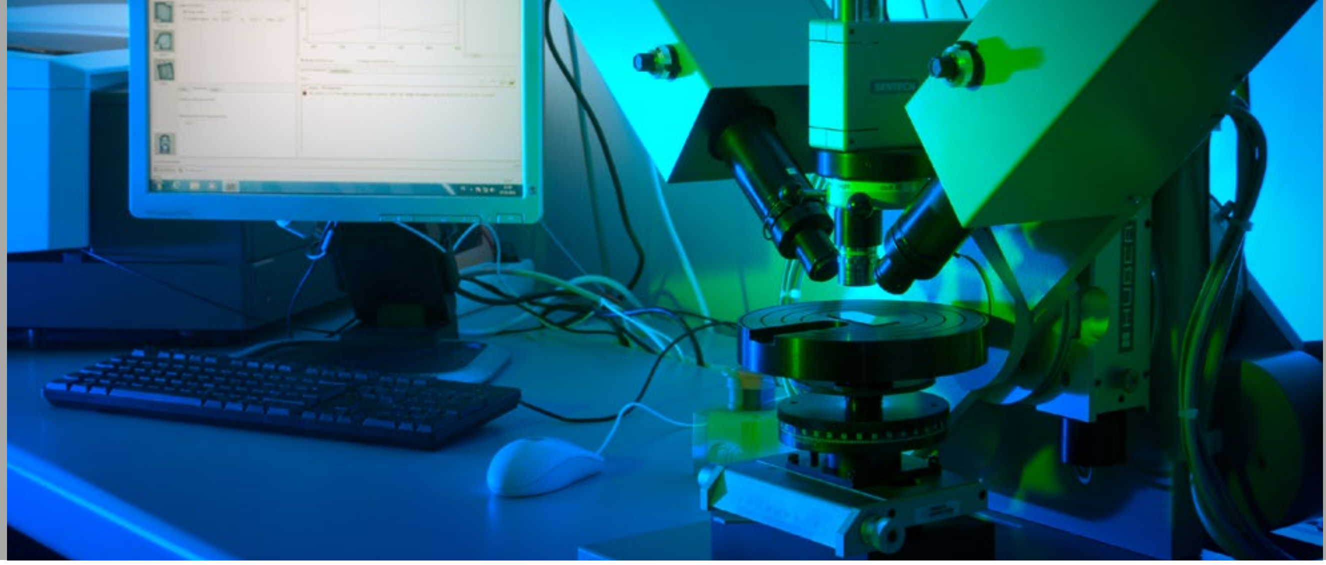
A fast and reliable analysis and quality control is the prerequisite for a successful coating development. We offer our customers:

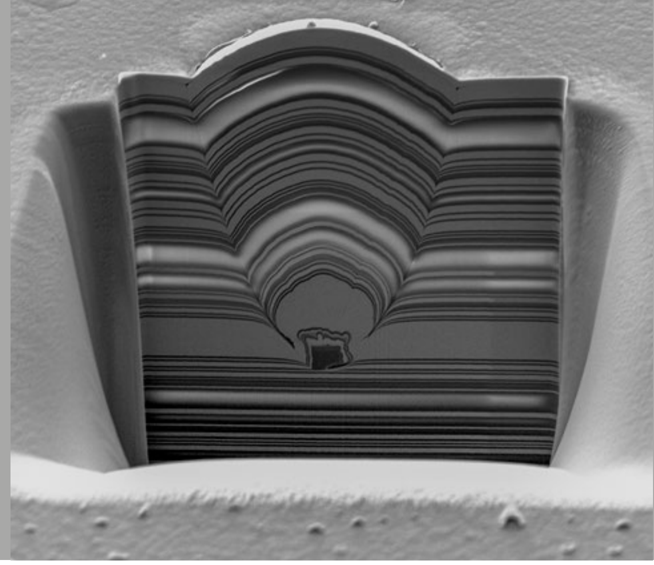
- Chemical, micromorphological, and structural characterization
- Mechanical and tribological coating characterization
- Optical and electrical characterization
- Test methods and product specific quality control methods
- Rapid and confidential failure analysis
- Testing of corrosion resistance

Application – We transfer research results in the production level

To guarantee an efficient technology transfer we offer a wide range of know how:

- Cost-of-ownership calculations, development of economical production scenarios
- Prototype development, pilot production and sample coating procedures
- Equipment concepts and integration into manufacturing lines
- Consulting and training
- Research and development during production





ANALYSIS AND QUALITY ASSURANCE

Chemical and structural analysis

- Energy-dispersive X-ray spectroscopy (EDX)
- Electron microprobe (WDX, EPMA)
- Secondary ion mass spectrometry (SIMS)
- X-ray photoelectron spectroscopy (XPS)
- Glow discharge optical emission spectroscopy (GDOES)
- X-ray fluorescence analysis (RFA / XRF)
- X-ray diffractometer (XRD, XRR)

Microscopy

- Scanning electron microscope (SEM)
- SEM with FIB (Focussed Ion Beam)
- Confocal laser microscope (CLM)
- Scanning tunnel and atomic force microscope (STM, AFM)
- FTIR microscope
- A variety of optical microscopes

Measurement of friction, wear and corrosion

- Pin on disk tester
- Ball-cratering test (Calo)
- Wazau high-load tribometer (in air, in oil)
- CETR high-temperature tribometer (in air, in oil)
- Plint roller tribometer (in air, in oil)
- Taber abraser test, abrasion test, sand trickling test, Bayer test
- Microtribology (Hysitron)
- Impact and fatigue tester (Zwick Pulsator)
- Salt spray test, environmental tests

Mechanical tests

- Micro and nano indentation (hardness, Young's modulus)
- Rockwell and scratch test (film adhesion)
- Cross-cutting test, butt-joint test (film adhesion)
- A variety of methods for the measurement of film thickness
- A number of profilometers

Measurement of optical properties

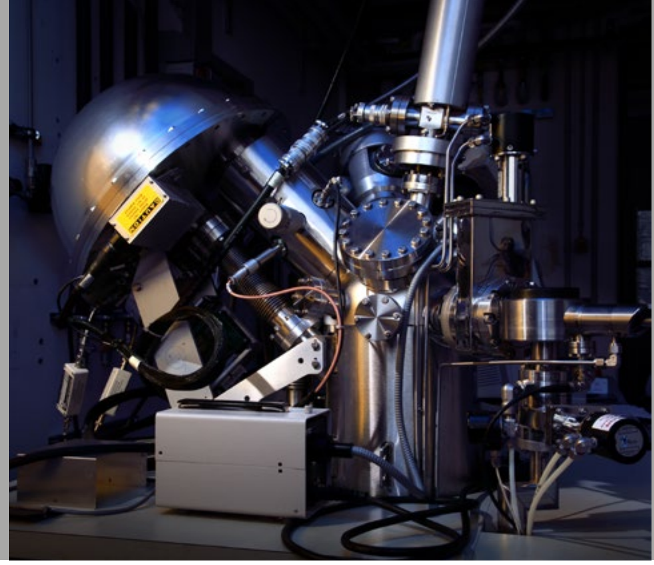
- IR-UV-visible spectrometer
- Ellipsometer
- Colorimetry
- Angular-resolved scattered light measurement (ARS)
- FTIR spectrometer

Specialized measurement stations

- Characterization of solar cells
- Measuring station for photocatalytic activity
- Contact angle measurement (surface energy)
- Measuring systems for electrical and magnetic coating properties (e. g. Hall, Seebeck, conductivity)
- Test systems for electrochemical wastewater treatment
- Measuring stations for the characterization of piezoresistive sensor behavior
- Biochip reader for fluorescence analysis
- Layer mapping system (0,6 x 0,6 m^2) for reflection, trans-mission, Haze and Raman measurement
- In-situ bondenergy measurement
- Magnetic characterization (vibration magnetrometer VMS)

Plasma diagnostics

- Absorption spectroscopy
- Photoacoustic diagnostics
- LIF – laser induced fluorescence
- High-speed imaging
- Optical emission spectroscopy OES
- Retarding Field Energy Analyzer RFEA
- Fiber thermometry
- Electrical performance test
- Numerical modeling



SPECIAL EQUIPMENT

- a-C:H:Me, a-C:H, hard coating production plant (up to 3 m³ volume)
- Coating facilities incorporating magnetron and RF diode sputtering
- Sputter plant for high-precise optical coatings
- In-line coating facility for large-surface optical functional coatings (up to 60 × 100 cm²)
- Industrial scale HIPIMS technology
- Plants for plasma diffusion
- Coating systems for hollow cathode processes
- Coating plant for thermal and plasma atomic layer deposition (ALD)
- Hot-filament-CVD units for crystalline diamond coatings (up to 50 × 100 cm²)
- Hot-filament-CVD unit for silicon-based coatings (up to 50 x 60 cm2)
- Plasma-activated CVD (PACVD) units, combined with plasma nitriding
- Atmospheric pressure plasma systems for coating and functionalization of large areas (up to 40 cm widths)
- Microplasma plants for selective functionalization of surfaces (up to Ø = 20 cm)
- Bond aligner with an integrated plasma tool for wafer pretreatment in the clean room
- Roll-to-roll set-up for area-selective functionalization of surfaces
- Machine for internal coating of bags or bottles
- Laser for 2D and 3D microstructuring
- 2 mask aligner for photolithographic structuring
- Laboratory for microstructuring (40 m² clean room)
- Equipment for electroplating processes
- 15-stage cleaning unit for surface cleaning on aqueous basis
- Clean room – large area coating (25 m²)
- Clean room – sensor technology (35 m²)
- Mobile atmospheric pressure plasma sources
- Nanosecond dye laser (Nd: YAG-Laser)
- CO_2-laser and Excimer-Laser
- EUV spectrography
- Semiconductor laser
- Picosecond laser

SUSTAINABLE SOLUTIONS WITH SURFACE AND THIN FILM ENGINEERING

Sustainability is currently perhaps the most important social guiding principle of the age. Not only in the European Union but also in Germany sustainable development processes are in first place on the agenda. In the field of surface and thin film engineering the Fraunhofer IST has for a number of years now been developing solutions for sustainable products and sustainable industrial production.

A large number of research subjects at the Fraunhofer IST are oriented by urgent future-related topics and by social trends, such as the implementation of an alternative energy supply, alternatives for scarce materials and raw materials, or mobility in the 21st century. The very thinnest high-performance coatings are in addition the basis for a variety of further products and high-tech applications which are viable for the future, especially when it is a matter of saving material and energy Some examples from our research into sustainable industrial products and processes:

Innovative materials

- At the Fraunhofer IST intensive research has been in progress on replacing indium tin (ITO) with alternative materials such as ones based on ZnO and SnO_2 and TiO_2.
- Low damage separations of indium free materials for high efficient LEDs are being developed.
- At the Fraunhofer IST alternative materials for the high-refractive-index tantalum oxide coatings used in optical industries are being developed.
- New materials like canal materials for TFIs and p-conductive materials are being developed for transparent contact films (TFTs).
- At the Fraunhofer IST a REACH-compliant plastic metallization is used as an alternative to chrome (VI).

Material efficiency

- With an additive galvanic metallization process, metals such as copper, for example, are applied to selected areas.
- Working materials with new properties are being found by combining different materials.

Production efficiency

- Optimized hard-material and nanostructured coating systems for forming or cutting tools increase service lives and make more economically efficient manufacturing possible.
- Faster to the goal: simulation means ever shorter development times. For example, highly efficient production chains are made possible by model-based design and implementation of coating processes.
- Modules with sensorized thin-film systems are built into deep-drawing systems and driving machines to ensure efficient forming and machining of components.
- Hard carbon-based coatings not only stop materials such as powders from adhering to tools but also prevent deposits on or fouling of surfaces in, for example, heat exchangers or exhaust systems.
- The application of nano particles as a source material at plasma spraying makes it possible to produce metal coatings on heat sensitive surfaces.

Energy efficiency

- Lower energy consumption due to the erosion protection of aero-engines: very hard multilayer coatings of ceramic and metal prevent excessive fuel consumption and falling efficiency levels.
- Broader and improved range of applications for lightweight components by means of wear-resistant, friction-reducing coatings which also protect against corrosion.

Clean environment

- With the diamond electrodes developed at the Fraunhofer IST water can be conditioned electrochemically – adapted to the infrastructure on the spot and without the use of chemicals.
- Photocatalytic coatings make self-disinfecting surfaces possible and the degradation of pollutants from the air.
- The functionalization of surfaces in plasma enables adhesive to be dispensed with when, for example, bonding materials. Plasma pretreatment is also suitable as a replacement for primers and as a way of improving the adhesion of paint systems.

Mobility in the future

- Low-friction and extremely wear-resistant coatings reduce the fuel consumption of car engines and extend both maintenance intervals and service life.
- New corrosion coatings on metallic bipolar plates make possible the economic production of powerful fuel cells for the automotive industry.
- Robust thin-film sensor systems in highly stressed parts of components increase reliability and safety in many fields of application, such as, for example, electromobility or wind power plants.
- Plasma produced functional coatings for components of lithium ion batteries raise the efficiency and the durability of these storages for electro mobile applications.

MECHANICAL AND AUTOMOTIVE ENGINEERING

The business unit "Mechanical and Automotive Engineering" has been developing particulary coating systems and surface technologies that reduce friction, which also protect against wear and corrosion and that are optimized according to the application. In addition to modifying coatings to suit different applications, the development and implementation of product- and production-adapted coating processes stands in the foreground. Furthermore are newly coating systems with up until now unknown characteristic profiles as well as sensorized surfaces for different fields of application developed and tested. Examples are:

- Carbon-barrier films for aaplications in fusion reactors
- High corrosion fixed carbon film systems for seal applications
- Corrosion protection films for metallic bipolar plates in fuel cells
- Thermoresistive thin film sensors to monitor engine components

Customers of the business unit include not only coating service companies but above all coating users from all areas of machine manufacturing and the automotive industry.

CONTACT

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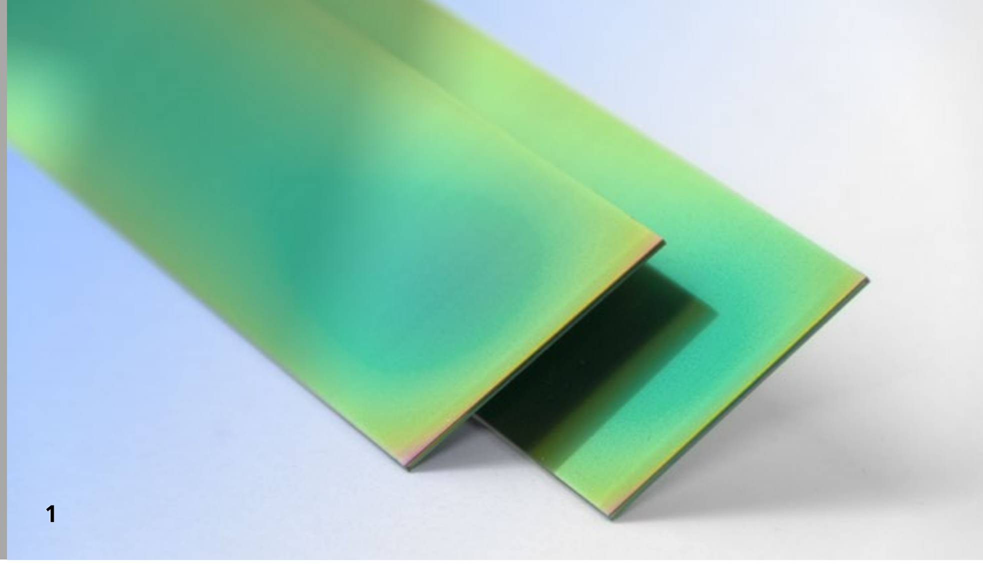
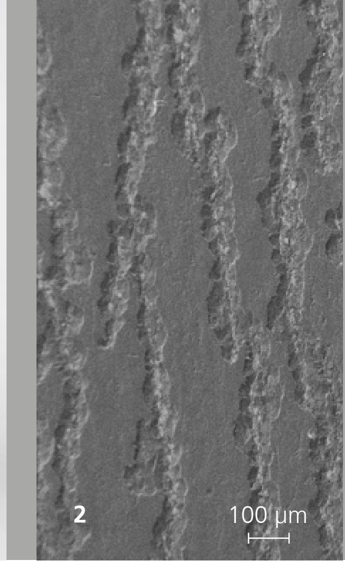
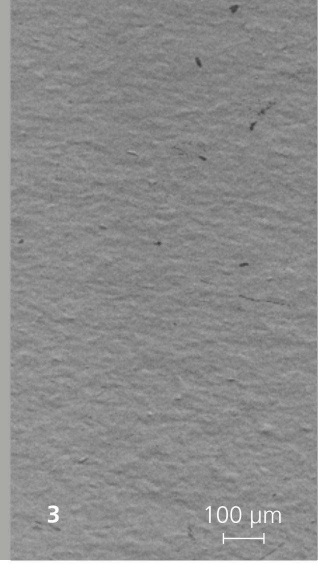






NEW MANUFACTURING APPROACH FOR ANTIFOULING COATINGS FOR PIPES

The formation of deposits on technical surfaces, also called fouling, interferes with the functioning of process plants, reduces productivity and impacts on product quality. Especially in the case of heat-transferring components the deposits also raise energy consumption while simultaneously lowering efficiency. New antifouling strategies with non-stick coating systems can for this reason yield considerable cost reductions in the chemical, pharmaceutical and foodstuffs industries. Together with partners from Belgium and Germany the Fraunhofer IST has developed a new approach to manufacturing pipes with an antifouling coating on the inside of the pipe.

Damage due to fouling

Problematic deposits arise in numerous systems from different mechanisms, such as, for example, crystallization, particle or bio-fouling. Calcium deposits, such as boiler scale, are ubiquitous in components carrying water. Fouling in heat exchangers affects not only the flow but heat transfer in particular. The consequences range from lower energy efficiency to complete loss of function. In sensitive areas, such as the manufacture of medicaments, the presence of deposits is often not acceptable.

Antifouling strategy: coating systems with low surface energy

Conventional measures for reducing deposits include a careful selection of the materials and media used or compromises in the process technology. Both approaches mean restrictions on the design of production facilities and additional costs. Further outlay arises from mechanical and/or chemically-acting cleaning procedures to remove deposits and keep components in good maintenance.

The approach taken by the Fraunhofer IST is to use anti-adhesive coating systems to counteract the formation of deposits. Modified DLC coatings (diamond-like carbon), such as SICON® – a coating of hydrocarbon modified with silicon and oxygen – are particularly promising here since not only do they have anti-adhesive functional properties but also a high degree of hardness and durability.

SICON® and other plasma-chemically deposited coating systems with low surface energy are already in successful use in many applications at the Fraunhofer IST for preventing adhesions. However a broad application in process engineering calls for coatings inside heat-transferring components, for example, on the interior of pipes. Direct coating of the inner walls of pipes is only possible to a limited extent with PACVD and PVD processes and in many cases does not deliver the coating quality required.

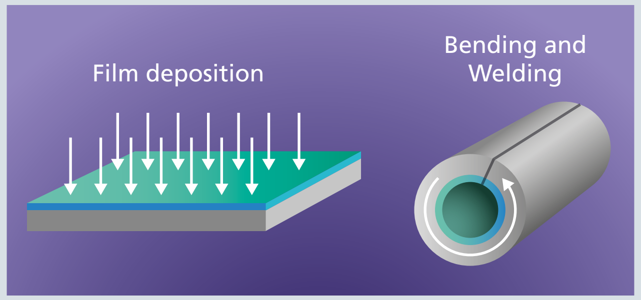
New manufacturing approach for internally coated pipes

A new approach to manufacturing has therefore been developed in collaboration with experts in forming and welding technologies. Here flat steel sheets are coated and then formed into pipes and welded (see sketch below). The coating must not suffer any damage during roll-forming of the pipes, its antifouling function must be guaranteed and it must have a high degree of durability. Currently pipes over a meter long can already be produced with an anti-fouling coating on the inside (Fig. 1). Appropriately adjusted PACVD processes mean that modified DLC coatings can be produced which remain entirely undamaged even with small pipe diameters (currently tested down to 12 mm) (Figs. 2 and 3).

Outlook

The effectiveness of the coating systems developed has already been demonstrated for various fouling mechanisms. Formation of deposits can be markedly reduced or even entirely prevented by SICON® coatings. Pipes more than one meter long and manufactured in the way we have described are at the present time being investigated and evaluated in special fouling-tests. In the future, complete heat transfer systems with piping provided with an anti-fouling coating on interior surfaces are to be built. Prototypes are to be trialed in particularly challenging production processes in process engineering.

Manufacturing approach for pipes with an antifouling coating on the inner wall.



1 *1 m long metal stripe with antifouling coating before role-forming.*

2-3 *Different coating systems on the inside of the pipe after the forming process: (2) Standard DLC coating shows damage due to the pipe-forming process, (3) Modified DLC coating is fully intact and functional even after pipe forming.*

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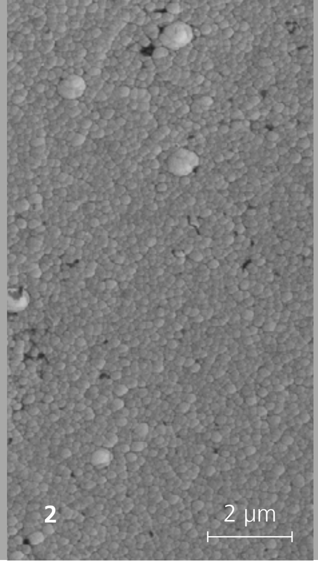
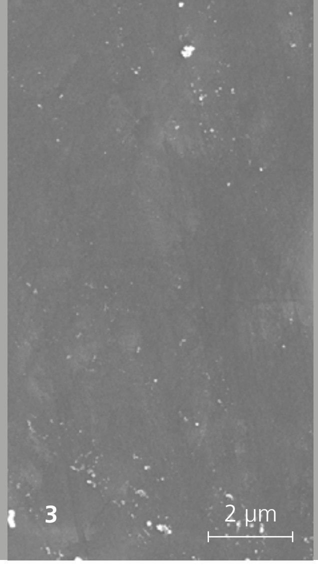




THERMALLY STABLE DLC COATINGS

Current developments in the automotive industry, such as higher power densities, downsizing or the use of low-viscosity oils, require the use of coatings with long-term stability which offer low friction coefficients and low wear rates even at temperatures up to 500 °C. The diamond-like carbon coatings (DLC coatings) currently established in industry, mostly hydrogenated amorphous carbon coatings (a-C:H coatings) but increasingly also hydrogen-free ta-C coatings, do meet requirements but only up to about 350 °C. One way of increasing the heat resistance of DLC coatings is to modify them by incorporating additional elements. As part of a development project in association with the company IHI Hauzer Techno Coating in Venlo, Netherlands, differently modified DLC coatings have been investigated at the Fraunhofer IST with regard to their mechanical and tribological properties up to 550 °C.

Coating preparation and high-temperature tests

In an initial step the modified DLC coatings were deposited by Hauzer Techno Coating in a Flexicoat® 1200 hybrid coating machine. The following technologies were used here:

- Arc evaporation
- Sputtering
- PACVD (plasma-assisted chemical vapor deposition) and
- Combinations of arc evaporation with sputtering and PACVD with sputtering.

Tungsten and silicon were used as modification elements for the a-C:H coatings and tungsten and hydrogen for the ta-C coatings. Following a four-hour annealing treatment at temperatures up to 500 °C in an ambient atmosphere, hardness, wear and friction coefficients were measured. Furthermore, with the high-temperature tribometer available at the Fraunhofer IST the friction coefficients could be measured directly at high temperatures, for example, at 450 °C in a normal atmosphere.

Assessment of different modified DLC coatings

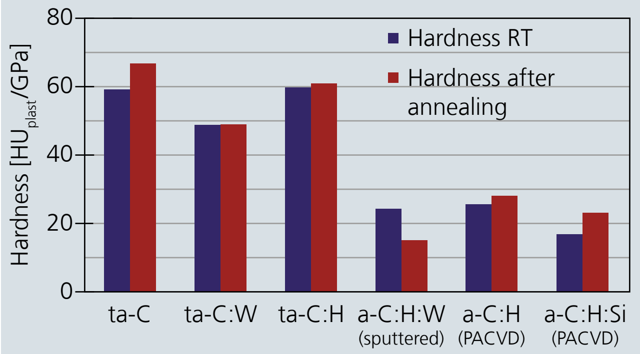
The changes in coating hardness resulting from annealing are shown in the diagram (top) for six selected coating materials. Apart from the a-C:H coatings modified with tungsten (a-C:H:W), hardness rises or remains unchanged. Furthermore it is clear that the surface roughness of the coatings and also the friction coefficients fall slightly after annealing.

For all coatings considerably higher friction coefficients were measured at 450 °C than at room temperature (see diagram, bottom). Comparatively minor increases can be seen with the ta-C:H and a-C:H:W coatings. Both friction and wear are taken into consideration in application-oriented assessments of coating potential. In the light of these criteria the a-C:H:Si coatings, for example, which have the lowest friction coefficients at room temperature, are less suitable for high-temperature applications on account of their high rates of wear. The studies carried out yielded valuable information about the suitability of differently doped DLC coatings for highly stressed tribological pairs with thermal loads up to temperatures in the range of 500 °C.

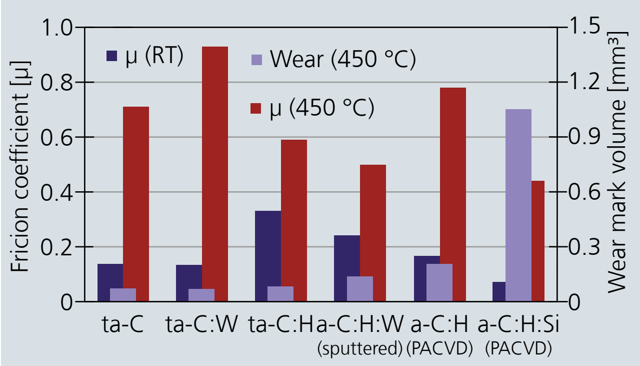
Outlook

The results of these investigations form a basis for being able to define friction- and wear-reducing DLC coatings for automotive components for use at higher temperatures. Further investigations are being prepared for development work, including tests under different load collectives, lubricated conditions, varied coating modifications and testing of the coatings on real components.

Comparison of layer hardness before and after annealing.



Fricion coefficients measured at room temperature (RT) and at 450 °C as well as the determined wear rates after the test.



1 High-temperature tribometer at the Fraunhofer IST.

2-3 REM surface images of an a-C:H:W coating before (2) and after (3) annealing.

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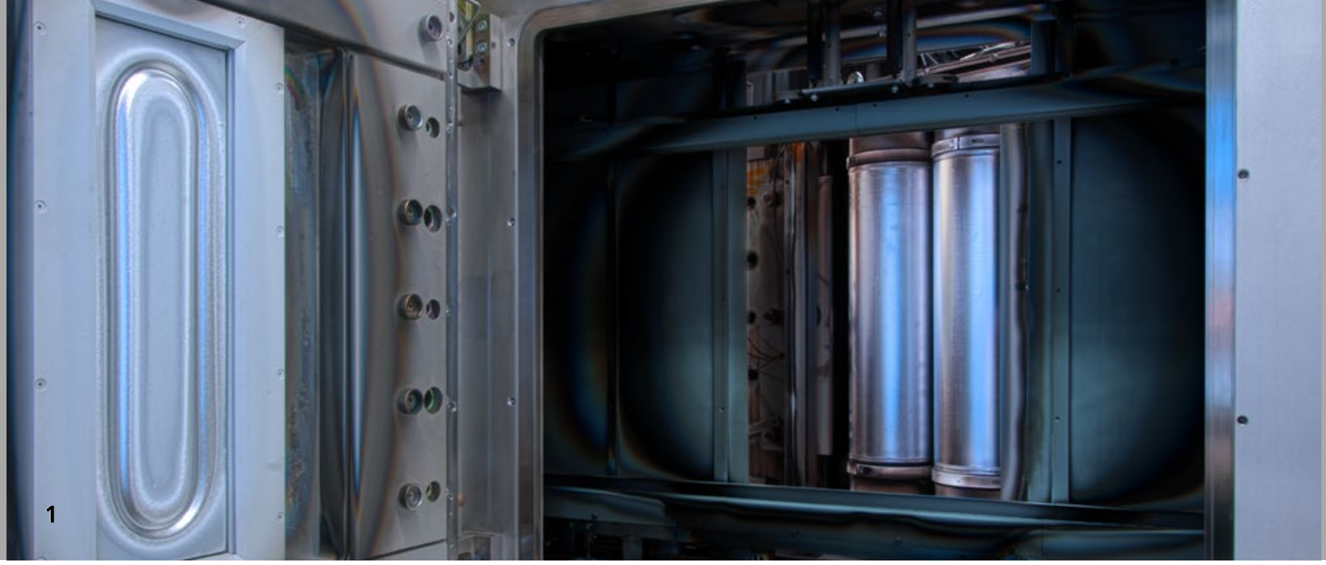


INSULATION COATINGS WITH HIGH DIELECTRIC BREAKDOWN STRENGTH

Insulating coatings play a crucial role in a multitude of applications. As the Industry 4.0 revolution unfolds the trend continues towards greater surveillance and monitoring of processes and workflows. This requires increased use of sensors or integrated sensor solutions. A reliable and proofed insulation is absolutely essential, especially in the case of sensor integration in technical, in most cases, metallic components. These insulation coatings, which are also used in other components and markets, must have a low defect density and a high dielectric breakdown strength. Research is therefore in progress at the Fraunhofer IST into processes by which defect-free insulating coatings can be produced on the industrial scale.

Vacuum deposition of insulating coatings

Silicon and aluminum oxide coatings deposited by vacuum coating processes are frequently used for insulation and functional purposes. Basically and depending on requirements, processes for depositing from the gas phase (Chemical Vapor Deposition CVD) and from the solid-state target (Physical Vapor Deposition PVD) are used here. Both methods have a number of advantages but also some disadvantages.

Silicon oxide films can, for example, be produced at a good quality and high rate by plasma enhanced CVD (PECVD). However, these processes react very sensitively to changes in batch loading and component dimensions. Aluminum oxide, on the other hand, is harder to produce by PACVD and is instead typically generated by radio-frequency sputtering from a ceramic target. Unfortunately the deposition rate is very low. As regards cost-effectiveness, a high deposition rate with high coating quality is however desirable for PVD processes.

Reactive MF sputtering of highly insulating Al_2O_3 coatings

While stoichiometric films with good insulating properties can be produced by conventional radio-frequency sputtering from a ceramic Al_2O_3 target, reactive sputtering processes also offer the potential for considerably boosting deposition rates. The reactive process does however confront the user with some special challenges. To generate a low-defect coating, arcing events must be avoided as much as possible in the deposition process. These arcs often arise between the metallic racetrack and redeposition zones, i.e. areas where the target surface is oxidized. A very fast reaction in the event of an arc is critical here. The use of tubular cathodes can minimize the formation of oxide layers on the target surface and thus also the creation of arc discharges.

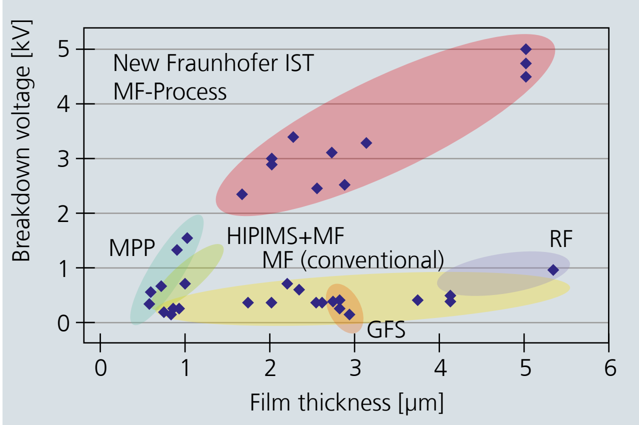
Characterization of highly insulating Al_2O_3 films on the industrial scale

A reactive process was developed at Fraunhofer IST by which highly insulating Al_2O_3 coatings can be generated. While conventional coatings with a thickness of approx. 5 µm have breakdown voltages in the range of 500 – 1000 V, specimens made by the new process exceeded the maximum test voltage of 5000 V. The deposition rate for the coatings was in the range of 2 µm/h (see diagram on the right side).

In further evaluation of the process from the point of view of industrial requirements, a carrier was fitted out over its full area with metallic reference samples in an inline coating system with cathode lengths of around 500 mm. The area under investigation on the carrier measured approx. 400 mm x 400 mm. The 5 µm Al_2O_3 coating was given a metallic top layer and a high-voltage tester (according to DIN EN 60243-1) then applied to check the breakdown voltage and defect density.

In all test specimens the breakdown voltage at the various points of measurement was higher than 2000 V. The majority of all measuring points had a breakdown voltage beyond 5000 V. Short-circuiting to the substrate could not be detected in any of the test pieces. The current process should now be expanded and qualified to cover also non-planar substrates.

Breakdown voltage of Al_2O_3 coatings as a function of the film thickness and the used deposition process.



1 *Inline coating system with dual magnetron for reactive Al_2O_3 deposition.*

2 *Ball bearing with thin film strain gage on its external radius.*

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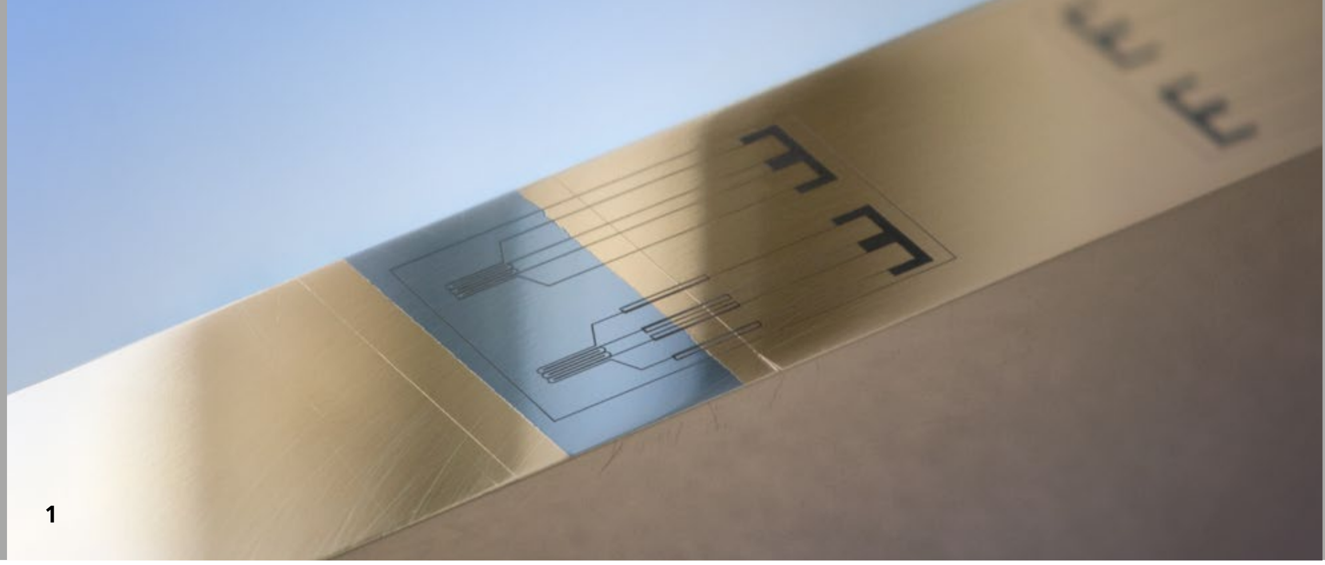

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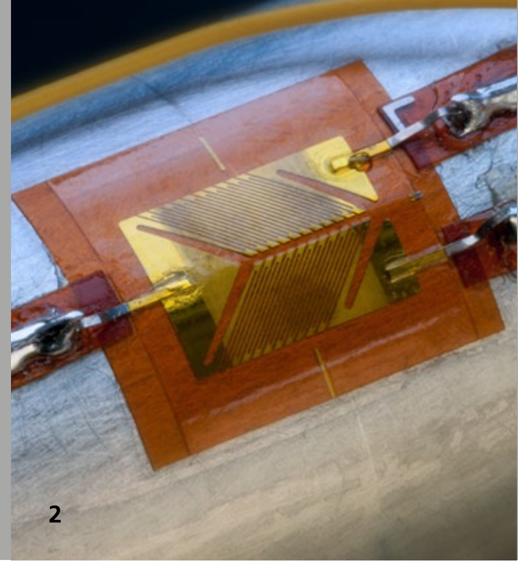

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COMPARISON OF FOIL AND SPUTTER STRAIN GAUGES

Strain gauges are objects of measurement used for measuring and analyzing the mechanical tensions, strains and forces in components. Since their introduction in 1938 they have rapidly developed further and prototype development is unimaginable without them. In most cases, foil based strain gauges are glued to a component. These however have a number of drawbacks since it can only be used up to a certain temperature and is vulnerable to moisture. To get round this and other disadvantages it is possible to apply the strain gauge directly on the sample surface using sputtering technology.

Sputter strain gauges

To improve investigation of how sputter strain gauges behave and also to help interested users make a direct comparison, a demonstrator has been built at the Fraunhofer IST which is equipped with both conventional film strain gauges and also thin-film strain gauges at comparable locations on the same spring element. In this way, response behavior, recording of dynamic and static processes, as well as drift and long-term behavior can be studied and compared.

Tests showed that the thin-film strain gauges responded instantaneously to deformations. In the comparison they picked up any dynamic event at least equally well as conventional film strain gauges. Particularly in the case of quarter bridges – in other words, without self-compensation via the bridge circuit – the thin-film strain gauges exhibited considerably lower virtual elongation due to temperature. One special advantage of the thin film strain gauge is that the sensor elements can be placed directly on the surface of the component. In combination with suitable laser structuring the strain gauge structures can be installed virtually anywhere, even specifically in areas with high strain. The direct connection via a ceramic isolating layer just 3 – 5 µm thick means that any deformation is transmitted directly without attenuation and recorded.

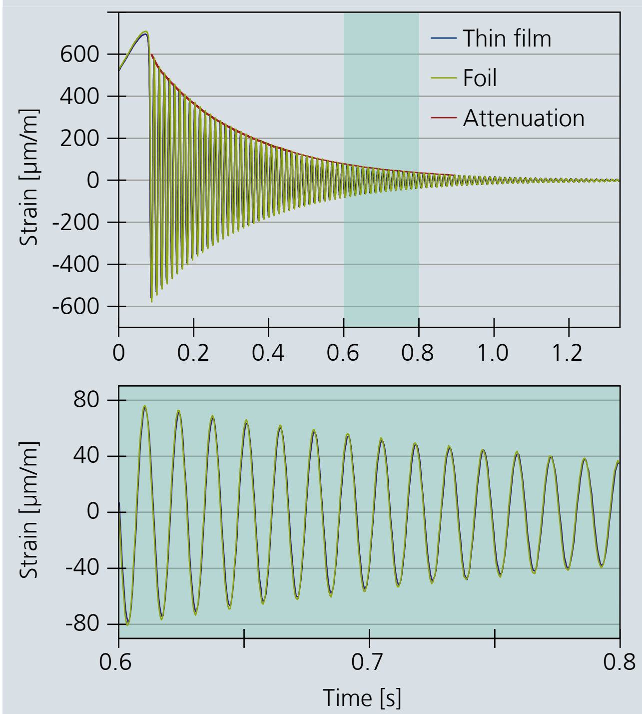
Applications for the customer

The thin film strain gauges developed at the Fraunhofer IST are applied to the substrates precisely as stipulated by the customer. It has been found that considerable time savings have been achieved in the characteristic initial ‚running-in' period. No impairment whatsoever of the signal has been observed.

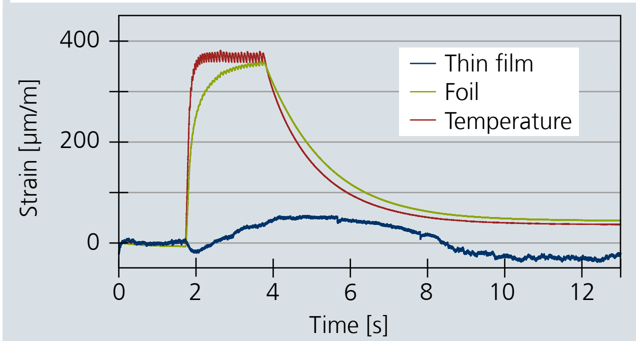
Outlook

On the basis of the accumulated knowledge and expertise, various customer-commissioned prototypes are being built. Here the sensor function is implemented by thin film technology on technical components. In addition, current research work is focusing on applications in the temperature range above 250 °C.

Dynamic loading of time-resolved elongation with thin film and foil strain gauges, full bridge.



Virtual elongation behavior of quarter bridges (thin film and foil strain gauges) as a function of temperature.



1 *Sputter strain gauge on a spring element.*

2 *Foil strain gauge on a test piece.*

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1

2

SENSORIZED WASHERS – UNIVERSAL AND INDIVIDUAL

The development of innovative washer systems for the direct measurement of the forces in screw joints by means of a piezoresistive thin-film sensor system is implemented individually in accordance with customer specifications. In this way a universally applicable measuring system finds a very wide range of possible applications. For its project partners from research and industry the Fraunhofer IST continuously further optimizes and modifies these so-called "smart washer systems".

The sensorized thin-film system

The basis of all sensorized washer systems is the piezoresistive sensor coating DiaForce®, an in-house development of the Fraunhofer IST. DiaForce® is an amorphous hydrocarbon coating which in addition to its piezoresistive behavior also has optimized tribological properties. Electrode structures are used for the local measurement of forces and are brought into direct contact with the sensor layer. These structures can be designed to customer specifications (see Figs. 1 and 2). With additional electrical isolation coatings it is possible to use the sensorized coating system with complete decoupling from the machine mass.

Potential for practical application

There is a continuously growing need for flexible, precise, rapid, resource-thrifty, zero-maintenance and fault-free production. For a constantly more efficient design of production processes a key factor is the implementation of sensor technology. The acquisition of key data during the manufacturing process facilitates continuous monitoring, an expanded understanding of the production process, fast response to changes, and greater flexibility in production. The wide range of variants in the production of sensorized washers permits measuring systems in the size range from M2 to M64 and even beyond this, with minimum thicknesses in the region of 0.5 mm. They can therefore be integrated even into parts of installations for which commercial system must be ruled out on account of the space they require. Sensorized DiaForce®-based thin-film systems have a clear advantage over piezoelectric systems as they can measure not only static but also dynamic force. Further advantages of the system are:

- Possibility of use as a condition monitoring system, recording measured data statically and dynamically over a long period of time.
- Retightening threaded connections will not then be necessary until a fall in preload is detected by the sensorized washer system.
- Improvement in maintenance conditions since there is no need to check screw joints with the torque wrench.

Outlook

Beside wire-bound data transmission, in which the shielded measurement wires are soldered to the thin-film sensor system on the washer system, for many customers wireless data acquisition is becoming increasingly important. For this reason the Fraunhofer IST in collaboration with partners from industry is developing wireless data transmission systems based on radio-frequency identification (RFID) technology.

1 *Washer with piezoresistive thin film sensor system.*

2 *Sensorized washer system with integrated thin film sensor system and Bluetooth data transmission system.*

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TOOLS

In its "Tools" division the Fraunhofer IST concentrates on the following areas among others:

- Plasma diffusion treatment and coatings of press hardening and forging tools
- Tool coatings for aluminium, magnesium and titanium processing
- Nano-structured and high-temperature resistant coatings for cutting tools
- Antiadhesive tool coatings for the molding of plastics
- Diamond abrasive coatings for precision grinding tools
- Thin film sensors for tool monitoring

Important customers of this business unit include coating service companies, tool manufacturers and users from, for example, the mold-making or automotive industries.

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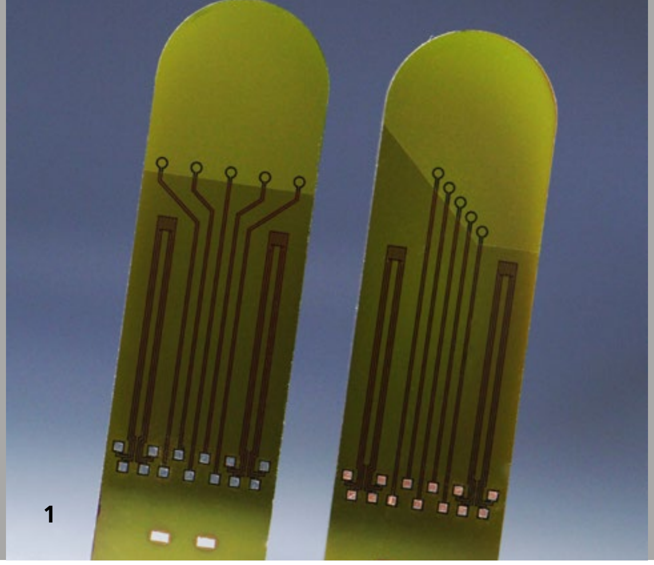

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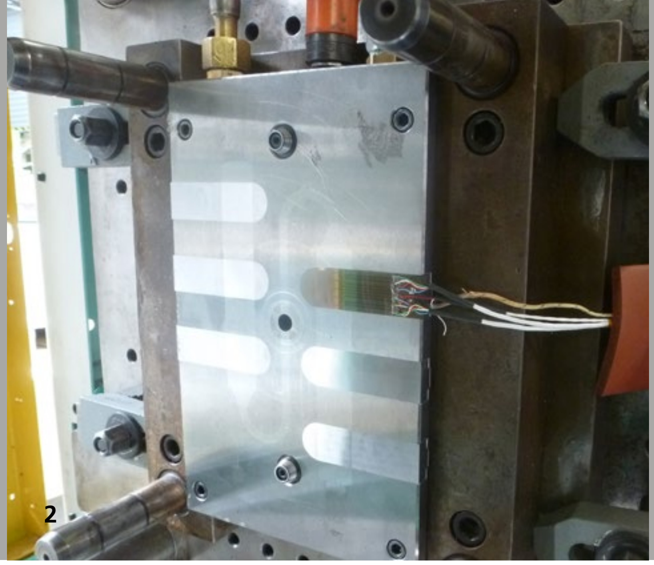

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MULTIFUNCTIONAL THIN FILM SENSOR MODULES

Wear-resistant thin film sensor systems are playing an ever greater role in the most varied applications, especially in the field of real-time acquisition of process data. For this reason the aim of the EU's »Sensorized Future« project is, among other things, to create a sensorized thin-film system which simultaneously during the plastic injection molding process picks up both the force and also the temperature distribution at the surface of the mold. For this purpose individual sensor modules have been developed at the Fraunhofer IST which can be fitted very precisely into the mold (see Fig. 2).

Thin film sensor systems with non-stick properties for plastics

At the Fraunhofer IST a thin film sensor system has been developed which consists of the following functional layers on a steel base body:

- the piezoresistive sensor coating (material: DiaForce®, d ~ 6 µm)
- a lithographically structured metal layer (material: chromium, d ~ 250 nm), and
- an isolating and wear-protective layer which at the same time has very good detachment properties with respect to the polymer melt (material: SiCON®, d ~ 3 µm).

In a plasma-assisted chemical vapor deposition process (PACVD) the surfaces to be treated are coated with the piezoresistive and tribologically resistant hydrocarbon coating DiaForce® in a thickness of 6 µm. The sensor coating has a hardness in the region of 24 GPa and a coefficient of friction with respect to steel in the region of 0.17. To make measurement of local loads possible, individual circular electrode arrays made of chromium are installed on the sensor coating by physical vapor deposition (PVD) in combination with photolithography and wet-chemical etching. The chromium layer has a thickness in the region of 0.2 µm. A 1.5 µm thick electrical isolation coating consisting of a hydrocarbon layer modified with silicon and oxygen is deposited locally. In a second PVD process a further chromium layer 0.2 µm thick is applied to this isolation coating. This layer is then structured with a meander design which is used for temperature measurement. Secondly, it contains conductors which run from the electrode structures already created for force measurement right up to the electrical connection area. The sensor structures must be protected against wear, which is the reason for the deposition of a final 3 µm thick top coating consisting of a further hydrocarbon layer modified with silicon and oxygen.

Integration of the sensor modules into the injection molding system

The wear resistance of the sensorized thin-film systems was investigated in the injection molding unit at the Sirris research institute in Belgium. Here polycarbonate (PC) and acrylonitrile butadiene styrene (ABS) were used as test polymers. In the tests the mold temperature was 60 °C while the melt temperature was 230 °C. The injection phase lasted in each case 1.8 s and a maximum pressure of 1000 bar was held for 3 s and was followed by a cooling phase of 25 s. Several hundred injection molding cycles were carried out with each plastic, after which the sensor surfaces were analyzed. Absolutely no traces of wear could be found.

Outlook

During the further course of the project, the focus will be on sensor properties. It is planned to record the temperature and also the force curves of the sensor structures and compare them with those of reference sensors, located extremely close to them beneath the surface of the mold.

The project

The "Sensorized Future" project is funded in the 13th Cornet Call (Collective Research Networking) by the Federal Ministry of Economics and Technology (BMWI) with the support of the German Federation of Industrial Research Associations (AiF) and runs until 30. 6. 2015.

1 Sensor modules with different structure designs.

2 Sensor module integrated into the injection molding line at Sirris in Belgium.

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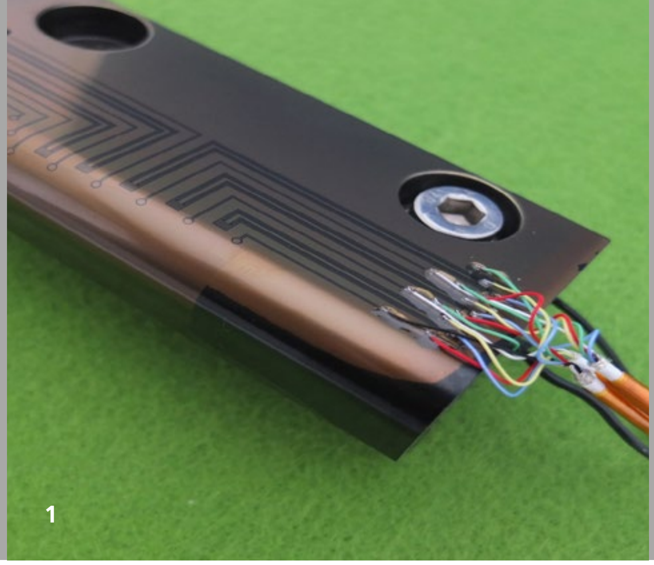
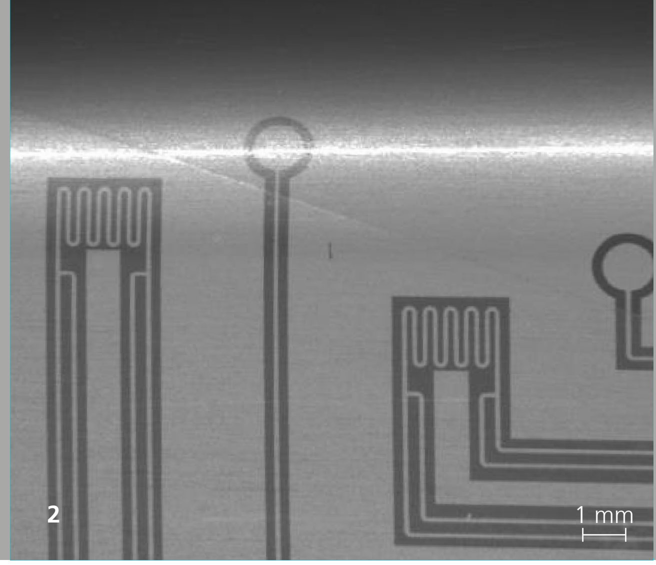
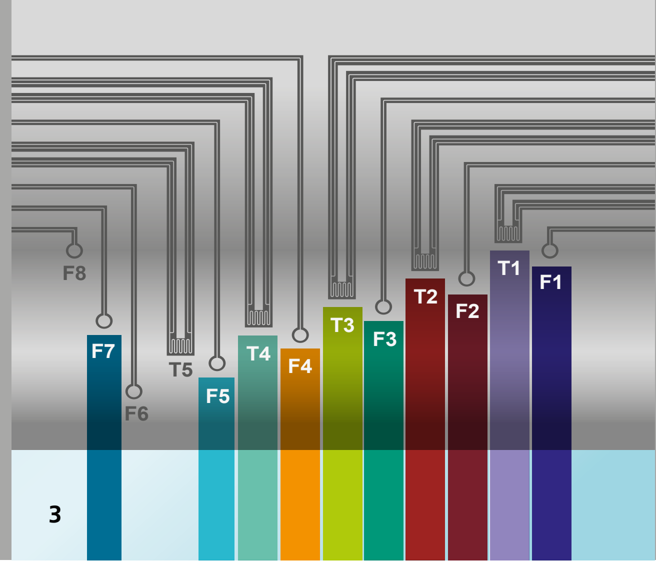






SENSOR MODULES FOR THE SHEET-BENDING PROCESS

In the production of sheet metal components, manufacturing defects often arise in the reshaped parts, such as creases, cracks and necking, and these mean a higher level of rejects. Integrating thin-film sensor systems makes it possible to regulate process control and thus even out fluctuations and minimize rejects. At the Fraunhofer IST a new kind of thin-film sensor system is being developed which stands in direct contact with the workpiece to be formed. Sheet infeed behavior is precisely determined by measurement of pressure and temperature distributions in the drawing process. Additional heat exposures are required for the drawing processes in the case of light metals such as magnesium and aluminum. The development of thin-film sensor systems for local force and temperature measurement in 2D and 3D geometries, in combination with tribological resistance is a special challenge here.

Structure of the thin-film sensor system

The aim of work at the Fraunhofer IST was to build a thin-film sensor system whose purpose was to detect temperature and pressure distributions on a strip drawing tool with a curved surface. The coating system consists of a piezoresistive amorphous hydrocarbon layer (DiaForce®, d ~ 6 µm), a lithographically structured metal layer (chromium, d ~ 250 nm) and an insulating and wear-protective layer (SiCON®, d ~ 3 µm). To increase the sensitivity of the pressure sensors and to enable integration of temperature sensors, the coating system is given an additional insolating coating (SiCON®, d ~ 1.5 µm) in the region of the conductors and contacts. As can be seen in Fig. 1, the force and temperature sensor structures are distributed via locally offset measuring points over the curved face of the tool. The temperature sensors (cf. Fig. 2) are meander structures made of chromium which are located between the force-sensing structures. The contact areas of the individual sensor structures are located on the edge region of the tool.

Integration of the sensor module into a strip drawing machine

At the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz the sensor module was fitted into a strip drawing machine in which load cases during the deep drawing of metal strip were investigated. The functional capability of the multifunctional thin-film system was tested with aluminum strip (AA6016) as an example. It was preheated to a temperature of 200 °C and shaped over the curved face of the deep-drawing tool. To keep frictional losses between the sheet metal and the sensorized coating system on the drawing tool as low as possible a special lubricating oil was used. An example of measurement results is shown in the diagram to the right. As a result of the contact between the hot sheet metal and temperature sensors T1 to T4 there is initially a rise in temperature. During the bending process the aluminum sheet moves over the individual sensor structures and thereby causes a fall in the sensor resistance of the force-measuring sensors F1 to F8. The bending process finishes with an abrupt unloading of the sensor structures which causes local resistance minima at each individual force sensor structure, as is clear from the diagram.

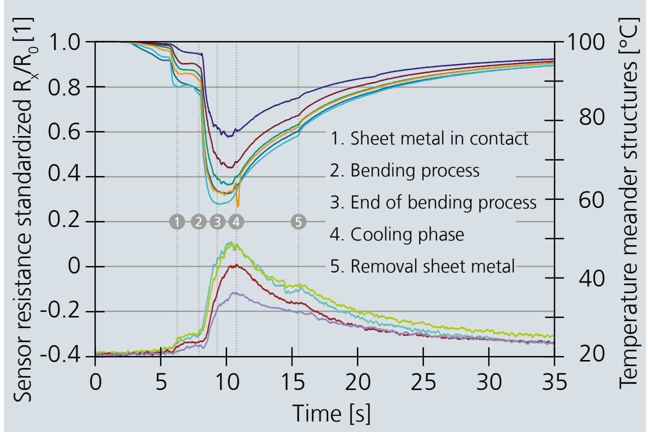
Outlook

In the further course of the project the plan is to transfer the multifunctional coating system to complex-shaped tools in deep-drawing machinesin order to measure loads and temperatures with spatial resolution during the sheet infeed movement.

The project

The results we have described were obtained within the SensoFut project (Sensorized Future – Sensing of temperature and pressure in harsh environments), on which the Fraunhofer IST worked together with the Fraunhofer Institute for Machine Tools and Forming Technology IWU and Sirris, the Belgian research association. SensoFut is funded in the 13th Cornet Call (Collective Research Networking) by the Federal Ministry of Economics and Technology (BMWI) and the German Federation of Industrial Research Associations (AiF) and runs until 30.6.2015.

Characteristic curves of the individual sensor structures (cf. Fig. 3) during the forming process (sheet metal drawing force F = 10 kN, metal temperature T = 200 °C).



1 Strip metal drawing tool with full thin-film sensor system.

2 Locally offset arrangement of the circular force sensor structure and temperature meander structures.

3 Coloured representation of the claimed force-measuring sensors F1 to F8 and temperature sensors T1 to T4 during the bending process.

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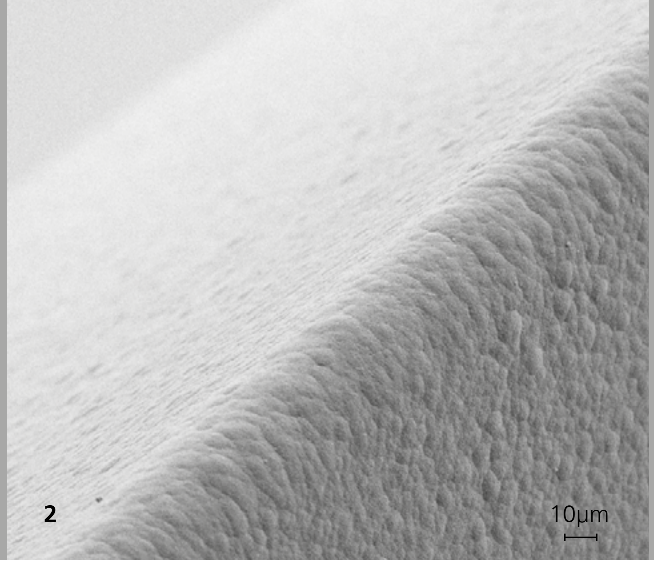
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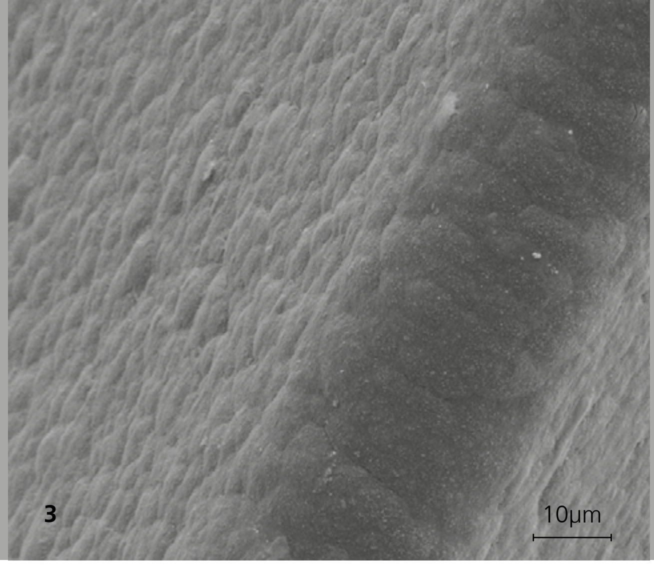
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INTERLAYERS FOR THE DIAMOND COATING OF CEMENTED CARBIDES

Diamond-coated carbide tools are eminently suitable for machining graphite, fiber-reinforced plastics and aluminum alloys. At the Fraunhofer IST interlayers are being developed as alternatives to a process which has to date been essential: etching pretreatment of the cemented carbide base body. With these new coatings, weakening of the boundary zone of the cemented carbide body can be avoided.

Currently hot-filament CVD diamond coatings on tools and components made of cemented carbide are only possible on a few types of cemented carbide and also require a costly pretreatment of the cemented carbide by etching. Without a chemical pretreatment of this kind, which removes the cobalt binder from the surface of the cemented carbide substrate, the diamond coatings would not adhere to the tool. However, pretreatment also at the same time weakens the flexural strength and the edge stability of the base body. But if interlayers are to replace a pretreatment of this kind, they must satisfy the following requirements:

- Suitability as a barrier against cobalt diffusion
- Good adhesion to different types of cemented carbide
- Ensures a stable attachment of the CVD diamond layer
- Thermal stability to approx. 900 °C

Hot-filament CVD interlayers on a silicon basis
The advantage of interlayer deposition by the hot-filament CVD process is that there is no need of a change of the deposition process for the subsequent diamond coating. In recent years the Fraunhofer IST has conducted fundamental research primarily into silicon carbide (SiC) interlayers and tested their adhesive strength. In later tests at the Institute for Machine Tools and Factory Management (IWF) of the Technical University of Berlin, extensions of the tool path were achieved not only in the machining of abrasive aluminum-silicon alloys but also in milling CFRP boards which were comparable with diamond-coated tools pretreated by etching.

Detailed thermal investigations indicated however that at the usual coating temperatures for diamond deposition the SiC interlayer reacts with cobalt and therefore does not have the required stability. The substrate temperature has to be lowered to a maximum of 700 °C to prevent the heat-activated reaction of the silicon carbide with cobalt from the cemented carbide substrate.

In addition to SiC interlayers, silicon nitride interlayers have also been investigated at the Fraunhofer IST. These are chemically stable at the CVD diamond deposition temperatures of 800 to 900 °C which are usual in industry. Until now SiN_x intermlayers of this kind have not been tested on tools but in the sandblasting adhesion test they are reaching service lives comparable with etched diamond-coated references.

PVD tungsten interlayers
Another alternative to etching pretreatment are tungsten interlayers, which are deposited by magnetron sputtering. Tungsten is admirably suitable as a stable cobalt barrier. However, ground cemented carbide surfaces do need to be pretreated by sandblasting to enable a strong mechanical connection of the diamond coating to the interlayer. What is important in the pretreatment of tools with a defined cutting edge is for the roughening process not to reduce the cutting-edge geometry excessively. By a suitable selection of the pretreatment parameters and subsequent tungsten coating, success has now been achieved in applying a CVD diamond coating to milling tools with 10 % cobalt in the cemented carbide with no etching pretreatment, and then using the tools successfully in machining graphite.

Outlook
Further development work aims at extending diamond coating to a large variety of cemented carbide types, tool and component geometries. Here three promising interlayers are already currently available at the Fraunhofer IST. The challenge lies in the individual adjustment of the process parameters to the tools to be coated and in demonstrating cost-effectiveness.

1 Diamond-coated milling tool with tungsten interlayer in use in graphite machining.

2-3 Scanning electron microscope image of the coated cutting edge before (2) and after (3) use: nanocrystalline CVD diamond film with tungsten interlayer on a milling tool with 10 % cobalt in the cemented carbide.

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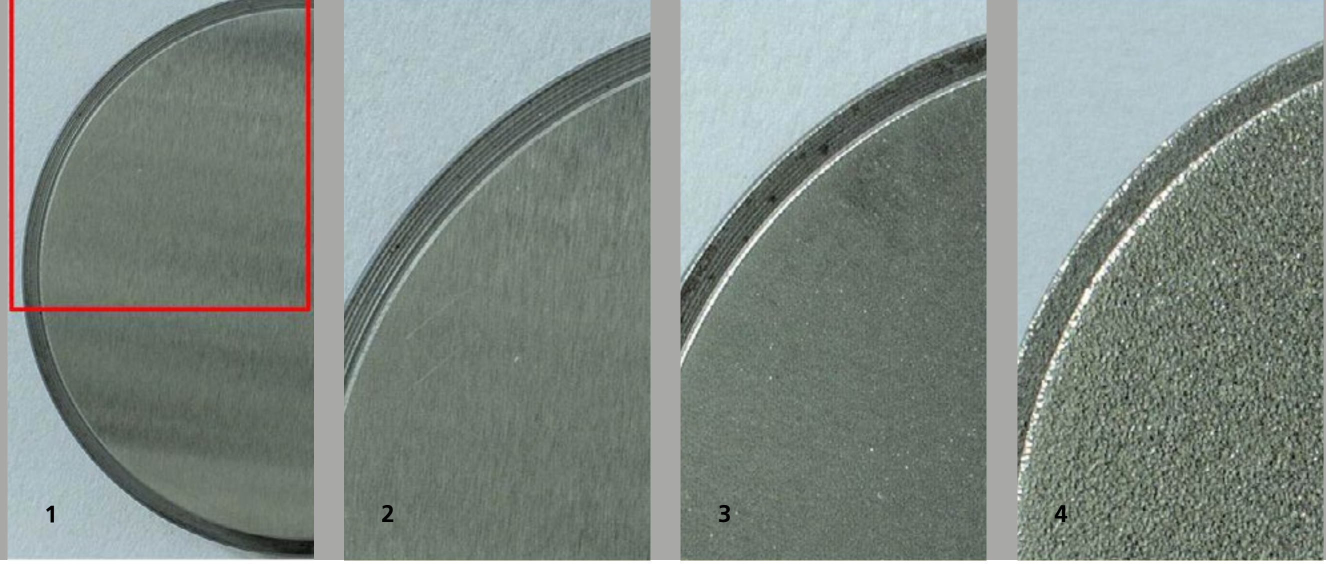

1-4 *Flat crush track, (2) ground variant: $R_a = 0.2$ µm, (3) blasted variant: $R_a = 1$ µm, (4) blasted variant: $R_a = 5$ µm.*

5 *Tribological loaded die geometry.*

STRUCTURING AND CONSERVATION OF DIE SURFACES

Particularly for tools under high tribological stress the structure of the surface can be regarded as a critical property. In the field of hot forging such tools are for example dies, which have very high flow paths for the material. A major role is played by the wettability of the surface, the ability to store lubricant particles in rough areas, or the setting of the contact areas during mechanical loading. By means of structuring processes such as blasting or grinding, stochastic topographies – in other words, irregular repetitions of geometrically indeterminate individual structures – can be deliberately obtained. To prevent the structures from rapidly flattening out in the production process even after just a few cycles, suitable conservation methods are required. Investigation of topographic surface properties and their retention by means of combined plasma technologies is a core task at the Fraunhofer IST.

Surface structuring

Stochastic structuring can be carried out over large surface areas by simple production technologies, such as sand blasting and thus is cost effectively. The following technical advantages are thus secured for the surfaces:

- Improved adherence of lubricants
- Creation of lubrication pocket effects
- Transportation possibilities for abrasive particles and lubricants
- Improved adhesion of hard coatings, for example, via the increase in surface area achieved
- Intensified diffusion treatment

Furthermore, even deterministic structuring, in which the individual structures are present in a regular geometric arrangement, can be important for forging processes. These do however require considerably greater effort in tool production since special technologies, such as, for example, laser structuring or the use of special milling tools, are often necessary.

Conservation by means of plasma technologies

Treating the tools by plasma nitriding with a following deposition of a hard coating aims at conserving the pre-defined topographies, slowing down leveling processes and thus extending the service life of the tools. In the case of plasma nitriding, nitrogen diffuses into the peripheral zone of the basic material, thereby increasing the hardness in the edge layer of the substrate. The depth of the nitrided zone can be influenced via the duration and temperature of nitriding, the amount of nitrogen in the process gas and the plasma parameters.

In the field of hot forging, various studies have demonstrated that thin hard coatings of titanium- and boron-based multilayer coatings Ti-B-N already have great potential for practical application in reducing wear. This is made possible by special material properties of the coatings, which create nanocomposites of tough TiN crystallites and hard, thermally stable TiB_2 crystallites. In this way tribologically and thermally highly stressable functional layers can be produced.

In so-called duplex treatment, plasma nitriding is combined with a subsequent step of hard coating. The advantages of this process combination lie in increasing the supportive effect of the zone close to the edge and in the improvement in coating adhesion which results from this.

Solutions for hot forging

Currently, within a German Federation of Industrial Research Associations' project work is in progress at the Fraunhofer IST into investigating the effects of surface and surface-layer modifications on the wear behavior of forging dies. Alongside a reference variant (cf. Fig. 1), various surface topographies were applied to test dies by shot peening (cf. Figs. 2, 3, 4). The ring compression test, as used in determining coefficients of friction, was used in order to characterize the topographic changes found after the tests. In the case of those tools with a high degree of surface roughness a marked change in the topography was noted after use. This is due to the complex interaction between the coating and the topography. In contrast, tools of low surface roughness exhibited only a small change in topography. Key surface data remained stable, especially with duplex-treated tools.

Current work indicates that a selective configuration of the topography followed by conditioning with plasma technologies has a significant influence on the in-service behavior of the treated tools (cf. Fig. 5). A suitable topography in combination with a wear-resistant thin coating and a modified nitrided layer can improve how the tool surface behaves during running-in, characterized by leveling and roughening processes. In subsequent work the potential demonstrated for wear reduction in industrial applications is being evaluated by means of systematic wear analyses in serial forging tests and subsequent industrial trials.

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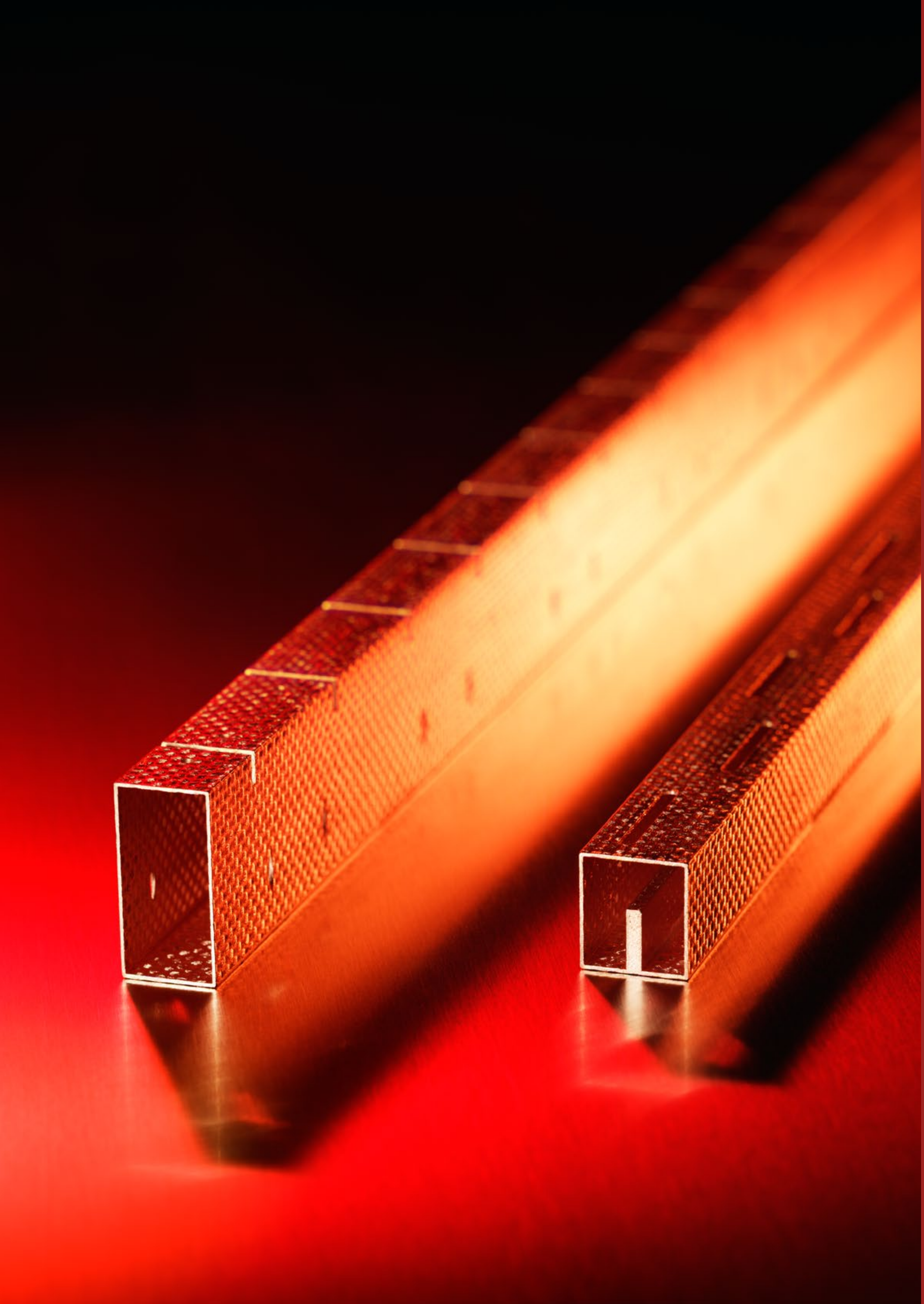

AEROSPACE

In the "Aerospace" business unit, processes and coatings are developed for special materials, such as lightweight materials, for which in many cases no established coating methods yet exists. The principle areas of application are wear and corrosion protection in aviation as well as optical and electrical functions in space travel. Currently the following areas are being tackled by the Fraunhofer IST:

- Galvanic metallization of CRP components
- Metallization of titanium components by process combinations
- Wear protection coatings for aircraft jet engines
- Bearing sensor systems for condition monitoring in aircraft
- Development of surfaces for molds which do not use release agents
- Galvanic coating of magnesium for lightweight design in aircraft

Customers include companies in the aerospace industry and their suppliers.

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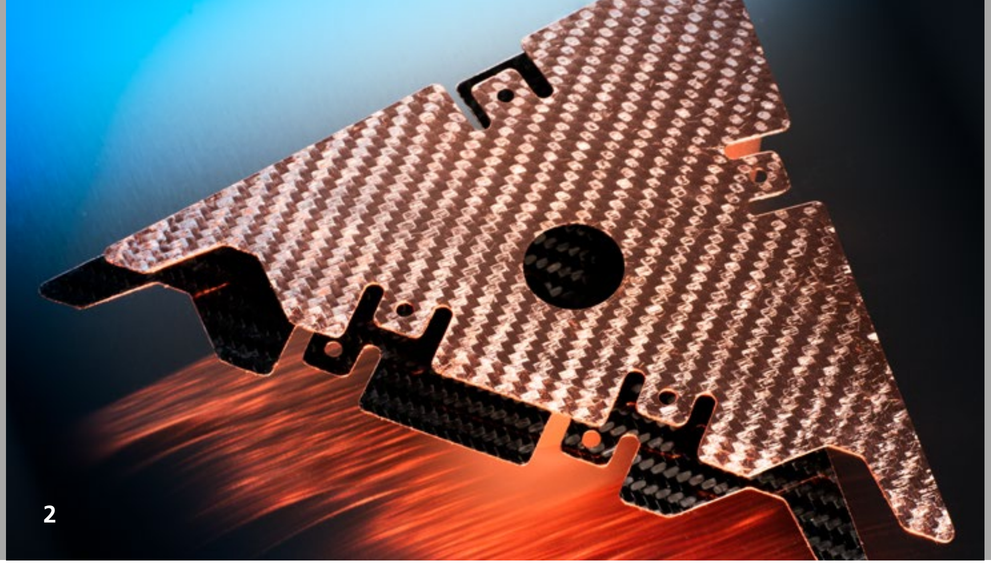

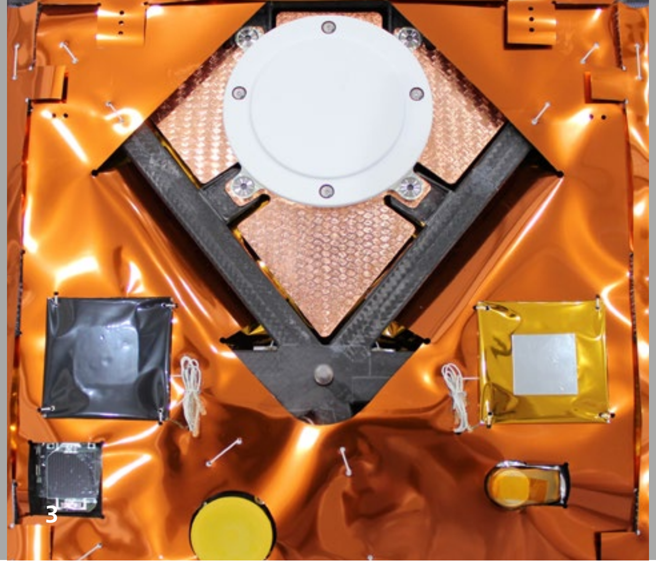

MASCOT – MOBILE ASTEROIDE SURFACE SCOUT

4.6 billion years – this is the age of our solar system as estimated by today's scientists. Investigations into the birth of the solar system have an important part to play in current research. Information about its origin may be provided by the comets and asteroids which came into existence at that time and since then have been traveling through space almost unchanged. The research satellite "Rosetta", for example, reached the Churyumov-Gerasimenko comet in August 2014 and on the 12^{th} of November set down its lander "Philae" on its surface. December 2014 saw the launch of another satellite, the Japanese Hayabusa II, with its "MASCOT" lander, on its way to asteroid 1999 JU-3. Parts coated at the Fraunhofer IST are on board.

Separation with the aid of thin films

One of the special challenges of space travel is that some functions must be successful only once but then with absolute reliability, even after a long time under difficult conditions. When Hayabusa II reaches the asteroid after a trip lasting four years, MASCOT, which is about the size of a shoebox, will be ejected from a height of about 100 meters. To make sure ejection functions safely after such a long flight the Fraunhofer IST coated the surface of the individual components of the separation mechanism between the satellite and the lander. The mechanism is a so-called ejector which consists of a sleeve and a plunger. The latter is restrained by a spring and not released until an impulse is given, which results in the lander frame being pressed out of the satellite. To combine high strength with lowest weight the sleeve has been made of titanium and the plunger from a special aluminium alloy.

It was the task of the Fraunhofer IST to coat the surface of the plunger. The customer, DLR (the German Aerospace Center), set high requirements for the coating: corrosion protection, wear-resistantance, no cold welding and a very low coefficient of friction were all mandatory. Several combinations of material were tested to achieve this. Ultimately successful was an anodized layer combined with polytetrafluoroethylene (PTFE) particles on and beneath the surface. Fig. 1 shows the separation mechanism.

The CFRP antenna

Once it has touched down on the asteroid, the lander will collect various data. It is equipped for this with an infra-red microscope, a camera, a radiometer for determining the temperature and radiation properties as well as a magnetometer for measuring the magnetic field.

To send the collected data from the lander to Hayabusa II and from there to earth, the DLR uses a so-called patch antenna – in other words, an antenna variant consisting of a polymer carrier and a metallized top and bottom face. The base plate is made of carbon-fiber-reinforced plastic (CFRP). To ensure the plate reaches the electrical conductivity required for an antenna it was electroplated with copper at the Fraunhofer IST. What was required here was a homogeneous coating thickness as well as very good adhesion of the metal coating to the CFRP under extreme changes in temperature. The procedure used had already been developed at the Fraunhofer IST for the CFRP waveguides in the European Space Agency's "Sentinel" mission and were successfully used there. The metallized base plate and also the complete patch antenna installed in the lander are shown in Figs. 2 and 3.

1 *Mechanism for separating the satellite and the lander.*

2 *Metallized CFRP base plate of the antenna.*

3 *Patch antenna built into the MASCOT lander.*

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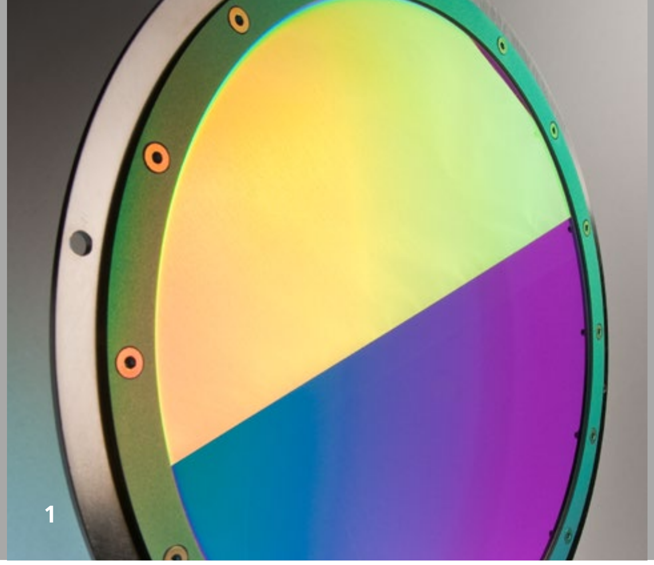

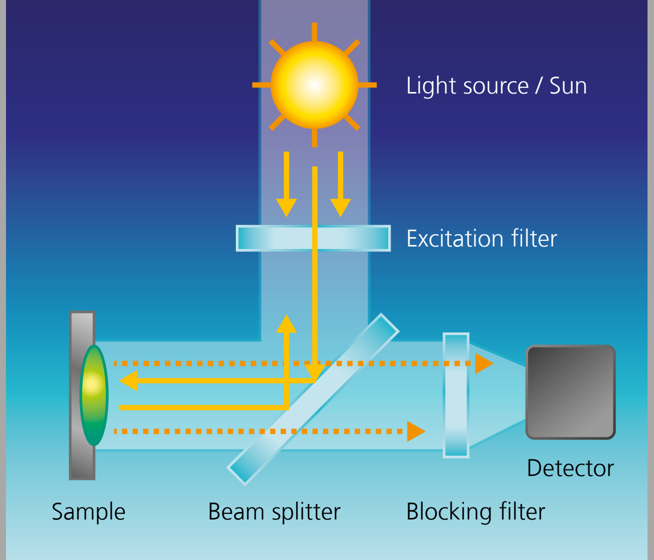

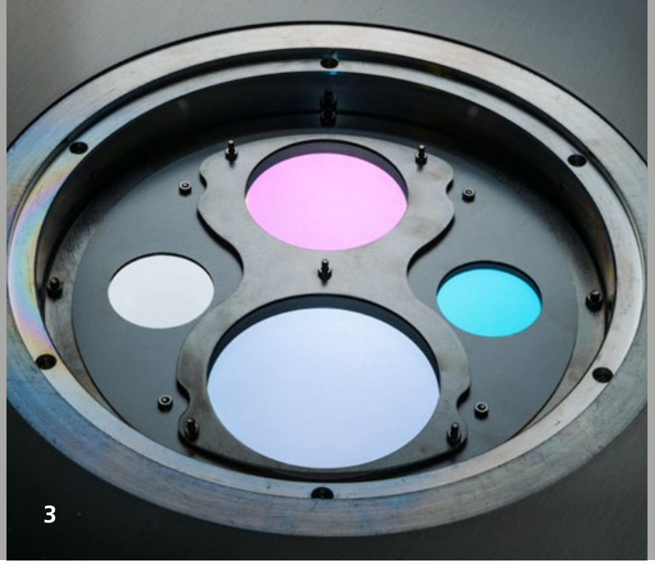

OPTICAL FILTER FOR SPACE APPLICATIONS

Optical measurement methods and instruments of the most varied types are becoming increasingly important in the field of space research. It is, for example, planned to push forward current research into and observation of "space weather" or the solar wind with the aid of the "Solar Orbiter" space probe. The satellite is scheduled to launch in 2017 and, applying spectroscopic measurement methods, will supply more precise information about events in the sun's corona. Even the James Webb Space Telescope, successor of the famous Hubble telescope, cannot manage without high-precision spectrometers. In most cases optical coatings play a crucial role in the measuring instruments used. The demands made of such coatings, which are primarily deposited by vacuum-based PVD (physical vapor deposition) are constantly increasing. With the new EOSS® coating platform, developed and built at the Fraunhofer IST, highly demanding optical coatings for space applications can be deposited.

The EOSS® coating concept of the Fraunhofer IST
With the EOSS® sputtering system not only extremely defect free coatings but also highly complex coating designs with several hundreds of layers can be produced on an industrial scale with extreme precision and uniformity of the coating and with high process reliability. The thickness of each individual layer falls within the range of a few nanometers. At the same time up to ten substrates each with a diameter of 200 mm are arranged on a turntable which rotates continuously and rapidly throughout the coating process. The use of cylindrical targets delivers crucial advantages since, in contrast to the situation with planar targets, the coating thickness distribution is extremely stable in the long term. Deviation is ±0.15 %.

Coating thickness distribution on optical systems such as lenses or filters is very important indeed since even the smallest deviations from the coating thickness specified and required will result directly in errors in imaging or analysis. With EOSS® technology not only are almost absolutely homogeneous coatings possible but selective lateral gradient filters can also be produced.

Example: fluorescence investigations on earth with the aid of optical filters
High-precision optical filters are used in spectrometers installed in satellites to study, for example, terrestrial vegetation. The central measured quantity is the chlorophyll content of plants, which is ultimately responsible for photosynthesis and carbon dioxide decomposition, and thus gives an indication of the condition of the vegetation. Chlorophyll, the green leaf pigment, is excited by sunlight and emits an electromagnetic radiation of a specific wavelength. The fluorescent light is picked up by a sensitive detector in the spectrometer. A schematic of a typical spectrometer is shown in Fig. 2. A spectrometer of this kind can contain up to three different filters: the purpose of the excitation filter is to permit passage of only the excitation light and filters out all wavelengths apart from the one of interest. The beam splitter is a dichroic cut-off filter. The blocking filter's job is to filter out the excitation light. The filters in a system of this kind must satisfy extraordinarily high demands: for example, the filter must have an optical density of more than 6 (OD 6) in the unwanted spectral regions.

Example: remote sensing with optical systems in satellites
Another example of optical systems in satellites is imaging spectroscopy, which is used among other things for the innovative remote sensing technology. Here a broad wavelength region extending beyond the visible is imaged with the aim of identifying minerals or measuring vegetation states from space. Precisely coated filters and mirrors are absolutely essential here. Selectively inhomogeneous filters are also being used increasingly here which allow preselection of certain light components depending on the position on the receiver.

Example: precision optical filters for laser projection
Figs. 1 and 3 show an example of an optical filter which was produced with the new EOSS® technology. This is a so-called "notch" filter, in which light transmission in the "green" spectral region of 532 ±10 nm is reduced by 6 orders of magnitude. Transmission here is thus less than 10^{-4} %. In the remaining spectral region between 200 and 1100 nm the filter has a high transmission of more than 95 %. This kind of filter serves as a blocking filter in Fig. 2. The high blocking effect is necessary due to the fact that fluorescent intensities are very low and the detectors can measure extremely low light intensities, which means that a high level of scattered-light suppression must be assured. In some cases notch filters with over OD10 are required today and this calls for almost flawless coatings. EOSS® technology is able to satisfy even extreme requirements of this kind.

1 Notch filter with an optical density of 6 at 532 nm and a broadband transmission between 200 and 1100 nm.

2 Schematic of an arrangement for measuring fluorescence.

3 Optical filter installed in the coating carrier.

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ENERGY, GLASS AND FAÇADE

In the "Energy, Glass and Façade" business unit the work of the institute concentrates among other things on the development of

- Inexpensive transparent conductive coating systems (TCOs) for photovoltaics and solar thermal panels,
- Semiconductor coatings for thin film photovoltaics,
- Analytical methods for the characterization of thin film photovoltaics,
- Improved functional layers and coating processes on architectural glass (Low-E, active or passive sun protection such as switchable glazing or coloring of glass) and automotive glass,
- Coating systems for fuel cells,
- Improved inexpensive high-temperature corrosion protection for turbine blades,
- Stable anodes and cathodes in lithium-ion batteries.

Clients include companies in the glass, photovoltaics, automotive and electrical industries, the energy and construction sectors, manufacturers of heating and sanitary equipment as well as plant manufacturers and coating contractors.

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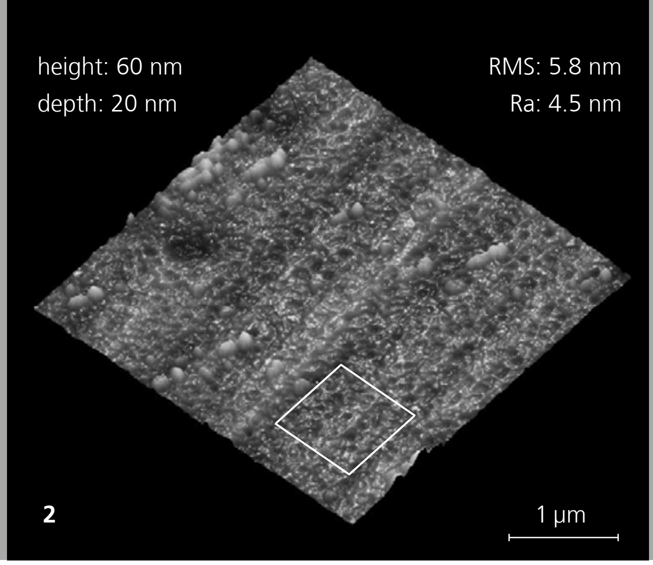

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BATTERY FOIL WITH A CARBON CONTACT LAYER

Renewable energies, new concepts of energy production or electric mobility are up-to-date topics of high relevance. Regarding this, there is a virulent need for more efficient energy storage systems. Within the project "Battery Foil with a Carbon Contact Layer" the improvement of lithium-ion batteries is envisioned at Fraunhofer Application Center for Plasma and Photonics – a department of the Fraunhofer IST.

New energy storage systems for electric mobility

Current German policy target at an enhanced usage of renewable energy sources. Goal is a decentralization of energy production by means of e.g. solar cells and local energy storage. Here, lithium-ion batteries (LIB) is the preferred system. In the area of electric mobility, LIB is currently penetrating the market. Up to now, German producers of storage cells for hybrid cars only play a minor role on the market, even though a "Leading Market for Electric Mobility" is planned to be realized by the year 2020.

Plasma coated current collectors for improved lithium-ion batteries

Project focus at Fraunhofer Application Center is laser structuring and the design of ultrathin carbon and copper films on aluminum foils. Furthermore, the characterization of the modified foil's electrical properties is intended. Here, an important aspect is the development of a novel method that guarantees a reliable and non-invasive measurement of the foil's electrical contact resistances. The novel battery foil will be implemented as current collector in LIB. The functionalization minimizes overall bulk resistances in electrodes and, as a consequence, a higher LIB quality and performance enhancements will be achieved.

Outlook

Until the end of the project the suitability of different laser and plasma processes for an industrial coating process is to be demonstrated.

The project

In the cooperation project of the Fraunhofer IST Application Center for Plasma and Photonics and the Fraunhofer Institute for Silicium Technology ISIT, a plasma generated carbon contact layer on aluminum electrode foils for lithium-ion batteries is to be developed. The Project "Battery Foil with a Carbon Contact Layer" is funded by the German Federation of Industrial Research Associations (Aif) with € 215,750.00 (€75,500 in 2014) for the Application Center.

1 *Carbon coated battery foil.*

2 *Surface morphology of aluminum battery foil (atomic force microscope).*

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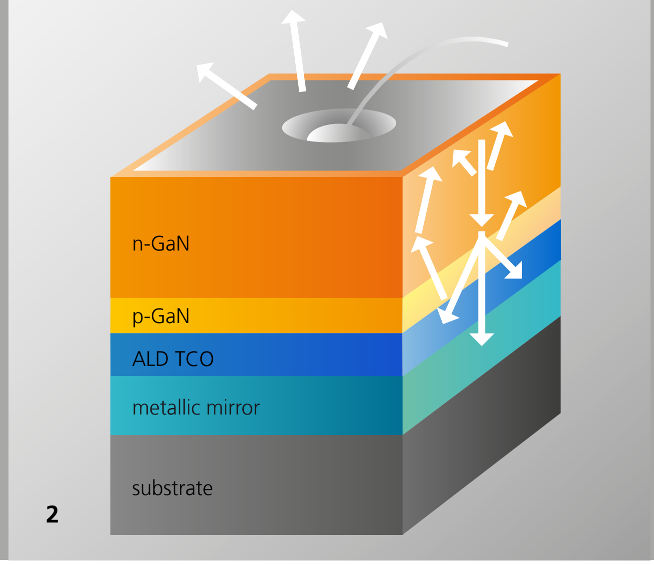
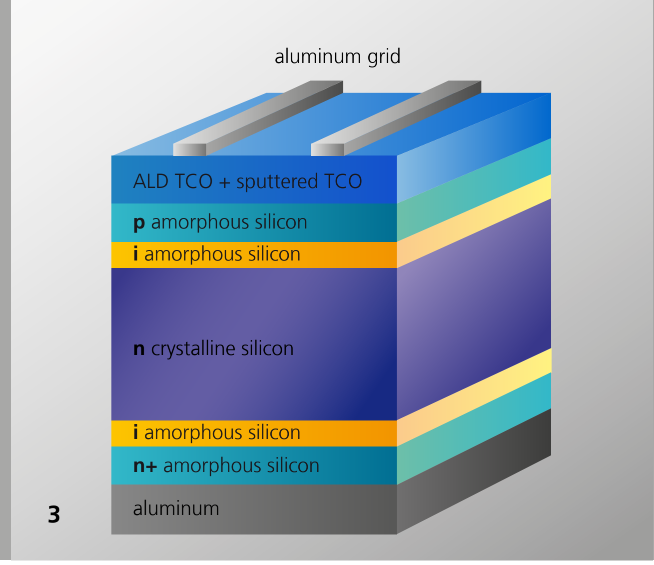




APPLICATIONS OF ATOMIC LAYER DEPOSITION (ALD)

Atmoic Layer Deposition (ALD) is a modified version of chemical vapor deposition (CVD). This process is characterized by two successive, self-limiting surface reactions which permit ultra-thin, pinhole-free and extremely homogeneous coatings to be deposited. At the Fraunhofer IST primarily thermal ALD processes are developed and analyzed.

Advantages of the Atomic Layer Deposition

- Highly conformal coatings on complex surface geometries, such as nano-rods
- Fewer defects and lowest number of pinholes in the films
- No plasma damage (when compared with other PVD and plasma-CVD techniques)
- Very high homogeneity of film properties

ALD for electronic applications

One of the major problems in thin-film electronics is the loss of efficiency due to the deposition processes, especially with sputtering processes which cause plasma damage on sensitive electronic surfaces. Apart from the loss in efficiency, such sputtering processes are not useful for coating high aspect ratio nanostructures on the electronic devices. At Fraunhofer IST, we have been developing processes for transparent conductive oxides with thermal atomic layer deposition. The electrical properties of the TCO films which have been developed are listed in the table on the right side.

Example: Coating of LEDs

All of these TCOs have been successfully tested in LED test structures. Some of them showed superior properties, such as lower forward voltages as compared with sputtered TCO films. This is attributed to the lack of plasma damage. Low forward voltages are desirable for high LED efficiencies.

Example: Coating of HIT solar cells

Pure and thin ZnO ALD films were also incorporated in HIT solar cell test structures as a protective layer prior to TCO sputter deposition. A decrease in defect density was observed, confirmed by the increased lifetime of photo-generated electron-hole pairs.

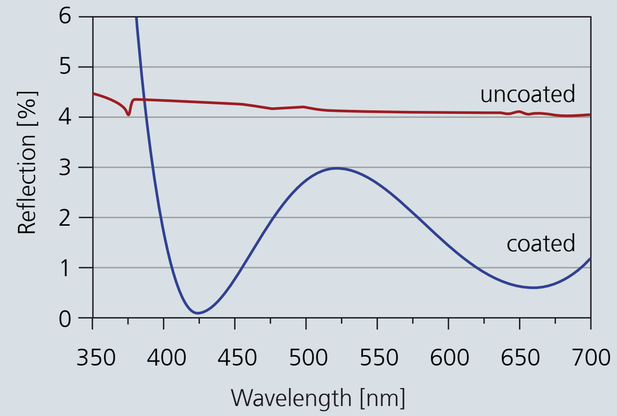
ALD for optical applications

Dielectric coatings have also been developed with thermal and plasma ALD: Al_2O_3, Nb_2O_5, SiO_2, TiO_2. An anti-reflective layer setup using Al_2O_3 and Nb_2O_5 has been successfully developed and is initially coated on a flat glass substrate. The setup consists of six alternating layers of aluminum oxide and niobium oxide. Later a glass sphere of 12 cm diameter was coated with this layer arrangement. Reflection measurements of the bare and coated glass spheres are shown in the graph on the right side. This demonstrates the special ability of ALD to coat with optical layer setup on 3D objects conformally and homogeneously.

Properties of TCO coatings produced by thermal ALD.

Coatings	Specific Resistance [Ωcm]	Mobility [cm²/Vs]	Charge carrier density [cm³]
ZnO:Al	2.2×10^{-3}	13.6	2×10^{20}
ZnO:Ti	9.3×10^{-4}	21.4	3×10^{20}
ZnO:Sn	4.7×10^{-3}	20.6	6.5×10^{19}
ZnO:Nb	1.1×10^{-3}	28.3	1.6×10^{20}
SnO_2	6.0×10^{-3}	26.7	3.9×10^{19}
SnO_2:Nb	3.2×10^{-3}	-	-
TiO_2:Nb	1.25×10^{-3}	19.08	2.6×10^{20}

Reflection spectra of the glass spheres (picture 1) with and without antireflective coating in the visible wavelength range.



1 *Glass sphere with (right) and without (left) antireflective coating.*

2 *Schematic structure of a light emitting diode coated with ALD.*

3 *Schematic structure of a HIT solar cell coated with ALD.*

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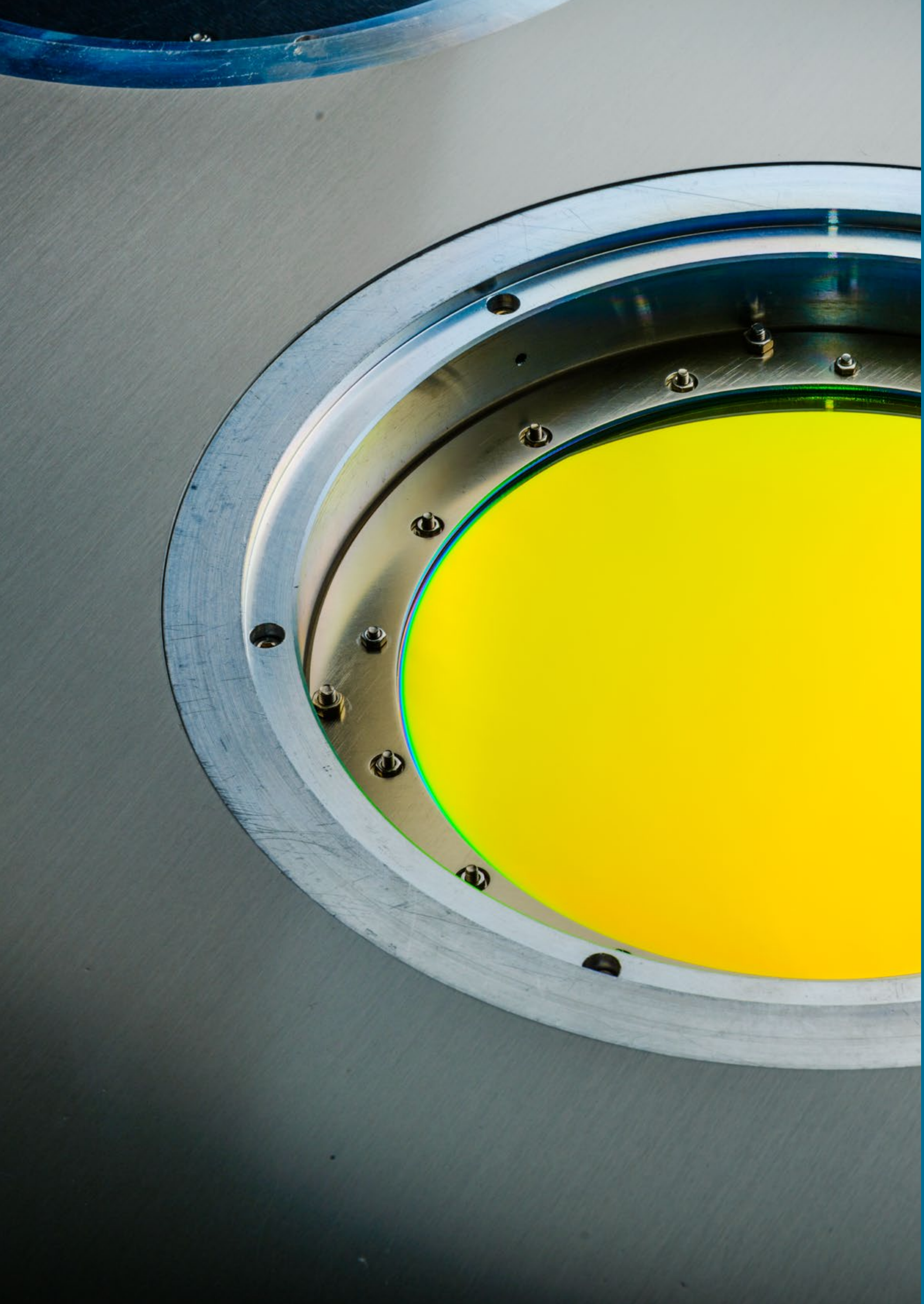

OPTICS AND ELECTRONICS

Topics in the business unit of “Optics and Electronics« include:

- The development of electrical contact and insulating coatings
- The development of coating systems for displays
- The development and design of multilayer coatings for optical filters
- The development of sensorized coatings
- The development of new materials and of structuring and metallization technologies as substitutes for ITO coating systems in flat-panel displays

Clients of this business field include companies in the optical industry, in telecommunications, the automotive industry, manufacturers of displays and data storage media as well as plant manufacturers and coating contractors.

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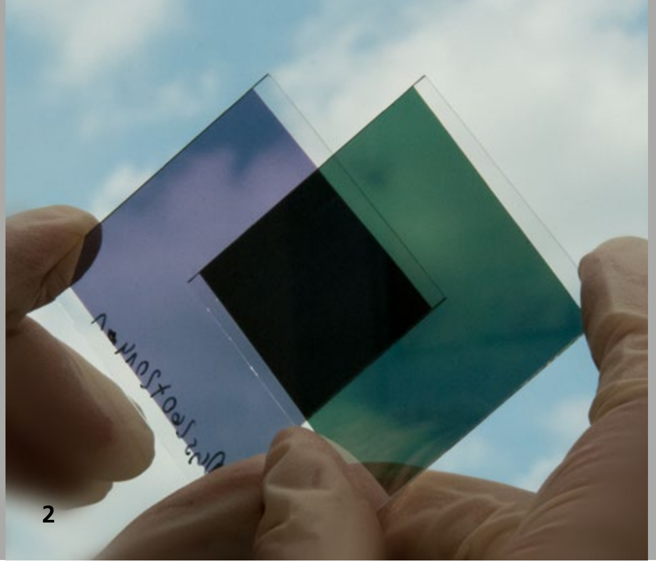

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OPTICAL INTERFERENCE COATING SYSTEMS ON POLYMER FILMS

With optical interference coating systems it is possible to provide surfaces with different optical functions such as reflection reduction or enhancement and spectrally selective filters. Production methods normally used for such coating systems include vacuum-based coating processes such as evaporation techniques, various types of sputter deposition, and plasma-enhanced chemical vapor deposition processes (PECVD). The energy input affecting on the substrate during coating is often critical for organic substrates such as, for example, polymer films. However, due to their bendability and low weight, films of this kind offer new application possibilities, for example, in the field of consumer optics. Optimized coating processes for high-quality optical interference coating systems on polymer films are therefore under development at the Fraunhofer IST.

The coating concept

For the work at the Fraunhofer IST a coating system is being used in which sputter deposition can be combined with PECVD. By using homogenization blends and selecting suitable process parameters, coating thickness conformity and the energy input into the coating process have been improved to the point where very sophisticated optical coating designs can be produced even on plastic film. Process control uses Mocca+®, the universal software likewise developed at the Fraunhofer IST. Here the deposition process is controlled with an optical broadband monitor by means of transmission measurements.

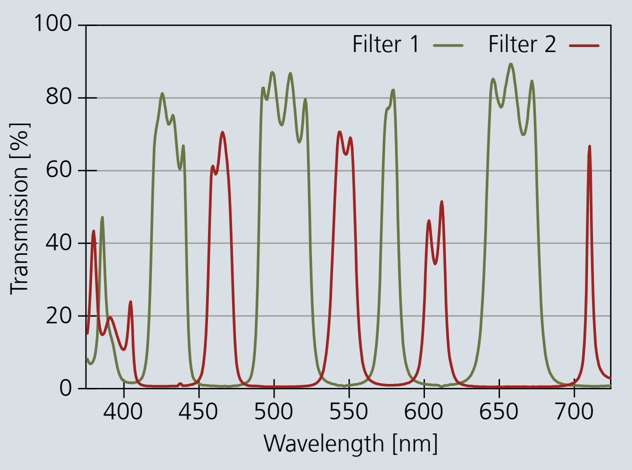
The results

With the selected method, triple bandpass filters with over 35 layers have been successfully deposited on PET films (see Figs. 1 to 3). These filters can, for example, be used for creating complementary RGB filters. The layer stack has adequate coating adhesion, in other words, cross-hatch adhesion values of 0 – 1 on polyethylene terephthalate (PET) and polycarbonate (PC) and an integral light scattering (haze) of less than 4 % on PET or 1.2 % on B270 glass.

Outlook

One core theme for future work at the Fraunhofer IST is the organic modification of these kinds of layer system. The aim here is to achieve better formability of the coated films and lower levels of tension.

Measured transmission spectra of two complementary RGB filter on PET film.



1 *Complementary RGB filter on PET film.*

2 *Complementary RGB filter on B270 glass.*

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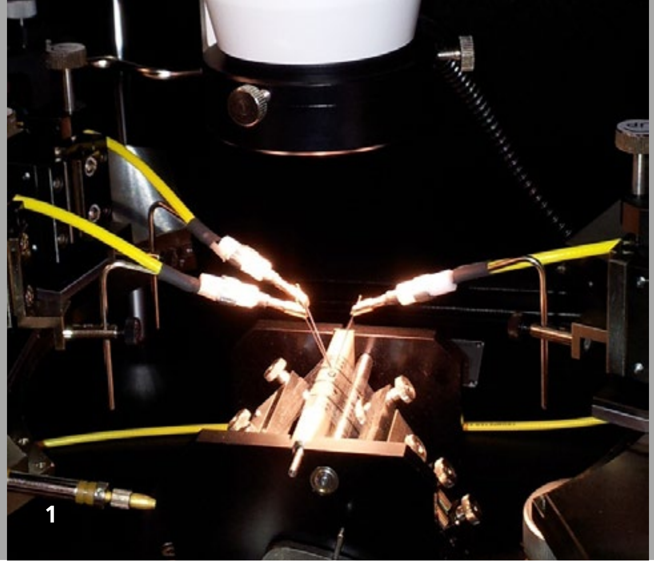

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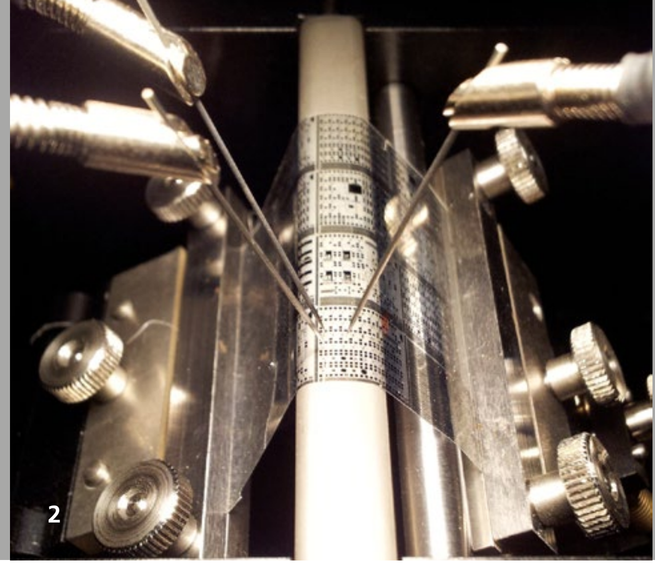


2

1+2 *The set-up for measuring flexible electrodes on bend and stretched film.*

MEASUREMENT OF FLEXIBLE TFTs UNDER BENDING LOAD AND TENSILE STRESS

The demands made of displays and touchscreens are constantly growing: they should be flexible, bendable and rollable. Applications of this kind have to deliver challenging optical, electronic and mechanical properties. For this reason a new measuring station has been developed at the Fraunhofer IST with which flexible electronic components can be studied. This is an important measuring instrument for upcoming "wearable" electronics if prediction of the durability of flexible components is to be possible

Measuring set-up

The set-up for measuring the properties of flexible electronics under loading by bending and tension can be seen in Fig. 1. The test pieces used here are 50 mm film sections with mounted thin film transistors held on both sides by a clamp. On one of the clamps there are two springs with a defined spring constant with whose help a defined length change can be set. A bending device in the central part of the measuring set-up enables the stretched film to be bend additionally with radii in the range of 2–10 mm. In this way the thin film transistors (TFTs) are subjected to define tensile stresses and bending load under which measurements can then be taken of their electrical properties.

Behavior of the thin film transistors (TFTs) in the bend and stretched states

The diagram to the right presents a comparison of the properties of a thin film transistor which were measured under bend state with bending radii of 3, 4 and 10 mm (without elongation). At this stage of deformation the characteristic curve of the TFTs exhibits only very minor changes. In the next stage the TFTs bend over the flexible substrate (radius 4 mm) were also measured in the elongated state. By way of example, current/voltage measurements are shown. Starting in the relaxed state, elongation was initially increased in steps (0.2 % – 0.3 % – 0.5 % – 0.8 % – 1.5 %) and then successively reduced again.

As the strain increases, the TFT curves show no major changes up to a 0.8 % change in length but from an elongation of 1.5 % the transistor suffers damage. However as elongation decreases there can be a certain amount of recovery provided no cracking has yet developed. A plastic deformation (without cracks) of the TFTs or substrates would therefore not impair the functional ability of the component.

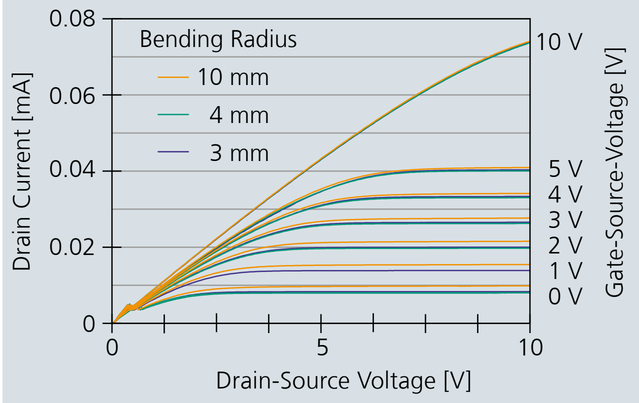
Outlook

The successful creation of the measurement station means that in future it will be possible at the Fraunhofer IST to optimize the mechanical stability of thin-film transistors under different bending states and tensile stresses.

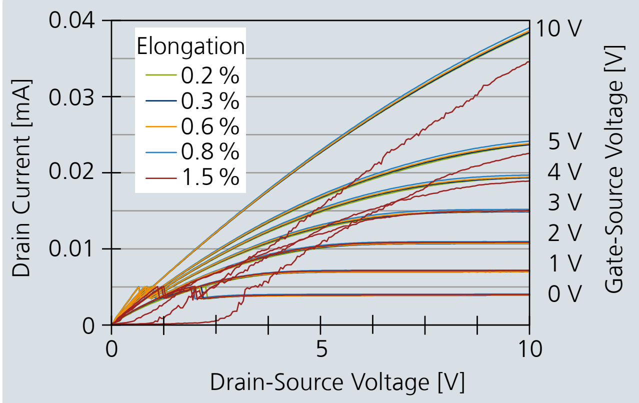
The project

The measuring set-up has been developed and used as part of the ORAMA EU research project, and sponsored by the European Commission within the 7th EU Research Program.

Comparison of the drain current and the drain-source voltage of a transistor for different gate-source voltages and bending radii.



Comparison of the drain current – drain-source voltage characteristics of a transistor (bending radius 4 mm) for increasing elongation.



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2

TEMPORARY BONDING BY MEANS OF POLYELECTROLYTE LAYERS

For many applications or individual operations in microsystem technology the wafers used have now become so large and thin that they would fracture if nothing were done about it. In such cases so-called temporary wafer bonds are used. Here, for example, silicon wafers are fixed to a handling wafer for processing. It must then be possible to detach them subsequently without mechanical damage. At the Fraunhofer IST polyelectrolyte intermediate layers are used to control the adhesion of the wafers.

Bonding with conventional adhesive films

The most important area of application for temporary bonding is microsystem technology. Above all the correct choice of adhesive is of crucial importance here. Not only the mechanical properties but also the thermal and chemical stability of the adhesive must satisfy the material requirements in force in downstream processing operations.

Intermediate layers consisting of waxes or thermoplastic materials such as UV-activated adhesive films have become well-established for temporary bonding. In most cases the layers are applied by spin coating or rolled on as a laminate. Adhesion force can be controlled by temperature increase or by ultraviolet irradiation so that the wafers can then be removed subsequently by mechanical means. The thinner the wafers, the more challenging the detachment process. Usually a costly process of cleaning is then necessary before the wafers can be further processed.

Bonding with polyelectrolyte intermediate layers

In collaboration with the Institut für Oberflächentechnik of the Technical University of Braunschweig (IOT) coatings using polyelectrolytes have been developed at the Fraunhofer IST which are suitable for temporary bonding and replace the adhesive layers and adhesive films we have mentioned. Polyelectrolytes are polymers with positively or negatively charged ionic groups. In aqueous solutions they usually adsorb very strongly onto surfaces of opposite charge. In this way single-layer polyelectrolyte films are created. Polyelectrolyte multilayers (PEMs) form by the successive adsorption of positively and negatively charged polyelectrolytes. The advantage of using polyelectrolytes is that they cover the surface only as a monolayer and thus build up evenly and can be easily removed again.

Separating by annealing

Temperature-related tests of the bond strength of silicon wafers with polyelectrolyte intermediate layers have shown that strength increases as temperature rises. However, once a certain temperature is reached, strength falls abruptly and remains low even after cool-down, which means that the wafers can be easily separated. The strength level can be set by selection of the temperature during annealing within the range between 100 °C and 250 °C. This means that in the first heat-treatment step substrate wafers can be bonded firmly onto a carrier wafer and then processed. Following a second annealing step the wafers can then be easily separated from each other at room temperature.

Outlook

Future work will concentrate on controlling the separation process over the most varied temperature ranges by using further polyelectrolyte combinations. These should be optimized for different wafer materials. In addition, more fundamental investigations are planned with a view to understanding the process of separation.

1 *Coating a wafer with a polyelectrolyte in the spin dryer.*

2 *Atmospheric-pressure plasma pretreatment of substrates for subsequent bonding.*

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ATMOSPHERIC PRESSURE PLASMA FOR OXIDATION AND REDUCTION PROCESSES

Surface treatments with atmospheric pressure plasmas are playing an ever more important role for many industrial processes. They are used, for example, for cleaning or activating / functionalizing surfaces. As part of the EU project "Reactive Atmospheric Plasma Processing (RAPID)", among other things the effects of such atmospheric pressure plasma treatments on inorganic surface such as metals or metal oxides are being studied. The focus of work at the Fraunhofer IST is on investigating the interactions between selected metals or semiconductors and various discharges at atmospheric pressure.

Atmospheric pressure plasma treatment for improving adhesion

Atmospheric pressure plasma treatments of inorganic materials are used, for example, for functionalizing surfaces. The plasma treated surfaces have modified properties, such as, for example, better wettability. In addition to full-area treatments, surfaces can also be modified locally by means of atmospheric pressure plasmas. Specific structures are created which will then have selectively improved adhesion properties before subsequent painting, bonding or metallization.

Reduction of inorganic oxides

Atmospheric pressure plasmas are furthermore suitable for reducing the oxidized surfaces of inorganic materials. The possible depth of such a plasma reduction ranges from a few to several tens of nanometers. Due to their redox potential, oxidized precious metals can be cleaned most effectively at an early stage of oxidation. The possibility and extend of reduction decreases from oxidized forms of noble metals like palladium and silver, through copper, tin and iron, down to oxides of zinc and silicon. Reducing by using atmospheric pressure plasmas mean that even electrical and optical properties can be selectively modified on the surface of metals and semiconductors. One example is a defined setting of the resistance if ITO (indium tin oxide) coatings.

Oxidation of inorganic materials

Inorganic materials normally oxidize to an extent which cannot be controlled. An atmospheric pressure plasma treatment of the surfaces allows the oxidation process to be speeded up. This rapidly results in very thin and dense oxide layers which prevent further oxidation of the substrates. This process has been used successfully for creating a ZnO corrosion protection layer.

Outlook

In the future one core theme will be the development of new concepts in the corrosion protection of zinc alloys via oxidation by atmospheric pressure plasma. Further work will go in the direction of the tailored design of the boundary surfaces of optical electronic component by reduction or oxidation of the inorganic substrates in atmospheric-pressure plasma, in particular via the possibilities of local treatment offered by the plasma printing process developed at the Fraunhofer IST.

The project

RAPID (Reactive Atmospheric Plasma processIng - eDucation network) is an education Initial Training Network (ITN) within Marie Curie actions. The RAPID project provides interdisciplinary training involving the disciplines physics, chemistry and engineering. The general focus of the project is to join fundamental research with applications of plasma technologies at atmospheric pressure therefore it unites academic and industrial partners.

1-3 *Comparison of untreated and plasma-treated silver surfaces.*

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LIFE SCIENCE AND ECOLOGY

At the center of activities in our "Life Sciences and Ecology" business unit is the development of surfaces and surface treatments for applications in medical sciences and technology, biotechnology and environmental technology. Examples include:

- Selective functionalization and coating of surfaces by means of atmospheric-pressure plasma processes (for example, for bioanalytics, medical technology or migration barriers)
- Diamond-coated electrodes for the electrochemical disinfection of water and for treating wastewater
- Metallization of plastic surfaces for biosensors
- Internal coating of microfluidic components, cell culture bags and tubing
- Biocompatible antifriction coatings (for example, diamond-like carbon coatings) for applications in medical technology, such as in prosthetics
- Plasma treatment for the restoration and conservation of cultural assets
- Disinfection of seeds and foods
- Plasma treatment of organical material and plasma medicine

Customers of this business unit include companies from pharmaceutical industry, biotechnology, medical technology, the foodstuffs industry, the chemical industry and environmental engineering.

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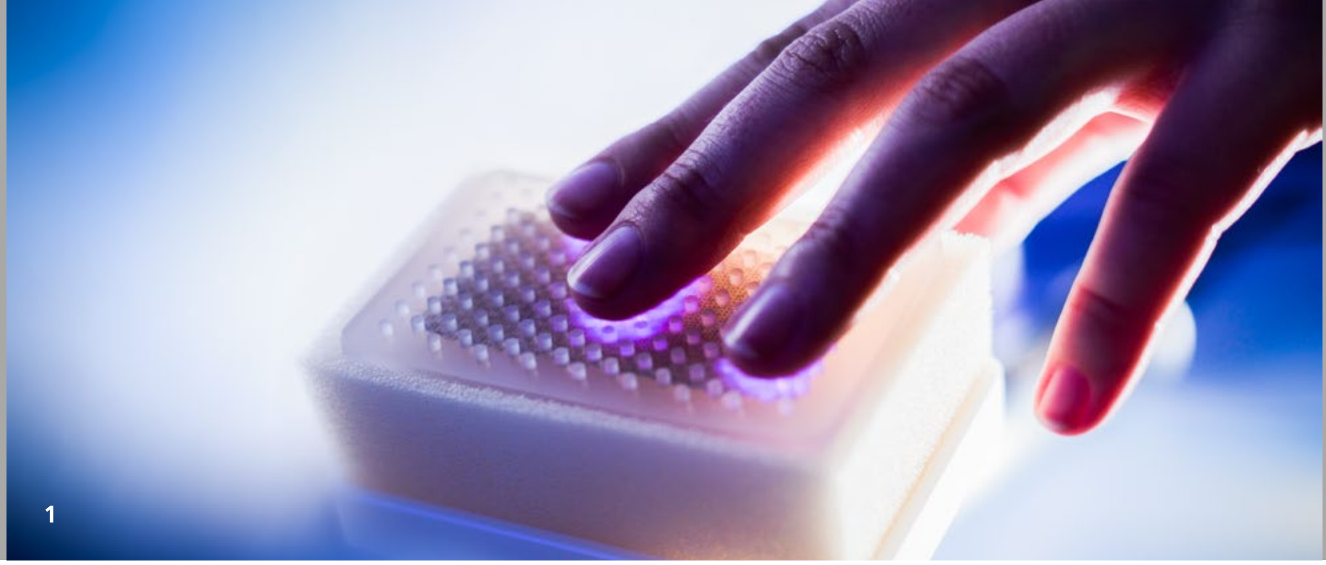
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PLASMA TREATMENT OF HUMAN SKIN: PLASMADERM®-THERAPY

In plasma medical treatments, physical plasma is to be used in direct contact with human skin – an approach that is intensively examined at the moment. Therefore, many different safety-related aspects have to be analyzed and official requirements have to be fulfilled for this application in human medicine. In 2013, the CINOGY GmbH has developed the first CE certified cold atmospheric plasma medical device: PlasmaDerm®.

The aim

Next to the "key actor" CINOGY GmbH, scientist from the Application Center for Plasma and Photonics of the Fraunhofer IST, the HAWK University of Applied Sciences and Arts and the Clinic for Dermatology, Venerology and Allergology at the University Medical Faculty in Göttingen are involved in the development. Together, they aim to develop new, plasma based therapy methods in targeted research projects, and to establish plasma technology as an innovative medical method for clinical applications in the medium term.

The therapy

With the recently developed PlasmaDerm® Technology, especially chronic wounds of different causes can be treated safely and pain-free. For the development of the PlasmaDerm® handset, the scientists around Prof. Wolfgang Viöl and Dr. Andreas Helmke from the Application Center for Plasma and Photonics of the Fraunhofer IST were rewarded with the Innovation Prize of the District of Göttingen 2014. During the therapeutic application, the mobile device brings tissue compatible cold plasma in direct contact with the wound surface. Here, a combination of a simulating electric field, reactive ambient air particles such as oxygen and ozone, and lowly dosed UV light unfolds to stimulate healing: Even resistant microorganisms are killed off and there are hints that especially the electric field working onto depth encourages the blood circulation and the self-healing powers. These combined effects are beneficial for wound healing, as shown in clinical studies and practical applications.

PlasmaDerm® product line

All PlasmaDerm® products are used for the local treatment of infected and germ polluted skin and skin wounds. With the different PlasmaDerm® gadgets, skin and wound areas of different sizes up to 22.5 square centimeters can be treated simultaneously. The smaller gadgets are constructed inflexible with spacers. The bigger gadget is flexible and fits to different body surfaces and features a sterile, exchangeable electrode element. The PlasmaDerm® product line, including the sterile spacers, has obtained the CE mark for medical devices according to EU Directive 93/42/EEC

Applications

A huge application field for the PlasmaDerm® technology is found in the treatment of chronic wounds. An example is the wound treatment with a combined plasma collagen therapy, described on the next pages in "WuPlaKo". Moreover, PlasmaDerm® offers potential treatments for hard to treat skin diseases, such as neurodermatitis or psoriasis.

Outlook

In the future, the interaction of plasma and absorbable Collagen wound dressing will be examined in the BMBF cooperation project "WuPlaKo" (2014-2016) to make use of the high therapeutic potential of these technologies in a combined application.

1 *Plasma treatment of human skin with the PlasmaDerm® handset at the Fraunhofer Application Center for Plasma and Photonics.*

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1

WOUND TREATMENT BY COMBINED PLASMA COLLAGEN THERAPY

Plasma medicine is a promising new discipline particularly in the field of dermatology. Especially in the medical field of chronic wound care such as leg ulcers, the currently available therapies often come up against their limits. With its cooperation partners, the Application Center for Plasma and Photonics of the Fraunhofer IST is working on a new and more effective therapy for wound treatment within the funded "WuPlaKo" project.

Plasma medicine in wound healing

Within the project, the advantages of biochemical wound care using body-absorbable collagen-based wound dressings are to be combined with the advantages of the physical plasma treatment of wounds. Although it is possible to kill off bacteria painlessly with plasma technology and stimulate the formation of new cells, this technology is still a long way from becoming routine clinical practice. Wounds cannot always be healed satisfyingly with existing methods. This applies especially to infection prevention, which can lead to life-threatening complications in special cases, like the development of biofilms or with particularly dangerous pathogens such as many group A streptococci or MRSA strains. In existing methods, the number of pathogens can only be reduced during dressing change in applying antiseptic solutions – however their effect does not last until the next change of dressings several days later.

So far, the first test samples for plasma-active collagen wound dressings have been produced. The wound dressing should deploy an antiseptic effect at the surface of the tissue when needed without change of dressings, thereby allowing a reduction of the number of microorganisms standing in the way of healing of the wound. Tests are currently in progress to aid in the development of suitable evaluation models. The innovative wound dressings generate cold plasma in the area of the wound, doing so by a dielectric barrier discharge (DBD). This is based on the PlasmaDerm® therapy of CINOGY GmbH, which was awarded the Innovation Prize of the District of Göttingen in 2014.

Outlook

In Germany, about four million people are suffering from chronic wounds; their lives are severely restricted by these exuding and painful afflictions. The new dressings could significantly shorten the time taken for the wounds to fully heal. Another advantage is that since no further treatments under anesthesia are necessary, the plasma-active collagen wound dressings could help in particular those individuals already suffering from heart disease or multiple disorders.

In the further course of the project, investigations will look at how the plasma interacts with the collagen and whether the plasma-collagen combination has a greater antimicrobial and regenerative effect.

The project

The "WuPlaKo" project, which started in the summer of 2014, is a collaboration between the CINOGY GmbH, the Application Center for Plasma and Photonics of the Fraunhofer IST, the medichema GmbH in Chemnitz and the Medical School of the University of Greifswald, and is funded by the Federal Ministry of Education and Research (BMBF) to the amount of € 750 000 as part of "SME-innovative medical technology" funding program. The aim of the project is to develop solutions for plasma-assisted wound healing.

Since 2013, the BMBF has assigned funding of € 20 million per year in total to the "SME-innovative medical technology" program to help researchers and companies reduce development risk in the field of medical technology and to boost innovations.

1 Plasma medical advice of the cooperation partner CINOGY GmbH.

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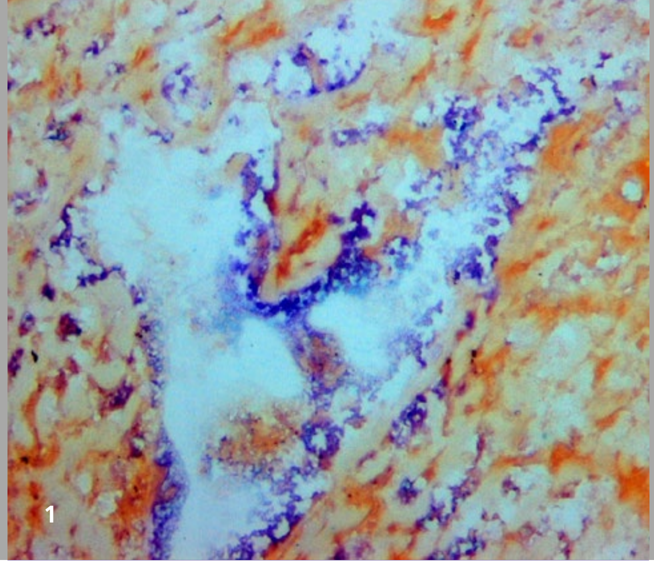
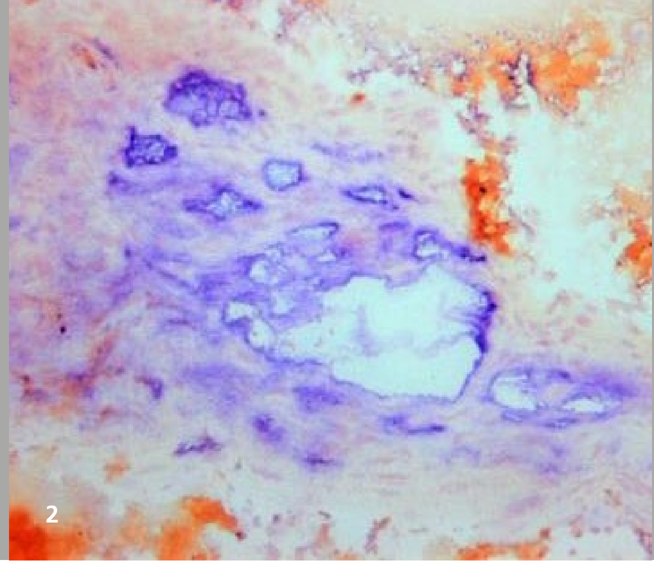
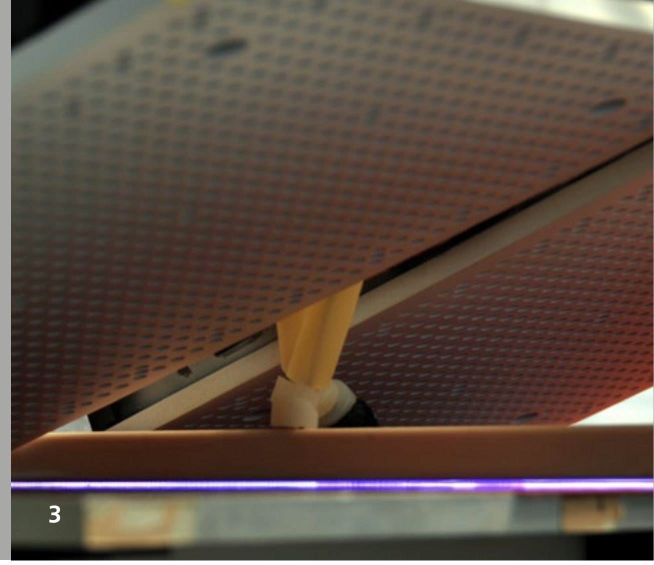






PLASMA COATINGS FOR HISTOLOGY

In medical diagnostics not only molecular biological but also morphological techniques such as the examination of tissue sections play an important role since examining histological specimens allow the presence of genes, mRNA and proteins to be detected locally in defined organ structures, in tumors or in the extra-cellular matrix of affected cells. Studying these histological preparations under the microscope require an adhesive surface on the glass slide. With the aid of atmospheric-pressure plasma processes, such surfaces can be produced inexpensively and rapidly in large quantities.

Histological examinations of tissue sections

In histological examinations tissue sections with only a few micrometers in thickness are mounted on glass slides, stained and analyzed with a microscope. To prevent the tissue section from floating off during the course of the preparatory steps required, the slide has to be given a sufficiently adhesive surface. Nowadays industrial spraying or immersive methods are used for this. The solutions used contain not only the film former but also a solvent. The latter evaporates after the spraying or immersion process, leaving only the film former as a thin film on the substrate.

Coating by atmospheric-pressure plasma processes

One drawback of spraying or immersive methods of this kind is that a considerable quantity of solvent is required in the production of the coatings. This step is followed by a cost-intensive drying process. Furthermore, applying a homogeneous coating by spraying is a challenge for the process technology. A promising alternative for the industrial-scale production of functional and homogeneous coatings is a plasma processes at atmospheric pressure on the basis of dielectric barrier discharges (DBD).

Adhesive surfaces for histological preparations

Organosilane compounds are typical film formers for creating adhesive surfaces by means of atmospheric-pressure plasma processes. Coatings based on these compounds can be deposited very homogeneously on glass surfaces in thicknesses of a few tens of nanometers. Atmospheric-pressure plasma treatments offer a whole series of advantages:

- Reduced costs due to less material required and omission of drying operations
- Reduced environmental burden since no organic solvents are used
- Improved imaging in microscopic examination due to the improved adhesion of tissue sections

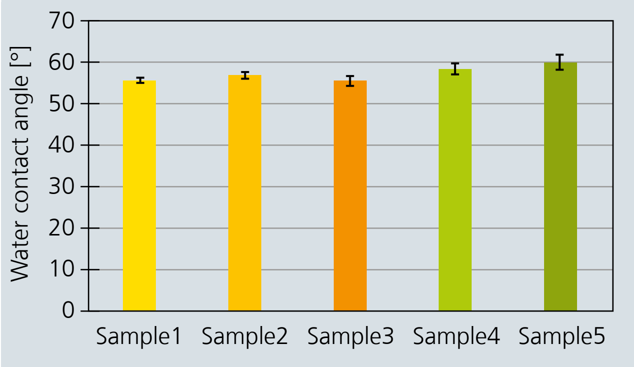
Applications

Application tests with tissue sections have indicated that the preparations adhere very cleanly to the coated surface without creasing. In addition, considerable improvements in the clarity and intensity of staining were gained without any problematic background reactions being observed compared to tissue sections on uncoated glass slides.

Outlook

Results underline the suitability of coatings deposited by atmospheric-pressure plasma processes for improving the adhesion of tissue sections. Inexpensive production without solvents and drying operations coupled with a high coating quality makes this method attractive for industrial implementation.

Water contact angle measurement on a plasma-coated glass slide.



1 Histological section of the spleen tissue of a rat on a coated slide.

2 Histological section of the spleen tissue of a rat on an uncoated slide.

3 Plasma installation for atmospheric-pressure coating.

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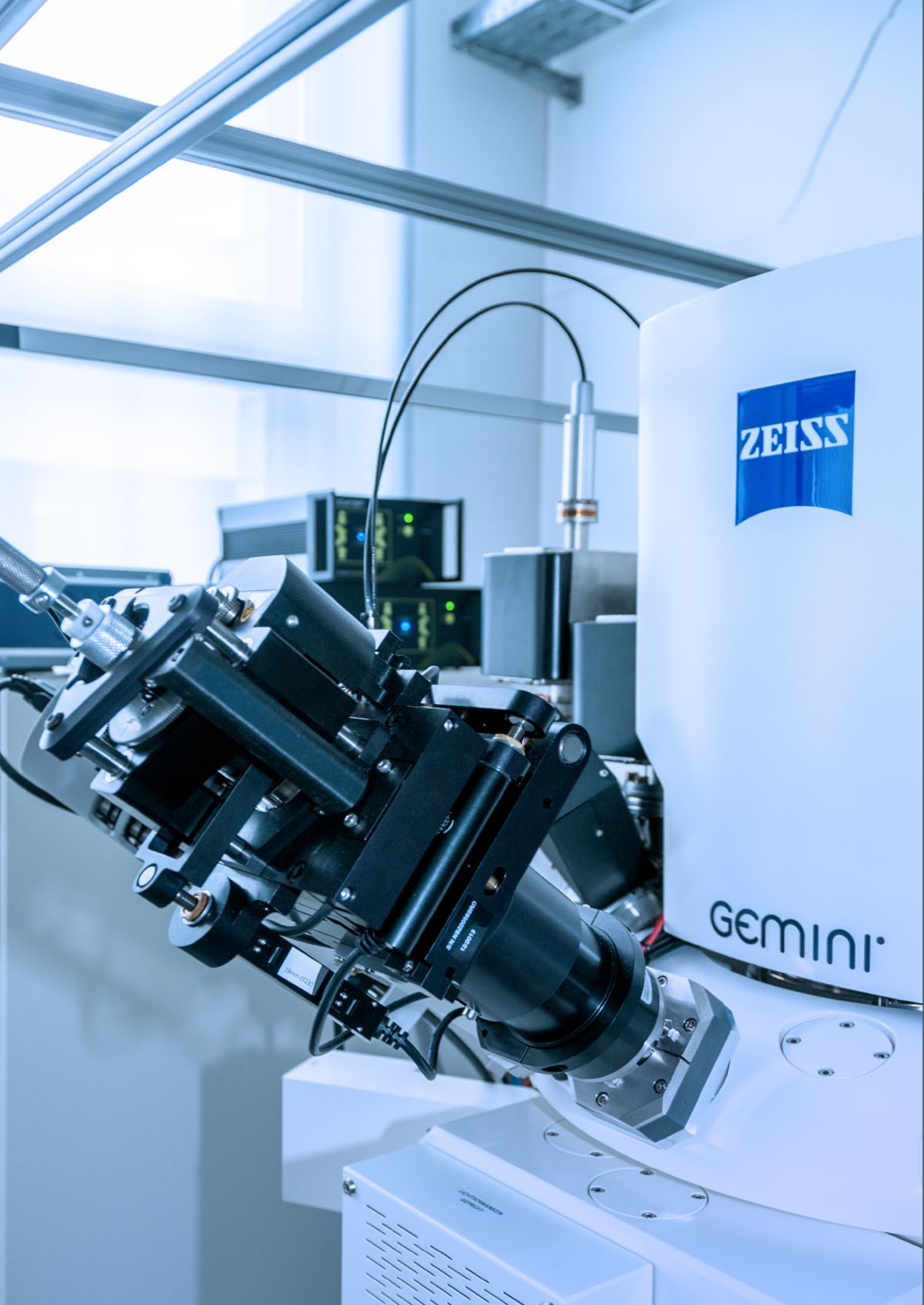
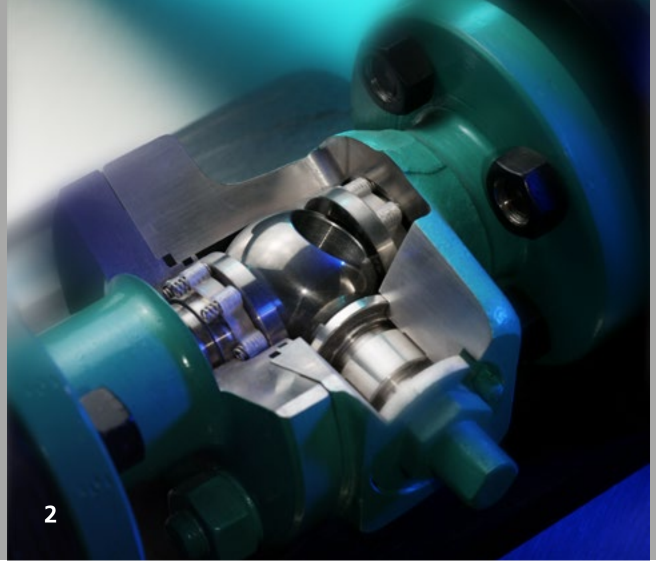


SERVICES AND COMPETENCIES

In pursuing the business units that were showcased in the previous chapters the Fraunhofer IST utilizes a wide spectrum of competencies in the fields of special coating systems on the one hand, and coating processes on the other hand:

- Low pressure processes
- Atmospheric pressure processes
- Micro- and nano technology
- Electrical and optical coatings
- Super hard coatings
- Friction reduction and wear protection
- Analytics and quality assurance

In addition the institute offers a broad spectrum of cross-sectional services: Surface pretreatment, thin film development, surface modification, process technology (including process diagnostics, modeling and control), surface analysis and thin film characterization, training, application-oriented film design and modeling, simulation, system design, device and equipment manufacturing and technoloy transfer.



AN OVERVIEW OF OUR COMPETENCIES

Low pressure processes
- Magnetron sputtering and highly ionized pulsed plasma processes like HIPIMS, MPP
- Hollow cathode processes
- PACVD processes
- Hot-wire-CVD-processes
- Atomic layer deposition (ALD)
- Modeling of low pressure processes
- Plasma diffusion process

Atmospheric pressure processes
- Multi component systems for electroplating
- Non-aqueous electroplating
- Atmospheric pressure plasma processes
- Micro plasma
- Low temperature bonding
- Plastics metallization
- Laser plasma hybrid processes
- Plasma medical applications
- Plasma diagnostics
- Plasma particle coating
- Oxidation and reduction of metals

Micro and nano technology
- Functionalizing of interfacial layers
- Micro and sensor technology
- Nano composite coatings

Electrical and optical coatings
- Optical coatings
- Transparent conductive coatings
- Diamond electrodes
- Silicon-based coatings for photovoltaics and micro electronics
- Oxide semiconductors
- Insulation coatings
- Piezoelectric coatings

Super hard coatings
- Diamond
- Cubic boron nitride (cBN)

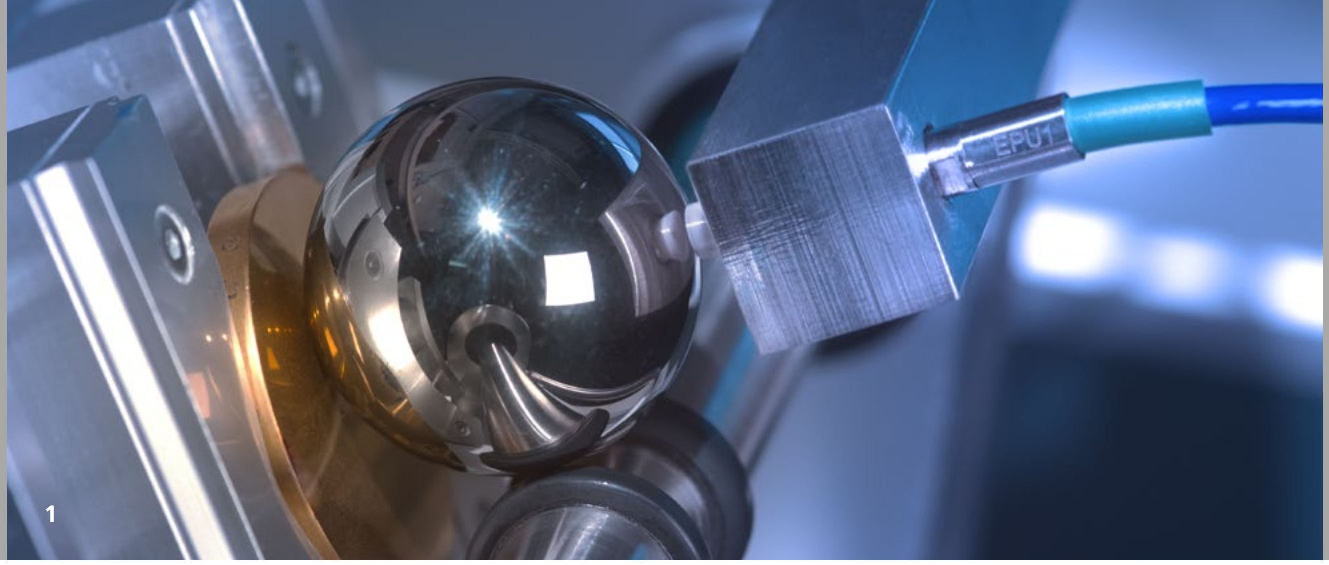
Friction reduction and wear protection
- Amorphous carbon coatings (DLC)
- Diamond coatings
- Hard coatings
- Plasma diffusion
- Dry lubricant coatings
- Erosion protection coatings
- Corrosion protection coatings

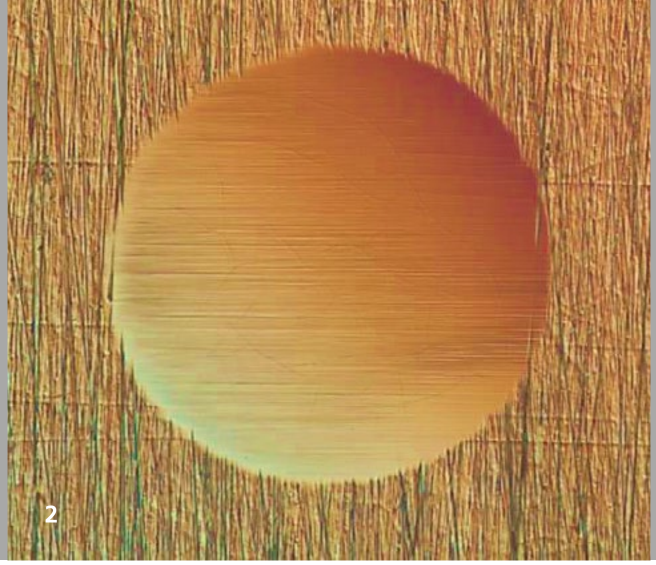
Analytics and quality assurance
- Chemical analysis
- Crystal structure analysis
- Microscopy
- Tribological tests
- Mechanical tests
- Optical measurement

1 *Strain gauges half bridge on an automotive con-rod bearing.*

2 *Coated ball valve: reduction in input power.*

3 *Improved stem cell growth on the surfaces of plasma-coated bags.*





WEAR AND COATING-THICKNESS MEASUREMENT IN A SINGLE STEP

For many years both the wear resistance and the thickness of coatings have been measured by the well-established ball-cratering method. This method has been further developed at the Fraunhofer IST such that wear and coating thickness measurement works automatically. In comparison with conventional crater grinding, time is saved and more reliable results are obtained.

The ball-cratering method

This method is easy to handle and at the same time provides very meaningful results. It is especially interesting from the aspect of low budget investment requirements. The standard DIN EN 1071 describes measurement of coating thickness and calculation of the wear coefficient. The functional reliability of components depends to a very great exent on these two characteristics.

A reliable determination of the crater diameter is the crux of the matter in calculating wear and coating thickness. Currently this requires the following three individual operations:

- the grinding process itself
- cleaning of the component, and
- a visual and microscopic appraisal of the crater.

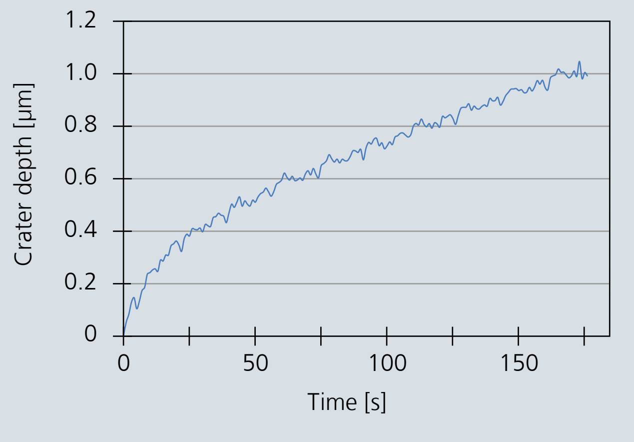
Particularly the evaluation of the grinding result, this means, measuring the crater diameter is a critical point because this requires manual processing. Thus the results are based on a great extent on the individual experience of the scientists. For this reason this commonly used method is not very suitable for industrial and automated quality assurance systems.

Automated wear and coating thickness measurement

The Fraunhofer IST's modified tester only requires one individual operation. In this newly developed method the penetration of the grinding ball, this means the crater depth, is measured continuously during the grinding process. For this reason there is no need for a subjective evaluation of the grinding result. A position sensor (see Fig. 1) detects the position of the rotating ball. The measured values for the crater depth are displayed in real time as a function of the grinding duration, as can be seen in the diagram to the right.

The idea behind further development of the ball-cratering method is to support coating development with innovative and efficient methods of characterization. The grinding process can now be followed on-line. This is a major step forward to achieve an improved understanding of material properties. Measurement of coating thickness should be determined via the different wear rates of the coating and base material.

Crater depth as a function of the grinding duration.



1 *Ball-cratering device with position sensor*

2 *Wear crater.*

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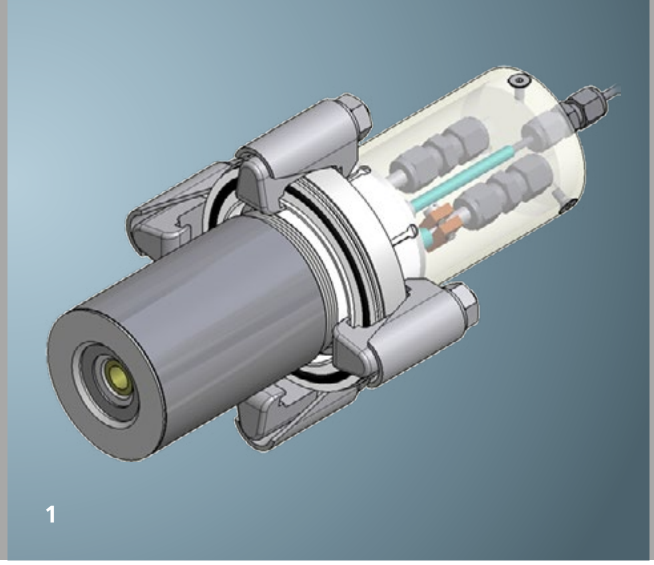

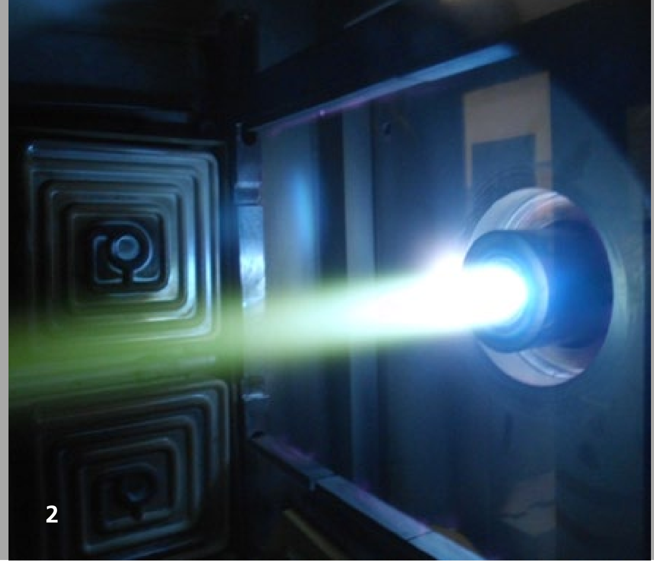

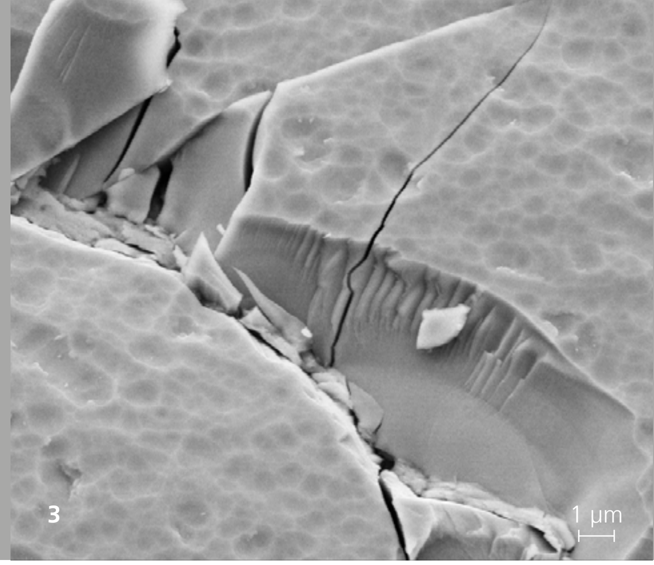

LOCALIZED COATING AT "HIGH PRESSURE"

With the aid of conventional low-pressure sputtering processes, flat component surfaces can be coated over large areas and very evenly. Acccordingly, magnetron sputtering is used commercially today in, for example, coating architectural glass. However, if a high-quality functional layer is needed on components with complex shapes or if three-dimensionally limited component areas are to be selectively coated, conventional methods will come up against their limits. For this reason a coating method is under development at the Fraunhofer IST which will combine the advantages of a sputtering method with those of a directed deposition.

High-pressure gas-flow sputtering source

For a number of years now hollow-cathode gas-flow sputtering (GFS) has been successfully used and further developed at the Fraunhofer IST. In this method cathode material is sputtered in an intensive hollow-cathode glow discharge and carried by a directed stream of gas to the component, on whose surface a coating is then deposited. For the selective coating of particularly challengingly shaped components, such as, for example, the compressor blades in modern aero engines, a strongly focussed variant of the GFS source has now been developed at the Fraunhofer IST (see Figs. 1 and 2). The first prototypes of the source have already been tested in house and at a project partner.

The newly developed high-pressure GFS source works under conditions which are extreme for sputter discharges: at a working pressure in the millibar range, power densities of up to 100 W/cm² are reached in continuous operation at the cathode. At the same time the source has a very compact design: the outlet opening has a diameter of 10 mm while the external diameter of the entire source measures 60 mm without the vacuum flange. These dimensions make possible a defined flow into even narrow gaps or holes. Penetration of the source into hollow spaces, such as, for example, into pipes, can also be attractive for an internal coating.

Localized coating

Depending on the actual shape of the component and the process parameters the static coating area has a diameter of about 25 mm. A local coating rate of more than 100 micrometers per hour is reached in this area. By moving either component or source a selective coating of limited areas of the component is possible. The high pressure GFS technology thus combines aspects of spraying techniques, in other words, a strongly directed transportation of material, with a PVD process in which layer-forming material is present atomically. That the coatings thus produced still have properties which correspond to those of coatings made by PVD has been confirmed by structural investigations of hard coatings, a titanium diboride-nickel composite. The compact microstructure can be seen in the SEM micrograph of the coatings (cf. Fig. 3). In this case microhardness measurements yielded values up to 30 GPa and thus demonstrated that increased pressure and a high coating rate did not have a negative effect on coating quality.

Outlook

The situation reached with the technology we have described can be taken further in various directions, depending on the specific application: the high power density at the cathode leads us already to expect an ionization of the sputtered layer-forming atoms, which is advantageous for compact hard coatings. The compact design of the source permits manipulator-guided operation, which is comparable with the technology of thermal spraying.

1 Diagram of the high-pressure GFS source prepared as a prototype at the Fraunhofer IST with a tubular sputtering target and an internal target diameter of 10 mm.

2 High-pressure GFS source for coating complex component geometries.

3 Fracture micrograph of a titanium diboride-nickel coating sputtered by a high-pressure GFS source at the Fraunhofer IST. Coating hardness is up to 30 GPa.

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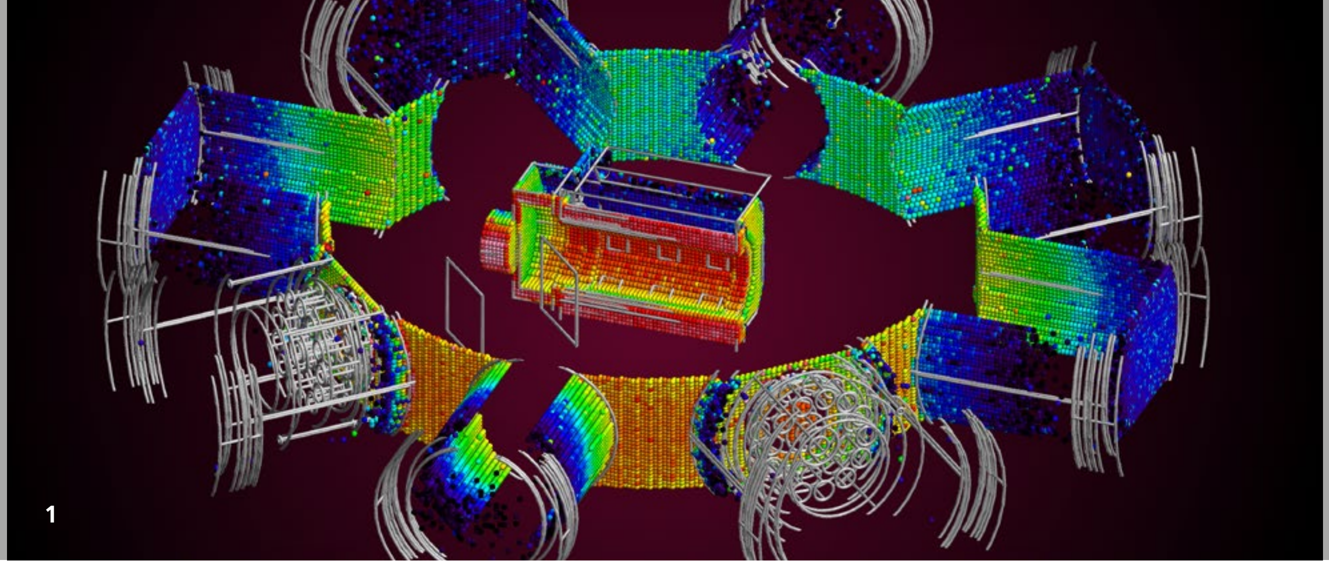
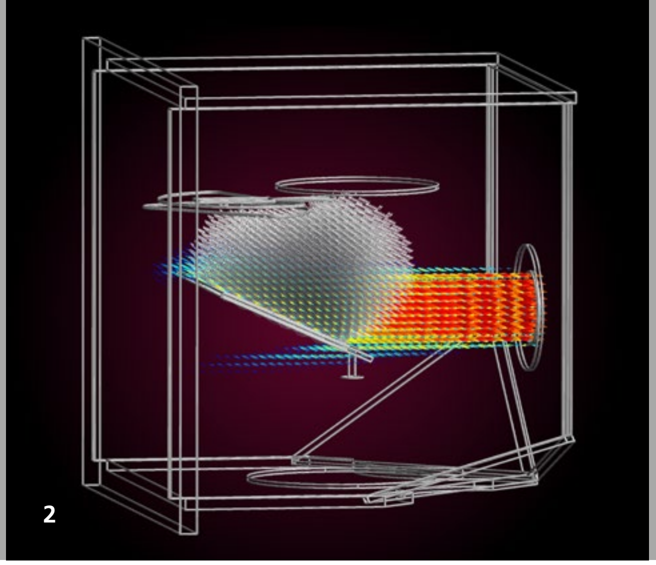




COUPLED SIMULATION

Modeling plasma-coating processes is a multi-scale problem in which both the process dynamics in the coating reactor and also the material-specific growth mechanisms on the molecular level have to be taken into consideration. In the Cornet project "Computer-Aided Process Refinement for Intelligent Coatings" (CAPRICe) the two aspects are linked together: gas flow and plasma-simulations supply details of growth conditions on the substrate which are input directly as information into layer-growth models. The concept of the "virtual coater" thus makes possible a model-supported prediction of coating thickness distribution and coating properties.

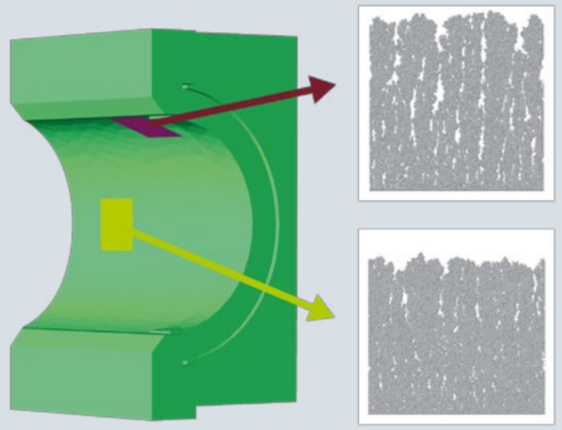
Modeling coating processes and coating properties
One problem which frequently and repeatedly crops up in transferring coating processes from the laboratory scale to industrial production is that the coating properties secured in the lab cannot be reproduced without further refinement in the scaled-up installation. While the thickness and composition of the coating depend in a mostly comprehensible way on the coating material and reactive gas supplies, a large number of factors, such as the reactor geometry or the substrate temperature, play a role in the formation of intrinsic layer properties, for example the crystalline structure, electrical conductivity or optical constants.

Example: simulation of coating 3D components
On the basis of a sputtering process on a 3D component, the angular distributions of particles hitting the substrate at different points are determined from the transport simulation. These angular distributions are passed on as an input variable to a software program for modeling layer growth by means of the kinetic Monte Carlo method. As the illustration to the right shows, different layer morphologies result, depending on position and angle of incidence on the substrate. While the coating is relatively dense in the middle of the component and has hardly any voids, in its outer part a rather columnar type of layer growth can be seen which is due to oblique angles of incidence.

Simulation competence at the Fraunhofer IST
The parallelized simulation environment developed at the Fraunhofer IST has been optimized for thermal evaporation, magnetron sputtering and CVD processes in the low-pressure range. It enables describing the process kinetics in realistic 3D reactor geometries. Connecting up to additional simulation methods for layer growth means that intrinsic coating properties such as density, structure and optical properties can be predicted.

The project
In the "CAPRICe" Cornet project, coating process and layer formation are described by modeling approaches which supplement each other: the Fraunhofer IST contributes its years of experience in the field of gas flow and plasma simulation while, in close connection with this, layer-growth simulations using the kinetic Monte Carlo and molecular dynamics methods are carried out at the University of Namur and at the Laser Zentrum Hannover. The simulations are validated by means of experiments at the CRM Group in Liège.

Simulated layer morphology in coating a 3D component in different positions.



1 Simulated particle flow with ion beam sputtering.

2 Simulated layer thickness distribution in the reactor.

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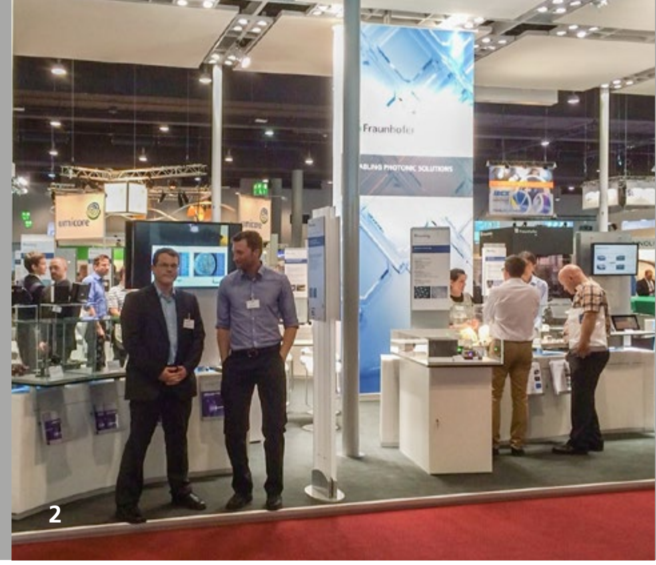
NAMES, DATES, EVENTS 2014

In 2014 the Fraunhofer IST once again appeared on various platforms. An overview of the most important events and activities of 2014 follows:



TRADE FAIRS, EXHIBITIONS, CONFERENCES

"Applied research for defense and security in Germany" conference
Berlin, February 3–5, 2014. At the "Applied research for defense and security in Germany" conference the Fraunhofer IST focused on central topics such as water purification, conditioning and disinfection. Under the motto "Safe water with diamond electrodes" the conference was shown how not readily degradable contaminants can be filtered out of (waste) water with the aid of diamond electrodes and without the additional use of chemicals and also with very low energy expenditure.

Laser Optics 2014
Berlin, March 18–20, 2014. As in the previous year the Fraunhofer IST was also represented in 2014 at Laser Optics, the international fair for optical technologies and microsystems. Various optical filters were exhibited, including notch filters and band-pass filters produced by the new EOSS® sputtering system developed at the Fraunhofer IST.

Analytica 2014
Munich, April 1–4, 2014. The Fraunhofer IST was present at Analytica with its Application Center for Plasma and Photonics. The focus here was on the great potential for innovation of atmospheric-pressure plasmas, which was illustrated by examples of the latest developments. Handheld devices for skin treatment and disinfection with plasma were shown. In this newly developed procedure a so-called cold plasma in direct contact with human skin is used for the first time.

Hannover Messe 2014
Hannover, April 7–11, 2014. The Fraunhofer Photocatalysis Alliance showcased the latest results of its research in the field of photocatalysis on a Fraunhofer joint booth with the theme "Researching for a future worth living". Taking the example of a stylized home, activities aimed at developing new, effective and more powerful photocatalysts for interior and exterior applications were demonstrated.

Optatec 2014
Frankfurt, May 20–22, 2014. Laser and plasma – two high-energy technologies – when used simultaneously make an innovative surface treatment possible and the development of new kinds of coating processes. With this hybrid technology developed by the Application Center for Plasma and Photonics of the Fraunhofer IST, transparent materials, for example, can be structured very effectively or special coatings applied to thermolabile substrates such as plastics, textiles or even paper. Examples of application of the laser-plasma hybrid technology in lens production were presented at Optatec as well as a plasma source.

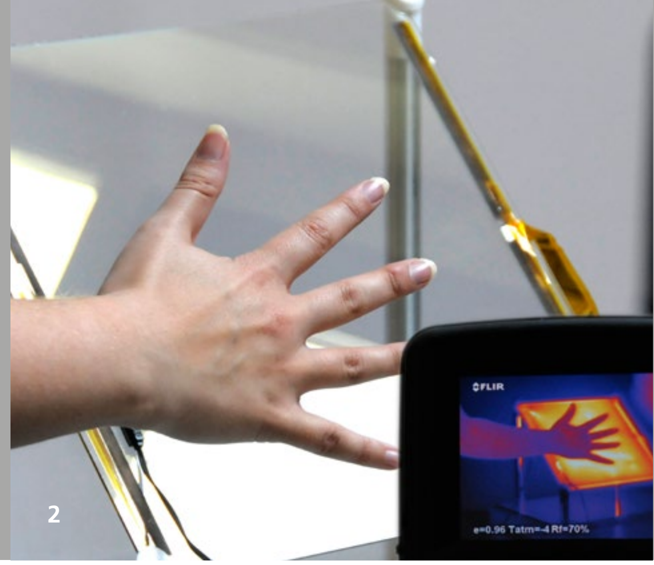
International Air Show (ILA)
Berlin, May 20–25, 2014. At the ILA Berlin Air Show 2014 the Fraunhofer IST presented for the first time its activities in the field of aviation and space travel, displaying its latest coatings for lightweight design and precision lenses. The emphasis was on galvanically metallized antennas made of carbon-fiber-reinforced plastic (CFRP), which can be used even under the extreme temperature conditions of space, as well as on various optical ultra-precision filters and broadband antireflection coatings.

10th International Conference of Coatings on Glass and Plastics – ICCG10
Dresden, June 22–26, 2014. Scientists from the Fraunhofer IST were present at the ICCG10 conference with numerous papers. For example, the further developed sputtering module Megatron® was presented, with which innovative, extremely thin films can be applied to glass. The materials making up these coatings can be varied as desired and entirely new coatings with an improved surface quality be produced.

5th International Conference on High Power Impulse Magnetron Sputtering (HIPIMS)
Sheffield, UK, June 30, – July 3, 2014. The International Conference on High Power Impulse Magnetron Sputtering (HIPIMS) is organized jointly by Sheffield Hallam University, the Fraunhofer IST and the competence network INPLAS e.V. and held alternately at the two locations. In 2014 scientists and representatives from industry gathered in Sheffield to report on this innovative technology in the field of plasma surface technology. Representatives of the Fraunhofer IST participated with numerous contributions such as, for example, an overview presentation of HIPIMS development over the last 15 years, or a paper dealing with reactive process controls.

1 *The stylized house for demonstrating various photocatalysis activities at the Hannover Messe 2014.*

2 *The stand at Optatec of the Application Center for Plasma and Photonics of the Fraunhofer IST.*



TRADE FAIRS, EXHIBITIONS, CONFERENCES

14th International Conference on Plasma Surface Engineering – PSE 2014
Garmisch-Partenkirchen, September 15 – 19, 2014. The Application Center for Plasma and Photonics of the Fraunhofer IST was represented at PSE 2014, the biggest plasma conference in Germany, on the joint booth of the competence network INPLAS e.V. The latest developments and applications in the field of laser-plasma hybrid technology were presented.

International Conference on Space Optics (ICSO) 2014
Tenerife, Spain, October 7 – 10, 2014. On Alliance Space's joint booth the Fraunhofer IST presented its newly developed sputtering platform EOSS®. With this sputtering system it is possible to produce simultaneously up to ten optical filters for space applications with the greatest precision and uniformity.

8th Hot Wire (Cat) Chemical Vapor Deposition Confenrence (HWCVD 8)
Braunschweig, October 13 – 16, 2014. In collaboration with the competence network INPLAS e.V. the Fraunhofer IST organized the "8th Hot-Wire (Cat) Chemical Vapor Deposition HWCVD 8" conference. Representatives of the Fraunhofer IST presented in several papers their latest developments and applications in the field of hot-wire CVD coating. The central topics here were, for example, the simulation of coating deposition or innovative intermediate layers for diamond coatings on hard metals.

8th International Suppliers Fair (IZB)
Wolfsburg, October 14 – 16, 2014. Friction reduction and wear protection are central concerns in the field of automobile production. At the International Suppliers Fair the Fraunhofer IST presented various tribological components, such as, for example, a crankshaft to which a diamond-like carbon coating (DLC) had been applied. Other items presented included sensorized component for applications in the automotive sector.

Glasstec 2014
Düsseldorf, October 20 – 24, 2014. Under the slogan "Our mission is glass" the Fraunhofer joint booth showcased a varied spectrum of practical solutions and research results related to the material glass – from the development, coating and processing of glass, plant engineering to simulation, analysis and characterization. The core themes of the Fraunhofer IST were ALD coatings on three-dimensional objects and the further development of the Megatron® coating module.

Euro India Technology Sourcing 2014
Metz, France, December 9 – 10, 2014. The Fraunhofer IST participated in Euro India Technology Sourcing 2014 with a paper on the subject of "water purification without the use of chemicals". The aim of the conference was to link European and Indian research bodies more closely together. Core themes included materials such as metals, chemicals, plastics and natural fibers as well as processes for industry, transportation and energy.

1 *Participants in the 8th Hot Wire (Cat) Chemical Vapor Deposition Conference (HWCVD 8) in front of City Hall in Braunschweig.*

2 *An exhibit dealing with the topic of "transparent heating" at glasstec 2014: the view through the thermal imaging camera demonstrates the thermal conductivity of the pane of glass.*

EVENTS, COLLOQUIA, WORKSHOPS

SVC presidency goes to the Fraunhofer IST
At this year's technological conference of the Society of Vacuum Coaters (SVC) in Chicago, Prof. Wolfgang Diehl, deputy director of the Fraunhofer Institute for Surface Engineering and Thin Films IST, was appointed as the first European president of the society and will occupy this important office until 2016. As deputy director of the institute and a renowned expert in the field of vacuum coating, Professor Diehl has over past years been a very active and dedicated participant in various SVC committees and rendered outstanding services to the success of the society and the conference. He has great plans for his term of office: the most important project at present is to organize a common venue for both SVC TechCon and the International Conference on Metallurgical Coatings and Thin Films ICMCT, which is also important for many participants. This would benefit both conferences as not only will visitors and exhibitors save on time and traveling costs but they will also profit from a broader coverage and a more intensive interaction between industry, universities and research institutes – and also at the international level. It is especially important to the new president that the identity and culture of these two conferences so steeped in tradition be retained even in the planned merger of the events.

Ribbon-cutting ceremony at the Application Center for Plasma and Photonics of the Fraunhofer IST
The celebratory ribbon-cutting ceremony for the new building was held on the Göttinger Zietenterrassen, hard upon its passing the interim evaluation, which was a major milestone for the Application Center for Plasma and Photonics, founded in 2012. In the meantime the 30 staff of the application center are engaged in their research work in the 1500 m² of the Euro 3.75 million building of the cooperation partner, the University of Applied Sciences and Arts (HAWK). In glorious weather more than 300 invited guests from politics, science and business celebrated the on-schedule completion of the building.

European Researchers' Night in Braunschweig
Braunschweig researchers did it and the Fraunhofer IST was there: on Friday, 26th September 2014 1271 researchers gathered on the Schlossplatz in Braunschweig on the occasion of European Researchers´ Night. This meant that the city of Braunschweig had won its bet, that it could mobilize at least 1000 scientists. In the EU corner IST employee Dr. Jan Gäbler gave out information about European research and the eleven EU projects running at the institute. Under the slogan "Going beyond limits – there's a researcher in everyone" Braunschweig, as one of 300 cities in 24 European countries and as the only city in Germany, won the contest for participation in European Researchers' Night.

Microplasmas at Atmospheric Pressure workshop
Eindhoven, Netherlands, December 10– 11, 2014.
Location-selective surface modifications with the aid of microplasmas at atmospheric pressure were a central topic at the "Microplasmas at atmospheric pressure" workshop. The Fraunhofer IST participated with two presentations. The latest results, for example, in the field of location-selective functionalization of surfaces for applications in biomedicine were presented.

PRIZES AND AWARDS

SVC Mentor Award 2014
At this year's conference of the Society of Vacuum Coaters (SVC TechCon 2014) Dr. Ralf Bandorf of the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig received the "Mentor Award", which is awarded each year for special developments and research work in the field of surface treatment and coating technologies. Recognition was thereby given to his developments in the field of high power impulse magnetron sputtering (HIPIMS) on the industrial scale and his contribution to founding and establishing a global HIPIMS network.

The Göttingen District Innovation Prize
The team at the plasma technology company CINOGY GmbH was extremely pleased when on 26th November it came first in the competition for the "Göttingen District Innovation Prize" in the category "Entrants with over 20 employees". The consortium from southern Lower Saxony consists of CINOGY GmbH as well as researchers and developers from the Application Center for Plasma and Photonics of the Fraunhofer Institute for Surface Engineering and Thin Films IST, the HAWK University of Applied Sciences and Arts and the Clinic for Dermatology, Venereology and Allergology of the University of Göttingen Medical School. For more information about the outstanding development PlasmaDerm® see page 72.

1 *Prof. Wolfgang Diehl at the SVC conference.*

2 *Ursula Haufe, managing director of the GWG Göttingen, Prof. Dr. Günter Bräuer, director of the Fraunhofer IST, Prof. Dr. Christiane Dienel, president of the HAWK, Prof. Dr. Wolfgang Viöl, Head of the Application Center and Dr. Alexander Kurz, senior vice president of the Fraunhofer-Gesellschaft (left to right.) at the ribbon-cutting ceremony for the Application Center's new building.*

3 *Winners of the "Göttingen District Innovation Prize": Dr. Dirk Wandke, Dr. Andreas Helmke, Prof. Dr. Wolfgang Viöl und Prof. Dr. Steffen Emmert (left to right).*

WE BID FAREWELL

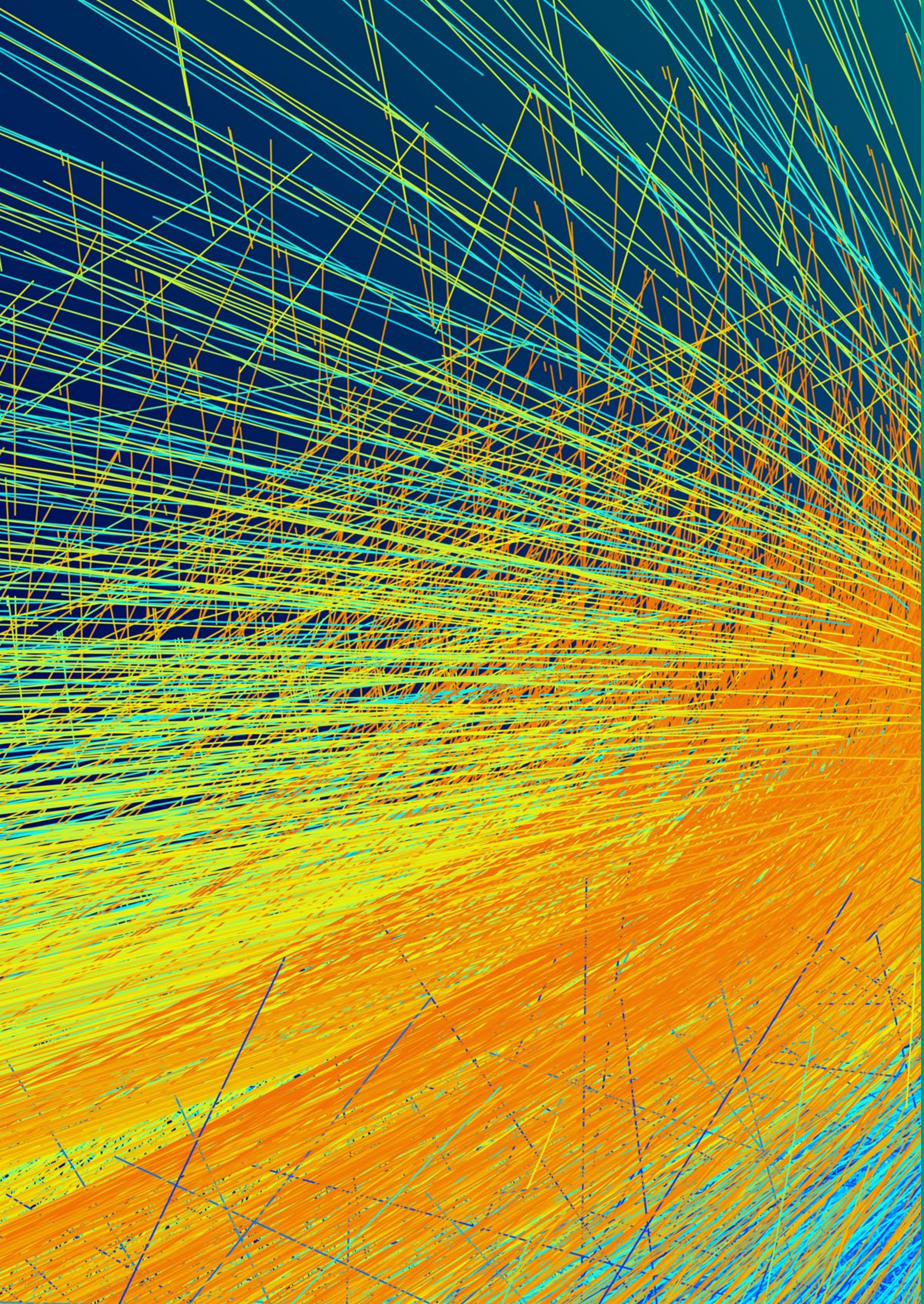
1 *Dr. Peter Willich.*

2 *Gebhard Klumpp.*

We are mourning two very highly esteemed individuals whose memory we all greatly honor. Our deepest sympathy goes out to their families.

Dr. Peter Willich died on 25th March 2014 at the age of 65 years. He was not only a renowned scientist and internationally recognized expert in analysis and quality assurance but also as a head of department participated in building up our institute from the very start and made a decisive contribution to shaping it through his successful work over 20 years. Here he was always very approachable, was always perspicacious with the necessary fine touch, and was known to and loved by everyone for his humor and warm heart.

Gebhard Klumpp died fully unexpectedly and much too early at the age of 47 years. For 16 years he had dedicated himself to our institute and with his creativity and outstanding manual skills made a significant contribution to its success in electroplating. Gifted with an almost incredible imagination he searched for creative solutions for unusual problems and was able to inspire all of his colleagues with his enthusiasm. With a great deal of love and technical expertise he trained surface coating technicians. His delight in his job as a master craftsman and electroplating technician and his teaching skills were highly valued, not just by his trainees. He was known to and loved by all for his sense of humor, his warm-heartedness and his readiness to help.



THE FRAUNHOFER IST IN NETWORKS

With its research and development activities the Fraunhofer Institute for Surface Engineering and Thin Films IST forms a part of various internal and external networks which function with different points of emphasis in the field where business, science and politics interact and even clash. Within the Fraunhofer Society the institute pools its competences with those of other Fraunhofer institutes in, amongst other things, the Fraunhofer Group for Light & Surfaces and in various Fraunhofer alliances in order to be able to offer customers and partners optimal - and even cross-technology – solutions for their specific tasks.

In addition the Fraunhofer IST also keeps an eye open for future scientists and researchers. For this reason the institute networks intensively with educators, students and schoolchildren in order to arouse an enthusiasm for the natural sciences and engineering at an early age and to encourage the upcoming generation of scientist.

THE FRAUNHOFER-GESELLSCHAFT AT A GLANCE

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 66 institutes and research units. The majority of the nearly 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, around 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

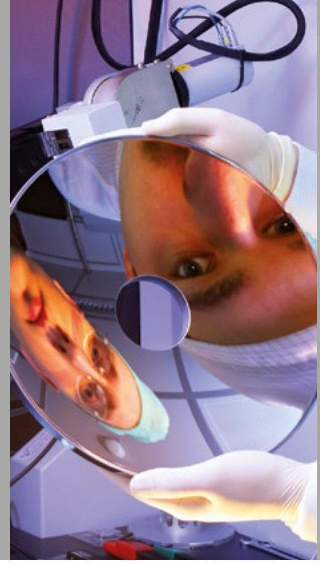
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.





FRAUNHOFER GROUP FOR LIGHT & SURFACES

Competence by networking
Six Fraunhofer institutes cooperate in the Fraunhofer Group for Light & Surfaces. Co-ordinated competences allow quick and flexible alignment of research work on the requirements of different fields of application to answer actual and future challenges, especially in the fields of energy, environment, production, information and security. This market-oriented approach ensures an even wider range of services and creates synergetic effects for the benefit of our customers.

Core competences of the group

- Surface and coating functionalization
- Laser-based manufacturing processes
- Laser development and nonlinear optics
- Materials in optics and photonics
- Microassembly and system integration
- Micro and nano technology
- Carbon technology
- Measurement methods and characterization
- Ultra precision engineering
- Material technology
- Plasma and electron beam sources

Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena
The Fraunhofer IOF develops solutions with light to cope foremost challenges for the future in the areas energy and environment, information and security, as well as health care and medical technology. The competences comprise the entire process chain starting with optics and mechanics design via the development of manufacturing processes for optical and mechanical components and processes of system integration up to the manufacturing of prototypes. Focus of research is put on multifunctional optical coatings, micro- and nano-optics, solid state light sources, optical measurement systems, and opto-mechanical precision systems.

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, Dresden
Electron beam technology, pulse magnetron sputtering and plasma activated high-rate deposition are the core areas of expertise of Fraunhofer FEP. Our business units include vacuum coating, surface modification and treatment with electrons and plasmas. Besides developing layer systems, products and technologies, another main area of work is the scale-up of technologies for coating and treatment of larger areas at high productivity. Our technologies and processes are applied in the fields of mechanical engineering, solar energy, biomedical engineering, environment and energy, for architecture and preservation purposes, in the packaging industry, for optics, sensor technology and electronics as well as in agriculture.

Fraunhofer Institute for Laser Technology ILT, Aachen
The Fraunhofer Institute for Laser Technology ILT is worldwide one of the most important development and contract research institutes of its specific field. Our technology areas cover the following topics: laser and optics, medical technology and bio-photonics, laser measurement technology and laser materials processing. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and rapid manufacturing. Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology.

Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig
As an industry oriented R&D service center, the Fraunhofer IST is pooling competencies in the areas film deposition, coating application, film characterization, and surface analysis. Scientists, engineers, and technicians are busily working to provide various types of surfaces with new or improved functions and, as a result, help create innovative marketable products. The institute's business segments are: mechanical and automotive engineering, aerospace, tools, energy, glass and facade, optics and electronics, life science and ecology.

Fraunhofer Institute for Physical Measurement Techniques IPM, Freiburg
Fraunhofer IPM develops and builds optical sensor and imaging systems. These mostly laser-based systems combine optical, mechanical, electronic and software components to create perfect solutions of robust design that are individually tailored to suit the conditions at the site of deployment. In the field of thermoelectrics, the institute has extensive know-how in materials research, simulation, and systems. Fraunhofer IPM also specializes in thin-film technologies for application in the production of materials, manufacturing processes and systems.

Fraunhofer Institute for Material and Beam Technology IWS, Dresden
The business areas joining, cutting and surface technology are the main foci of the Fraunhofer Institute for Material and Beam Technology IWS. The research and development activities base on a distinctive know-how in the field of material engineering and nanotechnology and include the possibility of material characterization. The IWS's special feature is its expertise in combining its know-how with its extensive experience in developing system technologies within the field of film- and laser technology.

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ENCOURAGEMENT OF YOUNG TALENT AND TRAINING AT THE FRAUNHOFER IST

Encouragement of young talent – what this means for the Fraunhofer Institute for Surface Engineering and Thin Films IST is not only being active both as a trainer and within the university context but also introducing young people to scientific topics, allaying their apprehensions and installing in them an enthusiasm for industry-oriented research. Supporting and mentoring schoolchildren and students with an interest in the fields of research carried out at the Fraunhofer IST was an important part of the institute's work in 2014 as well.

Collaboration with the Christophorus School in Braunschweig

With the aim of filling high school girls and boys with enthusiasm for scientific subjects the Fraunhofer IST as part of a collaborative project with the Christophorus School in Braunschweig extended invitations again this year to an event providing an introduction to surface engineering and thin films technology. More than 60 boys and girls gained a first impression of the development, production and characterization of thin films and their everyday use and also enjoyed a brief look into the laboratories.

KIWI vacation care

The "KIWI Researcher Days for the Curious" program organized by the Braunschweig House of Science and aimed at children during their school vacations was held for the fourth year now at the Fraunhofer IST. Under the slogan "Plasma illuminates – on the track of thin films" around 20 young researchers donned lab coats and safety glasses to tour large-scale coating systems and yellow rooms. In various tests and take-part events the youngsters, for example, electroplated coins or coated various slides. They also learnt about where thin films are needed, why they often have to be so thin and how they can be produced.

Visit of the Career Service of the Technical University of Braunschweig

As part of a program of the Career Service of the Technical University of Braunschweig 13 male and female students interested in science visited the Fraunhofer IST. The idea behind the program is to allow them to gather impressions of the world of work. Their visit to the Fraunhofer IST included attending talks by the two Technical University graduates, Annika Herrmann and Rowena Duckstein, who reported on their start at the Fraunhofer IST, their daily tasks and their fields of research. After this the students had a tour of the institute in which they could, as it were, look over researchers' shoulders and visit some of the laboratories at the Fraunhofer IST.

Future day for boys and girls at the Fraunhofer IST

For about ten years now the Fraunhofer IST together with the Fraunhofer WKI have opened their doors as part of the "Future day for boys and girls" with the aim of arousing an enthusiasm for science in high-school boys and girls. In this year a total of 21 young researchers – 12 girls and 9 boys– , wearing lab coats and eye shields, spent a whole day immersed in the fascinating daily research work of the two Fraunhofer institutes. At the Fraunhofer IST, for example, they were allowed to pretreat plastic cars with atmospheric-pressure plasma processes and then metallize them currentlessly with copper. In addition, plastic films were location-selectively functionalized. Films of this kind are normally used in engineering as the basis of biosensors or flexible printed circuits. At the end of day the youngsters could take their coated films home with them and hopefully the scientific spark has also started a fire burning in a few of them.

Master Block Course: "Surface Engineering and Thin Films"

In February 2014, Prof. Wolfgang Diehl, acting director of the Fraunhofer IST, ran for the third time a course on "Surface Engineering and Thin Films" at the Tshwane University of Technology (TUT) in Pretoria, South Africa. All in all 27 graduates and undergraduates from the Department of Chemical, Metallurgical and Materials Engineering attended. The course, which lasted one week, aimed at familiarizing the engineering students with the many and varied aspects of the physics of thin films and ultimately at arousing an appetite for pursuing this field of study or taking a doctorate. The density of the material and the short time available is a challenge to both teachers and students alike. The course has now been integrated into the curriculum of the university as a Short Learning Program (SLP), there is a final written examination and the credit points awards can be credited to their main course. From next year the course will also be opened up to interested local industry.

1 *A student from the Christophorus School closely examines a coated surface at the Fraunhofer IST.*

2 *Participants in KIWI Day 2014 at the Fraunhofer IST.*

3 *Students at the Tshwane University of Technology (TUT) in Pretoria, South Africa with Prof. Wolfgang Diehl, acting director of the Fraunhofer IST.*


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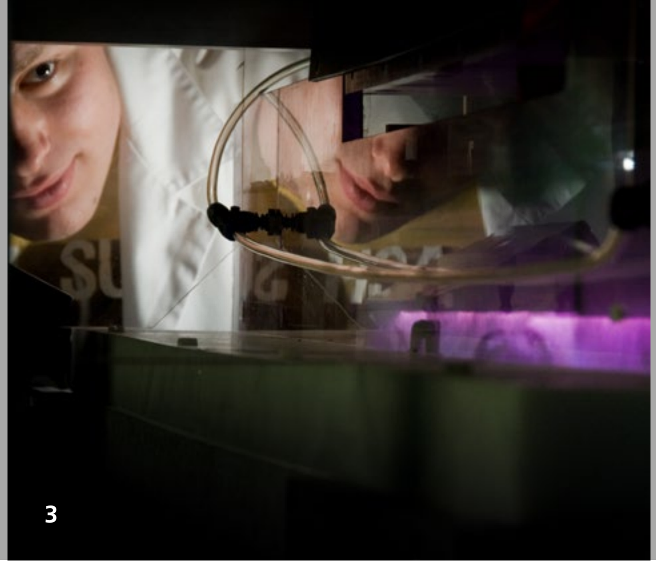
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10 YEAR ANNIVERSITY OF PHYSIK LAB ASSISTANT TRAINING

The Fraunhofer IST sees its educational task not only in connection with universities and technical engineering colleges but also in training in the field of technical professions. For ten years now the Fraunhofer IST has thus offered courses for training as a surface technology specialist and also as a physics lab assistant.

The physics lab assistant

Physics lab assistant – what does this mean precisely? According to the training plan for this job various subject areas are important: they range from vacuum technology, materials science and electrical engineering, optics, thermodynamics and mechanical engineering, to analysis, chemistry or even radioactivity. Physics lab assistants determine the properties of materials and technical systems by tests and series of measurements. To do so they plan test set-ups and carry out the experiments with the aid of diverse items of measuring equipment. They document, analyze or interpret the results and prepare them, for example, for the scientists or development engineers. In addition they carry out not only maintenance of the technical test and process apparatus but also repairs.

Training at the Fraunhofer IST

In 2004 Sven Pleger launched the physics lab assistant training program at the Fraunhofer IST. Since 2014 he has been supported in his work by a second trainer, Daniel Schulze. Training at the IST is very multifaceted. As a rule the trainees pass through nearly every work group and department of the institute. In at least 12 weeks they here acquire an extensive knowledge of surface engineering and thin film technology and comprehensive technical knowledge and expertise.

At the end of their training the soon-to-be physics lab assistants have a wide range of skills and abilities:

- Knowledge of the theoretical principles of surface engineering and thin film technology
- Independent performance of coating processes
- Independent operation of machinery and equipment
- Knowledge of various measuring devices and specific analytical procedures
- Evaluation and analysis of measurement results

Trainees at the Fraunhofer IST

In August 2004 the first two trainees started their work at the Fraunhofer IST, and both managed to complete successfully. This laid the foundation stone for establishing the »physics lab assistant« apprenticeship scheme at the Fraunhofer IST. Further generations of trainees followed – every two years two trainees – and so far all of them have completed their training successfully and obtained employment contracts at the IST. Many of them have used the IST as a springboard and are now working successfully in industry or subsequently graduated.

Survey

We asked four current and one former trainee how they like(d) the training and why they opted for the IST. Here are some extracts from their responses:

- Veysel Zeren, 3rd year: "Most of all I like the very close, friendly relationships between the people working at the Fraunhofer IST. That's why I want to stay at the IST once I've finished my training."
- Hendrik Thiem, 3rd year: "Here we are encouraged to work independently very quickly, which I think is great. Right from the start I was very taken with the IST's modern equipment as well."
- Julia Matheus, 1st year: "I felt very comfortable at the IST right away, we were shown everything and I felt very welcome. It's all very friendly here – a great working environment."
- Hannes Till Meyer, 1st year: "At the Fraunhofer IST they really look after the trainees, the trainers are very dedicated. I'd choose a physics lab assistant training course at the IST any time."
- Tobias Behrendt, former trainee: "The multifacetedness of the training was something very special for me. During our time we were able to work in virtually every department."

We are especially pleased that all of them would, given the possibility, once again choose this training course at our institute.

The Physiklaboranten.de portal

In collaboration with the Technical University of Braunschweig and the Federal Institute of Physics and Metrology (PTB) the training portal www.physiklaboranten.de was launched in 2011. Here the upcoming generation of scientists can find extensive information about the profession and ways of applying to the three participating institutions.

1-3 *Physics lab assistants during their daily work.*

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49 INPLAS-Mitglieder
(Stand Oktober 2014)

THE NETWORK OF COMPETENCE INDUSTRIAL PLASMA SURFACE TECHNOLOGY E.V. – INPLAS

The INPLAS e.V. competence network, accredited as a network in the "go-cluster" program by the Federal Ministry of Economics and Technology (BMWi) in Germany, has its registered offices at the Fraunhofer IST. The network has 49 members from academia and industry. About 200 individuals are actively involved in the various network activities, with nearly three-quarters coming from industry.

In 2014 INPLAS once again ran numerous successful activities, projects and events aimed at making plasma technology known in particular as a versatile tool in surface technology and promoting its application in industry. A selection of the year's activities is presented below.

INPLAS)))Talks 2014
The subject of this year's INPLAS)))Talks was "Plasma surface technology for electric energy storage devices and transducers". More than 40 participants discussed what possibilities plasma surface technology could offer in this field and which aspects could become interesting in the future.

8th Hot-Wire (Cat) Chemical Vapor Deposition Conference HWCVD 8 in Braunschweig
Numerous scientists from all over the world visited the "8th Hot-Wire (Cat) Chemical Vapor Deposition HWCVD 8" conference held in Braunschweig from 13th to 16th October 2014. Following venues in France, Canada and Japan the conference was this year held for the first time in Germany. In two years' time the community is invited to Philadelphia in the USA. Topics of the 2014 conference were process technologies, processes and coating materials, such as, for example, silicon-based or carbon-based materials, and also applications for the coatings produced. The focus here was on barrier functions, microelectronics, catalytic properties and solar applications.

Active work of the work groups
In the INPLAS work groups, members – above all a large number of partners from industry – come together to discuss and advance topics of common interest. The "Innovative Plasma Sources and Processes" work group headed by Dr. Bernhard Cord of Singulus Technologies AG met at the Ruhr-University Bochum in the spring and at SCHMID Vacuum Technology GmbH in Karlstein in the autumn. This year's topics were plasma diagnostics, plasma analysis and calculation for low-pressure plasmas. In parallel with this, samples from the six participants in a round-robin test "Al_2O_3 coatings" were analyzed and characterized at the Fraunhofer IST. Evaluation of the results should be completed in spring 2015.

The "Tool Coatings" work group headed by Hanno Paschke, Fraunhofer IST branch at the Dortmunder Oberflächencentrum (DOC), met in both Berlin and Braunschweig. The aim was to work out a project sketch centered on pretreatment processes for cutting tools with complex geometries.

In the "Combined surface technology" joint committee the topics of corrosion protection in the automobile were discussed at the Fraunhofer IST in Braunschweig and nanotechnology/anti-fingerprint coatings at BASF Coatings GmbH in Münster, Germany. The 3rd joint committee workshop, tackling the subject of coating, modifying and characterizing polymer surfaces was held at the Leibniz Institute for Polymer Research in Dresden.

In the DUV/VUV Optics work circle, headed by Werner Riggers, LASEROPTIK GmbH in Garbsen, representatives from the fields of optics and optical coatings have been meeting for years to exchange information and ideas about the latest developments. The work circle was for the first time a guest in Braunschweig.

Further press and publicity activities/service projects

- The "ExpertPlas" project: designing and implementing "PlasmaTalk", an on-line experts' forum
- IP4Plasma, EU project: responsible for dissemination
- Photonics Conference 2014
- Plasma Germany meeting in Braunschweig
- 5th HIPIMS conference in Sheffield
- 31st meeting of the Tool Coatings and Cutting Materials industry work group with its partners the Institute for Machine Tools and Factory Management (IWF) of the Technical University of Berlin, the Fraunhofer Institute for Production Systems and Design Technology IPK and the Fraunhofer Institute for Surface Engineering and Thin Films IST.
- INPLAS joint stand at PSE 2014 with partners BAQ GmbH, Fraunhofer Institute for Surface Engineering and Thin Films IST, Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, FHR Anlagenbau GmbH, tantec GmbH and W&L Coating Systems GmbH.

1 *International scientists at the HWCVD 8 conference in the Eintracht Braunschweig stadium.*

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Deutsche Gesellschaft für Materialkunde e. V.
www.dgm.de

Deutsche Forschungsgesellschaft für Oberflächenbehandlung e. V.
www.dfo-online.de

Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V.
www.dgo-online.de

Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS)
www.efds.org

European Photocatalysis Federation EPF
www.photocatalysis-federation.eu

F.O.M. Forschungsvereinigung Feinmechanik, Optik und Medizintechnik e. V.
www.forschung-fom.de

ForschungRegion Braunschweig e. V.
www.forschungregion-braunschweig.de

Forschungsgemeinschaft Werkzeuge und Werkstoffe e. V. (FGW)
www.fgw.de

Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID e. V.
www.faps.uni-erlangen.de/mid

Fraunhofer-Allianz Adaptronik
www.adaptronik.fraunhofer.de

Fraunhofer-Allianz autoMOBILproduktion
www.automobil.fraunhofer.de

Fraunhofer-Allianz Numerische Simulation von Produkten, Prozessen
www.nusim.fraunhofer.de

Fraunhofer-Allianz Photokatalyse
www.photokatalyse.fraunhofer.de

Fraunhofer-Allianz Proteinchips
www.proteinchips.fraunhofer.de

Fraunhofer-Allianz Reinigungstechnik
www.allianz-reinigungstechnik.de

Fraunhofer-Allianz Space
www.space-fraunhofer.de

Fraunhofer-Allianz SysWasser
www.syswasser.de

Fraunhofer-Netzwerk Elektrochemie
www.elektrochemie.fraunhofer.de

Fraunhofer-Netzwerk Nachhaltigkeit
www.fraunhofer.nachhaltigkeit.de

Fraunhofer-Verbund Light & Surfaces
www.light-and-surfaces.fraunhofer.de

German Flatpanel Display Forum DFF
www.displayforum.de

German Water Partnership
www.germanwaterpartnership.de

Göttinger Research Council
www.uni-goettingen.de

International Council for Coatings on Glass e. V.
www.iccg.eu

Kompetenznetz Industrielle Plasma-Oberflächentechnik e.V. (INPLAS)
www.inplas.de

Materials Valley e.V.
www.materials-valley-rheinmain.de

Measurement Valley e.V.
www.measurement-valley.de

Nano- und Materialinnovation Niedersachsen e. V. (NMN)
www.nmn-ev.de

Nanotechnologie Kompetenzzentrum Ultrapräzise Oberflächenbearbeitung CC UPOB e. V.
www.upob.de

NANOfutures European Technology Integration and Innovation Platform (ETIP) in Nanotechnology
www.nanofutures2010.eu

PhotonicNet GmbH – Kompetenznetz Optische Technologien
www.photonicnet.de

Plasma Germany
www.plasmagermany.org

Spectaris – Verband der Hightech-Industrie
www.spectaris.de

Wissens- und Innovations-Netzwerk Polymertechnik (WIP)
www.wip-kunststoffe.de

Zentrum für Mikroproduktion e. V. (ZeMPro)
www.microcompany.de

BOARD MEMBERSHIPS

Bandorf, R.: COST Action MP1004, Management Committee Delegate.

Bandorf, R.: Forschungsvereinigung Räumliche Elektronische Baugruppen 3-D MID e. V., Mitglied.

Bandorf, R.: International Conference on HIPIMS, Conference Chairman.

Bandorf, R.: OTTI-Fachforum Kathodenzerstäubung, Dozent.

Bandorf, R.: Society of Vacuum Coaters, Assistant Program Chairman.

Bandorf, R.: Society of Vacuum Coaters, Volunteer Mentor.

Bandorf, R.: Society of Vacuum Coaters, Dozent.

Bandorf, R.: Zentrum für Mikroproduktionstechnik e. V., Mitglied.

Bewilogua, K.: OTTI-Fachforum PVD- und CVD-Beschichtungsverfahren für tribologische Systeme, Fachliche Leitung.

Brand, C.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Mitglied.

Brand, C.: Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS e. V., Geschäftsführerin.

Brand, C.: Plasma Germany, Mitglied des Koordinierungsausschusses.

Brand, J.: Gesellschaft für Tribologie (GfT), Mitglied.

Brand, J.: International Colloquium Tribology, Tribology and Lubrication Engineering, Mitglied im Programme Planning Committee.

Bräuer, G.: AMG Coating Technologies, Mitglied des Beirats.

Bräuer, G.: Aufsichtsrat der PVA TePla AG, Mitglied.

Bräuer, G.: European Joint Committee on Plasma and Ion Surface Engineering (EJC / PISE), Chairman.

Bräuer, G.: International Conference on Coatings on Glass and Plastics (ICCG), Mitglied des Organisationskomitees.

Bräuer, G.: International Council for Coatings on Glass (ICCG) e. V., Mitglied des Vorstands.

Bräuer, G.: Institut für Solarenergieforschung, Mitglied des Beirats.

Bräuer, G.: Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS e. V., Vorstandsvorsitzender.

Bräuer, G.: Nano- und Materialinnovationen Niedersachsen e. V. (NMN), Mitglied des Vorstands.

Bräuer, G.: Zeitschrift »Vakuum in Forschung und Praxis«, Mitglied des Kuratoriums.

Bräuer, G.: Zentrum für Mikroproduktionstechnik e. V., Mitglied des Vorstands.

Diehl, W.: Deutsche Forschungsgesellschaft für Oberflächenbehandlung DFO, stellvertretender Präsident.

Diehl, W.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Mitglied des Vorstands.

Diehl, W.: Plasma Germany, Mitglied des Koordinierungsausschusses.

Diehl, W.: RETECZA NPO, Pretoria SA, Vorsitzender des Boards.

Diehl, W.: Society of Vacuum Coaters (SVC), USA, President.

Diehl, W.: Technologietransferkreis ForschungRegion Braunschweig, Mitglied.

Dietz, A.: Arbeitsgemeinschaft Elektrochemischer Forschung (AGEF), Mitglied.

Dietz, A.: Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO), Mitglied des Vorstands.

Dietz, A.: Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO), stellvertretender Vorsitzender Ortsgruppe Niedersachsen.

Dietz, A.: Fachausschuss »Forschung« der Deutschen Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO), Mitglied.

Dietz, A.: Fachausschuss »Kombinationsschichten« der Deutschen Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO), Mitglied.

Eichler, M.: Conference on Wafer Bonding for Microsystems 3D- and Wafer Level Integration, Local Chairman.

Gäbler, J.: DIN Normenausschuss NA 062 Materialprüfung, Arbeitsausschuss NA 062-01-72 AA »Chemische und elektrochemische Überzüge«, Mitglied.

Gäbler, J.: DIN Normenausschuss NA 062 Materialprüfung, Arbeitsausschuss NA 062-01-64 AA »Kohlenstoffschichten«, stellvertretender Obmann.

Gäbler, J.: European Technology Platform for Advanced Materials and Technologies EuMaT, Mitglied.

Gäbler, J.: European Technology Platform NANOfutures, Mitglied.

Gäbler, J.: ISO Technical Committee TC 107 »Metallic and other inorganic coatings«, P-Member.

Gäbler, J.: VDI-Richtlinien-Fachausschuss »CVD-Diamant-Werkzeuge«, Mitglied.

Keunecke, M.: SAE International, Mitglied.

Keunecke, M.: Society of Vacuum Coaters, Session Chairman.

Keunecke, M.: Society of Vacuum Coaters, Dozent.

Keunecke, M.: EFDS-Fachausschuss »Tribologische Schichten«, Mitglied.

Klages, C.-P.: Nano- und Materialinnovationen Niedersachsen e. V. (NMN), Fachbeirat Oberflächen.

Klages, C.-P.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Mitglied des wissenschaftlichen Beirats.

Lachmann, K.: COST Action MP1101 »Biomedical Applications of Atmospheric Pressure Plasma Technology«, Management Committee, Substitute.

Neumann, F.: Europäisches Komitee für Normung, CEN/TC 386 »Photocatalysis«, Mitglied.

Neumann, F.: Europäisches Komitee für Normung, CEN/TC 386 »Photocatalysis«, Delegierter des Technischen Komitees.

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Neumann, F.: DIN Deutsches Institut für Normung e. V., Normenausschuss 062 Materialprüfung, Arbeitsausschuss NA 062-02-93 AA »Photokatalyse«, Leitung des Arbeitskreises »Photokatalytische Selbstreinigung«.

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Paschke, H.: Fachausschuss FA10 »Funktionelle Schichten« der Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e. V. AWT, Mitglied.

Paschke, H.: Industrie-Arbeitskreis »Werkzeugbeschichtungen und Schneidstoffe«, Leitung.

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Paschke, H.: Kompetenznetzwerk für Oberflächentechnik »netzwerk-surface.net«, wissenschaftlicher Beirat (Sprecher).

Paschke, H.: Regionale Netzwerk-Initiative »In|Die Region-Ruhr«, Mitglied.

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Sittinger, V.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Workshop »Dünnschicht-Technologie für Energiesysteme – Wandlung, Speicherung, Effizienz, V2013«, Chairman, Programmkomitee.

Sittinger, V.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Workshop »Dünnschicht-Technologie für Energiesysteme – solare Anwendungen, V2013«, Programmkomitee.

Sittinger, V.: Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS), Workshop »Transparente leitfähige Materialien (TCO/TCM) – Festkörperphysikalische Grundlagen und Technologien«, Chairman, Programmkomitee.

Sittinger, V.: EFDS-Fachausschuss »Dünnschichttechnik für Großflächenbeschichtung«, stellvertretende Leitung.

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Sittinger, V.: Society of Vacuum Coaters, Volunteer Mentor.

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Thomas, M.: EFDS-Fachausschuss »Atmosphärendruck Plasmatechnologien«, Mitglied.

Viöl, W.: Bundesministerium für Bildung und Forschung BMBF, Mitglied des Expertengremium.

Viöl, W.: Deutsche Gesellschaft für Plasmatechnologie e. V. DGPT, Mitglied des Vorstands.

Viöl, W.: DFG Fachkollegien, Mitglied.

Viöl, W.: Gesellschaft Deutscher Naturforscher und Ärzte e. V. GDNÄ, Mitglied im Fachbeirat.

Viöl, W.: HAWK Hochschule für angewandte Wissenschaft und Kunst Hildesheim / Holzminden / Göttingen, Vizepräsident für Forschung und Transfer.

Viöl, W.: Hochschulrektorenkonferenz Forschungskommission Fachhochschulen.

Viöl, W.: Kompetenznetz für Nachhaltige Holznutzung (NHN) e. V., Vorstandsmitglied.

Viöl, W.: Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS e. V., Kassenwart.

Viöl, W.: Nationales Zentrum für Plasmamedizin, Kuratoriumsmitglied.

Viöl, W.: Nano- und Materialinnovationen Niedersachsen e. V. NMN, Mitglied des Fachbeirats.

Viöl, W.: Spectaris – Verband der Hightech-Industrie, Fachverband Photonik, Mitglied des Lenkungsausschusses.

INTERNATIONAL GUESTS

Frau Lerato Tshabalala, Department of Chemical & Metallurgical Engineering, Tshwane University of Technology, Pretoria, South Africa, 10. – 30. November 2014.

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