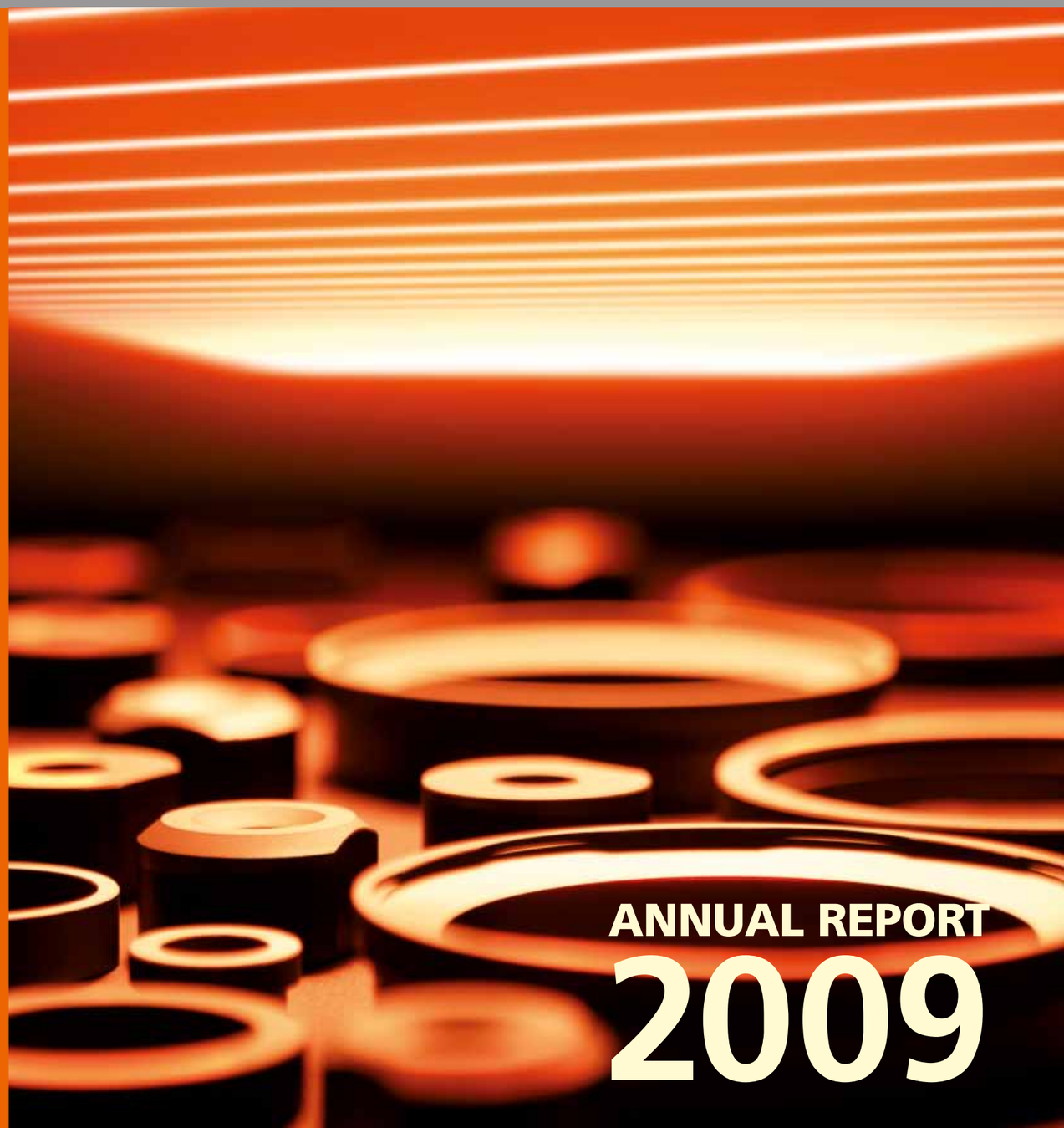
Fraunhofer
IST

FRAUNHOFER INSTITUTE FOR SURFACE ENGINEERING AND THIN FILMS IST

ANNUAL REPORT 2009

FRAUNHOFER IST



ANNUAL REPORT 2009

ANNUAL REPORT

2009

FOREWORD

Ladies and gentlemen,

In your hands you are holding our yearbook 2009. We are pleased to be able to once again offer you some interesting material about current developments from the Fraunhofer Institute for Surface Engineering and Thin Films IST.

For our institute the year 2009 was another very successful year with many highlights and exciting projects. You can find out more on the following pages.

At this point may we direct your attention to the people whose hard work and commitment, trust and support forms the foundations for the success of our institute: above all the employees of the Fraunhofer IST, our partners from research and development, our customers from industry, our sponsors, colleagues and friends.

To them all we extend our very cordial thanks.

Prof. Dr. Günter Bräuer

Dipl.-Ing. Wolfgang Diehl

1 *Director Prof. Dr. Günter Bräuer and deputy Dipl.-Ing. Wolfgang Diehl with diamond coated ceramic face seals.*

CONTENTS

HIGHLIGHTS 2009

For the Fraunhofer IST the year 2009 was characterized by the further expansion of cooperative activities on a national and international level.

Thin film photovoltaics was one of our key areas of interest in 2009 – our aim was to link and develop our core competencies in this field with research partners both within the Fraunhofer-Gesellschaft and beyond.

With the Helmholtz Zentrum Berlin (HZB) the foundation has been put in place for pioneering collaborative work. The complex nature of research activities in Lower Saxony in the field of solar energy generation was clearly revealed at a photovoltaics symposium in June in Hamelin. On the basis of this event the first discussions were held regarding joint projects with the ISFH – the Hamelin Institute for Solar Energy Research – as well as with the Next Energy research center in Oldenburg. The summer of 2009 saw the delivery and entry into service of our new pass-through silicon deposition unit based on hot-filament CVD. With this system we wish to demonstrate the potential for new solutions in the production of silicon-based thin-film solar cells.

The outstanding reputation of the Fraunhofer IST has been further boosted in the field of high power impulse magnetron sputtering (HIPIMS). Our institute has been coordinating a COST initiative with the title »HIPP Processes« and it has also in the meantime been decided to set up a HIPIMS joint research laboratory in collaboration with Sheffield Hallam University.

The Fraunhofer IST has been able to consolidate and considerably expand its activities in South Korea. Research projects are continuously underway and scientists exchanged with our long-term research partners, KITECH (the Korea Institute of Industrial Technology). In addition, our institute was able to gain new orders from the automotive and semi-conductor industries.

In South Africa in the summer of 2009 the Fraunhofer IST together with international partners launched the RETECZA initiative which has set itself the task of developing inexpensive and independent solutions for house construction, for infrastructure and for vehicles suitable for use in remote areas of South Africa. Our institute's contribution here is its expertise in the field of water treatment using diamond electrodes. Direct collaboration with TUT (the Tshwane University of Technology) in Pretoria is planned.

On the occasion of a visit to Saint-Étienne in France in September 2009 it was also possible to further strengthen and develop contacts with the local technical university as well as with the ViaMéca network. It is expected that this collaboration will remain an important part of our palette of international collaborations in the years ahead as well.

Under the slogan »Plasma – a bright advanage«, INPLAS, the Industrial Plasma Surface Engineering competence network chaired by the Fraunhofer IST, held a »parliamentary evening« on March 18th at the Fraunhofer Forum in Berlin which was attended by more than 100 participants. As part of an exhibition accompanying the event, users and plant manufacturers presented innovations from the field of plasma technology.

The institute's new semi-technical facility has been finished. Fitting out is far advanced and much of the facility is now occupied. It offers the best conditions for a further expansion of research activities, particularly in the field of tribological coatings. Integration of the Institute for Surface Engineering (IOT) of the Technical University of Braunschweig makes an even more intensive exchange possible between the two institutes and magnifies the synergistic effects of university research into fundamentals and the industry-related research typical of the Fraunhofer.

We have been left more or less unscathed by the economic crisis. Not only in our business fields but also in our areas of competence we have actually broadened our basis by the creation of a new Aerospace business field and the establishment of an independent Simulation group, reflecting the increasing importance attached to these areas. Although we are now employing considerably more staff in comparison with previous years we have still managed to almost break even. At 4.5 million euros revenues from industry reached an all-time high. Having set itself challenging goals, not only scientifically and technically but also economically, the Fraunhofer IST will continue on its successful course in 2010 as well.

1 *Convention Center Kwa Maritane, Pilanesberg, South Africa.*
2 *Cooperation with Gwangwon Province, South Korea.*

FROM THE BOARD OF TRUSTEES

As a member of the boards of trustees of the various Fraunhofer institutes in Lower Saxony I have become very familiar with the structure of the society. I particularly value the successful interplay between the head office in Munich and the various institutes, characterized as it is by a successful definition of scientific priorities, economic management and a high degree of autonomy of the institutes. The Fraunhofer-Gesellschaft has thus succeeded in achieving an outstanding profile as a research organization which operates close to industry and as a service provider to the commercial sector. Convinced by the Fraunhofer model, Lower Saxony has committed itself heavily to expanding the three institutes in the state and in recent years has also succeeded in setting up seven Fraunhofer project groups in the universities.

The Fraunhofer Institute for Surface Engineering and Thin Films in Braunschweig has a great importance in the research landscape of Lower Saxony. It is linked by the professors Günter Bräuer and Claus-Peter Klages to the Institute for Surface Engineering of the Technical University of Braunschweig and covers a wide spectrum extending from basic research to contract research. Students are included at an early stage in industry projects and come to regard the Fraunhofer-Gesellschaft as an employer of interest. Particularly welcome has been the collaboration between the Fraunhofer IST and other research institutes in Lower Saxony. In the region it is closely networked in joint projects with the German Aerospace Center (DLR) and the Federal Institute of Physics and Metrology (PTB). But in a more extended arena there are also possibilities for collaboration – for example, in the field of thin-film photovoltaics – with the Hamelin Institute for Solar Energy Research and the EWE research center in Oldenburg. It is a great benefit to the economy and scientific community in Lower Saxony that the network of Competence INPLAS has been able to add a »Lower Saxony Innovation Network for Plasma Technology«. With a new building jointly financed on the state and federal levels, the course is set for further growth and successful activity on the part of the Fraunhofer IST. I am certain that the competence we have here in applied plasma technology will become more visible within Germany and also throughout Europe.

Dr. Hans Schroeder

1 *Dr. Hans Schroeder, Ministry for Science and Culture of Lower Saxony, member of the board of trustees.*

BOARD OF TRUSTEES

Chairman
Dipl.-Ing. R. Lacher
Singulus Technologies AG
Chairman until June 30th 2009

Deputy
Prof. Dr. H. Oechsner
IFOS - Institut für Oberflächen- und Schichtanalytik GmbH an der TU Kaiserslautern

Dr. P. Lichtenauer
Plasmawerk Hamburg GmbH
Chairman since July 1th 2009

Dipl.-Ing. E. Dietrich
Frankfurt

Dr. U. Engel
Hagnau

Dr. R. Grün
PlaTeG GmbH

Prof. Dr.-Ing. Dr. h. c. J. Hesselbach
Präsident der Technischen Universität Braunschweig

Dr. H. Hilgers
Mainz

RD A. Kletschke
Bundesministerium für Bildung und Forschung

Prof. Dr. A. Möbius
Cookson Electronics Enthone GmbH

MinRat Dr. H. Schroeder
Niedersächsisches Ministerium für Wissenschaft und Kultur

Dr.-Ing. W. Steinbach
Burgmann Industries GmbH & Co. KG

Dr.-Ing. M. Steinhorst
DOC - Dortmunder OberfächenCentrum GmbH

Dr. G. J. van der Kolk
IonBond Netherlands BV

1 *The new view of Fraunhofer IST.*
2 *Dipl.-Ing. Roland Lacher.*

A new chairman for the board of trustees

A meeting of the board of trustees of the Fraunhofer IST on May 26th 2009 saw the departure into retirement of its long-serving chairman, Dipl.-Ing. Roland Lacher. Mr. Lacher headed the institute's board of trustees following its move from Hamburg to Braunschweig in 1994. As CEO of Singulus Technologies AG, the global market leader for CD, DVD and Blu-ray disk production line systems, Roland Lacher can be counted amongst Germany's top managers. Previous to this he had for several years been head of Leybold Systems GmbH in Hanau. The Fraunhofer IST has a lot to thank him for. For over 15 years he supervised with extraordinary dedication the development of the institute. His extensive experience as a manager of companies in the coating industry, his analytic way of thinking and his constructive, well-intentioned criticism have often helped us in choosing the right path to take. We wish Roland Lacher every happiness in his well-earned retirement.

As his successor, the board of trustees has selected Dr. Philipp Lichtenauer, CEO of Plasmawerk Hamburg GmbH. This company is concerned with atmospheric plasma technology, a technique used for surface modification, which is becoming increasingly important to the Fraunhofer IST as well. Dr. Lichtenauer has only been a board member for a few years but has already during this brief period of time given us outstanding support. We look forward to continuing to work together.

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 film deposition, coating 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
- Tools
- Energy, Glass and Facade
- Optics, Information and Communications
- Life Science and Ecology

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

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

On an office and laboratory area of more than 4000 square meters 97 tenured employees are addressing a variety of research projects. Its capabilities are supplemented by the competencies of other institutes from the »Fraunhofer Surface Technology and Photonics Alliance«. Many projects are supported by funding through the state (Land) Niedersachsen (Lower Saxony), the federal government, the European Union, and other institutions.

Goals

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

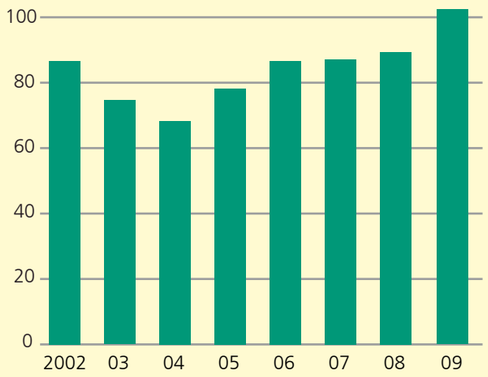
Talent management
In the period under review the Fraunhofer IST employed 106 employees, as compared with 97 in the previous year. More than half of these are scientists, engineers or doctoral students. Our research work is also supported by numerous graduands and student assistants as well as technical and commercial staff. In the year under review training opportunities in the vocational fields of physics and information technology were taken up by five young employees.

Operating budget
IIn 2009 the institute's operating budget increased to 12.3 million euros, which represented a growth of a good 20% over the previous year. Of this growth 40% was in personnel costs and 60% in material costs.

Earnings structure
In revenues from industry it was possible to increase the previous year's 4.3 million euros to 4.4 million euros. An increase was also recorded in public-sector revenues. Worth mentioning here is another increase in EU revenues in comparison with the previous year.

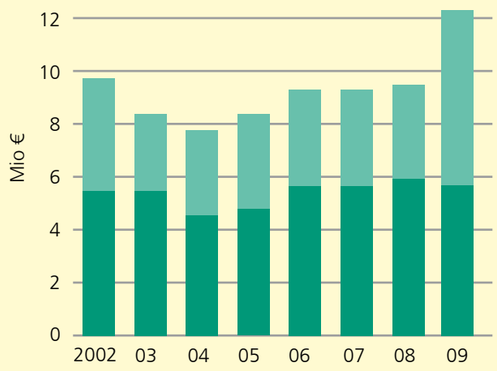
Investments
In the year under review 100% more funds were provided for investments than in the previous year. Of the 2.55 million euros 28% was dispensed on normal investments and 67% on strategic investments. Project investments made up 5%.

Employees.



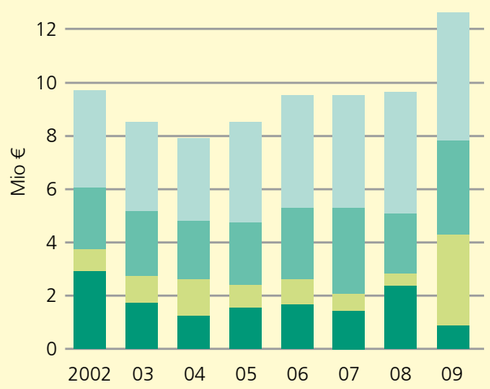
Employees

Personnel and material costs.



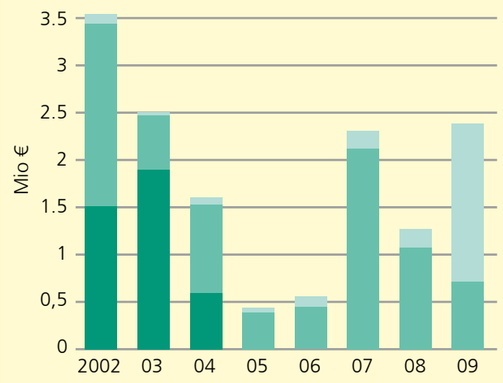
Cost of materials
Personnel costs

Revenue.



Earnings realized in the industrial sector
Earnings realized in the public sector
Internal programs
Basic financing

Capital expenditure.



Project investment
Normal and strategic investments
Initial Equipment

YOUR CONTACT PERSON

The Fraunhofer Institute for Surface Engineering and Thin Films (IST) was founded in 1990 and is your contact point for all matters concerning thin film technology. The Fraunhofer IST comprises the management and marketing departments and seven technical departments:

- Transfer Center Tribology
- New Tribological Coatings
- Diamond Technology
- Optical and Electrical Coatings
  - Optical Coatings
  - Sensoric Functional Coatings
  - Micro and Sensor Technologies
- Large Area Coatings
  - Magnetron Sputtering
  - Hollow Cathode Processes
  - Simulation
- Atmospheric Pressure Processes
  - Electroplating
  - Atmospheric Pressure Plasma Processes
- Characterization of Materials and Layers

ORGANIZATIONAL CHART

DIRECTOR

Prof. Dr. Günter Bräuer
Phone +49 531 2155-500
guenter.braeuer@ist.fraunhofer.de

DEPUTY

Dipl.-Ing. Wolfgang Diehl
Phone +49 531 2155-515
wolfgang.diehl@ist.fraunhofer.de

ADMINISTRATION

Dipl.-Kaufmann Michael Kaczmarek
Phone +49 531 2155-220 | michael.kaczmarek@wki.fraunhofer.de

MARKETING AND COMMUNICATIONS

Dr. Simone Kondruweit
Phone +49 531 2155-535 | simone.kondruweit@ist.fraunhofer.de

TRANSFER CENTER TRIBOLOGY Dr.-Ing. Jochen Brand

Phone +49 531 2155-600 | jochen.brand@ist.fraunhofer.de

Prototypes and small volume production | Device conceptions | Plasma diffusion | Cleaning technology

DORTMUNDER OBERFLÄCHENCENTER

Dr.-Ing. Jochen Brand
Phone +49 531 2155-600 | jochen.brand@ist.fraunhofer.de

NEW TRIBOLOGICAL COATINGS Dr. Klaus Bewilogua

Phone +49 531 2155-642 | klaus.bewilogua@ist.fraunhofer.de

Carbon-based coatings (DLC) | Hard and superhard coatings | Wetting behavior | Tool coating (forming, cutting, chipping) | PVD and PACVD processes

DIAMOND TECHNOLOGY Dr. Lothar Schäfer

Phone +49 531 2155-520 | lothar.schaefer@ist.fraunhofer.de

Tools and components | Diamond electrodes for electrochemical applications | Diamond coated ceramics DiaCer® | Hot-filament CVD processes | Large-area hot-filament CVD systems | Hot-filament CVD of Silicon-based coatings

OPTICAL AND ELECTRICAL COATINGS Dr. Michael Vergöhl

Phone +49 531 2155-640 | michael.vergoehl@ist.fraunhofer.de

OPTICAL COATINGS

Dr. Michael Vergöhl
Phone +49 531 2155-640 | michael.vergoehl@ist.fraunhofer.de

Optical and electrical coatings | Process engineering | Materials engineering

SENSORIC FUNCTIONAL COATINGS

Dr. Ralf Bandorf
Phone +49 531 2155-602 | ralf.bandorf@ist.fraunhofer.de

Multifunctional coatings with sensors | High Power Impulse Magnetron Sputtering (HiPIMS) | Microtribology

MICRO AND SENSOR TECHNOLOGIES

Dipl.-Ing. Saskia Biehl
Phone +49 531 2155-604 | saskia.biehl@ist.fraunhofer.de

Thin film sensors | Microstructuring 2-D und 3-D | Adaptronic systems

LARGE AREA COATINGS Dr. Bernd Szyszka

Telephone +49 531 2155-641 | bernd.szyszka@ist.fraunhofer.de

MAGNETRON SPUTTERING

Dr. Bernd Szyszka
Phone +49 531 2155-641 | bernd.szyszka@ist.fraunhofer.de

Large area electronics | Process technology | Transparent and conductive coatings | Process simulation

HOLLOW CATHODE PROCESSES

Dr. Thomas Jung
Phone +49 531 2155-616 | thomas.jung@ist.fraunhofer.de

Plasma sources | High rate processes | Oxide and carbon films | Erosion protection coatings

SIMULATION

Dr. Andreas Pflug
Phone +49 531 2155-629 | andreas.pflug@ist.fraunhofer.de

Plant and process development | Simulation of coating layer properties | Virtuel process analysis

ATMOSPHERIC PRESSURE PROCESS Prof. Dr. Claus-Peter Klages

Phone +49 531 2155-510 | claus-peter.klages@ist.fraunhofer.de

ATMOSPHERIC PRESSURE PLASMA PROCESSES

Dr. Michael Thomas
Phone +49 531 2155-525 | michael.thomas@ist.fraunhofer.de

Biofunctional surfaces | Microplasma | Low-temperature bonding | Surface functionalization and coating

ELECTROPLATING

Dr. Andreas Dietz
Phone +49 531 2155-646 | andreas.dietz@ist.fraunhofer.de

Composites | Light metal coatings | Process development | Plating on plastics

CHARACTERIZATION OF MATERIALS Dr. Peter Willich

Phone +49 531 2155-570 | peter.willich@ist.fraunhofer.de

ANALYSIS

Dr. Peter Willich
Phone +49 531 2155-570 | peter.willich@ist.fraunhofer.de

Micro and surface analysis | Microscopy and structure analysis | Industrial services

QUALITY CONTROL

Dr. Peter Willich
Phone +49 531 2155-570 | peter.willich@ist.fraunhofer.de

Testing of coatings and materials | Development of testing procedures | Industrial services

THE SCOPE OF RESEARCH AND SERVICES

Analysis and Quality Control

- High resolution scanning electron microscope with energy dispersive x-ray analysis (EDX)
- Electron Probe Microanalysis (EPMA)
- Secondary-ion mass spectrometer
- X-ray diffraction equipment for structural analysis and for reflectivity measurement
- Scanning tunnel and atomic force microscope
- Micro indenter and nano indenter for hardness and young's modulus determination of coatings
- Profilometer
- Automated, non-destructive measurement of film thickness
- Confocal scanning laser microscope
- Testing equipment for friction, wear and coating adhesion
- IR and UV-VIS spectrometer
- UV-VIS-NIR spectroscopic ellipsometer
- Equipment for surface energy measurement
- Equipment for corrosion and climatic testing according DIN EN
- Measurement equipment for electrical and magnetical coating properties
- VSM measuring station for magnetic films
- Systems for testing of electro chemical wastewater treatment
- Equipment and methods for the characterization of the photocatalytical activity

Special Equipment

- a-C:H:Me, a-C:H, hard coating production plant (up to 3 m^3 volume)
- Coating facilities incorporating magnetron and RF diode sputtering
- Coating systems for hollow cathode processes
- Plasma-activated CVD (PACVD) units
- Plants for plasma diffusion
- Hot-filament-CVD units for diamond coatings and silicon-based coatings (up to 50 × 100 cm^2)
- In-line coating facility for large-surface optical functional coatings (up to 60 × 100 cm^2)
- Equipment for electroplating processes
- Photolithographic equipment (40 m^2 clean room)
- 15-stage cleaning unit for surface cleaning on aqueous basis
- Laser for 3D microstructuring
- Atmospheric pressure plasma systems for coating and functionalization from microstructures up to large areas (40 × 100 cm^2)
- Industrial scale HiPIMS technology
- Two clean rooms with six coating units

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
- Plasma cleaning
- Plasma activation
- Plasma functionalisation
- Wet-chemical etching pretreatment
- Particle beam

COATING

We develop processes and coating systems

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

- Development of coatings
- Process technology, including process diagnostics, modeling and control
- Simulation of layer systems and processes

TESTING/CHARACTERIZATION

We ensure quality

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

- Test methods and product specific quality control methods, e.g. wear measurement on arbitrary parts
- Ply adhesion test methods
- Mechanical, chemical, micromorphological, and structural characterization
- Optical and electrical characterization
- Rapid and confidential failure analysis

APPLICATION

We transfer research results to 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

MECHANICAL AND AUTOMOTIVE ENGINEERING

The business area »Mechanical and Automotive Engineering« has been developing coating systems and surface technologies that reduce friction, protect against wear and corrosion and that are optimized according to the application. As well as adapting the coating for special applications and the development of new layer systems, developing and transposing the product and production-adapted coating processes has been in the foreground. This year successful work was carried out in the following areas:

- Saving resources and reducing CO_2 emissions in internal combustion engines
- Ultraviolet protective coatings for polycarbonate
- Strain measurement at high temperatures

Customers for this business area include not only coating manufacturers but also users in all areas of engineering from automotive to aerospace.

CONTACT

Dr.-Ing. Jochen Brand
Phone +49 531 2155-600
jochen.brand@ist.fraunhofer.de

Dipl.-Ing. Carola Brand
Phone +49 531 2155-574
carola.brand@ist.fraunhofer.de

SAVING RESOURCES AND REDUCING CO_2-EMISSIONS IN INTERNAL COMBUSTION ENGINES

Growing environmental awareness and a greater scarcity of fossil fuels coupled with rising mobility - against this background, the conservation and saving of resources and also the reduction of CO_2 emissions are important themes in the automotive industry which call for the development and deployment of new generations of engines which use energy more efficiently.

The aim is less friction and wear

In Triboman, a Fraunhofer research project aimed at reducing friction-related losses in the internal combustion engine, an integral approach is pursued. What this means is that not only materials but also processes for production, precision machining, structuring and coating are being developed which, by anticipating the running-in process and by the deliberate creation of tribologically effective edge zones – even during manufacture of the components – make it possible for friction and wear in internal combustion engines to be significantly and permanently reduced.

Interdisciplinary collaboration

The project partners (Fraunhofer IFAM, IWU, IPT, IST and IWM) supplement each other as far as the areas of competence of the various institutes are concerned: materials engineering, foundry technology, coating, production engineering, and tribology. This makes it possible for optimized materials and manufacturing processes to be developed holistically and with a technological orientation.

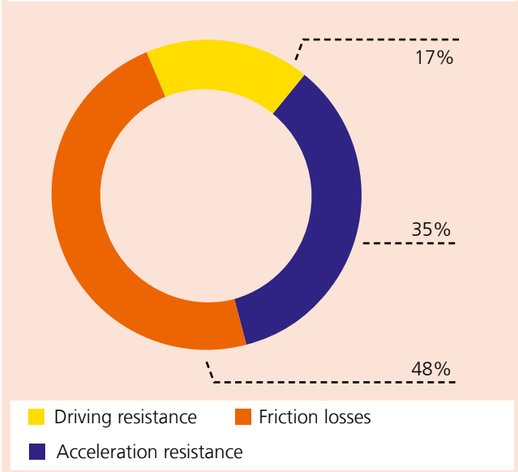
The Triboman project

Since a major portion of losses in the internal combustion engine is caused by friction in the area of those tribologically critical components the piston unit, crankshaft and valve train, it is precisely these components which are investigated in the Triboman project. At the Fraunhofer Institute for Applied Materials Research IFAM in Bremen, cast aluminum alloys with a friction-optimized structure and improved mechanical properties are being developed for cylinder crankcases. The Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz is working on the development of suitable finishing processes for use in the production of high-precision engine components with a defined surface microgeometry. In Aachen at the Fraunhofer Institute for Production Technology IPT work is in progress on the development of optimized contact surfaces by means of laser remelting and laser ablation. The development, adaptation and optimization of wear-resistant, hard and friction-reducing DLC and hard-material coating systems is one of the tasks of the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig. These coating systems make it possible to exert a positive influence on wear conditioning and on oil and fuel consumption. The life expectancy and loadability of the engine components can thus be increased significantly. The optimized components are tested by high-resolution radionuclide metrology in a piston ring / cylinder simulator and engine test stand at the Fraunhofer Institute for the Mechanics of Materials IWM in Freiburg.

Outlook

Being able to maintain and even extend the global lead of the German automotive industry also in the years ahead requires products and technologies which meet demands relating to energy and resource efficiency. By its research work on conserving resources by reducing losses, by cutting the emission of pollutants, by lowering fuel and oil consumption and by using more efficient manufacturing processes, the Triboman project is putting in place the essential requirements for successful future collaboration with the automotive industry.

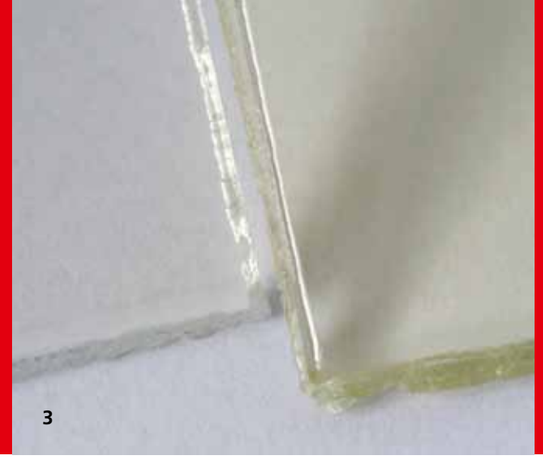
Energy consumption of an automobile.



CONTACT

Marko Petrik
Phone +49 531 2155-509
marko.petrik@ist.fraunhofer.de

Dr.-Ing. Jochen Brand
Phone +49 531 2155-600
jochen.brand@ist.fraunhofer.de



ULTRAVIOLET PROTECTIVE COATINGS FOR POLYCARBONATE

During the year under review the Fraunhofer IST succeeded in taking a great step forward in the development of thin ultraviolet protective coatings for polycarbonates. Composite coatings of zinc oxide and siloxane ensure good UV protection while at the same time offering high mechanical stability and flexibility. For this a new kind of hybrid coating process based on hollow cathode glow discharge has been used.

Polycarbonate: a versatile material

Against a background of lightweight construction and new design requirements in automotive engineering, polycarbonate is becoming increasingly important for glazing and lighting. Its low density, high transparency, ease of processing by injection molding and its fracture toughness make it an attractive material. Polycarbonate surfaces are however also very sensitive to scratching and degrade under intensive UV irradiation, thereby in the case of scratch resistant coatings impairing its service life. For this reason intensive research is in progress at the Fraunhofer IST into UV-protection solutions for polycarbonate. Great progress has been made by the development of PVD/PECVD hybrid coatings based on zinc oxide and siloxane. Even at low coating thicknesses from 400 to 1500 nanometers the inorganic zinc oxide component delivers an effective ultraviolet protection by absorption while a stabilizing, functional matrix is provided by the siloxane component produced simultaneously by plasma polymerization.

The production process

The UV protective coatings were produced by reactive gas-flow sputtering. Here an intensive hollow cathode glow discharge (figure 4) provides the sputtering of the zinc on the one hand while also simultaneously activating the incoming oxygen and silane molecules. The Zn-Si ratio and thus the photonic band gap can be set exactly by varying the reactive gas flow. Not only mixed coatings but also multilayer alternating coatings can be deposited with no difficulty. In the sputtering method presented here there is hardly any thermal load on the polycarbonate substrate. This dynamic process can coat to a width of about 20 cm but can be scaled up easily to greater widths.

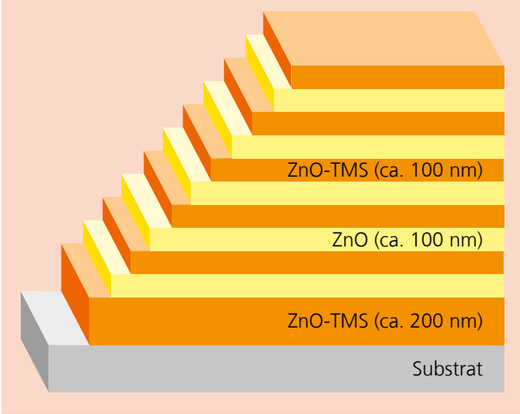
Properties of the UV protective coatings

The position and gradient of the absorption edge can be specifically adjusted by the process parameters at a wavelength of about 380 nm. The protected polycarbonate substrates were tested for up to 500 hours by exposure to ultraviolet light without any degradation being observed (figure 1). The siloxane component gives the coating system not only the desired band edge but also greater resilience and in addition probably also has good barrier properties. In strain tests and in the water boiling test, the multiple layer arrangement of the layers (see diagram) proved particularly advantageous.

Summary

The zinc oxide-siloxane composite coating developed at the Fraunhofer IST meets most of the various requirements applicable to an ultraviolet protective coating on polycarbonate. It provides effective protection of the polycarbonate surface against ultraviolet light, is highly transparent and adapts well to the plastic as far as mechanical resilience is concerned. The process can be scaled up to the industrial scale and can be combined readily with other vacuum processes to create a scratchproofing function, for example.

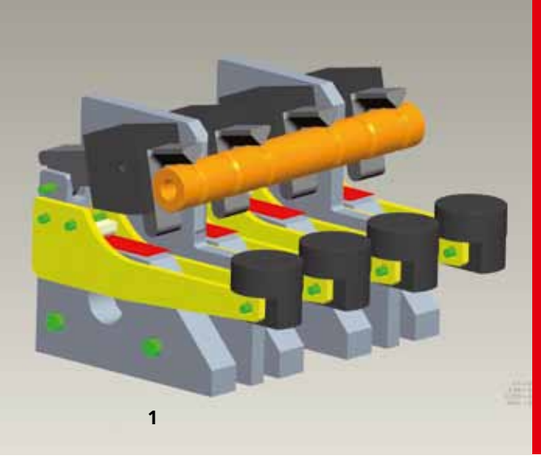
Schematic build-up of a protection system with multiple thin ZnO layers for UV absorption.

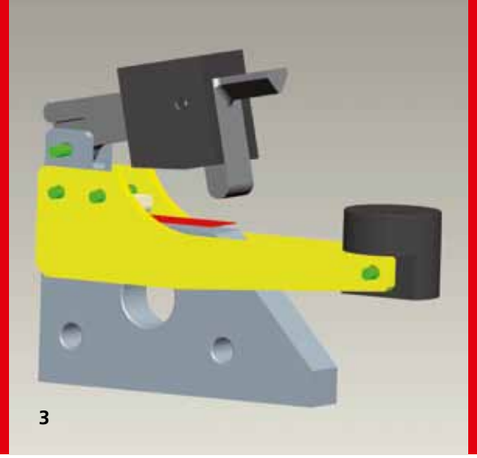


1 *Left: polycarbonate coated and without UV exposure; right: with coating after 500 h UV exposure.*
2 *Without coating and without UV exposure.*
3 *Left: protected with coated quartz glass after 500 h UV exposure; right: unprotected after 500 h UV exposure.*
4 *Linear gas flow sputtering source as basis for the PVD/PECVD hybrid process. The source shown supports a coating width of about 20 cm.*

CONTACT

Dr. Kai Ortner
Phone +49 531 2155-637
kai.ortner@ist.fraunhofer.de





STRAIN MEASUREMENT AT HIGH TEMPERATURES

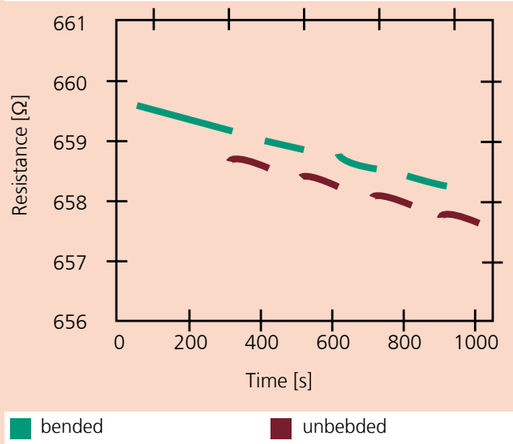
Conventional strain gauges can only be used within a relatively small temperature range. For applications on extremely hot surfaces, for example exhaust systems, engine blocks or drive units, sensor systems are required which are heat-resistant to above 1000 °C and widely independent from temperature.

Sputtered strain gauges for high operating temperatures
Strain measurements taken under service conditions are indispensable today in quality assurance for components which are exposed to high operating temperatures. For temperatures up to 1000 °C, weldable strain gauges in a metal shell are frequently used. For special applications it is also possible to glue strain gauges with or without ceramic mounts by using the corresponding adhesives. Sputtered strain gauges which are stable at high temperatures are currently being developed at the Fraunhofer IST; they are deposited directly on the work pieces and permit a high degree of measurement accuracy.

Characterization of strain gauges
The most important characteristic in developing materials for sputtered strain gauges is the change in electrical resistance due to strain and temperature. The aim is to secure the highest possible strain sensitivity (gauge factor) - in other words, a large change in resistance due to strain. At the same time the electrical resistance should be largely independent of the ambient temperature. If the temperature coefficient of resistance (TCR) is within the range of a few 100 ppm / K, the residual temperature dependence can be compensated using a bridge circuit. A suitable measurement system for characterizing the high-temperature strain gauges has been set up at the Fraunhofer IST. It is based on a high-temperature oven for operating temperatures up to 1300 °C.

An automated measurement unit is built into this oven for measuring the resistance of four strain gauge samples simultaneously. To determine the gauge factor the strain gauge samples are bended to a fixed radius of 750 mm, and afterwards the strain is released and the samples are unbended. As the samples cool down the temperature coefficient of electrical resistance is also measured.

Resistivity measurement using the example of a Pt-ITO layer (50 at % Pt) at 400 °C in bended and unbended state. Gauge factor: GF =2.9.



Design of the measurement equipment
Due to the high operating temperatures involved, the components of the measurement unit have been made from ceramic materials. Silicon carbide was selected for parts under mechanical stress and aluminum oxide for parts providing electrical isolation. The weights required for contacting and stretching the test substrates were made from zirconium oxide since this ceramic material has a particularly high density. The design had to take into account not only the specific constraints in producing ceramic components but also the thermal expansion over a large temperature range, from room temperature to 1300 °C. To ensure stable four-point resistance measurement, measurement leads of a largely corrosion-resistant nickel alloy were used.

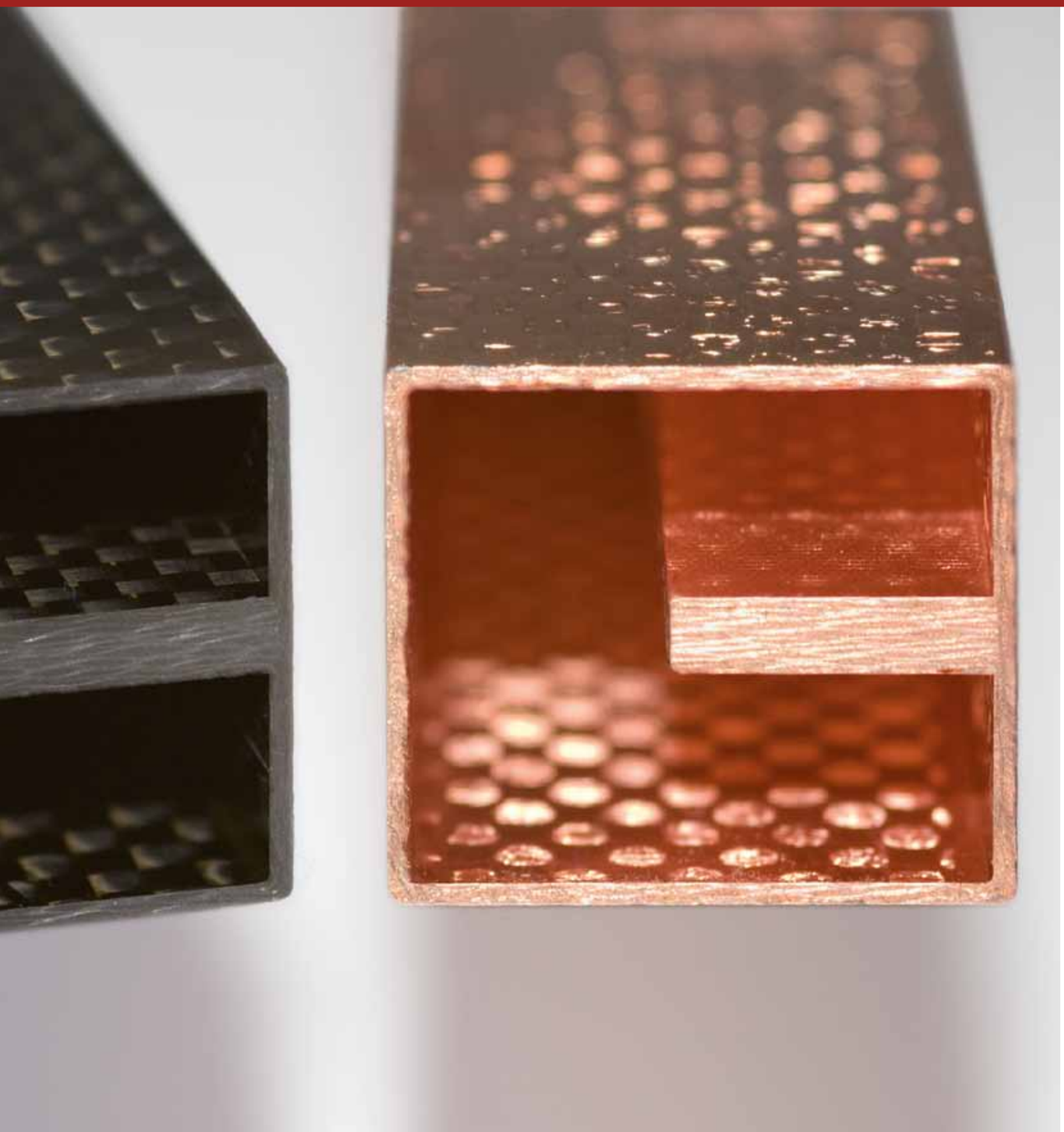
Strain measurements at high-temperatures
The first tests indicated that the measurement structure is stable up to 1000 °C. The gauge factor and TCR have already been determined at temperatures up to 800 °C for different strain gauge samples. In the case of resistance measurement, even after several high-temperature cycles there were only small deviations (<5 %) between measurements in the high-temperature oven and measurements at a second measurement setup designed for room-temperature. The graph to the left shows resistance values for a Pt-ITO layer at 400 °C in the bended and unbended states. Despite the superposed drift the strain sensitivity could be determined as a gauge factor of 2.9.

1 Design drawing of four coupled measuring stations for gauge factor and TCR determination.
2 View into the oven with the measuring stations installed.
3 Detail drawing of an individual measuring station.
4 View of the high-temperature oven with control unit for stressing the strain gauge samples.

CONTACT

Dipl. Phys. Ulrike Heckmann
Phone +49 531 2155-581
ulrike.heckmann@ist.fraunhofer.de

Dr. Ralf Bandorf
Phone +49 531 2155-602
ralf.bandorf@ist.fraunhofer.de



AEROSPACE

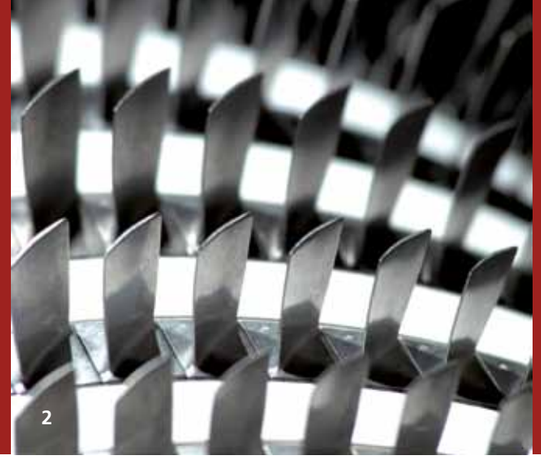
In the newly created Aerospace business field, processes and coatings are developed for special materials, such as lightweight materials, for which in many cases no established coating methods yet exist. The principle areas of application are wear and corrosion protection in aviation as well as optical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

- Coating of high-performance materials for aerospace applications
- Coatings on titanium components used in aerospace
- Detection of bearing damage by integrated thin-film sensor system

Customers include companies in the aerospace industry and their suppliers.

CONTACT

Dr.-Ing. Andreas Dietz
Phone +49 531 2155-646
andreas.dietz@ist.fraunhofer.de



COATING OF HIGH-PERFORMANCE MATERIALS FOR AEROSPACE APPLICATIONS

Aerospace engineering is to be counted amongst cutting-edge German technologies. What weight saving is in aircraft design, in the field of space flight means satisfying very demanding requirements: extreme cold, very rapidly changing temperatures and enormous mechanical loads call for new materials and innovative processes. In its new aerospace business field the Fraunhofer IST is for this reason tackling the coating of high-performance materials.

Coatings for aviation

There is one dominant topic in aircraft construction: weight reduction. This is necessary for reducing aircraft fuel consumption and thus CO_2 emissions released into the sky. If steel and aluminum were once the dominant materials used in the aircraft, they are now being increasingly replaced by carbon-fiber-reinforced plastic (CFRP) – an extremely lightweight and mechanically durable material. Lightweight metals such as magnesium or titanium are also waiting for their major deployment in aircraft. Until now the use of magnesium has been inhibited by three factors: deficient mechanical fatigue strength, the fire hazard represented by magnesium dust, and high susceptibility to corrosion. As part of the EU's IDEA project, coating methods have been developed at the Fraunhofer IST with a view to protecting new and mechanically improved magnesium alloys from corrosion.

These new kinds of thin-film sensors are to offer lower maintenance requirements and permanent condition monitoring. More and more complex control units, which today work increasingly on the basis of electrical or electromechanical systems and which replace electrohydraulic actuators, require a constant and dependable monitoring of their function.

Another way of saving on fuel is to optimize the aircraft turbines. Although a turbine operates more efficiently at a higher combustion temperature of the fuel, this does mean that certain components are subject to very high thermal stress. Thermal insulation coatings of yttrium-stabilized zirconium oxide (YSZ) help to regulate the heat balance. The Fraunhofer IST is developing new kinds of processes by which a reduction in the cost of depositing YSZ coatings becomes possible. Furthermore, components in the air stream are damaged - such as, for example, erosive attack on compressors during flight - thereby lowering the efficiency of the engine. A joint project with partners from industry has thus set its sights on making improvements by using new kinds of coating systems.

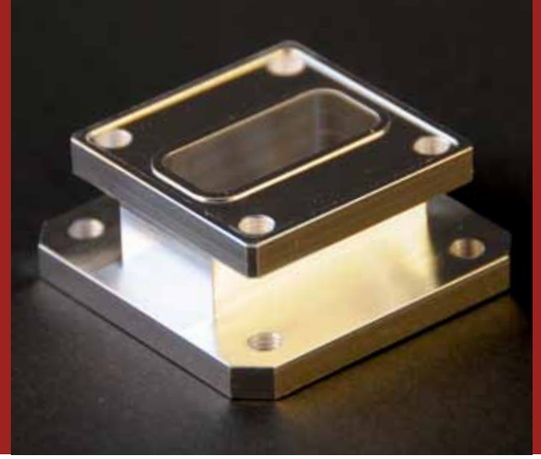
Coatings for space exploration

In aerospace a major role is played not just by weight, which has a direct effect on the »payload« which is economically available, but also by mechanical requirements. Extreme mechanical loads occur particularly when a rocket is launched. Some operational functions are only needed once but then with absolute dependability as their failure could mean the failure of the entire space mission. One example is the deployment of the solar sail for the power supply. Failures as a rule have catastrophic consequences and cannot be corrected in a rocket in space. This is where high-performance materials are required which can meet these demands. As is also the case in aviation, carbon-fiber-reinforced plastics (CFRPs) play a dominant role in space travel, with titanium also being increasingly used. For the ESA project SENTINEL, a satellite program for environmental monitoring, the Fraunhofer IST in collaboration with a major German aerospace company has developed a process for metallizing CFRP antennae. The technical challenge here was an absolutely flawless galvanic coating on the inner surface of the CFRP waveguide. A galvanic metallization of titanium is being developed for the ESA project BepiColombo, in which a satellite is to be sent to Mercury. What both projects have in common is that these components must function properly under extreme thermal conditions. Adhesion of the CFRP metallization must be assured within the temperature range from -200 °C to +100 °C while in the case of the titanium components temperature changes as great as between -200 °C and +400 °C are required. Technical challenges of this kind can only be solved by achieving an optimal mutual adjustment of the various coating techniques and materials. Today a large number of processes are still in the high price range but as they become more widespread and costs fall, they will also find everyday applications as well.

1 Computergrafik von Satelliten für das europäische Navigationssystem Galileo.
2 Verdichterschaufeln von Flugtriebwerken können durch angesaugte Fremdpartikel beschädigt werden.

CONTACT

Dr. Andreas Dietz
Phone +49 531 2155-646
andreas.dietz@ist.fraunhofer.de



COATINGS ON TITANIUM COMPONENTS USED IN AEROSPACE

Achieving a firmly adhesive coating on titanium components to be used in space satellites is a great challenge due to the high temperature fluctuations which occur. Conventional methods for carrying out extremely adhesive metallization fail on account of the tendency of all valve metals to passivate. A solution to this problem is offered by a combination of different coating methods.

Reliable functioning under extreme conditions

Due to their low specific weight and high strength, titanium and in particular the titanium alloy Ti6Al4V are used in many cases in satellites. On making contact with air, titanium has a tendency to passivate very quickly due to oxidation, with the result that it is often not possible to obtain good adhesion of coatings to the surface. In addition, high temperature fluctuations and different coefficients of expansion can cause detachments to occur between coating and component which have a massive effect on the functionality of the component. For the European Space Agency's BepiColombo mission to Mercury, the Fraunhofer IST has secured a considerable boost in the electrical surface conductivity of waveguide antennas made of titanium by applying a thin highly electrically conductive coating of silver. This silver coating serves as an optical function with high reflectivity. Functionality must not be impaired either under the extreme temperatures which prevail in space of -200 °C to +400 °C or by aggressive substances in the atmosphere of Mercury, such as sulfur, for example.

Combining different methods

It is more difficult to coat titanium and other so-called valve metals than, for example, steel or copper. For this reason conventional galvanic metallization is preceded by a step of activation by liquids containing fluoride in order to remove the thin layer of oxide. Purging processes are essential between activation and the galvanic metallization which follows and there is a risk of repassivation. At the Fraunhofer IST different coating methods have therefore been combined. To reduce the risk of repassivation, the components were treated in a vacuum chamber after an initial precleaning step. The thin passive layer was removed by plasma etching. The layer of titanium oxide was removed by bombarding the surface with high-energy argon ions and a chemically pure, highly active titanium surface was the result. In a second step a thin layer of copper about 1 µm thick was sputtered onto the surface as a bonding agent. The parts were then given further treatment at atmospheric pressure in a wet-chemical process step. Here a thin first layer of galvanically applied nickel acts as a barrier layer to prevent silver and copper from mixing by interdiffusion. The functional silver layer was then laid down on the nickel layer. Thermally stressed components were then given an additional protective coating. One special challenge here was to coat the inside of the component since the hydrodynamic conditions were usually more unfavorable for the incoming flow of the electrolytes. In addition, the screened electrical field also resulted in readily detectable measured differences in the layer distribution. This problem was solved by using specially prepared auxiliary anodes which supported the deposition process on the inner surfaces of the waveguide.

The test methods

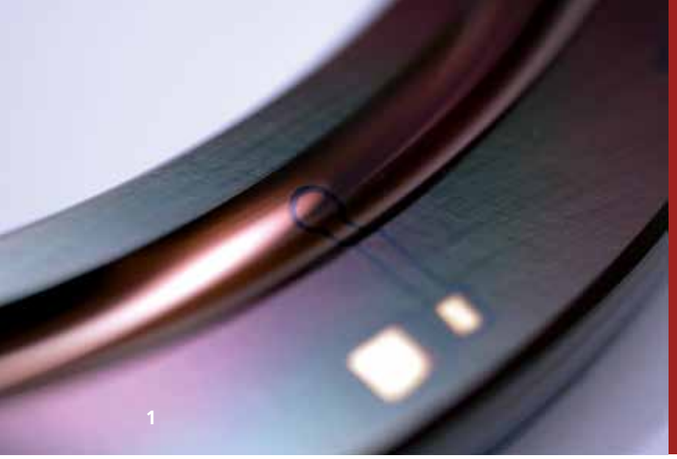
During tests with a thermal shock procedure the components were first plunged into liquid nitrogen at a temperature of -196 °C and then immediately exposed in an oven to great heat at +400 °C. The test pieces passed not only the subsequent testing of adhesive strength by means of a standardized pull test but also testing the integrity of the additional protective coating. Here the components were immersed in a solution containing sulfides without surface blackening occurring due to the formation of silver sulfide.

1 *Computer graphic of BepiColombo-probe MPO (Mercury Planetary Orbiter), investigating mercury's surface.*

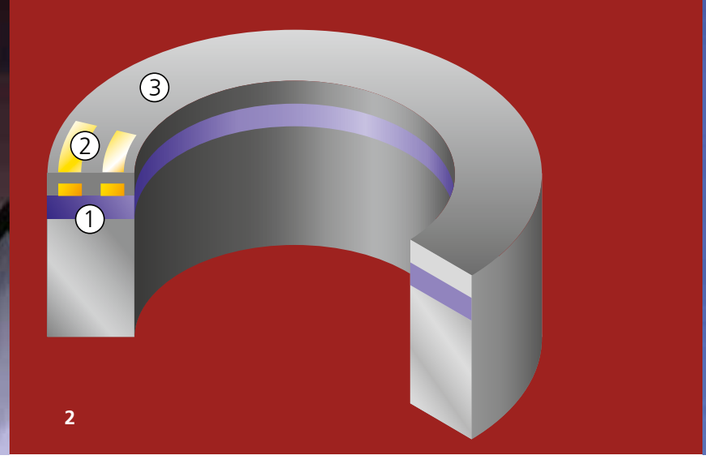
2 *Titanium waveguide, electro-silvered.*

CONTACT

Dr. Andreas Dietz
Phone +49 531 2155-646
andreas.dietz@ist.fraunhofer.de



1



2

3

DETECTION OF BEARING DAMAGE BY INTEGRATED THIN-FILM SENSOR SYSTEMS

With the aim of developing reliable sensor systems with long-term stability which can allow early detection of bearing damage in the raceway, researchers at the Fraunhofer IST installed thin-film systems on the outer shoulder of outside bearing rings and characterized them.

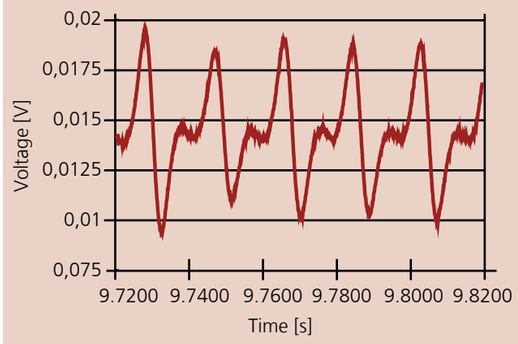
Area of application: civil aviation

In the field of flight control systems for commercial aircrafts the use of electrohydraulic actuators to operate the control surfaces is still state of the art. These fluidic systems have high maintenance requirements and are a major cost driver in flight operations. The trend not only in flight control systems in particular but also in other aircraft systems in general is therefore going increasingly towards a greater use of electrical or electromechanical systems. These electromechanical actuator systems are however considerably more complex in their design and thus more susceptible to faults. A condition monitoring system is built in so as to prevent effects occurring, ranging from a straightforward drop in efficiency to cases of irreversible jamming. The task of this system is to detect faults at the earliest possible stage and to predict the actuator's remaining service life. The thin-film sensor system described here can be an integral component of this system.

Sensor systems for increasing long-term stability

The Micro- and Sensor Technology group at the Fraunhofer IST has been involved for years in working on the integration of piezoresistive thin-film systems which in the bearing raceway directly detect the load cycles of each individual rolling element. In addition to simply measuring the load distribution in the raceway, it should also be possible to detect temperatures (figure 1). However, under the conditions prevailing directly in the main loading zone it is only a question of time and load exposure before the type of sensor coating systems in current use suffer wear. For this reason investigations were carried out at the Fraunhofer IST into a second application case whereby the coating system is positioned on the outer ring and outside the main loading zones – the goal here was to secure an increase in long-term stability. These new sensor systems were developed in collaboration with the DLR (German Aerospace Center) in Braunschweig as part of the European project entitled »More Open Electrical Technologies« (MOET) and were tested at the DLR.

Characteristic curves, recorded at the DLR in Braunschweig.



The piezoresistive thin-film system

In the first coating operation a 6 µm layer of the amorphous hydrocarbon DiaForce® is homogeneously deposited by a PACVD process on the shoulder of the outer bearing ring. In order to provide local measurement points, a number of separate chromium electrodes are created by the lift-off process with the aid of unilaterally adhesive polyimide masks cut by using a laser system. The contact areas are then coated with gold, thus producing a solderable connection. All metallizations are deposited by PVD processes. Finally, to provide electrical isolation and wear protection, a layer of SICON® is deposited over the entire surface with the exception of the contact areas (figure 2).

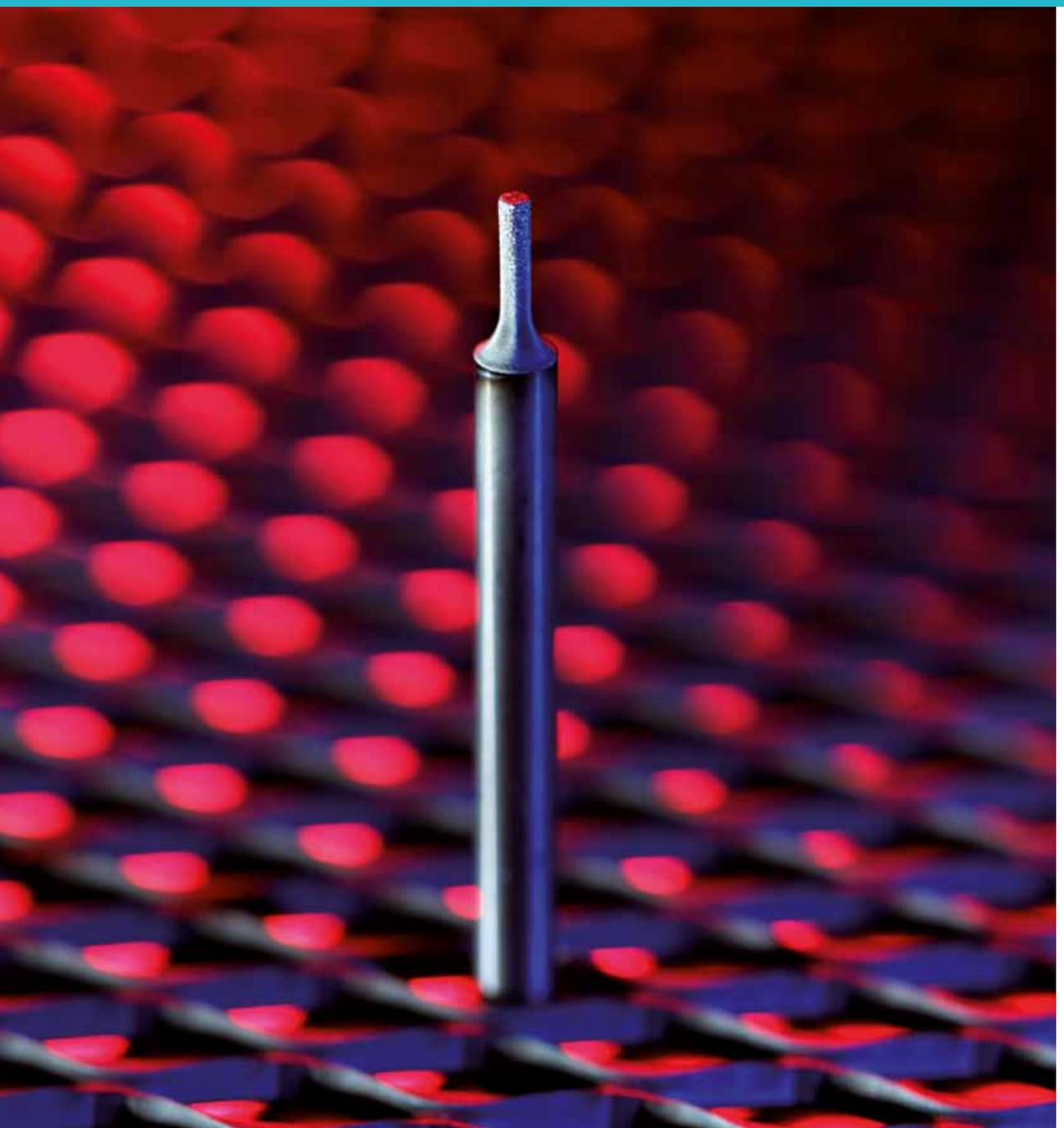
Characterization of the thin-film systems in the electromechanical actuator at the DLR Braunschweig

The bearing is rotated in a spindle drive. In these tests not only bearings with added damage but also undamaged bearings were tested. The results of these measurements show not only that bearing damage can be predicted very clearly but also that with this arrangement every single rollover can be detected in the height of a sensor structure (see diagram).

1 Axial bearing ring with sensor structured inside the raceway.
2 Schematic design of a thin film sensor system.
1 DiaForce® (d=6 µm);
2 Chrome (d=0,2 µm);
3 SiCON® (d=3 µm).
3 Outside bearing ring with thin film systems outside of the raceway.

CONTACT

Dipl.-Ing. Saskia Biehl
Phone +49 531 2155-604
saskia.biehl@ist.fraunhofer.de



TOOLS

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

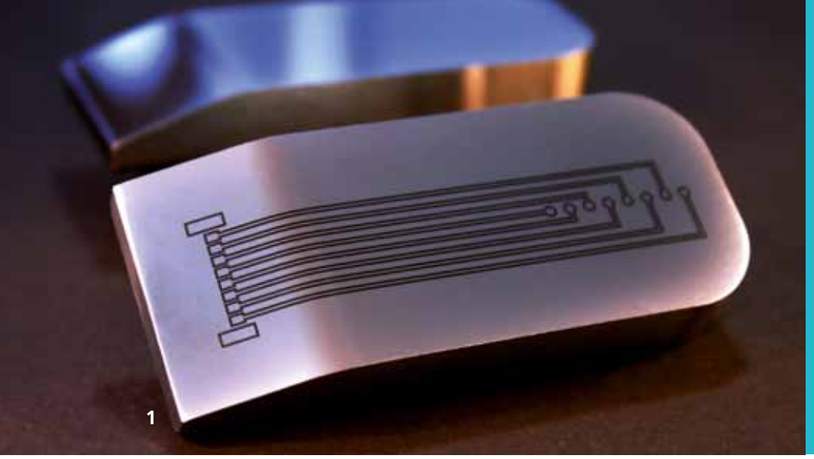
- Improvement in quality and performance in forming and cutting processes by means of anti-stick and wear-protection coatings
- Superhard coatings for cutting tools
- compeDIA® diamond abrasive coatings for precision grinding tools
- Cubic boron nitride coatings for the hard machining of steel
- Development of »intelligent tools« with integrated sensor functions
- Development of nanostructured composite coatings

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

CONTACT

Dr.-Ing. Jan Gäbler
Phone +49 531 2155-625
jan.gaebler@ist.fraunhofer.de

Dr.-Ing. Martin Keunecke
Phone +49 531 2155-652
martin.keunecke@ist.fraunhofer.de



OPTIMIZED CONTROL OF DEEP-DRAWING PROCESSES BY MEANS OF TOOLS WITH INTEGRATED THIN-FILM SENSORS

In many industrial forming processes, fluctuation in the process parameters leads to badly formed parts, tears or wrinkles. In order to improve cost-effectiveness in, for example, deep drawing and hydroforming, scientists at the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Fraunhofer Institute for Machine Tools and Forming Technology IWU have developed a new kind of sensorized thin-film system. Integrated into the tool, it comes into direct contact with the workpiece and thus follows the forming process very precisely. During the forming process the universal sensor modules supply the process data required for dynamic on-line process control.

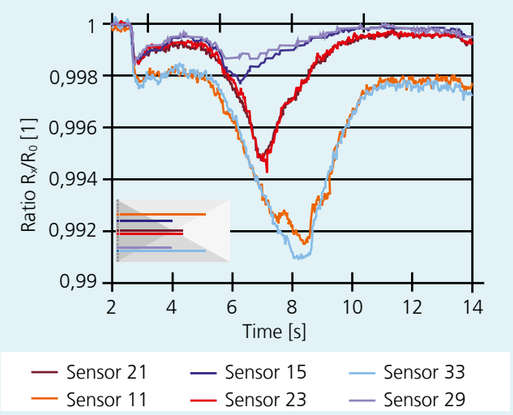
Sensorized thin-film system

The multifunctional thin-film sensor system has outstanding piezoresistive and tribological properties. This means that for the first time measurements can be taken in direct frictional contact with the workpiece. The coating system used for the sensor is built up in this way: first of all, a layer 6 µm thick of the piezoresistive hydrogenated carbon coating DiaForce® is applied evenly to the polished side of the tool insert. Onto this a layer of chromium only 100 nm thick is deposited and then structured by means of photolithography and wet-chemical etching. The contact areas of the individual sensor structures are located in the recessed part of the insert (figure 1). This makes photolithographic structuring a more complex matter. It is solved by the use of flexible masks. All of the sensor structures thus created are in contact with the sheet steel before the deep-drawing process. As forming progresses, they pass one by one out of the contact area. Thanks to a layer of SiCON® 3 µm thick, which serves as electrical insulation and wear protection, the thin-film system has long-term stability.

Behavior of the sensor system during forming

The tool insert together with the complete coating system was installed in an Erfurt EHP 1600 hydraulic press at the Fraunhofer Institute for Machine Tools and Forming Technology IWU (figure 2).

Characteristic curves of single sensor couples, arranged symmetrically on the sensor module.



The product in question was an engine mounting. At the beginning of the forming process the sheet metal lies flat on the sensor structures (figure 3). During the deep drawing process, the sheet moves gradually out of the contact areas of the individual sensor structures. The moment contact with a sensor structure is lost, a minimum level of sensor resistance is detected. At the end of the forming process the optimally shaped sheet has emerged beyond the sensor structures (figure 4). The graph shows results from these measurements.

Advantages of the integrated thin-film sensor

- Blank infeed measurement with a sensor resolution up to 100 µm
- Pressure-resistant
- Temperature-resistant
- Secures a high utilization ratio for machines
- Flexibility in use
- High sensitivity
- High process stability
- Reproducible forming processes

Outlook

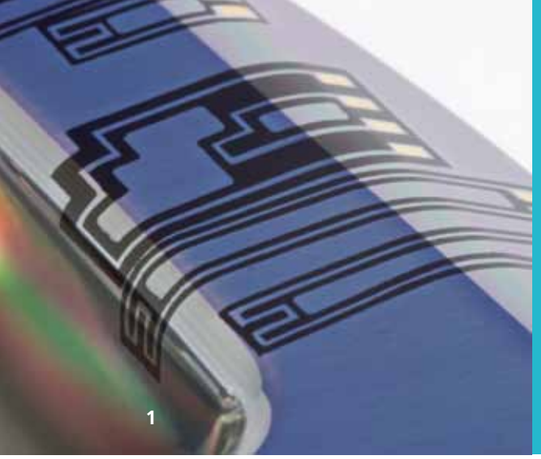
Currently this thin-film sensor system is being tested with regard to its tribological long-term stability with a view to extending its range of application beyond deep drawing to hydroforming and shear cutting.

The ORUM research and development project is subsidized with funds from the Federal Ministry of Education and Research (BMBF) within the concept of »Research for tomorrow's manufacturing«.

1 Sensor module with thin-film sensor system.
2 The Erfurt EHP 1600 hydraulic press.
3 Steel blank in position on the sensor module before deep drawing.
4 Formed steel sheet outside the sensor module after deep drawing.

CONTACT

Dipl.-Ing. Saskia Biehl
Phone +49 531 2155-604
saskia.biehl@ist.fraunhofer.de



1 *Tool with sensor structures.*
2 *Cooling phase during the hot forming process.*

PROCESS CONTROL IN HOT FORMING BY MEANS OF INTEGRATED THIN-FILM SENSORS

Thin-film sensor systems integrated directly into the surface of hot forming tools offer for the first time the possibility of following every individual forming process in situ.

Integrated sensors for optimized processes
Integrated sensor systems in metal forming and particularly in hot forming make precise process monitoring and optimization possible during the forming process and are for this reason of great interest, especially in the production of more complex components. As part of the SenWerkUm project funded by the Federal Ministry of Education and Research (BMBF) – SenWerkUm is an acronym derived from the German for sensor-aided material design and coating development for metal forming – a thin-film system has been developed at the Fraunhofer IST which is thermally stable and wear-resistant and which has in addition outstanding sensory capabilities.

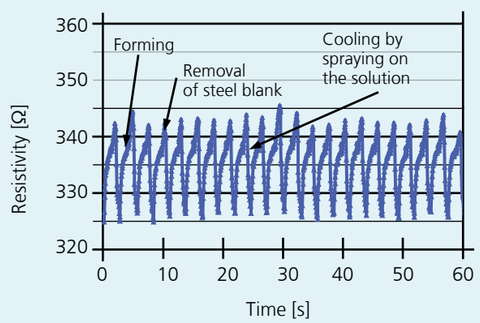
Forming tools with complex geometries
Before coating, the surface of the tools (manufactured by Hirschvogel Umformungstechnik GmbH) was optimized in both form and surface roughness ready for the next coating process. An electrically isolating modified aluminum oxide coating (AlON) with a thickness in the range of 2.5 µm was deposited as the first layer. The sensor structures were then made by the lift-off process from a layer of chromium only 200 nm thick. What is of special interest here is that the structures can be generated even on these complex geometries - thanks to the use of flexible masking (figure 1). Alternatively the sensor structures can also be engraved by a laser system into a homogeneous layer of chromium. The laser cuts a trench in the chromium layer only a few micrometers wide. Some sensor structures can be seen in figure 1. These sensor elements must be protected against wear by a second electrically isolating top coating of AlON 2 µm thick. The contact areas of the sensor meanders are located in a slanted area.

Quality control at individual sensor structures
To determine the sensor-related quality of the individual structures, the initial resistances between the contacts are measured and then the temperature-dependent resistance curves recorded at all intact structures in an oven with an air atmosphere. They show the linear rise in resistance as temperature rises which is typical of metals. The characteristic change in resistance is at 1 ohm/N and the temperature coefficient at 10^{-3} K-1.

The sensor system in industrial service
The tool incorporating a thin-film system installed very well in the forming machine at Hirschvogel Umformungstechnik GmbH. The photograph in figure 2 was taken during production testing with the »sensor tool« installed. Sensor signals were recorded simultaneously for 1000 forming cycles. In each case a 100Cr6 steel blank at a temperature of 1100 °C was formed into a diesel injection component. The cycle time lies in the region of a few seconds. The results from these measurements can be seen in the diagram.

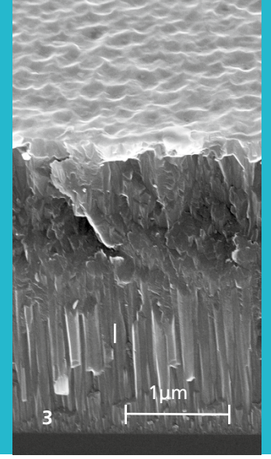
Outlook
A thin-film sensor system with a total thickness less than 5 µm was tested under the extreme conditions of hot forming. Currently the long-term use of the sensor system for monitoring and optimizing the processes is being examined.

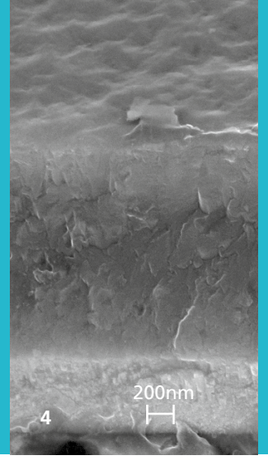
Characteristic curve of a sensor structure during hot forming.



CONTACT

Dipl.-Ing. Saskia Biehl
Phone +49 531 2155-604
saskia.biehl@ist.fraunhofer.de





DEVELOPMENT OF HARD TOOL COATINGS BY MEANS OF MAGNETRON SPUTTERING

Harder, more wear-resistant and further optimized: tool coatings produced by magnetron sputtering boost cost-efficiency in industrial production.

Increasing cost-efficiency

Since many years the use of tool coatings is well established in industrial production. The gold-colored TiN coatings are even known to home improvers. They offer an effective way of reducing tool wear at cutting edges and flanks. In machining the trend aim to higher machining rates, hard and dry machining and to new materials which are difficult to machine. This means that there must be a continuous further development of tool coatings. Using the physical vapor deposition (PVD) technique of magnetron sputtering makes it possible to produce smooth and droplet-free coatings with a wide range of applications, such as, for example, machining steel, cast iron, non-ferrous metal and also materials which are difficult to machine. On the basis of various standard hard coatings the Fraunhofer IST offers the possibility of coating systems adapted to specific applications and the development of combinational and nanocomposite coating systems so that even future requirements in production can be satisfied.

Further development of TiAlN coatings

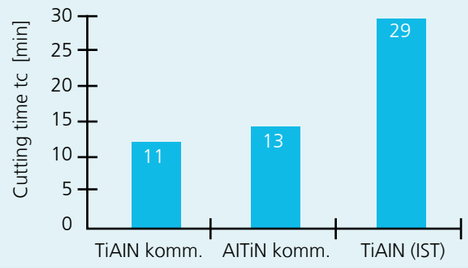
In recent years the use of titanium aluminum nitride (TiAlN) coatings became increasingly widespread for tools, especially for cutting tools. In comparison with TiN coatings, TiAlN coatings offer greater wear protection and higher resistance to oxidation. These improved properties increase tool performance and make higher cutting speeds possible.

In first turning tests of stainless steel (V4A) a significant increase in performance and longer tool life were obtained with the Fraunhofer IST's TiAlN coatings compared to commercially coated tools.

Machining tests.

Treatment	Turning
WSP	CNMP 120408-SM
Material	1.4571
KSS	wet
Cutting rate v_c	140 m/min
Cutting depth a_p	2 mm
Feed rate	0,22 mm/ U
Durability criterion	0,4 mm VB_{Kerb}

Turning test with commercial TiAlN coating developments and Fraunhofer IST developments.



Development of nanostructured and nanocomposite coating systems

The further development of TiAlN coating systems aims not only at higher hardnesses and wear resistance, an improved layer morphology or structure, and special interlayer systems but also in the direction of nanostructured and nanocomposite coatings. Combining several phases and special deposition conditions make it possible to obtain some very promising combinations of properties. Pulsed magnetron sputtering techniques are particularly suitable for this, being a flexible technology by which different phases can be produced and different elements can be combined in a single coating. Currently, in the »Nano HM« project funded by the Federal Ministry of Education and Research (BMBF), nitridic and boridic hard coatings are being developed by combination with further elements such as, for example, Cr, Si, C or W to prepare nanostructured coatings. The aim is to create improved tool properties for machining. Pulsed magnetron sputtering has proved to be a particularly promising technique for these coating requirements. It has been possible to create nanocrystalline coatings with crystallite sizes in the 20 nm range and coating hardnesses greater than HV 4000.

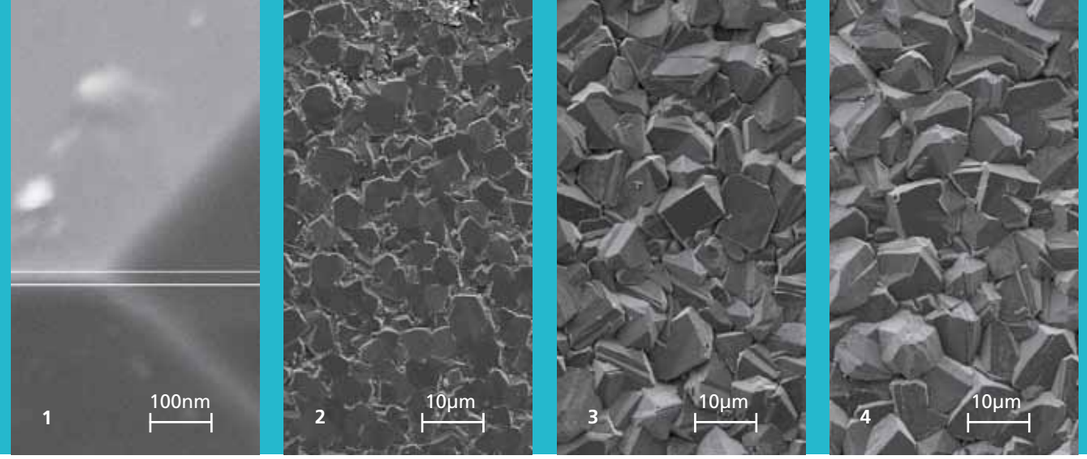
Outlook

Further investigations aim at using pulsed magnetron sputtering to develop super hard, nanostructured tool coatings as well as processes with a high level of cost-efficiency and quality so as to achieve significant performance increases in machining, not to mention opening up new fields of application.

1 Milling and tapping tools with different coatings.
2 Indexable inserts with hard coatings.
3 SEM cross section image of a TiAlN coating with a gradual change in morphology.
4 SEM cross section image of a hard coating with adhesion layer.

CONTACT

Dr.-Ing. Martin Keunecke
Phone + 49 531 2155-652
martin.keunecke@ist.fraunhofer.de



CVD DIAMOND FILMS AS AN ABRASIVE LAYER FOR PRECISION GRINDING

In addition to individual cutting edges being as sharp-edged as possible and the abrasive coating having a constant thickness, what is of prime importance in the precision grinding of hard and brittle materials such as ceramics, hard metal, cermet or glass is the finest possible grit size. Here CVD diamond films offer a great potential which has been successfully put to the test in a project conducted in collaboration with the University of Bremen and funded by the German Federation of Industrial Research Associations (AiF).

Topography of the abrasive coating

With their tetrahedron- or pyramid-shaped diamond crystallite tips, the CVD diamond abrasive layers developed at the Fraunhofer IST have a different topography to the bonded diamond grit still used in abrasive coatings. By adjusting the duration of coating, the size of these crystallite tips can – corresponding to the desired grit size – be kept very small: down into the submicrometer range. Even the sharpness of the individual micro-blades is very high. Measurement of the edge radius yielded values of just 20 nm (figure 1). Measurement of the cutting-edge angles gave wedge angles of approx. 96°, clearance angles between 16° and 77° and negative rake angles in the range between -15° and -74°.

Recoating

Ceramic grinding wheel bodies are expensive to produce: for this reason trials were carried out for the first time on recoating worn-down CVD diamond films to allow them to be reused. It emerged that during a brief coating process the flattened crystallite tips grow out again to exactly the same height level as crystallite tips without wear (figures 2 to 4). Even the size of the crystallites was identical.

Grinding results

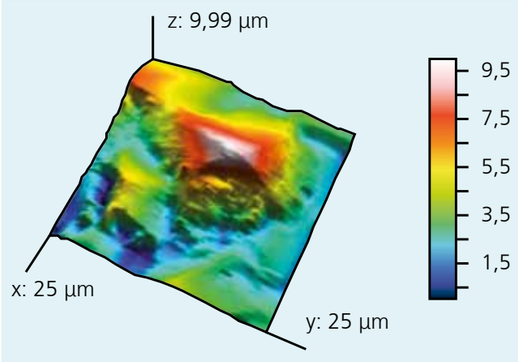
During grinding tests in the Laboratory for Precision Machining of the University of Bremen it was found that higher surface qualities in ceramic, glass and cermet workpieces could be achieved with CVD diamond-film abrasive layers (Ra = 0.02 µm in the case of glass) than with conventional, metallic and synthetic resin-bonded diamond grinding tools (Ra = 0.08 µm).

The tool of these innovative abrasive dressing wheels is ten to twenty times longer than conventional diamond grinding wheels.

Outlook

In view of these positive results, a follow-up project is planned which aims to develop CVD diamond abrasive wheels for processing extremely hard materials (such as diamond, cubic boron nitride and ruby).

Illustration of a CVD diamant crystallite point with the confocal laser scan microscope.



1 Measurement of the cutting-edge radius in the SEM.
2 Worn CVD diamond film before recoating.
3+4 CVD diamond film after recoating (figure 3) in comparison with the unworn area (figure 4).
Imaging of a CVD diamond crystallite point with the confocal laser scanning microscope.

CONTACT

Dr.-Ing. Jan Gäbler
Phone +49 531 2155-625
jan.gaebler@ist.fraunhofer.de

ENERGY, GLASS, FACADE

In the business area »Energy, Glass and Facade« some of the developments the Institute concentrate on are:

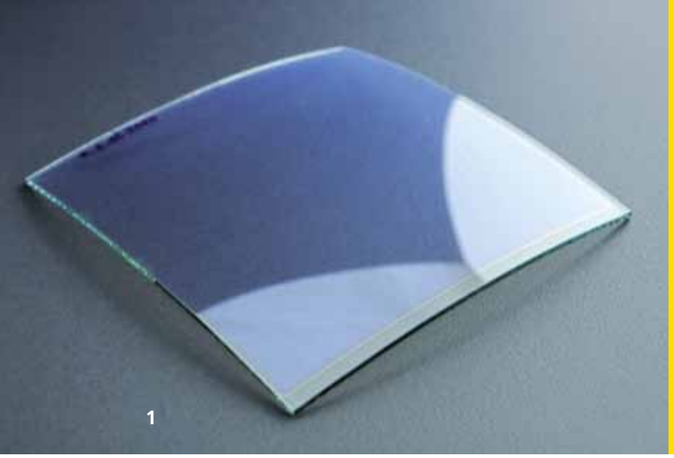
- Coating systems and associated processes for photovoltaic applications
- Low cost transparent conducting oxide coating systems (TCOs) for photovoltaics and photothermal applications
- Semiconductor materials for thin film photovoltaics
- Characterization methods for solar cells
- Improved functional layers and coating processes for architectural glass
- Coating systems for fuel cells
- Improved low cost high temperature corrosion protection for turbine blades

Our customers include the glass, photovoltaic and electronic industries, energy and construction, heating and sanitary fitting manufacturers and plant manufacturers as well as contract coaters.

CONTACT

Dr. Bernd Szyszka
Phone +49 531 2155-641
bernd.szyszka@ist.fraunhofer.de

Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de



NEW APPLICATIONS FOR TRANSPARENT CONDUCTIVE COATINGS BY HIPIMS

Transparent conductive coatings based on tin-doped indium oxide (ITO) have been developed at the Fraunhofer Institute for Surface Engineering and Thin Films IST using high power impulse magnetron sputtering (HIPIMS). In addition to their outstanding optical and electrical properties they also have very good mechanical and chemical stability.

Background

Since the 1940s SnO_2:F-coated glass panels produced by spray hydrolysis have been used as electrically heatable low-emitting glazing in aircraft. Transparent and conductive SnO_2:F coatings are already used as low-emitting outer layers in the field of architectural glass coating. They prevent moisture condensing on the outer side of the glazing. But since the mechanical stability and even the optical properties of SnO_2:F coatings are not satisfactory they have not been used or only to a limited extent. In the mid-1970s the Glaverbel company developed and marketed under the name Hortiplus a single glazing with a SnO_2:F coating for use in greenhouses. Another TCO system with good electrical, optical and chemical stability is ITO coating. This does, however, require high temperatures (300 °C) in its manufacture.

The solution concept

The problem of the inadequate stability of a low-emitting coating system on Position 1 (outer coating) is solved by the HIPIMS process. This is because with this process it is possible, under specific pulse and power conditions in coating deposition at room temperature, to set the texture and morphology of the coating such that the aforementioned properties are obtained in a subsequent operation of tempering and possibly bending. At thicknesses of 140 nm the coatings achieve a specific resistance of 300 µΩcm with an optical transmission of more than 80% on 2 mm float glass. Testing of mechanical and chemical wear indicates suitability for use on outside surfaces. Coatings produced by the HIPIMS method passed the following tests:

- Taber test (DHaze < 2%) for use in Posn. 1
- Scratch test
- Salt spray test
- Damp storage
- Acids / bases test

Advantages of the coating

Transparent protective heating systems are frequently required in industrial applications in order to ensure that the column can be inspected visually. To take a heating coating on a glass tube as an example, here the good transparency of the material glass can be combined with its ability to be heated and with further properties (figure. 2). Transparent heating coatings open up various possible new uses for glass as a basic material:

- Heating without visual restrictions, such as by using heating wires
- Coating curved surfaces
- Reduction in heating energy due to reflection of long-wavelength thermal radiation
- Thermal insulation due to the low-E effect
- Improvement in mechanical and chemical protection
- Coating flat surfaces followed by shaping (figure 1)

Applications for the coating

The coating system can withstand the stresses arising from the processes used for tempering and shaping glass and is suitable for a wide range of applications:

- Low-emitting coatings for external applications for preventing tarnishing on outside surfaces
- Transparent heatable protective coatings
- Transparent areal homogeneous heating without thermal peaks on flat or curved substrates
- TCOs with greater damp-heat stability

The HIPIMS method thus makes TCO layers with long-term stability possible, thereby opening up completely new areas of application.

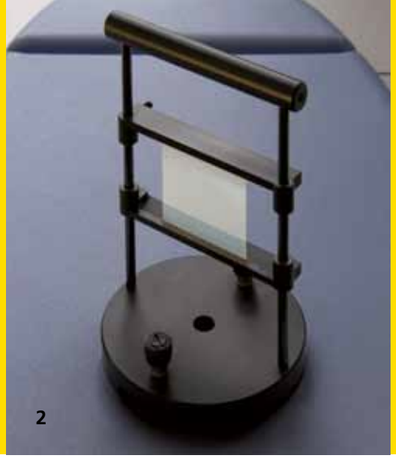
1 Curved ITO coating on glass following a tempering and bending process at 650 °C.
2 Coated glass tube for a distillation column of the BASF Group.
3 Thermogram of a heating coating on a glass tube of the BASF Group used in protective heating.

CONTACT

Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de

Dr. Bernd Szyszka
Phone +49 531 2155-641
bernd.szyszka@ist.fraunhofer.de

1



2

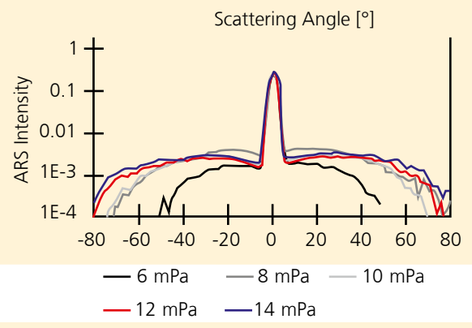
ANGULAR-RESOLVED LIGHT SCATTERING MEASUREMENTS ON ROUGH TRANSPARENT CONDUCTIVE OXIDES

Rough zinc or tin oxide coatings are of great interest on account of light trapping and good light coupling in solar cells. Their light scattering properties are characterized as a function of scattering angle.

Motivation

Silicon thin-film solar cells require a suitable design for light trapping to be able to convert the sunlight hitting the cell into electricity effectively. In many cases a transparent and conductive front contact made of aluminum-doped zinc oxide (ZnO:Al) is used for this purpose. The ZnO:Al is structured by a wet-chemical etch process. The solar cell absorber is then deposited onto this rough coating. This leads to a light scattering film on top of the solar cell. In this manner the optical path length of the light can be significantly increased, light absorption boosted and a larger short-circuit current generated in the cell. Silicon tandem solar cells are used to cover a wider range of the solar spectrum. They consist of amorphous (a-Si:H) and nanocrystalline silicon (µc-Si:H). The a-Si:H absorbs the short-wavelength blue part of the spectrum while the µc-Si with its smaller band gap absorbs the long-wavelength red and infrared components of the light. It is precisely for the µc-Si absorber that an appropriate light scattering is important since the absorptance otherwise would only be low due to the indirect band gap and the small film thickness in comparison with the wavelength. At the Fraunhofer IST these structured front contacts are characterized angle-dependently with regard to their light scattering properties.

Angle-resolved light scattering measurement on ZnO:Al samples sputtered with varying oxygen partial pressure and then etched at 740 nm.



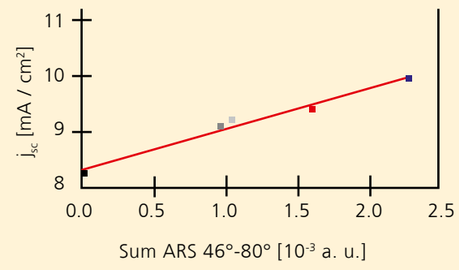
Principle of angular-resolved light scattering measurements (ARS)

To permit characterization of the light scatter behavior of the rough TCO coatings the sample is illuminated monochromatically in a spectrometer. Both the sample and the detector can be moved in an in-plane geometry.

Correlation of light scattering and the short-circuit current in thin-film solar cells

The examined reactively sputtered ZnO:Al samples were deposited at different oxygen partial pressures and etched in diluted hydrochloric acid. The light scattering was measured at 740 nm, where the sample was illuminated with vertical incidence from the coated side. The detector was moved in 2° steps. Results of the measurements are shown in the left-hand graph. Tandem a-Si:H / µc-Si:H solar cells were applied to these coatings and their external quantum efficiency gave a value of the current generated in the µc-Si:H bottom cell. As the oxygen partial pressure increases, the etched structure becomes sharper and smaller and the high-angle scattering of the light increases. Integrating the ARS signal from 46–80° indicates a linear correlation between the high-angle scattering of the light and the short-circuit current generated in the µc-Si:H cell. This method has thus been used to assess rough TCOs for their suitability for light trapping in solar cells.

Generierter Rotstrom in auf diesen Schichten angefertigten Solarzellen, die in Zusammenarbeit mit dem Forschungszentrum Jülich hergestellt und mittels Quantenausbeute charakterisiert wurden.



j_{sc}=8.4(2) + 970(95)* ARS_{Summe} ▪ Rotstrom

R^2_{korr}=0.96 — Linear Adjustment

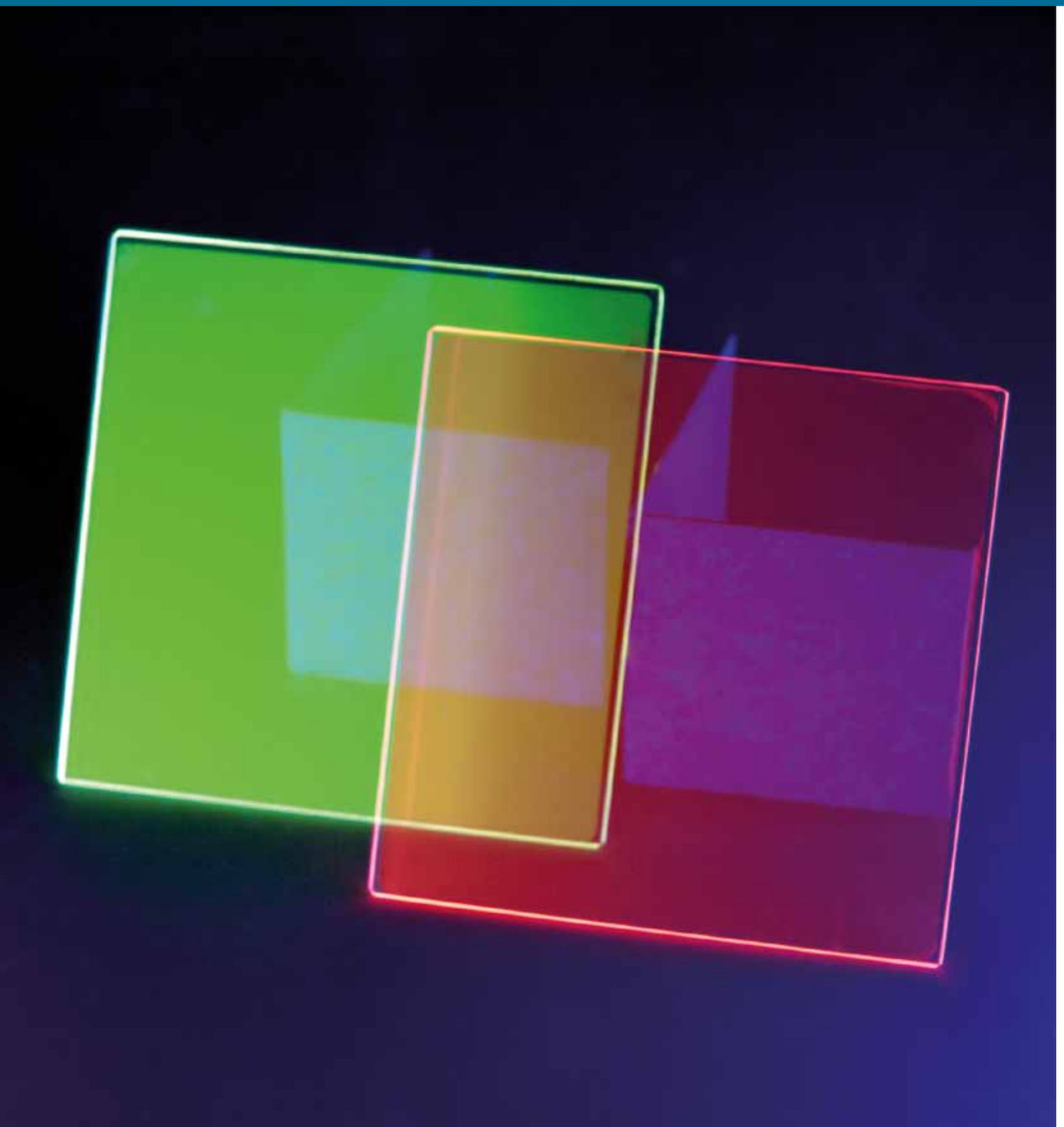
1 *ARS measurement accessory from OMT Solutions for a PerkinElmer spectrometer.*
2 *Sample holder with an etched ZnO:Al sample.*

CONTACT

Dipl.-Phys. Wilma Dewald
Phone +49 531 2155-669
wilma.dewald@ist.fraunhofer.de

Dr. Volker Sittinger
Phone +49 531 2155-512
volker.sittinger@ist.fraunhofer.de

Dr. Bernd Szyszka
Phone +49 531 2155-641
bernd.szyszka@ist.fraunhofer.de



OPTICS, INFORMATION, COMMUNICATION

Topics falling within the business area »Optics, Information and Communication« include:

- Developing electrical contact amd insulating layers,
- Developing coating systems for displays,
- Developing and designing multilayer coatings for optical filters,
- Metallizing plastics for 3D-MID and
- Developing new materials, structurizing and metallizing technologies to substitute ITO layer systems for flat panel display applications

Customers of this business area include the optical and automotive industries, telecommunications, manufacturers of displays and data-storage as well as plant manufacturers and contract coaters.

CONTACT

Dr. Michael Vergöhl
Phone +49 531 2155-640
michael.vergoehl@ist.fraunhofer.de

Dr. Ralf Bandorf
Phone +49 531 2155-602
ralf.bandorf@ist.fraunhofer.de

NEW MATERIALS FOR APPLICATIONS IN TRANSPARENT ELECTRONICS

In the year under review, at the Fraunhofer IST p-conducting materials were produced that open the path into the future of transparent electronics. The coating method applied here was used for the first time worldwide to produce a transparent p-conductor.

Production of transparent p-type conductors

Most semiconductor devices require for their function both n- and p-conducting materials. For applications in transparent electronics, such as transparent OLEDs, transparent solar cells or transparent displays, until now the necessary p-transparent materials have not been available. While transparent n-type layers such as ITO or doped zinc oxide (Al-ZnO, In-Ga-ZnO) can already be produced with good electrical and optical properties, until now the appropriate p-conducting counterpart has been missing. Therefore, $CuCrO_2$ (also called »Delafossite«) has been produced at the Fraunhofer IST.

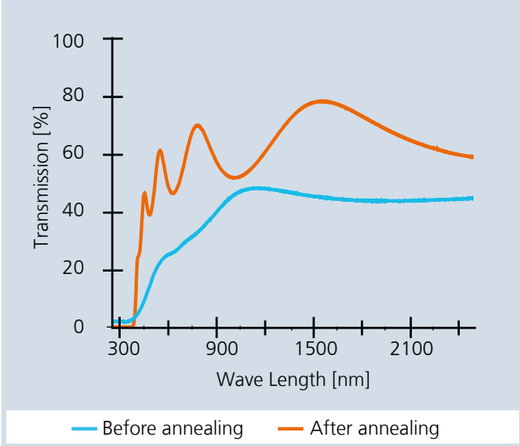
The manufacturing process

To produce films with the desired chemical composition, reactive gas flow sputtering (GFS) was used, which utilizes a hollow cathode plasma. This coating process, compared to conventional sputtering, works at higher pressures (0.5 mbar). Among other things this leads to significantly lower particle energies and, consequently, less substrate damage. With a suitable choice of process parameters (sputtering gas and reactive gas flow) and proper material composition of the hollow cathode it is possible to produce coatings which contain the correct chemical composition. Only the arrangement of atoms is random, so that there are amorphous structures. In order to obtain the desired crystal structure (the »Delafossite«), after manufacturing the layers must be annealed in a tube furnace with a specific gas composition at 700 °C. Thereby, the thin films crystallize into the desired structure.

Transparent and p-conductive

After the successful synthesis, the materials are not only transparent but also show p-conductivity. A Seebeck coefficient of +477 µV / K was determined, where the value of the sign marks the type of charge carrier (in this case positively charged »holes«). The need for annealing can be seen very clearly in the transmission spectrum. Before annealing, the sample is dark and opaque. Thereafter, the transparency in the visible transmission spectrum is clearly visible.

Transmittance spectrum of gas flow sputtered $CuCrO_2$. Due to thermal after-treatment the light transmission is considerably increased.



Summary

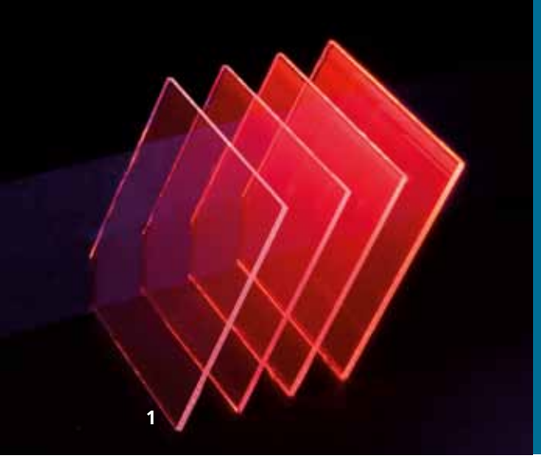
At the Fraunhofer IST, p-conducting materials can be produced using a stable and reproducible process. The p-TCOs offer high transparency in the visible spectrum of light while offering high conductivity values at the same time.

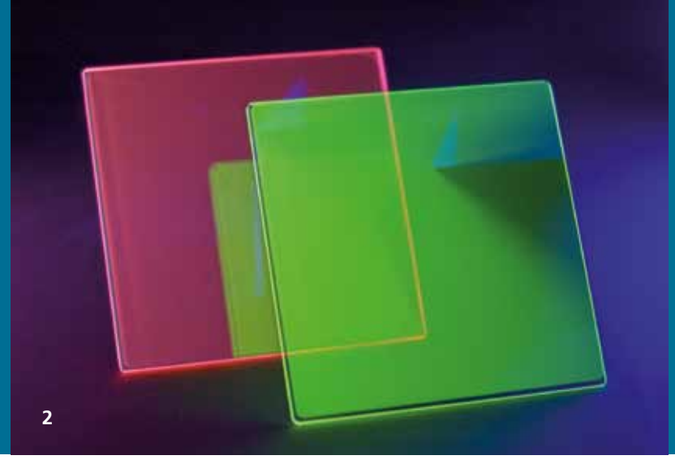
1 *Plasma from a gas flow sputtering source.*

CONTACT

Christina Polenzky
Phone +49 531 2155-571
christina.polenzky@ist.fraunhofer.de

Dr. Kai Ortner
Phone +49 531 2155-637
kai.ortner@ist.fraunhofer.de





MEASUREMENT METHOD FOR THE STANDARDS-COMPLIANT DETERMINATION OF THE PHOTOCATALYTIC ACTIVITY OF SURFACES

The photocatalytic luminescence of tailored organic dyes is a fast and dependable measuring technique for evaluating the photocatalytic activity and effectiveness of surfaces and powders. The aim is to secure a standardized comparability of photocatalytically active systems in order to increase market transparency.

Photocatalytically active coating systems, surfaces and powders promise self-cleaning, cleaning-supportive and antimicrobial properties. Photocatalytic activity in general determines how effectively and efficiently adsorbed substances, for example, bacteria, dirt or water, can decomposed. However, a direct comparison between different materials is a very complex matter, due to the complicated mechanisms of action at the boundary surface between the photocatalyst and the reactant. The luminescence method developed at the Fraunhofer IST promises a highly sensitive and fast way of analyzing these active systems.

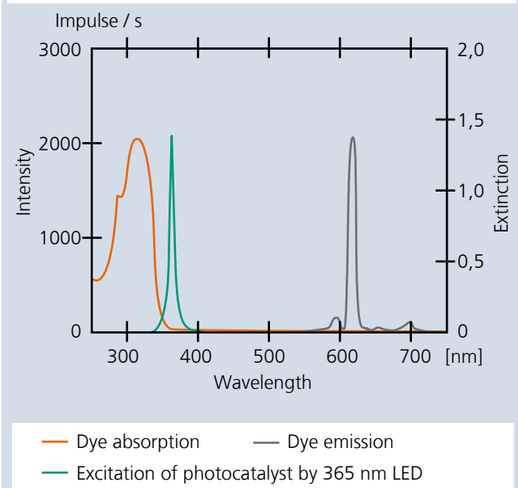
The new measurement method

Photocatalytically active materials absorb photons of capable energy from the solar spectrum. The generated electron-hole pairs reduce or oxidize adsorbed water, oxygen and organic compounds. The radicals thus formed, particularly the hydroxyl radicals (•OH) produced during the oxidation process, destroy the luminescence center of the previously applied dye and this leads to decay of the luminescence intensity. This degradation is used as a measure of photocatalytic activity.

Precise application of the luminescence dye

The precision of the measurement method depends on the reproducible precise application of the dye to the surface to be tested. The dye is deposited as a homogeneous and thin layer by means of a thermal vacuum coating process. This method circumvents the limitations of conventional application methods, such as, the disturbing influence of water- or solvent-based systems or the deep diffusion of the test reagent into the surface of porous materials. The use of tailored rare-earth complexes guarantees an aggregation- and photostable organic thin film which is transparent in the excitation region of the photocatalyst and has a high degree of solid-state luminescence. The use of high-power UV / Vis-LEDs permits a narrow-band excitation of the photocatalyst with simultaneous measurement of the luminescence intensity without any disturbing absorption of the dye. The luminescence decay method makes it possible to quantitatively evaluate photocatalytic systems rapidly. Within a few minutes transparent and opaque surfaces, pellets, plastics and cement-like systems can be tested with regard to their photocatalytic effectiveness and efficiency.

Excitation and emission behavior of a rare earth complex.



Outlook

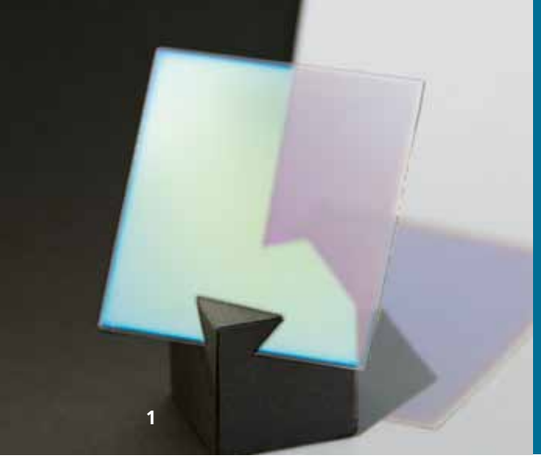
Current work in the »Photocatalysis« DIN standards committee and in the »Photocatalytic self-cleaning« work group as well as on the European level assure a standards-compliant further development of this testing method. The goal of further development work is to convert the luminescence measurement procedure into a European standard and to provide users in the year 2010 with a standard and automated measuring instrument.

1 *Rare-earth complex of different coating thicknesses on glass substrates.*
2 *Luminescence dyes from different dye classes on glass.*

CONTACT

Dipl.-Chem. Tobias Graumann
Phone +49 531 2155-780
tobias.graumann@ist.fraunhofer.de

Dipl.-Ing. FH Frank Neumann
Phone +49 531 2155-658
frank.neumann@ist.fraunhofer.de



POLYMERS AND POLYMER-METAL OXIDE COMPOSITES FOR OPTICAL INTERFERENCE COATING SYSTEMS

Ceramic materials are in most cases being very hard and brittle. They have been used to date for manufacturing optical components such as dielectric mirrors for laser applications or spectral transmission and reflective coatings. Polymer coatings mean the advent of new properties in interference coating systems, such as mechanical flexibility, but it has yet not been possible to produce them in the optical quality required.

Optical interference coatings

Optical interference coatings are of great importance in surface and coating technology. They consist of a sequence of coatings of different thicknesses and different refractive indices. With these coating systems it is possible to obtain any spectral transmission and reflection characteristics. Metal oxides as well as nitrides and even fluorides are typically used for optical coating systems. Typically they have very good optical properties (low absorption, constant refractive indices) but in most cases are very hard and brittle. With flexible substrates or substrates with different coefficients of thermal expansion this often results in cracking when the coatings are subjected to mechanical or thermal loads. More flexible optical coatings, such as polymers or even composites of polymers and inorganic materials, are conceivable here. At the Fraunhofer IST, to demonstrate the practical viability of systems of this kind, simple optical interference coating systems have been created, consisting of polytetrafluoroethylene (PTFE) as low-index layers and tantalum pentoxide (Ta_2O_5) as high-index layers (see graph). The PTFE coatings were deposited with a high-frequency a.c. voltage (RF sputtering deposition) and the Ta_2O_5 coatings by reactive DC sputtering deposition. Areas of application for these mechanically flexible optical coating systems include, for example, contrast-improving display walls or glue-on plastic films as projection surfaces for head-up displays.

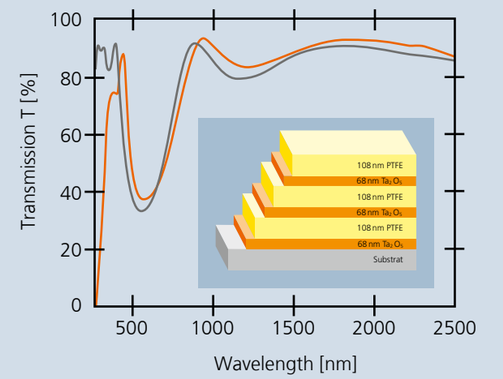
Results

Unlike many other polymers and organic compounds, PTFE can be deposited by sputtering as a transparent coating without its chemical structure being excessively altered. As is usual with non-conductive target materials, here too energy is input in sputtering by radio-frequency. These PTFE coatings deposited in an argon atmosphere are characterized by having low refractive indices (n = 1.38 to 1.40) and low absorption indices (k = 0.001) in the visible part of the spectrum. At 0.1 - 0.3 nm/s, sputtering rates fall within a range typical of comparable sputtering processes. These coatings are thus suitable as the low-index component in optical interference coating systems. Conventional Ta_2O_5 coatings reactively sputtered in an argon/oxygen atmosphere by means of a DC power input are used as the high-refracting component in the interference coating system. These coatings have high refractive indices (approx. n = 2.0) and low absorption indices (k < 0.001) in the visible part of the spectrum as well as good process stability. The transmittance spectra of a simple optical filter deposited without any in-situ controlling and consisting of six layers can be seen in the diagram.

Outlook

Polymer materials used as coating material are becoming increasingly important in many different applications. In association with partners from industry and research the Fraunhofer IST is investigating coating processes for polymer materials. The use of further polymer materials and also the production of new polymer-metal oxide composite coatings is scheduled for the future in order to further improve optical and mechanical properties.

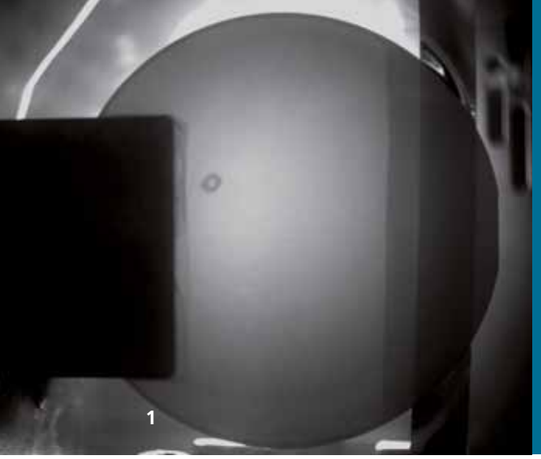
Transmission spectra of a simple optical filter system with sputtered PTFE and Ta_2O_5 layers.

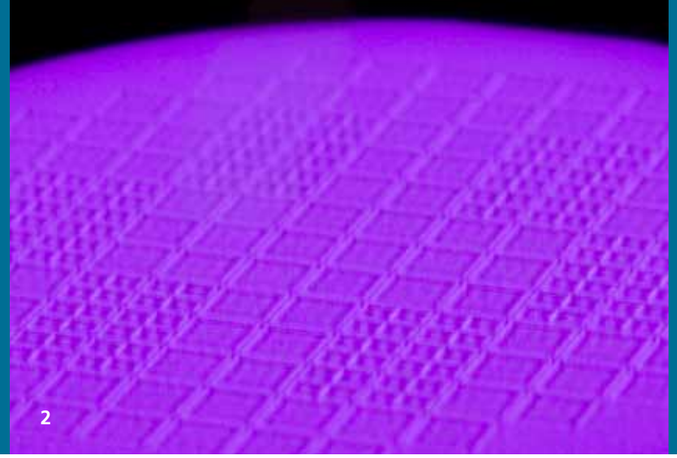


1+2 *Optical interference coating system with PTFE polymer layers on glass (1) and on plastic (2).*

CONTACT

Dr. Thomas Neubert
Phone +49 531 2155-667
thomas.neubert@ist.fraunhofer.de





BONDING HETEROGENEOUS COMPOSITES AND POLYMERS

New combinations of materials in innovative processes and products have a high degree of industrial importance. In many cases adhesives are used for joining the materials. Low-temperature bonding is an adhesive-free bonding technique for joining both homogeneous and heterogeneous material composites. By means of dielectric barrier discharge (DBD) at atmospheric pressure the Fraunhofer IST has been successful in bonding together not only inorganic material composites such as silicon and glass but also various polymers, doing so at low annealing temperatures.

High bond strength despite low temperatures
The surface-to-surface joining of glass and silicon wafers by means of bonding methods is of fundamental importance in the production of micro systems such as pressure sensors, thermopiles or microfluidic systems. The principle techniques used here are anodic bonding and direct bonding. What is problematic, however, is that the application of high voltages and the use of intermediate layers can, in the case of anodic bonding, result in damage to the structures on the wafer. In many cases adhesives have inadequate migration barriers, thereby limiting, among other things, the tendency to creep, migration and long-term stability. These problems can be avoided with direct bonding. At the Fraunhofer IST it has been demonstrated for the direct bonding of silicon that the bonding temperature can be reduced to as low as 100 °C without impairing a high bond strength. This means that technical problems in production such as, for example, damage to heat-sensitive coatings, can be prevented.

Low-temperature bonding of heterogeneous composites
The annealing temperature can have a considerable influence on the strength of the composite. High temperatures can cause problems, especially when materials with different coefficients of expansion are bonded. Current results show that plasma activation of heterogeneous composites – silicon and borosilicate glass, for example – can result in a marked increase in strength. Optimizing the parameters made possible a threefold increase in bond strength as compared with the untreated reference piece. The activation time here was as little as a few tens of seconds.

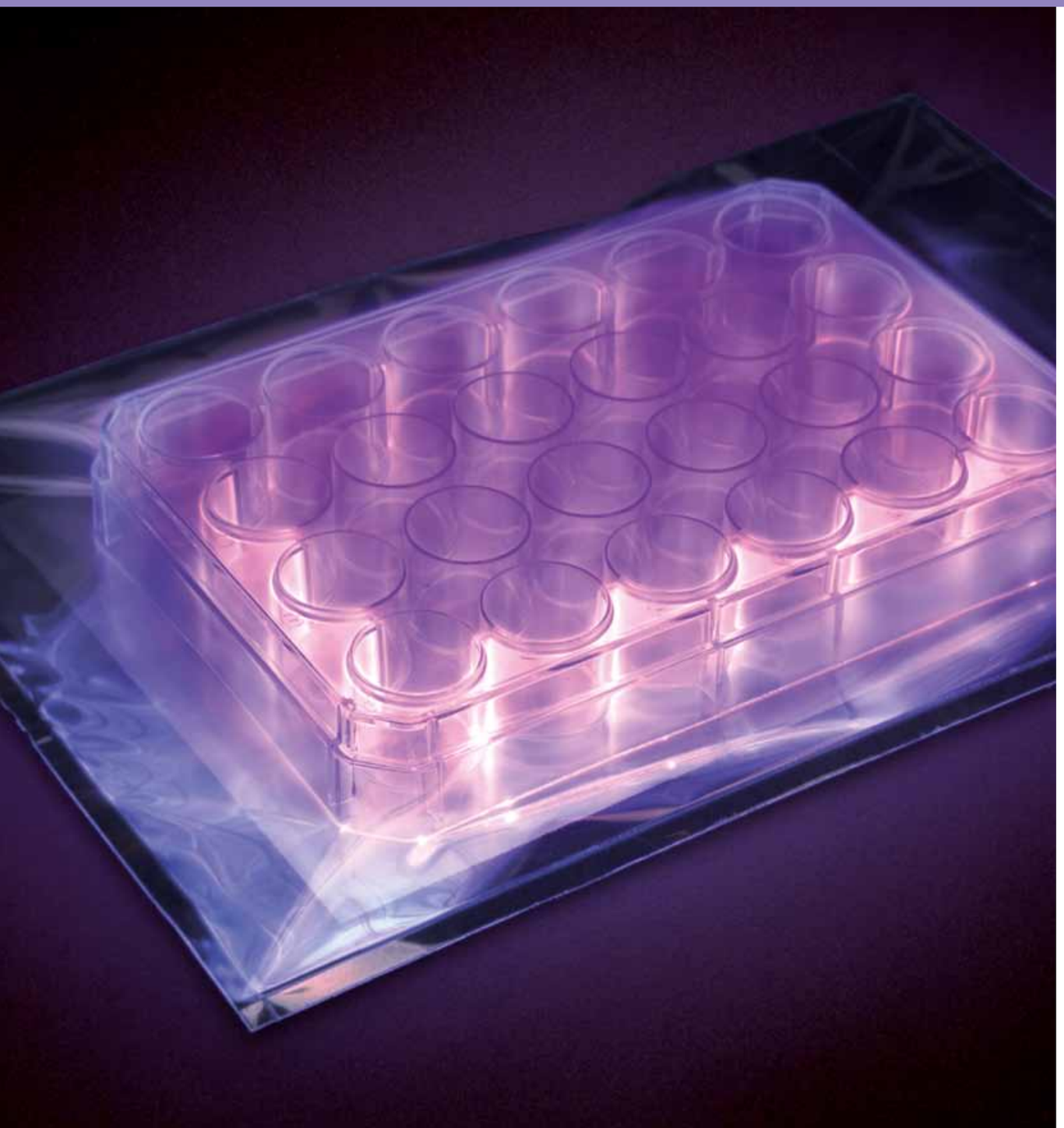
Joining lengths of plastic sheeting without adhesive
The heat-based techniques of laminating and doubling have become established as adhesive-free joining methods but ones which do, however, require the bonding partners to be compatible. With different plastics this is not normally the case. Furthermore, material properties as also optical quality or tactile properties frequently suffer when the bonding partners are melted. Thus there is a great demand for techniques which do not use adhesive and which operate at low temperatures. With dielectric barrier discharge at atmospheric pressure under oxygen-free conditions, functional groups can be created on the polymer surfaces to be joined by means of a pure gas-phase functionalization or coating. In a similar way to the direct bonding technique, these layers can be cross-linked at low temperatures via chemical reactions of the functional groups. This reaction is used for joining the substrates. In first tests it was possible to achieve an adhesion of 1.5 N / mm for a pairing of two identical polyethylene films by depositing a coating of 3-aminopropyl trimethoxysilane approx. 50 nm thick. This is an improvement in adhesion thirty times better than the untreated reference.

Outlook
Existing investigations are to be extended to cover further material combinations. The aim here is to identify the basic factors which influence joining and to create the plant-related conditions required to make implementation on an industrial scale possible. In addition to the full-area bonding of substrates, future work will also look at selective bonding in order to prevent sticking effects, for example. To this end a plasma tool has been developed in collaboration with the SÜSS MicroTec company which can be built into a bond aligner.

1 IR transmission image for a silicon wafer pair during oven tempering.
2 Treatment of a wafer with atmospheric-pressure plasma.

CONTACT

Dipl.-Phys. Marko Eichler
Phone +49 531 2155-636
marko.eichler@ist.fraunhofer.de



LIFE SCIENCE AND ECOLOGY

The focus of the business area »Life Science and Ecology« is the development of surfaces for applications in medical technology, biotechnology and environmental technology. Examples are:

- Selective functionalizing of surfaces for biochips or biosensors at atmospheric pressure
- Diamond coated electrodes for electrochemical disinfecting of water and treatment of waste water
- Metal coating of plastic surfaces for biosensors
- Coating of interior surfaces in components for microfluidics, cell culture bags and plastic bottles
- Friction-reducing biocompatible layers (i. e. diamond-like carbon layers) for medical applications, i. e. implants

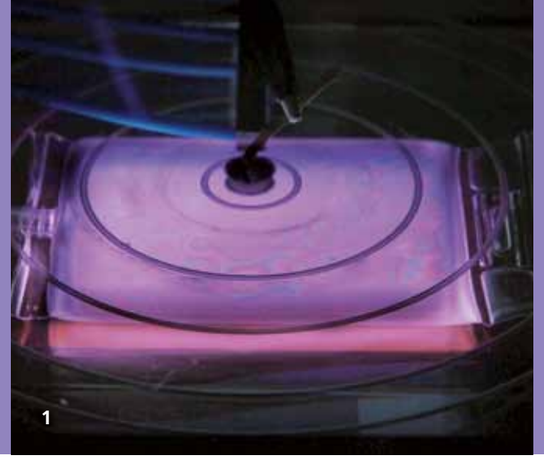
Our customers include the pharmaceutical-chemical industries, biotechnology, medical technology, food industry, chemical industry and environmental technology.

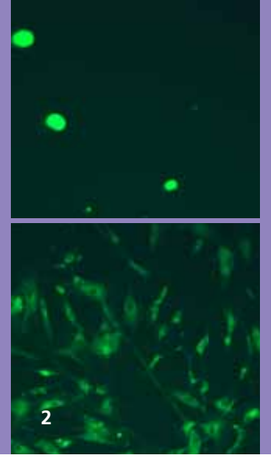
CONTACT

Dr. Simone Kondruweit
Phone +49 531 2155-535
simone.kondruweit@ist.fraunhofer.de

Prof. Dr. Claus-Peter Klages
Phone +49 531 2155-510
claus-peter.klages@ist.fraunhofer.de

Dr. Michael Thomas
Phone +49 531 2155-525
michael.thomas@ist.fraunhofer.de





INTERNAL COATING OF BAGS FOR USE IN STEM CELL RESEARCH AND MEDICINE

Living cells are being used more and more frequently in modern medicine methods such as stem cell therapy, blood transfusion and bone marrow transplantation or in the case of deep burns. Since the cultivation of cells in open systems is bound up with a high risk of cell cultures becoming contaminated, a new procedure has been developed in which work can be carried out inside closed bag systems. The internal surfaces of the bags are automatically coated by means of atmospheric-pressure plasmas so as to enable adherent cell growth on these surfaces.

Internal coating by means of atmospheric-pressure plasma

A coating method has been developed at the Fraunhofer IST which makes it possible to selectively equip the internal surfaces of cell culture bags with chemical functions or hydrophobic properties so as to enable adhesive cell growth in the bags. To coat the bags, they are filled with an inert gas and the vapor of a suitable film former, such as 3-aminopropyl-trimethoxysilane (APTMS). By using inert gases the breakdown voltage with respect to the air is reduced. This means that when an a.c. voltage is applied to the electrodes which are located above and below the bag the discharge can be selectively initiated inside the bag. Optimization of the filling process and the electrode geometry makes it possible to obtain homogeneous coating deposition on the internal surfaces of the bags.

Automated process

An automated filling and treatment system has been set up at the Fraunhofer IST for coating the inside of cell culture bags. Unlike a manual method this results in a very high reproducibility and homogeneity for the coatings. A programmable controller enables all process steps to be automatically executed one after the other:

- Venting
- Flushing
- Filling with a defined quantity of the process gas
- Plasma treatment or coating
- Degassing

Evaluation of the coating systems

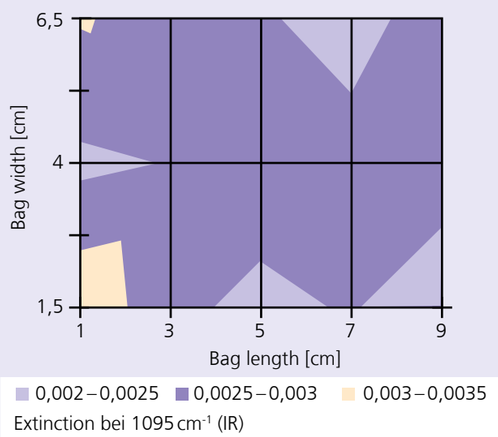
In addition to the straightforward functionalization of the surface by the effect of a helium plasma, various film formers have been investigated with regard to their suitability for adherent cell growth. These include not only organosilicon compounds but other volatile monomers with chemical functionalities, such as amino, epoxy or carboxyl groups. The uniformity of the thicknesses of the coatings was checked by means of FTIR-ATR spectroscopy (see diagram). By using fluorescent labeling or chemical derivatization it was possible to identify functional groups. In this way the number of primary amino groups, for example, could be determined by chemical derivatization using 4-trifluoromethyl-benzaldehyde, followed by evaluation of the FTIR-ATR spectra. It was possible to demonstrate that in APTMS-coated bags stored for a period of 24 weeks two primary amino groups per nm^2 were still available for subsequent reactions. Secondary modifications to these functional groups were achieved successfully.

Outlook

The developed automated set-up with filling unit and integrated plasma treatment enables the Fraunhofer IST to provide other researchers with coatings precisely suitable for their requirements. Further aims of development are:

- to prevent the adhesion of proteins
- a targeted selection of cells by antibodies
- to extend the time for which thrombocyte concentrates can be stored.

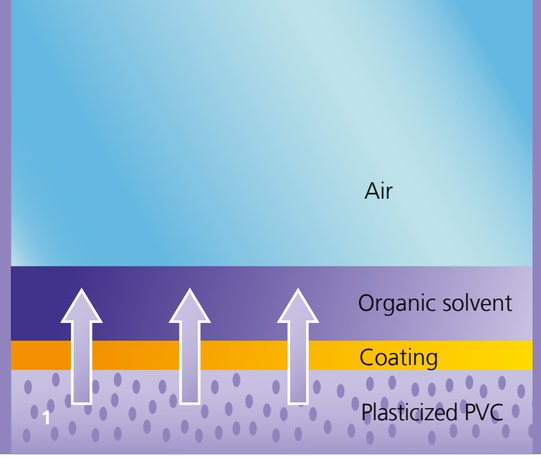
Homogeneity of an APTMS coated bag.



1 *Plasma treatment of a bag.*
2 *Cell cultivation in the closed bag; (top) untreated bag, no adherent growth, (bottom) APTMS-coated bag with adherent cell growth.*
3 *Complete system for the automated internal coating of cell culture bags.*

CONTACT

M. Sc. Kristina Lachmann
Phone +49 531 2155-683
kristina.lachmann@ist.fraunhofer.de



PLASTICIZER BARRIERS ON PVC FILMS BY MEANS OF ATMOSPHERIC-PRESSURE PLASMA

Due to its competitive pricing, polyvinyl chloride (PVC) has a very wide range of applications. However, in the case of the frequently used plasticized PVC, the plasticizers it contains, which include, for example, phthalates or trimellitates, have to be prevented from escaping. This is for both environmental and material-related reasons.

Plasma polymer films as a barrier layer

The solutions so far available for protecting against plasticizer escape – such as, for example, by painting, in which coating thicknesses are normally at least 10 µm, or by a later operation of crosslinking the PVC surfaces by ultraviolet irradiation – are often bound up with relatively high material costs, have an environmental impact or result in problems in subsequent processing as well as having an unsatisfactory barrier effect. In a joint research project of the Fraunhofer IST and the FILK (Research Institute for Leather and Plastic Webs), investigations are underway into plasma polymer films deposited at atmospheric pressure as a barrier against plasticizer migration. The aim is to develop an inexpensive and environmentally friendly alternative to existing coating methods.

Deposition and properties of the barrier layers

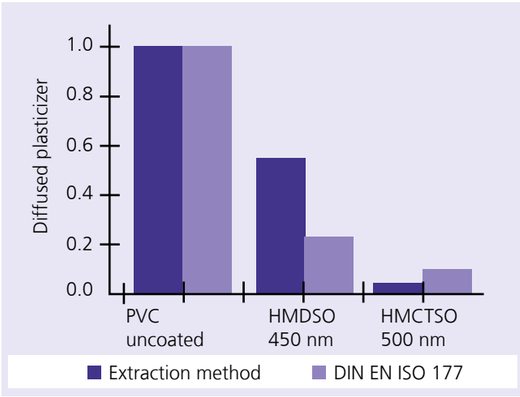
Coating deposition is by dielectric barrier discharge (DBD). The use of film formers based on organosilicon conjunctions appears promising. REM and AFM images indicate that under suitable deposition conditions larger-sized pores or holes are absent from the deposited siloxane coatings. With process gas mixtures of hexamethylcyclotrisiloxane (HMCTSO) and air, coatings have been deposited which, at a thickness of about 500 nm, give a barrier effect of up to 90% as measured by the test procedure described in DIN EN ISO 177 (see diagram). At the present time the adhesion and mechanical stability of the coatings are still a challenge.

Fast method of measuring plasticizer migration

The method described in DIN EN ISO 177 is based on gravimetric measurements over a period of 30 days. As part of this project a new method has now been developed at the Fraunhofer IST which within a few hours delivers results which permit an estimate of the barrier effect. This method is based on extracting the plasticizer from the film by means of a suitable solvent (figures 1 and 2), such as decane, for example, and then quantifying it by infrared spectroscopy.

Outlook

Future work will aim at securing a further improvement in the barrier effect as well as in the adhesion and mechanical stability of the barrier layers. The fast method for determining plasticizer migration developed at the Fraunhofer IST is also to be further optimized.



1+2 Extraction of plasticizers from PVC film in order to determine the barrier effect of the coatings. Left: extraction process, right: extraction tube.

CONTACT

Dr. Jochen Borris
Phone +49 531 2155-666
jochen.borris@ist.fraunhofer.de

Dipl.-Ing. Mercedes Cerezuela Barreto
Phone +49 531 2155-671
mercedes.cerezuela.barreto@ist.fraunhofer.de

SERVICES AND COMPETENCIES

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

Low pressure processes

- Hollow cathode processes
- PACVD- and hot-filament CVD processes
- Magnetron sputtering and HiPIMS

Atmospheric pressure processes

- Electroplated multi-component systems
- Electrochemistry
- Atmospheric pressure plasma-processes
- Plastics metallization
- Corrosion protection

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

Super hard coatings

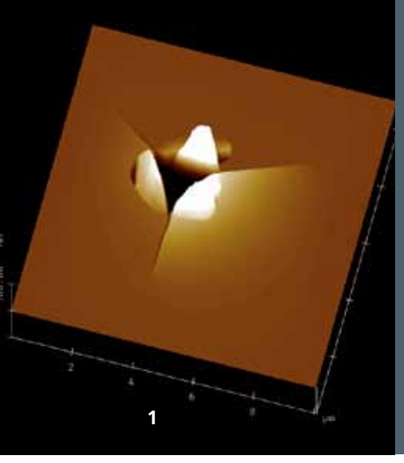
- Diamond
- Cubic boron nitride (cBN)

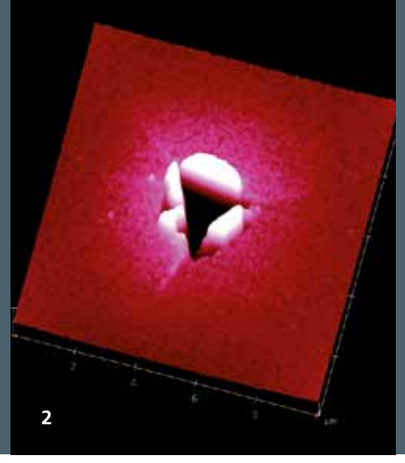
Wear protection and friction reduction

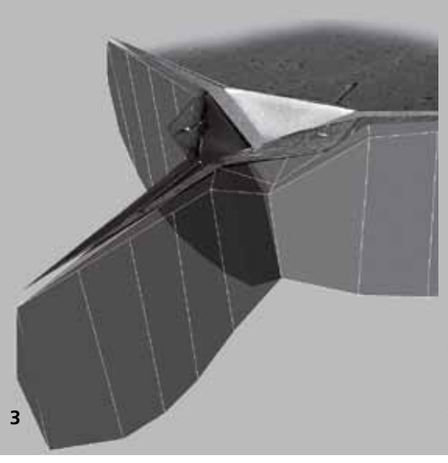
- Diamond-like carbon coatings (DLC) and diamond
- Hard coatings
- Plasma diffusion
- Dry lubricant coatings

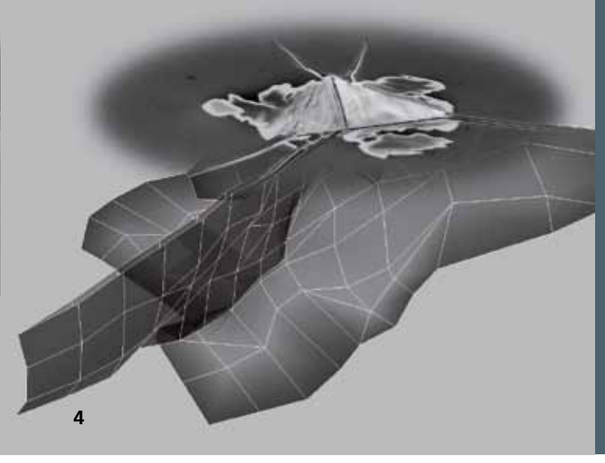
Analysis and Testing

In addition the institute offers a broad spectrum of cross-sectional services: Surface pre-treatment, thin film development, process technology (including process diagnostics, modeling and control), surface analysis and thin film characterization, training, application oriented film design and modeling, system design and technology transfer. The department Characterization of Layers with its capabilities in coating and surface analysis as well as in measuring and testing is an important factor in the success of the institute. The following selected articles are about our technologies and layer characterization.









DETERMINATION OF FRACTURE TOUGHNESS OF THIN COATINGS BY NANOINDENTATION

Nanoindentation as a technique for determining fracture toughness has been tested at the Fraunhofer IST. Of the large number of models published, six have been validated with the aid of our own test pieces and data from the literature.

Fracture toughness of thin coatings

Fracture toughness K_{IC} is a material parameter which describes the growth of existing cracks in materials. In the case of solid materials it is determined by means of standardized crack extension experiments. However, this method cannot be used with thin coatings. Since the beginning of the 1980s models have been published which claim to allow K_{IC} to be determined by indentation experiments. The number of different models now stands at more than twenty and it is not clear which delivers the best results. A selection of six models have been tested and evaluated at the Fraunhofer IST.

The measurement method

To determine K_{IC} a »cube corner« diamond indentor is pressed with sufficient load P (~30 mN) into the material so that cracks are created in the material, starting from the corners of the triangular impression. The crack lengths »c« and impression size »a« are measured by means of atomic force microscopy or scanning electron microscopy and these values then enter into the model beside the hardness H and the modulus of elasticity E of the material. The following materials were investigated: silicon (100), SiO_2 (fused silica), Al_2O_3 (sapphire), Si-DLC (diamond-like carbon), aC (amorphous hydrogen-free carbon), SnO_2, ZnO:Al, In_2O_3:Sn (ITO). The first three of these were bulk materials while the last five are thin coatings (thickness 0.5 to 5 µm). Validation was based on comparisons with K_{IC} reference values from the literature.

The models used

(1) $$K_C = A\left(\frac{E}{H}\right)^{1/2}\frac{P}{c^{3/2}}$$

(2) $$K_C = A\left(\frac{E}{H}\right)^{2/5}\frac{P}{c^{3/2}}$$

(3) $$K_C = A\left(\frac{E}{H}\right)^{2/5}\frac{P}{a\sqrt{l}}$$

(4) $$K_C = x_V\left(\frac{a}{l}\right)^{1/2}\left(\frac{E}{H}\right)^{2/3}\frac{P}{c^{3/2}}$$

(5) $$K_C = \frac{\lambda'}{t_f}\left(\frac{E}{H}\right)^{1/3}\frac{P}{c^{1/2}} + \psi'\sigma_R t_f^{1/2}$$

(6) $$K_C = \sqrt{\frac{E}{1-\nu^2}\frac{U}{F}}$$

Results

The graph shows the root mean square deviation between the measured K_{IC} values and the values from the literature. Equations 2 and 3 (Niihara) and also Equation 6 (Li) gave the best agreement with the literature. But, there is a number of sources of errors which, irrespective of the model, can lead to deviations from the reference values.

(a) Errors in determining the crack lengths since these can in some cases lie in the submicrometer range. (b) Undefined crack geometries: the models assume specific crack geometries beneath the surface (for example, Palmquist cracks or halfpenny cracks) which in reality do not necessarily have to be present. Examples may be seen in the illustrations at the top of the page: in figure 3, a well-defined halfpenny crack in SiO_2; in figure 4, an undefined crack geometry in silicon.

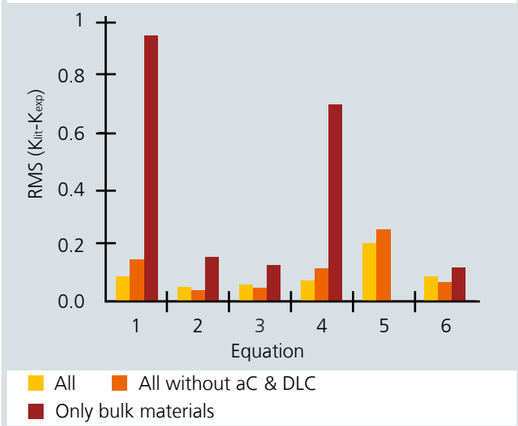
Finally, the coating thickness, the substrate material and intrinsic layer stresses also have a serious and hard to estimate influence on the determined fracture toughness. To a great extent this is not taken into account in the models. These sources of errors can resultin deviations of the measurement results in the range of 30 - 50%.

Summary

Although determining fracture toughness by means of nanoindentation offers a way of characterizing trends and rough differences between materials, it should, however, not be used when precision measurements are required.

[1] J.I. Jang, G.M. Pharr; Acta Materialia 56 (2008) p. 4458
[2+3] K. Niihara, et. al., J. Mat. Sci. Let. 1 (1982) 13
[4] M.T. Laugier, J. Mat. Sci. Lett. 6 (1987) 897
[5] J.M. Jungk, et al; Acta Materialia 54 (2006) 4043
[6] X. Li, D. Diao, B. Bhushan; Acta Mater. 45(11) (1997) 4453

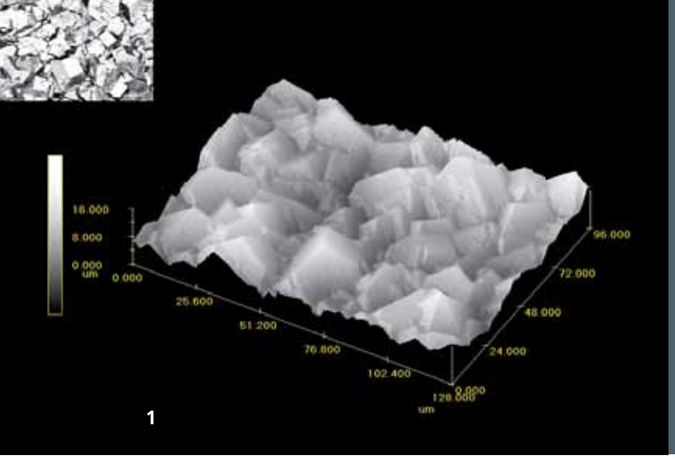
Mean square deviation of K_{IC}-values from experiment and from literature for the six models and for different subsets of samples.



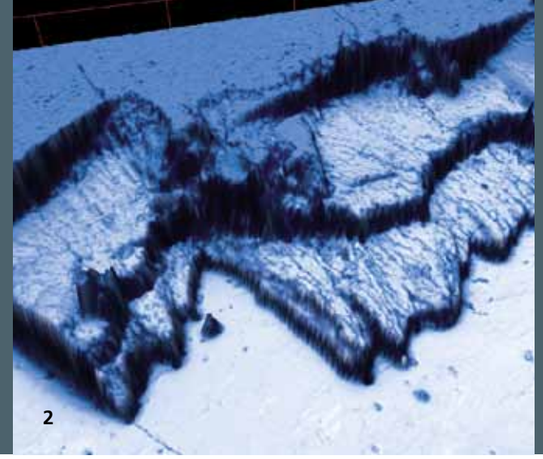
1 *AFM image of an impression in silicon.*
2 *AFM image of an impression in SnO:Al.*
3 *3D FIB tomogram of crack geometry beneath the surface of amorphous SiO_2.*
4 *3D FIB tomogram of the crack geometry beneath the surface of crystalline silicon.*

CONTACT

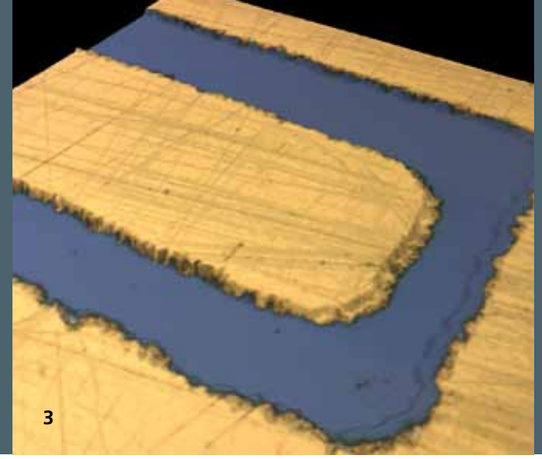
Dr. Kirsten Ingolf Schiffmann
Phone +49 531 2155-577
kirsten.schiffmann@ist.fraunhofer.de



1



2



3

DEEP INSIGHTS INTO DAMAGE ANALYSIS AND QUALITY ASSURANCE

Quality assurance in the case of coatings calls for a rapid analysis of the surface quality and one appropriate to their function. Confocal laser-scanning microscopy is very suitable for a wide variety of investigations into surface topography.

Surfaces are interfaces. They are exposed to special influences and often have specific functions to perform. If this top layer is flawed or of lower quality, this can quickly lead to far-ranging effects. For this reason the surface quality of coatings is an important quality criterion. By means of informative test procedures, which permit a fast and appropriate evaluation, a rapid detection of deviations in coating quality from a given standard is possible and losses due to defective batches can thus be kept low.

Confocal laser-scanning microscopy

With laser-scanning microscopy the surface can be scanned rapidly and contactlessly. In most cases it gives adequate lateral resolution and accurately analyzes the height of structures to 10 - 20 nm. In a few seconds images are recorded from a large number of focal planes at various depths and assembled to generate a 3-D image.

Evaluation

Different types of objects can be measured. Contactless 3-D measurements are highly precise in different kinds of 3-D analysis and make it possible to analyze the following parameters:

- Height
- Width
- Shape
- Angle
- Radius of cross-sectional profiles
- Surface-roughness analyses of line profiles and area-related roughness

Since the measuring point is visible on the screen, high-precision measurement results can be obtained for each microscopically small point.

Possible applications

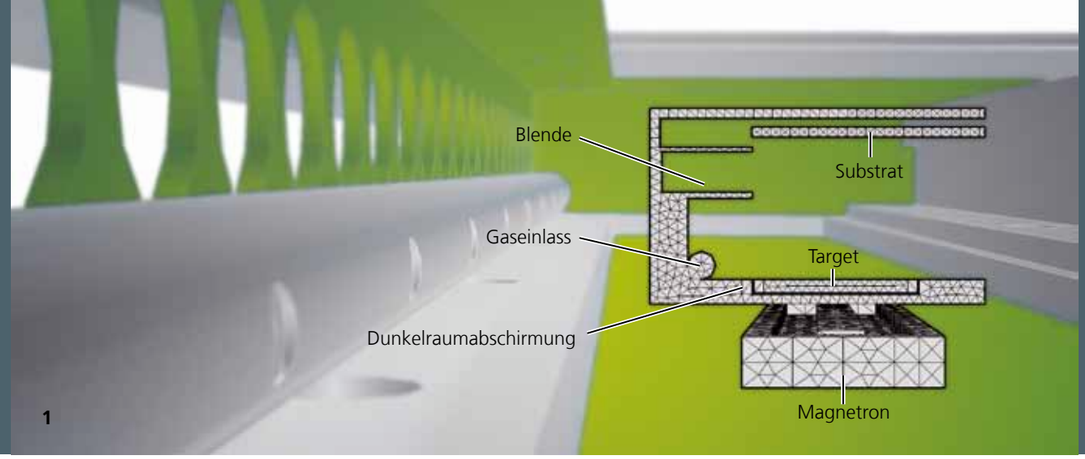
The instrument is very suitable for damage analysis. The components to be investigated do not have to be vacuum-tight as is the case with scanning electron microscopy. Furthermore, the surface is not additionally stressed by scanning with a diamond needle, as is the case with tactile measuring systems. Due to a very good vertical resolution, layer properties can be investigated (figure 1). An image of a coarsely crystalline diamond film is shown. The individual diamond crystals can be measured geometrically. Figure 2 shows an example for the damage analysis of an area of multilayered spalling about 3 µm thick. It is possible to measure the overall coating thickness and even that of the individual levels. Figure 3 shows part of a finger structure 400 nm thick. This example concerns a multilayer coating system of gas sensors used for measuring oxygen.

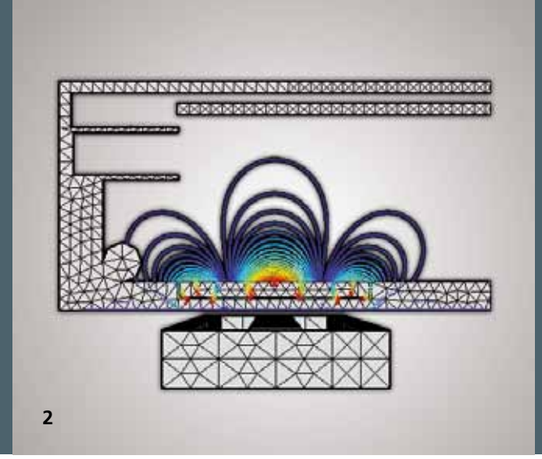
1 *Diamond film.*
2 *Multilayered spalling.*
3 *Sensor film for gas analysis.*

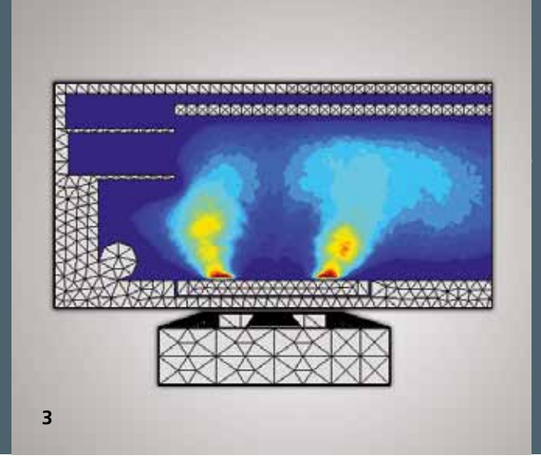
CONTACT

Dipl.-Ing. Reinhold Bethke
Phone +49 531 2155-572
reinhold.bethke@ist.fraunhofer.de

Antje Hipp
Phone +49 531 2155-575
antje.hipp@ist.fraunhofer.de







PIC/MC SIMULATION OF GAS FLOWS AND GAS DISCHARGES IN PLASMA REACTORS

At the Fraunhofer IST a parallel Particle-in-Cell Monte Carlo (PIC/MC) simulation software program has been developed with which gas flows and gas discharges can be simulated with spatial and temporal resolution in computational domains of any degree of complexity.

The particle-based Particle-in-Cell Monte Carlo simulation model is particularly suitable for simulating gas flows and gas discharges in the low-pressure or low-temperature range since the dynamics of gases and plasmas is simulated by means of representative macroparticles in a computational grid. The changes in particle states are calculated in discrete time steps as a function of field, wall and particle interactions. The averaged particle states thus supply a spatially and temporally resolved image of the macroscopic state variables in a gas or plasma.

Special features of the software

The PIC/MC simulation software at the Fraunhofer IST stands out on account of its efficient parallelization scheme. It allows PIC/MC processes, which require a lot of computing time and memory, to be distributed over any number of networked computer systems. Together with an automated distribution procedure securing an optimum computing load, the PIC/MC simulation program can thus be applied even to more challenging problems with a low degree of abstraction. A further special feature of the PIC/MC simulation software is an import filter for »finite-element surface meshes« for defining any reactor geometry. The freeware program »GMSH« is used as a mesh generator and this means that proprietary CAD file formats can be processed. The user-friendly interface is based on an automatically generated parameter file. In addition, various multiscaling functionalities, such as, for example, splitting grid cell and time step widths, make it possible to handle – with adequate performance – problems of industrial relevance in which time and longitudinal scales can vary over several orders of magnitudes.

Simulation at the Fraunhofer IST

Interest in the PIC/MC simulation software is reflected in the numerous inquiries and projects dealing with this topic, for example, in a large number of installations of the PIC/MC software in companies operating in the field of large-area coating. The IST has responded to this and other interest expressed in simulations in the field of surface technology by setting up a dedicated »Simulation« group. Areas of competence at a glance:

- Particle-in-cell Monte Carlo simulation
- Simulation-aided evaluation of surface analysis methods such as spectrophotometry, ellipsometry and X-ray reflectivity
- Evaluation of light-scattering behavior as a function of surface morphology
- Simulation of the mechanical properties of coating systems

Outlook

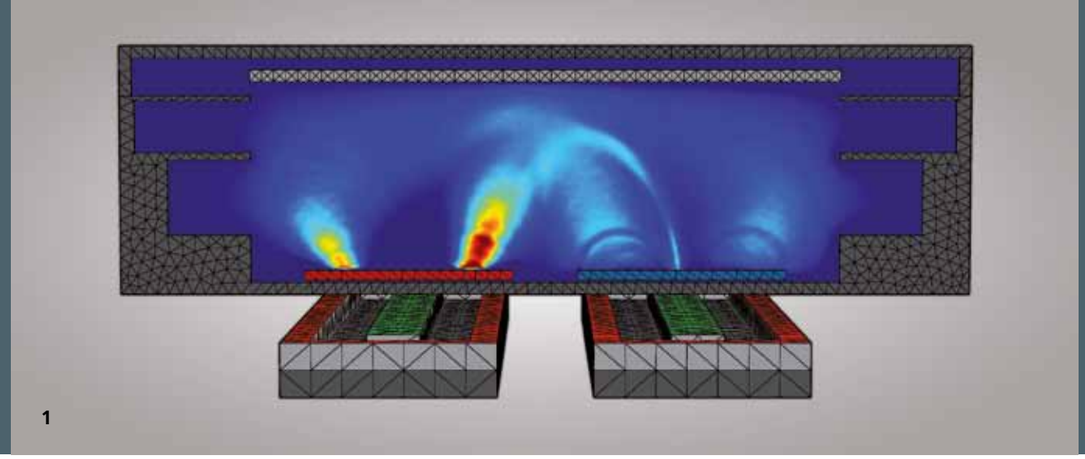
The PIC/MC simulation software is under continuous further development as regards variability and performance. This includes new techniques in numerical field computation which are expected to deliver speed increases up to one order of magnitude. As part of the BMBF »Plasma technology grid« project (page 78), incorporation into the D-Grid is impending, thus opening up further CPU resources for large and complex problems. Using D-Grid computing capacities offers freedom from the necessity of keeping one's own high-performance computing infrastructure available for PIC/MC simulation. Within this context a browser-based user interface is being implemented to make using the simulation software even more comfortable.

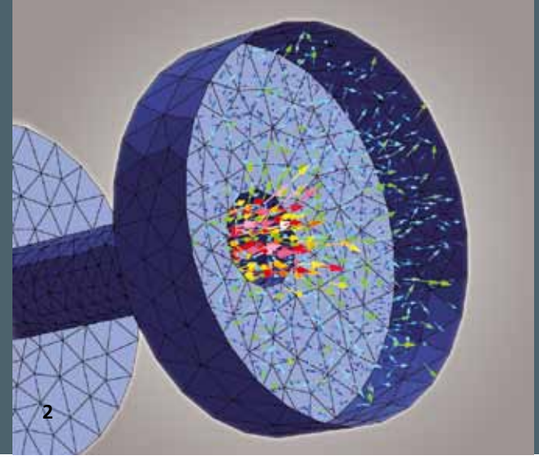
1 Layout of a magnetron sputtering chamber and its mapping as a »finite element mesh« in PIC/MC simulation space.
2 Isolines of magnetron magnetic field strength along the y axis.
3 PIC/MC-simulated electron density distribution of an RF-excited magnetron discharge.

CONTACT

Dipl.-Ing. Michael Siemers
Phone +49 531 2155-521
michael.siemers@ist.fraunhofer.de

Dr. Andreas Pflug
Phone +49 531 2155-629
andreas.pflug@ist.fraunhofer.de





PIC/MC SIMULATION WITHIN THE CONTEXT OF THE »PLASMA TECHNOLOGY GRID«

Simulating complex problems in the field of plasma coating technology calls for the use of parallel codes running on modern high-performance computers. One alternative to buying one's own hardware is to use a grid infrastructure or cloud computing. The particle-in-cell Monte Carlo (PIC/MC) simulation software developed at the Fraunhofer IST for low-pressure gas flows and gas discharges is currently, as part of the BMBF's Plasma Technology Grid project, being ported for utilization in the D-Grid. Performance increases of up to 50% have been achieved by using the latest parallelization techniques and optimized calculation modules. Handling of the code has also been considerably simplified.

Description

The progressive scaling-up of industrial production lines makes improvements necessary not only in throughput but also in the precision of coating installations. The increasing size and complexity of these installations makes it more difficult to develop them further with the aid of purely experimental methods. This is where simulation methods come in. They allow the acquisition of a detailed understanding of complex plasma coating processes with the result that the number of expensive prototypes can be reduced. As part of the BMBF's Plasma Technology Grid project, coordinated by INP Greifswald, a plasma modeling platform within the D-Grid infrastructure is being established in association with nine funded partners from the business, science and research sectors (www.pt-grid.de). The Fraunhofer IST's contribution here is porting its own development, the particle-in-cell Monte Carlo simulation environment for low-pressure plasma coating processes. In addition to accessing greater hardware resources, the aim is to set up an internet-based service portal which will allow small and mid-sized companies an entry into the world of plasma modeling. The advantage is that expensive investigations in high performance computing hardware and lengthy training periods can be omitted.

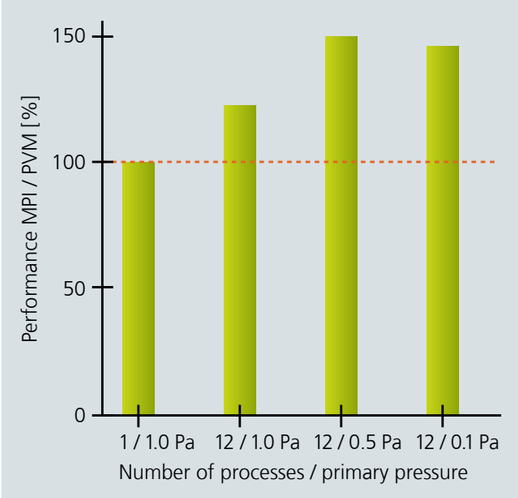
Porting the PIC/MC software environment

To simplify installation on external computer hardware and to ensure a better connection to a grid engine, the PIC/MC simulation software has been ported to OpenMPI, which is the de-facto standard for message based parallelization. In addition to delivering improved compatibility, this also reduces network latencies and results in performance increases of up to 50%. This applies in particular to calculations in the case of low pressures with a high communication fraction (see graph and figure 2). Furthermore, during the course of porting, there were considerable improvements in the parallelization and performance of the field computation modules. Validation of the ported version with the aid of test cases such as, for example, the model of a bipolar magnetron sputtering process shown in figure 1, has been completed. There are no significant differences in calculation results between the previous and the new version.

Outlook

In the next step an internet-based user interface will be implemented. The user is to be able to create locally a CAD model of the reactor geometry and upload a mesh representation to an internet portal. For the simulation parameters the internet portal then generates input masks corresponding to the surface element types in the geometry and allows remote operator control and run-monitoring of the simulation. The final results can be accessed and worked on locally with further post-processing tools. This approach means that the user does not need to tackle scripting languages or get involved with different programming environments while entry thresholds for using the simulation software have been lowered.

Benchmark of the PIC-MC fluid simulation (Fig. 2) before and after porting. At high communication load the new version, ported to MPI, scales considerably better.

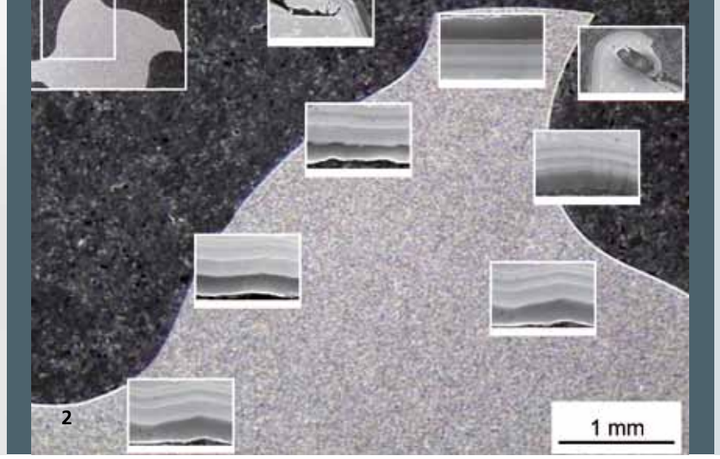


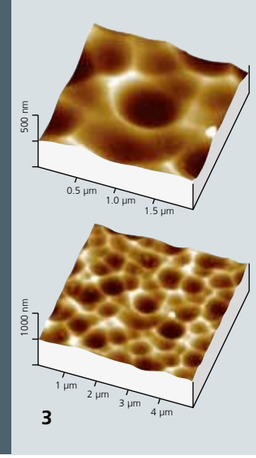
1 *PIC/MC simulation of a 2D-model of a magnetron coating installation. Simulation was carried out using the PIC/MC simulation environment ported to MPI.*

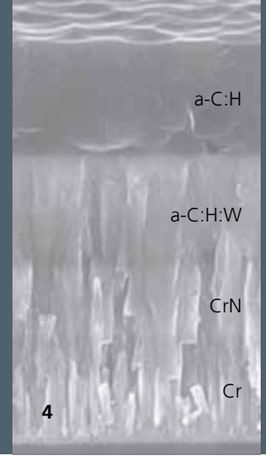
2 *Pipe flow geometry for comparative benchmarking of PIC/MC flow simulation (see also graph).*

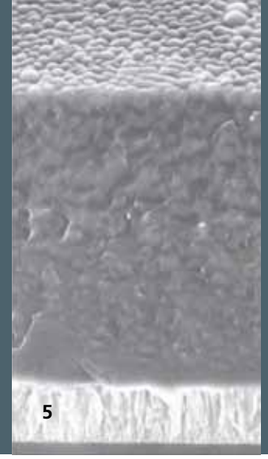
CONTACT

Dr. Andreas Pflug
Phone +49 531 2155-629
andreas.pflug@ist.fraunhofer.de









MAGNETRON SPUTTERING FOR THE DEPOSITION OF HARD AND WEAR RESISTANT DLC COATINGS

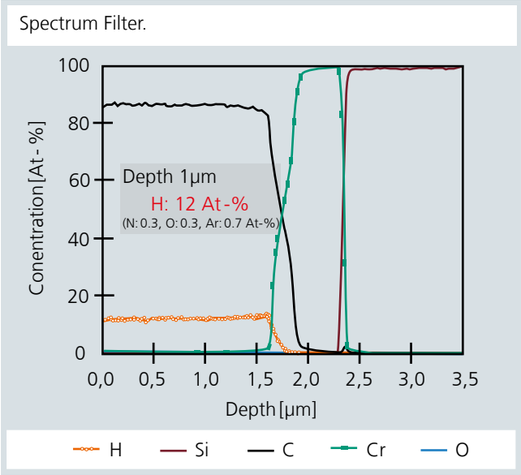
DLC coatings are in widespread use in industry but harder and more wear resistant DLC coatings are required for further increases in performance in tribological applications. Coating deposition by a modified magnetron sputtering method here offers a great potential.

DLC coatings

Diamond-like carbon (DLC) coatings combine a large number of interesting and exceptional properties, such as, for example, high hardness, high wear resistance and low coefficients of friction. For this reason DLC coatings have a high potential in tribological applications. DLC coatings are already used today in many industrial applications, such as in the automotive industry, in mechanical engineering and for tools. Due to relatively low deposition temperatures (< 200 °C) many components can be coated without exceeding annealing temperatures. DLC coatings consist of a network of sp^2- and sp^3-bonded carbon atoms and hydrogen. Hard DLC coatings (plastic universal hardness or HUplast ≥ 30 GPa) are under high internal compressive stresses which often have a negative effect on layer adhesion and thus limit applications for the coatings. DLC coatings (a-C:H coatings) are in most cases manufactured industrially by PACVD methods. A relatively new development is the deposition by means of reactive magnetron sputtering with graphite targets. The designation C-DLC has been introduced for a-C:H coatings produced in this way. This method is suitable for securing a higher coating hardness, or for depositing modified DLC coatings, both on variable intermediate layers, thus following the trend towards higher hardness, adhesive strength and heat resistance.

C-DLC with booster and pulsed magnetron sputtering

Booster technology here means support for the UBM effect (Unbalanced Magnetron) by additional electromagnetic coils. This results in an increase in ion density in the substrate region. Such a technique permits the deposition of C-DLC coating systems with hardnesses greater than 40 GPa. The hydrogen content of the DLC coatings correlates in this method with the layer hardness and, at the hardness of 40 GPa and more, is in the range of 10 atom %, in contrast to commercial DLC coatings with approx. 15 - 20 atom %. Higher reactive-gas flow rates (C_2H_2) make higher coating rates possible and thus improve the cost efficiency of the processes. Pulsed magnetron sputtering, without booster support, offers similar advantages. The ion density is increased even with this method and due to the pulsed operation of the targets high reactive-gas flow rates and thus higher coating deposition rates are possible.



Process optimization for components, tools and the development of modified C-DLC coatings

One advantage of PVD deposition is the use of different intermediate layer systems and a gradual transition to the DLC layer. Due to this high degree of flexibility, tailored intermediate layer systems can be developed and applied. Despite the high compressive stresses in the DLC coatings, they have a very good adhesion and performance, even under cyclic loads. Currently optimum equipment utilization combined with a high coating hardness above HV 4000 and the deposition of C-DLC coating systems on components with complex geometries are under development.

In addition, the Fraunhofer IST is using d.c. or pulsed magnetron sputtering techniques to dope C-DLC coatings with additional atoms so as, for example, to reduce friction or to achieve higher operating temperatures. The first series of tests already suggests that the reactive sputtering with acetylene of silicon-based targets could be a very promising technique.

Outlook

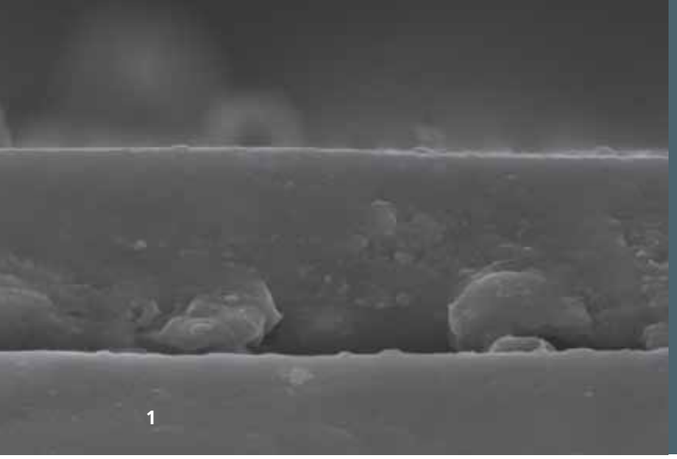
Further development work at the Fraunhofer IST is directed towards higher deposition rates, doping with different elements such as boron, nitrogen or silicon in order to modify wetting behavior and surface energies, and also to higher heat resistances in the coatings.

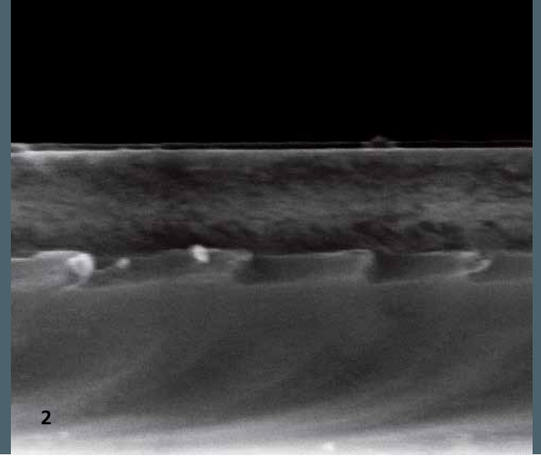
1 *A milling cutter with a C-DLC coating system.*
2 *Microscope image of the coated milling cutter in a cross section view (incl. SEM detailed images).*
3 *Two AFM images of the surface of the C-DLC coating system (»dimpled surface«).*
4 *SEM fracture cross section image of a C-DLC coating system.*
5 *SEM fracture cross section image of a sputtered a-C:H:Si coating.*

CONTACT

Dr. Klaus Bewilogua
Phone +49 531 2155-642
klaus.bewilogua@ist.fraunhofer.de

Dr.-Ing. Martin Keunecke
Phone +49 531 2155-652
martin.keunecke@ist.fraunhofer.de





DENSE ISOLATING COATINGS BY MEANS OF MODULATED PULSE PLASMA (MPP) SPUTTERING

Modulated pulse plasma (MPP) sputtering is a technique for pulsed highly-ionized plasma deposition. With this method it is possible to influence the ionization of the plasma within a macropulse so that coating properties can be obtained which are better than conventional sputtering methods and additionally offer higher deposition rates than HiPIMS processes.

MPP: sputtering technology

Modulated pulse plasma (MPP) is an alternative approach to the common HiPIMS technology which has been intensively investigated for a number of years now. In contrast to HiPIMS, which works typically with single micropulses, MPP uses macropulses made up of multiple pulse segments. By changing the t_{on} and t_{off} duration of the individual pulse segment within the macropulse, different voltage levels can be adjusted at the target. This makes it possible to have a low- and a high-ionized phase within one macropulse. The low-ionized phase is primarily used for igniting and stabilizing the plasma. For reactive sputtering the duration of the high-ionized phase was set to approximately 30 % of the total macropulse length. Characteristic values for a MPP process are peak power densities up to a few hundred W/cm², mean power levels up to 20 kW and a macropulse duration of up to 3000 microseconds (µs).

MPP: process control

To stabilize the plasma and produce a glasslike coating it is necessary to create a suitable sequence of pulse segments within a macropulse. In this way it is possible to deliberately limit the voltage rise during plasma ignition and during the transition from the low- to the high-ionized phase. Due to the low-ionized phase and the limited voltage rise the target is optimally prepared for the high-ionized phase. This means that a higher coating quality can be achieved at deposition rates of industrial interest.

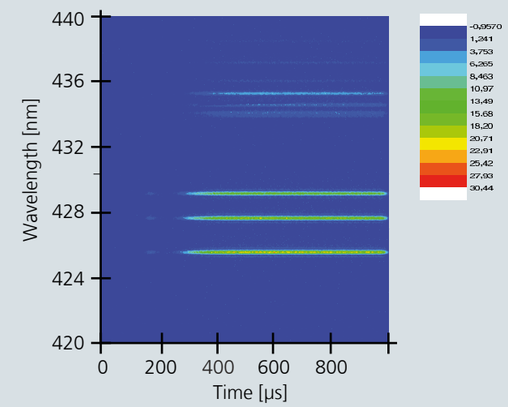
Alumina coatings as isolators

Alumina coatings (Al_2O_3) as electrical and chemical barrier layers are normally produced by the reactive sputtering of metallic targets. As compared with conventional sputtering methods, MPP sputtering delivers improvements in the deposition rate, structure as well as dielectric strength. The deposition rate lies within the range of comparable, controlled medium-frequency processes. In contrast to the usual columnar growth a denser glasslike coating is produced. With the same stoichiometry the dielectric strength can be increased significantly with a glasslike coating structure.

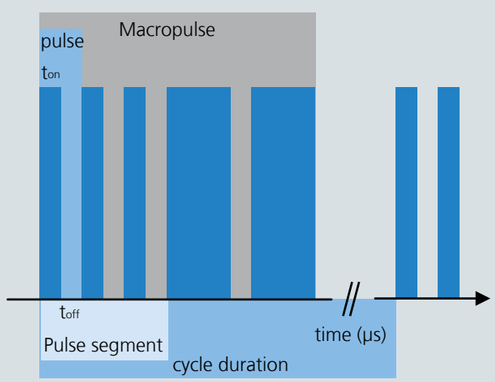
Outlook

The modulated pulse plasma method makes possible a process with optimized coating properties. In comparison with radio-frequency sputtering (RF), which is state of the art for industrial aluminum oxide deposition processes, the coating deposition rate can be raised approximately tenfold with MPP sputtering. With optimized coating properties the coating thickness can be reduced and the duration of the process cut further.

Build-up of an MPP pulse pattern, OES diagram of MPP pulse.



Sequence of a MPP macropulse.



1 *REM image of a MPP coating.*

2 *REM image of a conventional coating.*

CONTACT

Dr. Ralf Bandorf
Phone +49 531 2155-602
ralf.bandorf@ist.fraunhofer.de

1 *Q-Plas e-learning on the PC.*

Q-PLAS: A NEW FURTHER EDUCATION PROGRAM WITH PRACTICAL TRAINING

The wide variety of possible applications for plasma technology means that product characteristics can be further developed and improved and even new product solutions created. Although plasma technology has been very thoroughly researched and the corresponding techniques have now matured, so far only a few companies have exploited the possibilities of securing competitive advantages and of opening up new markets. In most cases the reasons for this are a lack of knowledge about the potential of plasma technology as well as incorrect assumptions about the requirements bound up with its use in industrial manufacturing.

Plasma technology has made a decisive impact on the quality level, on the functionalities of many products and on production methods. A large number of modern products would be inconceivable without plasma technology: CDs, Blu-ray disks, DVDs, hard drives, anti-reflection coated and scratch-resistant spectacles, thermal insulation coatings and anti-reflection coatings on windowpanes and LCD television screens. Plasma technology offers some outstanding solutions in many other areas of application as well.

The problem

Until now only a few companies have exploited the possibilities of plasma technology for securing competitive advantages and for opening up new markets. In most cases the reasons for this are a lack of awareness of the potential of plasma technology as well as incorrect assumptions about the requirements bound up with its use in industrial manufacturing. No suitable comprehensive courses are available in which technicians or graduate engineers, for example, can acquire a basic technical knowledge not only of the engineering science aspects but also of the relevant plasma physics.

The solution

With Q-Plas, a qualification initiative funded by the Federal Ministry of Education and Research (BMBF) and developed under the auspices of the Fraunhofer IST in Braunschweig, there is now a program available which makes it easier for companies, especially small or medium-sized enterprises, to effect an entry into plasma technology. Companies are given an opportunity to acquire the knowledge upon which a well-founded assessment of the possible applications and potentials for plasma technology within their own business field is based. Q-Plas is a concept which combines events requiring physical attendance (practical sessions in the lab) with a virtual learning program (e-learning).

Workshop for decision-makers

The decision-makers workshop addresses all decision-makers who are enthusiastic about innovation and also potential users of plasma technology who wish to gain a rapid overview of the plasma field. On the basis of a large number of examples, participants will learn about the great potential offered by plasma technology. The first workshop was held at the Fraunhofer IST in November 2009 with numerous interested participants from various branches of industry finding out about the opportunities which Q-Plas can offer.

E-learning and practical training

The e-learning side is modular in structure - in other words, course contents can be combined on an individual basis. Students are assigned a tutor accompanies them for the entire duration of the e-learning course. The primary target group includes skilled workers, technicians and engineers seeking to acquire a basic knowledge for their practical work. Participants in the practical lab sessions are given direct access over three days to actual plasma installations, thereby gaining insight into the processes and practical work, thus learning to apply and deepen the knowledge they have gained from e-learning. The groups are given concrete problems to discuss after which their proposed solutions can be tried out in practice.

Implementation and launch

This qualification initiative has been developed in collaboration with the Leibniz Institute of Plasma Research and Technology (INP) in Greifswald, with the Research Center for Micro-Structure Engineering (FMT) of the University of Wuppertal and with the Ruhr University of Bochum. The VDI Technologiezentrum GmbH supports and accompanies the project as project sponsor. Q-Plas is currently in the certification phase, but from the summer of 2010 Q-Plas will be open for all interested parties.

CONTACT

Dipl.-Ing. Marko Petrik
Phone +49 531 2155-509
marko.petrik@ist.fraunhofer.de

Dipl.-Ing. Carola Brand
Phone +49 531 2155-574
carola.brand@ist.fraunhofer.de

NAMES, DATES, EVENTS 2009

In 2009 the Fraunhofer IST once again appeared on various platforms. An overview of the most important events and activities of 2009 follows:

- Trade fairs and conferences
- Workshops
- Exhibitions and institute visits
- Trips abroad
- Committee activity
- Prizes and honors

TRADE FAIRS AND CONFERENCES

SVC 2009
Santa Clara, California, May 9-14, 2009. A Kawasaki Ninja motorcycle formed the centerpiece of the Fraunhofer IST stand at the 52nd conference of the Society of Vacuum Coaters (SVC). The institute's presentation focused on motorcycle-related surface engineering and thin film applications, such as, for example, tribological coatings, developments in the field of photo-catalytically active and optical coatings and also large-area coating. Great interest was also aroused by contributions concerning the DataPlas patent database and on simulation in surface engineering and thin film technology.

Hannover Fair 2009
Hannover, April 20-24, 2009. The Fraunhofer IST, together with the Fraunhofer Alliance for Photocatalysis, the Fraunhofer MAVO METCO project, the Fraunhofer IWM and the Network of Competence INPLAS, participated in the joint stand of the Fraunhofer-Gesellschaft at this premier trade fair in the field of surface technology which is held every other year. Scientists presented examples of actual applications for surface engineering and thin film technology centered on a racing car. Key topics included thin-film sensor systems, tribological coatings on components and tools, as well as applications for coating glass and plastics. In the racing car itself, making a simulated pit stop, the Fraunhofer IST's Micro- and Sensor Technology group demonstrated a smart washer for measuring the clamping force of screwed connections. The washer, which has a DiaForce® piezoresistive sensor coating, makes possible a simple diagnosis of the strength of the screwed connection. On Fraunhofer's Adaptronics joint stand and also its main stand, Fraunhofer IST scientists showed how adaptronic and sensoric components could become even more inexpensive by the use of new material systems. On the Simulation joint stand, the IST showcased the latest results in the field of simulation in product and process development.

PVSEC 2009
Hamburg, September 21-25, 2009. At the technical exhibition accompanying the 24th PVSEC European solar energy conference in Hamburg the Fraunhofer IST presented, as part of the Fraunhofer MAVO METCO project, transparent conductive coatings for different photovoltaic and heating-layer applications.

Produktronica 2009
Munich, November 10-13, 2009. The Fraunhofer IST participated in the »Research association for three-dimensional assemblies 3-D MID e.V.« joint stand at the 18th Produktronica, the world's leading trade fair for innovative electronics production. Amongst other items on view were intelligent washers, thin-film sensor systems, compressed air cylinders with encoded coatings, flexible circuit boards and sputtered strain gauges for monitoring bearings.

OTTI TCO conference
Neu-Ulm, September 30-October 2, 2009. The Fraunhofer IST was also in Neu-Ulm at the third OTTI conference focusing on »Transparent conductive oxide coatings (TCO)«. In the technical exhibition accompanying the conference the Fraunhofer IST presented the latest developments for industrial surface technology including some in the field of electrically conductive contact layers.

OTTI Glass and Solar conference
Jena, October 28-29, 2009. At the first OTTI conference on glass and solar technology the Fraunhofer IST presented its extensive technical knowledge and expertise, ranging from production to applications in the field of glass and solar technology.

Glass Performance Days 2009
Tampere, Finland, June 12-15, 2009. In conjunction with the Fraunhofer MAVO METCO project the Fraunhofer IST participated in the »Glass Expo« exhibition accompanying the Glass Performance Days (GPD) in Tampere, Finland. For four days an international public was able to view the institute's exhibits, which included a heating layer on a glass tube, a gas flow sputtering source, a dichroic filter, a transparent solar cell, various p-TCOs and also glass which is first coated and then given curvature.

Opening of the »House of Science«
Braunschweig, May 18, 2009. At the opening of the House of Science the Fraunhofer IST was a participant in the accompanying exhibition and with an auto engine and various engine components presented applications for surface engineering and thin film technology in the automotive field.

WING-nano.DE.2009
Ulm, April 1-3, 2009. At the BMBF conference focusing on the topic of »Raw materials for innovations«, the Fraunhofer IST's Micro- and Sensor Technology group was represented with a contribution to the SenWerkum project, which is funded by the Federal Ministry of Education and Research (BMBF).

RETECZA
Kwa Maritane, Pilanesberg, South Africa, June 22-24, 2009. The Fraunhofer IST took part in the founding event and first conference of the RETECZA Initiative. Within the context of a »resource-driven technology concept center« inexpensive and autonomous solutions are to be developed for house construction, infrastructure and also for motor vehicles suitable for use in remote regions of South Africa. In addition to the South African hosts, experts from the USA, Sweden, Italy and Germany took part in the conference. Here the Fraunhofer IST will contribute its expertise in the field of »Water treatment with diamond electrodes«. Direct collaboration with the Tshwane University of Technology (TUT) in Pretoria is planned.

Fraunhofer traveling water conference
China, November 2009. As part of the first Fraunhofer Traveling Conference, which was organized by the Business Development department of the Fraunhofer-Gesellschaft, six institutes showcased their areas of competence in the field of »Water« in various major cities in China, including Beijing, Shanghai and Ningbo. Here too the Fraunhofer IST contributed its expertise in »Water treatment with diamond electrodes«.

WORKSHOPS

18th meeting of the »Tool coatings and cutting materials« industry work group
Berlin, March 25-26, 2009. In March the »Tool coatings and cutting materials« industry work group met in Berlin at the PTZ (Production Technology Center). Here industry work groups which until then had been separately organized, such as the »Tool coatings and cutting materials«, »Ceramic machining«, »Machine tools« (the »Berlin Group«), »Dry-ice blasting and material removal« and »Microproduction technology« groups, were brought together on a one-off basis in a joint event at the Berlin Industry Work Group (BIAK). With more than 200 participants from the most varied small and medium-sized companies and concerns in Germany, Austria, Luxembourg and Switzerland, the plenary sessions on the first day and the special workshops on the second day were very well attended.

19th meeting of the »Tool coatings and cutting materials« industry work group
Berlin, September 29, 2009. At the September meeting of the »Tool coatings and cutting materials« industry work group at the PTZ (Production Technology Center) in Berlin the focus was, among others, on the following topics: internal stresses in CVD-diamond-coated tools, PVD coatings for hobbing cutters, batch machining of CFRP components, internal cooling of cutting tools, and magnetic finishing as an alternative surface finishing method.

1st workshop for decision-makers: Q-Plas
Braunschweig, November 12, 2009. Under the slogan »With plasma technology to new products« all decision-makers keen on innovation and interested potential users of plasma technology who wanted an overview of plasma technology and opportunities of further training in this field were invited to the Fraunhofer IST. The workshop was organized by Q-Plas, a further training program funded by the Federal Ministry of Education and Research (BMBF).

PRICES

The technology transfer prize of the Braunschweig Chamber of Commerce and Industry awarded to scientists of the Fraunhofer IST
For their successful work on the development, application and transfer of the diamond-coated ceramic composite material DiaCer® for ceramic seals, Dr. Lothar Schäfer and Dr. Markus Höfer have been awarded the €10,000 technology transfer prize for 2009 of the CCI Braunschweig. In close collaboration with the companies EagleBurgmann Germany GmbH & Co. KG and Condias GmbH, the prize winners built on their research results to bring the concept of ceramic face seals up to readiness for production. These seals, which as yet are unique on the market, are sold globally by EagleBurgmann under the trade name DiamondFaces®.

Combining the two materials enables the extreme properties of diamond coatings to be coupled with the advantages of ceramic bodies. The diamond-coated seals developed by the researchers are particularly characterized in application by offering maximum wear protection and low coefficients of friction under the highest stresses, thereby considerably extending the service lives of the seals. »Pumps in challenging areas of application such as oil production often suffer from heavy wear due to rock particles getting into the seal gap. Acceptable service lives have been achieved for the first time with diamond-coated face seals«, explains Lothar Schäfer. The deposition of a diamond film only a few micrometers thick on the ceramic seal creates a new high-performance composite material, the DiaCer® diamond-coated ceramic. Neither a lack of lubrication nor abrasive particles getting into the sealing gap can harm these diamond-modified seals. »This application presents the greatest challenges to the precision of our coating technology since the planeness of the slide faces should not change by more than a few hundred nanometers«, explains Dr. Markus Höfer. In this way an extremely high-performance and internationally competitive product has been created which is regarded by industry insiders as a breakthrough innovation in the field of seals and which has also been given two international product awards.

Every year the technology transfer prize of the Chamber of Commerce and Industry of Braunschweig honors scientists and now also entrepreneurs for their exemplary commitment to and high personal engagement in transfer-oriented research.

1 *From left: CCi president Dr Wolf-Michael Schmid, Dr Markus Höfer, Dr Lothar Schäfer, jury chairman Prof Werner Gramm.*

EVENTS

Girls' Day at the Fraunhofer IST
In 2009 young girls once again had the chance to spend a working day at the Fraunhofer IST. The eight participants in Girls' Day focused on trying out their technical skills as, they fabricated microstructures in the yellow-light laboratory wearing clean-room clothing. Decorative images were structured into a chromium layer by means of photolithography followed by wet-chemical etching. The girls then used optical microscopes and profilometers to examine the patterns. By doing so the young students gained insight into the full process chain typical of microtechnology. »The amount of interest with which the students mastered these challenging tasks is amazing. We very much hope to see some of them working here at the institute in the future«, said the institute's equal opportunities officer, Saskia Biehl, about the commitment displayed by the girls.

Visit of the Minister of Science of Lower Saxony to the Fraunhofer IST
In May 2009 the Minister for Science and Culture of Lower Saxony, Lutz Stratmann, visited the Fraunhofer IST. The science minister came in person to learn more about the latest results of research at the institute.

The Fraunhofer IST is a new board member of the DFO
At the general meeting of the DFRO (Deutsche Forschungsgesellschaft für Oberflächenbehandlung e.V.), Wolfgang Diehl, acting director of the Fraunhofer IST, was elected as a new member of the DFO executive board.

The Fraunhofer IST is on the board of directors of the SVC
The acting director of the Fraunhofer IST, Wolfgang Diehl, was elected in 2009 to the board of directors of the Society of Vacuum Coaters (SVC) as a representative of the Fraunhofer IST. This means that the Fraunhofer IST is now represented in one of the most influential international societies for surface coating.

Fraunhofer-Truck on the Kohlmarkt in Braunschweig
Braunschweig, March 28, 2009. Fascinating, visionary and open to everyone: The Fraunhofer-Truck stopped in Braunschweig. For a whole day the Fraunhofer IST in collaboration with the Fraunhofer WKI showed high-tech surfaces »at your fingertips«. Energy-saving functional surfaces for the architectural and automotive industries, for example transparent and electro-conductive coatings, were presented. These coatings allow thermal insulation on glass so that heat remains inside in wintertime and stays out in the summer. A pendulum driven by nitrogen was also shown to demonstrate the advantage of friction-reducing coatings as used for, e.g., motors. That way future was brought to life / An event which brought future to life.

Parliamentary Evening 2009 - »Potentials of plasma technology«
The first Parliamentary Evening of the INPLAS e.V. competence network, focusing on the theme of plasma technology, was held on March 18, 2009 in the Fraunhofer representative office in Berlin. The aim was to present the cross-sectional technology's broad and in many cases still unutilized potential for applications and future use to a top-level audience from politics, economy, industry, and science. In her speech, Edelgard Bulmahn, Member of the Bundestag, gave an overview of plasma applications to date and outlined visions for the future. A film specially produced for this evening revealed the diverse ways in which plasma surface technology is already being used today - from the automotive industry, aerospace, optics, medicine and life science, information technology, energy and environmental technology to mechanical engineering and tool manufacture. At the accompanying industrial exhibition »Plasma: a bright advantage«, the Fraunhofer IST provided an insight into the application of plasma technology in the field of surface and thin film technology, showcasing an automotive engine, multiple engine components and coated turbine blades.

Board Memberships

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

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

Bandorf, R.: Society of Vacuum Coaters (SVC), »High Power Impuls Magnetron Sputtering«, Co-Chairman.

Bandorf, R.: International Conference on Metallurgical Coatings and Thin Films (ICMCTF), »High Power Impulse Magnetron Sputtering«, Chairman.

Bandorf, R.: International Conference on HIPIMS (HIPIMS 2010), Conference Co-Chair.

Bandorf, R.: COST Action MP0804 Highly Ionised Pulse Plasma Processes (HIPP processes), Action Chair.

Bandorf, R.: International Symposium on Discharges and Electrical Insulation in Vacuum 2010, Local Organizing Committee Member.

Bewilogua, K.: DGM-Arbeitskreis »Materialkundliche Aspekte der Tribologie und der Zerspanung«, Mitglied.

Brand, C.: Arbeitskreis Plasmaoberflächentechnologie (Plasma Germany), Mitglied des Koordinierungsausschusses.

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

Brand, J.: Europäische Forschungsgesellschaft Dünne Schichten e.V. (EFDS), Leitung des Fachausschusses »Tribologische Schichten«.

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

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

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

Bräuer, G.: Europäische Forschungsgesellschaft Dünne Schichten e.V. (EFDS), Mitglied.

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

Bräuer, G.: International Conference on Coatings on Glass (ICCG), Mitglied des Organisationskommitees.

Bräuer, G.: ISFH, Mitglied des Beirats.

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

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

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

Diehl, W.: Deutsche Forschungsgesellschaft für Oberflächenbehandlung DFO, Mitglied des Vorstands.

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

Diehl, W.: ForschungRegion Braunschweig, Mitglied des Lenkungskreises.

Diehl, W.: Glass Performance Days (GPD), Mitglied des Advisory Boards.

Diehl, W.: Humboldt-Stiftung, Gutachter.

Diehl, W.: Society of Vacuum Coaters (SVC), Mitglied des »International Relations Committee«.

Diehl, W.: Society of Vacuum Coaters (SVC), Mitglied des Board of Directors, Chairman »Thin Film Photovoltaics«.

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 DGO, Mitglied.

Dietz, A.: Gesellschaft für Korrosionsschutz (GfKorr), Mitglied.

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

Gäbler, J.: Industrie-Arbeitskreis »Werkzeugbeschichtungen und Schneidstoffe«, Leitung.

Gäbler, J.: Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS, Arbeitsgruppenleiter Werkzeuge.

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

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

Jung, T.: Arbeitskreis »Mechanische und Schutzschichtanwendungen« im Kompetenzzentrum Ultradünne funktionale Schichten Dresden-Chemnitz, Mitglied.

Keunecke, M.: European Technology Platform for Advanced Materials and Technologies EuMaT, Mitglied.

Keunecke, M.: International Conference on Metallurgical Coatings and Thin Films (ICMCTF), »Carbon and Nitride Materials: Synthesis-Structure-Property Relationships – Session D1«, Chairman.

Klages, C.-P.: Fachausschuss »Oberflächen und Beschichtungen in der Bio- und Medizintechnik« (FABM) der Europäischen Forschungsgesellschaft Dünne Schichten e.V. (EFDS), Mitglied.

Klages, C.-P.: International Journal of Refractory Metals & Hard Materials, Mitglied des Editorial Advisory Boards.

Klages, C.-P.: Projektbegleitende Arbeitsgruppe »Sensorik« der Fachhochschule Westküste, Mitglied.

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

Neumann, F.: CEN/TC386 »Photocatalysis«, Mitglied der Arbeitskreise WG4 »Selfcleaning« und WG6 »Light Sources«, Europäisches Komitee für Normung.

Schäfer, L.: Industriearbeitskreis »Werkzeugbeschichtungen und Schneidstoffe«, Mitglied.

Schäfer, L.: International Conference on New Diamond and Nanocarbons NDNC-2008, Program Committee Member.

Schäfer, L.: Nano- und Materialinnovationen Niedersachsen e.V. (NMN), Mitglied.

Schäfer, L.: Nanotechnologie-Kompetenzzentrum Ultrapräzise Oberflächenbearbeitung CC UPOB e.V., Mitglied.

Schäfer, L.: VDI-Richtlinien-Fachausschuss »CVD-Diamant-Werkzeuge«, Mitglied.

Schiffmann, K.: Arbeitskreis »Rasterkraftmikroskopie in der Werkstoffwissenschaft« im Fachausschuss »Metallographie« der DGM, Mitglied im Lenkungsausschuss.

Thomas, M.: Fachausschuss »Oberflächen und Beschichtungen in der Bio- und Medizintechnik« (FABM) der Europäischen Forschungsgesellschaft Dünne Schichten e.V. (EFDS), Mitglied.

Vergöhl, M.: Arbeitskreis »Dünne Schichten für die Optik«, DIN Deutsches Institut für Normung e.V., Mitglied.

Weber, M.: Europäische Forschungsgesellschaft Dünne Schichten e.V. (EFDS), Leitung des Fachausschusses »Beschichtung von Formen und Werkzeugen für die Kunststoffverarbeitung«.

International Guests

Frau Yang Ying, B. E., Institute of Metal Research, Chinese Academy of Sciences, Shenyang, Volksrepublik China, 19.11.2008–27.11.2009.

Patent Applications

Bandorf, R.: Gehäuse mit einer Beschichtung.

Biehl, S.: Aktuator mit integriertem Zustandsüberwachungssystem, Verfahren zur Zustandsüberwachung sowie Verfahren zur Herstellung eines Aktuators.

Biehl, S.: Drehzahlmessung für rotierende Maschinenelemente mit Hilfe piezoresistiver Dünnschichtsysteme.

Biehl, S.: Kontaktlose Drehmoment- und Kraftmessung.

Biehl, S.; Hauschild, F.; Staufenbiel, S.: Signalführungsvorrichtung und Sensor mit einer solchen.

Bruns, S.; Werner, O.; Vergöhl, M.: Verfahren zur Abscheidung von Oxinitridschichten.

Jung, T.: Gasflusssputterquelle.

Jung, T.: Hohlkathoden-Plasmaquelle.

Klages, C.-P.; Michel, B.; Eichler, M.: Verfahren zum zwischenschichtfreien Verbinden von Substraten, Vorrichtung zur Durchführung einer Plasmabehandlung sowie deren Verwendung.

Neumann, F.; Graumann, T.: Verwendung von lumineszenten Organometallverbindungen zur Bestimmung der Aktivität des photokatalytischen Abbaus von photokatalytisch aktiven Oberflächen durch Lumineszenzlösung.

Pflug, A.; Siemers, M.; Sittinger V.; Szyszka, B.; Ulrich S.: Magnetron-Beschichtungsmodul sowie Magnetron-Beschichtungsverfahren.

Sittinger, V.; Szyszka, B.; Dewald, W.: Verfahren zur Herstellung einer optimierten Ätzstruktur von ZnO:Al-Schichten als Frontkontakt für Silizium-Dünnschichtsolarzellen.

Szyszka, B.; Pflug, A.; Rademacher D.; Vergöhl, M.: In-Situ-Messaufbau für den Einsatz in Beschichtungsanlagen.

Thomas, M.; Eichler, M.; Klages, C.-P.; Nagel, K.: Verfahren zur Herstellung von Antireflexschicht bildenden Beschichtungen sowie Antireflexbeschichtungen.

Thomas, M.; Klages, C.-P.; Dohse, A.: Plasmastempel und Verfahren zur Plasmabehandlung einer Oberfläche.

Publications

Albert, A.; Biehl, S.: ORUM – optimierte Regelung von Umformprozessen. In: wt Werkstattstechnik online 99 (2009), 10, S. 779–784.

Bandorf, R.; Heckmann, U.; Lübke, M.; Schnabel, S.; Bräuer, G.: Development of Me-DLC films for strain gauge applications. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, Santa Clara, CA, USA, May 9–14, 2009. Albuquerque: SVC, 2009, pp. 26–30.

Bandorf, R.; Vergöhl, M.; Werner, O.; Sittinger, V.; Bräuer, G.: HiPIMS-Technologie und Anwendungsfelder. In: Vakuum in Forschung und Praxis 21 (2009), 1, S. 32–38.

Bandorf, R.; Paulkowski, D.; Pape, F.; Phataralaoha, A.; Büttgenbach, S.; Gatzen, H. H.; Bräuer, G.: Mikrotribologie. In: Vollertsen, Frank (Hrsg.) u. a.: 4. Kolloquium Mikroproduktion: Fachbeiträge der vier SFB der Mikrotechnik, Bremen, 28.–29. Oktober 2009. Bremen: BIAS-Verlag, 2009, S. 197–203.

Bethke, R.; Rager, B.; Diehl, W.: Actual trends in patents on plasma and surface engineering. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings: Santa Clara, CA, USA, May 9–14, 2009. Albuquerque: SVC, 2009, pp. 149–152.

Bewilogua, K.; Keunecke, M.; Thomsen, H.; Wittorf, R.; Ivanov, Y.; Zufraß, T.: Advanced magnetron sputter technique for deposition of superhard a-C:H coatings. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings: May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 661–665.

Bewilogua, K.; Bräuer, G.; Dietz, A.; Gäbler, J.; Goch, G.; Karpuschewski, B.; Szyszka, B.: Surface technology for automotive engineering. In: CIRP annals 58 (2009), 2, pp. 608–627.

Biehl, S.: Dünnschichtsensorik: Ein innovatives Überwachungssystem in Tiefziehprozessen: Sensoren, Oberflächentechnik, Umformtechnik. In: wt Werkstattstechnik online 99 (2009), 6, S. 420.

Biehl, S.: Dünnschichtsensorik: Vielfältige Anwendungsmöglichkeiten. In: IQ-Journal 8 (2009), 3, S. 13.

Biehl, S.; Hauschild, F.; Wolf, L.: Dünnschichtsensorik auf Titandioxidbasis zur Messung von Sauerstoffkonzentrationen bei niedrigen Temperaturen. In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress 2009: Proceedings, Berlin, 12.–14. Oktober 2009. Berlin [u. a.]: VDE-Verlag, 2009, getr. Zählung.

Biehl, S.; Staufenbiel, S.; Weber, M.; Woitschach, O.; Kräusel, V.; Mintenbeck, D.; Merz, J.: Dünnschichtsensorik zur Prozessüberwachung in Stanzprozessen. In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress 2009: Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u.a.]: VDE-Verl., 2009, getr. Zählung.

Biehl, S.: Kraftmessende Unterlegscheiben auf Basis neuartiger sensorischer Dünnschichtensysteme. In: PLUS 11 (2009), 12, S. 2902–2905.

Biehl, S.; Staufenbiel, S.; Hauschild, F.: Novel measurement and monitoring system for forming processes based on piezoresistive thin film systems. In: Schmid, Ulrich (Ed.) u. a.: SPIE Europe <Cardiff>: Smart sensors, actuators and MEMS IV: May 4–6, 2009, Dresden, Germany. Bellingham, Wash.: SPIE, 2009, 73621J-1–73621J-5 (Proceedings of SPIE 7362).

Biehl, S.; Staufenbiel, S.: Piezoresistive Dünnschichtsensorik integriert in Unterlegscheibensystemen zur Kraftmessung. In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress 2009: Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u. a.]: VDE-Verl., 2009, getr. Zählung.

Boentoro, W.; Pflug, A.; Szyszka, B.: Scratch resistance analysis of coatings on glass and polycarbonate. In: Thin solid films 517 (2009), 10, pp. 3121–3125.

Boota, M.; Pleger, S.; Erbas, S.; Gäbler, J.; Schäfer, L.: Hot-filament chemical vapour deposition of diamond on nickel based super alloy (CMSX-4) for the development of advanced cutting tools. In: Institute of Physics/Applied Mechanics Group: 7th International Conference on Modern Practice in Stress and Vibration Analysis: September 8–10, 2009, Murray Edwards College, Cambridge, UK; MaMiNa: Special Session: Abstracts and Papers. Cambridge: MaMiNa, 2009, pp. 14–20.

Von Borries, G.: Empirische Modelle zur Bewertung des tribologischen Verhaltens von Kohlenstoffschichten. Stuttgart: Fraunhofer IRB Verl., 2009 (Berichte aus Forschung und Entwicklung 28). Zugl.: Braunschweig, Techn. Univ., Diss., 2008.

Borris, J.; Dohse, A.; Hinze, A.; Thomas, M.; Klages, C.-P.; Möbius, A.; Elbick, D.; Weidlich, E.-R.: Improvement of the adhesion of a galvanic metallization of polymers by surface functionalization using dielectric barrier discharges at atmospheric pressure. In: Plasma processes and polymers 6 (2009), S1, pp. S258–S263.

Borris, J.; Thomas, M.; Dohse, A.; Hinze, A.; Möbius, A.; Elbick, D.; Weidlich, E.-R.; Schüßler, F.; Franke, J.; Klages, C.-P.: Reel-to-reel patterned plasma activation of polymers at atmospheric pressure for the cost-efficient production of flexible printed circuits. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry: ISPC-Proceedings, Bochum, July 26–31, 2009. http://www.ispc-conference.org/ispcproc/papers/349.pdf.

Brand, J.: Dünne Schichten für effiziente Produkte und Prozesse. In: Ingenieur-Spiegel (2009), 1, S. 74–76.

Corbella, C., Bialuch, I., Kleinschmidt, M., Bewilogua, K.: Up-scaling the production of modified a-C:H coatings in the framework of plasma polymerization processes, Solid State Sciences 11 (2009) 1768.

Corbella, C.; Bialuch, I.; Kleinschmidt, M.; Bewilogua, K.: Up-scaling the production of modified a-C:H coatings in the framework of plasma polymerization processes. In: Solid state sciences 11 (2009), 10, pp. 1768–1772.

Dewald, W.; Sittinger, V.; Werner, W.; Szyszka, B.: Influence of strong magnetic fields on the growth of DC magnetron sputtered ZnO:Al films from a ceramic target. In: 24th European Photovoltaic Solar Energy Conference and Exhibition: Conference: September 21–25, 2009, Exhibition: September 21–24, 2009, Proceedings. Hamburg, 2009, pp. 2824–2826.

Dewald, W.; Sittinger, V.; Werner, W.; Jacobs, C.; Szyszka, B.: Optimization of process parameters for sputtering of ceramic ZnO:Al_2O_3 targets for a-Si:H/µc-Si:H solar cells. In: Thin solid films 518 (2009), 4, pp. 1085–1090.

Eichler, M.; Michel, B.; Hennecke, P.; Thomas, M.; Klages, C.-P.: Atmospheric-pressure plasma activation of silicon for MEMS packaging. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry: ISPC-Proceedings, Bochum, July 26–31, 2009. http://www.ispc-conference.org/ispcproc/papers/428.pdf.

Eichler, M.; Michel, B.; Hennecke, P.; Klages, C.-P.: Bondenergie-Messung in situ während des Temperns beim Direktbonden von Glas und Silizium. In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress, Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u. a.]: VDE-Verl., 2009, getr. Zählung.

Eichler, M.; Michel, B.; Hennecke, P.; Klages, C.-P.: Comparison of bonding kinetics for borosilicate glass and silicon wafers by in situ fracture surface energy measurements during annealing. In: Knechtel, R. (Ed.) u. a.: Conference on Wafer Bonding for Microsystems, 3D- and Wafer Level Integration, December 6–8, 2009, Grenoble, France; [WaferBond, 09]. Grenoble, 2009, pp. 15–16.

Eichler, M.; Michel, B.; Hennecke, P.; Klages, C.-P.: Effects on silanol condensation during low temperature silicon fusion bonding. In: Journal of the Electrochemical Society 156 (2009), 10, pp. H786–H793.

Eichler, M.; Michel, B.; Gabriel, M.; Klages, C.-P.: Einsatz von Mikroplasmen für die Herstellung von Silizium-Mehrlagenaufbauten. In: Vakuum in Forschung und Praxis 21 (2009), 4, S. 6–9.

Eichler, M.; Thomas, M.; Klages, C.-P.: Plasmagestützte Oberflächenmodifizierung in fluidischen Systemen mit gedeckelten Kavitäten (Plasma-enhanced surface modification in sealed microfluidic channels). In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress, Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u. a.]: VDE-Verl., 2009, paper P7.8.

Eichler, M.; Thomas, M.; Borris, J.; Michel, B.; Klages, C.-P.: Surface reactions controlled by dielectric barrier discharge at atmospheric pressure for high performance large-scale production. In: Japan Society of Applied Physics u. a.: Extended Abstracts of Second International Symposium on Atomically Controlled Fabrication Technology, November 25–26, 2009, Osaka University, Nakanoshima Center, Osaka, Japan. Osaka: Osaka Univ., 2009, pp. 20–21.

Gabriel, M.; Milde, S.; Eichler, M.; Klages, C.-P.: Lokale Plasma-Behandlung in einem Mask Aligner zur selektiven Veränderung der Oberfläche von Wafern. In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress, Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u. a.]: VDE-Verl., 2009, paper P8.24.

Gäbler, J.; Pleger, S.; Schäfer, L.: Tools coated with diamond by chemical vapour deposition. In: Institute of Physics/Applied Mechanics Group: 7th International Conference on Modern Practice in Stress and Vibration Analysis, September 8–10, 2009, Murray Edwards College, Cambridge, UK; MaMiNa, Special Session, Abstracts and Papers. Cambridge: MaMiNa, 2009, pp. 37–48.

Geddert, T.; Bialuch, I.; Augustin, W.; Scholl, S.: Extending the induction period of crystallization fouling through surface coating. In: Heat transfer engineering 30 (2009), 10–11, pp. 868–875.

Geddert, T., Albert, F., Bialuch, I., Augustin, W., Scholl, S.: Verringerung der Belagbildung durch beschichtete Oberflächen, Vakuum in Forschung und Praxis 21/3 (2009) 14.

Geddert, T., Albert, F., Bialuch, I., Augustin, W., Scholl, S.: Verringerung der Belagbildung durch beschichtete Oberflächen, Vakuum in Forschung und Praxis 21/3 (2009) 14.
Geddert, T.; Albert, F.; Bialuch, I.; Augustin, W.; Scholl, S.: Verringerung der Belagbildung durch beschichtete Oberflächen. In: Vakuum in Forschung und Praxis 21 (2009), 3, pp. 14–17.

Gerdes, H.; Wellhausen, J.; Bandorf, R.; Bräuer, G.: Optical emission spectroscopy of Ni, Cr, and NiCr for DC and high power impulse magnetron sputtering (HiPIMS). In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 588–591.

Gerdes, H.; Bandorf, R.; Heckmann, U.; Schmidt, V.; Kricheldorf, H.-U.; Bräuer, G.: Sputter deposition of strain gauges using ITO/Ag. In: Plasma processes and polymers 6 (2009), S1, pp. S812–S816.
Greiner, D.; Papathanasiou, N.; Pflug, A.; Ruske, F.; Klenk, R.: Influence of damp heat on the optical and electrical properties of Al-doped zinc oxide. In: Thin solid films 517 (2009), 7, pp. 2291–2294.

Heckmann, U.; Bandorf, R.; Gerdes, H.; Lübke, M.; Schnabel, S.; Bräuer, G.: New materials for sputtered strain gauges. In: Procedia chemistry 1 (2009), 1, pp. 64–67.

Hinze, A.; Lucas, N.; Büttgenbach, S.; Schiffmann, K.; Willich, P.; Franke, R.; Frank, R.; Klages, C.-P.: Quantitative CD ATR-FTIR and CD SEM-EDX analyses of locally amino-functionalized polymer surfaces. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry ISPC, Proceedings, Bochum, July 26–31, 2009. Bochum, 2009: http://www.ispc-conference.org/ispcproc/papers/125.pdf.

Hoffmeister, H.-W.; Wittmer, R.; Schuller, B. C.; Biehl, S.; Woitschach, O.; Staufenbiel, S.: Detektion kritischer Wuchtzustände mittels sensorintegrierter Werkzeugschnittstellen: Ein Beitrag zur Erhöhung der Sicherheit beim Zerspanen. In: Holztechnologie 50 (2009), 4, S. 32–37.

Horstmann, F.; Sittinger, V.; Szyszka, B.: Heat treatable indium tin oxide films deposited with high power pulse magnetron sputtering. In: Thin solid films 517 (2009), 10, pp. 3178–3182.

Keunecke, M., Weigel, K., Bewilogua, K., Cremer, R., Fuß, H.-G.: Preparation and comparison of a-C:H coatings using reactive sputter techniques, Thin Solid Films 518 (2009) 1465–1469

Kim, M. C.; Klages, C.-P.: One-step process to deposit a soft super-hydrophobic film by filamentary dielectric barrier discharge-assisted CVD using HMCTSO as a precursor. In: Surface and Coatings Technology 204 (2009), 4, pp. 428–432.

Klages, C.-P.: Amination of polymer surfaces with atmospheric-pressure plasmas: Processes, mechanisms, analysis and applications. In: Proceedings of International Symposium on Surface Science and Engineering using Atmospheric-Pressure Plasma, September 10, 2009, Hamamatsu City Information Processing Center, Hamamatsu, Japan, 2009, pp. 43–69.

Klages, C.-P.; Hinze, A.; Thomas, M.: Plasma-based surface animation of polymers at atmospheric pressure. In: The 10th Asian Textile Conference ATC-10, September 7–9, 2009, Ueda, Nagano, Japan. Tokio: Society of Fiber Science and Technology, 2009, 6 Bl.

Kohns, A.; Ortner, K.; Jung, T.: Hollow cathode gas flow sputtering of NixAly coatings on Ti-6Al-2Sn-4Zr-6Mo: Mechanical properties and microstructures. In: Advanced engineering materials 11 (2009), 1–2, pp. 67–70.

König, J.; Byrne, F.; Gäbler, J.: VDI-Fachausschuss »CVD-Diamant-Werkzeuge«. In: Diamant Hochleistungswerkzeuge dihw 1 (2009), 3, S. 10.

Lachmann, K.; Michel, B.; Klages, C.-P.: Density and aging behavior of primary amino groups on afterglow plasma-treated low-density polyethylene (LDPE). In: Plasma processes and polymers 6 (2009), S1, pp. S401–S405.

Lachmann, K.; Eckert, S.; Vogel, A.; Klinger, A.; Gebert, A.; Klages, C.-P.: Development of a multifunctional coating system for laser-induced material transport. In: Progress in organic coatings 64 (2009), 2–3, pp. 294–299.

Lucas, N.; Franke, R.; Hinze, A.; Klages, C.-P.; Frank, R.; Büttgenbach, S.: Microplasma stamps for area-selective modification of polymer surfaces. In: Plasma processes and polymers 6 (2009), S1, pp. S370–S374.

Mahrholz, J.; Shikolenko, S.; Szyszka, B.; Jung, T.: Deposition of amorphous silicon films by gas flow sputtering (GFS). In: 24th European Photovoltaic Solar Energy Conference and Exhibition, Conference: September 21–25, 2009, Exhibition: September 21–24, 2009, Proceedings. Hamburg, 2009, pp. 2879–2883.

Michel, B.; Giza, M.; Krumrey, M.; Eichler, M.; Grundmeier, G.; Klages, C.-P.: Effects of dielectric barrier discharges on silicon surfaces: Surface roughness, cleaning, and oxidation. In: Journal of applied physics 105 (2009), 7, 073302.

Michel, B.; Eichler, M.; Klages, C.-P.: Investigations on the effect of dielectric barrier discharge (DBD) treatment as a preconditioning method for low temperature silicon wafer bonding. In: Plasma processes and polymers 6 (2009), S1, pp. S173–S177.

Michel, B.; Eichler, M.; Klages, C.-P.: Investigations on the plasma-surface interaction during DBD-treatment for low-temperature direct silicon wafer bonding. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry ISPC, Proceedings, Bochum, July 26–31, 2009. Bochum, 2009: http://www.ispc-conference.org/ispcproc/papers/447.pdf.

Michel, B.; Eichler, M.; Klages, C.-P.: Multipin ac corona treatment – a new surface activation method for low temperature direct bonding. In: Knechtel, R. (Ed.) u. a.: Conference on Wafer Bonding for Microsystems, 3D- and Wafer Level Integration, December 6–8, 2009, Grenoble, France [WaferBond, 09]. 2009, pp. 63–64.

Michel, B.; Eichler, M.; Klages, C.-P.: Untersuchung der Aktivierungseffekte durch DBD bei Atmosphärendruck für das Tieftemperatur-Direktbonden (Investigations on the activation effects of DBD at atmospheric pressure for low temperature direct bonding). In: Verband Deutscher Elektrotechniker (VDE) u. a.: MikroSystemTechnik Kongress, Proceedings, 12.–14. Oktober 2009, Berlin. Berlin [u. a.]: VDE-Verl., 2009, paper P8.27.

Möbius, A.; Elbick, D.; Weidlich, E.-R.; Feldmann, K.; Schüßler, F.; Borris, J.; Thomas, M.; Zänker, A.; Klages, C.-P.: Plasma-printing and galvanic metallization hand in hand – a new technology for the cost-efficient manufacture of flexible printed circuits. In: Electrochimica acta 54 (2009), 9, pp. 2473–2477.

Ortner, K.; Kohns, A.; Turley, F.; Jung, T.: Erosionsschutzschichten für Flugtriebwerke. In: Vakuum in Forschung und Praxis 21 (2009), 3, S. 18–21.

Paulkowski, D.; Schiffmann, K.: Analysis of nanoindentation and nanoscratch experiments of thin amorphous carbon coatings and multilayers: Friction, wear and elastic; plastic deformation. In: International journal of materials research 100 (2009), 7, pp. 960–966.

Paulkowski, D.; Bandorf, R.; Schiffmann, K.; Bräuer, G.: Friction of flat-flat micro contacts coated with amorphous carbon. In: Gesellschaft für Tribologie <Aachen>: Reibung, Schmierung und Verschleiß: Forschung und praktische Anwendungen, Band II, 50. Tribologie-Fachtagung, 21.–23. September 2009, Göttingen, Werkstoffe und Werkstofftechnologien, dünne Schichten und Oberflächentechnologien, Maschinenelemente und Antriebstechnik, Fahrzeugtechnik. Aachen: Gesellschaft für Tribologie, 2009, S. 51/1–51/6.

Paulkowski, D. M.: Strukturelle Eigenschaften von dünnen amorphen Kohlenstoffschichten und ihre Auswirkungen auf Mikrotribologie und Deformationsverhalten. Stuttgart: Fraunhofer-Verl., 2009 (Berichte aus Forschung und Entwicklung 30). Zugl.: Berlin, Univ., Diss., 2009.

Pflug, A.; Siemers, M.; Szyszka, B.: Design tools and simulations for plasma processing in large area coaters. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 364–369.

Polenzky, C.; Rickers, C.; Vergöhl, M.: Properties of cosputtered SiO2-Ta2O5-mixtures. In: Thin solid films 517 (2009), 10, pp. 3126 - 3129.

Polenzky, C.; Ulrich, S.; Szyszka, B.; Bywalez, R.; Götzendorfer, S.; Löbmann, P.: Transparent P-conducting materials for application in highly efficient thin film solar cells. In: 24th European Photovoltaic Solar Energy Conference and Exhibition: Conference: September 21–25, 2009, Exhibition: September 21–24, 2009, Proceedings. Hamburg, 2009, pp. 285–288.

Röger, M.; Rickers, C.; Uhlig, R.; Neumann, F.; Polenzky, C.: Infrared-reflective coating on fused silica for a solar high-temperature receiver. In: Journal of solar energy engineering 131 (2009), 2, p. 021004 1–7.

Ruske, F.: Magnetronsputtern von hochleitfähigen ZnO:Al-Schichten für die Photovoltaik. Stuttgart: Fraunhofer-IRB-Verlag, 2009 (Berichte aus Forschung und Entwicklung 29). Zugl.: Gießen, Univ., Diss., 2008.

Ruske, F.; Pflug, A.; Sittinger, V.; Szyszka, B.; Greiner, D.; Rech, B.: Optical modeling of free electron behavior in highly doped ZnO films. In: Thin solid films 518 (2009), 4, pp. 1289–1293.

Siemers, M.; Pflug, A.; Szyszka, B.: Particle-in-cell Monte Carlo analysis of propagating plasma waves in DC magnetron discharges. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 13–16.

Sittinger, V.; Dewald, W.; Werner, W.; Szyszka, B.: Comparison of different ceramic Al-doped ZnO target materials. In: Photovoltaics international (2009), 6, pp. 101–108.

Sittinger, V.; Horstmann, F.; Boentoro, W.; Werner, W.; Szyszka, B.: Heat treatable TCO film for position 1 based on HiPIMS. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings : May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 254–257.

Sittinger, V.; Dewald, W.; Szyszka, B.: Large area deposition of Al-doped ZnO for Si-based thin film solar cells by magnetron sputtering. In: Glass Performance Days: Professionals, Products, Processing, Conference Proceedings, Tampere, Finland, June 12–15, 2009. Tampere, 2009, pp. 518–522.

Sittinger, V.; Diehl, W.; Szyszka, B.: Survey of thin film photovoltaics in Germany. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 81–87.

Stöhr, U.; Dohse, A.; Hoppe, P.; Thomas, M.; Kadel, K.; Klages, C.-P.; Reinecke, H.: Multilayer photoresist stamps for selective plasma treatment in micrometer scales. In: Plasma processes and polymers 6 (2009), 4, pp. 228–233.

Stöhr, U.; Dohse, A.; Hoppe, P.; Gehringer, A.; Thomas, M.; Klages, C.-P.; Reinecke, H.: Porous photoresist stamps for selective plasma treatment. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry ISPC, Proceedings, Bochum, July 26–31, 2009. Bochum, 2009: http://www.ispc-conference.org/ispcproc/papers/306.pdf.

Szyszka, B.; Georg, A.; Loebmann, P.; May, C.; Elsaesser, C.: A multidisciplinary approach towards advanced transparent conductive electrodes. In: Glass Performance Days: Professionals, Products, Processing, Conference Proceedings, Tampere, Finland, 12–15 June 2009. Tampere, 2009, pp. 644–648.

Szyszka, B.; Sittinger, V.; Dewald, W.; Pflug, A.; Ulrich, S.; Kaiser, A.; Werner, W.: Reactive magnetron sputtering of ZnO:Al: A status report. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 383–389.

Thomas, M.; Dani, I.; Lommatzsch, U.; Grünler, B.; Schulz-von der Gathen, V.; Viöl, W.; Weltmann, K.-D.; Klages, C.-P.: Recent and future applications of atmospheric pressure plasma technology in Germany. In: Proceedings of the 2nd International Symposium of Plasma Center for Industrial Applications (PLACIA) & Plasma Application Monodzukuri (PLAM) on Industrial Application of Advanced Plasma Technology, November 18, 2009, Science Exchange Plaza, Nagoya Science Park, Nagoya, Japan. Nagoya, 2009, p. 4.

Thomas, M.; Lachmann, K.; Dohse, A.; Thrane, M.; Morlock, J.; Klages, C.-P.: Surface amination of three-dimensional substrates by RotoTEC plasma treatment under defined gas atmospheres at ambient pressure. In: Von Keudell, A. (Ed.) u. a.: 19th International Symposium on Plasma Chemistry ISPC, Proceedings, Bochum, July 26–31, 2009. Bochum, 2009: http://www.ispc-conference.org/ispcproc/papers/351.pdf.

Uhlmann, E., Oyanedel Fuentes, J.A., Keunecke, M.: Machining if high performance workpiece materials with CBN coated cutting tools, Thin Solid Films 518 (2009) 1451–1454

Ulrich, S.; Dewald, W.; Szyszka, B.: Comparison of SnO_2:F based transparent conductive oxides for use in a-Si:H/µc-Si:H solar cells. In: 24th European Photovoltaic Solar Energy Conference and Exhibition, Conference: September 21–25, 2009, Exhibition: September 21–24, 2009, Proceedings. Hamburg, 2009, pp. 2814–2816.

Vergöhl, M.; Bruns, S.; Werner, O.: Process control and thin film properties of Al_2O_3 layers deposited by high power impulse magnetron sputtering. In: Society of Vacuum Coaters (SVC): 52nd Annual Technical Conference Proceedings, May 9–14, 2009, Santa Clara, CA, USA. Albuquerque: SVC, 2009, pp. 274–279.

Weber, M.: Werkzeugbeschichtungen für die Kalt- und Warmumformung von Aluminium- und Magnesiumlegierungen. In: Groche, P. (Hrsg.): Institut für Fertigungsforschung u. a.: Der Markt im Umbruch – Erfolg mit innovativen Strategien, Maschinen, Prozessen, 10. Umformtechnisches Kolloquium Darmstadt, 17. und 18. März 2009. Bamberg: Meisenbach, 2009, S. 151–163.

Werner, O.; Neumann, F.; Neubert, T.; Vergöhl, M.: Optisch dünne Schichten mit kontrollierten Eigenschaften durch plasmaunterstütztes Magnetronsputtern. In: Vakuum in Forschung und Praxis 21 (2009), 6, S. 10–16.

Wierner, M.; Wünsch, D.; Bräuer, J.; Eichler, M.; Hennecke, P.; Gessner, T.: Low temperature bonding of hetero-materials using ambient pressure plasma activation. In: Knechtel, Roy (Ed.) u.a.: Conference on Wafer Bonding for Microsystems, 3D- and Wafer Level Integration: 6th–8th December 2009, Grenoble, France, [WaferBond, 09], 2009, pp. 73 –74.

Lectures, Posters

Bandorf, R.; Gerdes, H.; Heckmann, U.; Bräuer, G.: Thin film strain gauges – potential and unique applications using HIPIMS deposition (Vortrag), 6th HIPIMS Days, Sheffield, Großbritannien, July 2009.

Bandorf, R.: Development of Thin Film Sensors (Vortrag), ACSEL Workshop, Golden CO, USA, April 2009.

Bandorf, R.: Technologies and Applications of HIPP Processes (Vortrag), ACSEL HPPMS/HIPIMS Workshop, Golden CO, USA, April 2009.

Bandorf, R.; Gerdes, H.; Loch, D.; Vergöhl, M.; Bruns, S.; Bräuer, G.: Oxide Coatings Deposited by HIPP Processes (Vortrag), International Symposium on Reactive Sputter Deposition RDS2009, Manchester, Großbritannien, Dezember 2009.

Bandorf, R.: HIPIMS, the Next Generation of Sputtering (Vortrag), Seminar Oberflächentechnik, Duisburg, Februar 2009.

Bandorf, R.: Funktionale Oberflächen – Neue Anforderungen an die Produktionstechnik (Vortrag), IHK Veranstaltung »Mehr Sein als Schein«, Detmold, April 2009.

Bandorf, R.; Heckmann, U.; Lübke, M.; Schnabel, S.; Bräuer, G.: Development of Me-DLC Films for Strain Gauge Applications (Vortrag), 52nd Annual Technical Conference of Society of Vacuum Coaters (SVC), Mai 2009.

Bandorf, R.; Schmidt, M.; Gerdes, H.; Hesse, F.; Mark, G.; Bräuer, G.: Investigation of Ti-Si-C-Films Prepared by DC, HiPIMS, and Superimposed HiPIMS (Poster), 36th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April 2009.

Bewilogua, K., Keunecke, M., Thomsen, H., Wittorf, R., Ivanov, Y., Zufrass, T.: Advanced magnetron sputter technique for deposition of superhard a-C:H coatings, 52nd SVC Technical Conference, Santa Clara, CA, USA, May 2009.

Bewilogua, K., Keunecke, M., Weber, M., Weigel, K., Wittorf, R.: Advanced sputter techniques for deposition of hard a-C:H coatings, Seventh Asian-European International Conference on Plasma Surface Engineering, Busan, Korea, September 2009.

Biehl, S.: Innovative Dünnschichtsensorik und ihr Anwendungspotenzial (Vortrag), 2. Adaptronik Workshop, Hannover Messe, April 2009.

Biehl, S.: Innovative Thin Film Sensors and their Applications (Vortrag), IAO-Forum »Intelligente Werkstoffe«, Stuttgart, März 2009.

Biehl, S.: Novel Measurement and Monitoring System for Forming Processes based on Piezoresistive Thin Film Systems (Poster), SPIE Europe Microtechnologies for the New Millenium, Dresden, Mai 2009.

Piezoresistive Dünnschichtsensorik integriert in Unterlegscheibensystemen zur Kraftmessung (Vortrag), MikroSystemTechnik Kongress 2009, Berlin, Oktober 2009.

Biehl, S.: Sensorgestützte Werkstoffauslegung und Schichtentwicklung für die Umformtechnik, Projekt SenWerkUm (Poster), WING-nano.DE2009, Ulm, April 2009.

Biehl, S.: Thin Film Sensor Systems and their Applications (Vortrag), Korea-Germany Seminar on Materials and Components Technology, Hannover Messe, April 2009.

Boota, M.; Pleger, S.; Erbas, S.; Gäbler, J.; Schäfer, L.: Hot-filament chemical vapour deposition of diamond on Nickel based super alloy (CMSX-4) for the development of advanced cutting tools (Vortrag), Institute of Physics (Veranstaltung): 7th International Conference on Modern Practice in Stress and Vibration Analysis, Cambridge, Großbritannien, 2009, September 2009.

Borris, J.; Thomas, M.; Hänsel, R.; Stoll, M.; Klages, C.-P.: Surface Functionalization and Coating of Leather using Atmospheric Pressure Dielectric Barrier Discharges (DBD), 1st International Leather Engineering Symposium »Leather Industry-Environment and Progressive Technologies«, Izmir, Türkei, April–Mai 2009.

Borris, J.; Thomas, M.; Dohse, A.; Möbius, A.; Elbick, D.; Weidlich, E.; Klages, C.-P.: Reel-to-reel patterned plasma activation of polymers at atmospheric pressure for the cost-efficient production of flexible printed circuits (Poster), International Symposium on Plasma Chemistry 19 (ISPC 19), www.ispc-conference.org, Bochum, Juli 2009.

Böttger, M.; Wiegmann, B.; Zölner, M.; Kowalsky, W.; Johannes, H.-H.; Neumann, F.; Graumann, T.: Synthesis and Application of Luminescent Dyes for the Quantitative Determination of Photocatalytic Activity of a TiO2 Surface (Short-talk), The 14th International Conference on TiO2 Photocatalysis: Fundamentals and Applications, The Conference Center, Niagara Falls, New York, October, 2009.

Brand, J.: Intelligente Schichten für tribologische Anwendungen, Kooperationsforum Moderne Beschichtungs- und Oberflächentechnologien, Köln, Dezember 2009.

Bräuer, G.: »Added Value to Steel« – Möglichkeiten und Beispiele aus aktuellen Entwicklungsarbeiten des Fraunhofer IST, Workshop im Dortmunder Oberflächen Centrum, Dortmund, Juni 2009.

Bräuer, G.: Fraunhofer – The German Research Organization, AMAT Europa Engineering und Technology Konferenz, Frankfurt am Main, Juni 2009.

Bräuer, G.: Innovationsmotor Plasma - Beispiele und Potentiale, Kolloquium zur Verabschiedung von Prof. Dr. Jürgen Engemann, Wuppertal, März 2009.

Bräuer, G.: Magnetron Sputtering – Milestones of 30 Years (Invited Talk), 10th International Symposium on Sputtering & Plasma Processes, Kanazawa, Japan, Juli 2009.

Bräuer, G.: Photovoltaikforschung am Fraunhofer IST, Niedersächsisches Photovoltaik Symposium zum 29. Tag der Niedersachsen, Hameln, Juni 2009.

Bräuer, G.: Surface Technology for Automotive Engineering (Keynote Talk), 59th CIRP General Assembly, Boston, USA, August 2009.

Bräuer, G.: Surface Technology for Automotive Engineering, European Summer School on Advanced Manufacturing Processes, Saint-Étienne, France, 9. September 2009.

Bräuer, G.: Thin Film Solar Cell Technology in Germany, 2nd Mini-ICCG, Tokyo, Japan, Juli 2009.

Dewald, W.; Polenzky, C.; Sittinger, V.; Götzendörfer, S.; Bywalez, R.: Seebeck and Hall measurements on p- and n-TCOs (Poster), DPG Frühjahrstagung der Sektion Kondensierte Materie, Dresden, März 2009.

Dewald, W.; Sittinger, V.; Werner, W.; Szyszka, B.: Influence of strong magnetic fields on the growth of DC magnetron sputtered ZnO:Al films from a ceramic target (Poster), EU-PVSEC, Hamburg, September 2009.

Diehl, W.: Functional coatings produced by Plasma Process Technology (Vortrag), Topical Conference »Advanced Coatings Technologies for corrosion/erosion and decorative coatings«, , Albuquerque NM, USA, November 2009.

Diehl, W.: Diamond based electrochemical technology for water treatment, Fraunhofer Water Travelling Conference, Peking-Shanghai, China, November 2009.

Diehl, W.: Green power train coatings (Vortrag), RETETCZA Konferenz, Kwa Maritane, Südafrika, Juni 2009.

Dietz, A.; Hochsattel, T.: Coating properties of electrodeposited layers with self-healing effect (Vortrag), 216th ECS Meeting, Vienna, Austria, October 2009.

Dietz, A.; Kramer, H.-J.: Electrochemical treatment of organic polluted waste water (Vortrag), ACHEMA 2009, Frankfurt a. Main, Mai 2009..

Ehlers, J.; Hinze, A.; Klages, C.-P.; Gericke, K.-H.: Three-dimensional fluorescence imaging of DBD-plasma aminated porous polypropylene (Poster), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Eichler, M.; Michel, B.; Henneke, P.; Thomas, M.; Klages, C.-P.: Atmospheric-pressure plasma activation of silicon for MEMS packaging (Poster), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Eichler, M.; Michel. B.; Hennecke, P.; Klages, C.-P.: Bondenergie-Messung in situ während des Temperns beim Direktbonden von Glas und Silizium (Vortrag), Mikrosystemtechnik-Kongress 2009, Berlin, Oktober 2009.

Eichler, M.; Michel. B.; Hennecke, P.; Klages, C.-P: Plasmagestützte Oberflächenmodifizierung in fluidischen Systemen mit gedeckelten Kavitäten (Poster), Mikrosystemtechnik-Kongress 2009, Berlin, Oktober 2009.

Eichler, M.; Thomas, M.; Borris, J.; Michel, B.; Klages, C.-P.: Surface Reactions Controlled by Dielectric Barrier Discharge at Atmospheric Pressure for High Performance Large-Scale Production (Vortrag), Second International Symposium on Atomically Controlled Fabrication Technology, Osaka, Japan, November 2009.

Eichler, M.; Michel, B.; Henneke, P.; Klages, C.-P.: Comparison of bonding kinetics for borosilicate glass and silicon wafers by in situ fracture surface energy measurements during annealing (Vortrag), WaferBond `09, Grenoble, Frankreich, Dezember 2009.

Frach, P.; Glöß, D.; Zywitzki, O.; Vergöhl, M.; Neumann, F.; Hund-Rinke, K.; Trick, I.; Decomposition ability and bioactivity of photocatalytic TiO_2 based layers prepared by reactive pulse magnetron sputtering (Poster), 5. Thüringer Grenz- und Oberflächentage, Friedrichroda, September 2009.

Gäbler, J.; Pleger, S.; Schäfer, S.: Tools coated with diamond by chemical vapour deposition (Vortrag), Institute of Physics (Veranstaltung): 7th International Conference on Modern Practice in Stress and Vibration Analysis, Cambridge, Großbritannien, 2009, September 2009.

Gäbler, J.; König, J.; Feuchter, P.; Frank, M.; Mandelartz, J.; Blum, J.; Vetter, J.: Progress for Carbon Film Standardization in Germany (Vortrag), International Session for Standardization of Diamond-like Carbon Coatings during JNDF Symposium, Chiba, Japan, November 2009.

Gerdes, H.; Wellhausen, J.; Bandorf, R.; Bräuer, G.: Optical Emission Spectroscopy of Ni, Cr, and NiCr 80/20 for DC and High Power Impulse Magnetron Sputtering (HiPIMS) (Poster), 52nd Annual Technical Conference of Society of Vacuum Coaters (SVC), Mai 2009.

Heckmann, U.: Innovative Sensorschichten zur Dehnungs- und Kraftmessung (Vortrag), IHK Veranstaltung »Nanotechnologie bei Sensoren und Aktuatoren«, Stuttgart, April 2009.

Heckmann, U.; Bandorf, R.; Gerdes, H.; Lübke, M.; Schnabel, S.; Bräuer, G.: New Materials for Sputtered Strain Gauges (Poster), Eurosensors XXIII, Lausanne, Switzerland, September 2009.

Hoffmann, F.; Brand, J.: Schadensanalyse/-sensorik und Werkstoffanforderungen bei Windkraftantrieben, 2. Nano und Material Symposium Niedersachsen, Papenburg, Oktober 2009.

Hinze, A.; Lucas, N.; Büttgenbach, S.; Schiffmann, K.; Willich, P.; Franke, R.; Frank, R.; Klages, C.-P.: Quantitative CD-ATR-FTIR and CD-SEM-EDX analyses of locally amino-functionalized polymer surfaces (Vortrag), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Keunecke, M., Weigel, K., Bewilogua, K., Cremer, R. Fuss, H.-G.: Preparation and comparison of a-C:H coatings using reactive sputter techniques, 36th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April/May 2009.

Keunecke, M., Weigel, K., Bewilogua, K., Kölker, W., Jaschinski, P.: Superhard coatings prepared by pulsed magnetron sputtering, 36th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April/May 2009.

Klages, C.-P.; Hinze, A.; Willich, P.; Thomas, M.: Atmospheric-pressure plasma amination of polymer surfaces (eingeladener Vortrag), 7th International Symposium on Polymer Surface Modification: Relevance to Adhesion, University of Maine, Orono, Maine, USA, Juli 2009.

Klages, C.-P.; Hinze, A.; Thomas, M.: Plasma-based surface amination of polymers at atmospheric pressure (eingeladener Vortrag), Proceedings of the 10th Asian Textile Conference (ATC-10), Ueda, Japan, September 2009.

Klages, C.-P; Hinze, A.; Thomas, M.: Amination of polymer surfaces with atmospheric-pressure plasmas – processes, mechanisms, analysis and applications (eingeladener Vortrag), Proceedings of International Symposium on Surface Science and Engineering using Atmospheric-Pressure Plasma, Hamamatsu, Japan, September 2009.

Lachmann, K.; Eckert, K.; Blessenohl, M.; Vogel, M.; Klinger, A.; Gebert, A.; Klages, C.-P.: Investigations on a multifunctional film system for laser microdissection and laser pressure catapulting (Poster), 23rd Conference of the European Colloid and Interface Society, Antalya, Türkei, September 2009.

Michel, B.; Eichler, M.; Klages, C.-P.: Investigations on the plasma-surface interaction during DBD-treatment for low-temperature direct silicon wafer bonding (Vortrag), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Michel, B.; Eichler, M.; Henneke, P.; Klages, C.-P.: Multipin AC corona treatment – a new surface activation method for low temperatur direct bonding (Poster), WaferBond `09, Grenoble, Frankreich, Dezember 2009.

Neumann, F.; Baumann, S.; Utilization of Standardized High-Power UV and VIS LED Modules for Novel Photocatalytic Test Methods (Vortrag), Optronics World 2009, LaserEXPO 2009, Yokohama, Japan, April 2009.

Neumann, F.; Graumann, T.; Vergöhl, M.; Böttger, M.; Johannes, H.-H.: Novel UV and VIS solid state photocatalysis assessment utilizing the luminescence degradation of tailored organic dye thin-films (Short-talk), The 14th International Conference on TiO2 Photocatalysis: Fundamentals and Applications, The Conference Center, Niagara Falls, New York, Oktober, 2009.

Paschke, H.: Erhöhung der Werkzeugstandmengen durch borhaltige Mehrlagenbeschichtungen auf Schmiedegesenken (Vortrag), AiF-Anwenderforum »Gesenkbeschichtungen zur Standmengenerhöhung in der Warmmassivumformung«, Hagen, November 2009.

Paschke, H.; Weber, M.; Thomsen, H.; Kaestner, P.: Coating Systems for Hot Forming Tools (Vortrag), 7th International Conference on Industrial Tools and Material Processing Technologies (ICIT&MPT), Ljubljna, Slovenia, October 2009.

Paschke, H.; Weber, M.: Reibarme und verschleißfeste diamantähnliche Kohlenstoffschichten (DLC) für Komponenten und Werkzeuge (Vortrag), DiF-Seminar »Verschleissschutz technischer Oberflächen«, Bad Herrenalb, November 2009.

Paulkowski, D.; Bandorf, R.; Schiffmann, K.; Buck, V.: Influence of bias voltage on properties and microtribology of amorphous carbon coatings (Vortrag), 36th Leeds-Lyon Symposium on Tribology, Lyon, France, September 2009.

Paulkowski, D.; Bandorf, R.; Schiffmann, K.; Arfsten, J.: Friction on flat-flat micro contacts coated with amorphous carbon (Vortrag), GfT Tribologie Fachtagung 2009, Göttingen, September 2009.

Paulkowski, D.; Bandorf, R.; Pape, F.; Phataralaoha, A.; Büttgenbach, S.; Gatzen, H.H.; Bräuer, G.: Mikrotribologie (Vortrag), Kolloquium Mikroproduktion, Bremen, Oktober 2009.

Sittinger, V.; Ruske, F.; Pflug, A.; Dewald, W.; Szyszka, B.; Dittmar, G.: Optical on-line monitoring for the long-term stabilization of a reactive mid-frequency sputtering process of Al-doped zinc oxide films (Vortrag), International Symposium on Transparent Oxide Thin Films for Electronic and Optics (TOEO-6), Tokyo, April 2009.

Sittinger, V.; Dewald, W.; Szyszka, B.; Werner, W.; Wurczinger, D.: Evaluation of RF superimposed DC magnetron sputtering of Al-doped ZnO films (Poster), 24th European Photovoltaic Solar Energy Conference, Hamburg, September 2009.

Sittinger, V.; Dewald, W.; Werner, W.; Szyszka, B.; Ruske, F.: Comparison of different ceramic Al-doped ZnO target materials (Poster), 24th European Photovoltaic Solar Energy Conference, Hamburg, September 2009.

Sittinger, V.; Dewald, W.; Szyszka, B.: Large area deposition of Al-doped ZnO for Si-based thin film solar cells by magnetron sputtering (Vortrag), V2009, Dresden, Oktober 2009.

Sittinger, V.; Szyszka, B.; Dewald, W.; Bräuer, G.; Ruske, F.: Übersicht über die Einsatzgebiete und Anwendungen von TCOs (Vortrag), Dritte Fachtagung Transparente leitfähige Schichten (TCO), OTTI, Neu-Ulm, November 2009.

Stöhr, U.; Dohse, A.; Hoppe, P.; Gehringer, A.; Thomas, M.; Klages, C.-P.; Reinecke, H.: Porous plasma stamps for patterned surface coating (Vortrag), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Uhlmann, E., Oyanedel Fuentes, J.A., Keunecke, M.: Machining of high performance workpiece materials with cBN coated cutting tools, 36th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April/May 2009.

Werner, O.; Neumann, F.; Neubert, T.; Vergöhl, M.: Optisch dünne Schichten mit kontrollierten Eigenschaften durch plasmaunterstütztes Magnetronsputtern. In: VIP Vakuum in Forschung und Praxis 21 (2009), Nr. 6, S. 10-16.

Weber, M.: Reibarme und verschleißfeste Kohlenstoffschichten (DLC) für Werkzeuge und Bauteile (Vortrag), Werkstoffkompetenz in NRW, Rheinbach, September 2009.

Weber, M.: Auswirkungen der Nitrierparameter auf das Härtetiefenprofil und die Rissempfindlichkeit von Schmiedegesenken (Vortrag), AiF-Anwenderforum »Gesenkbeschichtungen zur Standmengenerhöhung in der Warmmassivumformung«, Hagen, November 2009.

Schiffmann, K. I.: Determination of fracture toughness of bulk materials and thin coatings by nanoindentation (Poster), Engineering Conference International: »Nanomechanical Testing in Material Research and Development«, Barga, Italien, Oktober 2009.

Schmolke, H.; Klages, C.-P.: Preparation and stability of poly(acrylic acid)-graft-poly(ethylene glycol) films on stainless steel investigated by FTIR-ATR Spectroscopy (Poster), 23rd Conference of the European Colloid and Interface Society, Antalya, Türkei, September 2009.

Thomas, M.; Lachmann, K.; Dohse, A.; Thrane, M.; Morlock, J.; Klages, C.-P.: Surface amination of three-dimensional substrates by RotoTEC plasma treatment under defined gas atmospheres at ambient pressure (Vortrag), International Symposium on Plasma Chemistry 19 (ISPC 19), Bochum, Juli 2009.

Thomas, M.; Eichler, M.; Dani, I.; Lommatzsch, U.; Grünler, B.; Schulz-von der Gathen, V.; Viöl, W.; Weltmann, K.-D.; Klages, C.-P.: Recent and future applications of atmospheric pressure plasma technology in Germany (Vortrag), The 2nd International Symposium of Plasma Center for Industrial Applications (PLA-CIA) & Plasma Application Monodzukuri (PLAM) on Industrial Application of Advanced Plasma Technology (Placia), Nagoya, Japan, 2009.

Dissertations

von Borries, G.: Empirische Modelle zur Bewertung des tribologischen Verhaltens von Kohlenstoffschichten. Braunschweig: Fraunhofer IRB Verlag, 2009 (Berichte aus Forschung und Entwicklung IST, Band 28). Zugl.: Braunschweig, Techn. Univ., Diss., 2008.

Paulkowski, D.: Strukturelle Eigenschaften von dünnen amorphen Kohlenstoffschichten und ihre Auswirkungen auf Mikrotribologie und Deformationsverhalten. Braunschweig: Fraunhofer IRB Verlag, 2009 (Berichte aus Forschung und Entwicklung IST, Band 30). Zugl.: Braunschweig, Techn. Univ., Diss., 2009.

Diploma Theses

Loch, D.: Prozessentwicklung und Charakterisierung für die reaktive Abscheidung von Aluminiumoxid mittels Modulated Pulse Plasma, Fachhochschule Oldenburg/Ostfriesland/ Wilhelmshaven, Oktober 2009.

Wellhausen, J.: Untersuchungen eines Hochleistungs-Impuls Plasmas beim Sputtern von Nickel-, Chrom-, Nickel-Chrom-Targets mittels optischer Emissionsspektroskopie, Hochschule für angewandte Wissenschaft und Kunst Göttingen, Dezember 2009.

Zickenrott, T.; Optimierung von Partikelströmen im reaktiven Co-Sputterprozess durch Einsatz angepasster Shaperblenden, Fachhochschule Braunschweig/Wolfenbüttel, Juli 2009.

Weiss, P.: Galvanische Abscheidung von Aluminium aus ionischen Flüssigkeiten, Hochschule für Technik und Wirtschaft, Aalen, September 2009.

Knorn, S.: Versuche zur Abscheidung von Aluminium aus ionischen Flüssigkeiten, Hochschule für Technik und Wirtschaft, Aalen, Juni 2009.

Recknagel, N.: Prozessentwicklung titanbasierter Hartstoffschichten an einer PA-CVD Anlage, Fachhochschule Dortmund, Juni 2009.

Prices and Awards

Höfer, M.; Schäfer, L.: Technologietransferpreis der Industrie- und Handelskammer Braunschweig, 13. November 2009.

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-Gesellschaft the institute pools its competences with those of other Fraunhofer Institutes in, amongst other things, the Fraunhofer Surface Technology Consortium, the Surface Technology and Photonics Group (VOP) 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.

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 more than 80 research units in Germany, including 59 Fraunhofer Institutes. The majority of the 17,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.6 billion. Of this sum, more than €1.3 billion is generated through contract research. Two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Only one third 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.

Affiliated research centers and representative offices in Europe, the USA and Asia provide contact with the regions of 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 LIGHT & SURFACES

Competence by networking
Six Fraunhofer institutes cooperate in the Fraunhofer Group 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 technologies

- Beam sources
- Micro- and nanotechnology
- Materials treating
- Opto-mechanical precision systems
- Optical measuring systems

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.
www.iof.fraunhofer.de

Fraunhofer Institute for Electron Beam and Plasma Technology, Dresden
Electron beam technology, pulse magnetron sputtering and plasma activated high-rate deposition are the core areas of expertise of Fraunhofer FEP. The 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.
www.fep.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT, Aachen
The Fraunhofer ILT is worldwide one of the most important development and contract research institutes of its specific field. The activities cover a wide range of areas such as the development of new laser beam sources and components, precise laser based metrology, testing technology and industrial laser processes. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and rapid prototyping.
Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology. We offer feasibility studies, process qualification and laser integration in customer specific manufacturing lines.
www.ilt.fraunhofer.de

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, information and communication, life science and ecology.
www.ist.fraunhofer.de

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.
www.ipm.fraunhofer.de

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.
www.iws.fraunhofer.de

CONTACT

GROUP CHAIRMAN
Prof. Dr. Andreas Tünnermann
Albert-Einstein-Straße 7
07745 Jena
Phone +49 3641 807-201

GROUP ASSISTANT
Susan Oxfart
Phone +49 3641 807-207
Internet www.vop.fraunhofer.de

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

The Fraunhofer IST has continued its intensive commitment to the Network of Competence INPLAS e.V. in the year under review. Basic aim of INPLAS is to pool the extensive practical and scientific competencies in the field of plasma technology which exist in Germany and Europe and to clearly communicate the great potential this technology has. Since July 2006 INPLAS has been accredited by the Federal Ministry of Economics and Technology (BMWi) and collaborates in the initiative »Kompetenznetze Deutschland«. INPLAS currently has members of whom 70% come from industry. The Network of Competence has its office at the Fraunhofer IST.

Activities in 2009

2009 was a particularly successful year for the network. One highlight on the political side was a Parliamentary Evening on the topic of plasma technology held in Berlin in March. Important events for INPLAS's work include an intensive expansion of the working groups, preparation of studies, strategic topics such as »New materials for functional surfaces« and »Prospects for plasma in 2020«, a great deal of activities at events and trade fairs such as the Hanover Fair, Materialica, V2009, and also an intensification of contacts with the French network ViaMéca.

Parliamentary Evening 2009
»Potentials of plasma technology«

The first Parliamentary Evening focusing on the subject of plasma technology was held on March 18, 2009 in Berlin, having been planned and organized by the INPLAS office. It demonstrated where plasma technology is already in service and what potential it has in the future, almost inconceivable today. In her speech, Edelgard Bulmahn, Member of the Bundestag, gave an overview of plasma applications to date and outlined visions for the future. How this ionized gas is already being used today in an extraordinarily versatile way was shown in an impressive short film »Plasma: the unknown quantity«, which was specially produced for this evening in the Spree Palais am Dom. The film clearly shows that there is virtually no field in which plasma surface technology is not being used in the most diverse ways – from the automotive industry, aerospace, optics, medicine and life science, information technology, energy and environmental technology to mechanical engineering and tool manufacture. The accompanying industrial exhibition »Plasma: a bright advantage«, involving twenty exhibitors covering seven different fields, gave a lasting impression of the great range of plasma technology and of developments in the German plasma scene.
Around one hundred guests from politics, industry and research organizations were impressed by the world of plasma technology.

Development of the working groups

Particularly the working groups »New plasma sources and processes« of Dr. Bernhard Cord, Singulus Technologies AG, and »Hard and superhard tool coatings« chaired by Dr. Jan Gäbler, Fraunhofer IST, were able to successfully continue their work over five meetings in all. Mini-workshops, technical discussions, and tests on specific topics formed the framework for an intensive exchange of information and ideas in relatively small groups.

Other activities

The acquisition of a funded project for intensifying contacts abroad made it possible to expand activities with the French mechanical engineering network ViaMéca which has about 200 members. The work planned for 2010 was finalized in preliminary project meetings in St Étienne and Düsseldorf. The first joint objectives are project studies and collaboration in education. A lot of effort was also put into intensifying work in the committee »Plasma Germany« (previously »AK Plasma«). The new internet site www.inplas.de was launched in December 2009, providing long-term support for the improved marketing of plasma surface technology and better service for our members.

1 The INPLAS work group »Tools« chaired by Dr Jan Gäbler (Fraunhofer IST, 2nd from right) meets during the meeting of the Joint Industrial Research Group for »Tool Coatings and Cutting Materials« at the IWF (Institute for Machine Tools and Plant Operation) in Berlin.

2 Edelgard Bulmahn, Carola Brand and Dr Stephan Küper of Leybold Optics GmbH in Alzenau; INPLAS members provide them with information about the various possible fields of application for plasma surface technology.

CONTACT

Dipl.-Ing. Carola Brand
Phone +49 531 2155-574
carola.brand@inplas.de

Dr.-Ing. Gerrit von Borries
Phone +49 531 2155-662
gerrit.von.borries@inplas.de

www.inplas.de

MEMBERSHIPS

Plasma Germany
www.plasmagermany.org

Competenz-Centrum Ultrapräzise Oberflächenbearbeitung
CC UPOB e. V.
www.upob.de

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

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

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

European Society for Precision Engineering
and Nanotechnology (euspen)
www.euspen.eu

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

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

Fraunhofer-Netzwerk Elektrochemie
Zentrum für Mikroproduktion e. V. (ZemPro)

International Council for Coatings on Glass e. V.

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

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

Nanotechnologie-Kompetenzzentrum
»Ultradünne funktionale Schichten«
www.nanotechnology.de

Neue Materialien Niedersachsen e. V. (NMN)
www.nmn-ev.de

PhotonicNet GmbH – Kompetenznetz Optische Technologien
www.photonicnet.de

Fraunhofer-Allianz Adaptronik
www.adaptronik.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 Syswasser
www.syswasser.de

Fraunhofer-Verbund Light & Surfaces
www.vop.fraunhofer.de

PICTURE INDEX

Cover picture
Großflächige Beschichtung von Gleitringdichtungen mit dem Heißdraht-CVD Verfahren. Bild: Reiner Meier, BFF Wittmar

S. 2: Jan Benz, Fraunhofer IST, Braunschweig

S. 3: Jan Benz, Fraunhofer IST, Braunschweig

S. 6: Wolfgang Diehl, Fraunhofer IST, Braunschweig

S. 10: Jan Benz, Fraunhofer IST, Braunschweig

S. 12: Jan Benz, Fraunhofer IST, Braunschweig

S. 14: Jan Benz, Fraunhofer IST, Braunschweig

S. 16: Reiner Meier, BFF Wittmar

S. 22: Reiner Meier, BFF Wittmar

S. 24: Reiner Meier, BFF Wittmar

S. 26; 1, 2, 3: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 28/29: Tobias Duffe, Fraunhofer IST, Braunschweig

S. 30: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 32; 1: European Space Agency - ESA;

S. 32; 2.: Rolls-Royce Group

S. 34; 1: European Space Agency - ESA;

S. 34; 2: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 36; 1: Manuela Lingnau, Fraunhofer WKI, Braunschweig

S. 37: Lisa Wolf, Fraunhofer IST, Braunschweig

S. 38: Reiner Meier, BFF Wittmar

S. 40; 1: Manuela Lingnau, Fraunhofer WKI, Braunschweig

S. 40; 2: Saskia Biehl, Fraunhofer IST, Braunschweig

S. 41; 3, 4: Sebastian Staufenbiel, Fraunhofer IST, Braunschweig

S. 42; 1: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 42; 2: Saskia Biehl, Fraunhofer IST, Braunschweig

S. 44: Dr. Martin Keunecke, Fraunhofer IST, Braunschweig

S. 46: Dr. Jan Gäbler, Fraunhofer IST, Braunschweig

S. 48: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 50; 1: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 51: BASF-Gruppe

S. 52: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 54: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 56: Christina Polenzky, Fraunhofer IST, Braunschweig

S. 58: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 60: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 62; 1: Philipp Hennecke, Fraunhofer IST, Braunschweig

S. 62; 2: Falko Oldenburg, Fraunhofer IST Braunschweig

S. 64: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 66; 1: Antje Dohse, Fraunhofer IST, Braunschweig

S. 66; 2: Oliver Schön, Helmholtz-Zentrum für Infektionsforschung (HZI), Braunschweig

S. 67: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 68; 2: Mercedes Cerezuela Barreto, Fraunhofer IST, Braunschweig

S. 70: Dr. Kirsten Ingolf Schiffmann, Fraunhofer IST, Braunschweig

S. 72; 1, 2: Dr. Kirsten Ingolf Schiffmann, Fraunhofer IST, Braunschweig

S. 72; 3: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 73: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 74: Reinhold Bethke, Fraunhofer IST, Braunschweig

S. 75: Reinhold Bethke, Fraunhofer IST, Braunschweig

S. 76/77: Michael Siemers, Fraunhofer IST, Braunschweig

S. 78/79: Dr. Andreas Pflug, Fraunhofer IST, Braunschweig

S. 80; 1: Dr. Martin Keunecke, Fraunhofer IST, Braunschweig

S. 84: Sandra Palm, Fraunhofer IST, Braunschweig

S. 86: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 88: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 89: Wolfgang Diehl, Fraunhofer IST, Braunschweig

S. 90: Anika Heddergott, Fraunhofer IST, Braunschweig

S. 92: Institut für Werkzeugmaschinen und Fabrikbetrieb IWF, TU Berlin, Berlin

S. 93: Falko Oldenburg, Fraunhofer IST, Braunschweig

S. 94: Wolfgang Diehl, Fraunhofer IST, Braunschweig

S. 116: Mandalla, photocase.com

S. 120: Fraunhofer-Verbund Light&Surfaces

S. 121: Reiner Meier, BFF Wittmar

S. 122; 1: Pia Gausemeier, Institut für Werkzeugmaschinen und Fabrikbetrieb IWF, TU Berlin, Berlin

S. 122; 2: Jochen Meusel, CONMEDIA, Braunschweig

All other pictures: Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig.

IMPRINT

Fraunhofer Institute for Surface Engineering and Thin Films IST

Director of the Institute
Prof. Dr. Günter Bräuer

Deputy Director of the Institute
Dipl.-Ing. Wolfgang Diehl

Bienroder Weg 54 E
38108 Braunschweig
Phone +49 531 2155-0
Fax +49 531 2155-900
info@ist.fraunhofer.de
www.ist.fraunhofer.de

Editorial und coordination:
Dr. Simone Kondruweit
Dipl.-Sozialwiss. Elena Droege
M. A. Anika Heddergott

Layout
Dipl.-Des. Falko Oldenburg

Print
Maul-Druck GmbH, Braunschweig
www.mauldruck.de