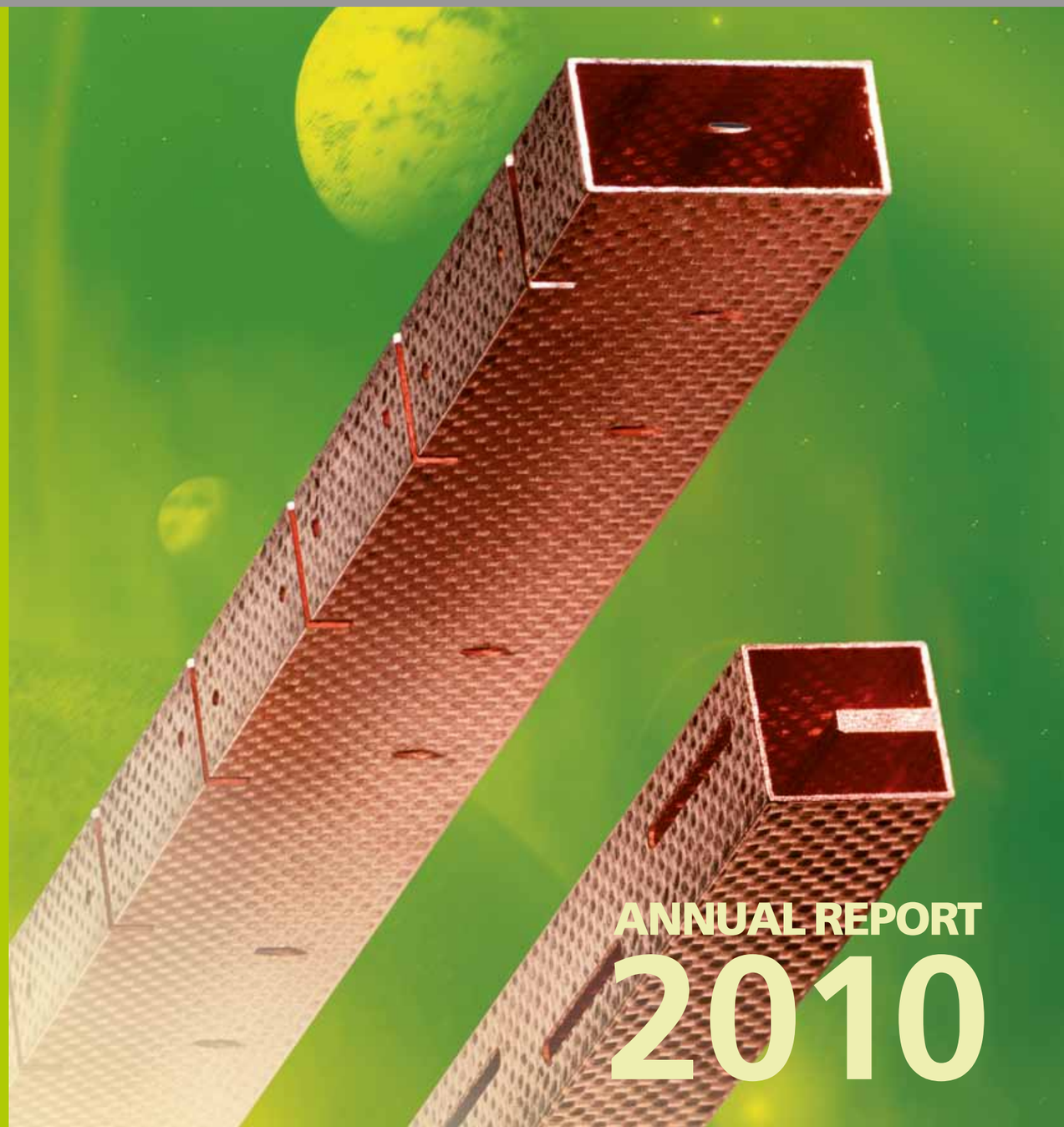
Fraunhofer
IST

FRAUNHOFER INSTITUTE FOR SURFACE ENGINEERING AND THIN FILMS IST

ANNUAL REPORT 2010

FRAUNHOFER IST



ANNUAL REPORT 2010

ANNUAL REPORT

2010

FOREWORD

Ladies and gentlemen,

In your hands you are holding our yearbook 2010. 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 2010 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.*

CONTENT

HIGHLIGHTS 2010

"Farewell to the ice scraper". Late in the autumn of 2010 headlines like this appeared in nearly all daily newspapers in Germany, and the sentiment was echoed by radio and television. Appropriately enough for the approach of winter, the Fraunhofer IST had introduced a non-fogging, non-icing glazing which represented the preliminary results of fifteen years of research in the field of transparent conductive coatings. The key to producing coatings of this kind is a so-called highly ionized plasma. This makes them harder than glass and thus usable for, among other things, the automobile windshield. Of course, drivers need to have a little patience before the new product goes into full-scale production at our project partners but its feasibility has been demonstrated and the bothersome labor of scraping away at windscreens on an icy winter morning should thus become a thing of the past.

The "non-icing window" is just one of the many highlights which the year 2010 had in store for our institute. At the annual Fraunhofer conference in May, a research team consisting of four Fraunhofer institutes and seven companies, lead-managed by scientists from the Fraunhofer IST was awarded the Stifterverband Award for Science 2010. The team was honored for its joint development of a new material composite – a diamond-coated ceramic – which would mean a longer service life for particularly heavily stressed tools and components while also improving their performance. This innovation has already entered service in the industrial sector. In the case of the face seals used by the EagleBurgmann of Germany for critical areas such as pumping oil, sand and gas mixtures the diamond coating extends their service life by a factor of 4 to 1000, depending on the application.

Denser, harder, more wear-resistant, more transparent – thanks to innovative plasma technology our surfaces and coatings are getting better and better. However not just plasma but also our electrochemical activities have something new to offer. When in the near future Sentinel 1, the first European observation satellite, starts sending and receiving information to and from the earth, it will be using antennas which were metallized in our electroplating installations. »Coatings for our future«: in 2010 too we have therefore with our current developments once again come somewhat closer to this guiding vision of the Fraunhofer Institute for Surface Engineering and Thin Films. The year under review has been a complete success not only from the technical and scientific points of view but also on the business side. Despite the economic crisis we posted an increase in our revenues from industry of more than 10 percent compared with 2009. In absolute terms - over 5 million euros - this was once again an all-time high.

On May 27 the Fraunhofer-Gesellschaft board, representatives from science, research and industry and also from the city of Braunschweig gathered to inaugurate the institute's new building for research from laboratory to large scale production. It offers the best conditions for a further expansion of research activities and for collaboration with the Institute for Surface Engineering (IOT) of the Technical University. For the second time in Braunschweig the International Conference on Coatings on Glass and Plastics ICCG 8 was held in June under the supervision of the Fraunhofer IST. Over the five days of the conference around 400 international experts from the glass and plastic coating community met in the Stadthalle Braunschweig to discuss the latest results from research and practical application. The fact that the international organization committee once again entrusted our institute with the role of local organizer underlines the importance of our work in these important fields of coating technology. On August 28, on the occasion of the 20th anniversary of the Fraunhofer IST, we, together with our neighbors and the Fraunhofer WKI, opened our doors to the citizens of Braunschweig to give them an insight into our work. How do you make lightning in the laboratory? What do you do with plasmas? How can diamond clean water? How do surfaces get wear-resistant and low-friction properties? Our employees answered these and many other question for our curious visitors. With more than 900 people attending we found the response almost overwhelming.

The Network of Competence for Industrial Plasma Surface Technology INPLAS set up and sponsored by the Fraunhofer IST continues to develop in an extremely satisfactory manner. In the autumn the information film »Plasma leuchtet ein« commissioned by the network received one of the top two awards at the first Cannes Corporate Media & TV competition, prevailing against strong competition from 27 countries. The film very vividly presents current key applications of plasma technology and its future potential.

Existing international cooperative activities of the Fraunhofer IST, particularly with France, South Africa and South Korea, were consolidated, new networking connections were created and sealed by the corresponding agreements. A HIPIMS Research Center was founded in conjunction with scientists from Sheffield Hallam University (UK) - HIPIMS stands for high power impulse magnetron sputtering - with a view to future collaboration on identifying the possibilities which highly ionized plasmas could offer the coating industry.

If we may be permitted in the following pages to show you a selection of results from one of the most successful years the Fraunhofer IST has experienced, we owe this above all not only to our contractors from industry and to our sponsors but also to our outstanding employees. Having set itself challenging goals, not only scientifically and technically but also economically, our institute will continue on its successful course in 2011 as well.

STIFTERVERBAND AWARD FOR SCIENCE 2010

Together with researchers from four other Fraunhofer institutes and partners from industry the Braunschweig Fraunhofer scientists Dr. Lothar Schäfer and Dr. Markus Höfer, Dr. Simone Kondruweit and Markus Armgard of the Fraunhofer Institute for Surface Engineering and Thin Films IST have been awarded the 50 000 Stifterverband Award for Science for their successful work on the development, application and technological transfer of the composite material, the diamond-coated ceramic – DiaCer®, for ceramic seals. The scientists from Braunschweig coordinated the project and were significantly involved in its success. The Stifterverband Award for Science 2010 is one of the most important scientific prizes in Germany.

The aim of a team made up of members from research and industry was to develop a material with a high level of wear protection. The solution it came up with means a longer service life for particularly heavily stressed tools and components while also improving their performance. Diamond is a material with outstanding properties: it is exceptionally hard, conducts heat well and has nothing to fear from chemical substances. Ceramics – and high-performance ceramics in particular – can also offer some special qualities: they are robust and can withstand extreme temperatures. Scientists from four Fraunhofer institutes together with partners from industry have succeeded in creating a new composite material and making it useful for practical applications. The composite material »DiaCer® diamond-coated ceramic« combines the best of both materials. Anywhere components or tools come under extreme stress, such as in pumps or in forming tools, DiaCer® offers maximum wear protection combined with low coefficients of friction.

The base is a silicon nitride or carbide ceramic modified by researchers from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden to enable it to be coated with diamond. Their task was to find out what form the ceramic would have to take for the diamond film to adhere firmly and evenly to the substrate. This is of crucial importance to service life. Material and component simulations carried out by colleagues at the Fraunhofer Institute for the Mechanics of Materials IWM in Freiburg yielded extremely useful information here as did contributions from colleagues at the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin relating to processing ceramics. »We, on the other hand, worked on the coating and designed the installations«, says project coordinator Dr. Lothar Schäfer of the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig. For the underlying hot-filament CVD coating technology, components and tools were first placed in a vacuum container. The researchers then introduced methane and hydrogen. To ensure the diamond film grows, wires are stretched a few centimeters above the objects to be coated and then brought up to white heat. This activates the gas, and carbon is deposited on the surface in the form of crystalline diamond. »Our method allows us to apply a diamond film measuring up to half a square meter«, says Schäfer. »That is unique worldwide«.

Two examples will illustrate the advantages. To take the face seals used by the EagleBurgmann company of Germany for critical environments such as pumping oil, sand and gas mixtures the diamond coating extends their service life by a factor of 4 to 1000, depending on the application. Drawing dies are a forming tool used in manufacturing wire. The special feature here is the internal coating which is made possible by a modification of the procedure. Drawing dies for different diameters have accordingly been coated so that even very thick wires and non-circular cross-sections can be produced. The test dies used in production at the Elisental wiremaking works, for example, showed hardly any wear even after many tonnes of wire had been produced. Face seals for pumps have in the meantime been coated with diamond by Condias GmbH and marketed by EagleBurgmann in a number of difficult areas of application. A large number of further applications are conceivable. »The bottom line is that DiaCer® is of interest for all components in mechanical engineering which require a high level of wear protection«, says Dr. Schäfer summing up.

Project partners

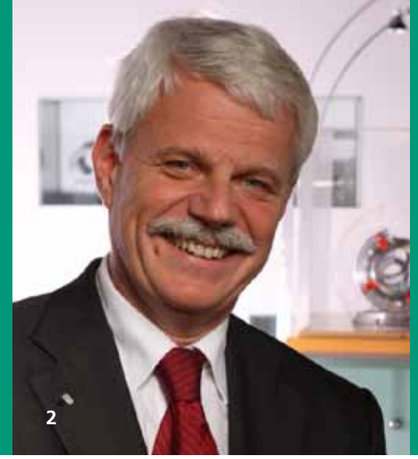
- Fraunhofer Institute for Surface Engineering and Thin Films IST
- Fraunhofer Institute for the Mechanics of Materials IWM
- Fraunhofer Institute for Ceramic Technologies and Systems IKTS
- Fraunhofer Institute for Production Systems and Design Technology IPK
- EagleBurgmann Germany GmbH & Co. KG
- Ceram Tec AG
- Condias GmbH
- Drahtwerk Elisental W. Erdmann GmbH & Co.
- Drahtzug Stein GmbH & Co. KG
- H. C. Starck Ceramics GmbH & Co. KG
- KSB AG

OTHER PRIZES AND AWARDS

2010 Arch T. Colwell Merit Award
Reinhold Bethke, a scientist at the Fraunhofer IST, was honored at SAE, the world's largest automotive conference in Detroit. For his publication on the frictional behavior of diamond-like carbon coatings when different engine oils are used, he received the Arch T. Colwell Merit Award.

Prize for the best presentation
At the »3rd International Symposium on Transparent Conductive Materials« at Analipsi in Crete, Christina Polenzky, a PhD student at the Fraunhofer IST, was received an award for the best oral presentation by a scientist of his or her own dissertation. Within the context of the subject of the dissertation – the »Production and characterization of p-conductive TCOs« – she presented the latest results regarding the production of $CuCrO_2$ by hollow-cathode gas-flow sputtering and regarding a p-conductive Cu-Al-O system.

Cannes Corporate Media & TV Award
Cannes Corporate Media & TV Award: With the ten-minute film »Plasma – a bright advantage« CONMEDIA and INPLAS e. V. in collaboration with the Fraunhofer IST gained second place in the Business and Industrial Films category. Receiving the prize were the producer Jochen Meusel of CONMEDIA for the client INPLAS e. V. and Carola Brand, manager of the Network of Competence for Industrial Plasma Surface Technology INPLAS at Fraunhofer IST.



BOARD OF TRUSTEES

1 *Members of the board of trustees.*
2 *Dr.-Ing. W. Steinbach EagleBurgmann Germany GmbH & Co. KG, member of the board of trustees.*

Chairman
Dr. P. Lichtenauer
Plasmawerk Hamburg GmbH

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

Dipl.-Ing. E. Dietrich
Frankfurt

Dr. U. Engel
Hagnau

Prof. Dr. H. Ferkel
Volkswagen AG

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

Dr. M. Müller
Robert Bosch GmbH

Dr.-Ing. A. Pawlakowitsch
Singulus Technologies AG

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

Dr.-Ing. W. Steinbach
EagleBurgmann Germany GmbH & Co. KG

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

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

Dr. E.-R. Weidlich
GRT GmbH & Co.KG

FROM THE BOARD OF TRUSTEES

For more than ten years now, EagleBurgmann has been working very successfully and intensively with the Fraunhofer Institute for Surface Engineering and Thin Films (IST). This collaboration stands among other things for joint projects of high scientific quality in applied research, conducted in cooperation with representatives of the business sector. As an example of the many other successful collaborations involving the Fraunhofer IST, I should at this point like to draw your attention to what industry recognizes as a success story and one which has been crowned with awards: the development of the DiaCer® technology. As a new composite material for extreme conditions, the "diamond coated ceramic DiaCer®" has been brought up to readiness for practical application and mass production by the combined knowledge and expertise of the Fraunhofer institutes in the fields of materials, coatings and application as well as where EagleBurgmann face seals are concerned. The main motivation for EagleBurgmann in developing a diamond-ceramic system lay in extending the service life of the seals and thus increasing customers' plant availability. The development of diamond coated face seals meant that the seals last very much longer in the most varied critical applications. This coating technology was transferred by the Fraunhofer IST to the highly successful company Condias where the DiamondFaces® coating is manufactured on an industrial scale. On the basis of further intensive collaboration between the Fraunhofer institutes and Condias, the application limits of the diamond-ceramic system have been extended even further and new areas of use opened up. These include, for example, a further reduction in the coefficient of friction, utilization in gas seals, and optimization of the coating process.

The adaptation of the technology for plain bearings is opening new doors in the field of energy-efficient machinery and equipment. This fruitful collaboration and rapid transformation of a research project into a saleable product has been recognized in the form of several prizes, including the Technology Transfer Prize of the CCI Braunschweig, the German Science Foundation prize in 2010, the Best Practice Award awarded by US management consultants Frost & Sullivan, or the 2008 Innovation Award given by the US magazine Flow Control in recognition of outstanding performance in fluid-handling technology. These are international awards and acknowledgements of which all involved can be very proud. But what is of crucial importance to these successes are the people behind those projects and undertakings. Enthusiasm for the new technologies of the associative partners motivates the staff at the Fraunhofer IST (and vice versa) to keep pushing their research work forward with great commitment, knowledge and expertise. Trustful and open communication between all those involved here forms the basis for rapid progress in development work. The work of the Board of Trustees supports the application-oriented direction of research. Interesting presentations of the latest results of research activities are accompanied by application-related information and suggestions from partners in industry and in the research institutes at the federal level and in the state of Lower Saxony. The Fraunhofer IST is therefore extremely well positioned for the future as well.

W. Steinbach

Dr.-Ing. W. Steinbach
EagleBurgmann Germany GmbH & Co. KG

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
- Aerospace
- 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:

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

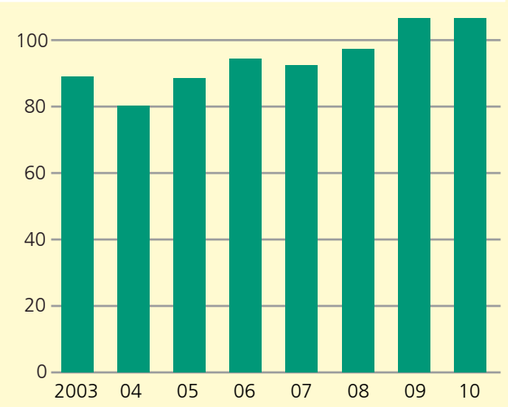
Personnel trends
There was no change in the number of employees (106). More than half of our employees were scientific personnel, doctoral candidates and engineers. Our research work is supported by technical staff, student assistants and graduands. A team of commercial staff is available for all administrative tasks. Training schemes exist in the IST in the fields of physics and IT. Currently five young employees are under training here.

Operating budget
Operating expenses run to a total of 12.1 million euros. In comparison with the previous year, personnel costs increased by 0.5 million euros and are now just over 7 million euros. Personnel costs here make up just over 60 percent of the operating budget.

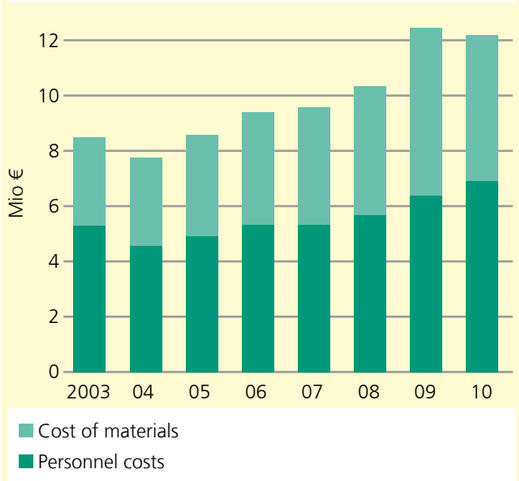
Earnings structure
While the revenues from industry amounted to €4.4 million in 2009, it was possible to earn €5.2 million in 2010. The revenues from the public sector amount to 3.4 million euros in 2010. Thus external revenues in total were increased by 600 thousand euros to 8.6 million euros. Because of the positive operative result, the already existing reserve of the institute was again increased.

Investments
In 2010 approx.1.4 million euros was dispensed on investment. One third of this was for normal investments while further investments were made possible within the context of special contributions.

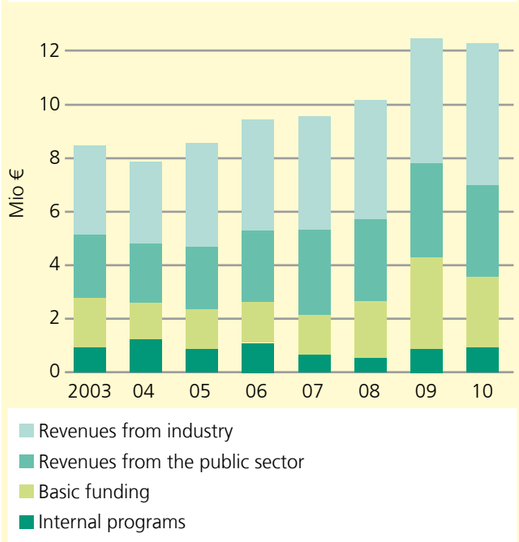
Employees.



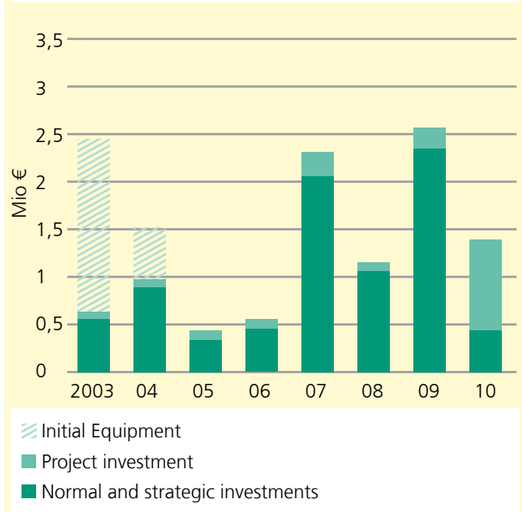
Personnel and materials cost.



Earnings structure.



Investments.



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
- Analysis and Quality Control

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.-Kfm. 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

DORTMUND SURFACE TECHNOLOGY CENTER (DOC)

Dipl.-Ing. Hanno Paschke
Phone +49 231 844-5453 | hanno.paschke@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-wire CVD processes | Large-area hot-wire CVD systems | Hot-wire 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

Dr. 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

Phone +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 | New semiconductor for photovoltaics and microelectronics

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 PROCESSES 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 | Microplasmas | 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

ANALYSIS AND QUALITY ASSURANCE Dr. Kirsten Schiffmann

Phone +49 531 2155-577 | kirsten.schiffmann@ist.fraunhofer.de

Microscopy and structure analysis | Industrial services | customer specific test engineering

THE SCOPE OF RESEARCH AND SERVICES

PRETREATMENT

We clean surfaces

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

- Effective aqueous surface cleaning including drying
- Special glass cleaning
- Plasma pretreatment and Plasma cleaning
- Plasma activation and Plasma 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
- Developement of plant components 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:

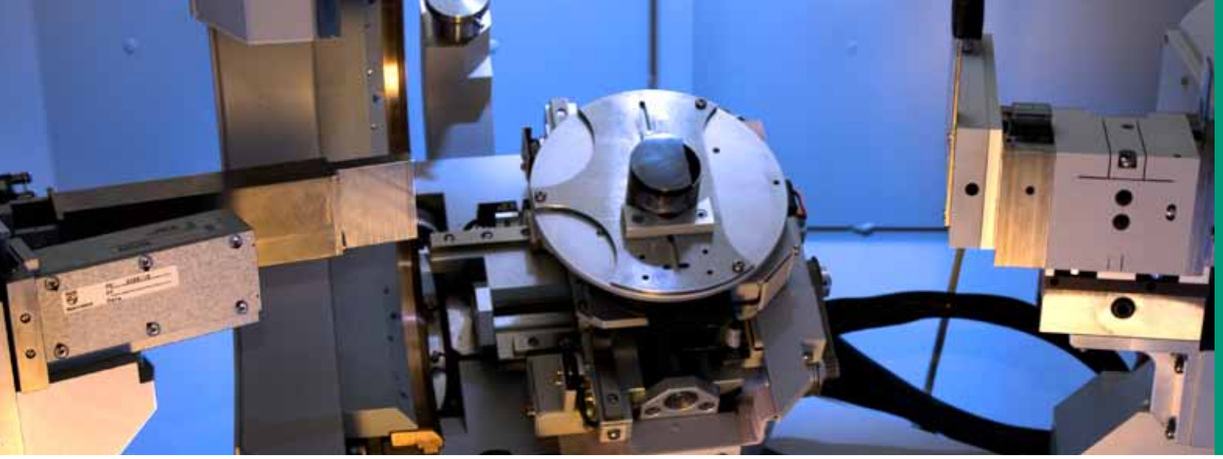
- Mechanical, chemical, micromorphological, and structural characterization
- Test methods and product specific quality control methods, e. g. wear measurement on arbitrary parts
- Ply adhesion test methods
- Optical and electrical characterization
- Rapid and confidential failure analysis
- Testing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

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



ANALYSIS AND QUALITY CONTROL

- High resolution scanning electron microscope with energy dispersive x-ray analysis (EDX)
- Electron probe microanalysis (EPMA)
- Secondary-ion mass spectrometer (SIMS)
- X-ray diffraction equipment for structural analysis and for reflectivity measurement (XRD, XRR)
- X-ray photoelectron spectroscopy (XPS)
- Glow-discharge spectroscopy (GD-OES)
- Scanning tunnel and atomic force microscope (STM, AFM)
- Micro indenter and nano indenter for hardness and young's modulus determination of coatings
- Profilometer
- Automated, non-destructive measurement of film thickness
- Testing equipment for friction, wear and coating adhesion
- Testing equipment for corrosion measurement
- 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
- Systems for testing of electro chemical wastewater treatment
- Equipment and methods for the characterization of the photocatalytical activity
- Measuring station for the characterization of solar cells

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
- Sputter plant for high-precise optical coatings
- In-line coating facility for large-surface optical functional coatings (up to 60 × 100 cm^2)
- Industrial scale HIPIMS technology
- PVD coating plant (elektronbeam and thermal)
- Plants for plasma diffusion
- Coating systems for hollow cathode processes
- Atomic layer deposition (ALD), coating plant forr thermal and Plasma-ALD
- Hot-filament-CVD units for diamond coatings and silicon-based coatings (up to 50 × 100 cm^2)
- Hot-filament-CVD unit for silicon-based coatings (up to 50 x 60 cm^2)
- Plasma-activated CVD (PACVD) units
- Atmospheric pressure plasma systems for coating and functionalization of large areas (up to 40 cm widths)
- Microplasma plants for selective functionalization of surfaces (up to ∅ = 20 cm)
- Bond aligner with an integrated plasma tool for wafers treatment 15-stage cleaning unit for surface cleaning on aqueous basis in the clean room
- Roll-to-roll set-up for area-selective functionalization of surfaces
- Machine for internal coating of components or e. g. bags or bottles
- Laser for 2-D and 3-D microstructuring
- 2 mask aligner for photolithographic structuring
- Laboratory for microstructuring (40 m^2 clean room)
- Equipment for electroplating processes
- 15-stage cleaning unit for surface cleaning on aqueous basis
- Clean room – large area coating (25 m^2)
- Clean room – sensor technology (35 m^2)

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:

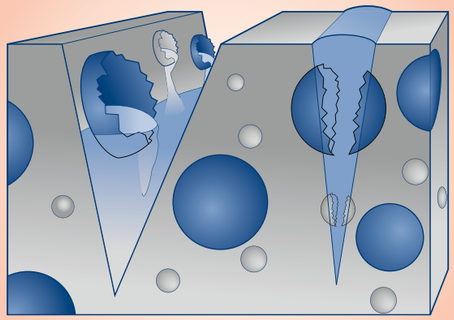
- Nanocontainers – small parts, big effect
- P^3T: A new technology for manufacturing flexible circuits, RFID antennas and biosensors
- Nanocomposites for sputtered strain gauges

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

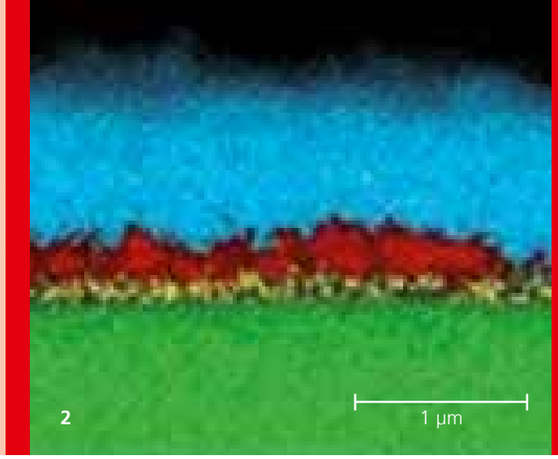
CONTACT

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



1



2

NANOCONTAINERS: SMALL PARTS, BIG EFFECT

Metallic surfaces can be modified by incorporating small nanocapsules containing special active substances into their matrix. With this new technique developed at the Fraunhofer IST, particles can now be installed precisely where they are required.

High-performance coatings for wear protection or even for non-stick applications have until now frequently been produced by commercial processes such as the composite deposition of PTFE in electroless nickel or SiC in nickel. Incorporation of liquids or chemically active substances in a coating requires them first to be kept in nanocontainers. These nanocontainers, having a diameter of approx. 200 nm, are then encapsulated in polymer, thus enabling them to be incorporated homogeneously in a metal matrix.

Galvanic composite deposition

A new concept involving functionalized nanocontainers has been developed at the Fraunhofer IST on the basis of galvanic composite deposition. Here particles consisting of liquid substances can be fixed not only into the matrix but also directly to the substrate surface so as, for example, to place high concentrations of special active substances in the locations where they are required. The basic aspects of this concept have been worked out at the Fraunhofer IST as part of a project funded by the VW Foundation.

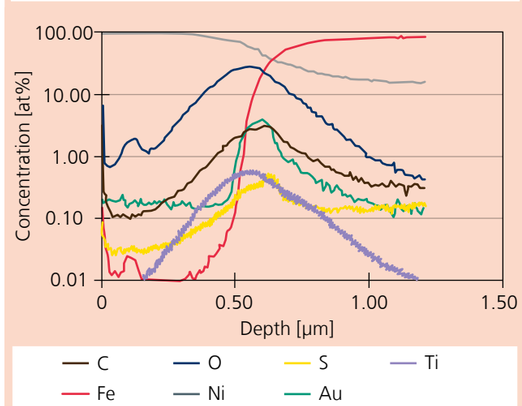
Properties of nanocontainers

Nanocontainers are mesoporous particles made, for example, of titanium dioxide encapsulated in polyelectrolyte (PE). Polyelectrolytes are water-soluble polymers carrying anionic or cationic charges. Familiar PEs include, for example, poly(allylamine hydrochloride) (PAH^+) or poly(acrylic acid) (PAA^-). The nanocontainers are encapsulated with alternating layers of differently charged PEs (LBL or layer-by-layer technology). Depending on the last PE the outermost layer of the nanocontainers will have either a negative or a positive charge.

Self-assembling monolayers fix nanocontainers in place

These mesoporous particles can then be attached by a so-called SAM layer (self-assembled monolayer) to the substrate which is to be coated. To do so the workpiece is galvanically coated beforehand with a thin film of gold. SAM layers consist of long-chain carbon molecules to one end of which a thiol group (-SH) is attached. This thiol group bonds to the gold surface. At the other end of the SAM layer there is a functional group which can carry an electrical charge. If this group has the opposite charge to the nanocontainers, this helps the particles adhere firmly. During subsequent galvanic metallization with, for example, nickel or zinc the particles remain attached to the surface and are enclosed by the metal. In the event of damage occurring, these particles can release the active substance they contain and thus provide the basis for a self-healing coating.

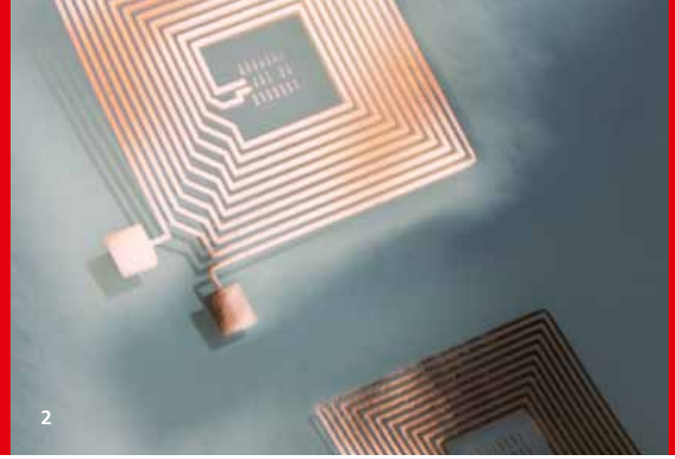
Depth profile of a electro-plated coating with self-healing effect.



1 Scheme of a self-healing coating with nanocontainers.
2 "Element mapping" of a cross-section polish: blue: nickel; red: titan; yelllow: gold; green: iron.

CONTACT

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



P³T: A NEW TECHNOLOGY FOR MANUFACTURING FLEXIBLE CIRCUITS, RFID ANTENNAS AND BIOSENSORS

In a joint project sponsored by the German Federal Ministry of Education and Research and known for short as P³T - which stands for Plasma Printing & Packaging Technology – the Fraunhofer IST, together with partners from science and industry, is developing a new kind of reel-to-reel technology for manufacturing flexible printed circuit boards, RFID antennas and biosensors. The P³T process chain starts with the plasma printing process, in which the substrate sheeting is structured at atmospheric pressure by location-selective plasma modification using microplasmas. This is followed by wet-chemical metallization, laying down of circuits and soldering. The aim is to develop a cost- and resource-efficient process.

Reel-to-reel plasma printing

The continuous plasma printing equipment consists of a deeply engraved metal roller and a stationary high-voltage electrode which is encased in an isolating material serving as a dielectric. The metal roller here functions as the counter-electrode. During plasma treatment the roller rotates together with the sheeting which is thus pressed against the roller surface by the electrode. As the sheet passes over the recesses of the roller structures, process gas-filled microcavities are created within which dielectric barrier discharges are generated (see graph). In this way the print image on the roller - in other words, the circuit structure, for example - is transferred to the sheeting in the form of a location-selective chemical functionalization. The plasma printing uses, for example, mixtures of nitrogen, hydrogen and helium as the process gas so as to create on the polymer surface the nitrogen-containing groups required for success in the metallization process which follows. A defined gas atmosphere is achieved in the plasma zone by means of a gas nozzle system positioned close to the electrode.

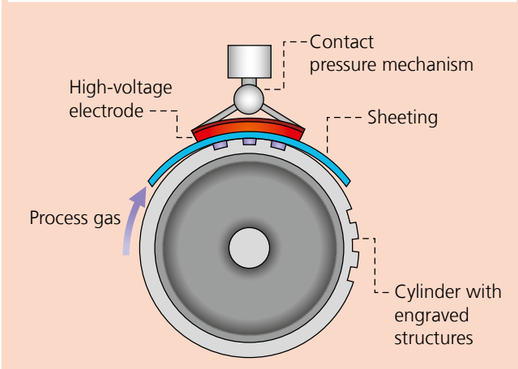
Material-saving additive technique in metallization

The plasma-functionalized areas of the sheeting are selectively metallized by electroless plating processes which may be followed by galvanic processes to reinforce the electroless metal layer. In contrast to commonly used subtractive processes the process developed at the Fraunhofer IST has fewer process steps, does not need etching chemicals, and in particular saves on valuable metal, such as, for example, copper. Expensive recycling processes are unnecessary. After metallization, circuitry is applied by the reel-to-reel method, followed by soldering using innovative energy-saving reflow-soldering methods.

Outlook

The cost efficiency and suitability of the P³T concept for resource-thrifty mass production are to be demonstrated in a prototypical production line which includes all of the process steps.

Reel-to-reel plasma printing.



1 Plasma printing set-up for the reel-to-reel process.
2 RFID antenna structure on polymer foil produced by P³T.

CONTACT

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

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

NANOCOMPOSITES FOR SPUTTERED STRAIN GAUGES

Strain gauges already have a wide range of applications today and this will in future be extended even further by the use of sputtered thin films as strain gauges. Investigation of special nanocomposites is revealing a great potential for innovative sputtered strain gauges with improved properties.

High measurement accuracy with strain gauges

Sputtered strain gauges have a multitude of advantages over conventional film strain gauges. They can, for example, be applied with a very high degree of automation and high positional accuracy, and since they are only a few micrometers thick they are easier to integrate into existing components. Of particular interest for high measurement accuracy however is the much greater sensitivity to strain of specially sputtered nanocomposite coatings in comparison with conventional metal foils.

Important variables in developing materials for strain gauges

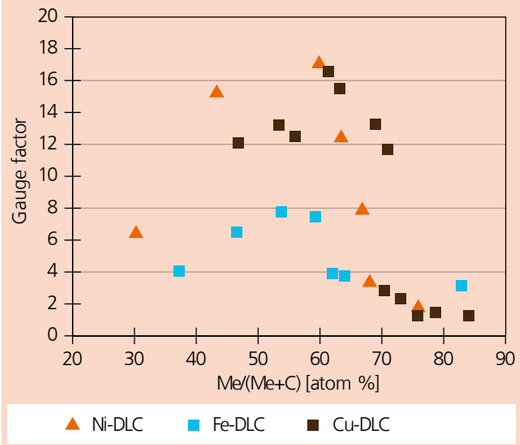
Strain gauges exploit the principle of electrical resistance changing under strain. The so-called gauge factor is a measure of the strain sensitivity of the strain gauge. The metal foils which are normally used have a gauge factor of approximately 2 while other materials can have much higher gauge factors. With semiconductors, gauge factors of more than 100 have been measured. However, semiconductors are not always suitable for use in strain gauges since they have a markedly temperature-dependent resistance, which is described by the temperature coefficient of electrical resistance (TCR). Particularly interesting for our strain gauge development are materials which have a high gauge factor coupled with a temperature coefficient approaching zero.

Nanocomposites for strain gauges

According to current research, nanocomposite coatings which are suitable for strain gauges consist of semiconducting matrix layers with embedded metal particles. These particles will ideally measure just a few nanometers in size. Nanocomposite coatings of interest are, for example, DLC coatings containing metal (Me-DLC). The resistance of the semiconducting DLC coating has a negative temperature coefficient (NTCR) while the metallic particles have a positive temperature coefficient of resistance (PTCR). When both materials are composed in a suitable ratio, these differing thermal characteristics lead to a temperature-independent resistance. Furthermore, the resistance of the coatings is dependent on the distance between the electrically conductive particles and thus changes much more markedly under strain than is the case with purely metallic coatings. Me-DLC makes it possible to achieve gauge factors above 10 with temperature-compensated strain sensitive coatings. The graph below shows the gauge factors of Me-DLC coatings with three different metals. The best results so far have been obtained with DLC coatings containing nickel (Ni-DLC).

Other interesting nanocomposites are for example Ti-Si-C coatings. Sputtering from a Ti-Si-C target results in coatings with nanocrystalline TiC particles (PTCR) in an amorphous SiC matrix (NTCR). Although these coatings with gauge factors of approximately 2 do not have greatly improved sensitivity to strain, they are still of interest for high-temperature applications since initial investigations have revealed very low temperature coefficients and thermal stability up to 700 °C.

Strain sensitivity of different Me-DLC coatings as a function of the metal content of the DLC coating.

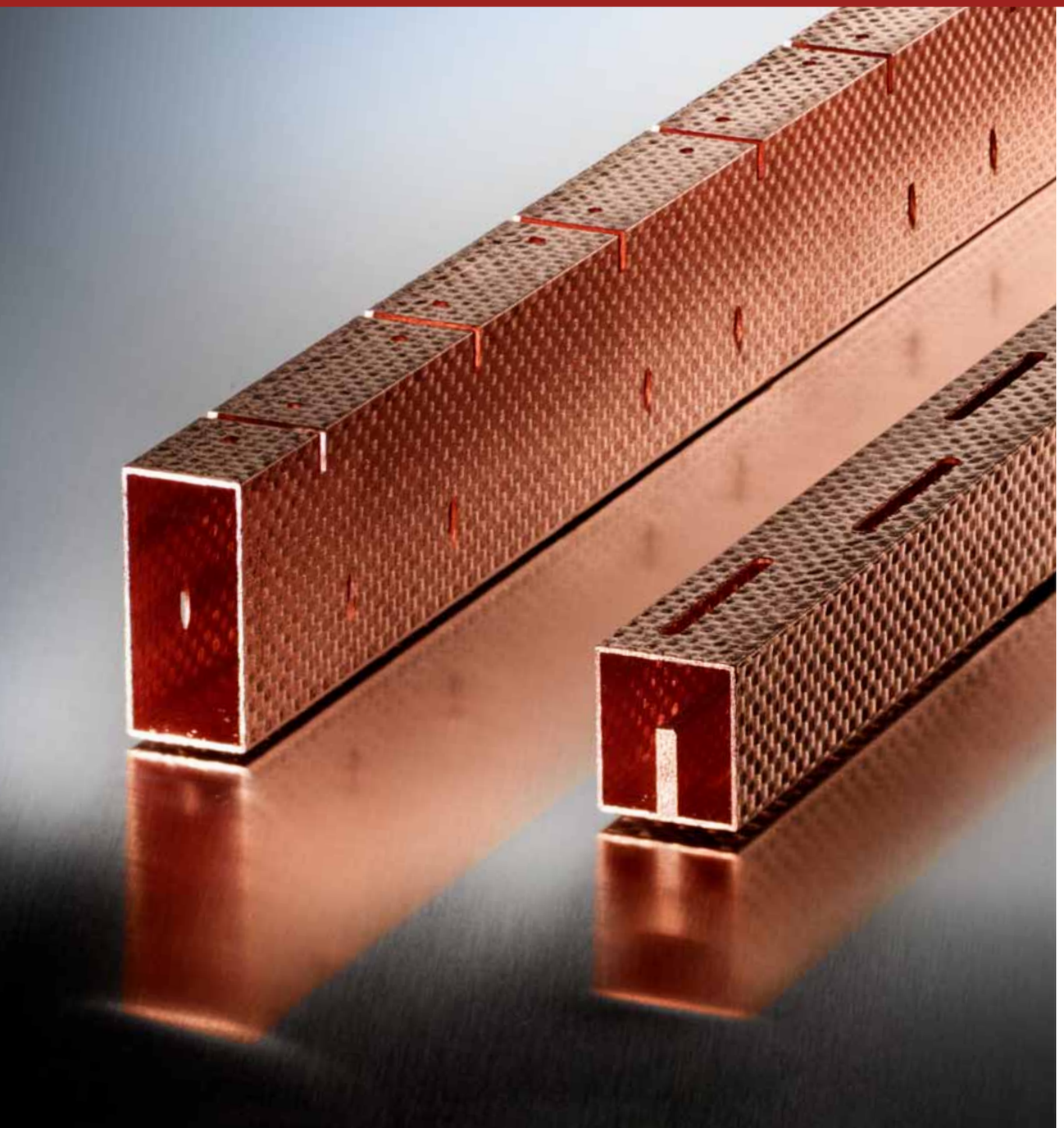


1 *Sputtered strain gauge on ball-bearing.*

CONTACT

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
- Wear protection coatings for turbines in jet planes
- Detection of bearing damage by integrated thin-film sensor system
- Development of surfaces for forming tools free of form release agent

Customers include companies in the aerospace industry and their suppliers.

CONTACT

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

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 side face of outside bearing rings and characterized them.

Area of application: civil aviation

In the field of flight control systems for commercial aircraft 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 actuating systems do however consist of a very large number of components which interact mechanically with each other thereby creating wear. A condition monitoring system is built in so as to prevent the effects of wear, 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 is an integral component of this system.

Sensor systems for state detection in primary flight control system actuators

The Micro- and Sensor Technology group at the Fraunhofer IST has already been working for years on the integration of piezoresistive thin-film systems which detect load directly in the bearing raceway. Since, however, the loads in the rolling surfaces are so high that sensorized coatings would suffer wear before the actuator reached the service life limit required in aviation, an application case has been investigated at the Fraunhofer IST whereby the coating system is on the outer ring and outside the main load areas. These new sensor systems were developed in collaboration with the Aviation Systems Engineering Institute of the DLR (German Aerospace Center) as part of the European project entitled »More Open Electrical Technologies« (MOET) and were tested at the DLR with regard to the necessary sensitivity and suitability for state detection.

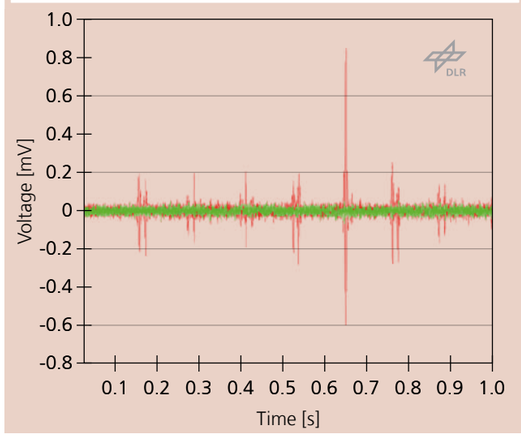
The piezoresistive thin-film system

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 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 (Fig. 1).

Detection of bearing damage in an electromechanical actuator

An actuator component test stand which simulated a direct-drive actuator was used for the tests at the DLR. The test stand for investigating bearings with the most varied types and degrees of damage consists of a permanently excited synchronous motor driving a roller spindle running in four-point bearings. Damage to the bearing results in a change in load distribution which in turn causes excitation of vibrations which can be measured by the coating system. The graph below compares the signals for an undamaged (green) bearing and a damaged (red) bearing.

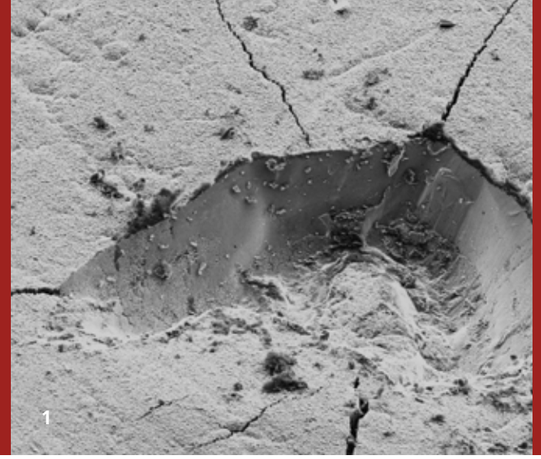
Comparison of thin-film sensor system signals for an undamaged and for a damaged bearing.

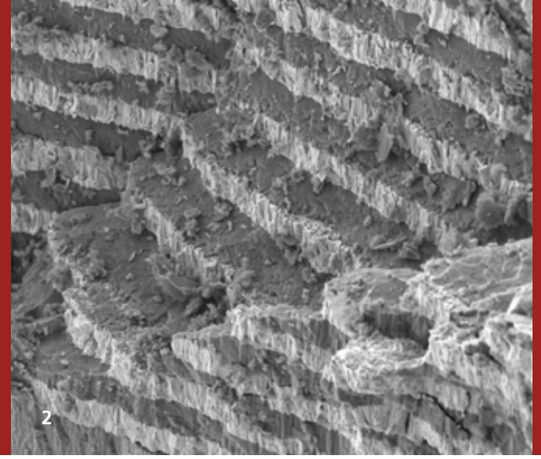


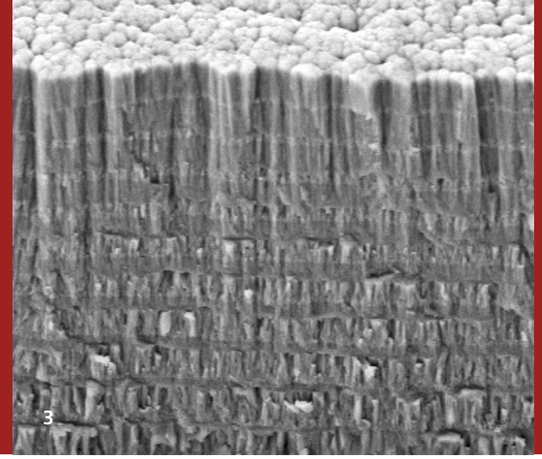
1 Bearing with a thin-film sensor system.
2 VFW 614 ATTAS and A 380 ATRA from DLR's fleet of aircraft in Braunschweig.

CONTACT

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







INNOVATIVE COMPOSITE COATINGS AGAINST PARTICLE EROSION IN GAS TURBINES

The erosive effect of wind-borne sand, volcanic ash, ice particles and even water drops getting into aircraft engines can be damaging to moving parts, which in turn leads to high costs, more frequent maintenance and even reductions in engine efficiency. The aviation industry thus has a considerable interest in high-performance erosion-reducing protective coatings. The complex stress profile of coating and component which is found when particles impact makes high demands of an intelligent coating design.

Requirements made of erosion protection coatings

Particles of different masses and shapes hit, for example, the surface of titanium compressor blades at different angles and at relative speeds up to approx. 400 m/s. Protective coatings, which for reasons of weight and shape retention measure between 10 and 30 µm thick, must withstand sharp-edged sand particles which may be ten times larger than the coating thickness. Should particles impact at a shallow angle, they can »peel off« metallic surfaces – this can be prevented by using ceramic surfaces with a high level of hardness. On the other hand, when large particles hit at a steep angle, brittle materials will fail very rapidly due to cracks forming. What would be useful here are fracture-resistant metals with a high modulus of elasticity. Metal-ceramic composite coatings such as are currently under development at the Fraunhofer IST will perform their protective function even under varied stress situations.

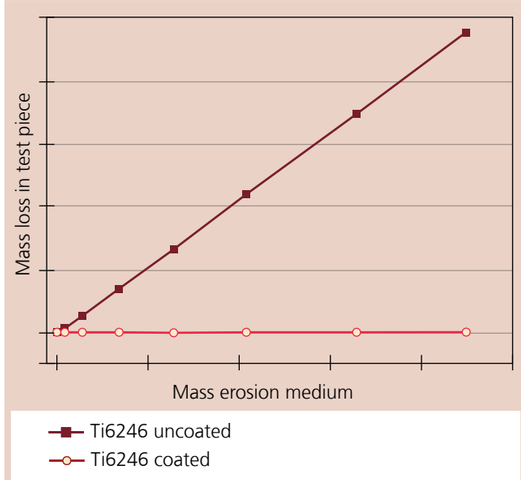
Sputtered metal-ceramic multilayer coatings

At the Fraunhofer IST ceramic layers of high hardness and metal layers with a high modulus of elasticity are deposited alternately using a high-rate sputtering process, gas-flow sputtering (GFS). Fig. 2 shows an example of a metal-ceramic composite multilayer coating which has been exposed to an erosion test. The different erosion behaviors of the metal (light) and ceramic (dark) components can be seen very clearly in the terracing. Deposition layer by layer makes it possible to obtain interesting degrees of freedom by which, for example, the hardness curve or elasticity modulus curve can be adapted to the stress situation. Fig. 3 shows by way of example a graduated coating system with the proportion of ceramic increasing towards the surface. This configuration aims at keeping mechanical stress peaks as low as possible at the substrate interface at the time of particle impact. The process parameters allow adjustment of not only the metallic or ceramic character of the layers but also the compactness and microstructure of the coating system – an important factor when it is a matter of securing a good balance between hardness and the internal stress of a layer.

Coating and source development at the IST

As part of the »Metal-ceramic multilayer coatings for the erosion protection of gas turbines« joint research project sponsored by the BMBF, the Fraunhofer IST is conducting research in collaboration with Rolls-Royce Deutschland Ltd & Co KG, Alstom AG, the Brandenburg Technical University of Cottbus and KCS Europe GmbH. The Fraunhofer coatings have already proved their effectiveness in erosion tests under conditions coming close to reality. It can be seen from the graph that the coated titanium surface has a much longer life expectancy than an uncoated reference. In addition to the development of coatings the Fraunhofer IST is also engaged in developing gas flow sputtering sources which have been tailored to coating complex-shaped components such as compressor blades or entire compressor disks.

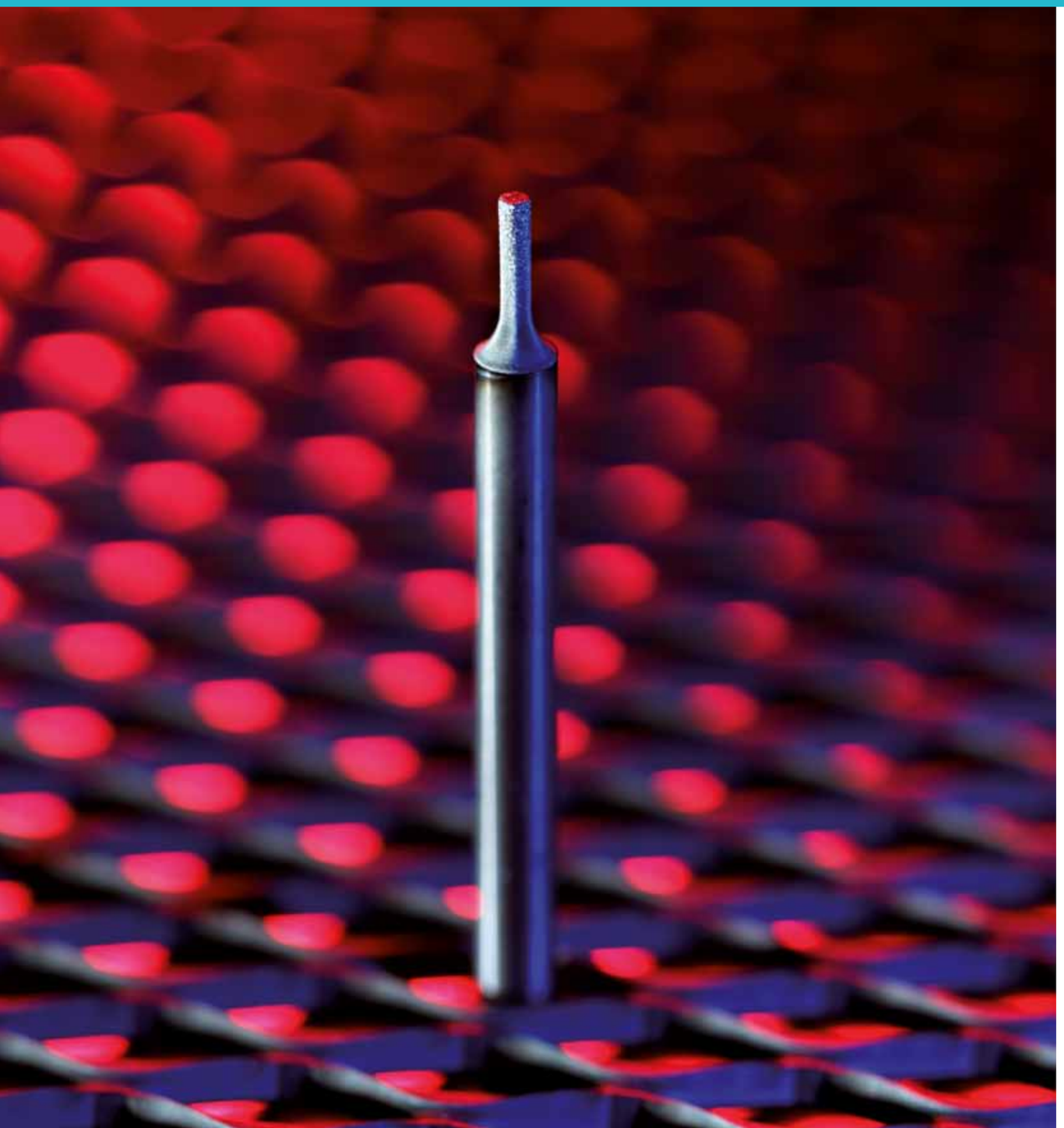
Erosion characteristics of a metal-ceramic composite multilayer coating system on titanium test pieces as compared with the uncoated reference with a shallow erosion angle (30°).



1 Erosion mechanisms are clearly revealed by the damage caused by the impact of a single particle.
2 Example of a metal-ceramic composite multilayer coating after an erosion test.
3 The graduation between the bottom of the coating which has a high metal content and the top which has a high ceramic content aims at achieving a good distribution of stresses at particle impact.

CONTACT

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



TOOLS

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

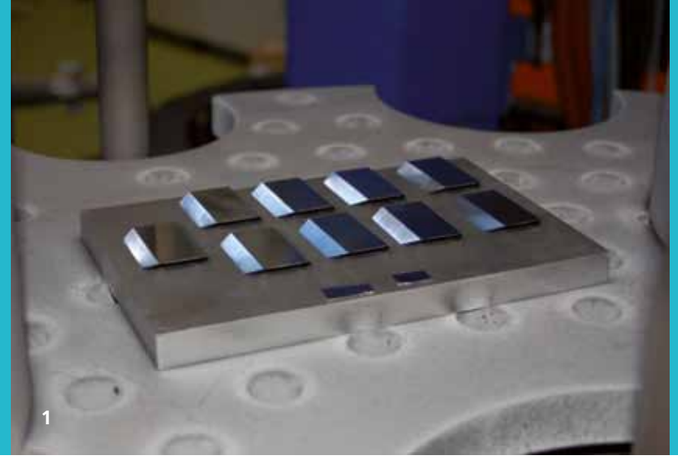
- Improvement in quality and performance in forming and cutting processes by means of anti-stick and wear-protection coatings
- Superhard coatings for cutting tools
- compeDIA® diamond abrasive coatings for precision grinding tools
- Wear-resistant coatings for hot forming
- Development of »intelligent tools« with integrated sensor functions
- Development of nanostructured composite coatings

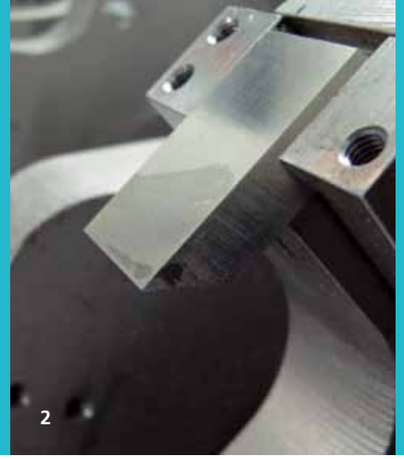
Important customers of this business division include coating service companies, tool manufacturers and users from, for example, the mold-making or automotive industries.

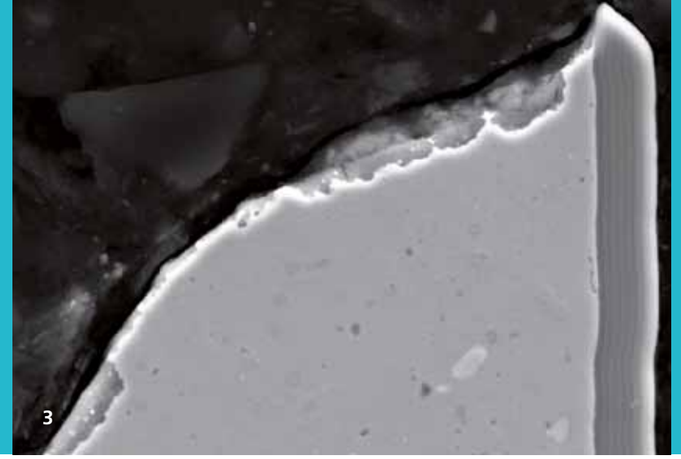
CONTACT

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







BIOMIMETIC TREATMENT CONCEPTS FOR INDUSTRIAL BLADES

We are familiar with principles in nature where evolution has produced results which are sometimes far superior to technical systems, for example, the teeth of rodents. Possessing a very specific dental structure, these animals are able to use their ever-sharp teeth to gnaw through even extremely hard materials such as concrete. By means of an adapted material concept combined with PACVD coating techniques, the underlying sharpening principle has been successfully made available to industrial cutting tasks. The resulting RODENTICS® concept was developed in conjunction with Fraunhofer UMSICHT in Oberhausen.

Nature as the model

Examination of the microstructural composition of a rat tooth reveals a system with an extremely complex structure. In the horseshoe-shaped outer zone it consists of an extremely wear-resistant material, dental enamel. This has omnidirectionally interwoven structures consisting of equally hard and elastic enamel prisms. These special structures in the enamel are called Hunter-Schreger bands (HSBs). The cutting face on the other hand consists of the soft, bonelike dentine. The extremely strong connection between the two materials is achieved by a three-dimensional interlocking structure, combined with an organic membrane. The soft dentine surface suffers wear during use thereby exposing the underlying hard enamel at the cutting edge. The rat's tooth never loses its sharpness.

Development of the material concept

In the technical reproduction of this system the two collaborating Fraunhofer institutes, the IST (in the Dortmunder OberflächenCentrum) and UMSICHT, succeeded in finding a material concept for wear control which could be used on an industrial scale. Here wear-resistant and high-wearing zones were arranged at the edge of the tool flank. Plastic extrudates made from a flexible polypropylene type and filled with titanium dioxide were cut in a specially designed test rig which creates an extreme level of abrasion (Fig. 2). During the cutting process the blade wear and cutting force as the significant process variables are measured via contour measurements and force measurements.

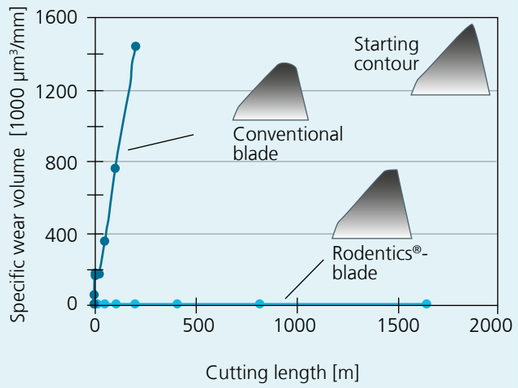
Technical implementation

The conventional blade made of hardened, high-carbon steel shows continuous wear at the cutting edge (graph). In the case of the biomimetic blade, however, after a short time a slight reduction in cutting force occurs at a virtually constant rate. The wear volume is almost impossible to measure by contact-based methods and after just a few cutting cycles the cutting contour has already been adapted by the tribological system (Fig. 3).

Outlook

A systematic approach has made possible the successful development of a handling concept in which the wear characteristics correspond to the biomimetic model and which will in the future be transferred for application in various industrial cutting tasks.

Specific wear volume (obtained from contour measurements) plotted against cutting length.



1 *Test blade after Rodentics treatment in the PACVD installation.*
2 *Cutting line at the Fraunhofer UMSICHT with built-in blade.*
3 *Blade contour after 25.000 cutting cycles, blade in cross-section view with free-standing cutting edge.*

CONTACT

Dipl.-Ing. Hanno Paschke
Phone +49 231 844-5453
hanno.paschke@ist.fraunhofer.de

BORON-CONTAINING TOOL COATINGS FOR HOT FORMING

In surfaces of tools used for hot forging wear occurs very rapidly due to high process forming forces and high application temperatures above 900 °C. The result is scale on the blanks and thermal shock exposure during the cooling lubrication phase. Recently developed ternary multilayer PACVD coating systems based on alternating material compositions as regards their boron, titanium and nitrogen content reveal some promising approaches for developing wear-reducing tool coatings.

Coating design with graded systems

Ternary systems of the Ti-B-N type have some very interesting structural properties. The PACVD deposition is forming nano-composites which consist of nanocrystalline fractions of TiN and TiB_2 as well as amorphous phases with different proportions of boron. It is now possible in the PACVD coating process to set gradients in the phase distribution as regards the boron and nitrogen contents by varying the process gas exposure. This makes different multilayer systems possible, with designs which differ in their phase composition (proportions of boron) and in the number of layers (right graph).

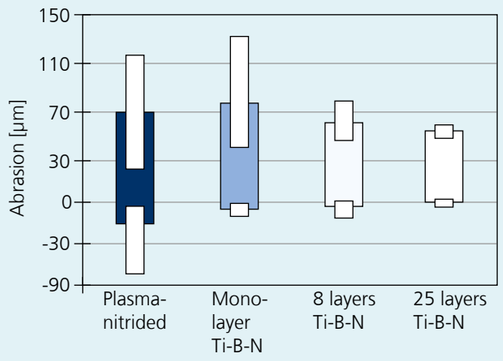
Application investigations

In collaboration with the Forging department of the IFUM (Institute of Metal Forming and Metal Forming Machines) in Hannover, various boron-containing multilayer designs were compared with references such as plasma- or gas-nitrided equivalents in joint industrial projects. The bolt shape selected for the test tools represents forging dies with extreme contours (Fig. 1). The forming processes carried out in an eccentric press with automated billet handling and cooling lubricant system reproducibly model real forming conditions.

Wear analysis

Analytical investigations of the test tools reveal in the most heavily stressed parts of the bolt significantly different wear patterns for the tested variants also in microsections (Fig. 2). Data for a wear analysis evaluation regarding adhesion (positive values) and abrasion (negative values) have been obtained by using a 3-D coordinate measuring machine to compare the contour after stress to the starting contour (left graph).

Wear analysis of forging processes after 3000 forging operations at 1150 °C.

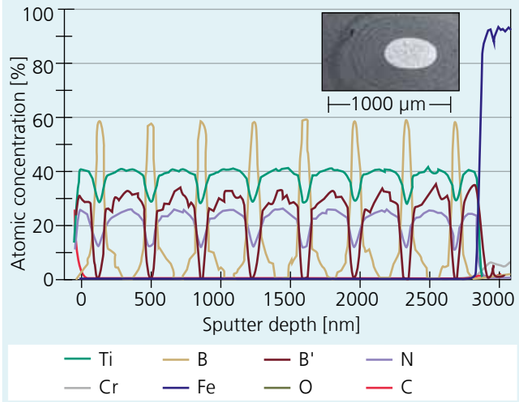


The measured values show statistical spread typical of forging processes but a clear trend can be seen in the evaluation of the different design variants. In the results low-boron variants with a high periodicity have the most suitable coating design for this application.

Outlook

The potential of these coating systems for hot-forging applications is currently being tested in industrial trials. Further work will be concerned with combining PACVD coating systems with nitriding treatments in both continuous and also two-step processes. Previous research indicates that the treatment parameters have a considerably influence on the cracking behavior of the tool surface.

Coating design of the successfully tested multilayer system Ti-B-N (B′ represents a low-boron standard).



1 Coated test tools in the PACVD installation.

2 Nitrided reference tool, wear pattern on the bolts of the test tool after 3000 forging operations at 1150 °C (left), test tool with optimized multilayer system Ti-B-N, wear pattern on the bolts of the test tool after 3000 forging operations at 1150 °C (right).

CONTACT

Dipl.-Ing. Hanno Paschke
Phone +49 231 844–5453
hanno.paschke@ist.fraunhofer.de

BASIC TECHNOLOGICAL PRINCIPLES IN FORMING TITANIUM ALLOYS

In an association of the Fraunhofer institutes IWU, IWM, IKTS and IWS, chaired by the Fraunhofer IST, basic principles are being worked out which will allow titanium alloys to be formed efficiently. The aim is to obtain greater cost-effectiveness in the production of titanium components in order to broaden their possible area of application.

The material titanium

As a material titanium is well-known for its outstanding properties. These include in particular a high specific strength, good corrosion resistance and biocompatibility. These properties can be even further improved by alloying additives. Titanium materials are thus of great importance to the aerospace sector, to the chemical industry and to medical technology and also in cases when components must be brine-resistant. Titanium is the fourth most commonly found metal in the earth's crust. In the long term we may assume a high level of availability and its increasing application.

The problem

Currently a broader application of titanium materials is opposed by high costs in their production and processing since efficient forming methods, such as, for example, deep drawing or hydroforming, can only be used with major restrictions. Even thin-walled complex components are thus in most cases produced by cutting – for example, by milling from solid blocks. The principle obstruction is the tribological situation at the interface of the titanium materials and the die. Titanium tends to adhere to a particularly high degree to the die surface. The result may be tearing of parts and damage to the surface. This effect is amplified by the forming temperatures of 250 °C – 950 °C which are required for processing titanium alloys. This makes high demands on both the dies and the forming processes.

Main research areas

The Fraunhofer institutes are working on solutions in the following areas of research:

- Development of tempered forming processes for improving the formability of titanium alloys based on hot-gas forming (IWU)
- Development of die materials for forming titanium within the temperature range up to 950 °C (IKTS)
- Development of adapted die coatings to reduce friction and wear (IST and IWS)
- Provision of material characteristic values for relevant titanium alloys and simulation of forming behavior (IWM)
- Development of adapted cutting and joining methods for the further processing of sheet metal parts (IWU)

Results to date

With the aid of tribometric tests at temperatures up to 900 °C, suitable die materials and coating have been selected for further investigation. The Fraunhofer IWU has been successful in using the forming process with high-strength titanium TiAl6V4 to make a first prototype of a fan blade, such as is used in aero-engines (Fig. 3). Satisfactory degrees of dimensional change can already be achieved with the new forming technology. There is however still a need for development work on the dimensional accuracy of the components. In addition, the first components for automotive exhaust systems have also been made from titanium by hot-gas forming (Fig. 4).

1 *Titanium sponge.*
2 *Fan rotor made of titanium.*
3 *Prototype of a fan blade for aero-engines made from TiAl6V4 by forming.*
4 *Part of an exhaust system made from titanium by hot-gas forming.*

CONTACT

Dipl.-Ing. Martin Weber
Phone +49 531 2155–507
martin.weber@ist.fraunhofer.de

DIE COATINGS FOR PRESS-HARDENING BORON ALLOY STEELS

The increasing demands made regarding the strength of sheet metal parts in automobile manufacturing have in recent years led to press hardening boron alloy steels taking on a greater importance. By combining deep drawing and hardening in a single process, component strengths above 1500 N/mm² can be achieved. High die wear is a disadvantage with this approach. A considerable improvement is however provided by the die coatings developed at the Fraunhofer IST as part of an IGF project.

Press hardening

High-strength steels, such as are used in manufacturing highly stressed sheet metal parts, normally have very poor formability. As a remedy for this situation, press hardening has become established in recent years. Here blanks which have been cut to size are heated to 950 °C and then formed and hardened within a cooled die. The hardness of the steel - 22MnB5 is used in the great majority of cases - is here boosted from an initial 600 N/mm² to as much as 1600 N/mm². As we have said, high die wear is a disadvantage with this method. From die surface temperatures of about 800 °C conventional lubricants can no longer be used. In addition, scaling of the die surface occurs due to the heating, which results in significant abrasion wear. To prevent scaling the metal sheets are frequently coated. AlSi coatings are in common use but do have a marked tendency to cause material to adhere to the die surface which then has to be regularly removed (Fig. 1).

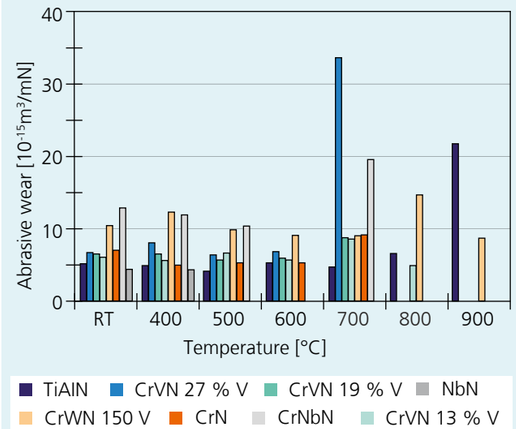
Project contents

The objective of the research project »Process lubrication – press hardening« (IGF project 14979 N) was to improve tribological conditions on the die surface. To do so the suitability of various modified chromium nitride, boron and carbon coatings was checked in preliminary tests. Tempering tests at different temperatures provided information about changes in the coatings at temperatures up to 1000 °C (Fig. 2). Application tests with the strip drawing test and deep drawing (Fig. 3) were then carried out on selected coatings at the IFUM (Institute for Forming Technology and Machines) at the University of Hannover. The test grid included six die coatings, three die steels and the sheet metal 22MnB5, both uncoated and with different coatings.

Results

The various sheet coatings had the greatest influence on the wear behavior of the dies. While there was more abrasive wear with uncoated sheets, the selection of a suitable sheet coating meant significant reductions in wear and in the occurrence of accretions in comparison with the AlSi coatings which have so far predominated. Further improvements in wear behavior may be achieved by using chromium nitride coatings modified with vanadium or tungsten (Fig. 4).

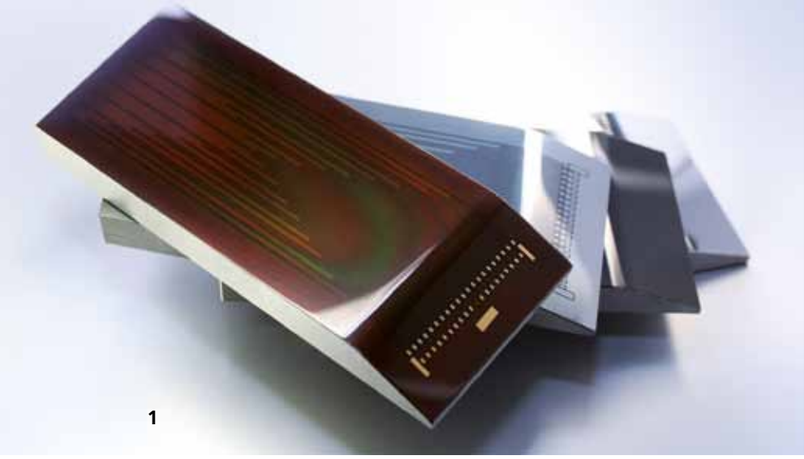
Wear resistance of the coatings after temper tests (2 hours in ambient air).

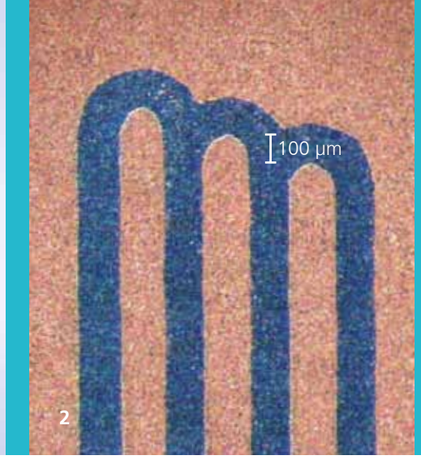


1 Die wear in press hardening.
2 Comparison of coating changes following heat treatment at 800 °C in the ball-crater test: cracking and marked surface oxidation with CrN (bottom), less change with CrWN (top).
3 Deep-drawing testing.
4 Optimized die following drawing tests.

CONTACT

Dipl.-Ing. Martin Weber
Phone +49 531 2155–507
martin.weber@ist.fraunhofer.de





DEVELOPMENT OF SENSOR MODULES FOR THE OPTIMIZATION OF DEEP-DRAWING PROCESSES

Badly formed parts, fractures and wrinkles reduce the cost-effectiveness of forming processes. The causes of these problems are to be found primarily in fluctuations in process parameters, such as, for example, material properties. Such fluctuations can be evened out by means of process control regulated by an integrated thin-film sensor system and the rejects rate thus mimimized. The Fraunhofer IST is developing new kinds of sensorized thin-film systems which get in direct contact with the workpiece and track the forming process very precisely.

Sensorized thin-film system

The coating system consists of the piezoresistive hydrogenated carbon coating DiaForce® which is homogeneously deposited in a thickness of 6 µm onto the polished side of the die insert. To this is applied a thin layer of chromium only 200 nm thick which is structured by photolithography and wet-chemical etching. Flexible masks make structuring possible even in low-lying contact areas. Before the actual deep-drawing process starts, the sensor structures are all in contact with the steel sheet and as deep drawing proceeds each structure in turn moves out of the contact area. To give these chromium structures long-term stability they are given a 3 µm SiCON® coating which provides electrical isolation and wear protection. The individual steps in the production process for the sensor modules can be seen in Fig. 1. Different base body shapes are produced and different electrode arrangements structured. Fig. 2 shows a microstructure from a section of an electrode configuration as shown in Fig. 3 in which the nearby electrodes have a difference in lenght of just 100 µm.

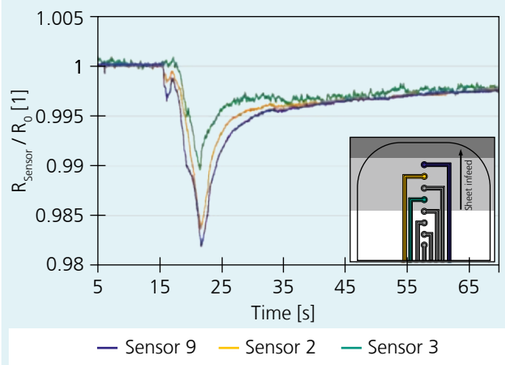
Behavior of the sensor system during forming

Test series have been carried out with the sensor modules in different installations. Here it was demonstrated that incorporating these sensorized die inserts in the drawing cushion of the forming systems was a simple matter. During the deep drawing process the sensorized thin-film system is in direct frictional contact with the steel sheet. The characteristic signal curve will have a resistance minimum at every electrode structure once the sheet has moved out of contact. The general functional capability of the sensor modules has been validated in a test installation at the Fraunhofer IWU. The modules were tested at AWEBA Werkzeugbau GmbH under industrial conditions in forming thick sheet metal. These were deep drawing steel rounds with a diameter of 266 mm and a thickness of 6 mm. The adjacent graph shows a characteristic signals plot. Sensor modules have also been tested in engine mounting production. Here an Erfurt EHP 1600 hydraulic press was fitted out with the sensor modules and here too their functional capability was successfully demonstrated.

Outlook

Currently the sensor modules are being used in production to test their long-term stability. Their area of application should not be restricted to deep drawing alone but should also include other forming processes, such as hydroforming or sheet metal bending. These developments are results from the ORUM project funded by the Federal Ministry of Education and Research (BMBF) within the general concept »Research for tomorrow's production«. ORUM is a German abbreviation for the optimized control of forming processes by means of integrated thin-film sensor systems (project reference 02PU2040). ORUM is supervised by the project sponsors the Karlsruhe Research Center (PTKA), Division of Production and Manufacturing Technologies (PFT).

Resistance curves for three sensor structures during the forming of thick metal sheet.



1 Step-by-step creation of the sensor modules for quantity production.
2 Micrograph of an electrode peak area of Fig. 3.
3 Sensor module with a resolution of 100 µm.

CONTACT

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

Dipl.-Ing. (FH) Sebastian Staufenbiel
Phone +49 531 2155-765
sebastianstaufenbiel@ist.fraunhofer.de

1

2

THIN-FILM FORCE SENSORS FOR MONITORING CUTTING PROCESSES READY FOR PRACTICAL APPLICATION

The cost-efficiency of cutting processes is reduced by the occurrence of poorly punched sheet metal parts or by cutting-tool fractures. There is an ever-greater need for on-line process monitoring systems. The cutting force is directly affected by die-clearance reductions and tool wear. Piezoresistive thin-film sensors based on the amorphous hydrocarbon DiaForce® coating are being developed to detect the cutting force. The complete coating system is only 9 µm thick but has nevertheless outstanding tribological and sensor-related properties. Due to their small size these thin-film sensors can be installed directly in the die force path and can thus measure the cutting force directly without disturbing influences.

Thin-film sensor integration

A sensorized three-layer system is applied to standardized steel disks. Spatially resolved pressure states can be measured at different points due to 200 nm thin chromium electrodes fabricated by wet-chemically etching. To protect the sensor structures the top layer of the system is wear resistant and electrically isolating coating in a thickness of 3 µm. A Flex-Board is connected to the sensor contact pads and carries the signals from the die to the electronic circuitry which processes them. Software developed for the cutting process enables early detection and correction of deviations in the cutting process, such as, for example, a tool-edge fracture or welded accretions on the cutting punch.

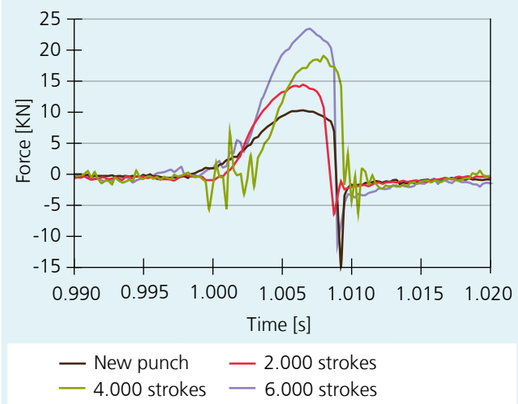
Behavior of the sensor system during testing

Extensive series of tests at the Fraunhofer IWU have been concerned with validating the integration of the sensor modules into the tools, fault symptom detection and long-term stability. Proprietary force sensors were used for running plausibility checks on the sensor signals. This is where the great potential of thin-film sensor systems was revealed. The sensors not only can detect the compressive stress but can even measure the return stroke when the cutting punch withdraws from the female part. It was possible to determine cutting-edge wear by a time delay of up to 25% in the force curves (Fig. 1). Welded accretions on the punch shaft on the other hand produced an increase in cutting force which provided very precise information about the wear situation (Fig. 2).

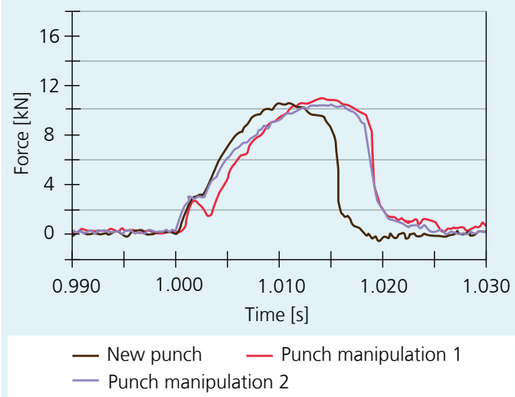
Outlook

This thin-film sensor system can be used universally in the direct force flow path of cutting tools. The electronics developed by HSG-imit especially for cutting processes should monitor the processes and warn the operator before machine downtimes occur. Process monitoring can thus conserve resources and minimize material costs. The broad area of application for these sensor systems opens up the prospect of inexpensive industrial production in high quantities.

Weld accretions on the cutting punch result in a cutting-force increase.



Cutting-edge wear results in a delayed cutting-process.



1 *Thin-film sensor system with Flex-Board connection for monitoring cutting processes.*
2 *Sensor module in its housing.*

IGF project 16113 BG of the EFDS (Europäische Forschungsgesellschaft Dünne Schichten eV), Gostritzer Strasse 63, 01217 Dresden has been financed via the German Federation of Industrial Research Associations (AiF) as part of a program for promoting industrial community research and development (IGF) of the Federal Ministry of Economics and Technology on the basis of a resolution of the German Bundestag.

CONTACT

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

Dipl.-Ing. (FH) Sebastian Staufenbiel
Phone +49 531 2155-765
sebastian.staufenbiel@ist.fraunhofer.de

1 *Hot-wire-CVD-diamond coating of a silicon-nitride drawing die with a diameter of 26 mm.*

DIAMOND-COATED CERAMIC DIACER® – A CAPABLE COMPOSITE MATERIAL FOR CHALLENGING REQUIREMENTS

Ceramics and diamond are often used in industry when challenging demands are made of materials. The performance of the individual materials can be boosted and their utilization extended by combining both materials in the form of the diamond-coated ceramic DiaCer®. The Fraunhofer institutes IKTS, IPK, IST and IWM have cooperated in the development of this composite material and in collaboration with partners from industry have brought it up to readiness for industrial application. This successful collaboration between Fraunhofer researchers and partners from industry was recognized in 2010 by the Award for Science for Joint Projects in Applied Research of the German Stifterverband.

The composite material DiaCer®

DiaCer® is based on ceramic substrates, either of silicon nitride or of silicon carbide, onto which a polycrystalline diamond film is deposited. To do so, the Fraunhofer IST uses coating processes based on hot-filament chemical vapor deposition (HF-CVD). These processes were developed in the institute not only for coating areas measuring up to 50 cm by 100 cm but also for diamond deposition onto complex geometries and then transferred into industry. The silicon-based ceramics are particularly well suited for the deposition of diamond films since the formation of Si-C bonds between the diamond film and the ceramic means that especially high adhesive strengths can be obtained. Furthermore, the thermal coefficients of expansion of diamond and of the ceramics are not as diverse as is the case with metallic substrates. During the process of cooling down from the deposition temperature (800 °C - 900 °C), this results in what are relatively moderate thermally induced stresses in the DiaCer® composite material. In addition to the joint development and testing of DiaCer® disposable inserts for machining and of DiaCer® face seals and plain bearings, DiaCer® drawing dies for wire manufacturing have also been developed and tested as an example of forming tools.

DiaCer® drawing dies with internal diamond coating

In the development of a coating process for diamond-coated drawing dies one major challenge lay in getting the diamond film inside the drawing die to build up to an adequate thickness with good adhesion. For this purpose a modified HF-CVD process was developed at the Fraunhofer IST. In this process variant, drawing die prototypes were produced with diameters from 1 mm to 27 mm. This in practice makes diamond drawing dies available throughout the full range of diameters relevant to industry. The table shows a selection of successful trials in industrial wire-drawing processes. These investigations were carried out using industrial wire-drawing machines at Drahtwerk Elisental, Drahtzug Stein and Durum. The DiaCer® drawing dies were in each case only used in the final drawing stage and were still intact following the replacement of several sets of carbide drawing dies upstream due to wear. The advantages of the DiaCer® drawing dies include a longer tool life, savings in set-up times, increases in drawing-process productivity. Also of great interest to partners from industry is in particular compliance with extremely tight tolerances over a long period of production and the greater degree of flexibility with regard to feasible drawing-die geometries (shaping dies).

Outlook and acknowledgments

Currently complete sets of DiaCer® drawing dies are being trialled in a nine-stage drawing process. The focus of future R&D work will be on avoiding or reducing the use of drawing agents and in developing economically efficient production processes for DiaCer® drawing dies. Work on the DiaCer® composite material was in part funded within the WING general program of the Federal Ministry of Education and Research with the participation of partners from industry. The companies Allgemeine Gold- und Silberscheideanstalt, DiaCCon, Drahtzug Stein, Drahtwerk Elisental, Durum and H. C. Starck Ceramics were in particular involved in the development work relating to DiaCer® drawing dies.

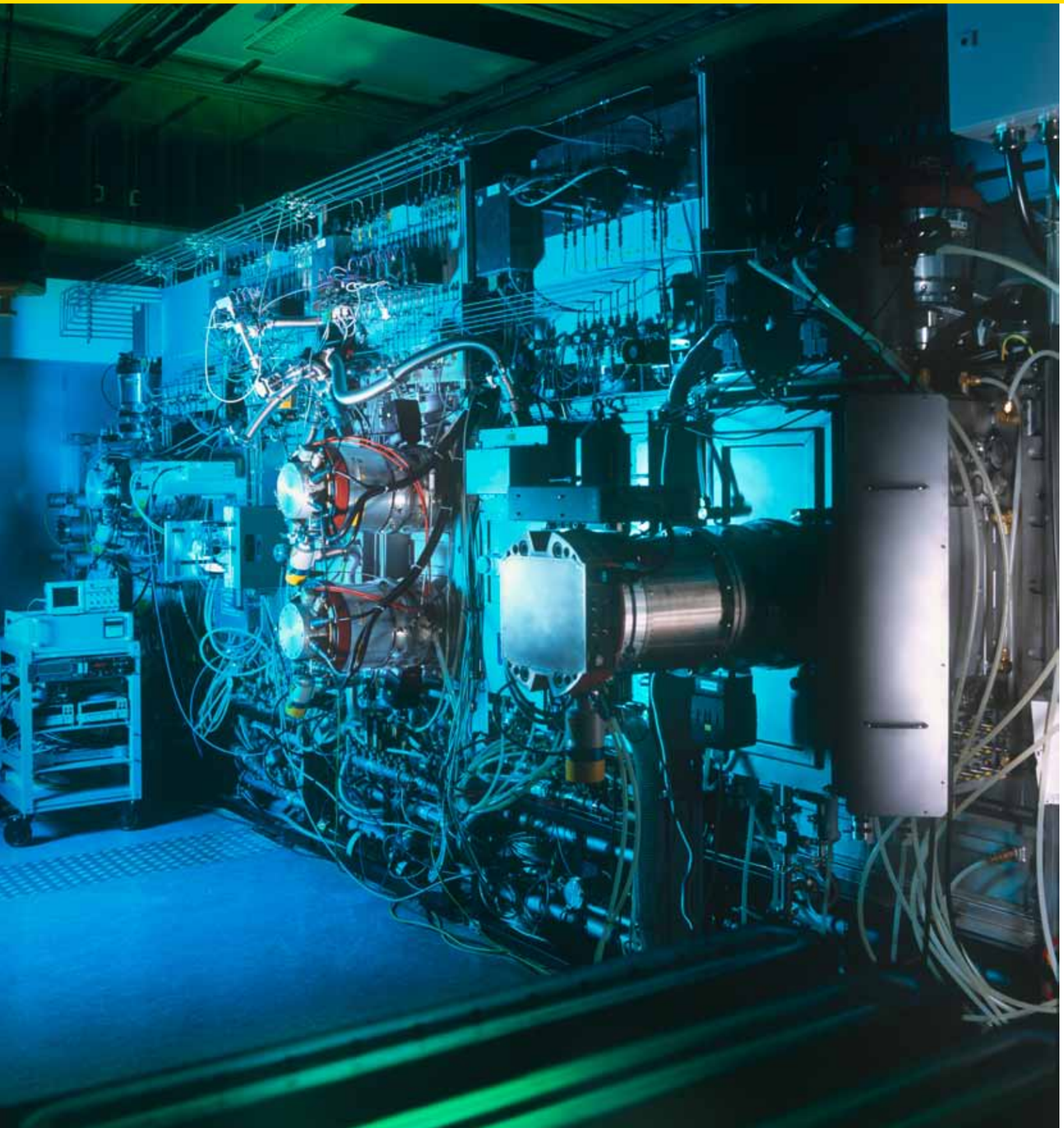
Life expectancies of DiaCer® drawing dies in comparison with conventional drawing dies. PCD = sintered polycrystalline diamond.

Wire material	Quantity of wire drawn in tonnes	Reference dies
Al and Mg alloys	> 60	Life expectancy 7 times longer than carbide dies
Iron alloys	> 70	Like PCD drawing dies
Filled Ni, NiCr and FeCr wires, fillings: particles of WC, Si etc.	> 7.5	Like PCD drawing dies

CONTACT

Dr. Lothar Schäfer
Phone +49 531 2155-520
lothar.schaefer@ist.fraunhofer.de

Dr. Markus Höfer
Phone +49 531 2155-620
markus.hoefer@ist.fraunhofer.de



ENERGY, GLASS, FACADE

In the business area »Energy, Glass, Facade« some of the developments the institute concentrates on are:

- Coating systems and associated processes for photovoltaic applications
- Low cost transparent conducting oxide coating systems (TCOs) for photovoltaics, photothermal applications, architectural and automotive glazing,
- 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

THE ICEFREE WINDSHIELD

Driving during the winter is sometimes not a lot of fun. One reason for this is fogged-up or icy windows. At the Fraunhofer Institute for Surface Engineering and Thin Films IST a new coating for automotive glazing which can help solve this problem is currently under development. The transparent film is as conductive as a metal – the glass thus becomes a heat reflector, which prevents the windshield from cooling down and icing over. There is thus no need for the lengthy process of heating the windows until they are clear - something which in the case of electric vehicles consumes a great deal of energy.

Preliminary work in the 1980s

The point of departure for our work was the results obtained back in the 1980s at the University of Uppsala for non-icing windshields based on transparent conductive SnO_2:F coatings produced by pyrolysis. A vehicle with a low-E coating remains completely free of ice while the uncoated windshield is significantly iced up. Unfortunately this technology could not be taken further since the coarse SnO_2:F coating proved to be very susceptible to wear and could not provide the stability required for use in the automobile. The present innovation is based on the fact that transparent conductive and thus low-emitting (low-E) films can be produced very inexpensively and with much better properties than those previously available. This new PVD coating which is applied at room temperature to glass is in particular not only flexible but also extremely resistant to chemical and mechanical stress. This means a marked improvement in its wear characteristics as compared with uncoated glass.

HIPIMS sputtering of TCOs

These property combinations were previously considered impossible and the key to achieving them lies in a new kind of process control, namely high power impulse magnetron sputtering (HIPIMS). With this method the sputtered material is ionized to a considerable extent. Researchers at the Fraunhofer IST have been able to demonstrate that at the transition to conditions with a maximum level of ionization, layers of nanocrystalline indium tin oxide (ITO) form which exhibit no grain growth even when the glass is bent at ~650 °C.

Coating properties

In the laboratory setup used at the Fraunhofer IST and manufactured by the Advanced Energy company, the current flow in the HIPIMS pulse derives from the capacity and charging voltage of the underlying capacitor bank. In addition, a regulatory device shortens the pulse duration so as to prevent marked arcing at the cathode. With both the 2.0 kV and the 2.5 kV charging voltages, layers which are almost X-ray amorphous are created first. After annealing at ~650 °C they show a sharply pronounced X-ray peak. This is a concomitant of a transition from the amorphous to the crystalline phase and does not occur with 3 kV charging voltage. Nanocrystalline layers already come into existence here, showing a broad peak in the Θ-2Θ diagram which is only changed to an insignificant extent by annealing. These layers have a grain size, as measured by X-ray diffraction, of only ~20 nm. Due to the Hall-Petch relation this nanocrystalline growth results in the layers hardening and in a higher thermal stability. The electrical and optical properties of the coatings correspond fully to those of conventional ITO coatings, the only difference being a higher layer resistance.

Potential for practical application

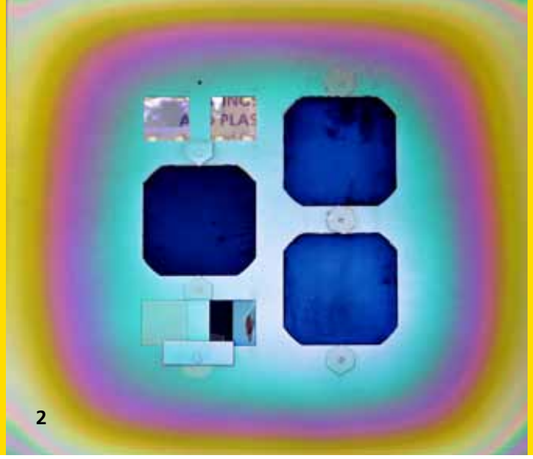
The icefree windshield, which has been developed jointly with VW and Audi, offers a genuine safety-related innovation for the automotive sector. The electrical conductivity of the coatings does however dampen wireless communication. This means that some adjustment work will be necessary as regards GPS and cell phone aerials as well as emergency call systems. In the context of electromobility the technology receives a further boost in importance since here passive, energy-neutral solutions are required. What is very much not wanted is the need to heat up the vehicle interior at great expense and at the cost of the battery charge. Other user areas of application emerge from the transition to triple glazing in buildings. Here too improved insulation means more and more condensation on the outside of the glass panes, something our technology can efficiently prevent. The coating can also be used as a heating conductor: in chemical process engineering, for example, reactor vessels can be equipped with a transparent heating system. Completely new areas will also open up in the field of transparent oxidic electronics where the new technology offers ways – in combination with sol-gel p-TCOs for example – of creating transparent diodes and circuitry based on this.

[1]: I. Hamberg et al., Applied Optics 26 (1987) 2131

1 *Large-area coating at the Fraunhofer IST.*

CONTACT

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



LARGE-AREA SILICON-BASED COATINGS WITH HOT-WIRE CVD

Hot-wire chemical vapor deposition (HWCVD) is a promising technology by which silicon-based coatings can be deposited at low cost. In photovoltaics amorphous silicon films (a-Si:H) are used among other things as absorbers and for passivation.

The coating process

Hot-wire CVD (chemical vapor deposition) is an established coating technique for diamond films. In comparison with well-proven plasma-supported coating methods it can offer a range of advantages in particular in the production of silicon-based coatings:

- Cost-saving due to high film rates, a high level of gas conversion and low investment
- Readily scalable up to large areas
- Substrate-friendly deposition without ion bombardment (no plasma)
- Cold processes at below 100 °C are possible

At the Fraunhofer IST several hot-wire CVD systems are available for producing silicon-based films. Fig. 1 shows an in-line system with seven chambers, three of which are equipped with coating modules with an excitation zone measuring 500 mm x 600 mm. The modules are separated from each other by intermediate chambers. The substrates can be fed into the system from either side.

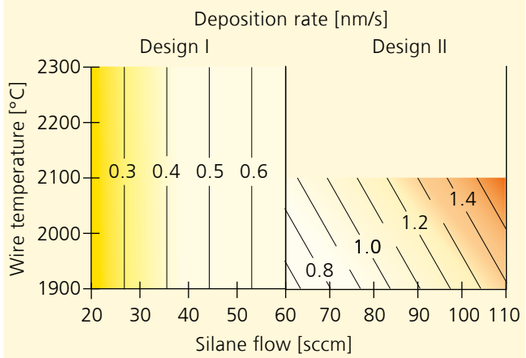
High quality and deposition rate: a-Si:H as absorber

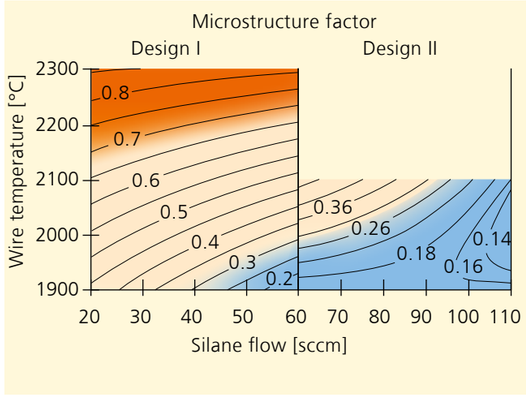
As a first step the quality of the a-Si:H films produced in the in-line system was determined from Fourier transform infrared (FTIR) spectra by means of the microstructure factor. The microstructure factor describes how the silicon atoms are bound to hydrogen. A low microstructure factor is desirable and indicates a large number of Si-H bonds and few $Si\text{-}H_2$ or $Si\text{-}H_3$ bonds. The microstructure factor was determined as a function of various process parameters with the aid of the statistical design of experiments. In the second step, undertaken in collaboration with the IEK5 photovoltaics research group of the Jülich Research Center, three p-i-n solar cells with absorbers were produced on the basis of this experimental design and the electrical parameters measured. The graph on the facing page shows the deposition rate and the microstructure factor as a function of wire temperature and silane flow. The results were obtained from two statistical designs of experiment. Good values for the microstructure factor were achievable even at high rates above 1.5 nm/s. The efficiencies measured after annealing for three of the solar cells produced, lay between 4.5 percent and 5.1 percent at rates between 0.9 nm/s and 1.5 nm/s. It should be borne in mind here that the component parts of the cell were fabricated in different locations, something which usually means lower values for efficiency.

Outlook

Future work on the deposition of silicon-based films by hot-wire CVD will cover on the one hand aspects of material optimization for specific applications – for example in photovoltaics and microelectronics – and on the other hand production-specific challenges relating to reducing production costs for silicon-based films. The aim is to secure the transfer of hot-wire CVD technology for silicon-based films into industrial-scale manufacturing processes such as has already been achieved with diamond films.

Deposition rate (top) and microstructure factor (bottom) as a function of wire temperature and silane flow.





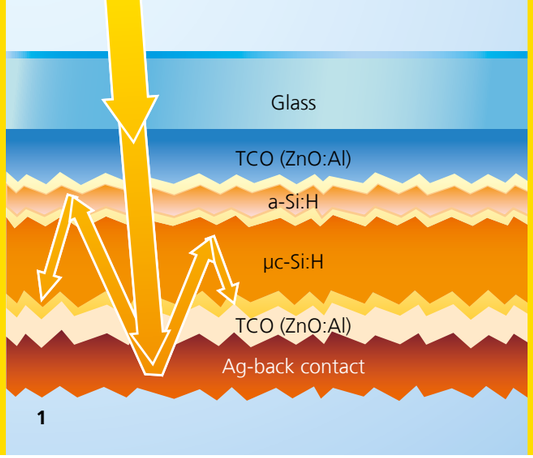
1 *Seven-chamber in-line coating system for hot-wire CVD.*

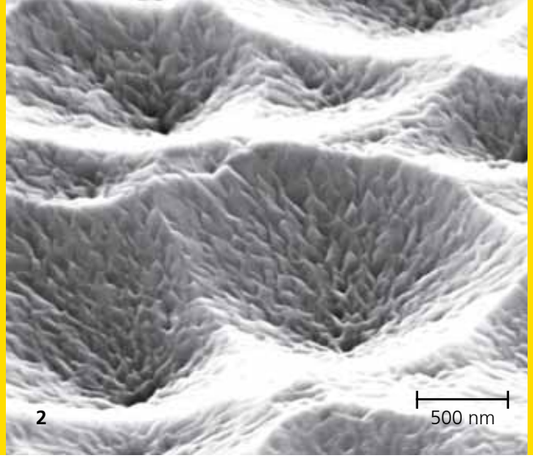
2 *Substrate carrier with different substrates and interference lines due to static coating.*

CONTACT

Dipl.-Ing. Artur Laukart
Phone +49 531 2155-508
artur.laukart@ist.fraunhofer.de

Dr. Lothar Schäfer
Phone +49 531 2155-520
lothar.schaefer@ist.fraunhofer.de





OPTIMIZED LIGHT TRAPPING IN THIN-FILM SILICON SOLAR CELLS BY MEANS OF SEED LAYERS

At the Fraunhofer IST seed layers for transparent conductive contacts have been developed on the basis of aluminum-doped zinc oxide (AZO). These layers not only result in outstanding optical and electrical properties but also give the AZO the desired light-trapping structures, these being created by wet-chemical etching in diluted hydrochloric acid.

To support the enormous development in thin film photovoltaics the Fraunhofer IST has been working for a number of years now on coatings for solar cells. These include not only transparent conductive oxide layers (TCOs) but also antireflection coatings, diffusion barriers, metal contact layers and PV absorber films. Typical thin-film solar cells include a-Si:H/µc-Si:H tandem cells (see Fig. 1), CIGS or CdTe cells.
One drawback of the silicon thin-film tandem cell is that the absorptivity of the microcrystalline coating is too low. The various approaches taken to increase absorptivity range from antireflective coatings to index-matching, from metallic back reflectors to structuring the front contacts (Fig. 2). In this way the light can be trapped in the cell (light trapping) and be reflected several times back and forth until a large part has been absorbed. Here the Fraunhofer IST is focusing on the development of doped zinc oxide (ZnO) coatings which are deposited either by reactively sputtering metallic targets or by sputtering ceramic targets. Sputtering of ceramic targets is currently used by industry.

The solution concept

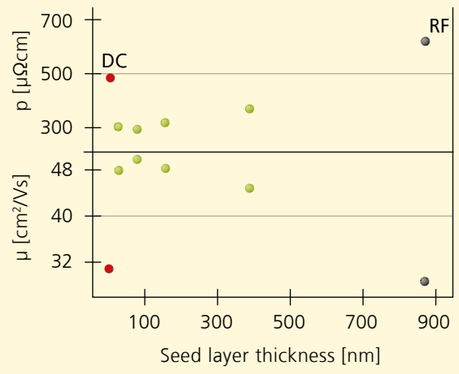
In collaboration with its clients the Fraunhofer IST has developed a seed layer which not only improves the optical and electrical properties of the ZnO:Al coatings but also results in an optimized morphology following wet-chemical etching. First of all, a few nanometer thin RF seed layer was developed on the basis of ZnO:Al. The rest of the film was then deposited at a faster rate by DC sputtering. The whole film has a thickness of about 900 nm. The electron mobility of a layer deposited solely by DC or RF sputtering (red and black) is around 30 cm²/Vs (see graph). Applying a seed layer increases this drastically to almost 50 cm²/Vs and with increasing seed layer thickness the mobility approaches the low value of the RF coating. The charge carrier density (not shown here) behaves in a similar fashion with increasing thickness of the seed layer. However, due to the weakness of the change, this has on the whole a much lower influence on the conductivity of the layer than does the mobility.

With a thin seed layer the growth of an additional DC layer is so good that the specific resistance drops markedly due to the improved mobility (graph). Values of less than 300 µΩcm were achieved. With greater seed-layer thicknesses the specific resistance approaches that of a layer produced by RF sputtering alone. In the experiment presented here the standard RF process was adjusted with a high rate in mind rather than a high layer quality. This is what determines the low specific resistance in the case of a pure RF process. An excellent seed layer can be deposited with RF sputtering and, in collaboration with a client, has been transferred to a DC process as well.

Advantages of the coating

Use of a seed layer means that, firstly, a layer with very good optical and electrical properties is produced which can be etched homogeneously over a large surface area. Secondly, the surface etching structure is identical to a purely RF-sputtered layer, which means very good light-trapping properties and thus high levels of solar cell efficiency. The RF seed layer process can also be transferred to a DC seed layer process.

Change in the specific resistance and mobility as a function of the RF seed layer thickness. Reference layer: unetched, 30 x 30 cm².

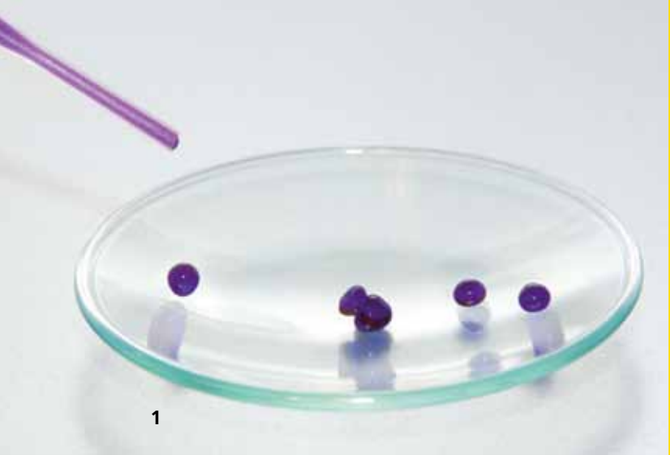


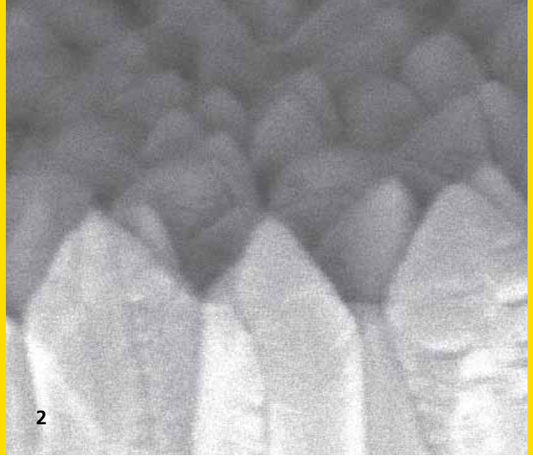
1 Diagram of a silicon thin-film solar cell.
2 Etched zinc oxide with optimized light-conducting structure due to the use of a seed layer.
3 Homogeneously etched ZnO:Al layer, 30 x 30 cm², deposited on a seed layer.

CONTACT

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

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





TRANSPARENT, RESISTANT AND HYDROPHOBIC SURFACES

The Fraunhofer IST develops transparent hydrophobic and ultrahydrophobic coatings. Applications are to be found in architectural glazing and plumbing units, not only on glass but also on plastics.

Background

There are various applications in which a transparent smooth surface should be designed such that water drains off very easily when the surface is slightly inclined. Surfaces of this kind are referred to as hydrophobic. The greater the contact angle of the water drops and the smoother the surface, the more marked will be the effect. Contact angles of 120° are to be regarded as typical of hydrophobic surfaces. One characteristic benefit of hydrophobic coated transparent surfaces is that the view is not impaired by water drops sticking obstinately to the glass. With an ultrahydrophobic coating there is even a self-cleaning effect due to the water drops running off.

Developments

A large number of hydrophobic coatings are based on specifically selected functional molecules. Due to their organic nature many of these coatings tend to have poor abrasion resistance. Coatings with very good abrasion characteristics, such as SICON®, developed at the Fraunhofer IST, tend however to have reduced transmission. Mixing in organic layers of other components is an approach which will allow optimization with regard to transparency, water repellency and mechanical load capacity. In this regard loading tests are being carried out at the Fraunhofer IST which come as close as possible to the customer's end application, including automatic mechanical wear tests. For certain applications, hydrophobic coatings alone will not be adequate, for example when it is necessary that water drops run off already at the lowest inclination. »Ultrahydrophic« surfaces of this kind are possible when a specifically selected surface roughness is combined with a hydrophobic layer. At the Fraunhofer IST ultrahydrophobic and yet transparent coatings were developed in collaboration with partners from industry. The structures of suitable rough surfaces here have to be very small and are shown in the scanning electron microscope image in Fig. 2. Only in that way is it possible to ensure that these structures scatter the visible light so little that the coating remains transparent. This coating system was sputtered and has structures with widths of 100-200 nm – in other words, below the wavelength of visible light (380-680 nm). A coated curved glass in Fig. 1 points out both the transparency and the ultrahydrophobic surface as can be seen from the tinted water drops.

Outlook

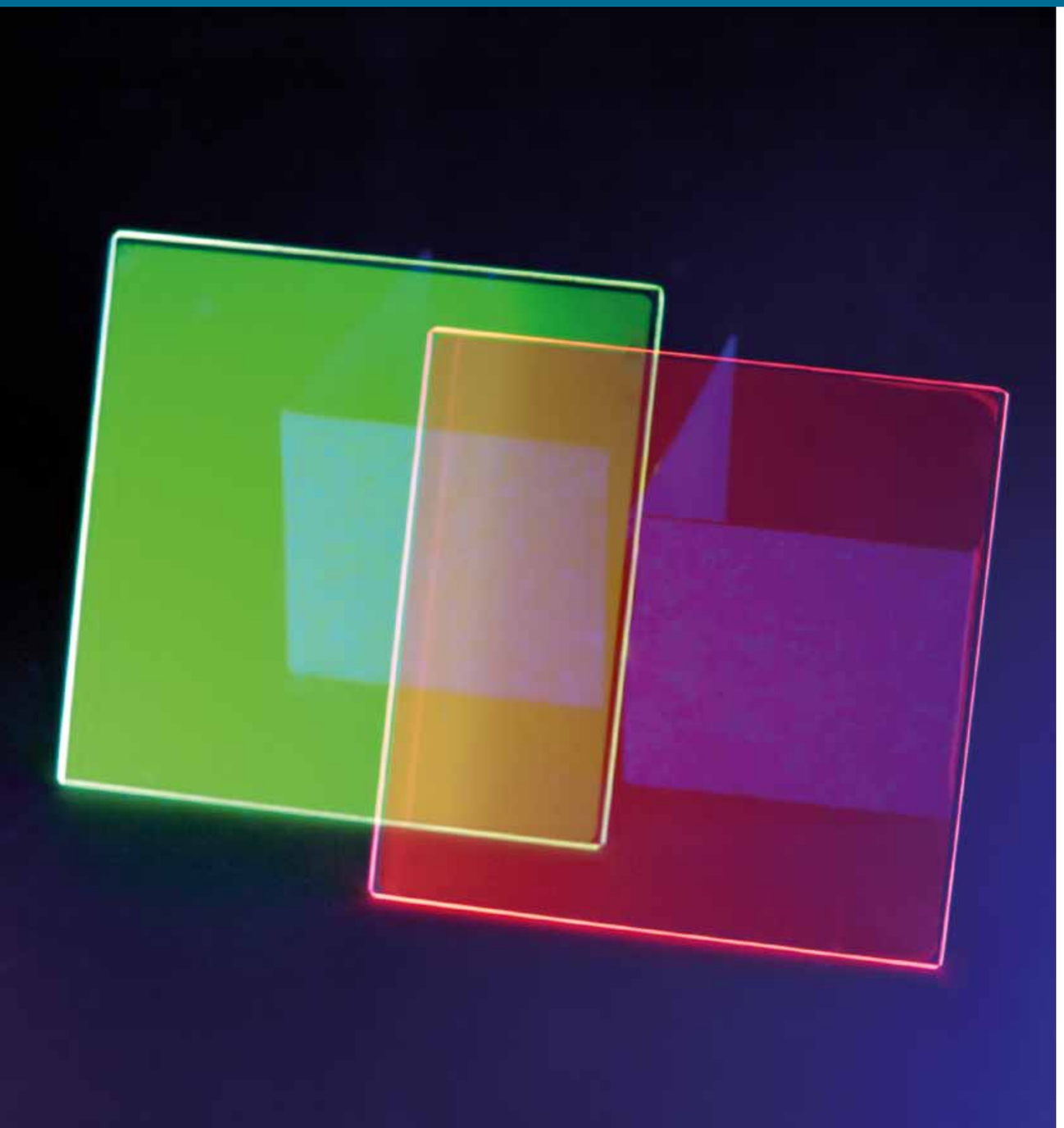
In addition to mechanical requirements, chemical and environmental aspects can also be taken into consideration. Existing coating processes in use at the Fraunhofer IST will in addition permit the coating of plastics.

1 *Tinted water drops on an ultrahydrophobically coated glass bowl.*
2 *SEM image of a rough-surfaced crystalline ZnO coating for ultrahydrophobic surfaces.*

CONTACT

Dipl.-Phys. Oliver Werner
Phone +49 531 2155-532
oliver.werner@ist.fraunhofer.de

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



OPTICS, INFORMATION, COMMUNICATION

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

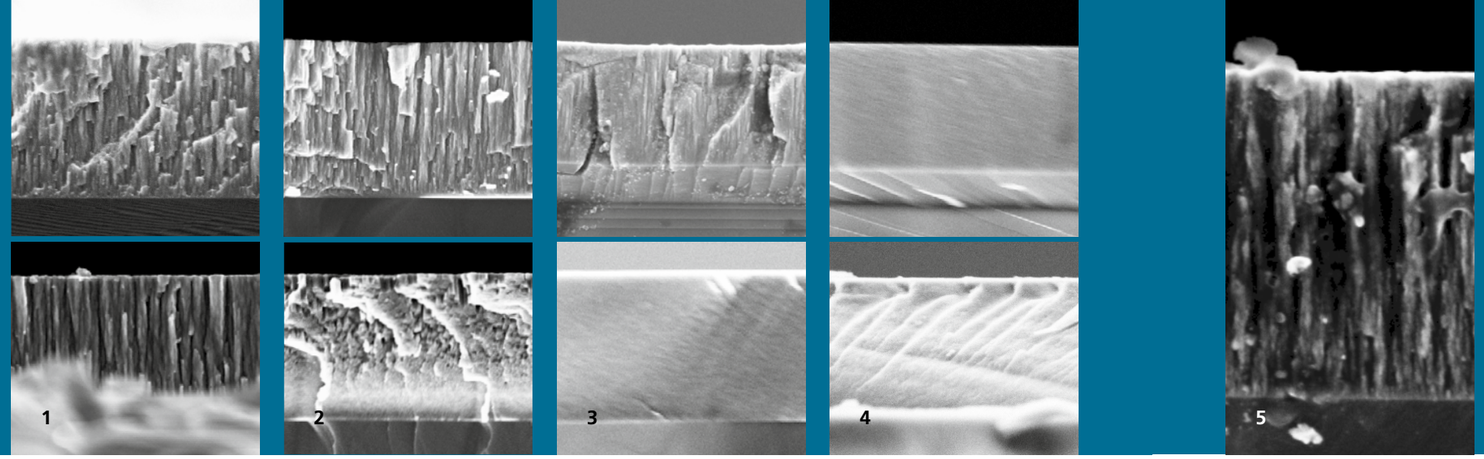
- Developing electrical contact and insulating layers,
- Developing coating systems for displays,
- Developing and designing multilayer coatings for optical filters,
- Developing sensor coatings
- Developing new materials, structurizing and metallizing technologies to substitute ITO layer systems for 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



HIPIMS DEPOSITION OF ELECTRICALLY CONDUCTIVE CERAMIC NANOCOMPOSITE COATINGS

So-called MAX phases usefully combine ceramic and metallic properties. The coatings produced are electrically conductive and ductile and yet are resistant to oxidation and wear. By means of high power impulse magnetron sputtering (HIPIMS) - rather than the classic PVD methods - the resulting coating properties can be modified to give, for example, greater hardness, lower electrical resistance, and a glass-like structure.

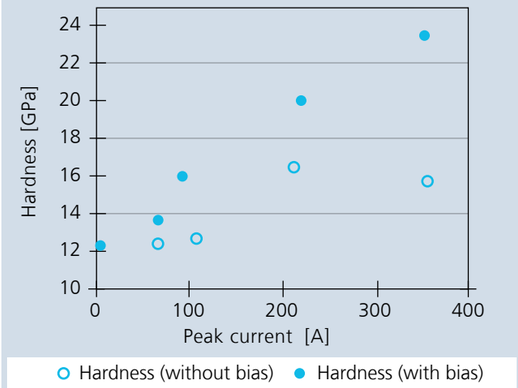
MAX films

Conductive ceramics, so-called $M_{n+1}AX_n$ phases, have been known as a bulk material since the 1960s (M: metal, A: A-group element, X: C or N). These ternary materials combine the properties of metals and ceramics in such a way that they have good electrical conductivity and are ductile while simultaneously possessing ceramic properties such as a high wear resistance and oxidation resistance. Since the late 1990s these coatings have also been deposited as thin films. These films, which can handle high levels of tribological and thermal stress, are used in various electrical applications such as, for example, electrical contacts.

Selecting the film morphology

The emergent structure and layer morphology of the coatings can be permanently influenced via the energy of the impacting particles during film growth. Fig. 1 shows the fracture faces of some coatings as a function of the target peak current during the pulse process and of the substrate bias voltage. As the peak current Imax increases, the fracture micrographs show a transition from a columnar to a glasslike structure. If a bias voltage is applied to the substrate, this change in structure will already take place at a lower peak current and thus with a higher deposition rate.

Hardness of the films as a function of the pulse peak current and bias voltage.



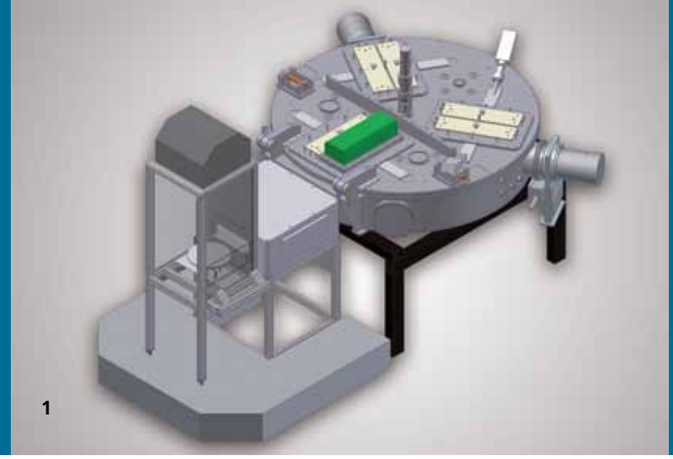
Mechanical and electrical properties

As the peak current rises the electrical resistance of the films falls by half. At the same time the nano-hardness increases to around 23 GPa. At about 4.5 g/cm³ the density falls within the range of the bulk value for Ti_3SiC_2. The bias voltage only has a minor influence on the deposition rate. Hardness, on the other hand, is markedly dependent on the bias, which means that when there is a bias applied, denser, harder films are possible with a lower peak current density and thus at a higher deposition rate.

1-4 SEM fracture faces as a function of the pulse peak current and the bias voltage.
1 63 A at 0 V (top)
65A at 100V (bottom).
2 104 A at 0 V (top)
90 A at 100 V (bottom).
3 212 A at 0 V (top)
220 A at 100 V (bottom).
4 358 A at 0 V (top)
351 A at 100 V (bottom).
5 DC reference
3.9 A at 100 V.

CONTACT

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



SPUTTERING OPTICAL FILMS WITH ROTATABLE CATHODES

Magnetron sputtering is an important technology for producing thin functional coatings and has applications in the fields of sheet glass, photovoltaics, display technology and in the optical industry. The performance of optical coatings is considerably reduced by coating defects among other things. The incidence of such defects can be markedly reduced by using new kinds of cylindrical sputtering sources and also suitable process control.

Experimental set-up

At the Fraunhofer IST, various SiO_2 coatings were created by reactive pulsed magnetron sputtering in the »Dyscus« rotating table sputtering system manufactured by FHR Anlagenbau GmbH. Over the course of various optimization steps it was possible to minimize the base level of particle exposure. These steps included optimization of substrate handling and of the process set-point. A bipolar pulsed sputtering process was employed for power input, using a dual magnetron with planar cathodes (650 x 120 mm², own design) and tubular cathodes (target length 550 mm, SCI). The process was controlled by a lambda sensor. Various target materials and production variants (Si, Nb, SiOx, sprayed, bonded) were investigated. It emerged from the results that the optical properties of SiO_2 coatings are relatively independent of the type of cathode and that refractive indices vary between n (550 nm) = 1.465 and 1.471. It should be emphasized that in the case of the coatings deposited by the tube a markedly higher deposition rate is achieved than with coatings made using the planar target. Various process parameters were included in measurement of particle exposure:

- Cathode type (planar, cylindrical)
- Oxygen partial pressure (oxidic mode, transitional mode: stoichiometric coatings with metallic cathodes)
- Process power

During the course of the project it was possible to reduce the particle exposure by several orders of magnitude. In this way a clean environment and a reduction in the process power, especially in the case of planar cathodes, considerably improves the particle exposure. In contrast to this, no dependence on power level could be detected in the case of the tubular cathodes. However, the shape of the target (thickness, production type) did have an influence on particle input. In this example the cleanest processes were achieved using tubular cathodes. In the best case the particle level was only slightly higher than with the ion-beam sputtered coatings produced for the purposes of comparison.

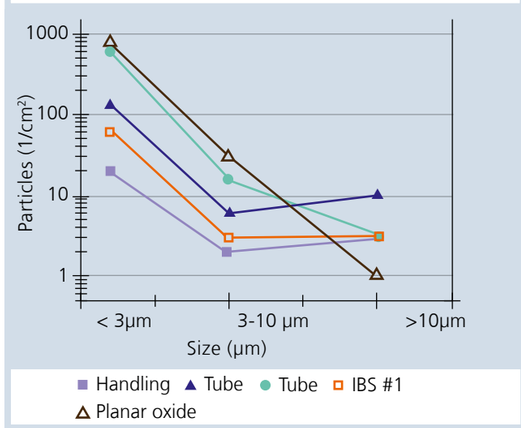
Summary

Low-defect coatings can be produced by magnetron sputtering using not only planar but also cylindrical cathodes. Previous results indicate that in the case of SiO_2 cylindrical cathodes have a lower level of flaws and are in addition less sensitive to higher process power levels. Preventing arcs remains of crucial importance in preventing particles.

Acknowledgements

These results were obtained as part of the »Low-particle coating processes« project (project 15615N) funded from the budgetary resources of the Federal Ministry of Economics and Labor (BMWA) via the Arbeitsgemeinschaft industrieller Forschungsvereinigungen »Otto von Guericke« e.V. (AiF).

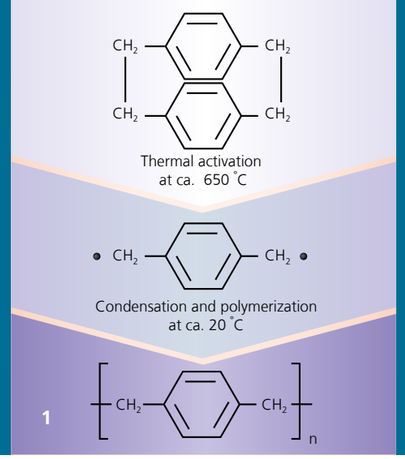
Particle exposures with different processes.

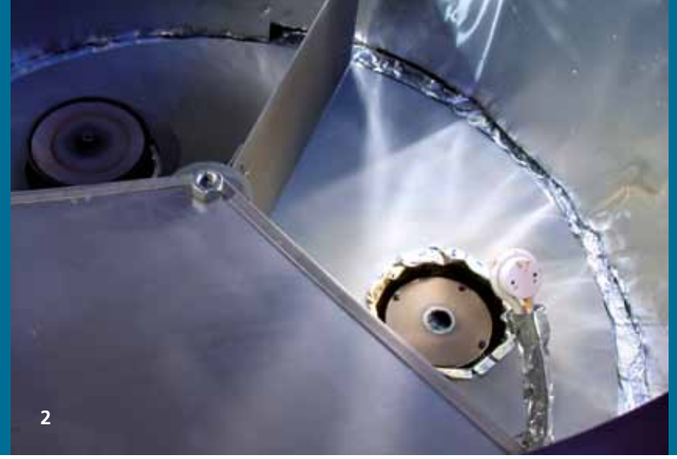


1 *Diagram of the sputtering system »DYSCUS«.*
2 *Linear double magnetron (top), cylindrical double magnetron (bottom).*

CONTACT

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





RATE CONTROLLED PARYLENE® DEPOSITION AT LOW-PRESSURES FOR OPTICAL APPLICATIONS

Parylene® coatings provide interesting optical, mechanical and chemical properties. Optical interference coatings require homogeneous, rate-controlled deposition at pressures less than 10^{-2} mbar as well as the ability to combine with other gas-phase coating methods (vapor deposition, sputtering). Here a coating source has been developed at the Fraunhofer IST which can be operated in conventional vacuum coating installations.

Parylene® coatings

Parylene® is a tradename for polymers consisting of different variants of para-xylylene. Gas phase coating methods usable with these materials have been known for years and are used in industry for coating electrical components, for diffusion barriers or in the medical sector for biocompatible coatings. In the deposition process in most cases a solid dimer is vaporized at a temperature of around 150 °C. The vapor is thermally activated at temperatures around 650 °C, thereby creating gaseous radicals which can polymerize by condensation onto the components to be coated (Fig. 1).

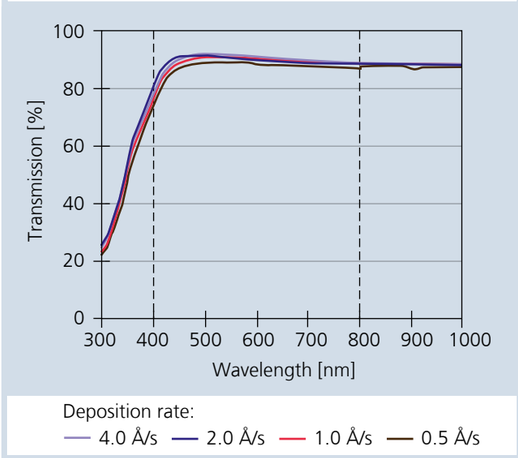
Results

Application of this method for optical coating systems requires a precise control of the coating thickness and coating rate. Furthermore, Parylene® deposition must take place under low-pressure conditions (< 10^{-2} mbar) since not only is a higher quality required for optical coatings but it must also be possible to combine this method in series and in parallel with other coating processes. This is not the case with the classic Parylene® coating process. Accordingly a deposition rate-controlled Parylene® coating source for low pressure has been developed at the Fraunhofer IST in collaboration with partners from industry (Fig. 2). This coating source permits the deposition of Parylene® coatings which are fully transparent in the visible spectrum, with a refractive index of n = 1.65, and with high optical quality and coating adhesion to glass, polycarbonate and PMMA substrates. The deposited coatings also have a high crack onset strain of more than 24 percent and good resistance to solvents such as water, isopropyl alcohol and acetone. With the source which has been developed the coating rate can be regulated within a range from 0.01 nm/s to a few nm/s with 5 percent accuracy.

Outlook

Further modification of the polymer coatings is possible by combining the Parylene® coatings with ceramic or metallic coating materials. This should further raise the refractive index of the coatings while still retaining a high mechanical flexibility or reduce the permeability of the coatings to molecules.

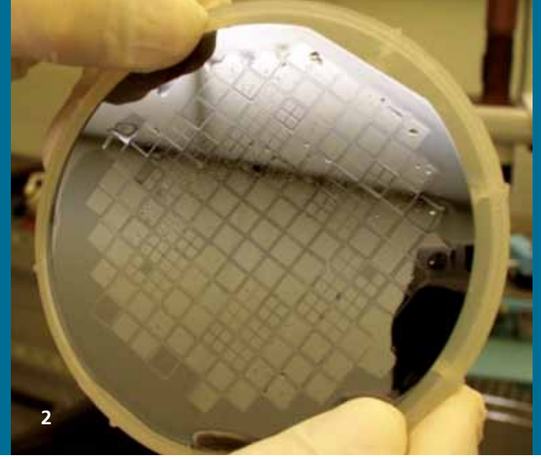
Transmission spectra of thin Parylene® coatings.



1 Polymerization of paraxylylene.
2 High vacuum Parylene® source regulated by oscillating crystal.

CONTACT

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



MARKET LAUNCH OF THE "SELECT" PLASMA

The Fraunhofer IST and SÜSS MicroTec, a world leader in producing equipment and process solutions for the semiconductor industry and related sectors, have successfully completed the launch of SELECT, a technology enhancement for bond aligners and mask aligners. Selective plasma activation of wafer surfaces is possible with this upgrade kit.

Market launch

Fraunhofer Institute for Surface Engineering and Thin Films IST and SÜSS MicroTec, a global supplier of equipment and process solutions for the semiconductor industry and related markets today announced the launch of SELECT, a technology for bond aligner and mask aligner that selectively activates parts of wafer surfaces through plasma. Local treatment of the surface prior to wafer processing replaces standard process steps and reduces the overall cost per wafer. Selective plasma activation can be applied to a variety of MEMS, optical and solar applications using direct wafer bonding or surface modification for the creation of micro mirror arrays, micro valves, sensors or micro fluidic channels. The SELECT toolkit is an upgrade option of SÜSS MicroTec's MA/BA8 Gen3.

Applications

The patent pending technology of Fraunhofer IST bases upon atmospheric pressure plasma selectively modifying the molecular level surface. Conventional surface treatment of complete wafers without selection can damage the functionality of micro components or electronics. With selective treatment it is possible to protect those sensitive areas by activating only specific parts of the wafer. Selective plasma activation is used with planar wafers as well as with topography wafers where plasma activation is provided either in the cavities or on the elevated structures.

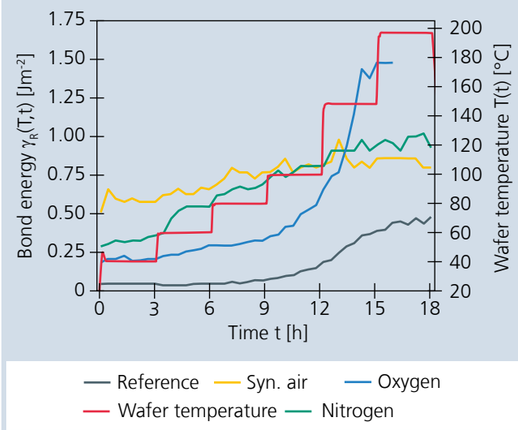
Advantages

While selective plasma treatment in wafer bonding applications significantly reduces the post-bond anneal temperature from 1000 °C down to 200 °C, it also protects sensitive devices. The technology therefore impressively increases the process window for direct bonding. With the SELECT toolkit being applied in both direct bonding as well as other wafer processing applications a ground-breaking new approach seems possible for device processing in the semiconductor industry. The treatment of selected parts of wafers reduces the costs of producing a device through streamlining processes and increasing throughput at the same time. The new technology has the potential to completely change the cost-of-ownership model for a large variety of applications.

Low temperature bonding

Previous work aimed particularly at the activation of silicon and glass wafers for subsequent direct bonding. To characterize the bond strength, a process has been developed which makes it possible to determine the bond strength *in situ* during annealing in the furnace. In addition to activation, the plasma processes presented in the graph are also suitable for cleaning, oxidizing, coating, or etching surfaces locally and all over the surface. This opens up manifold options for application in the fields of micro system technology.

In situ bond energy measurements on silicon wafers during annealing. Plasma activation of the wafer pairs was carried out in different process gases before bonding.

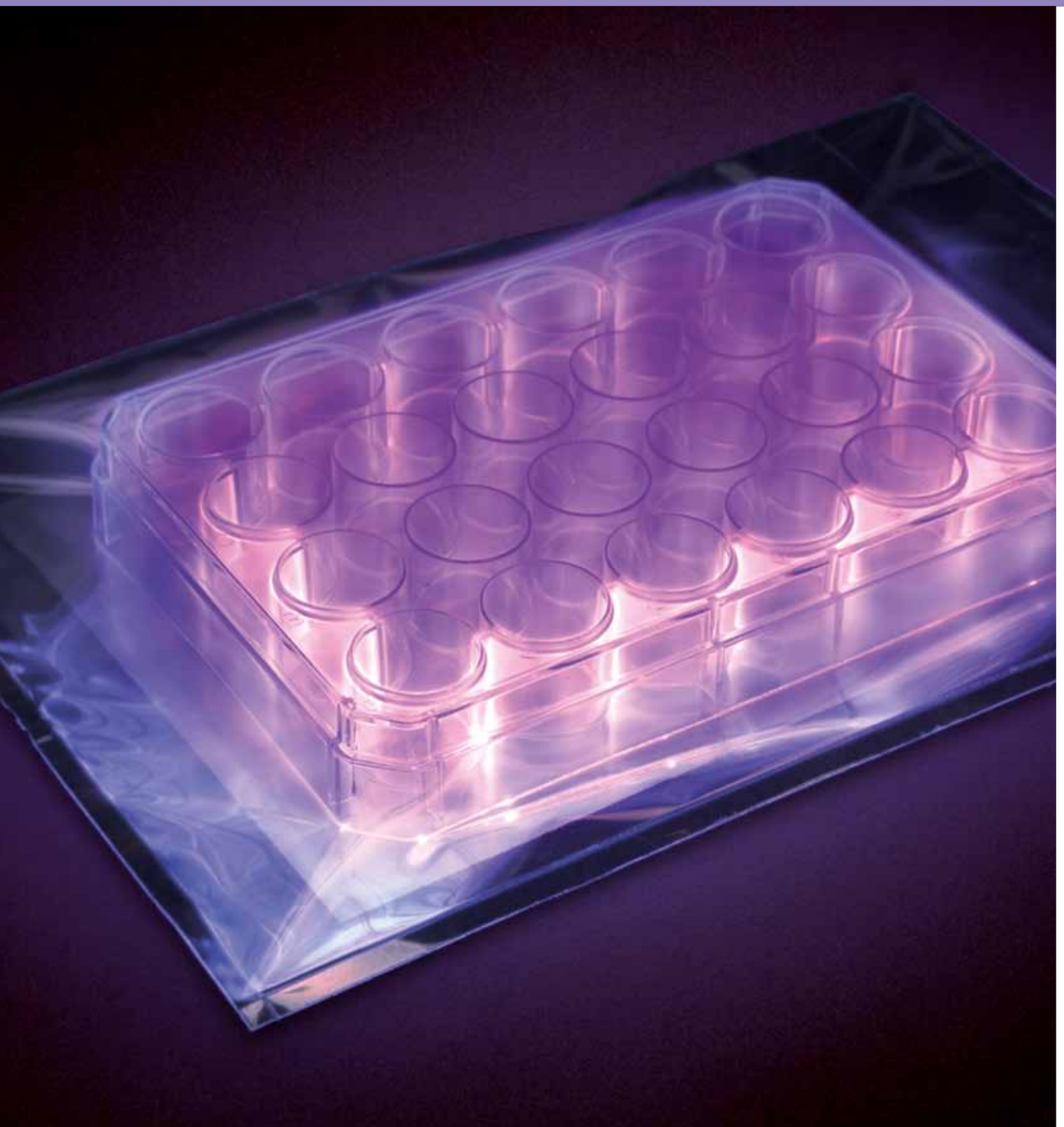


1 *Local treatment of a silicon wafer by plasma printing. The ITO electrode connection can be seen at center.*

2 *Partially hydrophilized wafer: The water film wets the areas hydrophilized by the plasma and in the untreated areas gathers into droplets.*

CONTACT

Dr.-Ing. 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 and coating of surfaces with atmospheric pressure plasma processes (e.g. bio analytics, medical technology as migration barrier)
- Diamond coated electrodes for electrochemical water disinfection and treatment of waste water
- Metal plating of plastic surfaces for biosensors
- Internal coating of microfluidic components, cell culture bags and tubings
- Friction-reducing biocompatible layers (i. e. diamond-like carbon layers) for medical applications, i. e. implants
- Plasma treatment for restoration and conservation of cultural heritage objects

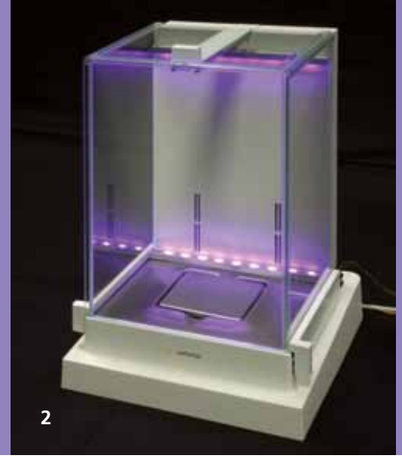
Our customers include the pharmaceutical-chemical industries, biotechnology, medical technology, food industry, chemical industry and environmental technology.

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



ANTIMICROBIAL ULTRA-PRECISION ANALYTICAL BALANCES

Permanently antimicrobial surfaces – this has now been made possible by an innovative concept developed at the Fraunhofer IST for integrating photocatalytic coating systems in indoor applications. Intelligent illumination concepts are here combined with adaptive coating methods. A successful example of this which is currently under development is the use of photocatalysts in CUBIS precision balances manufactured by Sartorius AG.

Applications for precision balances

Balances are used today by research and industry under the most varied environmental and service conditions. While the larger scales used in industrial and commercial environments are frequently exposed to marked contaminative, corrosive and abrasive influences and thus have to be very robust, precision balances in the laboratory are sensitive to even the slightest contamination or electrostatic charge. Between these extremes there is a very broad range of applications. This means that the requirements made of the surface properties of the basic materials such as, for example, glass, plastic or metal will also be very diverse:

- Prevention of static charges
- Self-cleaning
- Ease of cleaning
- Disinfection

This is where photocatalytic coatings come in. By absorbing sufficiently energetic light – in most cases ultraviolet radiation – adsorbed organic compounds are broken down into water and carbon dioxide. In other words, the surfaces are made antimicrobial by the photocatalytic coating: the cell walls of the bacteria disintegrate and the cells undergo lysis. A further effect is photoinduced superhydrophilicity. By irradiation with suitable light, water spreads on the surface, with contact angles of less than 10° being achieved. Two central approaches are required for activating the photocatalytic effect in precision balances:

- The use of miniaturized LEDs for coupling light into the transparent substrates
- Modification of the photocatalyst material to boost activity in the visible range

The light concept

Light can be coupled into the transparent materials of the precision balance by means of easily integrable miniature LEDs. The concept utilized for coupling light in and out ensures that generated heat is diverted to stabilize the microclimate within the instrument. The wavelengths used are closely tied to the excitation level of the photocatalytic semiconductor. By default narrow-band excitations are provided at 365 nm (UV) and 405 nm (VIS) but the illumination spectrum can also be shifted on a broad-band basis into the visible range (white-light excitation) to ensure design and UV protection guidelines. An adapted light sensing system adjusts the intensity, wavelength and homogeneity of the lighting to the user's requirements.

The coating concept

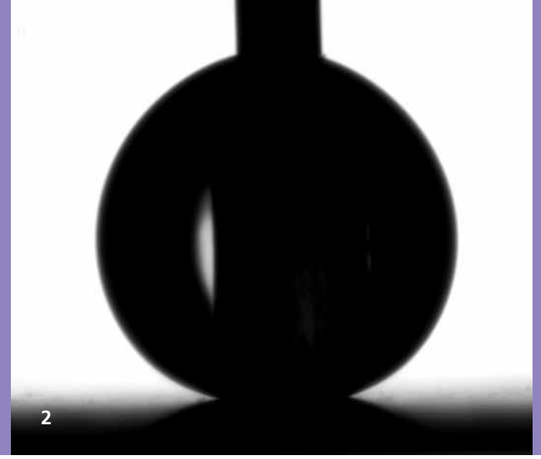
VIS-active TiO_2 photocatalysts are produced by reactive pulsed magnetron sputtering processes. Transparent coatings with a high degree of homogeneity and purity can be achieved through defined settings of the plasma conditions. By doping with transition metals such as, for example, molybdenum or tungsten the band position of the photocatalytic semiconductor can be shifted to a limited extent into the long-wavelength range to enable surfaces to be excited by visible light > 400 nm. Alongside photocatalytic functionality, antistatic influences are also taken into consideration by the use of transparent conductive oxides (indium tin oxide, for example). The optical, electrical and photocatalytic design is thus oriented to the user's requirements profile.

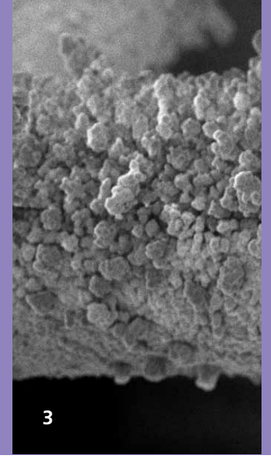
1 *Sartorius analytical balance, model CUBIS (MSA 524S-000-DU).*
2 *Functionalized precision balance with integrated LEDs.*

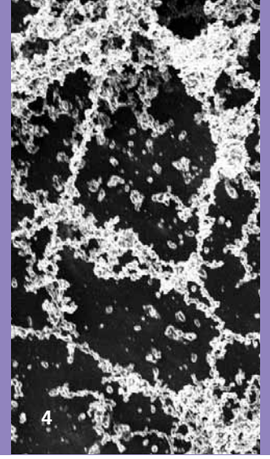
CONTACT

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







PRODUCING SUPERHYDROPHOBIC COATINGS BY ATMOSPHERIC-PRESSURE PLASMA PROCESSES

Water-repellent and self-cleaning coatings can be produced with the aid of atmospheric-pressure plasma processes. The basis of these coatings is a microstructured surface which has been provided with a hydrophobic top layer. With atmospheric-pressure plasma processes it is possible to coat temperature-sensitive components such as plastics, textiles, leather and also to apply internal coatings to closed systems, such as bags or tubes.

Superhydrophobic coatings

Superhydrophobic surfaces are commonly found in nature, such as the leaves of many plant species or the plumage of waterfowl. On lotus leaves, water forms drops with contact angles greater than 150°. When it rains, adherent particles are thus simply flushed away from the leaf surface with the beaded water droplets – the part thus cleans itself (the »lotus effect«). We have been successful at the Fraunhofer IST in producing coatings of this kind by means of an atmospheric-pressure plasma process.

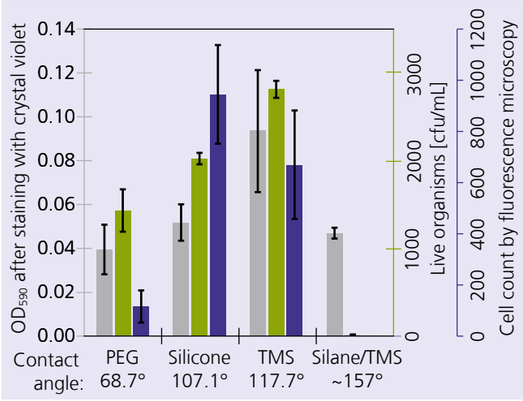
Coating process

Coatings have been produced at the Fraunhofer IST by means of dielectric barrier discharges. With the aim of obtaining a microstructured surface with the greatest possible surface roughness, silicon oxide particles in combination with a thin hydrophobic coating based on organosilicon or fluorocarbon monomers were applied to different surfaces. In this way it has been possible to achieve a contact angle greater than 150° on polymer sheeting, silicone or textiles. When plastic bags were coated internally, contact angles up to 140° were obtained with this coating system.

Applications

With atmospheric-pressure plasma processes it is possible to coat even temperature-sensitive substrates such as plastic, leather or textiles. In the case of plastic bags or tubes internal coating can be achieved. The stability of the coatings is considerably boosted by the use of a dual-layer structure. The suitability of these coatings as dirt-repellent surfaces is thus being investigated. A further potential application of the coating system – reducing biofilm formation – was identified during one test series conducted in collaboration with Prof. Krull's work group at the Institute for Bioprocess Engineering at the Technical University of Braunschweig. After application of the coating a reduced growth of Escherichia coli K 12 cells on silicone film was observed. This effect is probably to be attributed to a reduction in the contact surface between the rough surface structures and the bacterial cells, thereby impeding the attachment of the cells.

Adhesion of E. coli K 12 to different coatings.

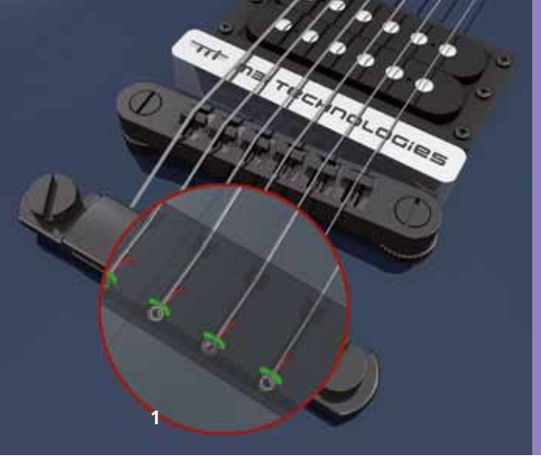


1 *Water droplets (stained with fuchsine) on a superhydrophobic non-woven.*
2 *Water contact angle measurement on a superhydrophobically coated surface.*
3 *Superhydrophobic coating on a non-woven.*
4 *Internal coating of a plastic bag with a superhydrophobic coating.*

CONTACT

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

Dipl.-Ing. Torsten Baranski
Phone +49 531 2155-678
torsten.baranski@ist.fraunhofer.de



THIN-FILM SENSOR SYSTEM FOR GUITAR TAILPIECES

In conjunction with M3i Technologies GmbH the Fraunhofer IST is developing an innovative method for measuring the tensile forces applied to the strings when a guitar is played. Building into the instrument a thin-film sensor system based on a piezoresistive DiaForce® layer is to be seen as a very promising way of measuring these forces.

Guitars are equipped with innovative coating-based sensor systems

Virtuoso guitar-playing is based on a faultless technique. Measurement of string tension is an important part of converting a guitarist's style as unambiguously as possible into control data. This is because playing includes various techniques involving string tension (bending) or vibrato. Unfortunately the corresponding string tensions cannot be measured by the Laser Pitch Detection system developed by M3i Technologies. A tailpiece coated with DiaForce® is therefore being developed in collaboration with the Micro- and Sensor Technology Group at the Fraunhofer IST which will make the Tension Sensing function possible.

Development of a thin-film sensor system based on a piezoresistive DiaForce® coating

Development work started with »intelligent« washers adapted to the tensile forces on the strings and equipped with contacts. This washer-based sensor system consists of washers polished on one side and having an internal diameter of 3 mm, an external diameter of 9 mm and a thickness of 1.5 mm. The washers were given a piezoresistive DiaForce® sensor coating on one side.

Both steel foil and metallized plastic foils were used as electrode material. They were laser-cut and applied directly to the sensor functional layer. As Fig. 1 shows, these »intelligent washers« have been built into the guitar. Various contact materials, coating thicknesses and deposition processes were investigated before parameters were obtained which permitted dependable measurement of the tensile forces in the guitar and their variations in each string. The sensor coating systems were applied to our own specially produced tailpieces using previously determined process parameters in order to demonstrate a solution for string tension measurement which would be feasible for high-volume production. In one variant of the thin-film sensor system the electrodes are deposited in a structured form directly onto the DiaForce® coating (Fig. 2). First trials in the development process have produced some very promising results.

Outlook

A further possible application of the DiaForce® coating is currently being investigated: coated tailpieces could in future replace hexaphonic pickups. For this to be possible the coating would however have to be sensitive enough to convert into a usable resistance change any vibrational energy still remaining at the tailpiece.

1 Sensor washers integrated into the tailpiece.
2 Tailpiece with thin-film sensor system.

CONTACT

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

SERVICES AND COMPETENCIES

In pursuing the business areas that were showcased in the previous chapters the Fraunhofer 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

- Magnetron sputtering and HIPIMS
- Hollow cathode processes
- PACVD- and hot-filament CVD processes
- Hot-wire-CVD-processes
- Atomic layer deposition (ALD)

Atmospheric pressure processes

- Electroplated multi-component systems
- Electrochemistry
- Atmospheric pressure plasma-processes
- Micro plasma
- Low temperature bonding
- 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 for photovoltaics and microelectronics
- Oxide semiconductors
- Insolation coatings

Super hard coatings

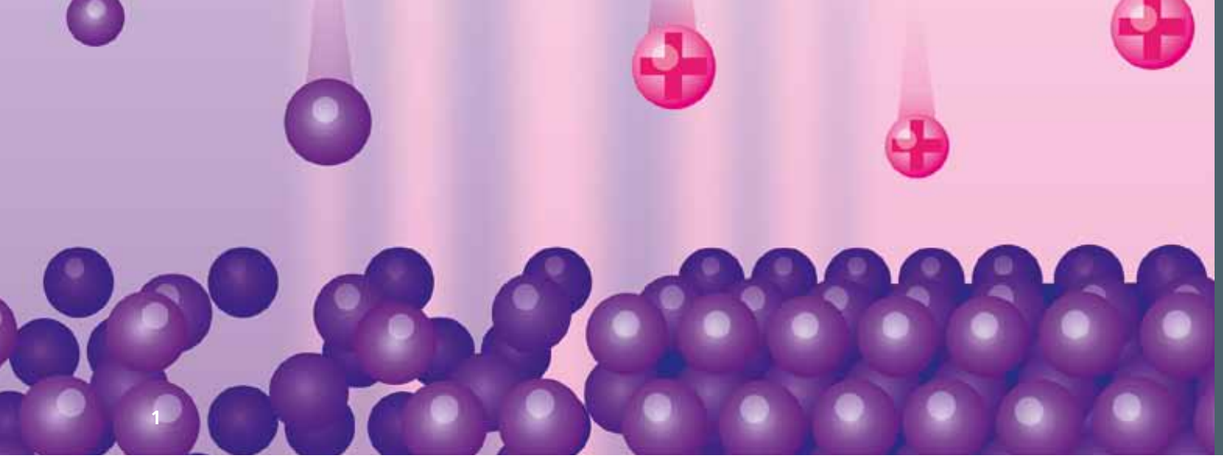
- Diamond
- Cubic boron nitride (cBN)

Wear protection and friction reduction

- Diamond-like carbon coatings (DLC)
- Diamond coatings
- 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.)



HIGHLY IONIZED PULSED PLASMA PROCESSES– HIPP PROCESSES

Highly ionized pulsed plasma processes (HIPP processes) are characterized by a significantly increased proportion of ions in the material forming the coating. This means that the properties of the coatings can be significantly improved.

Highly ionized pulsed plasma processes on the threshold of industrial production
During the last ten years highly ionized pulsed plasma processes such as HIPIMS (high power impulse magnetron sputtering) and MPP (modulated pulse power sputtering) have been the focus of intensive and fundamental investigations. Short, extremely powerful pulses can generate plasmas with electron densities three orders of magnitude higher than in conventional PVD processes and thus have a permanent effect on coating properties such as improved hardness, density, wear resistance and the crystalline structure. Certain selected processes currently stand on the threshold of industrial integration. In special cases conventional methods are being ousted here or unique types of coating properties can be generated and new markets opened up for the first time. The challenge of the next decade is the successful integration of HIPP processes. This calls for extensive expertise in the field as well as an informed selection of the right technology for the particular processes desired.

The Fraunhofer IST's expertise and equipment
For a number of years now the Fraunhofer IST has been involved in the development of processes, generators, and control systems for HIPP processes. The focus is on HIPP processes (including HIPIMS and MPP) in the field of glass coatings, TCOs, photovoltaics, optical, electrical and sensor coatings, and tribology. Since 2009 the Fraunhofer IST is leading a COST Action relating to »Highly ionized pulsed plasma processes«.* The Fraunhofer IST has at its disposal nearly all commercially available high-power pulse generators as well as its own generator, control, and process concepts for HIPP processes. At the present time at least six laboratory and industrial scale coating plants are equipped with HIPP technology for customer-specific development work. The Fraunhofer IST has these generators at its disposal:

- Advanced Energy (HIPIMS, R&D prototype)
- Hüttinger Elektronik GmbH + Co. KG (HIPIMS)
- Magpuls GmbH (HIPIMS)
- Melec GmbH (HIPIMS)
- ZPulser LLC (MPP)

Outlook
In conjunction with Sheffield Hallam University the Fraunhofer IST and INPLAS e. V. are hosting the 2nd International Conference on HIPIMS. The IST will thus be working more intensively with Sheffield Hallam University in the joint HIPIMS research laboratory set up in Sheffield during the course of the year under review.

** COST-Action MP0804*
Highly Ionized Pulse Plasma Processes, HIPP-Processes; www.hipp-cost.eu

1 *Principle: difference between HIPP und regular sputtering.*

CONTACT

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

HIGH-RATE PACVD DEPOSITION OF DLC COATINGS

Due to their unusual properties including high hardness and a low friction coefficient, amorphous carbon films with diamond-like properties (DLC – diamond-like carbon) are of outstanding importance, at the present time especially in the automotive industry.

Plasma-assisted chemical vapor deposition (PACVD)
The DLC deposition process most widespread in industry today is plasma-assisted chemical vapor deposition (PACVD). Here the substrate is excited by a pulsed DC voltage (in the 100 kHz range) in a precursor-argon mixture. Ions from the plasma and radicals contribute to forming the coating. With PACVD processes, different DLC modifications can be prepared when the corresponding precursors are used. High deposition rates are of special interest for effective and low cost industrial solutions. By applying additional microwave excitation (MW PACVD) plasma densities and thus deposition rates as well can be increased considerably. Higher deposition rates and lower process costs are of great interest, particularly for hard a-C:H coatings currently established in the industry.

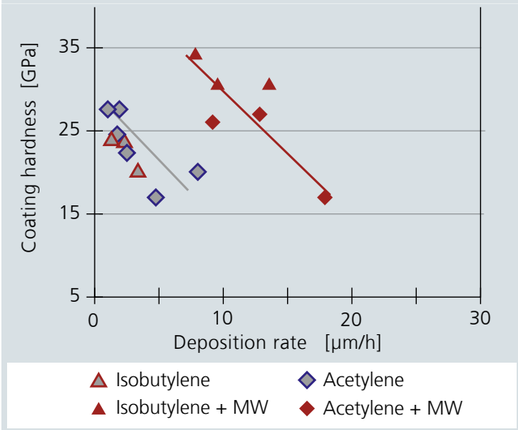
High-rate processes for depositing hard a-C:H coatings
In a project funded by the German Federation of Industrial Research Associations (AiF), with the Institute of Physics of the Technical University of Chemnitz as project partners, the MW PACVD method was used to investigate whether there are any hydrocarbon precursors which would allow further increases in the deposition rates of pure a-C:H coatings as compared with the 'standard' precursor acetylene (C_2H_2) but while still retaining coating properties, especially hardness. The precursors investigated were toluene – C_7H_8, isobutylene – C_4H_8, cyclopentene – C_5H_8 and cycloheptatriene – C_7H_8.
Work at the Fraunhofer IST was carried out using an industrial coating machine (Fig. 1). Our research revealed only minor deposition rate differences for the precursors under consideration when coatings with same properties were considered. Other important results emerging were:

- Vital for high deposition rates are high power levels at the substrate although this can also lead to greater thermal load on the substrates
- Higher substrate performances can be achieved without any problems for the precursors acetylene (C_2H_2) and isobutylene (C_4H_8)
- Increasing coating hardnesses correlates with decreasing deposition rates
- By using additional microwave excitation considerably higher deposition rates can be achieved while maintaining and sometimes increasing coating hardnesses.

These investigations show that acetylene (C_2H_2) and isobutylene (C_4H_8) are the most promising precursors for high-rate deposition of hard a-C:H coatings. Higher rates can be achieved primarily by means of higher power densities.

Outlook
An innovative PACVD coating machine equipped with two linear microwave sources and a rotating substrate planetary is being put into operation at the Fraunhofer IST with the intention of further optimizing the processes for depositing different DLC modifications.

Correlation of coating hardness and deposition rate for PACVD deposition using acetylene and isobutylene precursors, excitation with pulsed direct voltage (light-blue symbols) and with additional microwave excitation (red).

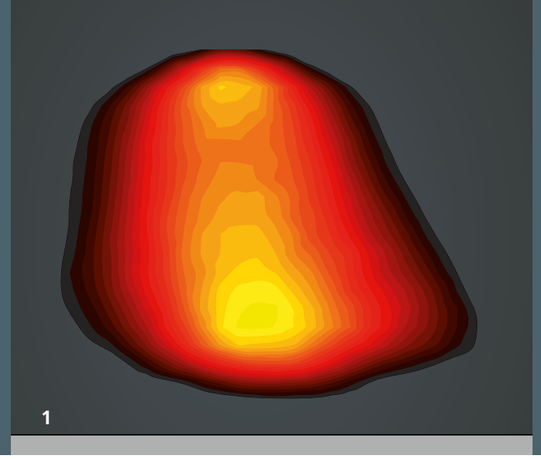


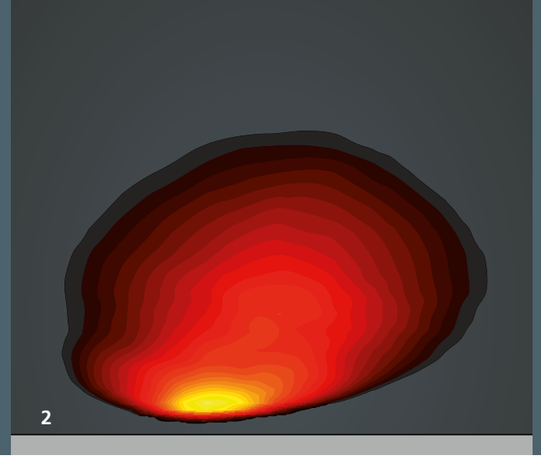
1 PACVD machine DLCarbon 1100 with a linear micro wave plasma source (Roth&Rau AG).
2 PACVD machine DLCarbon 1100, open chamber with linear micro wave plasma source.

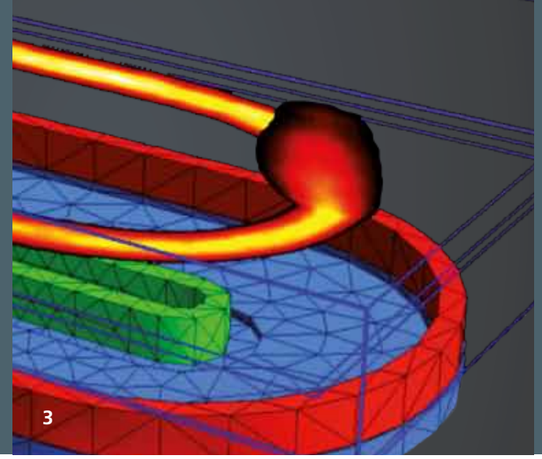
CONTACT

Dipl.-Ing. Ingmar Bialuch
Phone +49 531 2155-656
ingmar.bialuch@ist.fraunhofer.de

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







NEW 3-D PLASMA SIMULATION FOR INDUSTRY-SPECIFIC PROBLEMS

At the Fraunhofer IST a parallel particle-in-cell Monte Carlo (PIC/MC) simulation environment has been prepared with which gas flows and gas discharges can be simulated with spatial and temporal resolution. A tenfold increase in performance has been achieved thanks to the new development of a parallel-mode field calculation method. Now for the first time near-industrial plasma densities for large 3-D geometries can be handled without undue cost or effort.

On account of the cost savings they offer in comparison with experimental methods, virtual simulation tools are becoming increasingly important for the progressive optimization of industrial coating plants as regards throughput and precision. The PIC-MC software developed at the Fraunhofer IST covers the complex interactive processes found within low-pressure plasmas. The computing time required does however rise markedly with the problem size and the plasma density, which is proportional to the power of the coating source. In the case of large 3-D geometries, electrical field calculation for the charged particles has until now taken up as much as 90 % of the computing time. A new development had become absolutely essential for field calculation.

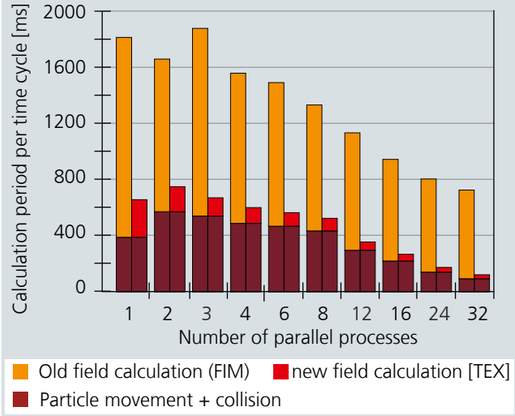
Performance gains due to new field calculation

To determine the electrostatic field of any charge distribution the Poisson equation has to be solved. It can be converted by discretization into a linear equation system which can then be solved numerically by means of freeware packages (UMFPACK, PETSc). However these packages either soon come up against the limits of the main memory and do not calculate in parallel – in other words, using several processors simultaneously – or parallelization does not scale up in a satisfactory manner. Since the positions of particles are time-resolved during a PIC-MC simulation, the charge distribution changes constantly and slowly. For this reason it makes sense to tackle the field calculation iteratively, using the solution of the previous time step and thus providing a very rapid convergence. The procedure used is based on the Gauss-Seidel algorithm with the addition of »successive overrelaxation« (SOR) to speed up convergence. When combined with the parallelization made possible by the message-passing interface (MPI) enormous gains in performance could be achieved.

Fig. 1 shows a simulated electron density distribution within a 3-D PVD reactor model with an output of approx. 30 W/m. This configuration has a spatial resolution of about one million grid cells. The computation times were averaged over the first thousand time steps and plotted separately against the number of central processing units (CPUs) used (see graph on the facing page). It is evident that the new field calculation is up to twenty times faster and also becomes considerably more efficient as the number of processes rises. The proportion of total computing time including particle movement and collision taken up by field calculation thus falls from over 90 percent to below 20 percent. When extrapolated to full PIC-MC simulation (around one million time steps) the computing time with 32 CPUs drops from about one week to a single day.

This is why 3-D simulations have until now been carried out with the power greatly reduced (<1 W/m) since the lower particle density means faster convergence. However, using plasmas with such low densities means that realistic descriptions of all phenomena will not be possible since the particle cloud then extends far beyond the target plane (Fig. 1). Not until power levels are higher (>10 W/m) does the plasma localize close to the target and a plasma distribution is obtained which comes close to a realistic sputtering process (Fig. 2).

Measured CPU time in PIC-MC simulation with the old and new methods of field calculation.



Outlook

The development of the hardware architecture results in an ever-increasing number of CPU cores – from »multi-core« to »many-core« – making great demands on the scalability of the simulation. As progress continues with the development of adapted algorithms for the PIC-MC software it will be possible in future to handle problems of ever greater complexity and magnitude. Following the successful implementation of electrical field calculation, the focus of discussion will be on the expansion of magnetic field calculation in order to be able to simulate inductively excited plasmas.

1-2 Cut through the 3-D-plasma distribution at low and high performance.

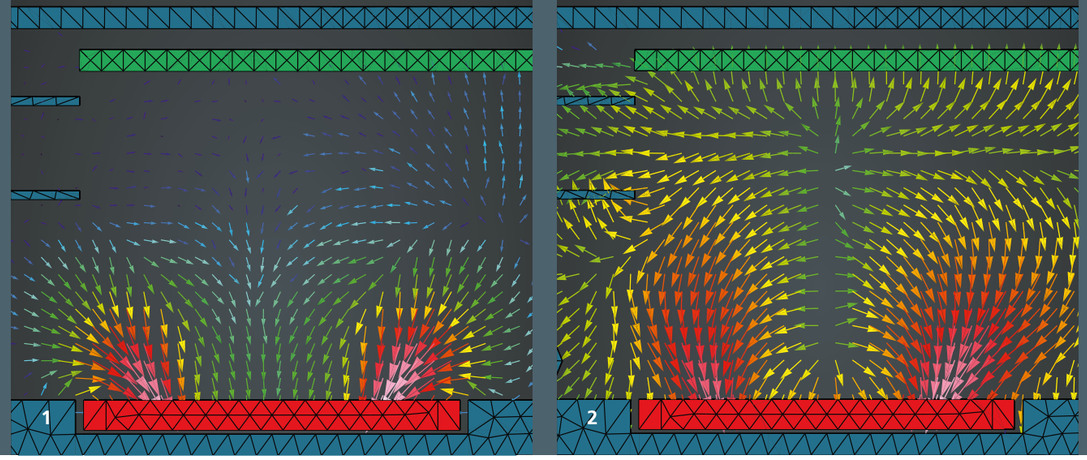
1 0,06 W/m, electron density $2{,}5^{12} – 2{,}5^{13}/m^3$

2 30 W/m, electron density $5{,}5^{14} – 5{,}5^{15}/m^3$

3 Simulated electron distribution in a PVD reactor.

CONTACT

Dipl.-Phys. Christoph Schwanke
Phone +49 531 2155-644
christoph.schwanke@ist.fraunhofer.de



SIMULATION OF ION BOMBARDMENT IN MAGNETRON SPUTTERING

In addition to their thickness and composition, thin films are characterized by further aspects such as, for example, their crystalline structure, density, morphology, electrical conductivity or mechanical tension. The totality of all coating properties essentially derives from the particle flows and particle energies during the growth process. These parameters depend to a great extent on the installation geometry, on the design of the coating source and on process parameters and are only accessible with difficulty by experimental means. This results in major restrictions on the transferability of coating processes between different types of installation. With particle-in-cell Monte-Carlo simulation, on the other hand, we can make detailed predictions of the growth parameters in the substrate and develop process technologies tailored to the film properties required.

As part of a number of funded projects, a parallel simulation environment for describing gas flows and gas discharges in the low-pressure range has been developed at the Fraunhofer IST. The program models gases and charged particles by means of representative simulation particles. The Boltzmann transport equation is solved by the continuous movement of the particles, updating of the field distribution and a statistical treatment of collisions. By an appropriate selection of the grid cell size and of the number of simulation particles the precision of the simulation can be flexibly adjusted to requirements. This simulation method can be used for a wide variety of low-pressure coating processes, such as, for example:

- Magnetron sputtering
- Plasma-enhanced chemical vapor deposition (PECVD)
- Ion-assisted sputtering
- Evaporation and atomic layer deposition (ALD).

In all cases the simulation is able to deliver coating rate distributions for substrates of any shape, detailed pressure distributions and also particle flows and energy distributions of ions and precursors at the substrate. In this way a detailed understanding of the process is built up. Instabilities occurring in the process, inhomogeneities and other unwanted side-effects can be systematically analyzed and removed. The software can be used as a tool not only for designing the vacuum tanks but even for new coating sources.

Example: sputtering process with DC or high-frequency AC excitation

Figs. 1 and 2 show by way of example an arrangement for magnetron sputtering with argon as the sputter gas. The sputtering target (red) is connected to either a DC or an AC source. The arrows represent the current density of the Ar^+ ions, with the scale here ranging from $10^8/cm^2s$ (blue) to $10^{14}/cm^2s$ (pink). In the case of DC excitation most of the Ar^+ ions are attracted by the negatively charged sputtering target. Ion bombardment of the target creates sputtered particles and secondary electrons. The latter create further Ar+ ions by impact ionization with the Ar atoms in the gas. The substrate (green) is only bombarded to a minor extent by ions. In contrast to this, with high-frequency AC excitation (13.56 MHz) ions are created even in the free space between target and substrate due to electron oscillation. Since the plasma has a markedly positive potential the ions are accelerated in the direction of all surrounding surfaces and thus bombard even the substrate. In this way modified film properties can be produced, such as, for example, lower surface roughness, higher density or modified crystalline phases.

Outlook

With particle-in-cell Monte-Carlo simulation it is possible to obtain a detailed prediction of the deposition conditions at the substrate as a function of the installation design and process parameters. Process technologies can thus be developed which are tailored to deliver the film properties required. Furthermore the transferability of a coating process to different installation types is simplified.

1+2 Arrangement for magnetron sputtering with argon as the sputter gas.
1 At direct current.
2 At alternating current.

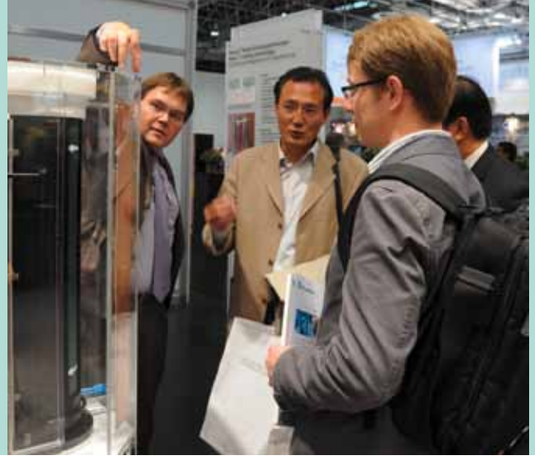
CONTACT

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

NAMES, DATES, EVENTS 2010

In 2010 the Fraunhofer IST once again appeared on various platforms. An overview of the most important events and activities of 2010 follows:

- Trade fairs and conferences
- ICCG8 – International Conference on Coatings on Glass and Plastics
- Workshops
- Events



TRADE FAIRS AND CONFERENCES

»Karlsruher Arbeitsgespräche«
Karlsruhe, March 9–10, 2010. The tenth BMBF conference »Karlsruher Arbeitsgespräche Produktionsforschung« was held on March 9 and 10, 2010. Under the slogan »Production in Germany has a future« the Fraunhofer IST presented one project centered on the subject of 'Integrated thin-film sensor systems' and another on the subject of »plasma printing«.

Hannover Messe 2010
Hannover, April 19–23, 2010. This year the Fraunhofer IST was represented at the Hannover Fair by the Micro- and Sensor Technology group in the Fraunhofer Alliance Adaptronics. With the aid of a steam engine various applications were presented, ranging from temperature sensors to high-pressure tube hydroforming.

1st International Conference on HIPIMS
Sheffield, July 6–7, 2010. A further building block in the collaboration between the Fraunhofer IST, the Sheffield Hallam University and INPLAS e. V. is the joint setting-up of an international annual HIPIMS conference to be held alternatingly in Sheffield or in Braunschweig. This arrangement kicked off in June 2010 in Sheffield with the 1st International HIPIMS Conference, a great success with 120 participants from all over the world.

PVSEC 2010
Valencia, September 6–10, 2010. On the joint Fraunhofer stand, the Fraunhofer IST together with two other Fraunhofer institutes ILT and IPA demonstrated their expertise in the field of thin-film photovoltaics by means of a wide variety of examples of their application. A major focus of the presentation was the new »C^2« system module for a magnetron sputtering unit of the Fraunhofer IST. With this module, surfaces can already be coated with entirely new combinations of materials.

6th International Conference on Hot-Wire Chemical Vapor Deposition
Paris, September 13–17, 2010. At the »6th International Conference on Hot-Wire Chemical Vapor Deposition (CatCVD) Processes – HWCVD 2010« at the École Polytechnique in Paris-Palaiseau, France the Diamond Technology department of the Fraunhofer IST premiered the new hot-wire CVD in-line system. An invited lecture and a video conveyed an authentic impression of the new high-tech system. What this system can already do in the field of silicon coatings was demonstrated by several substrates coated with silicon and silicon nitride, including two large coated planar substrates measuring 500 x 600 mm^2.

PSE 2010
Garmisch-Partenkirchen, September 13–16, 2010. At PSE 2010, the 12th International Conference on Plasma Surface Engineering and Germany's largest international plasma conference, the Fraunhofer IST together with the Fraunhofer FEP, SOFTAL and MELEC companies as well as the French network ViaMéca, were represented on a joint stand organized by the Network of Competence INPLAS e. V. Here the Fraunhofer IST showcased a wide spectrum of its developments.

IFAT ENTSORGA 2010
München, September 13–17, 2010. Within the context of the Fraunhofer Alliance Water Systems (SysWasser) the Fraunhofer IST presented technology developed at the institute for hygienization and cleaning of waste water based on diamond electrodes.

Glasstec 2010
Düsseldorf, September 28–October 1, 2010. Be it the icefree windshield, current research results in the field of transparent conductive oxides (TCOs), or the new system module »C2« for the cylindrical co-sputtering technology or superhydrophobic surfaces, the wide spectrum of what the Fraunhofer IST can do for glass was clearly visible at the world's largest glass fair. In the ‚Glass Technology Live' exhibition accompanying the conference the Fraunhofer IST presented the latest developments in the field of large-area transparent conductive coatings.

Biotechnica 2010
Hannover, October 5–7, 2010. The Fraunhofer IST was represented at Lower Saxony's joint stand with the latest results of research into the internal coating of stem cell and blood bags for medical technology.

Euroblech 2010
Hannover, October 26–30, 2010. At the world's leading trade fair for the sheet metal industry the Fraunhofer IST presented the latest results of research in the field of titanium forming. A broad range of subjects was presented, including innovative forming processes for titanium components (especially those made of higher-strength titanium alloys), the necessary forming processes and die materials, and adapted die coatings.

K 2010
Düsseldorf, October 27–November 3, 2010. This year too the Fraunhofer IST was represented on the joint Fraunhofer stand at the world's largest plastics fair. Over the seven days of the fair the institute showcased new technologies. The focus was on atmospheric pressure plasma processes, for example, technologies for plasma printing, such as for producing printed electronic circuitry, for flexible PCBs or for biosensors. Additionally, films on polycarbonate with high photocatalytic activity were presented

denkmal 2010
Leipzig, November 18–20, 2010. At one of the most important European fairs centered on the topic of monument conservation and restoration, scientists from the Fraunhofer IST presented new methods for the careful cleaning of silver surfaces in atmospheric-pressure plasma.

ICCG 8 – HIGH-TECH COATINGS ON GLASS AND PLASTICS

From June 13 to 17, 2010 the 8th International Conference on Coatings on Glass and Plastics as the leading conference in the field once again offered experts and decision-makers from science and business an important platform for discussing future trends, new technologies, developments and applications and making interesting contacts. This international conference, held for the second time in Braunschweig, was organized under the supervision of the Fraunhofer IST and the International Organizing Committee of the ICCG.

Over the five days of the conference more than 400 participants expected a varied program put together by a committee of international experts and consisting of papers dealing with markets and trends in the field of glass and plastics, on the technology of plasma and ion sources, on atmospheric-pressure plasma processes, on process control and characterization, on the properties of thin films and on a multiplicity of different applications, from fields including photovoltaics, automotive engineering, architecture, displays and flexible electronics.
This comprehensive menu of information was supplemented by a panel discussion on the subject of »Large-area thin films for energy efficiency« as well as a poster exhibition.
In the accompanying technical exhibition more than 40 international companies and research institutes presented their products and latest developments. The ICCG was for the second time organized by the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig. In the words of Professor Dr. Günter Bräuer, local chairman and director of the Fraunhofer IST: »This year too the ICCG has gone off very successfully again. This is an important conference – for our institute as well. It covers not only scientific but also application-related aspects and is a rendez-vous for the glass and plastics coating community.« Two selected scientific contributions at ICCG8:

How can photocatalytic activity be analyzed quantitatively?
Photocatalytic coatings are of great industrial interest in various applications such as self-cleaning, antifouling, antifogging and antimicrobial surfaces. The most well-known photocatalytic material and the one used most frequently in commercial products is crystalline titanium dioxide (TiO_2). Various coating methods can be used for the production of TiO_2 coatings such as, for example, magnetron sputtering, thermal vapor deposition, sol-gel methods, painting methods, thermal spraying methods or various CVD methods. All of these technologies are being investigated within the Fraunhofer Alliance Photocatalysis. So that the performance of various coatings created with these different technologies can be compared more satisfactorily the Fraunhofer Alliance Photocatalysis has developed new methods for a quantitative determination of photocatalytic activity. At ICCG8 Dr. Michael Vergöhl, spokesman for the alliance and head of the Optical and Electrical Coatings department at the Fraunhofer IST, presented a comparison of the various coating methods.
Dr. Michael Vergöhl, Fraunhofer IST

Structured metallization of plastic and glass surfaces by plasma printing
For the glass and plastics industries an important rôle is played by cost-effective and resource-thrifty technologies for the structured functionalization and coating of surfaces in the micron range. Fraunhofer IST scientists together with partners from industry and science are currently working on the development of a new technology for the location-selective treatment of polymer sheeting by a continuous process based on plasma printing at atmospheric pressure. In this way sheet surfaces, for example, can be functionalized such that a metallization with good adhesive properties can be added to plasma-treated areas by means of electroless processes. With these technologies flexible printed circuit boards, RFID antennae or biosensors among other things can be inexpensively manufactured while at the same time dealing sparingly with valuable raw materials such as copper. Plasma printing can however also be used for structuring glass or silicon surfaces, such as, for example, in the production of solar cells or MEMS.
Dr. Michael Thomas, Fraunhofer IST

WORKSHOPS

Kick-off workshop of the COST Action MP0804 work groups
Brussels, May 10–11, 2010. As part of COST Action MP0804, which is concerned with highly ionized pulsed plasma processes and their industrialization, the first joint workshop of the Action work groups was held in Brussels. 42 experts from the field of pulsed plasma processes, including, for example, HIPIMS and MPP, gathered to discuss various topics at a high level. The workshop looked at the generation of HIPP plasmas, the characterization of plasma and coatings, and also the modeling and simulation of HIPP processes. The scientific topics were supplemented by the applied results of research relating to processes for non-reactive and reactive coating depositions with industrial objectives. This workshop represented the official kick-off whistle for the work of the individual work groups.

3rd Workshop on the International Standardization of Carbon Films
Garmisch-Partenkirchen. The international standardization of carbon coatings was the central concern of a workshop organized by the Fraunhofer IST at PSE 2010 in Garmisch-Partenkirchen. At the »3rd Workshop International Standardization of Carbon Films« speakers from Europe and Asia presented the current state of research, standardization and industrial application. In the panel discussion which followed, many of the 50 or so participants stressed the need for an internationally uniform classification and nomenclature – an ISO standard – for amorphous carbon coatings (DLC) and CVD diamond films.

22nd and 23rd meetings of the »Tool coatings and cutting materials« industry work group
Berlin, Braunschweig – March, November 2010. This year saw two meetings of this industry work group, which is organized by the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Institute for Machine Tools and Factory Management (IWF) of the Technical University of Berlin. The first was on March 3 in Berlin in the Production Technology Center (PTZ) and the second on November 16 at the Fraunhofer IST in Braunschweig. At both events well-known experts from industry and research once again presented the latest findings and developments relating to the production and use of coated cutting tools and cutting materials, this time including the topics of materials in the power train, smooth diamond coatings, total cutting material systems, temperature control, the slip-rolling resistance of DLC coatings, grinding with CVD diamond films and coating systems for hard machining. In the accompanying industrial exhibition products for the optical measurement of the geometry and surface roughness of tools were showcased as well as monitoring systems for cutting processes.

EFDS workshop »Pulsed highly ionized plasmas – from basics to application«
Dresden, November 28, 2010. In conjunction with the Europäische Forschungsgesellschaft Dünne Schichten e. V. the Fraunhofer IST made the preparations for the »Pulsed highly ionized plasmas – from basics to application« workshop. An introduction to the subject of »pulsed highly ionized plasmas« was followed by various academic and industrial contributions relating to the state of the art in the field of pulsed highly ionized plasmas (PVD, PACVD, diffusion). The focus here was on plasma CVD and PVD processes with a particular in-depth treatment of high power impulse magnetron sputtering (HIPIMS).

On-line lecture »Plasma leuchtet ein«
The triumphal progress which plasma technology has already made to date and the potential it has for the future are subjects tackled by Professor Dr. Günter Bräuer, head of the Fraunhofer IST, in an on-line lecture entitled »Plasma surface technology – a glimpse into a hitherto almost unknown world«. In a compact and readily understandable treatment, supported by a large number of graphics and inserted videos, Professor Bräuer provides an introduction to the wide range of applications for plasma technology and the possibilities offered by thin films. The lecture can be ordered as a DVD from www.ist.fraunhofer.de.

EVENTS

Research for thin-film photovoltaics – the Fraunhofer IST and the Helmholtz-Zentrum Berlin (HZB) agree on close collaboration

How can the efficiency of solar cells be further improved? How can costs be lowered? In future the Fraunhofer IST and the HZB will together provide answers to these and other questions relating to thin-film photovoltaics.
The two institutes wish to bundle their central competences: the Fraunhofer IST brings its knowledge and expertise in thin-film technology while the HZB is a leader in the field of thin-film photovoltaics. To accelerate the transfer of technology the PVcomB competence center has been set up at the HZB. Production technologies for making thin-film modules from silicon and CIS are tested here with the Fraunhofer IST applying its research competence in the fields of surface technology and coating systems.

The Fraunhofer IST founds the HIPIMS Research Center

The Fraunhofer IST and Sheffield Hallam University in Sheffield UK have set up a joint HIPMS Research Center in order to further extend and consolidate the leading positions both institutions occupy internationally in this special field of PVD coating technologies. The aims of the center include collaboration on international projects, the exchange of employees and students, and the provision of lectures in both institutions. As part of a festive ceremony on the occasion of the 1st International Conference on HIPIMS in June 2010 in Sheffield, the center was introduced and opened by Vice-Chancellor Professor Mike Smith, SHU and Wolfgang Diehl, Vice-Director of the Fraunhofer IST.

RETECZA: global partnership for reducing poverty in South Africa

Within the context of the RETECZA 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. As the first successful project of the RETEZCA initiative the »hydrogen bike«, a hydrogen-fuelled three-wheeler, was introduced to the public in the presence of the South African research minister at the 2nd RETECZA conference in August 2010 in Kwa Maritane. There was an unusually great response from the press and other media, with television and radio reports being broadcast worldwide for more than three months. The Fraunhofer IST is working within the project in the field of »water treatment« on diamond electrodes for wastewater treatment and hygienization. Wolfgang Diehl, vice-director of the institute, represents the Fraunhofer IST on the project board.

Girls' Day at the Fraunhofer IST

In 2010 it was once again a case of girls only at the Fraunhofer IST. For the eight participants in Girls' Day the emphasis was on trying out their technical skills as, wearing clean-room clothing, they fabricated microstructures in the yellow-light laboratory. 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. In this way these young students experienced the full process chain which is typical of microtechnology. »Every year it gives us the same good feeling to see the amount of interest the students bring to mastering these challenging tasks. We very much hope that we will see some of them in the future as interns here at the institute«, said the institute's equal opportunities officer, Dr. Saskia Biehl, about the commitment displayed by the girls.

Opening of a new building at the Fraunhofer IST

Together with Prof. Dr. Alfred Gossner, Chief Financial Officer of the Fraunhofer Society and more than a hundred guests from research, industry and politics, the Fraunhofer Institute for Surface Engineering and Thin Films IST officially opened another institute building on May 28, 2010. The two departments »Tribology transfer center« and »New tribological coatings« moved into the new building whose construction took three years. From cleaning and pretreatment of workpieces to coating operations, work here is carried out on an industrial scale. Not only the Fraunhofer IST departments but also the University Institute for Surface Technology (IOT) headed by professors Bräuer and Klages is moving into the new building together with surface-hardening machines using so-called plasma-diffusion methods. This creates a unique opportunity for collaboration between research in fundamental principles and research which is close to actual applications. The infrastructure of the building complex has undergone changes, especially on the second floor. The two parts of the institute are linked by a glass bridge with electrochromic windows. The bridge represents the connecting element between the new and old parts of the institute and thus its future as well. With these electrically switchable coatings the Fraunhofer IST wishes to present a further area of application for the very latest thin-film technology. This high-tech glazing also makes a contribution to climate protection«, says Professor Bräuer, Director of the Fraunhofer IST.

2010 Open Day

How do the scientists make lightning in the laboratory and what do they do with a plasma? How can water be cleaned with diamond? The Fraunhofer IST together with the Fraunhofer WKI invited all interested members of the public from Braunschweig and district to come on August 28, 2010 to get answers to these and many other fascinating questions in surface engineering and thin films and in wood research. In the laboratories and on the Fraunhofer campus more than 900 visitors could spend the entire day going to participatory events, presentations and the items on a colorful basic program for large and small including a climbing wall, bouncy castle and much more, Here they could experience what lay behind the façades of these high-tech institutes. Open Day was also the occasion for the 20th birthday of the Fraunhofer IST.

Celebratory colloquium for Dr. Peter Willich – Farewell Monika Geertsema

With a celebratory colloquium the Fraunhofer IST bade farewell on June 22, 2010 to an internationally recognized expert and the long-serving head of the Analysis and Quality Assurance department at the institute, Dr. Peter Willich. Peter Willich was at the helm in building up the analysis department at the Fraunhofer IST and soon expanded it by adding the very successful field of externally commissioned analysis work. Right from the start his expertise made a significant difference to the profile of the institute. As part of this celebratory colloquium, Monika Geertsema, executive secretary, was bid farewell too. She had been working for the Fraunhofer IST since its establishment in 1994. She always put a lot of heart and determination into her work and showed an outstanding organizing ability.

BOARD MEMBERSHIPS

Bandorf, R.: COST Action MP0804, Action Chairman.

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

Bandorf, R.: Humboldt Stiftung, Gutachter.

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

Bandorf, R.: International Conference on Metallurgical Coatings and Thin Films, Session Chairman.

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

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

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

Borries, von, G.: Kompetenzzentrum »Ultradünne funktionale Schichten«, Mitglied.

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

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

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

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

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

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

Bräuer, G.: ISFH, Mitglied des Beirats.

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

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

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

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

Diehl, W.: Deutsche Forschungsgesellschaft für Oberflächenbehandlung DFO, 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 (GDP), Mitglied des Advisory Boards.

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

Diehl, W.: RETECZA NPO, Pretonia SA, Mitglied des Boards.

Diehl, W.: Society of Vacuum Coaters (SVC), Director, Mitglied des Executive Board.

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

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.: Fachausschuss »Kombinationsschichten« der DGO, Mitglied.

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

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

Gäbler, J.: European Society for Precision Engineering and Nanotechnology, 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.

Neumann, F.: CEN / TC386 »Photocatalysis«, WG2 »Air Purification«, WG4 »Selfcleaning«, WG6 »Light Sources«, Mitglied, Europäisches Komitee für Normung.

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

Keunecke, M.: European Society for Precision Engineering and Nanotechnology, Mitglied.

Keunecke, M.: International Conference on Metallurgical Coatings and Thin Films (ICMCTF), Session Chairman.

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

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

Schäfer, L.: Beirat der Condias GmbH, Mitglied.

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

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

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

Thomas, M.: Arbeitskreis Atmosphärendruckplasmaverfahren (AK-ADP), Mitglied.

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

INTERNATIONAL GUESTS

Herr Sang-gweon Kim, Ph.D., KITECH – Korea Institute of Industrial Technology, Incheon, Korea, 01.03.–31.12.2010.

PATENT APPLICATIONS

Bandorf, R.: Dünnschichtanordnung und Verfahren zur Herstellung einer Dünnschichtanordnung.

Bandorf, R.: Vorrichtung und Verfahren zum ionisierten Gasfluss-Sputtern.

Bandorf, R.: Vorrichtung und Verfahren zur Ratenbestimmung von ionisiertem schichtbildenden Material.

Biehl, S.; Staufenbiel, S.: Energieautarker sensorischer Kugelgewindetrieb.

Eichler, M.; Nagel, K.; Klages, C.-P.: Verfahren zur selektiven plasmagestützten Behandlung von sich gegenüberliegenden Innenflächen eines Hohlkörpers und Verwendung desselben.

Pflug, A.; Siemers, M.; Werner, W.; Szyszka, B.: Verfahren zur Reaktivgastrennung in In-line-Beschichtungsanlagen.

Szyszka, B.; Sittinger, V.: Anordnung umfassend eine transparente elektrisch leitfähige Schicht, Anordnung umfassend eine photoelektrische Vorrichtung und Verfahren zur Herstellung einer transparenten Elektrode.

PUBLICATIONS

Antsupov, G.; Brinksmeier, E.; Gäbler, J.: CVD-Diamantschichten als Abrasivbelag beim Schleifen. In: Klocke, F. (Hrsg.): WZLforum: 3rd European Conference on Grinding ECG. Aachen: Apprimus Wissenschaftsverlag, 2010, S. 12-1 – 12-3.

Bandorf, R.: Gepulste Hochleistungs-PVD-Verfahren. In: Europäische Forschungsgesellschaft Dünne Schichten (EFDS): Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung, Workshop am 24. November 2010 in Dresden. Dresden, 2010, getr. Zählung.

Bewilogua, K.; Keunecke, M.; Park, S. T.; Stein, C.; Weigel, K.; Richter, V.; Oyanedel Fuentes, J. A.: Cubic boron nitride coatings: sputter deposition, properties and application tests. In: Society of Vacuum Coaters (SVC): Technical Conference Proceedings 1991 – 2010. Albuquerque: Society of Vacuum Coaters, 2010, pp. 87 – 92.

Bewilogua, K.; Bialuch, I.; Keunecke, M.: PECVD-Verfahren mit gepulster Anregung zur Abscheidung von DLC-Schichten. In: Europäische Forschungsgesellschaft Dünne Schichten (EFDS): Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung, Workshop am 24. November 2010 in Dresden. Dresden, 2010, getr. Zählung.

Biehl, S.; Staufenbiel, S.; Hauschild, F.; Albert, A.: Novel measurement and monitoring system for forming processes based on piezoresistive thin film systems. In: Microsystem technologies 16 (2010), 5, pp. 879 – 883.

Biehl, S.: Piezoresistive Dünnschichtsensorik auf Basis amorpher Kohlenwasserstoffschichten und ihr Anwendungspotenzial. In: Suchentrunk, R. (Hrsg.): Jahrbuch Oberflächentechnik, Bd. 66. Bad Saulgau: Leuze, 2010, S. 324 – 330.

Bistron, M.; Behrens, B.-A.; Paschke, H.: Reduction of wear by boron based multilayer coatings on forging dies. In: Steel research international 81 (2010), 9, pp. 290 – 293.

Borris, J.: Oberflächenstrukturierung mittels Plasma-Printing bei Atmosphärendruck. In: Plasma + Oberfläche (2010), 1, S. 8 – 10.

Borris, J.: Plasma-Printing plus Galvanotechnik: Ressourceneffiziente Produktion flexibler Leiterplatten. In: JOT – Journal für Oberflächentechnik (2010), 3, S. 48 – 50.

Borris, J.; Thomas, M.; Dohse, A.; Klages, C.-P.; Möbius, A.; Elbick, D.; Prinz, U.; Wandner, K.-H.; Weidlich, E.-R.: P3T – a new technology for the cost and resource efficient inline production of flexible printed circuits, RFID antennas and biosensors. In: Circuit world 36 (2010), 4, pp. 18 – 21.

Borris, J.; Thomas, M.; Dohse, A.; Weidlich, E.-R.; Klages, C.-P.: P3T – ein neuartiger Ansatz zur Herstellung flexibler Elektronik im Rolle-zu-Rolle-Verfahren. In: Blasek, G. (Hrsg.); Dresdner Transferstelle für Vakuumtechnik: 18. Neues Dresdner Vakuumtechnisches Kolloquium (NDVaK): Beschichtung, Modifizierung und Charakterisierung von Polymeroberflächen, Leibniz-Institut für Polymerforschung Dresden e. V., 21. und 22. Oktober 2010. Dresden, 2010, S. 3 – 6.

Brand, P.-J.: Plasmatechnik und Galvanotechnik im Vergleich: Konkurrenz oder Ergänzung – ein Systemvergleich. In: Grüne Galvanotechnik: Stand und Perspektiven, Berichtsband über das 32. Ulmer Gespräch am 29. und 30. April 2010 in Neu-Ulm (Donau), Edwin-Scharff-Haus, Silcherstraße 40. Saulgau: Leuze, 2010, S. 46 – 52.

Bräuer, G.; Szyszka, B.; Bandorf, R.; Bewilogua, K.; Brand, J.; Vergöhl, M.: Gepulste Plasmen für industrielle Beschichtungsprozesse: Übersicht zu den Verfahren und Anwendungen. In: Europäische Forschungsgesellschaft Dünne Schichten (EFDS): Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung, Workshop am 24. November 2010 in Dresden. Dresden, 2010, getr. Zählung.

Bräuer, G.; Szyszka, B.; Vergöhl, M.; Bandorf, R.: Magnetron sputtering: milestones of 30 years. In: Vacuum 84 (2010), 12, pp. 1354 – 1359.

Bruns, S.; Vergöhl, M.; Werner, O.; Wallendorf, T.: High rate deposition of mixed oxides by controlled reactive magnetron-sputtering from metallic targets. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 185 – 189.

Cerezuela Barreto, M.; Borris, J.; Thomas, M.; Hänsel, R.; Stoll, M.; Klages, C.-P.: Barriereeigenschaften durch Nanobeschichtung: AD-Plasmapolymere auf PVC. In: Blasek, G. (Hrsg.); Dresdner Transferstelle für Vakuumtechnik: 18. Neues Dresdner Vakuumtechnisches Kolloquium (NDVaK): Beschichtung, Modifizierung und Charakterisierung von Polymeroberflächen, Leibniz-Institut für Polymerforschung Dresden e. V., 21. und 22. Oktober 2010. Dresden, 2010, S. 55 – 61.

Demir, M.; Weber, M.: Praxistaugliche Prozessschmierung für das Presshärten: Zusammenfassung. In: Institut für Fertigungsforschung, 7. Forum Tribologische Entwicklungen in der Blechumformung, 11. November 2010. Darmstadt, 2010, S. 147 – 164.

Dewald, W.; Sittinger, V.; Szyszka, B.; Gordijn, A.; Hüpkes, J.; Hamelmann, F.; Stiebig, H.; Säuberlich, F.: Angular resolved light scattering of structured TCOs for the application in a-Si:H / µc-Si:H solar cells. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 415 – 416.

Eichler, M.; Gabriel, M.: Local plasma treatment in a mask aligner for selective wafer surface modification. In: Suss report (2010), April, pp. 8 – 11.

Eichler, M.; Michel, B.; Hennecke, P.; Gabriel, M.; Klages, C.-P.: Low-temperature direct bonding of borosilicate, fused silica, and functional coatings. In: Colinge, C. (Ed.) u. a.; Electrochemical Society: Semiconductor Wafer Bonding 11: Science, Technology and Applications, in honor of Ulrich Gösele. Pennington, NJ: Electrochemical Soc., 2010, pp. 339 – 348 (ECS transactions 33, 4).

Gäbler, J.: CVD-Diamantschichten als Abrasivbelag zum Schleifen: AiF-Vorhaben 15038 N / 1. In: ZVO report (2010), 5, S. 36.

Gäbler, J.; Pleger, S.: Precision and micro CVD diamond-coated grinding tools. In: International journal of machine tools & manufacture 50 (2010), 4, pp. 420 – 424.

Graumann, T.; Neumann, F.: Measurement of photocatalytic properties of thin-films using novel solid-state luminescent dyes. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 241 – 243.

Hoffmeister, H.-W.; Schäfer, L.; Gäbler, J.; Wittmer, R.: Mikroschleifen mit CVD-Diamant-Schleifscheiben. In: Hoffmeister, H.-W. (Hrsg.) u. a.: Jahrbuch Schleifen, Honen, Läppen und Polieren: Verfahren und Maschinen, 64. Ausgabe. Essen: Vulkan-Verl., 2010, S. 206 – 212.

Jacobsen, H.; Prume, K.; Wagner, B.; Ortner, K.; Jung, T.: High-rate sputtering of thick PZT thin films for MEMS. In: Journal of electroceramics 25 (2010), 2 – 4, pp. 198 – 202.

Jandl, C.; Hertel, K.; Dewald, W.; Pflaum, C.: High performance computing for the simulation of thin-film solar cells. In: Wagner, S. (Hrsg.) u. a.: High performance computing in science and engineering, Garching / Munich 2009: Transactions of the Fourth Joint HLRB and KONWIHR Review and Results Workshop, December 8 – 9, 2009. Berlin [u. a.]: Springer, 2010, pp. 553 – 564.

Jandl, C.; Dewald, W.; Pflaum, C.; Stiebig, H.: Simulation of microcrystalline thin-film silicon solar cells with integrated AFM scans. In: 25th European Photovoltaic Solar Energy Conference and Exhibition / 5th World Conference on Photovoltaic Energy Conversion, Proceedings, Feria Valencia, Convention & Exhibition Centre, Valencia, Spain, September 6 – 10 (Conference), September 6 – 9, 2010 (Exhibition). Valencia, 2010, pp. 354 – 357.

Jandl, C.; Dewald, W.; Paetzold, U. W.; Gordijn, A.; Pflaum, C.; Stiebig, H.: Simulation of tandem thin-film silicon solar cells. In: Wehrspohn, R. B. (Ed.) u. a.: Photonics for Solar Energy Systems III. Bellingham, Wash.: SPIE, 2010, 772516 (Proceedings of SPIE 7725).

Keunecke, M.; Stein, C.; Bewilogua, K.; Koelker, W.; Kassel, D.; Berg, H. van den: Modified TiAlN coatings prepared by d. c. pulsed magnetron sputtering. In: Surface and Coatings Technology 205 (2010), 5, pp. 1273 – 1278.

Klages, C.-P.; Hinze, A.; Willich, P.; Thomas, M.: Atmospheric-pressure plasma amination of polymer surfaces. In: Journal of adhesion science and technology 24 (2010), pp. 1167 – 1180.

Koeßler, D.; Ortner, K.; Höfer, M.; Szyszka, B; Jung, T.: Preparation of photocatalytic TiO2-coatings by hollow cathode gas-flow sputtering. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for

Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 249 – 251.

Kondruweit, S. (Ed.); Szyszka, B. (Ed.); Pütz, J. (Ed.); International Organizing Committee of ICCG; Fraunhofer-Institut für Schicht- und Oberflächentechnik, Braunschweig: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010.

Kubart, T.; Nyberg, T.; Pflug, A.; Siemers, M.; Austgen, M.; Köhl, D.; Wuttig, M.; Berg, S.: Modelling of sputtering yield amplification effect in reactive deposition of oxides. In: Surface and coatings technology 204 (2010), 23, pp. 3882 – 3886.

Lachmann, K.; Dohse, A.; Thomas, M.; Pohl, S.; Meyring, W.; Dittmar, K. E. J.; Lindenmeier, W.; Klages, C.-P.: Surface modification of closed plastic bags for adherent cell cultivation. In: Orszagh, J. (Ed.) u. a.: HAKONE XII: 12th International Symposium on High Pressure Low Temperature Plasma Chemistry, Book of Contributed Papers Volume 2, Trencianske Teplice, Slovakia, September 12 – 17, 2009. Bratislava, 2010, pp. 533 – 537.

Mark, G.; Parra, E.; Bandorf, R.; Vergöhl, M.: New superimposed pulsed plasma technology using High Power Impulse Magnetron Sputtering (HiPIMS) combined with DC or MF-frequency. In: Society of Vacuum Coaters (SVC): Technical Conference Proceedings 1991 – 2010. Albuquerque: Society of Vacuum Coaters, 2010, pp. 224 – 228.

Matthai, A.; Bangert, S.; Grünhagel, O.; Hangleiter, B.; Schulz, U.; Szyszka, B.: Minerva: a project for the development of an ultra resistant coating on PC for automotive use. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 355 – 359.

Neubert, T.; Drost, S.; Vergöhl, M.: Organische Schichten für optische Interferenzschichtsysteme. In: 6. Thüringer Grenz- und Oberflächentage / 2. Thüringer Kolloquium »Dünne Schichten in der Optik«, Tagungsband: Plenarvorträge, Kurzvorträge, Posterzusammenfassungen, Gera, 7. – 9. September 2010. Jena: INNOVENT, 2010, S. 240 – 241.

Neubert, T.; Drost, S.; Nagel, K.; Vergöhl, M.: Polymer metal oxide composite layers for optical functional coatings. In: Society of Vacuum Coaters (SVC): Technical Conference Proceedings 1991 – 2010. Albuquerque: Society of Vacuum Coaters, 2010, pp. 308 – 312.

Paschke, H.; Weber, M.; Kaestner, P.; Bräuer, G.: Influence of different plasma nitriding treatments on the wear and crack behavior of forging tools evaluated by Rockwell indentation and scratch tests. In: Surface and Coatings Technology 205 (2010), 5, pp. 1465 – 1469.

Paulkowski, D.; Bandorf, R.; Schiffmann, K.; Bräuer, G.: Friction of flat-flat micro contacts coated with amorphous carbon. In: Tribologie und Schmierungstechnik 57 (2010), 4, pp. 41 – 43.

Pflug, A.; Siemers, M.; Schwanke, C.; Szyszka, B.: Simulation von Plasma-Beschichtungsprozessen: Ein neues Design-Werkzeug für die Vakuum- und Plasmatechnik. In: Vakuum in Forschung und Praxis 22 (2010), 3, S. 31 – 34.

Polenzky, C.; Ortner, K.; Szyszka, B.: Preparation and characterization of Cu'Me'''. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 281 – 283.

Rademacher, D.; Vergöhl, M.: In situ thickness determination of multilayered structures using single wavelength ellipsometry and reverse engineering. In: 2010 Optical Interference Coatings (OIC): Technical Digest, Topical Meeting and Tabletop Exhibit, Tucson, Arizona, USA, June 6 – 11, 2010. 2010, getr. Zählung.

Ring, S.; Säuberlich, F.; Wendelmuth, T.; Sittinger, V.; Szyszka, B.: Large area DC sputtered zinc oxide front TCO for a-Si / µc-Si tandem modules. In: 25th European Photovoltaic Solar Energy Conference and Exhibition / 5th World Conference on Photovoltaic Energy Conversion, Proceedings, Feria Valencia, Convention & Exhibition Centre, Valencia, Spain, September 6 – 10 (Conference), September 6 – 9, 2010 (Exhibition). Valencia, 2010, pp. 374 – 376.

Schiffmann, K.: Determination of fracture toughness of bulk materials and thin films by nanoindentation: comparison of different models. In: Philosophical magazine (2010), online publiziert am 28. Juni 2010, DOI: 10.1080 / 14786435.2010.487984, 16 Bl..

Sittinger, V.; Diehl, W.; Szyszka, B.: Dünnschicht-Photovoltaik in Deutschland: PV Dünnschichttechnologien im Überblick (a-Si / µSi, CIGS und CdTe). In: Vakuum in Forschung und Praxis 22 (2010), 5, S. 28 – 34.

Sittinger, V.; Horstmann, F.; Boentoro, W.; Werner, W.; Szyszka, B.: Heat treatable TCO film for position 1 based on HiPIMS. In: Schneider, J. (Ed.) u. a.; Technische Hochschule Darmstadt u. a.: Glass, facade, energy: Engineered Transparency, International Conference at Glasstec. 2010, pp. 565 – 574.

Sittinger, V.; Dewald, W.; Szyszka, B.; Säuberlich, F.; Stannowski, B.: New approach towards an optimized light trapping morphology of Al-doped ZnO films. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 269 – 271.

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. In: Thin solid films 518 (2010), 11, pp. 3115 – 3118.

Sittinger, V.; Dewald, W.; Werner, W.; Szyszka, B.; Ruske, F.: Transparent conducting oxide deposition techniques for thin-film photovoltaics. In: Photovoltaics international (2010), November, pp. 108 – 115.

Sittinger, V.; Szyszka, B.; Ulrich, S.; Pflug, A.; Ruske, F.; Dewald, W.: Übersicht über die Einsatzgebiete und Anwendungen von transparent leitfähigen Oxiden (TCOs). In: Galvanotechnik 101 (2010), 12, S. 2870 – 2879.

Stöhr, U.; Dohse, A.; Hoppe, P.; Gehringer, A.; Thomas, M.; Klages, C.-P.; Reinecke, H.: Porous photoresist stamps for selective plasma treatment. In: Plasma processes and polymers 7 (2010), 1, pp. 9 – 15.

Szyszka, B; Pflug, A.; Sittinger, V.; Ulrich, S.; Vergöhl, M.; Werner, W.; Kaiser, A.; Jung, S.; Bringmann, U.; Bräuer, G.; Köhl, D.; Austgen, M.; Wuttig, M.; Weis, H.; Herwig, W.; Polle, A.; Herlitze, L.: Rotatable target serial co-sputtering: a new core technology for industrial large area glass coating? In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, p. 37.

Szyszka, B.; Löbmann, P.; Georg, A.; May, C.; Elsässer, C.: Development of new transparent conductors and device applications utilizing a multi disciplinary approach. In: Thin Solid Films 518 (2010), S. 3109 – 3114.

Szyszka, B.; Polenzky, C.; Löbmann, P.; Götzendörfer, S.; Elsässer, C.; Körner, W.: Pathways towards p-type oxide layer for optoelectronic applications. In: Advances in Science and Technology 75 (2010), S. 16 – 24.

Szyszka, B.; Pflug, A.; Sittinger, V.; Ulrich, S.: Sputteryield-Amplification – Ein lange bekannter, doch bisher kaum genutzter Effekt zur Ratenerhöhung von Sputterprozessen In: Vakuum in Forschung und Praxis 22 / 3 (2010), S. 15 – 17.

Thomas, M.; Eichler, M.; Borris, J.; Lachmann, K.; Barreto, M. C.; Klages, C.-P.: Erzeugung funktioneller Oberflächen durch plasmaunterstützte Beschichtung mittels dielektrischer Barrierenentladung (DBD-PACVD). In: 6. Thüringer Grenz- und Oberflächentage / 2. Thüringer Kolloquium »Dünne Schichten in der Optik«, Tagungsband: Plenarvorträge, Kurzvorträge, Posterzusammenfassungen, Gera, 7. – 9. September 2010. Jena : INNOVENT, 2010, S. 151 – 155.

Thomas, M.; Borris, J.; Klages, C.-P.: Micropatterning using atmospheric pressure plasma processes. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 99 – 101.

Thomas, M.; Hinze, A.; Klages, C.-P.: Optimierung von DBD-Plasmaquellen durch grundlegende Untersuchungen der Plasmaunterstützten CVD-Abscheidung. In: Europäische Forschungsgesellschaft Dünne Schichten (EFDS): Gasmanagement für Atmosphärendruck-Plasmatechnologien, Workshop am 15. April in Dresden. Dresden, 2010, getr. Zählung.

Thomas, M.; Borris, J.; Dohse, A.; Weidlich, E.-R.; Elbick, D.; Klages, C.-P.: Plasma-Printing: Strukturierte Oberflächenfunktionalisierung

und selektive nasschemische Metallisierung. In: Grüne Galvanotechnik: Stand und Perspektiven, Berichtsband über das 32. Ulmer Gespräch am 29. und 30. April 2010 in Neu-Ulm (Donau), Edwin-Scharff-Haus, Silcherstraße 40. Saulgau: Leuze, 2010, S. 102 – 106.

Thomas, M.; Borris, J.; Weidlich, E.-R.; Elbick, D.; Klages, C.-P.: Plasma-Printing: Strukturierte Oberflächenfunktionalisierung und selektive nasschemische Metallisierung. In: PLUS 12 (2010), 12, S. 2828 – 2832.

Vergöhl, M.; Althues, H.; Frach, P.; Glöß, D.; Graumann, T.; Hübner, C.; Neumann, F.; Neubert, T.; Schottner, G.; Song, D. K.: Measurement of the photocatalytic activity of TiO2 films deposited by different methods. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 219 – 223.

Vergöhl, M.; Rademacher, D.: Particle generation during reactive sputtering of SiO2 with planar and cylindrical magnetrons. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 191 – 195.

Vergöhl, M.; Bruns, S.: Properties of TiO2 films deposited by bipolar reactive HiPIMS. In: Kondruweit, S. (Ed.) u. a.; International Organizing Committee of ICCG u. a.: Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG): Advanced Coatings for Large-Area or High-Volume Products, Braunschweig, Germany, June 13 – 17, 2010. Braunschweig, 2010, pp. 301 – 305.

Vergöhl, M.; Rademacher, D.; Fritz, B.: Sputtern optischer Schichten mit Rotatable-Kathoden: Partikelbelastung und Schichteigenschaften. In: 6. Thüringer Grenz- und Oberflächentage / 2. Thüringer Kolloquium »Dünne Schichten in der Optik«, Tagungsband: Plenarvorträge, Kurzvorträge, Posterzusammenfassungen, Gera, 7. – 9. September 2010. Jena : INNOVENT, 2010, S. 298 – 301.

Wäsche, R.; Hartelt, M.; Springborn, U.; Bewilogua, K.; Keunecke, M.: Wear of carbon nitride coatings under oscillating sliding conditions. In: Wear 269 (2010), 11 / 12, pp. 816 – 825.

Weber, M.; Kaestner, P.; Köster, K.; Thomsen, H.; Paschke, H.: Influence of different plasma nitriding treatments and coatings on the wear behaviour of forging tools for the production of automotive diesel injection parts. In: Society of Vacuum Coaters (SVC): Technical Conference Proceedings 1991 – 2010. Albuquerque: Society of Vacuum Coaters, 2010, pp. 519 – 524.

LECTURES, POSTERS

Antsupov, G.; Gäbler, J.; Brinksmeier, E.; Schäfer, L.; Riemer, O.; Rickens, K.: Precision Grinding with CVD Diamond Coated Grinding Wheels (Poster), 11th International euspen Conference, Delft, Niederlande, Mai / Juni 2010.

Antsupov, G.; Brinksmeier, E.; Riemer, O.; Gäbler, J.; Schäfer, L.: CVD Diamond Coating as Abrasive Layer for Grinding, 23. Treffen des Industrie-Arbeitskreises Werkzeugbeschichtungen und Schneidstoffe, Braunschweig, Deutschland, November 2010.

Antsupov, G.; Brinksmeier, E.; Riemer, O.; Gäbler, J.; Schäfer, L.: CVD Diamond Coating as Abrasive Layer for Grinding, 66. Kolloquium für Wärmebehandlung, Werkstofftechnik, Fertigungs- und Verfahrenstechnik, Wiesbaden, Deutschland, Oktober 2010.

Antsupov, G.; Brinksmeier, E.; Gäbler, J.: CVD-Diamantschichten als Abrasivbelag beim Schleifen, European Conference on Grinding, Aachen, Deutschland, November 2010.

Bandorf, R.; Gerdes, H.; Wallendorf, T.; Bräuer, G.: Characterization of HIPIMS discharges with tailored constant current phase (Talk), 1st International Conference on HIPIMS, Sheffield, United Kingdom, 6. – 7. Juli 2010.

Bandorf, R.; Gerdes, H.; Bräuer, G.: Influence of Target Material and Cathode Impedance on HIPIMS Plasmas (Invited Talk), MIATEC 2010, Metz, Frankreich, 15. – 18. Juni 2010.

Bandorf, R.; Gerdes, H.; Loch, D.; Bräuer, G.: Reactive Sputter Deposition of Alumina Coatings by HIPP Processes (Talk), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, 13. – 17. September 2010.

Bandorf, R.: Gepulste Hochleistungs-PVD-Verfahren (Talk), EFDS Workshop »Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung«, Dresden, Deutschland, 24. November 2010.

Bewilogua, K.; Keunecke, M.; Park, S.-T.; Stein, C.; Weigel, K.; Richter, V.; Oyanedel Fuentes, J. A.; Diehl, W.: Cubic Boron Nitride Coatings – Sputter Deposition, Properties and Application Tests, SVC 53th Annual Technical Conference Proceedings, Orlando, FL, USA, April 2010.

Bewilogua, K.: New developments of hard carbon and boron nitride coatings, Seminar Faculty of Mathematics and Physics, Charles University Prague, Prag, Tschechien, Oktober 2010.

Bewilogua, K.; Bialuch, I.; Keunecke, M.: PECVD-Verfahren mit gepulster Anregung zur Abscheidung von DLC-Schichten, Workshop »Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung«, Dresden, Deutschland, November 2010.

Biehl, S.: Energieautarke µ-Systeme in Werkzeugmaschinen (Talk), BMBF-Öffentliches Statusmeeting für energieautarke Mikrosysteme (EAS) und autonome vernetzte Sensorsysteme (AVS), Berlin, Deutschland, 25. – 26. Februar 2010.

Biehl, S.: Optimierte Regelung von Umformprozessen durch integrierte Dünnschichtsensorik (Poster), Karlsruher Arbeitsgespräche, Karlsruhe, Deutschland, 9. – 10. März 2010.

Biehl, S.: Hydrogenated carbon layer system for sensory applications (Poster), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, 13. – 17. September 2010.

Biehl, S.: Das Anwendungspotenzial von sensorischen Dünnschichtsystemen für den funktionsintegrierten Leichtbau (Talk), Nano- und Materialinnovationen Niedersachsen e. V. (NMN) AK Funktionsintegrierter Leichtbau, Braunschweig, Deutschland, 28. September 2010.

Biehl, S.: Energieautarke hochverschleißfeste Dünnschichtsensoren für Anwendungen im Maschinenbau (Talk), Deutsche IMAPS Konferenz, München, Deutschland, 12. – 13. Oktober 2010.

Biehl, S.: Dreidimensionale Strukturierung von Dünnschichtsystemen für sensorische Anwendungen »3dThinSens« (Talk), Öffentliche Präsentation der Wissenschaftlichen Projekte des Jahres 2010 von vdi / vde Berlin, MST-Vision, Berlin, Deutschland, 25. November 2010.

Biehl, S.: Measurement and Monitoring System for Forming Processes based on Piezoresistive Thin Film Systems (Talk), Nanosens 2010, Wien, Österreich, 2. – 3. Dezember 2010.

Boentoro, T. W.; Szyszka, B.: Mechanical characterization of hard coating on polycarbonate substrate with finite element analysis (Poster), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Boentoro, T. W.; Öngün, Y.; Szyszka, B.: Entwicklung eines Kratztestmodells für dünne Schichten auf Polycarbonat Substrat und Miteinbeziehen von Spannungsrelaxation (Talk), Deutsche SIMULIA-Konferenz, Heidelberg, Deutschland, September 2010.

Borris, J.; Thomas, M.; Lachmann, K.; Cerezuela-Barreto, M.; Klages, C.-P.: Erzeugung funktioneller Oberflächen durch plasmaunterstützte Beschichtung mittels dielektrischer Barrierenentladung (DBD-PACVD) (Talk), 6. Thüringer Grenz- und Oberflächentage, Gera, Deutschland, September 2010.

Borris, J.; Thomas, M.; Dohse, A.; Möbius, A.; Elbick, D.; Weidlich, E.-R.; Klages, C.-P.: P3T – neuartiger Ansatz zur Herstellung flexibler Elektronik im Rolle-zu-Rolle-Verfahren, 18. Neues Dresdner Kolloquium, Dresden, Deutschland, Oktober 2010.

Borris, J.; Thomas, M.; Dohse, A.; Möbius, A.; Elbick, D.; Weidlich, E.-R.; Klages, C.-P.: P3T – neuartiger Ansatz zur Herstellung flexibler Elektronik im Rolle-zu-Rolle-Verfahren (Talk), 4. Fachtagung mit Ausstellung – Transparent leitfähige Schichten (TCO) mit Grundlagen TCO (»OTTI«-Tagung), Neu-Ulm, Deutschland, November 2010.

Bräuer, G.: Innovative Oberflächen durch funktionale Beschichtung (Talk), DPG Frühjahrstagung, Regensburg, Deutschland, 22. März 2010.

Bräuer, G.: Patent Situation in HIPIMS Technology (Talk), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, 12. September 2010.

Bräuer, G.: Status der Dünnschicht-Photovoltaik in Deutschland (Talk), NMN Symposium, Celle, Deutschland, 7. Oktober 2010.

Bräuer, G.: Gepulste Plasmen für industrielle Beschichtungsprozesse – Übersicht zu den Verfahren und Anwendungen (Talk), EFDS Workshop »Gepulste hochionisierte Plasmen – von der Grundlage zur Anwendung«, Dresden, Deutschland, 24. November 2010.

Bruns, S.; Werner, O.; Bandorf, R.; Wallendorf, T.: Flexible Control for Reactive Pulsed Magnetron Sputter Process (Poster), 1st International Conference on HIPIMS, Sheffield, United Kingdom, 6. – 7. Juli 2010.

Cerezuela Barreto, M.; Borris, J.; Thomas, M.; Hänsel, R.; Stoll, M.; Klages, C.-P.: Barriereeigenschaften durch Nanobeschichtung – AD-Plasmapolymere auf PVC, 18. Neues Dresdner Vakuumtechnisches Kolloquium, Dresden, Deutschland, Oktober 2010.

Cerezuela Barreto, M.; Borris, J.; Thomas, M.; Hänsel, R.; Stoll, M.; Klages, C.-P.: Reduction of plasticizer leaching from PVC by barrier coatings deposited using DBD processes at atmospheric pressure (Poster), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Dewald, W.; Sittinger, V.; Szyszka, B.; Gordijn, A.; Hüpkes, J.; Hamelmann, F.; Stiebig, H.; Säuberlich, F.: Angular resolved light scattering of structured TCOs for the application in a-Si:H / µc-Si:H solar cells, Proceedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Dewald, W.: Light scattering and light management for a-Si:H / µc-Si:H thin film solar cells using textured TCO films, ORAMA Summer School, Analipsi / Hersonissos, Kreta, Griechenland, Oktober 2010.

Dewald, W.; Sittinger, V.; Ulrich, S.; Pflug, A.; Szyszka, B.; Schulte, M.; Hüpkes, J.; Hamelmann, F.; Stiebig, H.: Optical characterization of differently prepared doped ZnO for thin film silicon tandem solar cells (Poster), 3rd International Symposium on Transparent Conductive Materials (TCM), Analipsi / Hersonissos, Kreta, Griechenland, Oktober 2010.

Diehl, W.; Sittinger, V.; Szyszka.B.: Thin Film Photovoltaics in Germany (Talk), SVC 53th Annual Technical Conference, Orlando, FL, USA, April 2010.

Diehl,W.; Gäbler, J.; Biehl, S.; Hauschild, F.; Kaestner, P.; Thomsen, H.; Paschke, H.; Staufenbiel, S.; Weber, M.: New multifunctional coating systems for forming and cutting tools (Keynote Paper), AFRIMOLD, Johannesburg, Südafrika, August 2010.

Diehl, W.; Bandorf, R.; Bewilogua, K.; Biehl, S.; Brand, J.; Jung, T.; Keunecke, M.; Klages C. P.; Kondruweit, S.: Functional Coatings produced by Plasma Processes – Technology and Recent Applications (Plenary Paper), 11th European Vacuum Conference / 6th European Topical Conference on Hard Coatings, Salamanca, Spanien, September 2010.

Diehl, W.; Sittinger, W.; Szyszka, B.: Survey of Thin Film Solar Technologies in Germany (invited Talk), 9th Symposium of European Vacuum Coaters, Anzio, Italien, Oktober 2010.

Diehl, W.; Bandorf, R.; Bewilogua, K.; Biehl, S.; Brand, J.; Jung, T.; Klages, C. P.; Kondruweit, S.; Szyszka, B.; Thomas, M.; Vergöhl, M.; Bräuer, G.: Plasma Process Technology – State of the Art and Recent Applications (Plenary Paper), 1st Korea-Japan Symposium on Surface Technology, Incheon, Korea, November 2010.

Dietz, A.; Hochsattel, T.; Moustafa, E.: New properties of electro-deposited composite coatings with functionalized nano-container, International Conference on Functional Nanocoatings, Dresden, Deutschland, März 2010.

Dietz, A.; Hochsattel, T.; Moustafa, E.: Neue Eigenschaften von Dispersionsschichten mit funktionalisierten Nanocontainern, Galvanik-Symposium, Dresden, Deutschland, November 2010.

Eichler, M.; Michel, B.; Hennecke, P.; Gabriel, M.; Klages, C.-P.: Low-Temperature Direct Bonding of Borosilicate, Fused Silica and Functional Coatings (Talk), 218th ECS Meeting, Las Vegas, NV, USA, Oktober 2010.

Gerdes, H.; Bandorf, R.; Parker, P.; Kelly, P.; Bräuer, G.: MF-Superimposed-Reactive HIPIMS for Deposition of ZnO:Al (Poster); Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Graumann, T.; Neumann, F.: Some aspects of novel luminescent dye solid-state photocatalytic assessment method (Poster), Third International Conference on Semiconductor Photochemistry, University of Strathclyde, Glasgow, Schottland, 12. – 16. April 2010.

Graumann, T.; Neumann, F.: Measurement of photocatalytic properties of thin-films using novel solid-state luminescent dyes (Talk), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Heckmann, U.; Bandorf, R.; Petersen, M.; Gwozdz, V.; Peters, M.; Bräuer, G.: Nanocomposite thin films as sensor material for strain gauges (Talk), Twefth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Keunecke, M.; Stein, C.; Bewilogua, K.; Koelker, W.; Kassel, D.; van den Berg, H.: Modified TiAlN coatings prepared by d.c. pulsed magnetron sputtering, 37th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April 2010.

Keunecke, M.; Bialuch, I.; Bewilogua, K.; Hofmann, D.; Kunkel, S.: Silicon modified DLC coatings deposited by PACVD and PVD sputter techniques (Poster), 37th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April 2010.

Keunecke, M.; Kölker, W.; van den Berg, H.; Chudoba, T.; Hünsche, I.; Kessel, H. U.; Richter, V.; Ziegele, H.: Zerspanwerkzeuge aus nanoskaligen Materialien und superharten Schichten zur Trocken-, Hart- und Gussbearbeitung (NanoHM), 22. Industrie-Arbeitskreis »Werkzeugbeschichtungen und Schneidstoffe«, PTZ Berlin, 3. März 2010.

Klages, C.-P.; Eichler, M.; Michel, B.: Atmospheric-pressure plasma activation of silicon and glass surfaces for low-temperature direct bonding (invited Talk), AVS 57th International Symposium & Exhibition, Session Atmospheric Pressure Plasmas, Albuquerque, NM, USA, 17. – 22. Oktober 2010.

Lachmann, K.; Dohse, A.; Thomas, M.; Klages, C.-P.: Tailor-made coatings by atmospheric-pressure plasma in closed plastic bag systems (Talk), Cells meet surface, Braunschweig, Deutschland, Mai 2010.

Lachmann, K.; Dohse, A.; Thomas, M.; Pohl, S.; Meyring, W.; Dittmar, K. E. J.; Lindenmeier, W.; Klages, C.-P.: Surface modification of closed plastic bags for adherent cell cultivation (Talk), HAKONE XII: 12th International Symposium on High Pressure Low Temperature Plasma Chemistry, Trencianske Teplice, Slowakei, 12. – 17. September 2010.

Laukart, A.; Harig, T.; Höfer, M.; Schäfer, L.: Large Area Deposition of Silicon Thin Films by Hot Wire Chemical Vapor Deposition (HWCVD) (Poster), 6th International Conference on Hot-Wire Chemical Vapor Deposition (Cat-CVD) Process, Ecole Polytechnique, Palaiseau, Frankreich, 13. – 17. September 2010.

Neubert, T.; Drost, S.; Vergöhl, M.: Organische Schichten für optische Interferenzschichtsysteme, 6. Thüringer Grenz- und Oberflächentage (ThGOT), Gera, Deutschland, September 2010.

Papa, F.; Gerdes, H.; Bandorf, R.; Ehiasarian, A. P.; Bräuer, G.; Hendriks, A.; Tietema, R.; Krug, T.: The Influence of Pulse Shape and Peak Current Density on High Power Pulsed Sputtering Discharges (Poster), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Paschke, H.; Weber, M.; Kaestner, P.; Bräuer, G.: Influence of Different Plasma Nitriding Treatments on the Wear and Crack Behaviour of Forging Tools Evaluated by Rockwell Indentation and Scratch Tests (Poster), 37th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April 2010.

Paschke, H.; Weber, M.; Bräuer, G.; Bistron, M.: Boron containing coating systems for hot forming tools (Talk), 37th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, USA, April 2010.

Paschke, H.; Stueber, M.; Ziebert, C.; Bistron, M.; Mayrhofer, P.: Composition, microstructure and mechanical properties of boron containing multilayer coatings for hot forming tools (Poster), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Paschke, H.; Weber, M.: Reibarme und verschleißfeste diamantähnliche Kohlenstoffschichten (DLC) für Komponenten und Werkzeuge (Talk), DiF-Seminar »Verschleissschutz technischer Oberflächen«, Krefeld, Deutschland, Juni 2010.

Petersen, M.; Heckmann, U.; Bandorf, R.; Gwozdz, V.; Schnabel, S.; Bräuer, G.: Me-DLC Films as Material for Highly Sensitive Temperature Compensated Strain Gauges (Poster), Diamond 2010, Budapest, Ungarn, 5. – 9. September 2010.

Pflug, A.; Vergöhl, M.; Szyszka, B.: Gasentladungs-Sputtern (Talk), OTTI-Fachtagung »Schichtherstellungstechniken für die Präzisionsoptik«, Regensburg, Deutschland, 21. Januar 2010.

Pflug, A.; Siemers, M.; Schwanke, C.; Dewald, W.; Ulrich, S.; Sittinger, V.; Szyszka, B.: Simulation of the ion energy distribution function in magnetron sputtering (Talk), 3rd International Symposium on Transparent Conductive Materials (TCM), Hersonnisos, Kreta, Griechenland, Oktober 2010.

Pflug, A.; Siemers, M.; Schwanke, C.; Dewald, W.; Ulrich, S.; Sittinger, V.; Szyszka, B.; Koehl, D.; Austgen, M.: PIC-MC simulation of

magnetron discharges in Ar / O_2 gas mixtures (Talk), Reactive Sputter Symposium RSD, Gent, Belgien, Dezember 2010.

Polenzky, C.: Statusbetrachtung Multi-Komponenten-Oxide und amorphe TCOs (Talk), 4. Fachtagung mit Ausstellung – Transparent leitfähige Schichten (TCO) mit Grundlagen TCO (»OTTI«-Tagung), Neu-Ulm, Deutschland, November 2010.

Polenzky, C.; Ortner, K., Szyszka, B.: Preparation and characterization of $CuCrO_2$ (Talk), DPG Frühjahrstagung, Regensburg, Deutschland, März 2010.

Polenzky, C.; Ortner, K.; Szyszka, B.: Preparation and characterization of Cu'Me'''O_2 (Talk), Proccedings of the 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Polenzky, C.: The 4-coefficient method (Talk), ORAMA Summer School, Analipsi / Hersonissos, Kreta, Griechenland, Oktober 2010.

Polenzky, C.; Ortner K.; Szyszka B.: Preparation and characterization of p-TCOs (Talk), 3rd International Symposium on Transparent Conductive Materials (TCM), Analipsi / Hersonissos, Kreta, Griechenland, Oktober 2010.

Rademacher, D.; Richter, U.; Vergöhl, M.: In-Situ Thickness Determination of Multilayered Structures using Single Wave-length Ellipsometry and Reverse Engineering (Poster & Talk), Optical Interference Coatings (OIC), Tucson, AZ, USA, Juni 2010.

Rechberger, M.; Paschke, H.; Kühne, T.: Fangen, Abbeißen, Verschlingen: Zähne als Vorbild für selbstschärfende Industriemesser (Talk), 5. Bionik-Kongress, Hochschule Bremen, Deutschland, 22. – 23. Oktober 2010.

Schäfer, L.: Mit Diamanten Wasser reinigen – Wie geht das? Umweltchemisches Kolloquium des Instituts für Ökologische Chemie und Abfallanalytik, TU Braunschweig, Deutschland, 29. Juni 2010.

Schäfer, L.; Höfer M.; Klaaßen E.; Kramer H.-J.: The status of electrochemical water treatment and water disinfection using diamond electrodes (invited talk), 2nd Annual RETECZA Conference, Kwa Maritane Bush Lodge, Südafrika, 11. – 13. August 2010.

Schäfer, L.; Armgardt, M.; Harig, T.; Höfer, M.; Laukart, A.: Upscaling and industrialization of HWCVD processes for diamond and silicon based coatings (invited talk), 6th International Conference on Hot-Wire Chemical Vapor Deposition (Cat-CVD) Process, Ecole Polytechnique, Palaiseau, Frankreich, 13. – 17. September 2010.

Schäfer, L.; Armgardt, M.; Harig, T.; Höfer, M.; Laukart, A.: Large area diamond and silicon-based coatings by hot wire activated CVD technologies (invited talk), 5th International Symposium on Vacuum based Science and Technology SVST5, Kaiserslautern, Deutschland, 28. – 30. September 2010.

Schäfer, L.; Höfer, M.; van Geldern, M.; Otschik, J.; Schrüfer, A.: Diamantbeschichtete Gleitringdichtungen und Gleitlager für höchste Anforderungen (invited Talk), 3. Nano und Material Symposium Niedersachsen, Congress Union Celle, Deutschland, 6. – 7. Oktober 2010.

Schäfer, L.: Von der Materialforschung zum Produkt – DiaCer® Diamantbeschichtete Keramikkomponenten (invited Talk), 3. MATERIALICA Ceramics Kongress, München, Deutschland, 20. Oktober 2010.

Schnabel, S.; Kotula, S.; Ulrich, S.; Szyszka, B.: Back contact optimization for P3HT:PCBM bulk heterojunction solar cells (Poster), Internationale Konferenz mit Fachausstellung, Organische Photovoltaik, Würzburg, Deutschland, September 2010.

Schwanke, C.; Pflug, A.; Siemers, M.; Szyszka, B.: Parallel Particle-in-Cell Monte-Carlo Algorithm (Poster), PARA2010 – State of the Art in Scientific and Parallel Computing, Reykjavik, Island, Juni 2010.

Siemers, M.; Pflug, A.; Schwanke, C.; Szyszka, B.: Applied PIC-MC Simulation for Process Analysis and Development (Talk), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Sittinger, V.; Dewald, W.; Szyszka, B.: Industrialisierung der TCO-Technologie für die Dünnschichtphotovoltaik (Talk), TCO-Workshop OTTI, Neu-Ulm, Deutschland, November 2010.

Sittinger, V.; Dewald, W.; Kaiser, A.; Werner, W.; Szyszka, B.: Large area deposition and long-term stabilization of a reactive mid-frequency sputtering process of Al-doped zinc oxid films (Talk), Asia-Pacific Interfinish (APIC), Singapur, Oktober 2010.

Sittinger, V.; Horstmann, F.; Boentoro, T. W.; Werner, W.; Szyszka, B.: Heat Treatable TCO Film for Position 1 Based on HiPIMS (Talk), 1st engineered transparency, international conference on glasstec, Düsseldorf, Deutschland, September 2010.

Sittinger, V.; Werner, O.; Kühnert, B.; Szyszka, B.; Wiese, R.; Voss, N.: Development of a sensor platform for control and optimization of industrial plasma processes (Poster), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Sittinger, V.; Dewald, W.; Szyszka, B:, Säuberlich, F.; Stannowski, B.: New approach towards an optimized light trapping morphology of Al-doped ZnO films (Poster), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Sittinger, V.; Dewald, W.; Werner, W.; Szyszka, B.: Magnetron-Sputterprozesse für TCO´s: i-ZnO, AZO und ITO, Teil 1: Forschung und Entwicklung an AZO (Talk), EFDS Workshop »Transparente Leitfähige Oxide«, Dresden, Deutschland, Juni 2010.

Sittinger, V.; Diehl, W.; Szyszka, B.: Thin film PV on large area: State of the art and perspectives (Talk), DPG Frühjahrstagung der Sektion Vakuumphysik und Vakuumtechnik, Regensburg, Deutschland, März 2010.

Staufenbiel, S.: Optimierung von Produktionsprozessen durch Einsatz von Kraftsensoren in Dünnschichttechnologie am Beispiel von Stanz- und Schneideprozessen in der Blechbearbeitung (Talk), Innovative F&E- Aktivitäten der Mikrosystemtechnik (IGF-Tag), HSG-IMIT, Villingen-Schwenningen, Deutschland, 18. März, 2010.

Stein, C.; Keunecke, M.; Bewilogua, K.; Kölker, W.; van den Berg, H.: c-BN coating systems with different interlayers for cutting inserts (Talk), Twelfth International Conference on Plasma Surface Engineering (PSE), Garmisch-Partenkirchen, Deutschland, September 2010.

Szyszka, B.; Austgen, M.; Bräuer, G.; Bringmann, U.; Britze, C.; Herlitze, L.; Herwig, W.; Jung, S.; Kaiser, A.; Koehl, D.; Pflug, A.; Polle, A.; Sittinger, V.; Ulrich, S.; Vergöhl, M.; Weis, H.; Werner, W.; Wuttig, M.: Rotatable Target Serial Cosputtering – A New Core Technology for Industrial Large Area Glass Coating? (Talk), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Szyszka, B.; Sittinger, V.; Dewald, W.; Ulrich, S.; Pflug, A.; Gurram, S. K.; Polenzky, C.: Large area in-line magnetron sputtering of TCOs (invited Talk), 3rd International Symposium on TCOs, Kreta, Griechenland, Oktober 2010.

Szyszka, B.; Sittinger, V.; Dewald, W.; Ulrich, S.; Pflug, A.; Gurram, S. K.; Polenzky, C.: Magnetron sputtering of TCO films – an overview on the state of the art & recent results, 1st Orama Summer School, Kreta, Griechenland, Oktober 2010.

Szyszka, B.; Sittinger, V.; Ulrich, S.; Pflug, A.; Schäfer, L.; Höfer, M.: Dünnschichtphotovoltaik auf Glas, Glass Technology Live, glasstec, Düsseldorf, Deutschland, 1. Oktober 2010.

Szyszka, B.; Ulrich, S.; Polenzky, C.; Löbmann, P.; Götzendörfer, S.; Elsässer, C.; Körner, W.: The Challenge of Oxide Electronics – An Overview on Materials, Processes & Applications (invited Talk), SVST-5, Kaiserslautern, Deutschland, September 2010.

Szyszka, B.; Polenzky, C.; Löbmann, P.; Götzendörfer, S.; Elsässer, C.; Körner, W.: Pathways towards p-type oxide layers for optoelectronic applications (invited Talk), CIMTEC 2010, Montecatini Terme, Italien, Juni 2010.

Szyszka, B.; Bewilogua, K.; Brand, J.; Bräuer, G.; Dietz, A.; Diehl, W.; Gäbler, J.; Klages, C.-P.; Schäfer, L.; Vergöhl, M.; Willich, P.: Industrial thin film processes – Key technologies for cost effective light weight construction, ACMA Workshop Light Weight Construction, Neu-Delhi, Indien, März 2010.

Szyszka, B.; Ulrich, S.; Polenzky, C.; Löbmann, P.; Götzendörfer, S.; Elsässer, C.; Körner, W.: The Challenge of Oxide Electronics – An Overview on Materials, Processes & Applications, (invited Talk), 2nd International Workshop on Vacuum Electronics, Physikzentrum Bad Honnef, Deutschland, November 2010.

Szyszka, B.; Sittinger, V.; Ulrich, S.; Pflug, A.; Dewald, W.; Polenzky, C.: Übersicht über die Einsatzgebiete und Anwendungen von TCOs, 4. Fachtagung mit Ausstellung – Transparent leitfähige Schichten (TCO) mit Grundlagen TCO (»OTTI«-Tagung), Neu-Ulm, Deutschland, November 2010.

Szyszka, B.; Polenzky, C.; Löbmann, P.; Götzendörfer, S.; Elsässer, C.; Körner, W.: Oxidische Elektronik – ein neues Wachstumsgebiet für die Informations- und Kommunikationsbranche, 4. Fachtagung mit Ausstellung – Transparent leitfähige Schichten (TCO) mit Grundlagen TCO (»OTTI«-Tagung), Neu-Ulm, Deutschland, November 2010.

Szyszka, B.; Sittinger, V.; Ulrich, S.; Pflug, A.; Schäfer, L.; Höfer, M.: Dünnschichtphotovoltaik auf Glas, OTTI-Fachforum »Schichten auf Glas«, Regensburg, Deutschland, Mai 2010.

Szyszka, B.; Polenzky, C.; Loebmann, P.; Göetzendörfer, S.; Elsässer, C.; Körner, W.: Pathways towards p-type oxide layers for optoelectronic applications (Talk), Proceedings of the CIMTEC 2010 – 5th Forum on New Materials, Montecatini Terme, Italien, Juni 2010.

Thomas, M.: Erzeugung reaktiver Gruppen auf Oberflächen durch Funktionalisierung oder Beschichtung mittels DBD (Talk), Haftungsverbesserung durch Oberflächenfunktionalisierung mittels Atmosphärendruckplasma, 5. Workshop des AK-ADP, Potsdam, Deutschland, 9. – 10. Juni 2010.

Thomas, M.; Borris, J.; Klages, C.-P.: Micropatterning using atmospheric pressure plasma processes (Poster), Advanced Coatings for Large-Area or High-Volume Products, 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Thomas, M.; Hinze, A.; Klages, C.-P.: Optimierung von DBD-Plasmaquellen durch grundlegende Untersuchungen der Plasmaunterstützten CVD-Abscheidung (Talk), Gasmanagement für Atmosphärendruck-Plasmatechnologien, EFDS-Workshop, Dresden, Deutschland, 15. April 2010.

Thomas, M.; Borris, J.; Dohse, A.; Weidlich, E.-R.; Elbick, D.; Klages, C.-P.: Plasma-Printing: Strukturierte Oberflächenfunktionalisierung und selektive nasschemische Metallisierung, 32. Ulmer Gespräch, Neu-Ulm, Deutschland, 29. – 30. April 2010.

Vergöhl, M.; Rademacher, D.; Fritz, B.: Particle generation during reactive magnetron sputtering of SiO_2 with cylindrical and planar cathodes (Poster & Talk), Optical Interference Coatings (OIC), Tucson, AT, USA, Juni 2010.

Vergöhl, M.; Rademacher, D.; Fritz, B.: Particle generation during reactive magnetron sputtering of SiO_2 with cylindrical and planar cathodes (Poster), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Vergöhl, M.; Rademacher, D.; Richter U.: In-Situ Thickness Determination of Multilayered Structures using Single Wavelength Ellipsometry (Talk), 3rd NanoCharm Workshop, Berlin, Deutschland, Oktober 2010.

Vergöhl, M.; Althues, H.; Frach, P.; Glöß, D.; Graumann, T.; Hübner, C.; Neumann, F.; Neubert, T.; Schottner, G.; Song, D. K.: Measurement of the photocatalytic activity of TiO_2 films deposited by different methods (Talk), 8th International Conference on Coatings on Glass and Plastics (ICCG), Braunschweig, Deutschland, Juni 2010.

Weber, M.; Demir, M.: Praxistaugliche Prozessschmierung für das Presshärten (Talk), 7. Forum Tribologische Entwicklungen in der Blechumformung, Darmstadt, Deutschland, 11. November 2010.

Weber, M.: Entwicklung technologischer Grundlagen für die Umformung von Titanlegierungen (Talk), Fraunhofer Symposium »Netzwert«, München, Deutschland, 7. – 8. Dezember 2010.

Weiss, P.; Dietz, A.; Ladwein, T.: Galvanische Abscheidung von Aluminium aus ionischen Flüssigkeiten, Oberflächentage des ZVO, Berlin, Deutschland, September 2010.

DISSERTATIONS

Eigenbrod, V. J.: Superhydrophobe Oberflächen mit Fluorpolymeren in hierarchischen Strukturen. Stuttgart: Fraunhofer-IRB-Verl., 2010 (Berichte aus Forschung und Entwicklung, 31). Zugl.: Braunschweig, Techn. Univ., Diss., 2010.

Weinhold, R.: Herstellung und Charakterisierung ternärer Zink-Legierungsüberzüge auf Stahlfeinblech. Aachen: Shaker, 2010. Zugl.: Braunschweig, Techn. Univ., Diss., 2010.

DIPLOMA THESIS

de Vries, M.: Herstellung und Charakterisierung von transparenten Siliziumnitridschichten mittels High Power Impulse Magnetron Sputtering, Fachhochschule Südwestfalen, September 2010.

Drost, S.: Binäre Metall-Mischschichten für Elektroden von organischen Solarzellen, Ostfalia Hochschule für angewandte Wissenschaften, Wolfenbüttel, März 2010.

Kodlubaj, K.: Charakterisierung des Ionenstroms und des Ionenanteils in hochionisierten Plasmen, Hochschule für angewandte Wissenschaft und Kunst Göttingen, Mai 2010.

Schmalz, M.: Konstruktion und Optimierung eines 8" Hochtemperatursubstratheizers, Ostfalia Hochschule für angewandte Wissenschaften, Wolfenbüttel, Dezember 2010.

Schnabel, S.: Evaluation von mittels Gasflusssputtern hergestellten Titanoxid-Schichten für den Einsatz in der organischen Photovoltaik, Technische Universität Braunschweig, Juni 2010.

Scholtalbers, M.: Ionisierte Abscheidung von M-A-X-Schichten mittels Hochleistungsimpuls-Magnetronsputtern, Jade Hochschule, Wilhelmshaven, November 2010.

MASTER'S THESIS

Gwozdz, V.: Me-C:H als sensorische Schicht für Dehnungsmessstreifen, Goethe Universität, Frankfurt am Main, November 2010.

BACHELOR'S THESIS

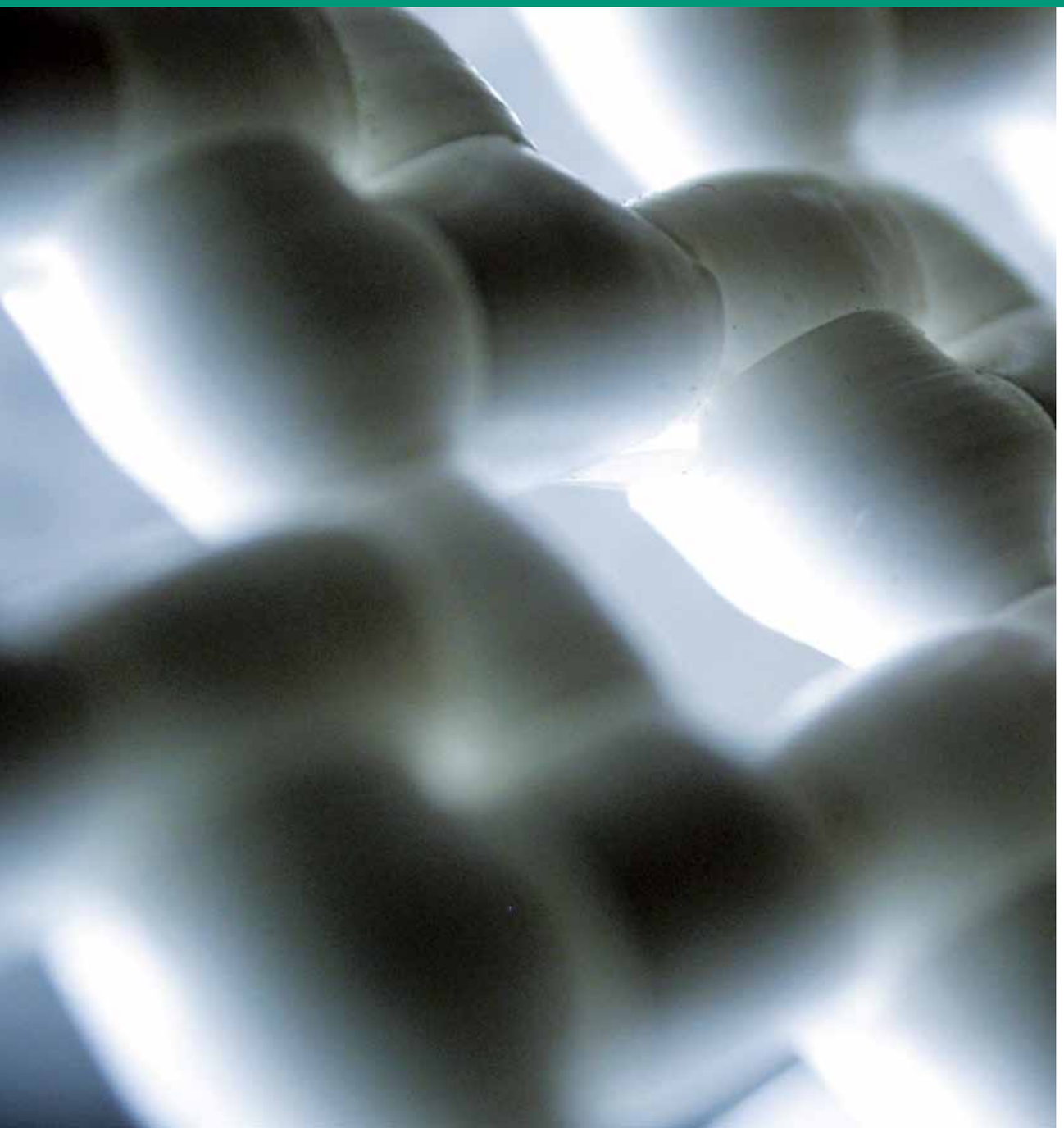
Baumer, M.: Bauteilgerechte TiN-Prozessentwicklung als Basis für borbasierte Schichtsysteme (Bachelor-Arbeit), Fachhochschule Dortmund, März 2010.

Ben Abdallah, S.: Untersuchungen zur lokalen Behandlung von Siliziumwafern, Fachhochschule Hannover, Juli 2010.

Hanke, C.: Konstruktion und Inbetriebnahme eines Versuchsstandes zur Plasmabehandlung und -beschichtung (Bachelor-Arbeit), Fachhochschule Magdeburg Stendal, April 2010.

Klaaßen, E.: Ozongenerator – Elektrolytische Erzeugung von Ozon, Ostfalia Hochschule für angewandte Wissenschaften, Wolfenbüttel, März 2010.

Peters, M.: Herstellung und Charakterisierung von Cu-DLC für den Einsatz in Dehnungsmessstreifen, Helmut Schmidt Universität Hamburg, Dezember 2010.



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 60 Fraunhofer Institutes. The majority of the more than 18,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.65 billion. Of this sum, more than €1.40 billion is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

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

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

INPLAS: Network of Competence for Industrial Plasma Surface Technology e. V.

Network of Competence for Industrial Plasma Surface Technology e. V. has its offices at the Fraunhofer IST. INPLAS has been accredited as a competence network by the Federal Ministry of Economics and Technology (BMWi) and counts as one of the hundred best networks in Germany. INPLAS currently has 33 members of whom 70 percent come from industry. INPLAS was a winner at the Cannes Corporate Media & TV Awards in 2010.

In 2010 as well, in its numerous successful activities, INPLAS once again contributed to further consolidation of plasma technology and to raising its profile. The most important areas of work of the network are presented below.

Development and conceptual design of new topics for research

Findings have been successfully communicated to all member organizations of Plasma Germany and now flow into the following processes:

- BMBF invitation to tender »Innovative applications in plasma technology« as part of the »Optical technologies« funding program of June 2010.
- »Photonics 2020« strategy process

Cooperation with ViaMéca, the French mechanical engineering network

With support of the Federal Ministry of Economics and Technology (BMWi) and the Initiative Kompetenznetze Deutschland a cooperation agreement for close collaboration between the two networks in the fields of research, training and public relations was signed at the Hannover Messe 2010.

Public relations

In 2010 INPLAS was once again actively involved in various events and conferences:

- Technical conferences including the ICCG in Braunschweig and the HIPIMS conference in Sheffield.
- INPLAS joint stand at the Plasma Surface Engineering (PSE) international conference in Garmisch-Partenkirchen.
- »Plasma Rally« in PSE exhibition, designed and realized by INPLAS for Plasma Germany.

Active work of the working groups

The joint committee ‚Combination Coatings' was founded by DGO (Deutsche Gesellschaft für Galvano- und Oberflächentechnik) and INPLAS at Fraunhofer IST in September 2010. The aim is to bundle competencies in this field and utilize them more intensely. The working group »New plasma sources and processes« chaired by Dr. Bernhard Cord of Singulus Technologies AG met regarding the topic of »Plasma diagnostics and control technology« while the »Tooling« working group chaired by Dr. Jan Gäbler of Fraunhofer IST examined »New markets and test procedures«.

Major award for a short film

The INPLAS information film »Plasma – a bright advantage« won the Silver Dolphin prize at the Cannes Corporate Media & TV Awards in the face of strong competition from a field of 350 entrants from 27 countries.

1 INPLAS joint stand at the 2010 Plasma Surface Engineering (PSE) conference in Garmisch-Partenkirchen.
2 Participants in the founding meeting of the joint committee ‚Combination Coatings' of DGO and INPLAS.
3 Cannes Corporate Media & TV Awards: Carola Brand and Jochen Meusel receive the »Silver Dolphin« for the information film ‚Plasma - a bright advantage'.

CONTACT

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

Network coordinator
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

European Technology Platform for Micro- and NanoManufacturing (MINAM)
www.minamwebportal.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)
www.microcompany.de

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

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

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

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

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

PhotonicNet GmbH – Kompetenznetz Optische Technologien
www.photonicnet.de

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
Fraunhofer IST scientists are able to apply a metall coating on carbon-fiber reinforced plastic antennas for the ESA »Sentinel-Mission«. Picture: Reiner Meier, BFF Wittmar

S. 2: Falko Oldenburg, Fraunhofer IST
S. 3; 1: Jan Benz, Fraunhofer IST
S. 6; 1: Jan Benz, Fraunhofer IST
S. 6; 2: Myriam Schaller, Fraunhofer IST
S. 7; 3: Jan Benz, Fraunhofer IST
S. 8; 1: Dirk Mahler
S. 10; 1: Elena Dröge
S. 11; 2: EagleBurgmann Germany
S. 12: Jan Benz, Fraunhofer IST
S. 14: Jan Benz, Fraunhofer IST
S. 16: Reiner Meier, BFF Wittmar
S. 20: Jan Benz, Fraunhofer IST
S. 21: Dr. Kirsten Ingolf Schiffmann, Fraunhofer IST
S. 22: Jan Benz, Fraunhofer IST
S. 24: Reiner Meier, BFF Wittmar
S. 26; 1: Matthias Römer, GfG / Gruppe für Gestaltung GmbH
S. 28; 1: Jochen Borris, Fraunhofer IST
S. 28; 2: Falko Oldenburg, Fraunhofer IST
S. 30; 1: Falko Oldenburg, Fraunhofer IST
S. 32: Reiner Meier, BFF Wittmar
S. 34; 1: DLR: Institut für Flugsystemtechnik
S. 35; 2: DLR: Institut für Flugsystemtechnik
S. 36; 1: Dr. Kai Ortner , Fraunhofer IST
S. 36; 2: Dr. Kai Ortner , Fraunhofer IST
S. 37; 3: Dr. Kai Ortner , Fraunhofer IST
S. 38: Reiner Meier, BFF Wittmar
S. 40; 1: Hanno Paschke, IST / DOC
S. 40; 2: Marcus Rechberger, UMSICHT
S. 41; 3: Marcus Rechberger, UMSICHT
S. 42; 1: Hanno Paschke, IST / DOC
S. 43; 2: Jan Benz, Fraunhofer IST
S. 44; 1: Martin Weber, Fraunhofer IST
S. 44; 2: Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
S. 45; 3: Matthias Demmler, Fraunhofer IWU
S. 45; 4: Matthias Demmler, Fraunhofer IWU
S. 46; 1–2: Martin Weber, Fraunhofer IST
S. 47; 3–4: Martin Weber, Fraunhofer IST
S. 48; 1: Manuela Lingnau, Fraunhofer WKI
S. 48; 2: Sebastian Staufenbiel, Fraunhofer IST
S. 49; 3: Sebastian Staufenbiel, Fraunhofer IST
S. 50; 1: Manuela Lingnau
S. 51; 2: Manuela Lingnau
S. 52; 1: Tino Harig, Fraunhofer IST
S. 54: Reiner Meier, BFF Wittmar
S. 56; 1: Reiner Meier, BFF Wittmar
S. 58; 1: Reiner Meier, BFF Wittmar
S. 58; 2: Artur Laukart, Fraunhofer IST
S. 60; 1: Falko Oldenburg, Fraunhofer IST
S. 60; 2: Dr. Volker Sittinger, Fraunhofer IST
S. 61; 3: Jan Benz, Fraunhofer IST
S. 62; 1: Jan Benz, Fraunhofer IST
S. 62; 2: Oliver Werner , Fraunhofer IST
S. 64: Falko Oldenburg, Fraunhofer IST
S. 66; 1–4: Michael Scholtalbers, Fraunhofer IST
S. 67; 5: Michael Scholtalbers, Fraunhofer IST
S. 68; 1: Hans-Ulrich Kricheldorf, Fraunhofer IST
S. 69; 2: Hans-Ulrich Kricheldorf, Fraunhofer IST
S. 70; 2: Jan Benz, Fraunhofer IST
S. 72; 1: Krees Nagel, Fraunhofer IST
S. 72; 2: Krees Nagel, Fraunhofer IST
S. 74: Falko Oldenburg, Fraunhofer IST
S. 76; 1: Dr. Stefan Fischer, Jannis Fatouros, MRC Systems GmbH
S. 76; 2: Sartorius AG
S. 78; 1: Torsten Baranski, Fraunhofer IST
S. 78; 2: Kristina Lachmann, Fraunhofer IST
S. 79; 3: Torsten Baranski, Fraunhofer IST
S. 79; 4: Kristina Lachmann, Fraunhofer IST
S. 80; 1: M3i Technologies
S. 80; 2: Manuela Lingnau, Fraunhofer WKI
S. 82: Dr. Kirsten Ingolf Schiffmann, Fraunhofer IST
S. 84; 1: Falko Oldenburg, Fraunhofer IST
S. 86; 1: Jan Benz, Fraunhofer IST
S. 86; 2: Jan Benz, Fraunhofer IST
S. 88; 1–2: Christoph Schwanke, Fraunhofer IST
S. 89; 3: Christoph Schwanke, Fraunhofer IST
S. 90; 1–2: Andreas Pflug, Fraunhofer IST
S. 92: Jan Benz, Fraunhofer IST
S. 94; 1: Antje Dohse, Fraunhofer IST
S. 95: Anika Heddergott, Fraunhofer IST
S. 96; 1: Myriam Schaller, Fraunhofer IST
S. 96; 2: Myriam Schaller, Fraunhofer IST
S. 98: Saskia Biehl, Fraunhofer IST
S. 100; 1: Myriam Schaller
S. 100; 2: Elena Dröge
S. 116: Mandalla, photocase.com
S. 120; 1–4: Fraunhofer-Verbund Light&Surfaces
S. 121; 5: Reiner Meier, BFF Wittmar
S. 122; 1–2: Sandra Palm, INPLAS/Fraunhofer IST, Braunschweig
S. 123; 3: Petra Bögge-Dörfler, INPLAS/nemo kommunikation & design

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