Fraunhofer Institut Werkstoff- und Strahltechnik

Annual Report 2005

Internet: www.iws.fraunhofer.de

Fraunhofer Institut Werkstoff- und Strahltechnik

Annual Report 2005

CERTIFICATE

DIN EN ISO 9001:2000

hereby certifies that the company

Fraunhofer Institut Werkstoff- und Strahltechnik

business field:
X-Ray and EUV Optics, PVD Thin Film Technology, CVD Thin Film Technology, Thermal Coating, Joining & Surface Treatment, Ablation and Cutting

location:
Winterbergstr. 28 * D-01277 Dresden

has implemented and effectively applies a quality management system according to the standard (12/2000) mentioned above. The conformity was inspected during the certification audit documented in audit report no. A0307203. This certificate is only valid in connection with the successful performance of the surveillance audits.

Date of the first certification:	30.12.1997	Date of the last recertification:	29.10.2003
This certificate is valid until:	28.10.2006	Certificate-registration no.:	91297819/3 duplicate

Accredited by TGA of the German Accreditation Council

Reg.Nr.: TGA-ZM-05-91-00

Prologue

Editor: During 2004 the new part of the IWS building was finished. Your hope was that the new building would significantly improve the working conditions and allow for future growth. Have expectations been met in 2005?

Prof. Beyer: Absolutely. Meanwhile the remainder of the new laboratories has been commissioned. After a break of 18 months we were able to reopen our spraying technology laboratory in the middle of 2005. During the fall of 2005 we were able to finish our VR laboratory. Now we are fully back in operation to move reenergized into the next year.

Editor: Very good working conditions and new laboratories do not necessarily lead to a balanced budget and into an economic boom, however. Outside factors are considerably contributing to the situation. What is the current economic situation of the IWS?

Prof. Beyer: The availability of public funding in 2005 was even less than in 2004. As a consequence our public revenues dropped significantly and were mainly carried through EC projects. This development was anticipated however, and we already began in early January 2005 to reduce costs. As a result we were able to break even in 2005.

Editor: The performance of a Fraunhofer Institute is always measured based on successes in commercializing research results. Are there any highlights in 2005 that make you especially proud?

Prof. Beyer: But of course. Technologies that have been transferred to industrial manufacturing include four developments in the area of laser hardening, a hybrid process for coating and hardening, as well as a process for laser welding with filler material. We are especially proud of the development of a measurement system to monitor exhaust gases for the process control of a CVD system. The system was deployed in a manufacturing plant of a major company in the microelectronics industry.

Editor: Since the end of November laser experts are talking about IWS. Your fiber laser workshop seems to have stimulated the fiber laser discussion all over Europe. Do you see yourself in a pioneering role in this area?

Prof. Beyer: I believe that the development of fiber lasers led to a quantum leap in laser materials processing. And of course, it makes the researcher's heart happy to enter unknown research territory and to seize the opportunity to participate and even lead in newest development trends. Our colleagues from the Fraunhofer Surface Technology and Photonics Alliance VOP as well as my employees share this feeling with me. In any case, the fiber laser and all its potential applications will have a lasting effect on our institute.

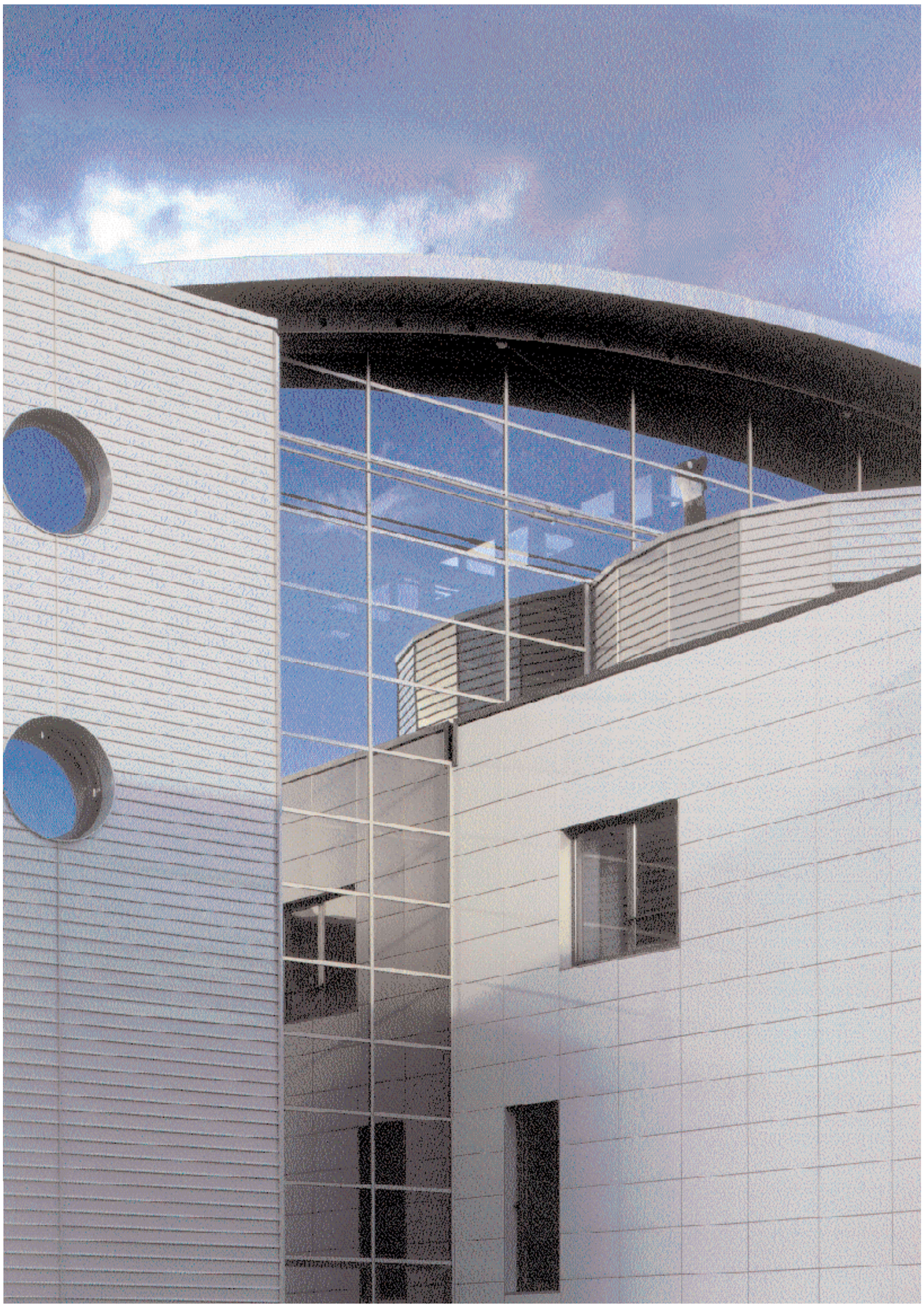
Editor: That sounds almost like a starting signal to race forward into the next year.

Prof. Beyer: Exactly, because it will be an exciting year that we start in full optimism.

Editor: Thank you very much for the interview.

Tolle, Lege! Tolle, Lege!

Take Up and Read!
Augustinus



Fraunhofer-Institut für
Werkstoff- und Strahltechnik IWS

Fraunhofer Institute for
Material and Beam Technology IWS

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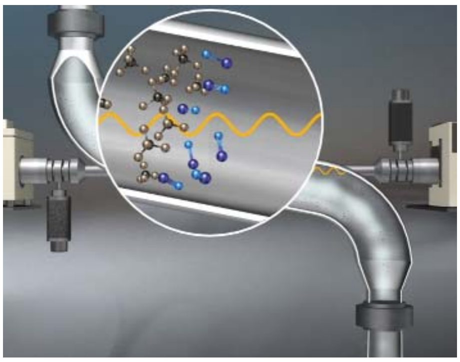
Contents

Federal Minister Bulmahn visited DOC

»We think beyond steel.« That was the slogan of Dr. Michael Steinhorst who greeted the guest from Berlin on July 14th 2005. Mrs. Bulmahn selected the DOC as one of her stops during the innovations tour in the current Einstein year. The IWS operates a laboratory at the Dortmunder OberflächenCentrum of the ThyssenKrupp Stahl AG. Executive director Steinhorst presented steel as a high-tech product. Due to numerous possibilities in alloying steel the material offers opportunities like no other material.

Federal Minister for Research Edelgard Bulmahn during a discussion with employees of the Fraunhofer IWS project group at the Dortmunder OberflächenCentrum (DOC)



Function principle of the in-situ multi-gas sensor ISPROM® for the continuous monitoring of process relevant gases, which has been transferred to industry

Visitors at the Fraunhofer workshop on fiber lasers at IWS

1st international workshop »Fiber Laser«

The first Fraunhofer workshop »Fiber Laser« was held at IWS on November 22nd 2005. In the recent past fiber lasers have been primarily used in the area of telecommunications. However, the multi-kilowatt systems that are meanwhile available enable materials processing. The new possibilities have been demonstrated to the 180 participants at the workshop.

ISPROM® - in-situ process sensor monitors 300 mm wafer production at the Infineon plant in Dresden

Quality and costs of wafer manufacturing depend on optimal process conditions. In many production steps these conditions correlate directly with the composition of the process gas mixture. In cooperation with the company SEMPA Systems Fraunhofer IWS researchers developed an in-situ multi-gas sensor (ISPROM®) based on infrared Fourier transformation spectroscopy (FTIR). The sensor has been successfully field tested in a 300 mm wafer production tool (CVD TEOS/O_3 process) at the Infineon plant in Dresden.

Saxonian-British nanotechnology forum in London

On October 3rd more than 100 guests from Saxony and Great Britain met at the Saxon-British nanotechnology forum in London. This meeting represented the major event of the project initiative »D Saxony UK 2005«, which was initiated to introduce the Free State of Saxony to the British public as a cultural, science, and economic region. The speech of Minister President Georg Milbradt opened the event.

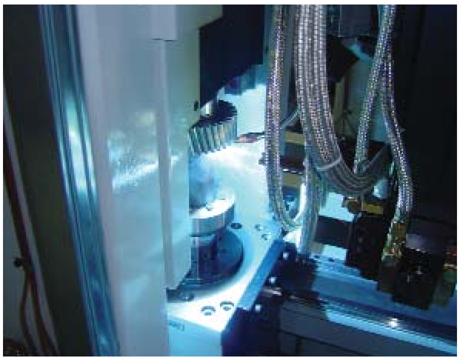
Minister President Georg Milbradt at the opening ceremony of the Saxon-British nanotechnology forum, organized by the Fraunhofer IWS

The Fraunhofer IWS in cooperation with the nanotechnology competence center »Ultrathin Functional Films« organized the event for the Saxony State Ministry for Economy and Labor.

Laser beam welding - IWS process developments for industrial manufacturing

System for a laser welding process with filler material at ZF Gotha (System integrator Arnold, process development by IWS)

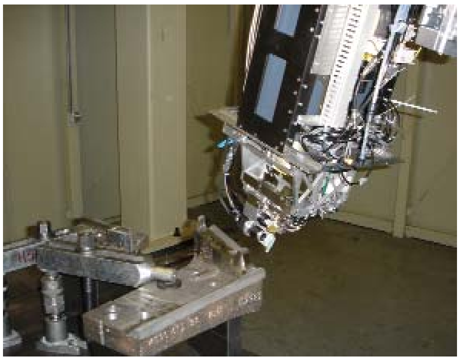
Laser beam welding processes to join components have been transferred to production at the ZF Achsgetriebe GmbH in Gotha (September 2005) and the Winkelmann-Palsis Motorgetriebe GmbH in Ahlen (October 2005). At the ZF Gotha facility the process is used to weld two components (differential and hollow shaft). To control the quality we integrated for the second time a plasma spectroscopic monitoring system as well as a laser cleaning process.



IWS laser welding process with filler material

Laser beam hardening - IWS process development for industrial manufacturing

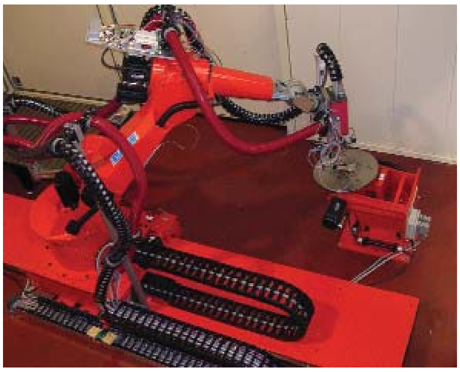
Within the BMBF project »Integrated Hardening« the Fraunhofer IWS developed a laser-hardening gantry for large tools. During the summer of 2005 the system was deployed at the BWM Fahrzeugtechnik GmbH in Eisenach. This system provides a timely and cost efficient way to harden tools after cutting processes.



IWS process development: laser hardening gantry at BMW Eisenach

Robot for the laser hardening and laser deposition welding

A joint effort between the ALOtec Dresden GmbH and the Fraunhofer IWS led to the implementation of a robot system at the Swiss hardening shop Gerster AG in Egerkingen. The robot provides laser deposition welding capability as well as the ability to perform temperature controlled hardening processes. The system is equipped with the following modules from the IWS lasertronic® family: lasertronic® LompocPro for laser power control, E-MaqS pyrometer for temperature data collection and DCAM for off-line programming.



Process and system development at IWS: robot for the laser hardening and laser deposition welding for the hardening shop Gerster AG (Switzerland)

Our goal:

To custom solve problems! Our customer's problems are only solved if the customer is making money with the solution. This is what we are working on.

Keine Begeisterung sollte größer sein als die nüchterne Leidenschaft zur praktischen Vernunft.

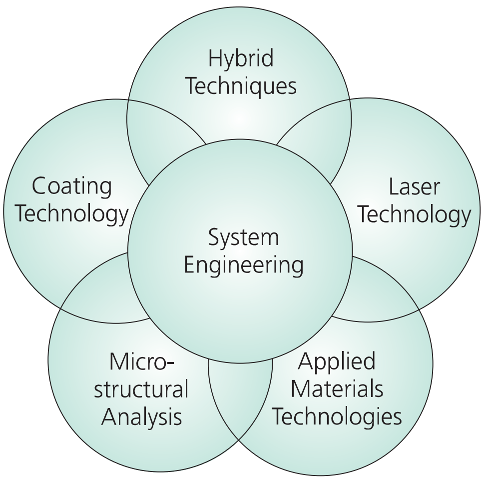
No enthusiasm should be larger than the sober passion for practical reason.

Helmut Schmidt

Overview

The Fraunhofer Institute for Material and Beam Technology conducts application-oriented research and development in the areas of laser and surface technology.

Key points are:
- laser beam welding, cutting and ablation,
- surface treatment as well as
- the deposition of thin films.



The main working areas of IWS, which enable us to provide you with one-stop solutions

A special feature of the IWS is the experience in beam and coating technologies in combination with a profound know-how in materials and comprehensive capabilities of material characterization. In order to offer optimized solutions for industrial production, we exploit the option of coupling beam technologies with other power sources. This leads to so-called *hybrid technologies*, which combine advantages of laser techniques with special features of other techniques in a cost-effective manner.

Through the close collaboration with system suppliers and equipment manufacturers, we are able to offer our customers *one-stop solutions* based on novel concepts. As a basis for this, the working system, the process, and the component performance must all be taken into overall consideration. The excellent facility at IWS enables us to respond to customer's requests with state of the art equipment. Furthermore, we are capable of running pilot production and testing, in house.

Laser technology

- laser welding and soldering
- laser hardening, re-melting and cladding
- laser surface modification with additional materials (alloying and dis-perging)
- repair coatings
- rapid prototyping
- laser cutting and parting
- laser cleaning and ablation (for restoration and technical purposes)
- laser finishing
- microstructuring, engraving and marking

Thin film technology

- thin film technology on the basis of laser, vacuum arc, CVD, sputtering and electron beam processes
- film systems and processes for hard coatings with carbides, nitrides, oxides, etc.
- super hard amorphous carbon films
- nanometer multilayer films for X-ray optical components
- atmospheric pressure plasma-assisted CVD
- plasma spraying

Hybrid processes

- induction assisted laser welding of heat treatable steels
- plasma augmented laser processing (welding, re-melting)
- laser assisted plasma spraying
- thin film deposition through combined laser, vacuum arc, electron beam and CVD processes
- modeling of short time heat treatment processes

Materials testing

- characterization of laser irradiated materials and components
- wear and fatigue tests
- mechanical, tribological and optical film properties
- thermal shock resistance and temperature stability of ceramics
- failure analysis

Structure analysis

- metallographical material characterization
- structure analysis with electronmicroscopy (REM, TEM)
- characterization of surface properties with optical spectroscopy

System technology

- development of system components such as high speed beam scanners, flexible laser beam shaping units and welding monitors
- optimization of laser machining systems
- process diagnostic of PVD and CVD processes
- coating modules for atmospheric pressure plasma CVD and PVD processes

Our offer

We offer one-stop solutions in:

- consulting
- feasibility studies
- contract research and development
- process testing
- system development jointly with industrial partners
- design and implementation of pilot systems
- material and component testing
- failure analysis
- training of scientists, engineers, operators and laboratory assistants

Contacts

The Fraunhofer IWS offers you service and contract work and guarantees strict confidentiality upon request.

Business fields	Core services: Laser processing tech.	Coating processes	Materials tech. / analysis	Simulation	System technologies
joining					
welding	■		■	■	■
soldering	■		■		
adhesive bonding		■	■		
cutting	■				■
surface technology					
removal / cleaning	■		■	■	■
wear protection	■	■	■	■	■
repairs	■				■
friction reduction		■	■		■
oxidation protection	■	■	■		■
functional coatings		■	■		■
microtechnology	■	■	■		■
optics					
X-ray optics, EUV optics		■	■	■	■
IR optics			■	■	
rapid prototyping, rapid tooling	■		■		■
process monitoring	■	■			■

Internet: www.iws.fraunhofer.de

Organization and contacts

External Project Groups

CCL - USA
Prof. Asmussen
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Laser Applications
Mr. Stiles
Coating Technology
Dr. Schülke

DOC
Dr. Zwick
phone: +49 (0) 231-844-3512

Executive Director Prof. Dr. Beyer

Deputy Director Dr. Leson
Assistant Mrs. Weinberg
phone: +49 (0) 351-2583 ext. 420

Infrastructure

Administration
Dr. Wilhelm
ext.: 312

Marketing
Dr. Krautz
ext.: 332
Communication
Dr. Jäckel, ext.: 444
Media Technology
Dr. Völlmar, ext.: 434

Surface Engineering and Coatings

X-Ray and EUV-Optics
Dr. Leson
ext.: 317

- **Coating** – Dr. Braun, ext.: 432
- **Nanotechnology Center of Competence** – Dr. Leson, ext.: 317

PVD Thin Film Technology
Prof. Schultrich
ext.: 403

- **Carbon Coatings** – Prof. Schultrich, ext.: 403
- **PVD Coatings** – Dr. Zimmer, ext.: 257

CVD Thin Film Technology
Dr. Hopfe
ext.: 402

- **Atmospheric and in-line CVD** – Dr. Dani, ext.: 405
- **Process Monitoring** – Dr. Grählert, ext.: 406

Thermal Coating
Dr. Nowotny
ext.: 241

- **Thermal Spraying** – Dr. Berger, ext.: 330
- **Cladding** – Dr. Techel, ext.: 255

Laser Materials Processing

Joining and Surface Treatment
Prof. Brenner
ext.: 207

- **Welding** – Dr. Standfuß, ext.: 212
- **Bonding** – Dr. Jansen, phone: +49 (0) 351-463-35210
- **Surface Treatment** – Dr. Bonß, ext.: 201
- **Materials Testing/Characterization** – Dr. Winderlich, ext.: 224

Ablation and Cutting
Dr. Morgenthal
ext.: 322

- **Laser Cutting** – Dr. Morgenthal, ext.: 322
- **Microprocessing/Cleaning** – Mr. Klotzbach, ext.: 252

System Engineering and Laser Processing
Dr. Morgenthal / Dr. Pollack, ext.: 322 / 239

- **Nanotechnology** – Dr. Leson, ext.: 317
- **Simulation** – Dr. Lange, ext.: 328; Dr. Mahrle, ext.: 407
- **Diode Laser** – Dr. Bonß, ext.: 201
- **Rapid Prototyping / Tooling** – Dr. Techel, ext.: 255
- **Production Technology** – Prof. Günther, phone: +49 (0) 351-463-33343

TECHNISCHE UNIVERSITÄT DRESDEN

Lehrstuhl Laser- und Oberflächentechnik LOT

Chair for Laser and Surface Technology
Prof. Dr. Beyer
Deputy Prof. Dr. Günther
Assistant Mrs. Petermann
phone: +49 (0) 351-463-31993

Guest companies located at Fraunhofer IWS:

- EFD Induction GmbH Freiburg, Dresden Branch
- ALOtec Applied Laser and Surface System Technology GmbH Dresden
- AXO Dresden GmbH
- Arc Precision Dresden GmbH

Connection to the University of Technology (TU Dresden)

Chair for Laser and Surface Technology

During 2005, 33 colleagues were employed in the university department. The third party revenues yielded more than 1.0 million €.

The department of laser and surface technology is the driving component of the institute for surface technology and production metrology at the faculty of mechanical engineering. The performed projects are more basically oriented and are intended complementaryly to the work of the IWS. The teams deal with following subjects:

- production design
- laser technology
- surface technology
- film technology
- adhesive bonding
- ablation technology

The following courses were offered:
- Prof. Beyer: Manufacturing technology II
- Prof. Beyer: Laser basics / laser system technology
- Prof. Beyer: Plasmas in the production technology
- Prof. Beyer, Mr. Kötter: Rapid protocoating
- Dr. Leson, Prof. Beyer: Surface engineering / nanotechnology
- Prof. Schultrich: Thin film technology

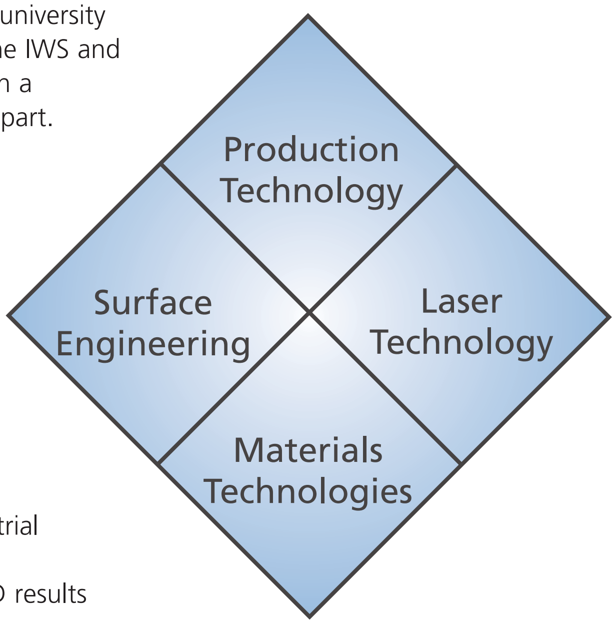
Cooperation Fraunhofer IWS - TU Dresden

A special agreement regulates the cooperation between the IWS and the TU Dresden. Prof. Beyer works simultaneously as the executive director of the IWS as well as a chairman at the University. The work is distributed as follows: Research and education are performed at the university and applied research and development are performed at the IWS. IWS employees are tied into projects at the university and vice versa. In the end the IWS and university form one unit with a different emphasis for each part.

The advantages for IWS are:
- cost effective basic research
- education of junior scientists for the IWS
- access to scientific helpers

The advantages for the TU are:
- R&D involvement in industrial projects
- integration of newest R&D results into education
- training of students on the most modern equipment

Learning is like rowing against the current - if you stop, you'll start to drift.
Benjamin Britten



Lehrstuhl
Laser- und Oberflächentechnik LOT

CD for manufacturing technology course (II)

CD for laser technology course

Centers and external project groups

Il est bien plus beau
de savoir quelque chose de tout
que de savoir tout d'une chose.

It is much nicer
to know a little about everything
than knowing everything
about just one thing.
Blaise Pascal

Joint booth of the German competence centers at the Nanofair 2005

Opening of the Nanofair 2005 at the international Congress Center in Dresden

Nanotechnology competence center »Ultrathin Functional Films«

Nanotechnology is a key technology of the 21st century. Already there are products in the market: Computer hard disks and read / write heads for data storage, which are coated with films only several nanometers thick, and scanning tunneling microscopes, which make the world of atoms and molecules visible, are only two examples. Ultrathin coatings are key elements of nanotechnology.

To consequently explore and develop industrial applications, 51 companies, 10 university institutes, 22 external research institutes and 5 associations combined their know-how and formed a collaborative network in September 1998. The Fraunhofer IWS coordinates this competence center for ultra thin functional coatings, which received an award from the Federal Ministry for Research. The work is focused on the organization of events and workshops as well as on mediating competent contact persons. In addition the group participates in trade shows and promotes public relations educational aspects in the area of nanotechnology.

International symposium Nanofair 2005

The international symposium Nanofair 2005 was held in the newly constructed international Congress Center and for the second time in Dresden. In a short period of time the event became a leading presentation and discussion forum in the area of nanotechnology in Europe. The forum especially addresses the interface between science and the economy and thus applied research and development.

Considering the importance of the event it was under the aegis of the Federal Minister for Research Edelgard Bulmahn and her French colleague François Goulard, Minister for Education and Research in France.

Dr. Andreas Leson from IWS, who was also responsible for the scientific program, chaired the conference, which was a great success. More than 250 participants from the scientific community and industry used the opportunity to inform themselves and discuss the latest developments and products in nanotechnology. Technical topics of the symposium were in the areas of electronics, materials, surfaces, optics, automotive industry and biosciences. The symposium was accompanied by an exhibition.

NanoCareer Forum

About 100 students from all over Europe met at the NanoCareer forum at the Fraunhofer IWS. The event was supported by the nanotechnology competence center. Topics included industry requirements for university graduates as well as the specific career opportunities in nanotechnologies. High-level representatives from European industry (AMD, Infineon, ASML, Minatec, Bayer, Degussa) illustrated current developments within their companies and how these translate into requirements for the potential future employees. The subsequent discussion about these topics was very lively. A representative of the European Commission explained the different opportunities provided through the European mobility programs. Touring the Fraunhofer IWS as well as VW's »Transparent Factory« completed the program.

Saxon-British nanotechnology forum

Saxony presented herself at the Saxon-British nanotechnology forum in London with the topics nano-electronics, photonics, nano-materials, -surfaces and -coatings as well as nano-biotechnology. Minister President Georg Milbradt opened the forum at which 130 participants informed themselves about current developments and research results, which were presented in three workshops and a common plenary session. Sir David King, Chief Scientific Advisor to HM Government and Prof. Bullinger, President of the FhG, presented at the plenary session. The Fraunhofer IWS was to a large extent responsible for planning and organizing the event. The meeting found its conclusion with a reception at the German embassy in London.

German-Canadian round table

A bilateral German-Canadian meeting addressing the scientific-technical cooperation in nanotechnology was held at the Fraunhofer IWS in combination with the Nanofair 2005 event. Leading German nanotechnology experts discussed with the 16 members of the Canadian delegation the possibilities of closer cooperation. Simultaneously the participants used the opportunity to learn about the latest IWS developments in the area of nanotechnology.

4th Ukrainian-German seminar on nano-sciences and nanotechnology

Current research results and new ways of cooperation were the topics of the bilateral seminar with German and Ukrainian participants, which was organized by and held at the Fraunhofer IWS. Current results in the areas of nano-materials, nano-electronics and nano-biotechnology were presented from both Ukrainian and German scientists. The Ukrainian participants used the opportunity to present their results at the Nanofair conference.

The »Year of Germany« in Japan

Within the »Germany Year« in Japan, the IWS participated in visiting the country. Saxony's Minister for Economy, Thomas Jurk, headed the delegation. During three well-visited seminars in Tokyo, Nagoya and Kyoto, IWS scientists presented ongoing research and development work in the area of nanotechnology with a special focus on automotive applications.

Discussion of participants at the NanoCareer forum (November 28th, 2005)

Students from all over Europe attended the NanoCareer forum

Presentation of Dr. Leson in Japan during the visit of a Saxon delegation on the occasion of the »Germany Year«

Wer alle seine Ziele erreicht hat,
hat sie zu niedrig angesetzt.

If you have reached all your goales,
you didn't aim enough.
Herbert von Karajan

Industrial project group at the Dortmunder OberflächenCentrum (DOC) at the ThyssenKrupp Stahl AG

Dr. Axel Zwick
Manager of the project group at DOC in Dortmund
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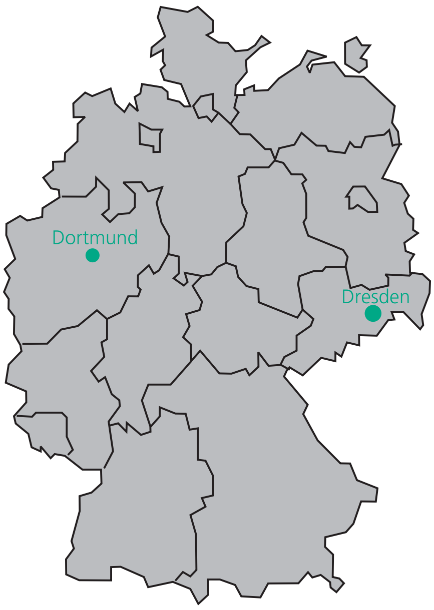
Facility of the Dortmunder OberflächenCentrum



www.iws.fraunhofer.de/doc

The ThyssenKrupp Stahl AG (TKS) concentrated its resources and competences in surface technologies with the formation of the DOC in which the Fraunhofer Society participates.

The DOC is the largest research and development center in the area of surface treatments for sheet steel in Europe. At DOC employees of TKS and the Fraunhofer IWS work jointly together in a new form of cooperation called the **»Public Private Partnership«**. A common goal is the development of innovative surface engineering processes and their transfer to industrial manufacturing.

One early outstanding result of this cooperation is a novel zinc alloy coating (ZE-Mg). The Fraunhofer project group demonstrated the case of laser welding in that these new coatings combine the corrosion protection of conventional zinc coatings at half the thickness with a significantly improved machinability of the coated material.

In addition hybrid and combination processes have been developed. Of special note are the hybrid welding of high strength steel components and the combination processes of cleaning and welding and welding and post galvanizing.

Beyond this the Fraunhofer project group offers in its 1,100 m² facility a number of complementing surface technologies. With modern equipment it is possible to produce nearly pore free and extremely adherent plasma spray coatings. Areas on components and tools facing aggressive wear can be coated with millimeter thick wear protection coatings through laser deposition welding techniques. Meter-long and ton-heavy parts can be coated in vacuum with nano- and micrometer high performance coatings such as the Diamor® film system, which provides an extreme surface hardness and excellent low-friction sliding properties.

The wide spectrum of the available processes and their combinations together with the expertise of the involved Fraunhofer Institutes guarantees cost effective and optimized problem solutions for our customers, whether it is TKS, a TKS-customer, or any other company. With the help of a mobile 4 kW solide state laser it is even possible to perform process development or »trouble shooting« directly at the customer's facility.

Fraunhofer Center for Coatings and Laser Applications (CCL)

Prof. Jes Asmussen
Center Director
CCL / USA
phone:
+1-517-355 4620

The USA activities of the Fraunhofer IWS Dresden are concentrated in the Center for Coatings and Laser Applications. The CCL is headed by Prof. Dr. Jes Asmussen (Michigan State University). Prof. Asmussen is an expert in the area of diamond coatings. His work ideally complements the expertise of the IWS in the area of DLC coatings. Therefore it is the goal to establish a carbon center under his guidance in East Lansing.

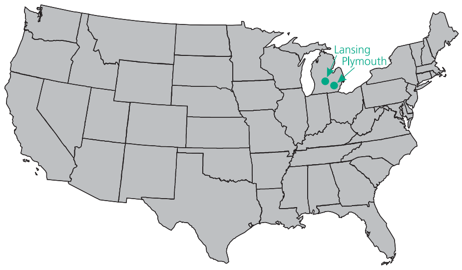
The CCL is comprised of two divisions, the »Coating Technology Division« at Michigan State University in East Lansing managed by Dr. Thomas Schülke, and the »Laser Applications Division« located in the building of Fraunhofer USA Headquarters led by Eric Stiles.

Laser Applications Division
2005 was another eventful year for the laser group of the CCL in Plymouth, Michigan. The location's proximity to the city of Detroit led to a close cooperation with the American automotive industry. The group performed numerous laser-welding projects, especially to join powertrain components such as differentials, transmissions, and drive shafts. A technology to laser-MIG weld high-tensile car body steels was developed.

Additional highlights were:
- development of a wear resistant coating for drilling equipment, deposited by laser deposition welding
- laser welding of titanium structures or aerospace applications.

Coating Technology Division
The CCL's thin film group is in East Lansing, Michigan. The technology spectrum of the group has been substantially increased due to the cooperation with the Michigan State University. In addition to the originally offered PVD technologies the group now works on microwave based CVD and material processing techniques. The tight integration with the university enables the group also to offer extended characterization services (material composition, electron microscopy, nano-indentation, atomic force microscopy) and process development services for the manufacturing of micro-electro-mechanical systems (MEMS).

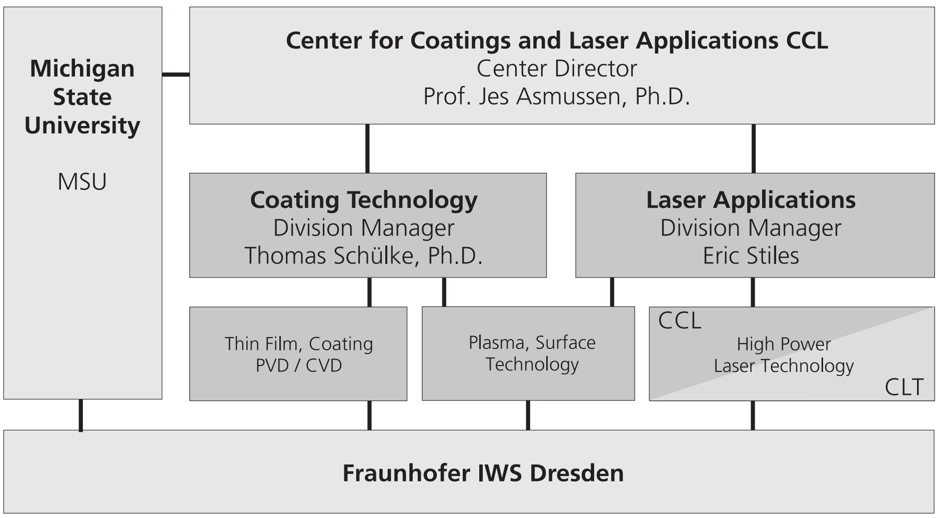
budget 2005	$3.07 million
- cost of sales	$1.22 million
- other expenses	$1.85 million



www.ccl.fraunhofer.org

Building of CCL, CLT (Center for Laser Technology), and Fraunhofer USA Headquarters in Plymouth, Michigan

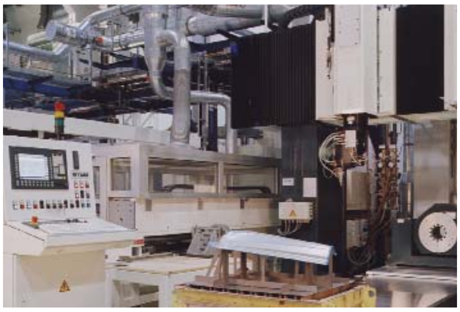
Building of CCL in East Lansing, Michigan



Institute equipment

The optimist proclaims that we live in the best of all possible worlds; and the pessimist fears this is true.
James Branch Cabell

View of the IWS technology hall



High-speed 3D laser cutting system with linear drives

Laser beam welding system with 6 kW CO_2 high power laser

Laser systems

several fiber lasers to 4 kW cw and 1 kW pm

several CO_2 lasers, 2 to 6 kW (HF-pumped)

several Nd:YAG lasers to 4.4 kW cw (lamp and diode pumped) and 1 kW pm laser

Nd:YAG laser system with pulse widths in the millisecond, nanosecond and picosecond range for the fine machining

several high power diode lasers, 1.4 to 4.0 kW

TEA CO_2 laser

excimer laser (193 and 248 nm)

frequency-multiplied Nd:YAG laser (532 and 355 nm)

pulsed Nd:YAG laser with OPO

Handling systems

3D double gantry system, 22 axis with two 3D motion processing heads, speed up to 40 m / min, workspace 10 x 3 x 1.5 m^3, two 4.5 kW CO_2 lasers

several CNC laser processing systems with up to 8 axis,
speeds up to 20 m / min, workspace 2.4 x 1.8 x 0.6 m^3 or 4 x 3 x 1.5 m^3, CO_2 laser beam sources 2.5 to 6 kW

laser induction hybrid gantry with 5 axes (6 kW CO_2 laser, 80 kW MF induction generator)

precision machines (accuracy class 5 µm) with 5 and 4 CNC-axes, with 6 kW CO_2 laser beams

combined CO_2 and Nd:YAG machine (2 or 3 kW) with 4 CNC-axes for precision cladding

cutting machine with linear drives up to 300 m min^{-1} feed with 3.5 kW CO_2 laser beams

universal Excimer-laser-micromachine

Coating systems

laser PVD (LPVD) coating device (Nd:YAG, Excimer, TEA CO_2 laser) in high vacuum and ultra high vacuum

equipment for film deposition with vacuum arc technology (Laser-arc, pulsed high current arc, DC-arc, plasma filter) and electron beam

devices for plasma-assisted CVD coating at atmospheric pressure (6 kW microwave, 30 kW dc-Arc)

systems for the deposition of ultra precision multi layers with PLD, ion beam sputtering, and magnetron sputtering

hybrid coating equipment: 40 kW electron beam and high current arc

devices for atmospheric (laser assisted as well) and vacuum plasma spraying with robot handling (APS, LAAPS, VPS)

device for the high velocity flame spraying (HVOF)

device for plasma-powder-cladding (PTA, 6 kW)

Special components

static and flexible dynamic beam shaping systems for beam power up to 10 kW

CNC sensor controlled wire feeder for laser welding

mobile medium and high frequency induction sources (4 - 20 kHz, 100 - 400 kHz)

modular powder nozzle system COAXn for laser beam precision build-up welding

process control systems for thermal spraying, laser beam build-up welding and laser welding

software package for DCAM off line programming of robots and CNC machines for all thermal coating processes

sensor system for 3D shape recording (automatic teach-in) for laser handling of components (on-line / off-line contour tracing)

beam diagnostic system for CO_2 and Nd:YAG laser

UV / VIS, FTIR und NIR diode laser spectrometer for process gas and plasma diagnostic

camera system for short-time process analysis (4 channel high speed framing camera with 5 ns exposure time)

Special equipment

mobile 4 kW Nd:YAG laser in a container

equipment for rapid prototyping by laser sintering

portable Nd:YAG laser (6 ns pulses of $5 \cdot 10^7$ W, repetition rate up to 20 Hz) with articulated beam guide and zoom optic (Art-Light NL 102) for outdoor cleaning

turnable laser handling system (400 ... 2000 nm, > 100 mJ) with flexible beam guide and controlled motion for the ablation of thin layers

laser handling station with industrial robot system and CO_2 slab laser

CNC treatment center for 5-axis milling and built-up welding

laser integrated milling center for generating and repair

mobile equipment for anti-slip equipment of tiled floors (by diode pumped Nd:YAG laser)

Measurement instruments

system for the structural analysis including preparation techniques:
- metallography
- transmission electron microscopy
- scanning electron microscopy

materials testing:
- servo hydraulic testing system
- mechanical stress / strain tester
- pendulum impact tester
- computer supported micro hardness test system, hardness test automat
- high frequency fatigue tester
- flat bending torsion machine
- different wear testing systems (abrasive, cavitation, oscillating wear)

laser acoustic systems for measuring the Young's modulus of thin films

laser shock instrumentation with high speed pyrometer

equipment for surface analysis:
- automatic spectral ellipsometer (270 - 1700 nm)
- UV / VIS spectrometer
- Raman micro spectrometer
- FTIR spectrometer, FTIR microscope
- depth sensing indentation device
- scratch tester
- profilometer
- tribometers
- residual stress measurement system

X-ray diffractometer (CuKα)
X-ray diffractometer (MoKα)

optical 3-D coordination system

Vacuum plasma spraying

Device for the deposition of nano-meter multi-layers on large areas

Device for the deposition of nitridic hard material layers

Das nächste Spiel
ist immer das schwerste.

It is always the next game
that is the most difficult.
Sepp Herberger

Total employees

The TU Dresden (chair for laser and surface technology) and the Fraunhofer IWS are connected through a cooperation agreement. A number of university employees are working closely with IWS employees on joint projects. Basic research is conducted at the university; application related process development and system technical work is done at IWS.

For 2005 the employees are divided up as follows:

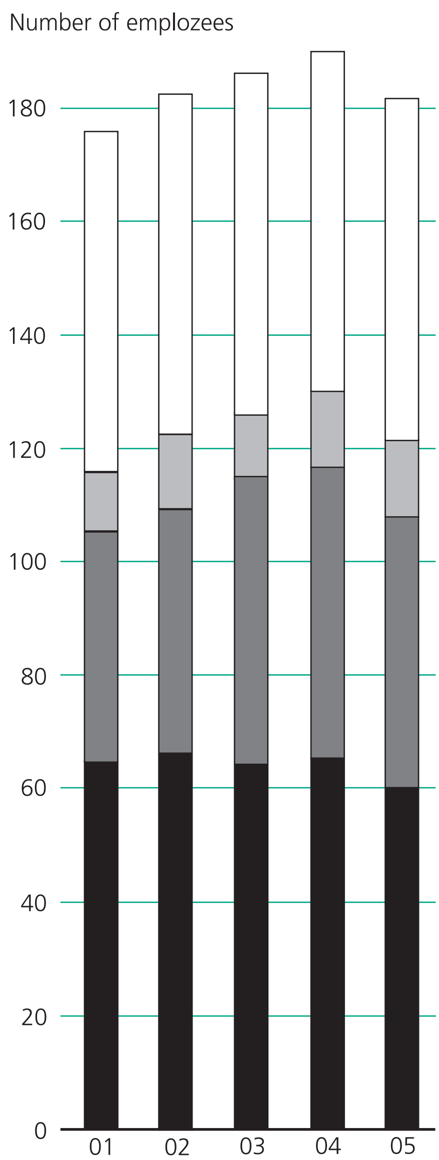
Employees of Fraunhofer IWS

	Number
Staff	**108**
- scientists	60
- technical staff	39
- administrative staff	9
Apprentices	**14**
Research assistants	**60**
Total	**182**

Employees of Chair for Laser and Surface Technology of TU Dresden

	Number
Staff	**33**
- scientists	20
- technical staff	12
- administrative staff	1
Research assistants	**8**
Total	**41**

Building	**8000 m^2**
- processing technology area	1600 m^2
- lab space, workshops	3070 m^2
- office space	2630 m^2
- conference rooms, seminar rooms etc.	700 m^2
Technology area at the DOC (Dortmund)	**1100 m^2**



Budget and revenue 2005 (preliminary*)

* actual cost determination not yet finalized

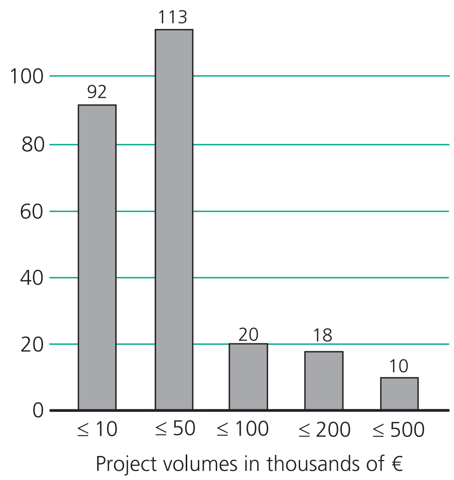
	million €	
Operational costs and investments 2005	**13.8**	
Budget	**11.8**	
- cost of sales	6.0	
- other expenses	5.8	
Investment	**2.0**	

	million €	%
Revenue 2005	**13.8**	
Revenue operations	**11.8**	
- industrial revenues	6.0	51
- revenues of public funded projects	2.0	17
- base funding IWS	3.8	32
Revenue investment	**2.0**	
- industrial revenues	0.1	
- revenues of public funded projects	0.0	
- base funding IWS	0.6	
- strategic investment	1.3	

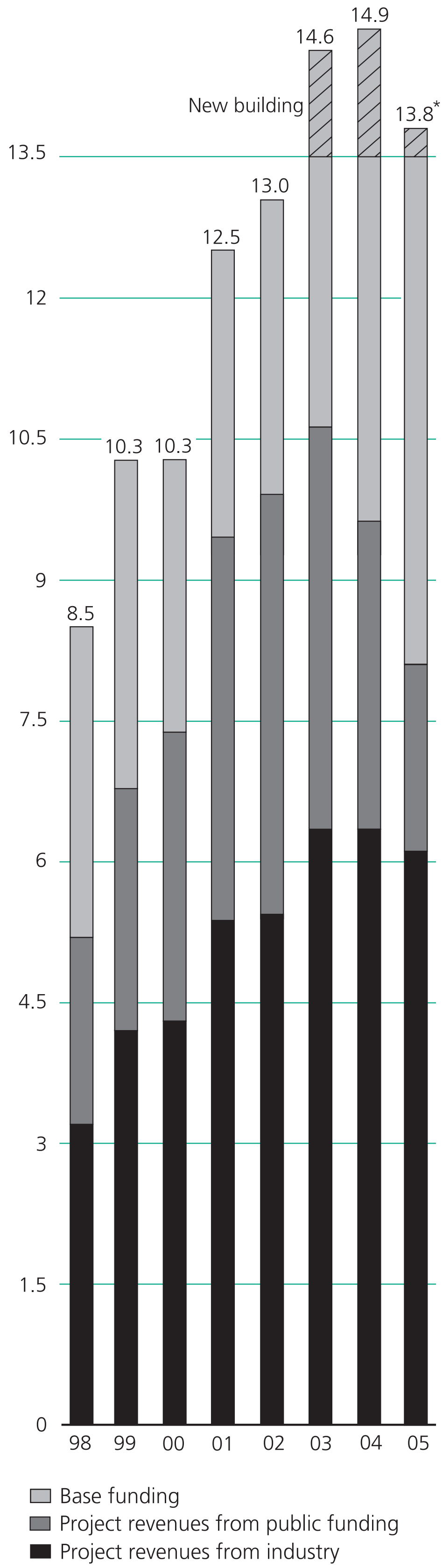
Projects

In 2005, IWS handled 253 projects. The distribution of the projects with respect to their volume is shown in the graphic below. One hundred thirteen of the projects were for 10 to 50 T€ (thousands of euro), for example.

Number of projects



Revenues in operations and investments without strategic investments (million €)



Committees

Board of trustees

The advisory committee supports and offers consultation to the Fraunhofer IWS. Members of the advisory committee in 2005:

P. Wirth, Dr.
Chairman of Rofin-Sinar Laser GmbH, committee chair

R. Bartl, Dr.
Director production planning MB Cars, DaimlerChrysler AG

I. Bey, Dr.
Manager of the Research Center Karlsruhe (project performing institution) and the production and manufacturing technologies section at the Research Center Karlsruhe GmbH

H. Bücher, Dr.
Coordinator innovation management and technology marketing,
German Aerospace Center (DLR)

S. Clobes, RD'in
Manager of the production systems and technologies department at the Federal Ministry for Education and Research (curator since June 2005)

D. Fischer,
General manager EMAG Leipzig Machine Factory GmbH

F. Junker, Dr.
Member of the board of directors of the Koenig & Bauer AG, Planeta-Bogenoffset

J. Klenner, Dr.
Leader Centre of Competence Engineering Structure, Airbus

P. Lenk, Dr.
General manager of von Ardenne Anlagentechnik GmbH

P. Linden, Dr.
Head of production technology of DaimlerChrysler AG

A. Mehlhorn, Prof. Dr.
Technical University Dresden

R. J. Peters, Dr.
General manager VDI Technology Center, Physics Technologies

W. Pompe, Prof. Dr.
Technical University Dresden

F. Schmidt, Dr.
Saxony Ministry of Science and Art

R. Zimmermann, MR Dr.
Saxony Ministry of Science and Art

U. Jaroni, Dr.
Member of the board, auto division of the ThyssenKrupp Steel AG
(Guest)

The 15th committee meeting took place on March 01, 2005, at Fraunhofer IWS in Dresden.

Scientific technical council (WTR)

Scientific technical council of the Fraunhofer-Gesellschaft supports and advises divisions of the Fraunhofer-Gesellschaft with regard to technical and scientific policy. The council consists of members of the institute management and an elected representative of the scientific and technical staff of each institute. IWS members of WTR in 2005 were:
- Prof. Dr. E. Beyer
- Dr. S. Bonß

Institute management committee

The institute management committee advises the executive director and participates in decision making concerning the research and the business policy of IWS.

Members of the committee are:

Prof. Dr. E. Beyer	Executive director
Dr. A. Leson	Deputy director
Dr. S. Wilhelm	Head of administration
Prof. Dr. B. Brenner	Department head
Dr. V. Hopfe	Department head
Dr. L. Morgenthal	Department head
Dr. S. Nowotny	Department head
Prof. Dr. B. Schultrich	Department head

Guests are:

Dr. S. Bonß	WTR agent
Prof. Dr. U. Günther	Agent of the chair / university
Dr. C. Krautz	Marketing
Dr. M. Panzner	Works committee
Dr. S. Schädlich	QM representative

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration. The organization also accepts commissions and funding from German federal and Länder ministries and government departments to participate in future-oriented research projects with the aim of finding innovative solutions to issues concerning the industrial economy and society in general.

By developing technological innovations and novel systems solutions for their customers, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. Through their work, they aim to promote the successful economic development of our industrial society, with particular regard for social welfare and environmental compatibility.

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, in other scientific domains, in industry and in society.

At present, the Fraunhofer-Gesellschaft maintains some 80 research units, including 58 Fraunhofer Institutes, at over 40 different locations in Germany. The majority of the roughly 12,500 staff are qualified scientists and engineers, who work with an annual research budget of over 1 billion euros. Of this sum, more than €900 million is generated through contract research. Roughly two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. The remaining one third is contributed by the German federal and Länder governments, partly as a means of enabling the institutes to pursue more fundamental research in areas that are likely to become relevant to industry and society in five or ten years' time.

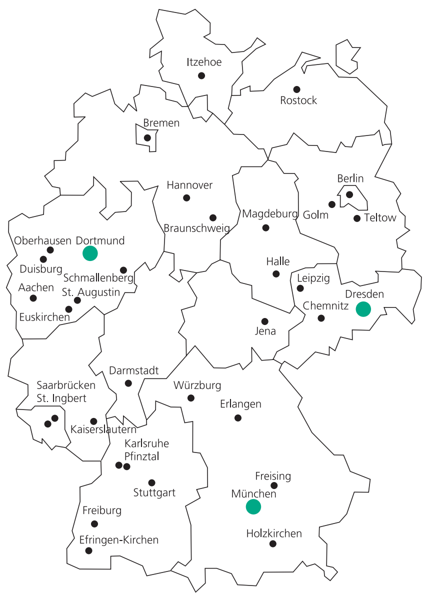
Affiliated research centers and representative offices in Europe, the USA and Asia provide contact with the regions of greatest importance to present and future scientific progress and economic development.

The Fraunhofer-Gesellschaft was founded in 1949 and is a recognized non-profit organization. Its members include well-known companies and private patrons who help to shape the Fraunhofer-Gesellschaft's research policy and strategic development.

The organization takes its name from Joseph von Fraunhofer (1787-1826), the illustrious Munich researcher, inventor and entrepreneur.

Le génie n'a pas de sexe.

Genius has no gender.
Madame de Staël



VOP

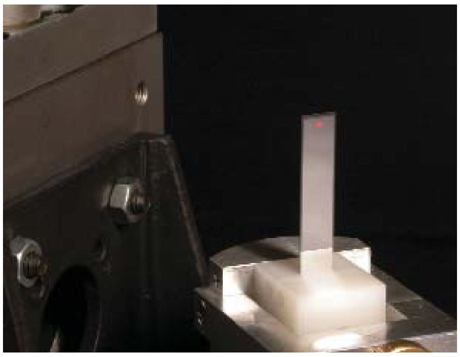
Fraunhofer Verbund Oberflächentechnik und Photonik

Competence by networking

Six Fraunhofer Institutes cooperate in the Surface Technology and Photonics Alliance VOP. Complementary competencies allow to adapt the research activities to the rapid technological progress in all industrial application fields in a permanent, apace and flexible way. Coordinated strategies, in line with the currents needs of the market, create synergy effects and provide a larger service for the benefit of the customers.

Fraunhofer Institute for Physical Measurement Techniques IPM

The Fraunhofer IPM develops optical systems for applications in spectroscopy and light exposure technology. A major focus is the realization of highly dynamical systems. Besides a rapid activation, they require special competencies in signal processing as realized through robust and low-maintenance measurement systems for the infrastructure monitoring of high-speed roads.



Fraunhofer Institute for Electron Beam and Plasma Technology FEP

The ambition of FEP is the research and development of innovative processes for the utilization of high performance electron beams and vacuum sealed plasmas for surface technology. Priority is given to problems like process monitoring, quality control, reproducibility, scaling, and profitability.

Fraunhofer Institute for Laser Technology ILT

In the area of laser technology, the interactive relationship between laser development and laser applications is of prime importance. New lasers allow new applications, and new applications set the stage for new laser systems. This is why the Fraunhofer ILT is continually expanding its core competencies through close cooperation with leading laser manufacturers and innovative laser consumers.

top: Fraunhofer FEP
middle: Fraunhofer IPM
bottom: Fraunhofer ILT

Core competences	FEP Dresden	ILT Aachen	IOF Jena	IPM Freiburg	IST Braunschweig	IWS Dresden
Coating and surface engineering	●	●	●	●	●	●
Beam sources	●	●	●	●		
Micro and nano technology		●	●	●	●	●
Materials treatment	●	●			●	●
Optical measurement techniques		●	●	●	●	●

Fraunhofer Institute for Surface Engineering and Thin Films IST

As an industry oriented R&D service centre, the Fraunhofer Institute for Surface Engineering and Thin Films IST is pooling competencies in the areas film deposition, coating application and film characterization. Presently, the institute is operating in the following business fields: mechanical and automotive engineering; tools; energy; glass and facade; optics; information and communication; life science and ecology.

Fraunhofer Institute for Material and Beam Technology IWS

The Fraunhofer IWS is conducting research in the areas of laser technology (e.g. laser beam welding, cutting, hardening), surface technology (e.g. build-up welding), micro machining as well as thin film and nano technology. The integration of material testing and characterization into research and development constitutes and upgrades the IWS spectrum.

Fraunhofer Institute for Applied Optics and Precision Engineering IOF

The core of the research activity of Fraunhofer IOF is optical systems engineering aimed at a steady improvement of light control. The institute's focus is on multifunctional optical coatings, optical measurement systems, micro-optical systems, systems for the characterization of optics and components for precision mechanics assemblies and systems.

Contact / coordination

Chairman of the network:
Prof. Dr. Eckhard Beyer

Coordination:
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www.ipm.fraunhofer.de
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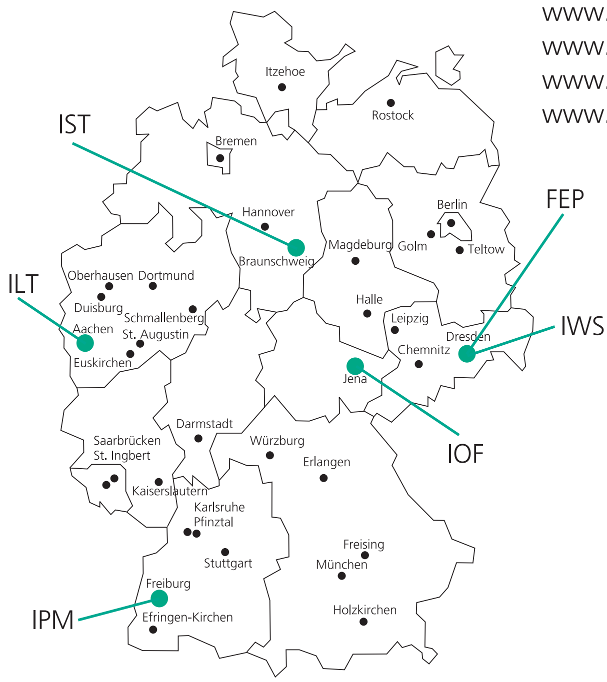
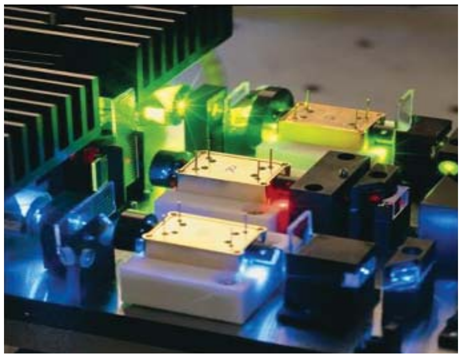
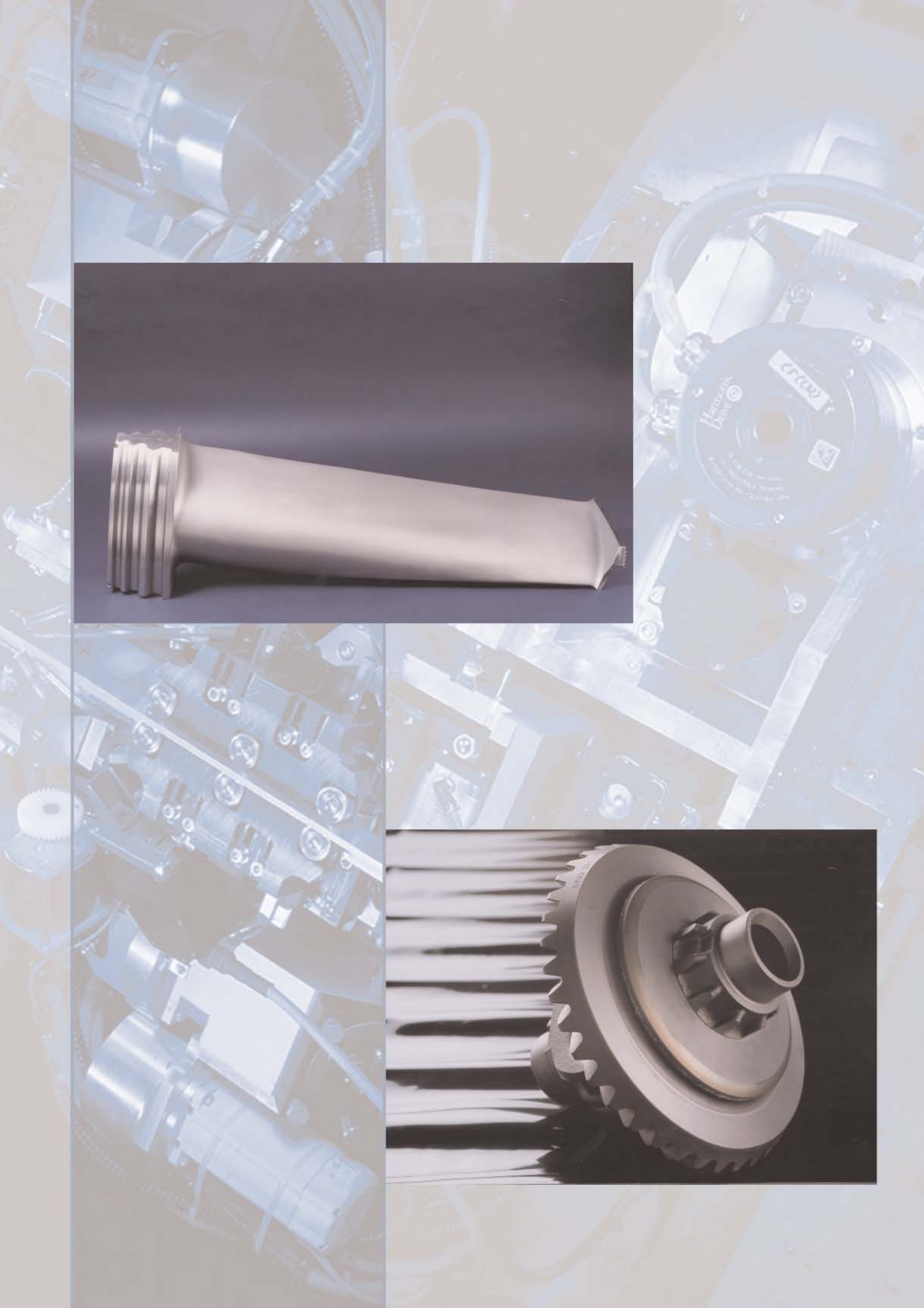
www.ist.fraunhofer.de
www.iof.fraunhofer.de
www.iws.fraunhofer.de





top: Fraunhofer IST
middle: Fraunhofer IOF
bottom: Fraunhofer IWS


Harmonic Drive

R&D-offer: Joining and surface treatment

Editor: In the 2004 annual report you discussed the two process technology branches of your department, the laser beam joining and the surface technologies. How do this year's results look in these areas?

Prof. Brenner: We are very pleased to report that as a result of public grants as well as numerous industrial projects, we were able to grow our competence in both directions. Seven industry transfers of complex problem solutions demonstrate our success in transferring technology to industry.

An example is the area of laser beam welding. We continued a special welding process development involving a specially adapted filler material to weld transmission components which could not be conventionally welded without leaving cracks. In the scope of a contract from the system manufacturer Arnold we transferred the final process to the manufacturing plant at ZF Gotha. I would also like to point out other development projects addressing the property characterization and improvement of laser beam welded components for the aircraft manufacturing industry, the use of fiber lasers, and the avoidance of hot cracks in materials especially prone to hot cracking. The work in the area of surface technologies focused on the design and successful implementation of four HLDL laser beam hardening machines. The systems are deployed at domestic (BMW) and foreign (Switzerland, Italy) customers and used for surface hardening processes in the tool making industry. These projects required significant resources but demonstrated the success of the chosen path to establish system engineering competence through the development of specific key components including software modules.

Editor: Catchword fiber laser; Is the fiber laser going to play an important role for future laser beam welding?

Prof. Brenner: Just recently the IWS acquired 1 kW and 4 kW fiber lasers exhibiting the highest beam quality (beam parameter product 0.35 or 1.8 mm · mrad). We were able to demonstrate exceptional results using these lasers in numerous welding experiments for the economically strategic material groups. Fiber lasers are well suited for welding, they can be easily integrated into robot systems, they are mobile and straightforward designed, and they have a high electro-optical efficiency. Therefore we are convinced that fiber lasers will have a great future.

Editor: In the past you have always stressed the holistic approach to work in your department. Recently a group working on adhesive bonding has been integrated into your department. How does this fit in with your holistic approach and what effects do you expect from the integration?

Prof. Brenner: The group »Adhesive Bonding« was integrated because we expect synergistic effects. From a strategic standpoint, we expect that in the future of lightweight construction there will be a strong demand for highly optimized and yet affordable materials. The consequence is the need to design with multiple materials. This design philosophy however, is in many cases no option for beam based welding processes. Adhesive bonding technology provides broad access to these markets and synergy effects developed through utilizing laser and plasma technologies to prepare surfaces prior to the adhesive bonding step, bonding area activation or location specific heating of the adhesives.

Wissenschaft ... handelt mit Wissen, gewonnen durch Zweifel.

Science ... deals with knowledge acquired through doubts.

Galilei in »Life of Galilei«
by Bertolt Brecht

Prof. Dr. Berndt Brenner
Department head
(phone: +49 (0) 351-2583-207,
berndt.brenner@iws.fraunhofer.de)

Dr. Steffen Bonß
Team leader surface treatment technologies
(phone: +49 (0) 351-2583-201,
steffen.bonss@iws.fraunhofer.de)

Optimized technologies for the hardening of steel components through laser and / or induction

If conventional hardening technologies are not suitable because of certain geometric shapes, material and wear conditions, laser hardening can be ideal to produce wear-resistant parts with an increase in service life. This technology is especially suitable for the selective hardening of multi-dimension faces, inner or hard to reach surfaces, sharp edges steps, bores and grooves, as well as for low distortion hardening. With a strong foundation of long term experience in the broad fields of wear protection and hardening, we are able to offer:

- development of surface hardening technologies with high power diode lasers, CO_2 lasers, Nd:YAG lasers and / or induction,
- prototype, process and system optimization.

Laser beam hardened turbo charger shafts

Dr. Jens Standfuß
Team leader welding
(phone: +49 (0) 351-2583-212,
jens.standfuss@iws.fraunhofer.de)

Welding of hard to weld materials

Laser welding is a modern welding process that is widely utilized in industry, especially in mass production. Such welding with a laser using an integrated heat treatment cycle, developed at IWS, offers a new process for the manufacturing of crack-free welded joints of hardenable steels, austenitic steels and special alloys. With our extensive experience in metal physics and an unique welding station with our integrated heat treatment process, we are able to offer:

- development of welding technologies,
- prototype welding,
- process and system optimization,
- preparation of welding instruction.

Laser beam welded transmission component

Dr. Bernd Winderlich
Team leader materials testing and characterization
(phone: +49 (0) 351-2583-224,
bernd.winderlich@iws.fraunhofer.de)

Complex materials and component characterization

The control of modern joining and surface engineering processes requires knowledge from structural changes to the resulting component properties. Based on long term experience and extensive equipment in the area of structural, microanalytical and mechanical materials characterization we offer:

- metallographic, electronmicroscopic (SEM, TEM) and microanalytical (EDX) characterization of the microstructure of metals, ceramics and compound materials,
- determination of material data for component dimensioning and quality assurance,
- property evaluation of surface treated and welded components,
- strategies for materials and stress adapted component design,
- failure analysis.

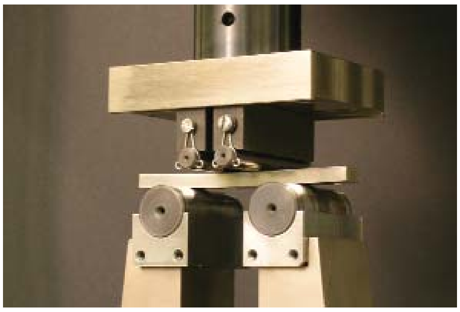
Dr. Irene Jansen
Team leader bonding
(phone: +49 (0) 351-463-35210,
irene.jansen@iws.fraunhofer.de)

Adhesive bonding technology

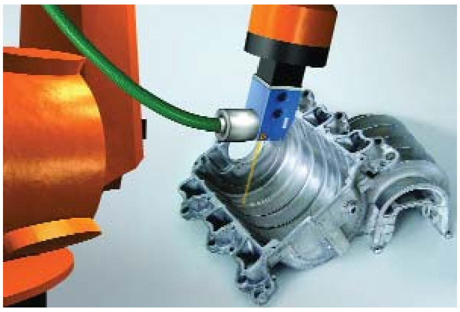
The main working areas of the group are:
- surface preparation through plasma and laser techniques as well as conventional pretreatment methods,
- constructive adhesive bonding of different materials (metals, plastics, glass, wood),
- characterization of surfaces and bonded systems through contact angel, roughness and film thickness measurements, light microscopy, SEM / EDX and spectroscopic methods,
- determination of the bond strengths and aging studies,
- simulation and implementation of a database.

Examples of projects 2005

further information:
www.iws.fraunhofer.de/projekte/001/e_pro001.html
www.iws.fraunhofer.de/branchen/bra01/e_bra01.html



Fatigue testing of laser gas alloyed Ti6Al4V



Nd:YAG laser based adhesive bonding surface prepossessing of an intake manifold made from magnesium in a high pressure die casting process

Dynamic beam shaping system for industrial laser surface treatment

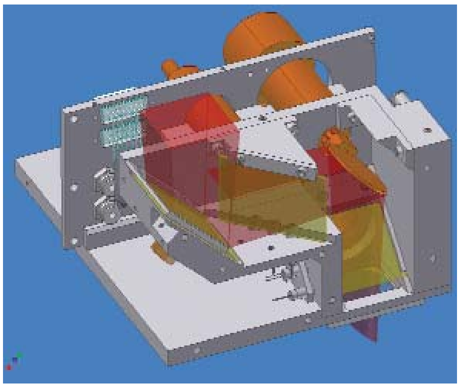


Fig. 1: Schematic view of the scanner head design showing the optical path

Fig. 2: Scanning system for high power diode lasers

Task

Over the past years reliable laser sources have become more and more affordable. As a result, laser surface treatment and refinement processes such as laser beam hardening, laser beam re-melting or laser beam alloying have become interesting for industrial niche applications to locally treat contours on component surfaces. Applying laser tracks of only millimeters in width is a very frequent requirement. For this task the laser manufacturers are already offering specially adapted optics. If variable track widths are needed or if the laser power distribution within the laser spot has to be adapted to the local requirements during processing however, one easily reaches the limits of the conventional static optical systems.

Solution

A solution with great flexibility is a beam shaping system based on scanning mirror optics, which uses one or more galvanometer scanner drives. These are controlled with freely programmable oscillation functions, which make it possible to vary the power distribution in the scanned laser spot. These systems already exist on the laboratory scale. However, for industrial applications they have to fulfill high demands with respect to robustness and process safety.

Results

Based on extensive laboratory testing, we designed a flexibly usable scanner head for high power diode and Nd:YAG lasers. Optical elements such as the deflection and scanning mirrors are temperature controlled. The reflected laser or heat radiation hits actively cooled surfaces and the functionality of sensitive plastic components is not impaired. The designer especially ensured that wear parts such as protection glasses and mirrors are easily accessible for replacement and that the optical components are protected from contamination. The casing is completely closed and can be permanently rinsed with cleaned pressurized air or nitrogen. The in-house developed programmable logic controller (PLC) is integrated into the beam shaping system. The system can therefore operate self-sufficiently and it can be integrated into other machine control systems.

Two options have been implemented for process control functions. A fast pyrometer is capable of collecting several surface temperature measurements within a single scanner motion and feeding the data to the laser power controller. Another option is to use a camera based temperature measurement system »E-MAqS«, which provides spatially resolved temperature data. The scanner head is designed in a way that both measurement systems can be used simultaneously. The system is operated via software that runs on a standard PC utilizing a special I/O board.

Contact

Dr. Steffen Bonß
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Double-sided simultaneous laser beam welding of large-size 3D aviation structures

Task

New machine concepts are required to tackle the double-sided simultaneous laser beam welding in any desired direction of large and spherically curved 3D components (see annual report 2003, p. 104, in German). Based on these concepts, we built a new laser beam welding machine (annual report 2004, p. 32, in German) including optical sensors and we implemented a novel CNC and software architecture. The system had to be evaluated through welding an especially strongly curve skin field.

Solution

The basic gantry design involves two independently movable Y bridges. To minimize machine space and to improve machine dynamics we chose a hybrid motion system so that both, the gantry and the machine table, could be used for the relative motion between laser beam and workpiece.

Each Y bridge is equipped with Z axes to mount units which can be independently rotated and swiveled. These units carry the two welding heads and optical sensors to detect the position of the seam during the stapling or welding processes. The workpiece is positioned using an additional third Z axis with a platform that can be freely rotated and swiveled around in space. The welding coordinates are determined based on CAD data. A specially developed postprocessor generates a complete NC program with all control commands for the laser, shielding gas, cross jet, and sensors and all the path data.

The seam path is determined based on the vector addition of the current machine position (nominal position) and the actual seam position provided by the sensor. A mean value is calculated from both sensors to increase accuracy and to avoid errors. The calculated nominal values are programmed within one NC set. Seam beginning and end as well as interruptions are also detected via sensor. The contour, which was calculated during the welding process, is once again traced with activated sensors to capture the seam edge angle. A special algorithm was developed to calculate the seam edge angle along the welding seam, see Fig. 1.

Results

The final stage of the startup, testing and optimization program of the system was the welding of an Airbus A318 skin field, see Fig. 2. The workpiece consists of the skin sheet and 14 stringers (longitudinal strips). The formation of the welding seam and especially the seam edge angle, which determines the strength of the joints, was in compliance with the customer specifications (Fig. 1). Thanks to the new machine concept the otherwise typical laser positioning errors during axes reorientation could be avoided. Thus there was no post-processing necessary. As a result we have a very capable welding system for the future production supporting process development.

The project was funded by the SMWK (FKZ:4212/02-05 and -06) and by Airbus.

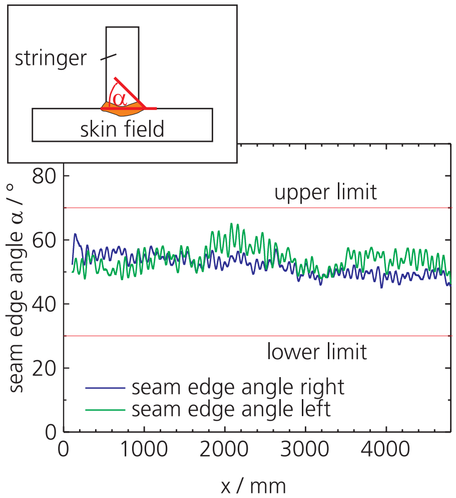

Fig. 1: Seam edge angle for one stringer of the welded skin field.

Fig. 2: Double-sided simultaneous welding of stringer skin field joints

Contact

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R&D-offer: Laser ablation and cutting, system engineering

Editor: Your department is increasingly using laser micro structuring and laser micro processing for R&D in the biomedical and biotechnology areas. What are the opportunities for photonics in life sciences?

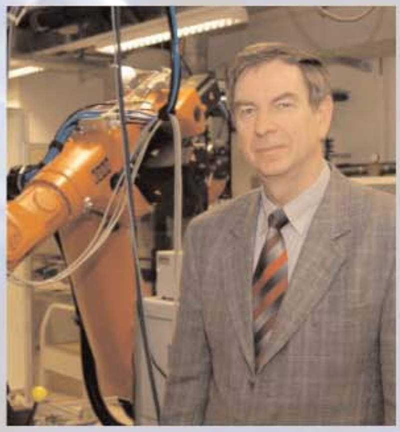
Dr. Morgenthal: Over the years the IWS has established strategic partnerships which enable us to establish a complex systems platform for life science applications. An example is the development of a universal chip for the marking-free detection of bio molecules such as DNA and proteins. Photonics offers possibilities to functionalize the surfaces of these chips, to generate complex cell guidance structures, to fabricate injection-molding tools and to cost effectively join or weld polymer chips. Market studies predict that the world market for molecular diagnostics will grow over the next five years from its current 1.5 billion US$ to 2.7 billion US$.

Editor: During the last year experts increasingly discussed remote technology in combination with on-the-fly processing of components and semi-finished parts. What is the potential in this area?

Dr. Morgenthal: The robot-guided remote welding with on-the-fly processing of large work pieces will replace many conventional point welding stations in the automotive industry. According to a McKinsey study, the driving factor is the potential to decrease cycle times by up to 60 %. At the Fraunhofer IWS we have developed a complete set of process and system technologies, which include compact and highly dynamic 3D beam deflection systems, software for corresponding laser and scanner controls and path planning tools for the effective off-line programming of the complex multiple axis processing systems.

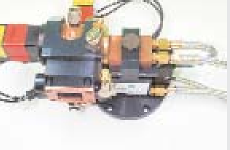
Jointly with our partners we are able to offer complete system and process solutions to our customers. We also anticipate that the newly available fiber and disk lasers will further this process since these solid-state laser beam sources offer improved beam quality, efficiency and longevity.

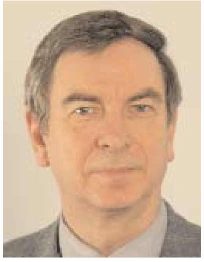
Beyond these areas the remote technology offers the additional potential to significantly increase the productivity of processes cutting contours in non-metallic materials.



Die ungelösten Probleme
halten einen Geist lebendig,
nicht die gelösten.

The unsolved problems
keep the spirit alive,
not the solved ones.
Erwin Guido Kolbenheyer





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Examples of projects 2005

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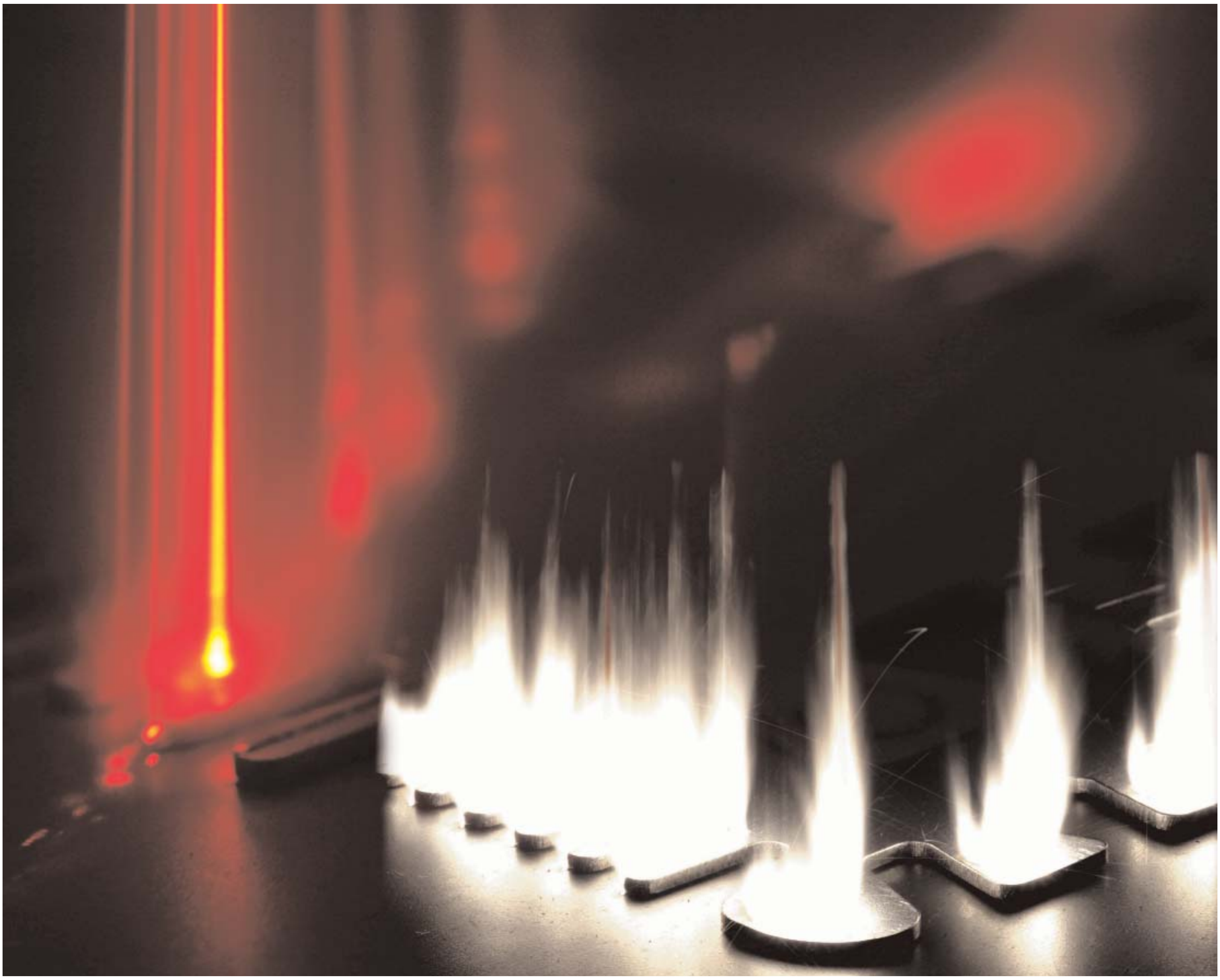

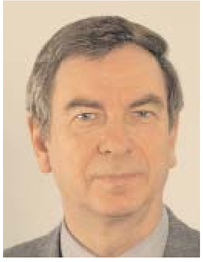

Dr. Lothar Morgenthal
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Cutting technology

We offer applied research for laser cutting with lasers of different wavelength and power to cut parts with millimeter to meter dimensions. The focus is on precision high speed cutting on highly dynamic cutting machines with linear drives or through beam scanning. For quality control we have a flat part scanner system for part dimensions of up to 1800 mm x 1200 mm.

In detail we offer:
- technology and system development, testing, and optimization,
- feasibility studies, prototype manufacturing for all variations of laser cutting on material samples and work pieces,
- development of system components for high speed processes as well as for process control.

System engineering and laser processing

The departments of the IWS offer the implementation of manufacturing ready and process adapted system solutions in the following areas:
- processing optics, beam scanners for high speed and precision processing, process monitoring and control,
- handling systems, process monitoring and control for the industrial utilization of high power diode lasers for surface engineering,
- prototype development of coating systems or their core modules for the PVD precision coating of high volume parts and the continuous atmospheric pressure sheet CVD including system and process control software,
- process monitoring and control for coating processes,
- measurement systems for coating characterization and non-destructive work piece testing through laser acoustic and spectroscopic methods.

Dipl.-Ing. Udo Klotzbach
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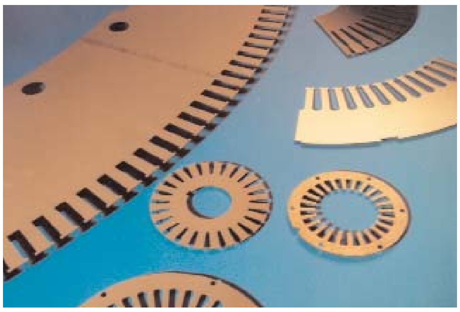
Micro structuring with laser

Extensive and modern equipment as well as our know-how foundation enable us to perform applied research in the area of micro and fine processing with laser beams for the miniaturization of functional elements in machine, system, and automotive engineering as well as for biomedical applications. Examples are 3D structures in the sub mm range and area structures on polymers, metals, ceramics or quartzitic and biocompatible materials.

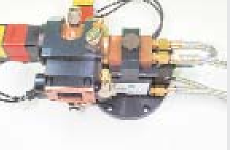
We offer:
- micro structuring of different materials with excimer, fiber and Nd:YAG lasers,
- micro drilling with high aspect ratios and different bore geometries,
- cleaning with laser technology.



Laser-cut electro sheet metals

Welding of the tube / base plate joint of an exhaust gas heat exchanger utilizing a beam scanning optics

Mobile system for the anti-slip preparation of natural stone



Remote welding with YAG lasers

Fig. 1: Beam defection optics lasertronic® SAO1.06 for the remote welding with high power YAG lasers

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Advantages

Automotive manufacturers and suppliers are currently very interested in remote welding with solid-state lasers. The process substitutes conventional resistance spot welding during the manufacturing of car bodies. The fast beam positioning significantly reduces the cycle time. As a result, the technically advantageous laser beam welding process becomes more cost effective. A recent study predicts for the remote welding technique a market share of 8 - 10 % in the entire automotive body-making sector by 2015. That is remarkable considering the short history of the high power remote technology. The first industrial implementations appeared in the USA during the late nineties using high power CO_2 lasers. On-the-fly processing with robot based remote systems is only possible since about a year and a half, when diode pumped YAG lasers became available as industrial products. Driving forces of this new technology are the cost pressures and the possibility to increase the flexibility of production lines.

Lasertronic® SAO1.06

The remote processing system consists of the developed 3D beam deflection optics and a conventional industrial robot. Using a special controller, both systems are operated as a coupled axes system. The laser source is a YAG high power laser with very good beam quality. CAD / CAM solutions for the off-line programming, path planning and job optimization complete the system solution.

During welding the three axes of the beam deflection optics handle the highly dynamic motion sections of the laser spot path. The robot simultaneously moves the beam deflection optics and thus provides the optimal location to reach the welding positions. The exact synchronization of the motion axes guarantees a high time and spatial accuracy.

Optics dimensioning and process imaging

The beam deflection optics for the remote welding with YAG lasers is a modular system and consists of a beam deflection unit focusing the beam. The core of the beam deflection unit is a set of mirrors, which are moved by galvanometer scanners. The dimensioning of the beam deflection optics can be adapted to the requirements of specific applications. All optical components are dimensioned to handle 4 kW laser power. Special cooling, monitoring and safety strategies ensure an error free operation even under tough production conditions. To monitor the welding process the beam deflection optics are equipped with components that handle process imaging and diagnostics.

Path planning and cycle time optimization

Process planning, optimization and control are important elements for the remote processing of 3D workpieces. Therefore the IWS and industrial partners developed path-planning software, which is embedded in a commercial CAD / CAM solution. It is possible to interactively plan the processing path and to optimize cycle times for specific parts. Thus the complex motion programming becomes very efficient and transparent for two dynamically very different systems, such as the robot and the beam deflection optics.

Flawless laser beam welding of transmission components through laser cleaning

Task

Fully automated laser welding processes in transmission manufacturing require the highest level of process safety to limit the cost for quality assurance. Foreign substances such as coolants and lubricants, contaminants, phosphate layers, preservatives and others may lead to flaws in the welding seam. A uniform cleanliness of the areas, to be welded, is critical for the reproducibility and quality of the welding process. It would therefore be very useful to have a cleaning step integrated into the joining process prior to the welding step. Pre-installed components such as differentials are a special challenge. A conventional wet cleaning is impossible because it would degrease the bearings. What is needed is a cleaning process that is limited to specified locations.

Solution

Laser cleaning with high beam intensity and extremely short interaction times is a solution for this problem (Fig. 1). The difference in optical properties of the component and the contamination is used to remove the contaminating layers without damaging the component. The absorbed laser energy is transformed into heat. The heat amount is sufficient to completely evaporate the material to be removed.

To achieve high material removal rates requires the combination of high laser power with extremely short interaction times. The beam deflection optics lasertronic® SAO10.6(1D) has been developed for this task at the IWS. The optics moves a high intensity laser beam spot very rapidly and accurately along the component's surface (Fig. 2).

This beam deflection optics is used to generate a high frequency motion of the spot in perpendicular direction to the welding path. The width of the cleaning track can be adjusted by varying the deflection amplitude of the galvanometer scanner. It is also possible to control the laser power for each scanner position. The cleaning parameters can be very flexibly adapted to the desired part geometry. A modular and expandable controller board in an industrial PC handles the pinpoint precise motion control of the galvanometer scanner. The digital communication with the laser system's CNC is based on the Profibus architecture.

Results

The laser cleaning of joints with subsequent laser beam welding has meanwhile been several times successfully transferred to industry. The application is the manufacturing of differential transmissions where cast iron and casehardened steels have to be welded. In these processes the laser cleaning takes the same cycle time as the laser beam welding. By using the beam deflection optics lasertronic® SAO10.6(1D) it was possible to use the pause times during the workpiece change for the cleaning process prior to welding. The same laser source was used for both process steps. Thus the laser utilization was doubled.

Fig. 1: Laser cleaning process

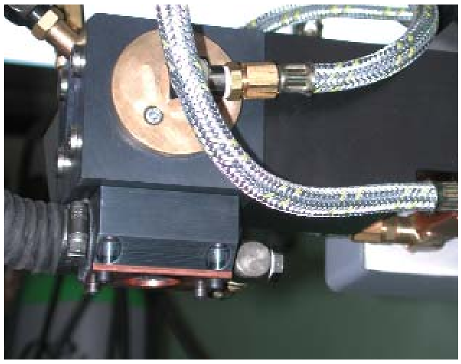

Fig. 2: Beam deflection optics lasertronic® SAO 10.6(1D)

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R&D-offer: Thermal coating

Editor: Thermal spraying processes are one of the key technologies in your department. As a result of the new installation of your laboratory you now have the attractive high velocity flame spraying technology HVOF at your disposal. What opportunities can you offer to your customers with this technology?

Dr. Nowotny: This process variation of thermal spraying opens up a completely new application potential. Only a few years ago, it was unthinkable that hard metal coatings could be used for intensive point and line loads. Today we can fabricate high performance carbide coatings, which are capable to withstand even the extreme stresses in combustion engines. New material based technology solutions can also be found where hard metals such as WC/Co cannot be used for large components for cost or weight reasons. We can now apply coatings with properties comparable to sintered hard metals. This possibility brings these materials back into the user's realm in the form of sprayed coatings.

Editor: Laser beam buildup welding is visibly developing into a standard process for precision tasks in modern manufacturing. What were you able to achieve in this area with respect to system and process technologies?

Dr. Nowotny: Laser powder buildup welding is increasingly being established in industrial manufacturing. This simultaneously raises the demand for high volume, manufacturing capable solutions that can be integrated into the production flow. Our off-line programming system DCAM has proven to be a reliable and comfortable tool for the production preparation. We have continued to develop the software and it is now available for the various laser technologies as well as for the thermal spraying. Besides path programming functionality for CNC machines and robots the program supports the design of processing strategies and the choice of process parameters. The modular powder nozzle system COAXn was expanded by smaller variations, which can be more easily integrated, and by special diode laser nozzles. Currently we are working on a version that can be used with fiber laser technology. One example for the commercialization of the entire process chain is a robot system, which is now used in production for the buildup welding and hardening in the tool making and repair industry.

Editor: The global demand is increasing for fast and generative manufacturing processes of prototypes, components and tools that are fabricated from the originally designed materials. What do we have available at the IWS in the area of rapid technologies?

Dr. Nowotny: We have a direct metal deposition (DMD) process, which is based on laser beam buildup welding. It is available on industrial system technology for the various titanium, nickel and cobalt alloys as well as for steels. We also offer the fast and flexible precise cast prototyping (pc_{PRO}) for plastic parts with complex shapes. The manufacturing of only one small component is already cost effective. For the fabrication of large tools we have further perfected the MELATO® technology. We have fabricated tools for customers in the automotive and metal industries, which have meanwhile been successfully and extensively field-tested under production conditions.

Wer die Laterne trägt,
stolpert leichter als wer ihr folgt.

He who carries the lantern
easier stumbles than those who follow.
Jean Paul

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Examples of projects 2005

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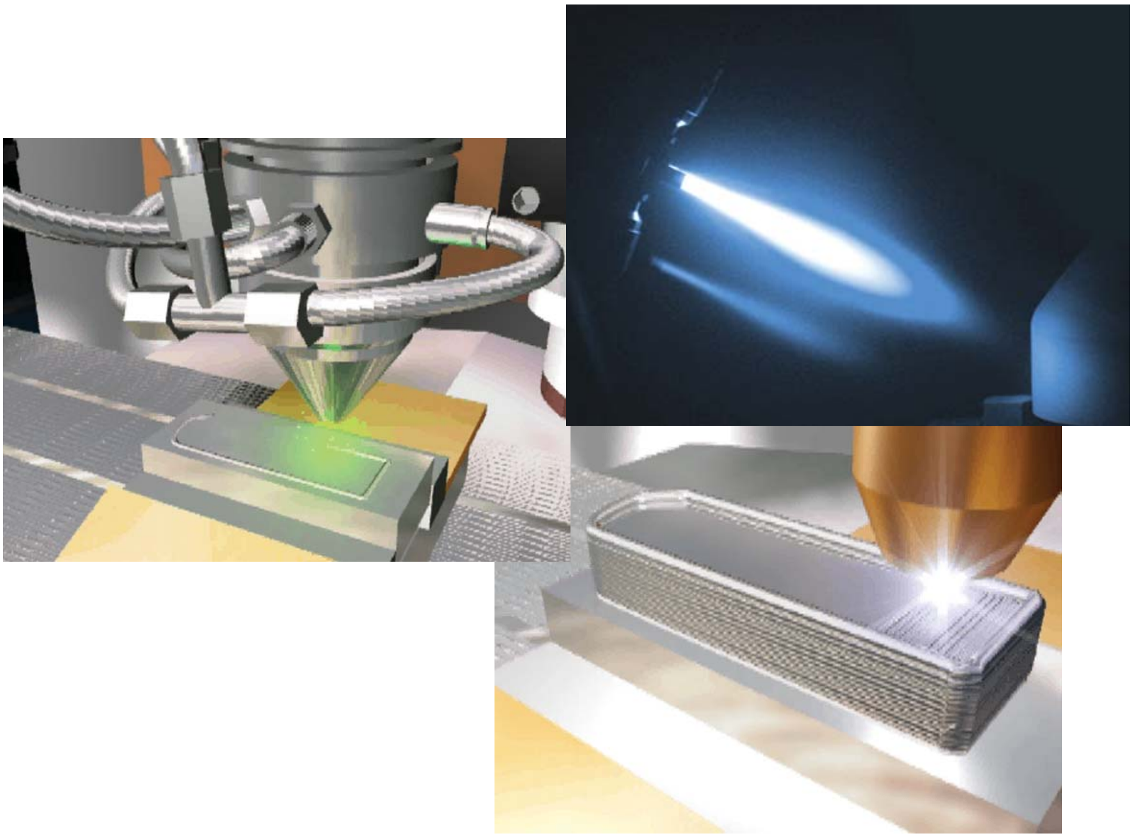

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Wear protection and functional coatings

The atmospheric (APS) as well as vacuum (VPS) plasma spray and flame spray processes are available at IWS for the coating of components made of steel, light metals or other materials with metals, hardmetals and ceramics. The hybrid technology Laser Assisted Atmospheric Plasma Spraying (LAAPS) complements the technology spectrum.

Based on the most modern spraying equipment, and in cooperation with other institutes of the Fraunhofer Institute Center in Dresden we offer:

- conception of stress adapted coating systems,
- development of complete coating solutions from the material to the coated part,
- development and manufacturing of system components,
- participation in system integration,
- support of the user with technology introduction.

Dr. Anja Techel
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Repair and generating

Laser beam and plasma powder cladding as well as hybrid technologies in combination of laser, plasma, and induction sources are available at the IWS for the repair and coating of components, moulds, and tools. Cladding, alloying or disperging of metal alloys, hard materials and ceramics can generate coatings and 3D structures. The complete process chain from digitizing and data preparation to the final processing can be utilized for all the technologies. For these application fields we offer:

- fast and flexible work piece digitization and data processing,
- precise repair and coating of components and tools, even with complex shapes,
- manufacturing of metallic and hard material containing samples and prototypes directly from the CAD data of the customer,
- system components and support during the introduction of the technology into production.

Plasma spraying of a shaft

Repair of gas turbine blades through buildup welding with high power diode lasers

Oxidation of HVOF-sprayed hardmetal coatings

Task

Oxidation determines the application limits of hardmetal coatings at high temperatures in atmospheric conditions. For this reason the oxidation behavior of HVOF (high velocity oxyfuel) sprayed hardmetal coatings (WC-12Co, WC-17Co, WC-10Co-4Cr, WC-20(W,Cr)$_2$C-7Ni, Cr_3C_2-25NiCr, (Ti,Mo)(C,N)-29Ni, (Ti,Mo)(C,N)-29Co) was studied. Also during the spray process oxidation and carbon loss occur and result in different starting conditions for atmospheric oxidation. Consequently, the specific action of different HVOF installations on oxidation of the material has to be taken into account.

Solution

Coatings of each composition were prepared using two different HVOF installations (Top Gun, Diamond Jet Hybrid) (Fig. 1). The coatings were oxidized with different combinations of time and temperature in a range of 350 - 900 °C.

Results

There is no significant influence of the different HVOF installations on the subsequent oxidation behavior of the coatings in atmospheric conditions. The coatings sprayed with the TopGun process are characterized by a higher degree of oxidation and carbon loss compared with those of the DJH process. The Cr_3C_2-NiCr and WC-(W,Cr)$_2$C-Ni coatings have the highest oxidation resistance. After an oxidation at 900 °C for 2 h the oxide scale thickness is below 10 µm. The oxidation resistance of the (Ti,Mo)(C,N)-Ni is only somewhat lower compared to the Cr_3C_2-NiCr and WC-(W,Cr)$_2$C-N coatings. The oxide scales of the (Ti,Mo)(C,N)-based coatings are characterized by a structure consisting of three subscales (Fig. 2). The outer subscale consists of the binder metal oxide (Co_3O_4 or NiO), the middle subscale of $CoMoO_4$ or $NiMoO_4$ and the inner subscale predominantly of TiO_2. The oxide scale thickness of the WC-Co and WC-Co-Cr is growing rapidly at temperatures above 600 °C (Fig. 3).

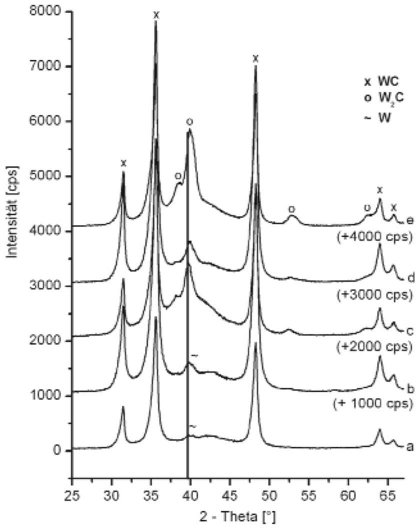

Fig. 1: X-ray diffraction pattern of the WC-Co and WC-CoCr coatings:
(a) WC-17Co (DJH), (b) WC-12Co DJH,
(c) WC-12Co (TG),
(d) WC-10Co4Cr (DJH),
(e) WC-10Co4Cr (TG)

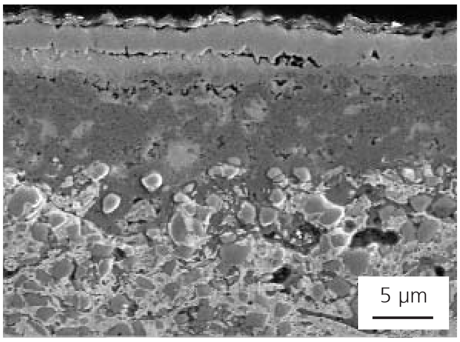

Fig. 2: SEM micrograph of a (Ti,Mo)(C,N)-Co coating after oxidation at 800 °C for 90 min

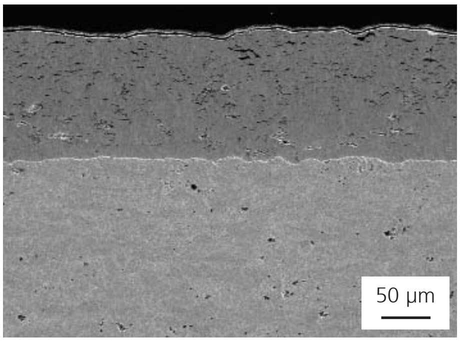

Fig. 3: SEM micrograph of a WC-17Co coating sprayed by DJH process after oxidation at 700 °C for 2h

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Off-line programming system for laser beam buildup welding

Task

For quite some time now laser beam buildup welding has been proven in industry as a coating and repair technology, but also as a method for rapid design changes. Increasingly inexpensive robot systems are used for a variety of 3D buildup welding tasks. It is common today to program robots by teaching (teach in programming) complex contours. However, this process is elaborate and time consuming. Therefore the task was to qualify the off-line programming system DCAM5 for the comfortable programming of robot systems.

Solution

The CAM system DCAM5 has been used for years for the programming of 3 and 5 axes portal machines for the laser beam buildup welding. The program makes it possible to generate individual tracks, lettering, areas and any desired volume elements on flat and curved surfaces.

As a first step 3D CAD data of the workpiece are either generated with the CAM system or imported. Then the software separates the surfaces, to be coated, and calculates the necessary paths. A variety of different coating strategies are considered. The corresponding parameters can be freely chosen such as feed, laser power, track width, overlap, starting point displacement, and in and over runs. The next step is the test of the path to avoid collisions between workpiece and machine components. This is especially necessary since the working distance is commonly less than 15 mm during laser buildup welding. If potential collisions are identified, it is possible to change the workpiece direction or angle along path segments or the entire path. The technological parameters can also be changed at this point.

The physical presence of the workpiece is not necessary up to this processing step. If the part to be coated becomes available, its position will be synchronized with the simulated data. Three prominent locations on the workpiece are transferred into the CAM system for the workpiece transformation. A final simulation of the planned paths has to confirm that the coating process has full access to the workpiece surfaces. If confirmed, the resulting programs are issued and the coating process can be started.

Results

The time to prepare buildup welding processes can be significantly reduced by using the off-line programming system DCAM5. The system also helps to use the machine optimally. Aside from programming 3 and 5 axes CNC machines, the system is also capable to program robots with simultaneous rotating and swiveling tables as well as a linear axis.

The use of the off-line programming system is not limited to laser buildup welding. It can be efficiently employed for all kinds of path controlled processes such as laser beam hardening, cutting, welding etc. Even applications such as dosing of solder or adhesives are feasible.

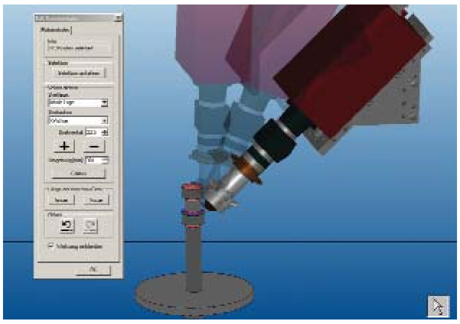

Fig. 1: Path calculation and simulation of the path motion in DCAM5

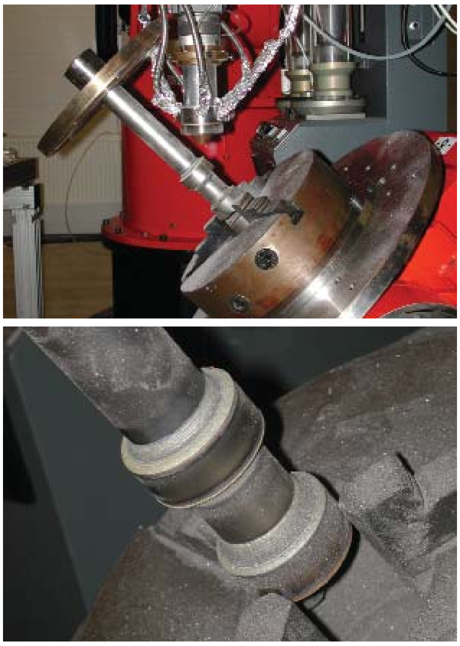

Fig. 2: Workpiece coating at the robot

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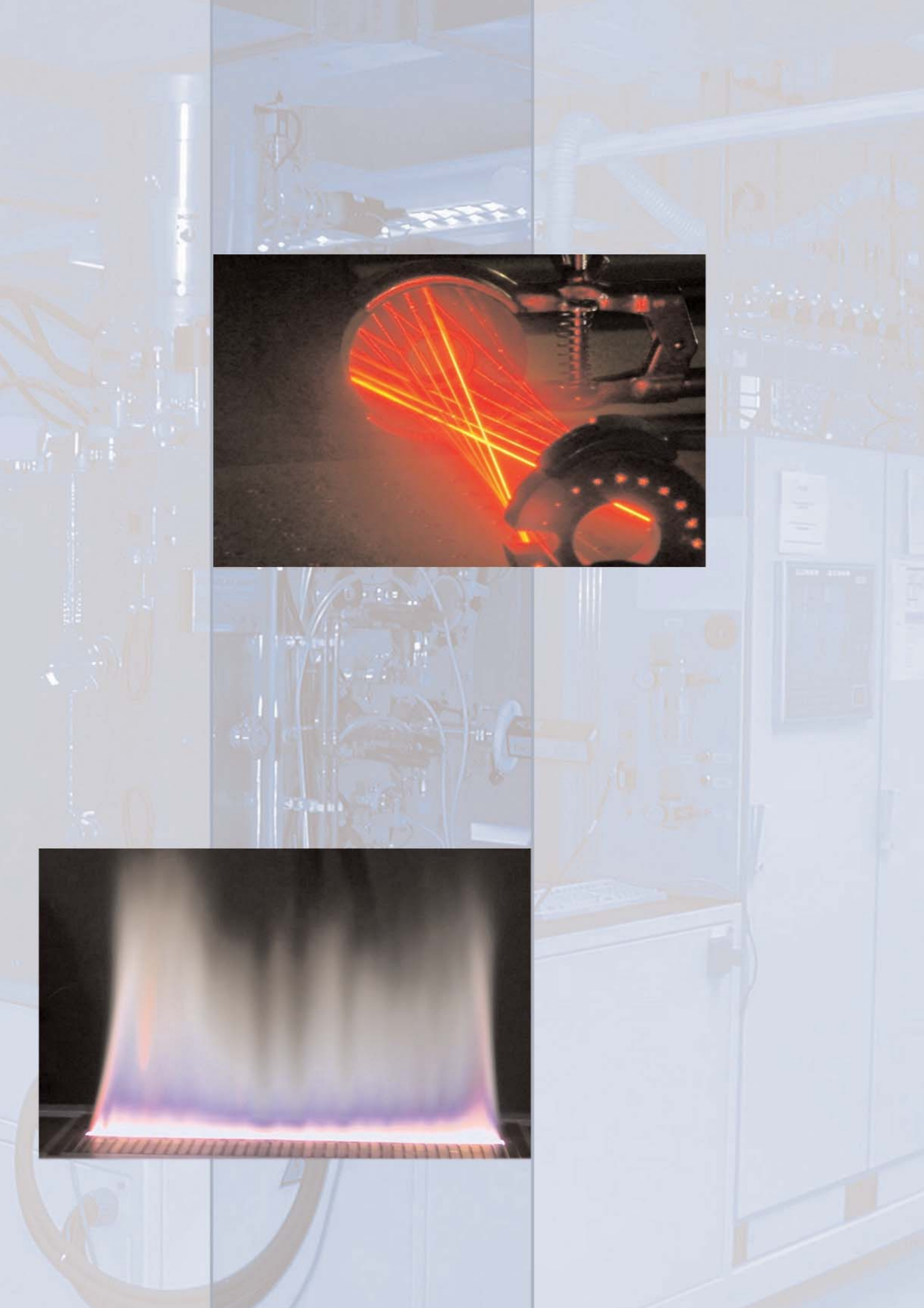
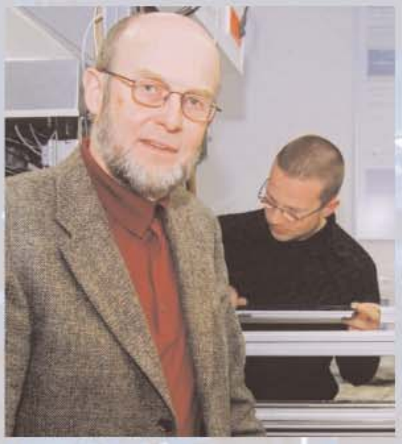


R&D-offer: CVD thin film technology



Editor: During the IWS expansion, your department »CVD thin film technology« received new and generous offices. However, your colleagues could rarely be found in their new offices. Why?

Dr. Hopfe: Well, they have been busy. To mention only a few typical tasks; they have been working on deposition machines, in the spectroscopy laboratory or they have been installing optical sensor technology at the customer site. The complexity and diversity of our tasks have been clearly increasing in the past year. We focused on starting up prototype machines for plasma assisted CVD processes on the development of coating systems for new applications, and on the implementation of highly sensitive sensors for the control of industrial systems. After a phase of internal consolidation both groups are now concentrating on an efficient and customer focused working style. We achieved a dynamic growth and were especially able to increase the project volume directly funded by industry. We were very fortunate to establish increasing cooperation opportunities with local companies. That not only creates »shortcuts« but also allows us to better fulfill our specific mission to support the development of the territorial industry.

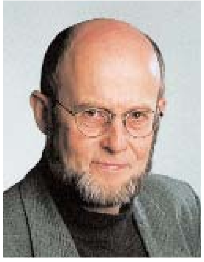
Editor: You and a medium-sized company in Dresden have jointly developed the multi gas sensor ISPROM®. During the last year the sensor has been transferred to a local microelectronics fabrication plant for long-term testing. How did the test go?

Dr. Hopfe: The field test is still running; and has been for more than a year. ISPROM® is being used in a CVD cluster tool, which is part of a 300 mm wafer line. The sensor continuously monitors in-situ the gas atmosphere in the reactor. Employees responsible for production report about the correlations between wafer quality and reactor state, which could be derived, thanks to an innovative sensor concept. Therefore the main goal is achieved and numerous opportunities for its application can now be pursued. Before the test, there were those thrilling questions regarding long-term sensor stability and whether it would prematurely malfunction in the industrial reactor. You may be able to imagine that the offer to test the, at the time, only laboratory tested device in the production line offered not only opportunities but also carried significant risks. Therefore we are now very optimistic, since the sensor functioned maintenance free and does not exhibit any degradation during the tough long-term test.

Editor: In your department you primarily focus on the development of atmospheric pressure plasma coating processes. In the past year you also performed developments in the area of plasma chemical etching. Is this an attempt to establish an additional focus area or potentially new business areas?

Dr. Hopfe: In the end, both. Plasma chemical removal (the so-called dry etching) is similar to PECVD in terms of the process technology. Therefore we can establish the process by only slightly changing our in-house developed plasma systems. The potential applications are numerous, ranging from the soft cleaning before deposition to large area material removal. Currently we are focusing on processes for the fabrication of photovoltaic power cells. An optimized surface texture aims at maximizing the energy coupling from the sunlight and thus increases the efficiency of the cells.

My interest is in the future because I am going to spend the rest of my life there.
Charles F. Kettering



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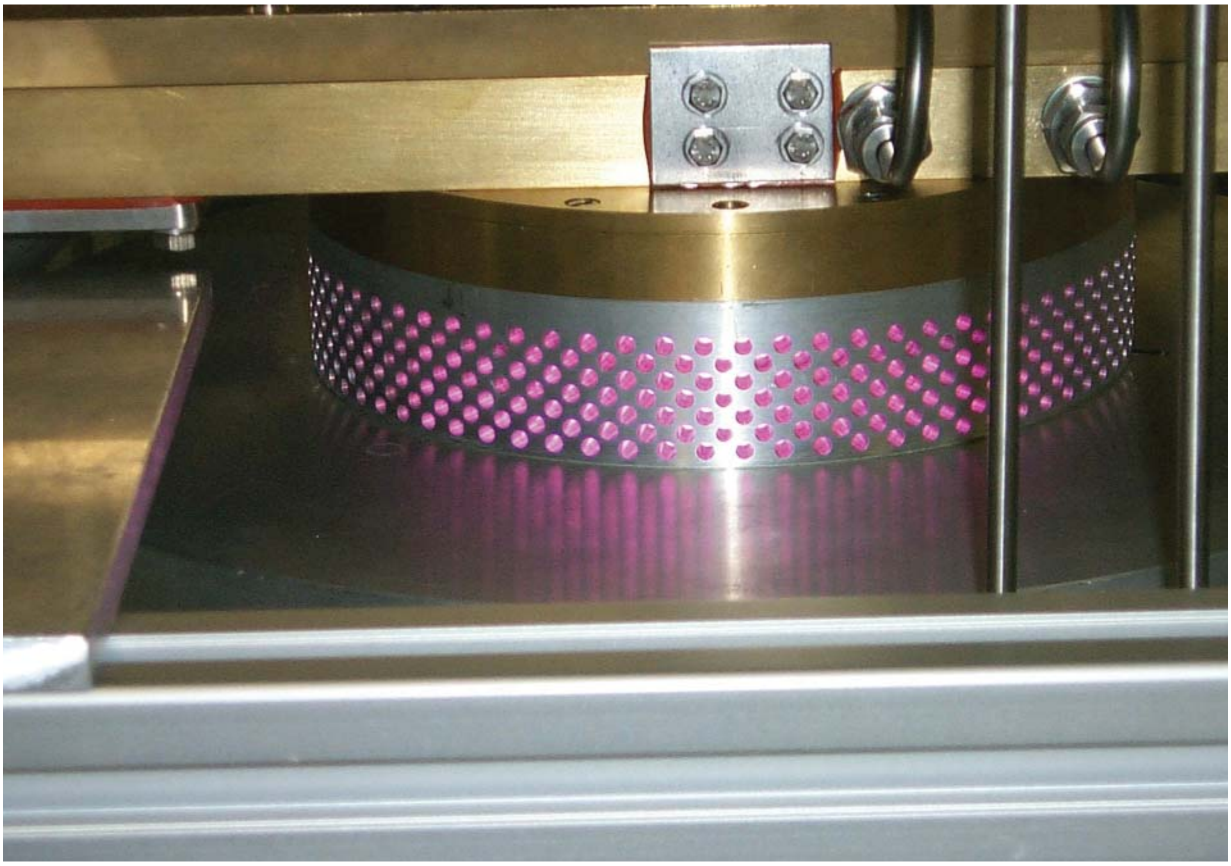

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Plasma activated CVD processes at atmospheric pressure

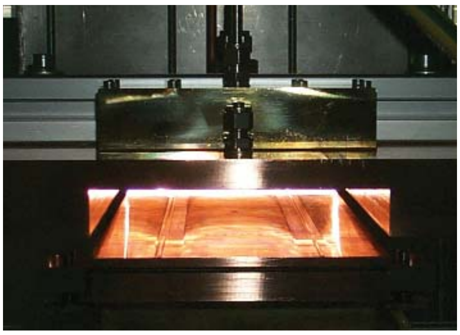
The large area deposition of high quality functional coatings is possible through atmospheric pressure plasma CVD processes (AP-PECVD), avoiding the need for expensive vacuum equipment. It is possible to implement continuous coating processes with high deposition rates on flat and even slightly curved temperature sensitive materials such as special steels, lightweight metals, glasses, and polymers.

At the IWS we develop prototype AP-Plasma-CVD in-line reactors with gas locks for the deposition of oxides and non-oxide coatings at atmospheric pressure. The optimization of the reactor design is based on experimental results and fluid dynamic simulations. The modular reactor design allows for a cost effective adaptation of the process to new application areas and coating materials.

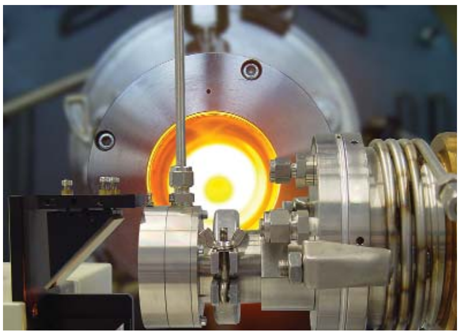
Process monitoring

In many cases the optimal function of industrial equipment and the quality of the manufactured products depend directly on the gas atmosphere inside the system. Therefore its composition has to be monitored at tight tolerance levels. An industry compatible gas analytics is essential for the quality control of chemical deposition, etching, and sintering processes and for monitoring the emissions of industrial machines. For customer specific solutions to continuously monitor the chemical composition of gas mixtures, IWS is using sensors that are alternatively based on either NIR diode laser or FTIR spectroscopy.

Furthermore we analyze surfaces and coating systems with spectroscopic methods such as FTIR spectroscopy, spectro-ellipsometry or Raman microscopy.



View of the coating area of the ArcJet-PECVD system



FTIR monitoring of high temperature processes

Dry etching of solar wafers with atmospheric pressure plasmas - surface texture and gas phase chemistry

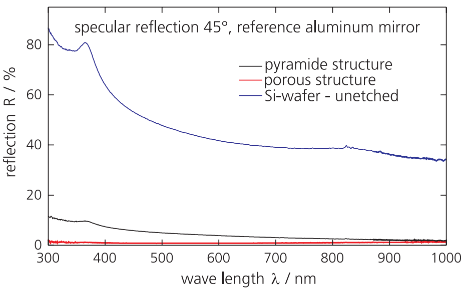


Fig. 1: Reflection spectra of the generated surface structures compared to an untreated surface

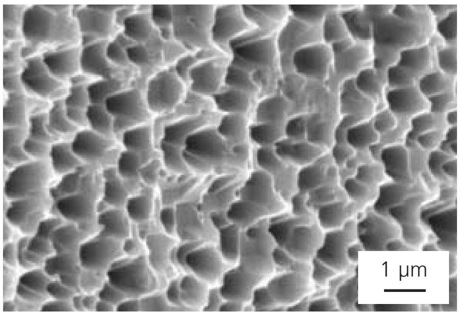


Fig. 2: Plasma chemically etched silicon surface - porous structure

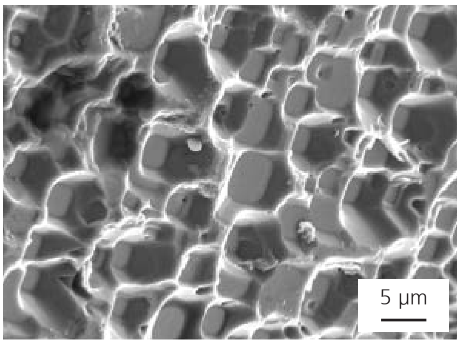


Fig. 3: Plasma chemically etched silicon surface - pyramid texture

Task

The costs of solar cells are critical for the competitiveness of photovoltaic energy generation. Opportunities for cost reduction are less expensive materials and more efficient in-line manufacturing processes. As a first step of a future in-line solar cell manufacturing process, we evaluated the feasibility of a pass-through plasma etching process at atmospheric pressure. This process would not only reduce the investment costs but also lower the wafer handling costs and cause less wafer breakage. Research is required to understand the plasma chemical etching process properties at atmospheric pressure and the influence of the etching conditions on the surface texture. A favorable surface texture improves light coupling and thus the efficiency of the solar cell.

Solution

A linear DC arc discharge with a processing width of 150 mm has been used as the atmospheric pressure plasma source. The plasma gas streams perpendicular through the arc and transports the excited species out of the source towards the substrate. The etching gases are those typically used in the microelectronics industry. Examples are the fluorine containing gases sulfur hexafluoride SF_6 and nitrogen tri-fluoride NF_3. To ensure the long-term stability of the plasma source, these reactive gases are introduced into the afterglow plasma. The substrate is a mono-crystalline Czochalski solar wafer and moves at speeds of up to 100 mm s^{-1} through the reactor. To transport the wafer, the pass-through reactor is open on both ends. A fluid dynamically optimized gas lock system controls the gas atmosphere in the etching zone and prevents gaseous reaction products from leaking into the environment. An exhaust gas disposal system cleans the exhausted gases. The plasma chemical reactions in the etching zone have been continuously monitored using FTIR gas phase spectroscopy.

Results

Using the described atmospheric pressure plasma process we achieved on polished Si wafers etch rates of 7 µm min^{-1} for SF_6 and 12 µm min^{-1} for NF_3. At a pass-through speed of 100 mm s^{-1} this corresponds to 0.7 µm for SF_6 and 1.4 µm for NF_3. The texture of the etched surfaces differs for varying process parameters. Low etch rates result in porous and nano-textured surfaces whereas high etch rates cause micro-textured surfaces, which consist of inverse pyramids. The surface texture strongly reduces the reflection of radiation. Using FTIR spectroscopy we were able to monitor the fragmentation of the etching precursor as well as the formation of the gaseous etching product (SiF_4). Their concentration ratios are very strongly influenced by the process parameter.

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ISPROM® - a multi gas sensor for the in-situ monitoring and control of industrial gas phase processes

Task

A vast number of fabrication steps in the semiconductor industry are based on gas phase processes. Examples are the film deposition using Chemical Vapor Deposition (CVD) or the plasma chemical etching. The quality and costs of the processed wafers depend to a high degree on the detection as well as the stabilization of optimal process conditions. The process performance is directly determined by the quantitative and qualitative composition of the process gas atmosphere. The goal of our work at the Fraunhofer IWS is to develop industrial-suited sensors for the continuous monitoring of gas atmospheres for quality control and process optimization.

Solution

In collaboration with the company SEMPA Systems, we developed the in-situ multi gas sensor ISPROM®, which is based on Fourier transformation spectroscopy.

To develop an industrial-suited sensor we benefited from longtime experience with FTIR based process characterization and monitoring. Another important tool was the extensive fluid dynamical simulation to identify optimal customized flow parameters.

Results

The ISPROM® multi gas sensor FTIR system is modular, flexible and can be integrated into an IT infrastructure. It is possible to monitor continuously and in-situ almost all process relevant gases directly in or in close proximity to the process chamber. Depending on the process phase the sensor simultaneously and continuously detects precursors, dopants, etching gases and, for the process control especially important, the intermediate and reaction products. The monitoring does not require a costly extraction and preparation of the gas mixture. The measurement occurs exactly where the gases originate from. The sensor works reliably and maintenance free even in strongly particle contaminated gas atmospheres.

The recorded temporal gas concentration data are sent via standard interfaces to the process control system, which then derives correlations to the process state and the expected product quality.

The developed in-situ multi gas sensor has been evaluated long term in a CVD production machine for 300 mm wafers (TEOS / O_3 process). The flexibly designed sensor system offers the possibility for online process monitoring and process control for a variety of industrial processes and is not limited to the semiconductor industry.

ISPROM
in-situ
process
monitoring

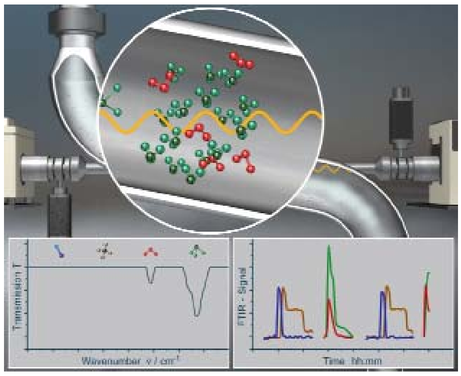

Fig. 1: Schematic of the in-situ multi gas sensor ISPROM® for the continuous monitoring of process relevant gas mixtures

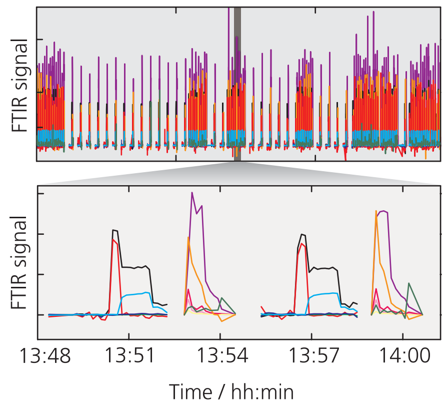

Fig. 2: Typical gas concentration plots for a CVD machine processing 300 mm wafers

Contact

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R&D-offer: PVD thin film technology

Editor: For years your department has focused on super hard amorphous carbon coatings (ta-C). What's new?

Prof. Schultrich: The most important development in this area is actually currently happening in the market place. Based on customer requests and projects especially from the automotive industry we clearly see an increased interest in ta-C coatings.

Editor: How do you explain this increasing demand?

Prof. Schultrich: I think it is primarily based on the ambitious goals of the automotive industry to reduce fuel consumption and emissions. The expected increase in tribological stresses is exceeding the performance capabilities of currently used materials and surface treatments. The ta-C coating combines a very high hardness with non-adhesive properties, which in many cases offers promising solutions. Certainly, the increasing level of awareness and understanding of ta-C coatings in comparison to various other carbon coatings plays an important role.

Editor: But there is certainly competition?

Prof. Schultrich: Yes, fortunately. Several companies have already gained positive experiences with ta-C coatings from competing institutions. Or they know about those experiences of their competitors and therefore come to us.

Editor: But in that case the IWS ta-C coating should exhibit convincing advantages?

Prof. Schultrich: Yes, our Diamor® coatings are especially distinguished in several areas; one advantage is the possibility to reliably deposit adhering coatings of five microns and thicker, thanks to an optimized coating design. The second key advantage is the available deposition technology, which is suitable for mass production. Last, but not least, we are, jointly with our partners, ready and capable to deliver industrial coating systems with integrated ta-C technology.

Editor: Where do you see the future potential for ta-C coatings?

Prof. Schultrich: To best utilize coating technology it has to become an integral part of the production process design from its very beginning. For example, a current focus is the design of surface topography, which is a result of both the machining process of the work piece and the coating process.

Editor: Are there other promising market segments besides the tribological components?

Prof. Schultrich: We have very promising test results from experiments machining non-ferrous materials and especially aluminum alloys. This is an area we will pursue. Forming tools offer new opportunities for smoothened Diamor® coatings. Currently we are testing these coatings as ultra barriers. We also took the risk to leap into a completely new applications area, the mass production of single wall carbon nano tubes, which is based on our experiences with carbon coatings.

An attempt is nothing,
only the result is what counts.
George Bernard Shaw

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Examples of projects 2005

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www.iws.fraunhofer.de/projekte/017/e_pro017-03.html

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Coating with super hard amorphous carbon

Amorphous carbon coatings with tetrahedral diamond bonds (ta-C) combine high hardness, low friction, and chemical inertness. Therefore they are exceptionally useful as protective coatings. The IWS developed ta-C coating systems (Diamor®) can be deposited with excellent adhesion in the thickness range from a few nanometers up to several tens of micrometers. The deposition occurs at low temperatures in vacuum through a special developed pulsed arc process. For the commercialization of Diamor® coatings the IWS delivers jointly with partners the technology as well as the necessary deposition sources and coating equipment. The offer also includes the laser acoustic quality control and process optimization equipment LAwave®.

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Coating through activated high rate processes

Processes involving the physical deposition from the vapor phase (PVD = physical vapor deposition) allow for the deposition of high quality tribological and functional coatings in the thickness range from a few nanometers to several tens of micrometers. At the IWS, we have a number of technologies at our disposal from high rate evaporation to highly activated plasma processes and their combinations. A special focus is the extensive utilization of arc discharges, which are the most effective source of energy rich vapor jets. Based on these technologies we offer:
- sample coatings,
- coating characterization,
- development of coating systems,
- customer specific adaptation of coating technologies,
- feasibility and cost studies,
- development and manufacturing of adapted equipment components.

Equipment for the deposition of super hard amorphous diamond-like carbon coatings (Diamor®) based on the Laser-Arc process

Metal evaporation through electron beam technology

Super hard carbon coatings for dry running gears

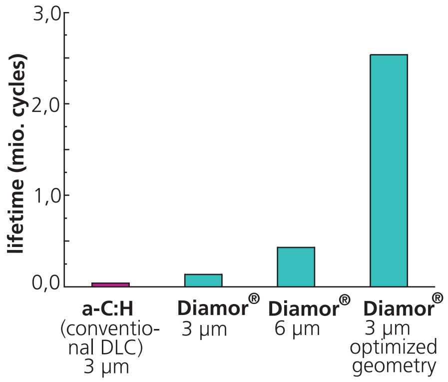

Fig. 1: Comparison of lifetimes (cycles until the coatings are worn through) for different coatings

Fig. 2: Gear coated with 3 µm Diamor®

Fig. 3: Diamor® coated gear with loss-minimized geometry

Contact

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Task

Conventional gear pairings in motors and transmissions are almost invariably made from steel. As such they require lubrication to avoid high friction losses or extensive wear will lead to destruction. Lubrication, however, always requires the need for maintenance and implies ecological and cleanliness issues. Lubrication free gears can be made from solid ceramics. These materials exhibit low wear. However, the high coefficients of friction lead to large power dissipation, heating and noise. The ideal solution would be a coating for conventional gears that provides lifelong wear protection and low friction such as in lubricated contacts.

Solution

Hard amorphous carbon coatings are promising candidates for this application since the combine the required properties of low wear and low coefficient of friction under dry conditions. The IWS developed Diamor® carbon coatings are especially predestined. They are highly diamond-like and super hard (H > 40 GPa). Initially the Diamor® coatings have been thoroughly tested in a two-disk tribometer. Friction and wear was determined for different contact pressure and the coating system was adapted to the required load. The measured coefficients of friction (coating versus coating, dry) did not exceed 0.15, even for contact pressures of more than 1,300 MPa and slippage of 30 %. The preliminary tests promised the possibility to use Diamor® coatings in high performance gear applications.

Results

The transfer of an optimized coating system was initially done for a gear pairing with conventional geometry (Fig. 2). Pairs coated with up to 6 µm of Diamor® were tested at different loads. After a brief run-in period the contact surfaces were highly polished. This was followed by a stationary state. The running noise was slightly higher than for oil-lubricated gears (85 dBA versus 82 dBA at medium loads).

Fig. 1. shoes the lifetime values of Diamor® coated gears at medium loads compared to a conventional DLC coating. With thicker coatings it is possible to achieve lifetimes that are sufficient for application. This is especially so for an optimized gear geometry. The loss minimizing geometry (Fig. 3) yields lifetimes of more than 2.5 million cycles.

These results are very promising for purely dry running applications. However the coatings also demonstrated their potential for being used in fail-safe and marginally lubricated contact applications. The investigations were part of the EU project »Oil free powertrain« and were partially performed at the Fraunhofer IKTS and at the Institute for Machine Elements and Machine Design at the TU Dresden.

Laser acoustic characterization of low-k dielectrics

Task

The ever-progressing integration of microelectronic circuits requires insulating materials with a low dielectric constant (low-k). Promising insulating materials are SiCOH xerogels with high porosity (up to 50 %), which achieve dielectric constants of k < 2.2. They exhibit good electrical properties. However, due to the high porosity, the mechanical strength is low. This is especially critical for copper damascene interconnect structures and has to be improved to withstand chemical mechanical polishing processes. The fabrication of highly porous low-k coatings with sufficient mechanical strength is therefore an important development task, which requires proper mechanical evaluation techniques. Our task was to identify a reliable characterization technique that measures the mechanical behavior of thin porous films. The high porosity is a difficulty for traditional tests. These tests also require much thicker coatings than those used in the described application.

Solution

The laser acoustic testing method LAwave® is based on surface acoustic waves. These mechanical waves only slightly deform the material and do not influence the pores. Thus the measuring device does not affect the measured data. The density and the elastic properties of the material determine the acoustic wave propagation. Therefore two important coating parameters can be determined, the density and the modulus of elasticity. The experimentally determined dispersion curve, propagation velocity as a function of frequency, is fitted by a theoretical curve to deduce density and modulus of elasticity. The modulus of elasticity is a fundamental mechanical material property, which indicates the elastic deformation behavior of the coating material. The density is a measure for porosity, which represents an important microstructure parameter of the low-k coating material. The test can also be applied to films in the submicron range.

Results

Careful and systematic experiments yielded the thinnest possible coatings for which it was still possible to independently determine density and modulus of elasticity. Fig. 1 shows dispersion curves measured for coatings in the thickness range from 72 to 821 nm. The lower limit to determine both properties is 155 nm. Below this limit it is only possible to determine the density of the coating.

The results are summarized in table 1. They express a good reproducibility of the measurements even for coatings that are thin enough to be technically interesting and too thin for conventional tests. The LAwave® test is simple and takes less than a minute. This is optimal for material development and technology control.

film thickness	modulus of elasticity E, GPa		density ρ, g / cm³	
	mean value	standard deviation	mean value	standard deviation
821 nm	1.8	0.01	0.866	0.002
422 nm	1.69	0.03	0.889	0.002
155 nm	1.96	0.6	0.87	0.013
99 nm	-	-	0.87	0.02
72 nm	-	-	0.91	0.02

Tab. 1: Results for the modulus of elasticity E and density ρ of low-k resistor films with decreasing film thickness

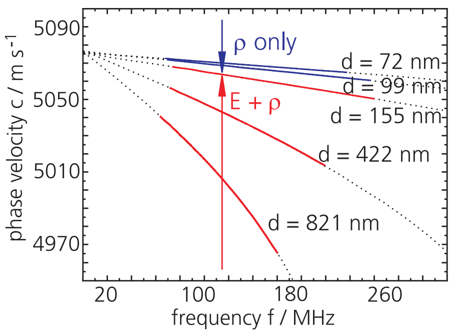

Fig. 1: Laser acoustic measuring curves for low-k resistor film with thickness in the range from d = 72 to 821 nm

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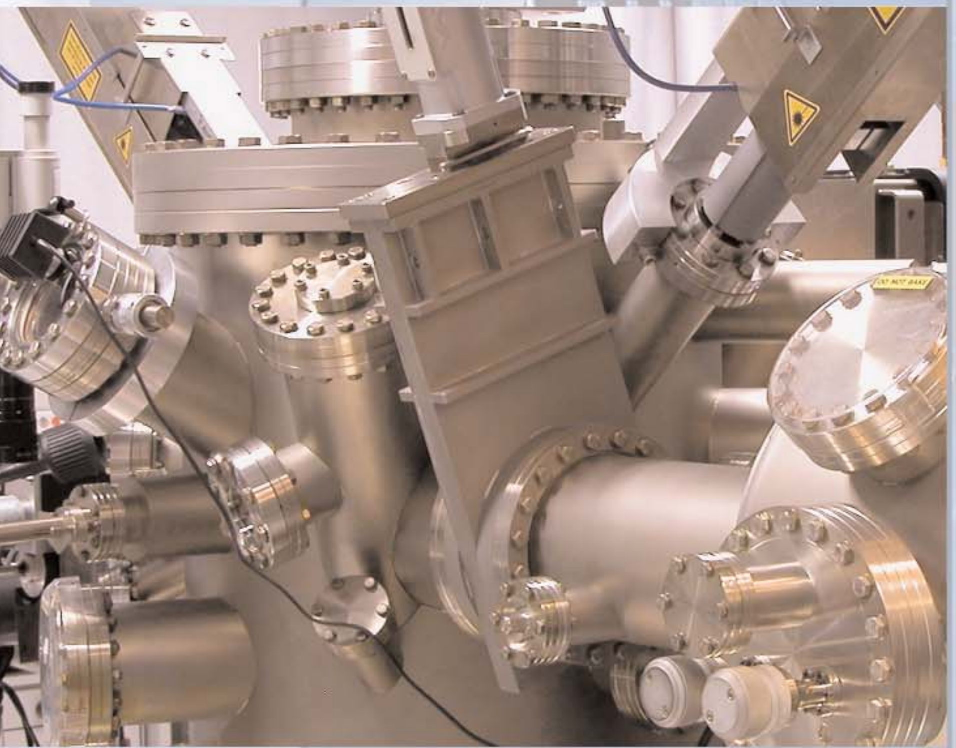

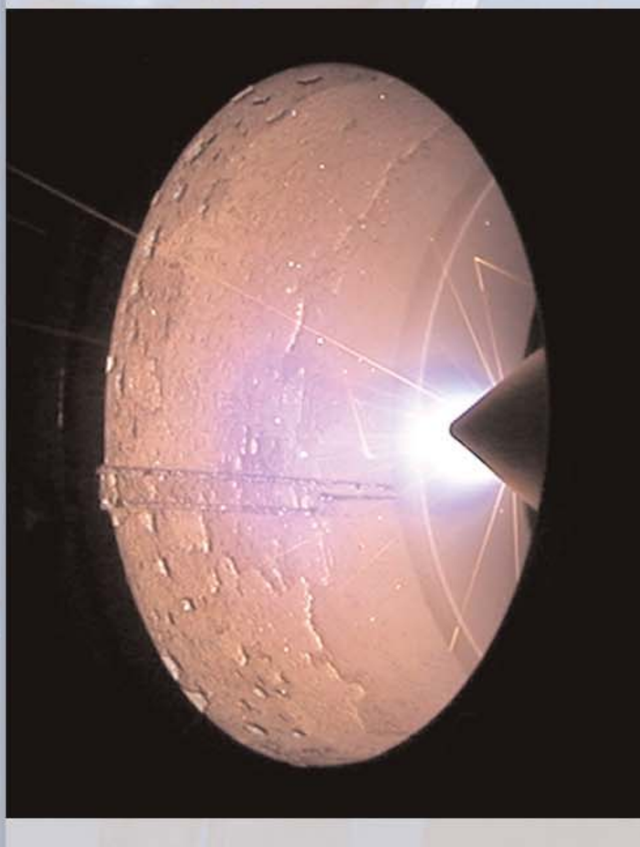

Editor: The core competencies of your department include the fabrication of X-ray optical components for classical applications of X-rays as well as for EUV applications. What progress did you make in 2005?

Dr. Leson: We clearly expanded our spectrum and are now able to offer high quality multilayer coating systems with excellent technical parameters for all interesting wavelength ranges. This is especially interesting for X-ray fluorescence analysis. In the area of EUV optics we are leading the world with respect to reflectivity for quite some time now. We continued to optimize other parameters such as the reduction of intrinsic stresses in the coating. In addition we were able to significantly increase our competence to generate gradient coating systems.

Editor: During 2005 you moved into new laboratory space in the IWS extension. What additional possibilities did you gain by doing so?

Dr. Leson: During the past few years our experimental possibilities were really quite limited due to insufficient laboratory space. The new laboratories enable us to utilize our existing systems much more efficiently. We can now operate the machines in clean-room conditions and therefore expect a significant improvement in precision and reproducibility during the fabrication of our multilayer coating systems. We also installed additional equipment; an ion beam sputtering system. It is a new coating technology for us and extends the possibilities we have had so far with magnetron sputtering and pulsed laser deposition. We hope to be able to utilize this new technique advantageously to fabricate very thin multi layers, only one to two nanometers thick.

Editor: Aside from precision coatings for X-ray components, your department also deals with other special coating systems. Which are those?

Dr. Leson: Pulsed laser deposition is not only used for X-ray optical components but also for the inside surface coating of components, which are difficult or impossible to coat with other PVD processes. Last year we perfected the process to coat inner component surfaces with very hard carbon coatings.

Entdecken heißt, sehen, was jeder gesehen hat,
und dabei denken, was niemand gedacht hat.

Discovery means to see what everyone saw,
but to think what no one thought before.
Albert Szent-Györgyi

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Examples of projects 2005

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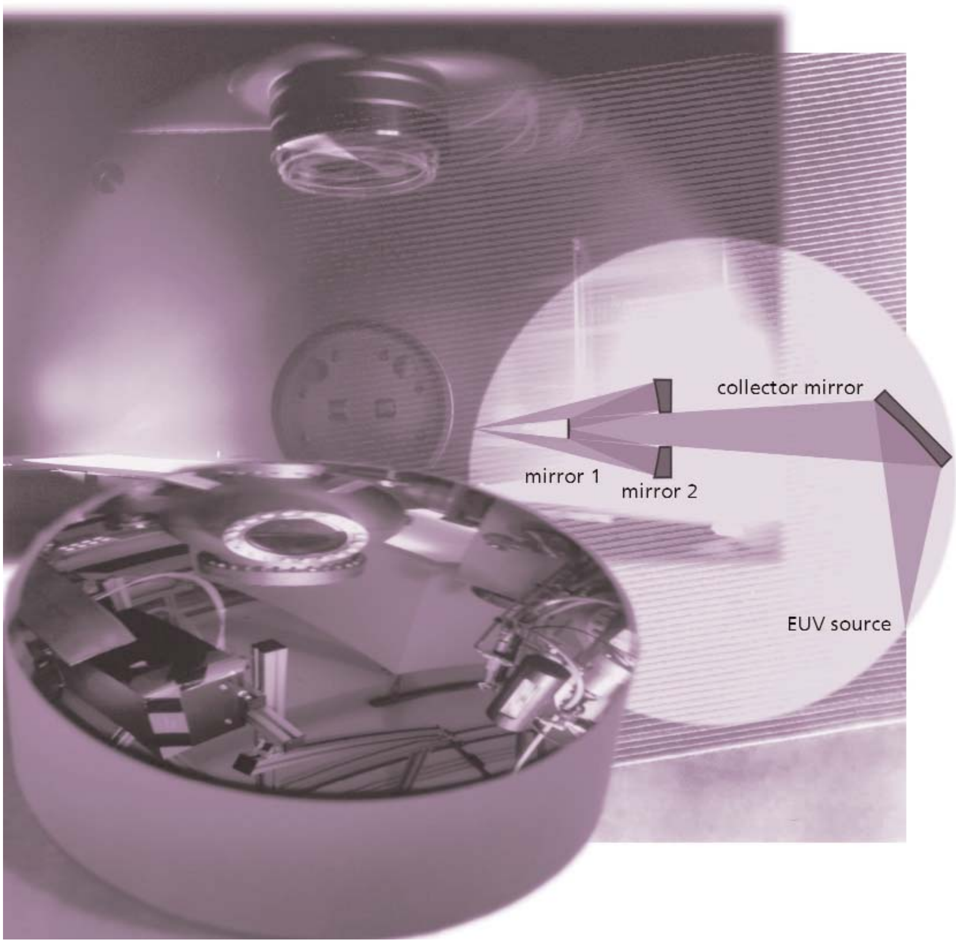

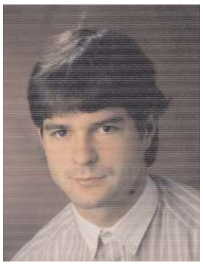

Dr. Stefan Braun
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Multilayer coatings for EUV and X-ray optical applications

Single and multilayer coating systems which are deposited through pulsed laser deposition and magnetron sputtering, are distinguished by:
- highest thickness accuracy,
- lowest interface roughness,
- high chemical purity,
- high lateral homogeneity and
- very good thickness reproducibility.

Coating systems of different material combinations can be deposited on plane and curved substrates with diameters of up to 150 mm with and without a gradient of the period thickness.

The main application area of these multilayer coatings is the production of X-ray optical components for beam shaping and monochromizing. Besides the synthesis of single and multilayer coatings according to customer specifications, we also offer our extensive experience in the area of preparation, characterization, and simulation of X-ray optical components.

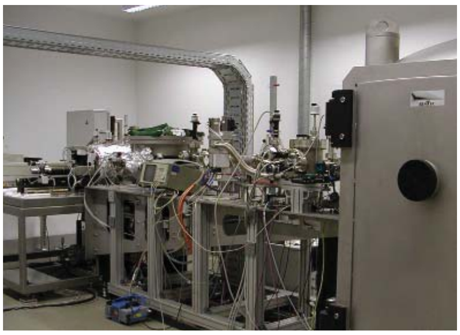
Metrology and applications

This group emphasizes on reflectometry, diffractometry, and the development of optical systems and measurement techniques.

Standard X-ray analysis tools apply Cu-Kα or Mo-Kα radiation for non-destructively measuring the coating thickness, roughness, and density as well as the qualitative phase analysis. Measurements are predominantly done on thin and / or multilayer coatings, but also on powders. Special beam shaping optical elements such as beam collimators and beam compressors have been developed to optimize the analysis techniques.

Optical components for applications in the range of extreme ultraviolet (EUV) radiation also require their characterization in the EUV range. Therefore we have developed a special laboratory tool, an EUV reflectometer, for the analysis in the wavelength range from 10 to 16 nm.

Substrate loading at an EUV precision coating machine for the manufacturing of nm-multilayer coatings



Overall view of the EUV reflectometer

Reflective coatings for the extreme ultra violet (EUV) spectral range

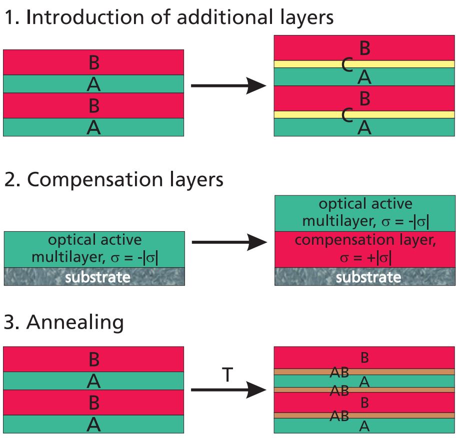


Fig. 1: Possibilities to reduce and compensate intrinsic stresses in nm multilayers

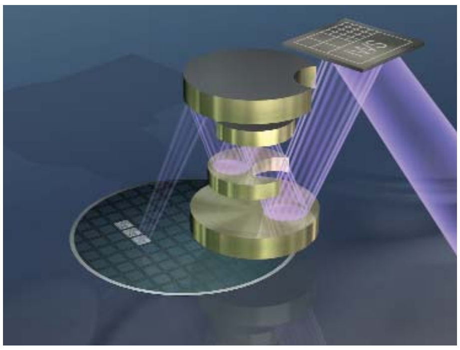


Fig. 2: Model of an EUV wafer stepper, which uses nanometer multilayer coating systems for the reflection of the radiation

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Task

According to the international technology roadmap of the semiconductor manufacturing industry, it will be necessary within in a few years to use extreme ultraviolet light (EUV). Light with a photon wavelength of 13.5 nm will be needed for the fabrication of structures, which are significantly smaller than 50 nm. The process requires reflective X-ray optics, which are made by depositing high precision nanometer multilayers. Over the past years we successfully developed highly reflective multilayer coatings based on Mo/Si.

The following criteria are essential to make reliable multilayer systems for high throughput, high precision and long lifetime:

- high reflectivity of the individual mirrors,
- precise film thickness gradients,
- low intrinsic stresses in the coatings.

We paid special attention to the compensation of the intrinsic stresses of the individual layers since these may cause deformation in lithography optics and micro mirrors.

Solution

The fabrication of highly reflective EUV mirrors requires coating techniques, which perform the deposition of multilayers with smooth surfaces. We are using magnetron sputtering at the lowest possible gas pressures. The introduction of barrier layers helps to reduce the diffusion as well as chemical reactions between the individual layers. Under these conditions we are able to produce mirrors with a reflectance of 70 %.

We use two methods to generate precise film thickness gradients; by varying the deposition time as a function of the mirror position or alternatively we can use masks with laterally varying transmission to deposit very well defined two dimensional film thickness gradients.

Aside from generating the high reflectance and the precise film thickness gradients, we have to conserve the highly precise surface contour of the mirror substrates. We therefore have to minimize the stresses within the reflective layers without reducing the reflectance.

The following measures help to reduce or compensate for the intrinsic stresses, which typically occur in nanometer multilayers:

- design changes by introducing additional layers to relax stresses,
- introduction of layers or layer stacks with opposite stress states for stress compensation,
- temperature treatment of the layers to relax stresses.

Results

By combining the three methods to reduce intrinsic stresses, one gets multilayers which are thicker than pure optical coatings but exhibit the same reflectance. The deformations of the mirrors can be avoided as a result of the significant reduction of the overall stresses. That means that we made progress in coating lithographic optics (Fig. 2) and micro mirrors.

Highly reflective monochromators for X-ray fluorescence analysis

Task

For many years X-ray fluorescence analysis (XRF) has been a powerful nondestructive method for qualitative and quantitative element analysis. It is used in manufacturing (e.g. the cement and pharmaceutical industries), quality assurance (e.g. detection of sulfur in fuels) and in environmental technology (e.g. monitoring of waste water and cleaning fluids).

All these applications require a continuous development of XRD system technology to lower the detection limits and measurement times. IWS research aims at improving the multilayer coatings, which are used for the monochromators. We are working on maximizing the reflectance and resolving power as well as on suppressing radiation reflections of high order.

Solution

A special advantage of the multilayer monochromators is the possibility to suppress reflections of higher order. For example, standard monochromators are unable to simultaneously detect oxygen and sodium because in the spectrum a second order sodium line overlaps the first order oxygen line. By varying the ratio of individual layers within one period, multilayer coatings specifically suppress higher order reflections. By using adapted materials it is possible to optimize the reflectance and resolving power of these special multilayer coatings.

Another challenge is the manufacturing of highly resolving multilayer monochromators. These require to precisely stack up 1,200 individual layers with thicknesses between 0.5 and 1.0 nm. Since these coatings are so thin, it is not possible to use barrier layers, which would reduce interface diffusion. Thus the materials choice is limited to only a few possibilities. It is also necessary to stabilize the deposition process to avoid any variation in deposition rate. W/B_4C multilayer coatings with 50, 300 and 600 periods and a period thickness of 1.24 nm have been analyzed at the synchrotron BESSY. The results showed that the increase in period number did not lead to an increase in the interface roughness of the individual layers.

Results

At the IWS we are able to customize multilayer monochromators by using appropriate materials and coating thicknesses. We improved the reflectance of the standard monochromators for XRF (IWS-ML-S) and developed multilayers for the suppression of higher reflective orders (IWS-ML-SOS). These coatings offer almost two orders of magnitude better suppression of second order reflections without significant losses in reflectance and resolving power.

For applications demanding high resolutions, we developed the monochromators IWS-ML-HR and IWS-ML-UHR. Those offer a 3 to 4 time improvement over standard systems.

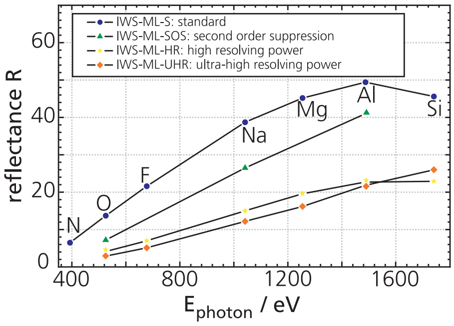

Fig. 1: Reflectance of different multilayer monochromators

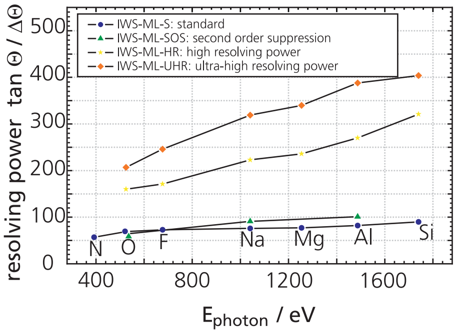

Fig. 2: Resolving power of different multilayer monochromators

Abb. 3: Utilization of an IWS multilayer monochromators in a XRF machine

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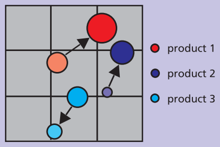

Offer: Marketing

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(phone: +49 (0) 351-2583-444,
ralf.jaeckel@iws.fraunhofer.de)

External and internal communications

The tasks of the communications group within the marketing department include the following areas of external and internal communications:
- processing of customer requests,
- trade fair and event organization, also for partners of the IWS,
- generation and actualization of printed media,
- generation and actualization of electronic media, also for our customers,
- product specific marketing,
- patent research, which is also offered to IWS partners.

Our marketing department colleagues support the technical departments in questions of strategic marketing as well as national and international research funding programs. During the last year we especially reinforced the areas of product marketing and patent management.

Dr. Siegfried Völlmar
Team leader media technology
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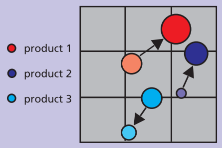
siegfried.voellmar@iws.fraunhofer.de)

Multi-media competence center

The presentation of research and development results demands the most modern communications technologies. The combination of text, image, video, and audio allows the tailored demonstration of complex technologies and processes based on physics and materials science. Even processes that are normally invisible to the naked eye or very fast can be visualized. Of special importance are safety relevant processes.

Our group offers the following services:
- generation of acquisition material for technologies and products,
- presentation design,
- photography and video taping with most modern digital technologies,
- recording of scientific events for live presentations or interactively usable CD-ROMs,
- 3D simulations of physical and technical processes,
- development of modern tools for »virtual reality« and »augmented reality« for technological research,
- development of a continuing education seminar collection in laser and surface technologies.



Optimization of surface cleaning and coating by virtual system simulation

Task

Industrial processes to clean and coat components are performed on machines which have a controllable range of parameters. A major issue during production is the shadowing of workpieces and system components, which is a result of the complex three-dimensional process. In many cases it takes the experience of long-term employees performing costly experiments to minimize these effects. In many cases it is also impossible to directly observe the process, which increases the difficulty. By combining the mathematical simulation of the processes with the visualization of systems and results, it could be possible to support the optimization of manufacturing flows. The task was to make this happen.

Solution

We developed a modular program packet, which allows the user to configure his specific system from subassemblies. The workpieces can be imported and placed within the system. For a number of coating and cleaning processes we offer modules that use simulation tools based on empirical knowledge phenomenological process descriptions. The system can be customized by choosing relevant modules. The software system only requires regular office PCs to run, so that it is affordable to small and medium sized companies. For more complex scenarios it is possible to directly use the simulation in virtual reality installation. Within the foreseeable future we expect affordable solutions.

Results

One application is the simulation of vacuum arc deposition in machines with defined workpiece motion and time controlled plasma sources (Fig. 1 and 2, program »SIMCOAT«). A requirement is the linearly propagation of the plasma particles. The results are thickness profiles, nanolayer structure and statements about the temperature regime in the machine and the coating zone.

The IWS software »FLAB« simulates the shot blast cleaning of cast parts in centrifugal blasting or overhead rail systems (Fig. 3). Physical properties such as the degree of coverage or the stress situation as a result of the surface processing are shown in false color.

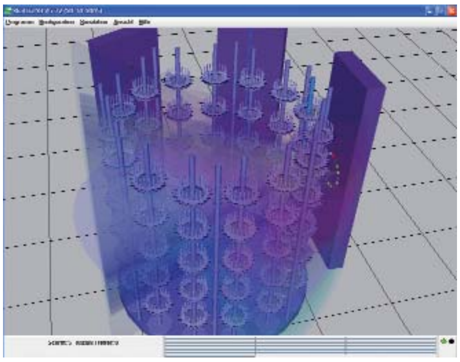


Fig. 1: Simulation of a coating machine with planetary with different plasma sources

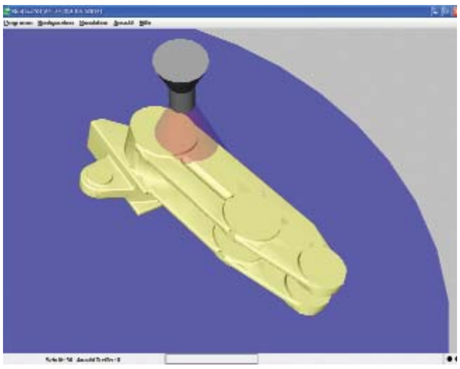


Fig. 2: Simulation of a cleaning or coating process with freely movable source

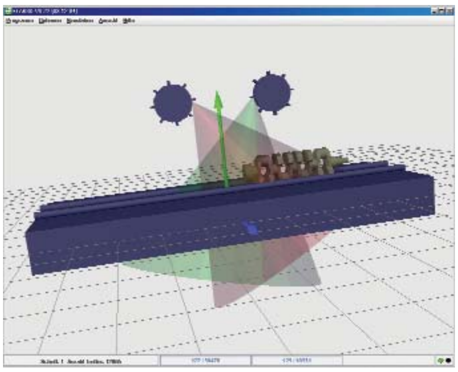


Fig. 3: Centrifugal blasting system for the cleaning of cast parts

Contact

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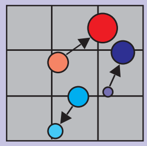

Generic implementation of laser processing technologies in immersive installations of virtual reality

Task

When implementing laser processing technologies, one faces complex three dimensional scenarios involving system behavior, workpiece specifics, material depending processing and extreme precision requirements. In reality, all requirements have to be implemented in a short time. We support this process with an accurate visualization. The task is to provide a development system to simulate and visualize the process and system technologies prior to implementation.

Solution

The solution lies in the unification of a visualization system and a software package to simulate potential system concepts.

The visualization can be used on a desktop computer as well as in VR installations. It enables the interaction with the virtual machine. At the IWS we have a VR system (Fig. 3). The three-page CAVE is equipped with optical tracking for the interaction with the 3D model, with an audio system for voice control, and with components for video conferencing. The system can run conventional VRML animations as well as our own freely programmable simulations.

The software package consists of tools to freely assemble systems for example based on blue prints, 3D scans of workpieces, or modeled components. Simultaneously, the motion concepts (rotations, translations, end point switches) are defined. The collision control is prepared for all components during the simulation of motion processes. It is also possible to model the beam path. The motion of optical elements is coupled to the dynamics of the processing system.

Prior to assembling the real machine or production testing, the software simulates the working rooms, accessibility, collision behavior, handling of additional components, beam shaping and conformance to technical specifications.

Results

Fig. 1 represents the combination of a laser beam hardening machine with a laser beam buildup welding machine. The control of the dynamics is done by coupling with the path planning system DCAM5 and with a virtual controller for the robot.

Fig 2. shows a beam shaping system and in particular how the beam is shaped and guided to the workpiece surface.

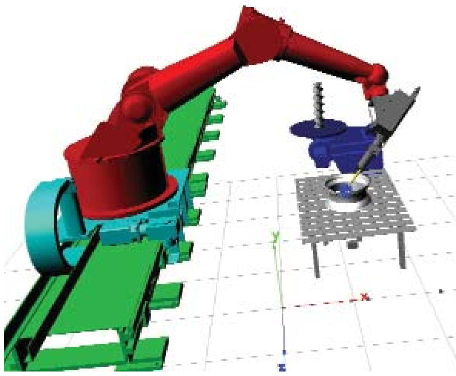

Fig. 1: Visualization of a combined machine for the hardening and buildup welding with a diode laser

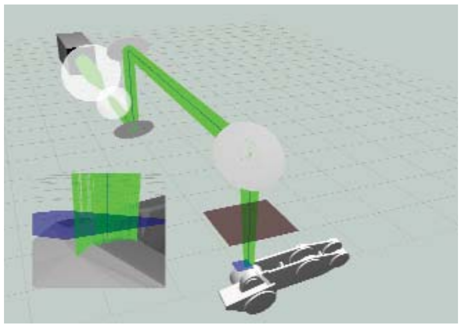

Fig. 2: Dynamic beam guiding system with calculated intensity profile at the workpiece surface

Fig. 3: VR installation for the visualization of machines and processes

Contact

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R&D-offer: Simulation and fundamentals

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Dr. Achim Mahrle
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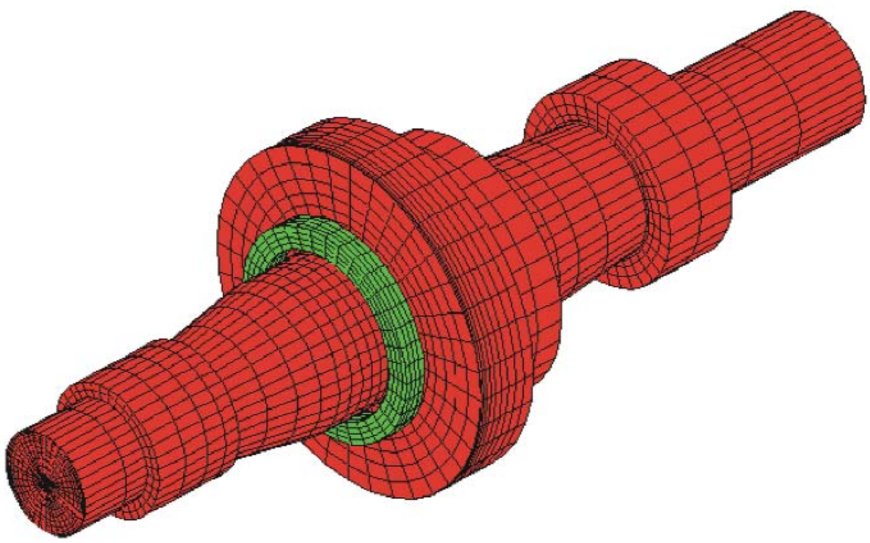
Examples of projects 2005

Process simulation and software development for the laser material processing

The saying goes »Trial and error outweighs the theoretical«. However, with modern high technologies »trial and error« might get very expensive. A possibly deep understanding of the processes in laser material processing makes their further development and optimization not only easier but also more cost-effective. Therefore process simulation at IWS has become an integral part of process development.



This is also true for process modeling up to the point of developing production capable software (e.g. laser hardening, laser powder deposition welding).

Model based estimates often make it easier to predict if, and by what means, it is possible to fulfill a detailed customer request. These models also help to find appropriate process windows. Analytical approximations as well as model experiments are also part of the IWS repertoire. They serve to visualize basic physical processes during laser materials processing and make them accessible for a detailed analysis. An example of this is the modeling of the influence of electromagnetic fields on the convection in the melting bath. Using these methods in combination with experimental data helps to determine so far unknown materials parameters such as absorption coefficients of technical surfaces.

further information:
www.iws.fraunhofer.de/projekte/059/e_pro059.html

Formation of thermoelectric currents in melting pools

Task

Using external static magnetic fields in the workpiece plane is a possibility to increase the speed and seam quality in laser beam welding. Experiments with fine-grained steel and aluminum alloys demonstrated the suppression of melt pool ejections. It was possible to significantly influence the quality of the top seam surface and the shape of the seam cross section. All these phenomena depend on the orientation of the magnetic field. The existence of thermoelectric currents in the melting pool has been postulated as an explanation. The interaction with the external magnetic field generates Lorentz forces in the melting pool, which cause the observed phenomena. The first question was whether it would be possible to theoretically derive and quantify these currents. In addition, we investigated how these currents would influence the geometry of the welding seam in the presence of external magnetic fields.

Solution

The basic equation of thermoelectricity implies that gradients in chemical potential and temperature or the sum of both may lead to a thermo-electrical current density. In the two dimensional case (corresponds to the welding of thin sheets) and under the assumption that the electrical conductivity in the melting pool does not depend on the temperature, it is possible to use Green's function to derive an analytic solution for the current density. The current density distribution can then be analyzed as a function of the Peclet number, which is the ratio of convective to conductive heat transport in the melting pool. The temperature field, which is generated by the laser, and the temperature-depending Seebeck coefficient have to be known.

Results

Fig. 1a shows the temperature field [in color, blue: isotherm of evaporation temperature (inside) and melting pool temperature (outside)] and the vector of the thermo-electrical current density (black arrows) for iron using a Peclet number of Pe = 4. The two isotherms confine the clearly visible homogeneous current density distribution. The direction of the current leads from the laser spot to the posterior rim of the melting pool and thus confirms the postulated current density distribution (Fig. 1b). In contrast the calculations for aluminum at Pe = 0.1 predict a reversed direction of the current in the melting pool (Fig. 2). In addition the current density exhibits two marked pairs of eddies: one pair in front of the laser spot and the other pair sideways behind the laser spot. Both pairs are located at the interface between liquid and solid material. This can be explained by a rapid change of the Seebeck coefficient at those locations. These thermoelectric currents in conjunction with the external magnetic field generate a Lorentz force, which can be directed to result in currents forming a more narrow and deeper welding seam.

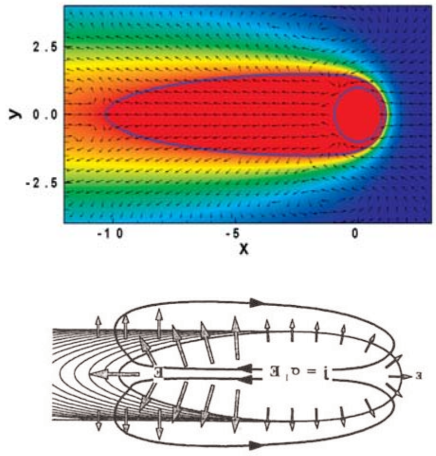


Fig. 1:
a) Temperature field [in color, blue: isotherm of evaporation temperature (inside) and melting pool temperature (outside)] and the vector of the thermo-electrical current density (black arrows) for iron at Pe = 4
b) Postulated current density distribution from Kern et al: Welding Research 79 (2000) 3 (for better comparison to a) rotated by 180)

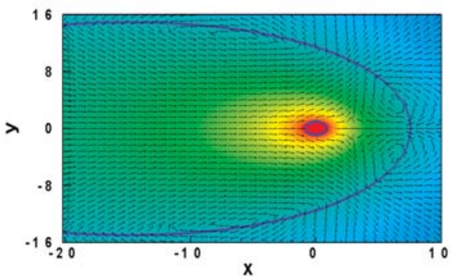


Fig. 2: Temperature field [in color, blue: isotherm of evaporation temperature (inside) and melting pool temperature (outside)] and the vector of the thermo-electrical current density (black arrows) for aluminum at Pe = 0.1

Contact

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Calculation of residual stresses during laser powder buildup welding

Task

Laser powder buildup welding is used to deposit hard and temperature resistant functional coatings for wear and corrosion protection. The material is deposited in the liquid state. The shrinking process of the material during cooling causes internal stresses. In particular for high strength materials, these stresses lead to the formation of cracks and to delamination of the coating. The formation of martensite in the substrate is additionally enhancing this effect. As a result the residual stresses limit the achievable coating hardness and process speed.

Within a DFG project we use process simulation and thermo-mechanical FEM calculations to search for new variants of energy deposition during laser cladding, which are able to minimize the residual tensile stresses.

Solution

The IWS software LAVA is used to simulate the shape and size of the melting pool and the resulting geometry of the welding track. The results are used as input data for the thermo-mechanical calculations, which are performed with the commercial FEM code SYSWELD. We calculate the residual stress distribution in the welding track and its vicinity in dependence on parameters such as feeding speed and track size. In addition we evaluate process variations with additional energy sources (laser, inductor) for pre- or post-weld heating.

Results

First calculations have been performed for the deposition of Stellite coatings on a construction steel. The results show tensile stresses in the welding track which are balanced by compressive stresses in the substrate. The martensite formation in the substrate increases these compressive stresses and thus, for reasons of equilibrium, also the tensile stresses in the coating.

Preheating helps to reduce the shrinking stresses and the cooling speed. As a result the formation of martensite can be suppressed. The local preheating with an inductor integrated in the process has some technological advantages. Currently we are performing systematic model calculations to search for optimal preheating parameters (preheating temperature or power, inductor size and position, feeding speed etc.).

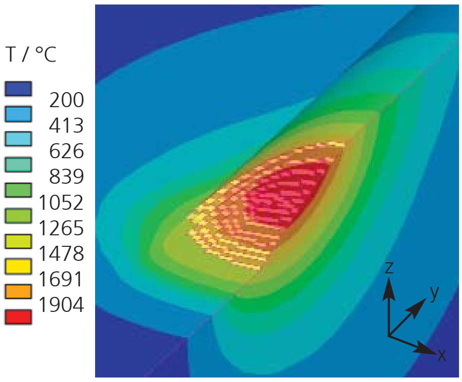

Fig. 1: Temperature distribution in the process zone during the formation of a welding track with laser powder buildup welding

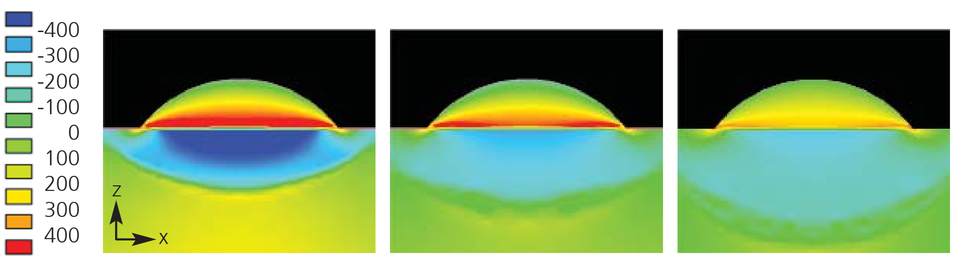

Fig. 2: Transversal stress distribution $\sigma_{xx}(x, y)$ in a welding track
a) without preheating,
b) local preheating with an integrated inductor (maximal preheating temperature 800 °C),
c) complete preheating of the entire workpiece to 500 °C

Contact

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Special events

February 2nd, 2005
Annual meeting of the nanotechnology competence center »Ultrathin Functional Films« at the Fraunhofer IWS

July 1st, 2005
Participation of the Fraunhofer Institutes Center during the »Long Night of the Sciences« of the state capital Dresden

July 14th, 2005
Visit of the Federal Minister for Research, Mrs. Buhlmann, at the ThyssenKrupp Steel AG surface center in Dortmund

September 21st, 2005
Workshop »BioMeT at location« at the Fraunhofer IWS Dresden

October 3rd, 2005
Saxon-British nanotechnology forum in London (Co-organizer: Fraunhofer IWS, Dresden)

November 22nd, 2005
1st International Fraunhofer Workshop »Fiber Laser«

November 23rd - 24th, 2005
»Workshop on Laser Applications in Europe« at the Fraunhofer IWS, Dresden

November 28th, 2005
»NanoCareer Forum - Where Education Meets Business« at the Fraunhofer IWS, Dresden

November 28th, 2005
»German-Canadian Round Table on Nanotechnology« at the Fraunhofer IWS, Dresden

November 29th - 30th, 2005
4th international nanotechnology symposium »Nanofair - New Ideas for Industry« in Dresden (Co-organizer: Fraunhofer IWS Dresden)

November 30th, 2005
6th special symposium on surface technology at the Dortmunder OberflächenCentrum at the ThyssenKrupp AG

December 1st, 2005
4th Ukrainian-German seminar »Nanosciences and Nanotechnology« at the Fraunhofer IWS in Dresden

Federal Minister for Research, Mrs. Buhlman, at the Dortmunder OberflächenCentrum at the ThyssenKrupp AG (July 14th, 2005)

The State of Saxony's Minister for Sciences, Barbara Ludwig, attends the »Long Night of the Sciences« (July 1st, 2005)

View into the foyer of the Fraunhofer IWS during the »Long Night of the Sciences« (July 1st, 2005)

Lecturing

Lectures at the Institute for Surface Technology and Production Metrology of the TU Dresden in winter semester 2004 / 2005:

- Prof. Beyer: Manufacturing technology II, (surface and coating technology)
- Prof. Schultrich: Thin film technology (special materials)
- Dr. Leson, Prof. Beyer: Surface engineering / nanotechnology
- Prof. Beyer: Rapid protocoating

Lectures at the Institute for Surface Technology and Production Metrology of the TU Dresden in summer semester 2005:

- Prof. Beyer: Laser basics / laser system technology
- Prof. Beyer: Practical training: Laser safety and process technology

Lectures at the Institute for Surface Technology and Production Metrology of the TU Dresden in winter semester 2005 / 2006:

- Prof. Beyer: Plasmas in production technology (mechatronics)
- Prof. Schultrich: Thin film technology (special materials)
- Dr. Leson, Prof. Beyer: Surface technology / nanotechnology
- Prof. Beyer / Mr. Kötter: Rapid protocoating
- Prof. Beyer: Robotics

Lectures at the Hochschule für Technik und Wirtschaft Dresden (HTWD):

- Dr. Nowotny: Laser materials processing

Committees

Prof. E. Beyer:
Member of the Executive Committee of the Fraunhofer-Gesellschaft

Prof. E. Beyer:
Cairman of the Fraunhofer Surface Technology and Photonics Alliance VOP

Prof. E. Beyer:
Director of the Institute for Surface Technology and Production Metrology IOF (TU Dresden)

Prof. E. Beyer:
Chairman of the work group »Engineering Sciences« as well as member of the board of the scientific society for laser technology WLT e.V.

Prof. E. Beyer:
Member of the Materials Research Association Dresden e.V.

Prof. E. Beyer:
Member of the Sachsenberg-Gesellschaft e.V.

Prof. E. Beyer:
Member of the Federal Association of Medium-sized Industries e.V.

Prof. E. Beyer:
Member of the board of trustees of the Palucca School Dresden, University for Dancing

Prof. E. Beyer:
Member of the European Research Society »Thin Films« e.V. (EFDS)

Prof. E. Beyer:
Member of the competence center »Aerospace Technology Saxony / Thuringia e.V.«

Prof. E. Beyer:
Member of the University Center for Aerospace (UZLR) of the TU Dresden

Prof. E. Beyer:
Member of the advisory board of the European Laser Institute (ELI)

Prof. E. Beyer:
Member of the board of directors of the Laser Institute of America

Prof. E. Beyer:
Member of the Society for Chemical Technology and Biotechnology e.V. (DECHEMA)

Prof. E. Beyer:
Member of the international advisory board of the Journal of Laser Applications (JLA)

Prof. B. Brenner:
Technical committee 9 of the AWT

Prof. B. Brenner:
Member of the advisory board of AiF

Dr. I. Jansen:
Member of the Society for Chemical Technology and Biotechnology e.V. (DECHEMA)

Dr. I. Jansen:
Member of the industrial task force »Intlaskleb« of the BMBF

Dr. R. Jäckel:
Working committee »Fairs and Public Relations« of the Materials Research Association, Dresden

Dr. G. Kirchhoff:
Working committee »Acoustic Emission Analysis« of the DGzfP

A. Kluge:
Speaker for the computer operators of the Fraunhofer-Gesellschaft

Dr. A. Leson:
Member of the international expert panel for the nanomat-program of Norway

Dr. A. Leson:
Speaker for the nanotechnology competence center »Ultrathin Functional Films«

Dr. A. Leson:
Committee member of the magazine »Vacuum and Research in Practice«

Dr. A. Leson:
Member of the future technologies board of the city of Dresden

Dr. A. Leson:
Member of the advisory council of the VDI

Dr. A. Leson:
Chairman of the VDI working circle »Study Programs in Nanotechnology«

Dr. A. Leson:
Member of the program committee of the VDI scientific advisory board

Dr. A. Leson:
Member of the international advisory board of the journal »Micromaterials and Nanomaterials«

Dr. A. Leson:
Member of the Board of the European Center for Micro and Nano Reliability e.V.

Dr. A. Leson, Dr. H.-J. Scheibe,
Prof. B. Schultrich, :
Task force plasma surface technologies of the DGO

Dr. S. Nowotny:
DVS working committee
V9.2 / AA 15.2 »Laser Beam Welding and Related Techniques«

Dr. S. Nowotny:
Association of Thermal Sprayers e.V. (GTS)

Prof. B. Schultrich:
Member of the board of directors of the European Research Society »Thin Films« e.V. (EFDS)

Dr. A. Techel, Dr. S. Nowotny:
VDI working committee »Rapid Prototyping« in the VDI district society, Dresden

Dr. B. Winderlich:
Work group »Stability and Construction« of the DVS-BV Dresden

IWS prizes in 2005

1. Best innovative product ideas

   E. Lopez, M. Rosina
   »Introduction of continuous atmospheric plasma processes to the solar cell production«

   Dr. S. Bonss, J. Hannweber,
   U. Karsunke, M. Seifert
   »Integrated hardening«

2. Best scientific technical performance

   F. Kretzschmar
   »On-line process control for the alloy welding of mixed joints from cast iron and case-hardened steels in powertrain applications«

3. Best scientific performance of a junior scientist

   H. Beese
   »Monitoring of critical trace gases in process and special gases through diode laser spectroscopy«

4. Best scientific student performance

   S. Lipfert
   »Improvement of the adhesion of super hard amorphous carbon coatings on inner surfaces«

   S. Saaro
   »Characterization of oxide coatings on thermal sprayed (HVOF) hard metal coatings«

5. Special prizes / exceptional thanks

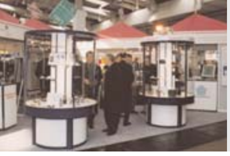
   M. Schwach
   »For his special performance during the comprehensive failure analysis, which lead to an image gain for IWS«

   I. Dani
   »For her exceptional performance during the organization, expansion and management of a working group at IWS«

   U. Klotzbach
   »For his exceptional performance as the managing director of the VOP and the simultaneously very successful expansion of his working group micro processing / cleaning«

Dr. Dani received a special prize for her exceptional performance during the organization, expansion and management of a working group at IWS

Dr. S. Bonß, J. Hannweber and U. Karsunke during the bestowal of the institute's prize for the best innovative product idea



Diploma theses

H. Behrends
(Technische Universität Dresden)
»Entwicklung einer virtuellen Laserbearbeitungsanlage«
»Development of a virtual laser processing machine«

T. Birkeneder
(Hochschule Mittweida (FH), University of Applied Sciences)
»Untersuchungen zum Laserstrahlschweißen von Aluminiumwerkstoffen im T-Stoß für luftfahrtspezifische Strukturen mit Festkörperlasern«
»Investigations of laser beam welding processes for aluminum materials in T-butt for aerospace specific structures using solid state lasers«

R. Böhme
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Laservorbehandlung faserverstärkter Kunststoffe vor dem Kleben«
»Laser pre-processing of fiber reinforced plastics prior to adhesive bonding«

W. Böhme
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Konzeption, Fertigung und Erprobung einer Schmelz- und Dosiereinheit für Schweißzusatzwerkstoffe«
»Conception, fabrication, and testing of a melting and delivery unit for welding filler materials«

K. Bretschneider
(Berufsakademie Sachsen, Staatliche Studienakademie Dresden (BA))
»Prototypische Umsetzung einer modularen Schnittstellenplattform für realistische Robotersimulationen von Lasermaterialbearbeitungstechnologien in CAM Systemen und virtuellen Welten«
»Prototype implementation of a modular interface platform for realistic robot simulations of laser materials processing technologies in CAM systems and virtual worlds«

C. Eydam
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Konzeption, Fertigung und Erprobung einer Gießvorrichtung zum Vordeponieren von Schweißzusatzwerkstoffen aus Aluminiumlegierungen«
»Conception, fabrication and testing of a casting device for the pre-deposition of welding filler materials made from aluminum alloys«

H.-G. Hänig
(Technische Universität Dresden)
»Usability Untersuchung von Werkzeugen für 3D-Objekte bei VR-Anwendungen«
»Usability investigations of tools for 3D objects in VR applications«

M. Hantke
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Konzeption und Konstruktion einer Prüfvorrichtung für getriebebautypische Laserstrahlschweißverbindungen«
»Conception and design of a test stand for transmission-like laser beam welding joints«

F. Heinrich
(Technische Universität Dresden)
»Implementierung einer Kollisionskontrolle in die Bahnplanungssoftware für eine Laserauftragsschweißanlage zur Reparatur von Turbinenschaufeln«
»Implementation of a collision control for the path planning software for a laser buildup welding machine to repair turbine blades«

S. John
(Fachhochschule Koblenz (FH))
»Konzeption, Aufbau und Inbetriebnahme eines Laser-Scanner-Systems zur Mikrostrukturierung mittels direktschreibendem Verfahren und KrF-Excimerlaser«
»Conception, implementation and startup of a direct-write laser scanner system for micro structuring using a KrF excimer laser«

S. Kühn
(Hochschule Mittweida (FH), University of Applied Sciences)
»Konstruktion eines Bewegungssystems für den simultanen Einsatz von zwei Hochleistungsdiodenlasern«
»Design of a motion system for the simultaneous utilization of two high power diode lasers«

J. Landgraf
(Technische Universität Dresden)
»Untersuchungen zum Laserstrahlschweißen der Werkstoffpaarung GTS45 / 16MnCr5 für Getriebeteile«
»Investigations of laser beam welding of the materials combination GTS45 / 16MnCr5 for transmission parts«

S. Lipfert
(Hochschule Mittweida (FH), University of Applied Sciences)
»Untersuchungen zur Haftfestigkeit von DLC-Schichten bei der Innenbeschichtung mittels Laserpulsabscheidung«
»Investigations of adhesion of DLC coatings on inner surfaces deposited through pulsed laser deposition«

L. Matulia
(Politecnico di Torino, Italien)
»Generieren hoch-karbidhaltiger Bauteile durch Auftragschweißen«
»Generation of high carbide content components through buildup welding«

S. Müller
(Technische Universität Dresden)
»Untersuchung des Rissausbreitungsverhaltens an laserstrahlgeschweißten Stumpfstoßverbindungen der Aluminium-Luftfahrtlegierung 6013«
»Investigation of the crack propagation behavior on laser beam welded blunt butt joints of the aerospace aluminum alloy 6013«

M. Norenz
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Qualifizierung von Systemen zur Prozessüberwachung für das Laserstrahl-Präzisionsauftragschweißen«
»Qualification of systems for the process monitoring of laser beam precision buildup welding«

M. Piske
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Strukturanalytische Charakterisierung von Lasermikrobohrungen«
»Structural analytical characterization of laser micro bores«

D. Römer
(Technische Universität Dresden)
»Methoden zur Usability-Evaluation von 3D-Benutzungsschnittstellen«
»Methods to evaluate the usability of 3D user interfaces«

S. Saaro
(TU Bergakademie Freiberg)
»Charakterisierung von Oxidschichten auf thermisch gespritzten (HVOF) Hartmetallbeschichtungen«
»Characterization of oxide coatings on thermal spray (HVOF) hard metal coatings«

K. Sanselzon
(Hochschule für Technik und Wirtschaft Dresden (FH))
»Laserinduktionsschweißen von Getriebebauteilen aus aufhärtungsempfindlichen Stählen«
»Laser induction welding of transmission components made from heat sensitive steels«

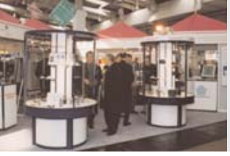
S. Sturm
(Technische Universität Dresden)
»Umformeigenschaften laserinduktionsgeschweißter hochfester Feinbleche«
»Forming properties of laser induction welded high-strength fine metal sheets«

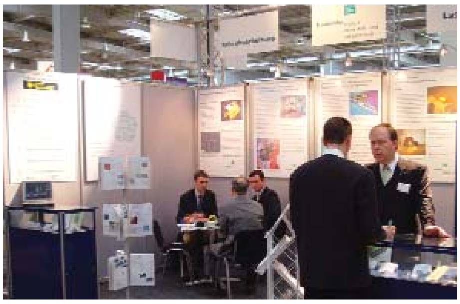
Doctoral theses

T. Himmer
(Technische Universität Dresden)
»Werkzeugfertigung durch Fügen von Metallblechen«
»Tool making through joining of metal sheets«

H. Wust
(Technische Universität Dresden)
»Die Wirkung von Laserstrahlung auf strukturelle, chemische und physikalische Eigenschaften von Holz«
»The influence of laser radiation on the structural, chemical, and physical properties of wood«

R. Zieris
(Technische Universität Dresden)
»Laserunterstütztes atmosphärisches Plasmaspritzen«
»Laser assisted atmospheric plasma spraying«





Presentation of the Fraunhofer IWS at the joint booth »Laser Technology« at the Hannover fair 2005, Hall 15

Presentation of the preprocessing of areas to be joined at the joint booth »Research Land Saxony« at the Hannover fair 2005, Hall 2

Presentation of the IWS at the joint booth »SurfPlaNet« at the Hannover fair 2005, Hall 6

Participation in fairs and exhibitions

Hannover Fair Industry 2005, April 11th-15th, 2005

The IWS participated in the joint booth »SurfPlaNet« of the VDI. At a 40 m^2 exhibition in Hall 6 we presented the latest applied research results in surface technology. The exhibition included diamond-like carbon coatings Diamor® for cutting and forming tools, modular powder nozzles for laser buildup welding, and the current state of thermal spraying. A main attraction was the robot, which can be used for both the laser buildup welding (with the newly developed IWS powder nozzle system) and laser hardening. This dual functionality was transferred to production for the first time in 2005.

Nearby, the nanotechnology competence center »Ultrathin Functional Films«, which is coordinated through IWS, demonstrated nanotechnology applications and products that had been contributed by the members of the center.

The IWS also participated in the joint booth »Laser Technology«, which was setup in the Micro Technology Hall 15. The exhibition on a 15 m^2 area included the newest applied research results in the area of laser materials and micro processing.

In addition the IWS jointly with the laser and surface technology department of the TU Dresden participated in the booth »Research for the Future« in Hall 2. We contributed with an exhibition on adhesive bonding process technology.

A total of 145 new and relevant customer contacts prove the value of exhibiting at the Hannover fair 2005.

Rapid.Tech 2005 Erfurt, May 31st - June 1st, 2005

For the first time the IWS participated in this specialized congress on applied rapid technologies. The central object in our booth was the casting-milling machine pcPro®, which is used for the highly precise rapid prototyping of cast parts. By integrating the casting process into a milling machine, it is possible to fabricate one half of a tool and directly finish the part in one setting. The high degree of automation leads to a significant increase in productivity while maintaining a high flexibility and part quality. A great application potential of this process combination is anticipated in areas where plastic parts are used.

Laser Fair 2005 Munich, June 13th - 16th, 2005

Jointly with three other Fraunhofer Institutes, the IWS presented in Hall B3 on a 230 m^2 area. The booth was coordinated by the IWS and its main theme was »Tailored Solutions for Laser Manufacturers and Users«. Exhibited were the latest technology developments in the areas of remote welding with YAG lasers and laser powder buildup welding. The audiovisual presentation of a beam scanning optics clearly demonstrated IWS competences: Dimensioning of the optics, optimization of cycle times, and quality assurance.

Simultaneously the IWS presented a micro structuring machine with a frequency tripled diode pumped Nd:YAG laser at the booth of Lambda Physics / Coherent.

Overall we found the trend confirmed that this laser fair has become a prime event for customer retention.

Welding & Cutting 2005 Essen September 12th - 17th, 2005

For the first time the IWS participated at this innovation forum of the DVS research association »Welding and Related Techniques e.V.«. 31 research institutes presented current research results and future trends in joining technologies.

Special IWS contributions included presentations about the laser beam welding of large area 3D structures for the aircraft industry and about the laser induction welding of transmission components for the automotive industry.

Trade Fair Parts2Clean 2005 Essen October 18th-20th, 2005

At this trade show the IWS presented a solution to partially clean components with laser radiation. The special feature of our process is its seamless integration into the automated fabrication process. The advantages are shorter cycle times, the possibility to clean surfaces prior to the subsequent step while the part is already mounted, and the avoidance of the need for other cleaning solvents. The process was introduced showing the example of removing remaining coolant, lubricants, and preservatives from surfaces prior to laser beam welding.

Fair Euromold 2005 Frankfurt / M., November 30th - December 3rd, 2005

The IWS participated for the tenth time at the branch fair for form, model, and tool making. The results of the MELATO® project were presented. This project is aimed at the rapid fabrication of complex shaped tools with dimensions of up to 1.5 m. The exhibited stamping and forming tools were fabricated based on the LOM process (laminated object manufacturing). Another exhibition topic was the 3D laser buildup welding for tool repairs and wear protection. Many new contacts to users were established.

Presentation schedule at the innovations forum of the Welding & Cutting Fair 2005

Presentation of the beam scanner optics for the remote welding with YAG lasers at the Fraunhofer booth during the laser fair 2005

Visit of the State Secretary of the BMBF, Prof. Dr. Meyer-Kramer, at the Fraunhofer booth during the Laser Fair

Patent applications

[P1] E. Beyer, S. Nowotny, J. Steinwandel, J. Höschele, A. Ohnesorge

»Integrierte Prozesskontrolle beim Laser-Pulver-Auftragschweißen mittels Koaxial-düse«

Anmelde-Az.: 10 2005 027 260.6

[P2] [M. Heintze, R. Möller, H. Wanka, E. Lopez, V. Hopfe, I. Dani, M. Rosina

»Verfahren zur Entfernung einer dotierten Oberflächenschicht an Rückseiten von kristallinen Silizium-Wafern«

Anmelde-Az.: 10 2005 040 596.7

[P3] A. Klotzbach, V. Fleischer, L. Morgenthal

»Verfahren zur Bearbeitung von Werkstücken mittels Laserstrahlung«

Anmelde-Az.: 10 2005 002 670.2

[P4] F. Kretzschmar, M. Leminski, L. Morgenthal, T. Schwarz, S. Thalheim

»Element und Verfahren zur Justierung eines Arbeitslaserstrahls«

Anmelde-Az.: 10 2005 012 556.5

[P5] L. Morgenthal, T. Schwarz, E. Pfeiffer

»Verfahren zur Bearbeitung von Werkstücken mittels Laserstrahlung«

Anmelde-Az.: 10 2005 027 836.1

[P6] O. Zimmer, M. Schwach, B. Schultrich, C.-F. Meyer

»Anordnung und Verfahren zur Herstellung von Partikeln«

Anmelde-Az.: 10 2005 029 155.4

Issued patents

[P7] S. Braun, H. Mai

»Methode zur Auswahl der Schichtdicken eines reflektierenden Elements für elektromagnetische Strahlung im extremen ultravioletten Bereich«

Veröffentlichungs-Nr.: EP 1 351 258 B1

[P8] B. Brenner, V. Fux

»Process for producing wear-resistant surface layers«

Veröffentlichungs-Nr.: US 6,843,866 B2

[P9] B. Brenner, B. Winderlich, J. Standfuß, J Schumacher, H. Brenneis, W. Zink

»Leichtbau-Strukturbauteil insbesondere für Flugzeuge und Verfahren zu seiner Herstellung«

Veröffentlichungs-Nr.: DE 103 01 445 B4

[P10] A. Hartmann, F. Kretzschmar, A. Klotzbach, L. Morgenthal, D. Pollack, T. Schwarz

»Verfahren und Vorrichtung zur Laserbearbeitung von Werkstücken«

Veröffentlichungs-Nr.: DE 199 63 010 B4

[P11] G. Mäder, W. Grählert, V. Hopfe, H. Beese, E. Hofmüller,

»Verfahren und Vorrichtung zur Untersuchung von Gasen oder Gasgemischen mittels Laserdiodenspektroskopie«

Veröffentlichungs-Nr.: DE 103 60 111 B3

[P12] T. Holz

»Röntgenoptische Anordnung«

Veröffentlichungs-Nr.: EP 1 323 170 B1

[P13] T. Holz

»Vorrichtung zur Röntgenfluoreszenz-analyse«

Veröffentlichungs-Nr.: DE 199 32 275 B4

[P14] A. Lenk

»Verfahren und Vorrichtung zur regelbaren Veränderung der Punktgröße bei der Laser-Innengravur«

Veröffentlichungs-Nr.: DE 199 25 801 B4

[P15] A. Lenk, G. Wiedemann

»Verfahren zum Trennen / Schneiden von Bauteilen, Werkstücken und / oder Probekörpern beliebiger Dicke, Größe und weiterer Abmessungen aus Beton, Werkstein und anderen mineralischen Baustoffen mit wirtschaftlich vertretbaren Trennungsgeschwindigkeiten«

Veröffentlichungs-Nr.: DE199 22 169 B4

[P16] S. Nowotny, K. Tangermann, R. Meier

»Beschichtungsverfahren für Bauteile aus Magnesiumlegierungen«

Veröffentlichungs-Nr.: DE 199 59 378 B4

[P17] S. Rochler, M. Taschenberger, S. Siegel

»Verfahren zur Bestimmung des Vorhandenseins von anorganischen, organischen oder Oxidschichten auf metallischen Substraten oder der Messung von Oberflächentemperaturen von Kunststoffsubstraten«

Veröffentlichungs-Nr.: DE 199 49 977 B4

[P18] C. Wallenhauer

»Schaltungsanordnung zur Reduzierung von Messfehlern analoger pulsförmiger Messsignale eines Detektors«

Veröffentlichungs-Nr.:
DE 10 2004 004 260 B3

Protection of trademarks

[P19] »IRspec XL«

EU-Gemeinschaftsmarke
Eintragungs-Nr.: 003 705 266

[L01] L.-M. Berger, S. Saaro, M. Woydt

»Comparative Study of Self-Mated HVOF-Sprayed Hardmetal Coatings Under High Temperature Dry Sliding Conditions«

Powder Metallurgy World Congress & Exhibition - PM 2005 (2005) S. 299-304

[L02] L.-M. Berger, S. Saaro, R. Zieris, M. Woydt

»Oxidation und ungeschmierter Hochtemperatur-Gleitverschleiß von thermisch gespritzten Hartmetallschichten«

6. Industriefachtagung »Oberflächen- und Wärmebehandlungstechnik« (OWT '05) und 8. Werkstofftechnisches Kolloquium (WTK) (2005) S. 207-216

[L03] L.-M. Berger, M. Woydt, R. Zieris

»Comparative Study of HVOF-Sprayed Hardmetal Coatings under High Temperature Dry Sliding Conditions«

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[L04] L.-M. Berger, R. Zieris, S. Saaro

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[L05] J. Berthold, B. Schultrich

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[L06] E. Beyer, I. Jansen, H. Wust

»Laser in der Klebtechnik«

Kleben - Swiss Bonding 2005 (2005) S. 3-14

[L07] S. Beyer, D. Klemm, M. Bobeth, W. Pompe, O. Trommer, P. Gawlitza

»Improvement of the Adherence of Thermal Barrier Coatings for Rocket Combustion Chambers«

Advanced Engineering Materials 7 (2005) 1-2, S. 54-58

[L08] G. Blasek, B. Schultrich

»Potenzial der Vakuum- und Plasmaverfahren für die dekorative Kunststoffbearbeitung«

Beschichtung und Modifizierung von Kunststoffoberflächen - 13. NDVak (2005)

[L09] S. Bonß,

»Laserstrahlhärten im Großwerkzeugbau«

Photonik 37 (2005) 6, S. 18

[L10] S. Bonß, J. Hannweber, U. Karsunke, M. Seifert, B. Brenner, E. Beyer

»Integrierte Härterei - Laserstrahlhärten im Großwerkzeugbau«

6. Industriefachtagung »Oberflächen- und Wärmebehandlungstechnik« (OWT '05) und 8. Werkstofftechnisches Kolloquium (WTK) (2005) in press

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»Low Cost Camera Based Sensor System for Advanced Laser Heat Treatment Processes«

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[L12] H.-H. Böttcher, O. Rieder, H. Planck, F. Kretzschmar, D. Pollack, L. Morgenthal

»Laserstrahlschweißen von Textilien - Möglichkeiten und Grenzen«

Melliand Textilberichte 86 (2005) 9, S. 632-633

[L13] S. Braun

»EUV Microscope Far Below 1 Micron«

NanoS - The Nanotech Journal (2005) 2, S. 15

[L14] S. Braun, R. Dietsch

»Herstellung und Anwendung von Multischicht-Röntgenoptiken«

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[L15] S. Braun, T. Foltyn, L. van Loyen, A. Leson, K. Walter, K. Bergmann, W. Neff

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[L16] S. Braun, A. Leson

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[L17] B. Brenner, J. Standfuß, L. Morgenthal, E. Beyer

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[L18] R. Delmdahl, F. Sonntag

»Rapid Prototyping with Excimer Laser and UV-Scanner«

Lasers in Manufacturing 2005 (2005) S. 853

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[L20] T. Foltyn, S. Braun, L. van Loyen, A. Leson

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[L22] R. Gnann, A. Techel, E. Willenborg

»Laserapplikationen im Werkzeugbau - Entwicklung und industrielle Anwendung«

8. 3D-Erfahrungsforum Innovation Werkzeug- und Formenbau (2005) S. 9.1-9.9

[L23] R. Grimme, M. Krieg, J. Hauptmann

»Lokale Reinigung von Funktionsflächen. Verfahren, Möglichkeiten und Grenzen«

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[L24] R. Hässler, I. Jansen

»Thermische und mechanische Untersuchungen an Epoxidharz-Aluminium Verbunden«

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[L25] T. Himmer, A. Techel, S. Nowotny, E. Beyer

»Recent Developments in Metal Laminated Tooling«

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[L26] A. Jahn, B. Winderlich, B. Brenner, A. Zwick, R. Imhoff, S. Trümper

»Laser Hybrid Welding of Fatigue Loaded Structural Components Made of Quenched and Tempered HSLR Steel S1100QL«

58th IIW Annual Assembly and International Conference (2005) IIW-Doc. No. IV-886-05

[L27] I. Jansen, H. Wust, E. Beyer

»Haftung optimieren. Laserstrahlung verbessert die Alterungsbeständigkeit von Klebverbindungen«

mo metalloberfläche 59 (2005) 7-8, S. 34-35

[L28] I. Jansen, H. Wust, R. Böhme

»Vorbehandlung von faserverstärkten Kunststoffen mit Nd:YAG-Laserstrahlung«

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[L29] R. Jäckel

»Ultradünne funktionale Schichten - Kompetenznetzwerke in Dresden«

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[L30] J. Kaspar, A. Luft, J. Bretschneider, S. Jacob, S. Bonß, B. Winderlich, B. Brenner, E. Beyer

»Laser Nitriding: A Promising Way to Improve the Cavitation Erosion Resistance of Ti-6Al-4V«

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[L31] J. Kaspar, A. Luft, S. Nolte, M. Will

»STEM and TEM Characterization of Micro-Holes Produced in Steel by Helical Drilling with Laser Pulses in the ns to fs Range«

Lasers in Manufacturing 2005 (2005) S. 763-768

[L32] G. Kirchhoff, L. Brummer

»Prüfstand für Thermoschock- und Temperaturwechselfestigkeit«

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[L33] A. Klotzbach, V. Fleischer, L. Morgenthal, E. Beyer

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[L34] U. Klotzbach, T. Kuntze, M. Panzner, F. Sonntag, G. Spiecker, E. Beyer

»Excimerlaser und Mikrospiegelarrays als flexible hochdynamische Einheit - Ablenkungsmanöver für Laserstrahlen«

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[L36] D. Lepski, M. Beck, A. Mahrle, F. Brückner, E. Beyer

»Prozessmodelle in der Lasermaterialbearbeitung«

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[L37] A. Leson

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[L40] A. Leson

»Nanotechnologie - Anwendungen und Perspektiven für den Automobilbau«

Micromaterials and Nanomaterials (2005) 4, S. 12

[L41] A. Leson

»Superhard Amorphous Carbon Coatings«

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[L42] A. Leson

»Nanotechnology - Applications and Perspectives for the Automotive Industry«

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[L43] A. Leson, T. Geßner

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MST-News (2005) S. 42

[L44] L. van Loyen, T. Böttger, S. Schädlich, S. Braun, T. Foltyn, A. Leson, F. Scholze, S. Müllender

»Laboratory LPP EUV Reflectometer Working with Non-Polarized Radiation«

Applied Surface Science 252 (2005) 1, S. 57-60

[L45] S. Martens, V. Weihnacht, L-M. Berger

»Oil-Free Powertrain: Ceramic Coatings«

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[L46] P. Mottner, G. Wiedemann, G. Haber, W. Conrad, A. Gervais

»Laser Cleaning of Metal Surface - Laboratory Investigations«

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[L47] S. Nowotny

»Gepanzert: Oberflächen hart im Nehmen. Modulares Pulverdüsensystem zum Auftragsschweißen mit Lasertechnik«

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»Laserstrahl-Auftragschweißen in der Triebwerkinstandsetzung«

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»Robotersystem zum Präzisionsauftragschweißen mit Diodenlaser«

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[L50] S. Nowotny

»Rapid Repairing: An Efficient Manufacturing Concept for Reconditioning of Worn Components and Tools«

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[L51] S. Nowonty

»Turbinenreparatur per Laserauftragschweißen«

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[L54] S. Nowonty, S. Scharek, F. Kempe

»Laser System Technology for Precise Repairing of Moulds and Tools«

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[L55] S. Nowotny, S. Scharek, F. Kempe, A. Schmidt, E. Beyer

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[L56] E. Pfeiffer

»3D-Präzisionsbearbeitung mittels Hochgeschwindigkeits-Laserschneiden«

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[L57] O. Rieder, H. Planck, L. Morgenthal

»Diodenlasersystem im Einsatz beim Thermofixieren textiler Flächen aus Chemiefasern«

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[L58] T. Sander, J. U. Schmidt, H. Schenk, H. Lakner, S. Braun, T. Foltyn, A. Leson

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[L61] P. Schaaf, M. Shinn, E. Carpene, J. Kaspar

»Direct Laser Synthesis of Functional Coatings«

Lasers in Manufacturing 2005 (2005) S. 399-406

[L62] H.-J. Scheibe, T. Schülke, M. Becker, M. Leonhardt, E. Beyer, C.-F. Meyer, B. Schultrich, H. Schulz, V. Weihnacht

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[L63] D. Schneider

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[L64] D. Schneider, T. Schwarz, B. Schultrich

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[L65] B. Schultrich

»Superharte Beschichtungen für tribologische Beanspruchung«

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[L66] H. Schulz, M. Leonhardt, H.-J. Scheibe, B. Schultrich

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[L67] H. Stiele, S. Bonß

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[L68] T. Stucky, U. Baier, C.-F. Meyer, H.-J. Scheibe, B. Schultrich

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[L69] A. Techel

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[L72] J. Tuominen, J. Latokartano, J. Vihinen, P. Vuoristo, T. Mäntylä, T. Naumann, S. Scharek, L.-M. Berger, S. Nowotny

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»Superharte Kohlenstoffschichten für Automobilkomponenten«

Funktionelle Oberflächen für den Automobilbau (2005)

[L74] G. Wiedemann, K. Püschner, H. Wust, A. Kempe

»The Capability of the Laser Application for Selective Cleaning and the Removel of Different Layers on Wooden Artworks«

Lasers in the Conservation of Artworks - LACONA V (2005) S. 179-190

[L75] H. Wust, U. Schwarz, K. Rehm

»Schmalflächenbeschichtung - alle Probleme gelöst?«

Die Holzbearbeitung - HOB 52 (2005) 5, S. 148-149

[L76] R. Zieris, L.-M. Berger, I. Schulz, S. Martens, R. Enzl

»Investigation of Ceramic and Hardmetal Coatings in an Oscillating Sliding Wear Test«

Thermal Spray Solutions - ITSC 2005 (2005)

[L77] O. Zimmer

»Vacuum Arc Deposition by Using a Venetian Blind Particle Filter«

Surface and Coatings Technology 200 (2005) 1-4, S. 440-443

[L78] O. Zimmer, B. Schultrich, T. Stucky, I. Endler, R. Schober, J. Vetter

»Beschichtung von Formwerkzeugen - Chancen oder Kostenfaktor?«

Beschichtete Werkzeuge - höhere Wirtschaftlichkeit in der Ur- und Umformtechnik (2005)

[L79] P. Zinin, S. Berezina, D. Schneider, D. Fei, D. A. Rebinsky, M. H. Manghnani, S. Tkachev

»Brillouin Scattering and Laser-SAW Technique for Elastic Property Characterization of Diamond-Like Carbon (DLC) Films«

Review of Progress in Quantitative Nondestructive Evaluation 760 (2005) 1, S. 1182-1188

[T01] L.-M. Berger

»Hartmetallschichten - eine praxisorientierte Beschreibung der Werkstoffe«

International Thermal Spray Conference & Exposition - ITSC 2005, Basel (CH) 02.-04. Mai 2005

[T02] L.-M. Berger

»Correlation between Oxidation and Tribological Properties of Thermalliy Sprayed Hardmetal Coatings«

COST 532 Meeting, Prag (CZ) 17. Februar 2005

[T03] L.-M. Berger, S. Saaro, M. Woydt

»Comparative Study of Self-Mated HVOF-Sprayed Hardmetal Coatings Under High Temperature Dry Sliding Conditions«

Powder Metallurgy World Congress & Exhibition - Euro PM, 2005 Prag (CZ) 02.-05. Oktober 2005

[T04] L.-M. Berger, S. Saaro, R. Zieris, M. Woydt

»Oxidation und ungeschmierter Hochtemperatur-Gleitverschleiß von thermisch gespritzten Hartmetallschichten«

6. Industriefachtagung »Oberflächen- und Wärmebehandlungstechnik« (OWT '05) und 8. Werkstofftechnisches Kolloquium (WTK), Chemnitz (D) 29.-30. September 2005

[T05] L.-M. Berger, M. Woydt, R. Zieris

»Comparative Study of HVOF-Sprayed Hardmetal Coatings under High Temperature Dry Sliding Conditions«

16. International Plansee Seminar, Reutte/Tirol (A) 30. Mai - 03. Juni 2005

[T06] L.-M. Berger, R. Zieris, S. Saaro

»Oxidation of HVOF-Sprayed Hardmetal Coatings«

International Thermal Spray Conference & Exposition - ITSC 2005, Basel (CH) 02.-04. Mai 2005

[T07] J. Berthold, B. Schultrich

»Ultradichte Kohlenstoffschichten als Barriere für Kunststoffolien«

EFDS-Workshop »Dünne und ultradünne Schichten mit Barrierefunktion«, Wörlitz (D) 03. Juni. 2005

[T08] E. Beyer

»Der CO_2-Laser«

Neueste Entwicklungen der industriellen Lasertechnik Wolfsburg, (D) 20. Oktober 2005

[T09] E. Beyer

»Fiber lasers of the new generation«

1. Workshop »Faserlaser«, Dresden (D) 22. November 2005

[T10] E. Beyer, I. Jansen, H. Wust

»Laser in der Klebtechnik«

19. International Symposium Swiss Bonding 2005, Rapperswil (CH) 23.-25. Mai 2005

[T11] G. Blasek, B. Schultrich

»Potenzial der Vakuum- und Plasmaverfahren für die dekorative Kunststoffbearbeitung«

13. Neues Dresdner Vakuumtechnisches Kolloquium - NDVaK, Dresden (D) 13.-14. Oktober 2005

[T12] S. Bonß

»Integrierte Härterei - Laserstrahlhärten im Großwerkzeugbau«

61. Kolloquium für Wärmebehandlung und Werkstofftechnik, Fertigungs- und Verfahrenstechnik, Wiesbaden (D) 05.-07. Oktober 2005

[T13] S. Bonß, J. Hannweber, U. Karsunke, M. Seifert, B. Brenner, E. Beyer

»Integrierte Härterei - Laserstrahlhärten im Großwerkzeugbau«

6. Industriefachtagung »Oberflächen- und Wärmebehandlungstechnik« (OWT '05) und 8. Werkstofftechnisches Kolloquium (WTK), Chemnitz (D) 29.-30. September 2005

[T14] S. Bonß, M. Seifert, J. Hannweber, U. Karsunke, E. Beyer

»Low Cost Camera Based Sensor System for Advanced Laser Heat Treatment Processes«

24th International Congress on ICALEO 2005, Miami (USA) 31. Oktober - 03. November 2005

[T15] S. Braun

»Nanostructures for Non-Volatile Memories«

1st Workshop »Synthesis and Analysis of Nanomaterials and Nanostructured«, Wroclaw (PL) 21.-22. November 2005

[T16] S. Braun, A. Leson

»Röntgenoptiken für die Elektronik und Analytik«

Nanotechnologie in der industriellen Anwendung, Regensburg (D) 26.-27. November 2005

[T17] S. Braun. T. Foltyn, W. Friedrich, A. Leson, R. Dietsch, D. Weißbach

»Nanometer Multilayers as Monochromators for the X-Ray Fluorescence«

54th Annual Conference on Applications of X-Ray Analysis - The Denver X-Ray Conference, Colorado Springs (USA) 01.-05. August 2005

[T18] S. Braun, T. Foltyn, W. Friedrich, M. Menzel, A. Leson, F. Schäfers

»Improved Nanometer Multilayers for X-Ray Fluorescence Analysis«

Optical Systems Design 2005 - Advances in Optical Thin Films II, Jena (D) 12.-16. September 2005

[T19] S. Braun, R. Dietsch, T. Foltyn, M. Menzel, A. Leson

»Multilayer Monochromators for X-Ray Spectrometry»

PRORA 2005: Prozessnahe Röntgenanalytik, Berlin (D) 24.-25. November 2005

[T20] B. Brenner, G. Göbel, D. Dittrich, R. Schedewy, J. Standfuß

»New results in the fiber laser welding of light metal and steel materials«

1st International Fraunhofer Workshop on Fibre Lasers, Dresden (D) 22. November 2005

[T21] B. Brenner, A. Jahn, B. Winderlich, J. Standfuß

»Neuere Entwicklungen zum Laserstrahlschweißen höherfester Feinbleche«

Fügen-Intensiv-Konferenz »Das Fügen zukünftiger Leichtbaukonzepte«, Bad-Nauheim (D) 07.-09. März 2005

[T22] B. Brenner, J. Standfuß, L. Morgenthal, E. Beyer

»New Applications with Laser Hybrid Processes and Remote Welding«

ExpoLaser Conference »The Laser Tool: State of the Art and Trends«, Piacenza (I) 17.-19. November 2005

[T23] I. Dani

»Atmosphärendruck-Mikrowellen-PECVD zur Abscheidung von SiO_2-Schichten«

XII. Erfahrungsaustausch »Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen«, Mühlleithen (D) 15.-17. März 2005

[T24] R. Delmdahl, F. Sonntag

»Rapid Prototyping with Excimer Laser and UVScanner«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T25] R. Dietsch, T. Holz, S. Braun, T. Leisegang, D. Meyer

»Analytische Anwendungen röntgenoptischer Systeme«

Nanofair 2005: New Ideas for Industry, Dresden (D) 29.-30. November 2005

[T26] R. Dietsch, S. Braun, T. Foltyn, P. Gawlitza, T. Holz, A. Leson, M. Menzel, D. Weißbach

»Design and Application of Multilayer X-Ray Optics for X-Ray Analysis«

AXAA 2005 Conference & Exhibition, Perth (AUS) 14.-18. Februar 2005

[T27] R. Franke, B. Brenner, C. Ulbricht, W. Zink

»Zur Bewertung des Festigkeits- und Schadenstoleranzverhaltens laserstrahlgeschweißter Rumpfstrukturen«

Festigkeit gefügter Bauteile, Braunschweig (D) 01.-02. Juni 2005

[T28] P. Gawlitza

»Laserplasmen zur Abscheidung spannungsarmer Schichten auf Innenflächen«

XII. Erfahrungsaustausch »Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen«, Klingenthal-Mühlleithen (D) 16.-18. März 2005

[T29] W. Grählert

»In-situ Gasanalytik mittels Laserspektroskopie«

14. Treffen des »Arbeitskreises Ausrüstungen, Materialien und Dienstleistungen für die Halbleitertechnologie Dresden« gemeinsam mit dem »Arbeitskreis Equipment von Silicon Saxony«, Dresden (D) 15. März 2005

[T30] T. Himmer

»Recent Developments in Metal Laminated Tooling«

24th International Congress on ICALEO 2005, Miami (USA)
31. Oktober - 03. November 2005

[T31] V. Hopfe

»Atmospheric Pressure Plasma CVD and Plasma Chemical Etching for High Throughput Processing«

International Conference on Metallurgical Coatings and Thin Films - ICMCTF 2005, San Diego (USA) 02.-06. Mai 2005

[T32] V. Hopfe, E. Lopez, M. Rosina, I. Dani, H. Wanke, M. Heintze, R. Möller

»Trockenätzen von Solarwafern mit Atmosphärendruck-Plasma - Gasphasenchemie und Oberflächenstrucktur«

Freiberger Siliciumtage, Freiberg (D) 15.-17. Juni 2005

[T33] M. Jäger, M. Rabenau, R. Poll, F. Sonntag

»Perfusion Chamber for Cell Tests with Micro Patterned Surface«

14th International Conference of Medical Physics (ICMP 2005) & 39th Annual Conference of the German Society for Biomedical Engineering (BMT 2005), Nürnberg (D) 14.-18. November 2005

[T34] A. Jahn, B. Winderlich, B. Brenner, A. Zwick, R. Imhoff, S. Trümper

»Laser Hybrid Welding of Fatigue Loaded Structural Components Made of Quenched and Tempered HSLR Steel S1100QL«

58th IIW Annual Assembly and International Conference, Prag (CZ)
10.-15. Juni 2005

[T35] I. Jansen

»Plasmavorbehandlung von Magnesiumlegierungen«

Seminar bei PlasmaTreat, Steinhagen (D) 24. Februar 2005

[T36] I. Jansen

»Elektrisch leitfähiges Kleben«

Seminar bei EPCOS, Deutschlandsberg (A) 10. März 2005

[T37] I. Jansen

»Klebtechnik - Fügeteilvorbehandlung mit Plasma- und Lasertechnologien«

Kolloquium am Fraunhofer IZFP Dresden, Dresden (D) 15. September 2005

[T38] I. Jansen

»Dauerhafte Klebverbindungen durch Oberflächenbehandlung mit Plasma- und Lasertechnologien«

5. Dresdner Materialforschungstag, Dresden (D) 11. November 2005

[T39] J. Kaspar, J. Bretschneider, S. Bonß, B. Winderlich, B. Brenner, E. Beyer

»Laser Nitriding: A Promising Way to Improve the Cavitation Erosion Resistance of Components Made of Titanium Alloys«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T40] J. Kaspar, A. Luft, E. Beyer

»Helical Drilling of Metals and Silicon with ns to fs Pulses: A microscopic Approach«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T41] D. Klaffke, B. Schultrich, V. Weihnacht

»Einfluss von Umgebungsmedien und Gegenkörperwerkstoff auf das tribologische Verhalten dünner ta-C-Schichten«

Tribologie-Fachtagung, Göttingen (D) 26.-28. September 2005

[T42] A. Klotzbach, V. Fleischer, L. Morgenthal, E. Beyer

»Sensor Guided Remote Welding System for YAG - Laser Applications«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T43] A. Kunze, F. Sonntag, M. Rabenau, R. Poll

»Perfusion Chambers for Cell Tests with Micro Patterned Surface«

14th International Conference of Medical Physics (ICMP 2005) & 39th Annual Conference of the German Society for Biomedical Engineering (BMT 2005), Nürnberg (D) 14.-18. November 2005

[T44] A. Lange, E. Beyer

»Conditions for the Formation of Thermoelectric Currents in Laser Melted Pools«

18th Meeting on Mathematical Modelling of Materials Processing with Lasers, Igls/Innsbruck (A) 19.-21. Januar 2005

[T45] A. Lange, E. Beyer

»Formation of Thermoelectric Currents in Weld Pools«

Conference on Lasers and Electro-Optics / Europe 2005, München (D) 12.-17. Juni 2005

[T46] R. Lenk, A. Nagy, H.-J. Richter, A. Techel

»Werkstoffkonzepte für das Lasersintern von SiC«

Rapid Prototyping - Verfahren und Anwendung in der Keramik, Erlangen (D) 29.-30. November 2005

[T47] D. Lepski, M. Beck, A. Mahrle, F. Brückner, E. Beyer

»Prozessmodelle in der Lasermaterialbearbeitung«

23rd CADFEM User's Meeting, Bonn (D) 09.-11. November 2005

[T48] A. Leson

»Entwicklungsschwerpunkte in der Nanoelektronik«

Trendqualifikationen Nanotechnologie, Halle (D) 16. Februar 2005

[T49] A. Leson

»Nanotechnologie - Vision oder Realität«

120. Öffentliche Sitzung der Naturwissenschaftlichen Gesellschaft ISIS Dresden e.V., Dresden (D) 17. März 2005

[T50] A. Leson

»Nanotechnologie - Zukunftschancen oder Fiktion«

96. MNU-Kongress, Kiel (D) 20.-24. März 2005

[T51] A. Leson

»Nanotechnologie - Anwendungen und Perspektiven für den Automobilbau«

2. Fachkongress MicroCar 2005, Leipzig (D) 21.-22. Juni 2005

[T52] A. Leson

»Nanometerschichten für den Automobilbau«

Workshop Nanomaterialien: Der »unsichtbare« Nutzen, Bayreuth (D) 29. Juni 2005

[T53] A. Leson

»Superhard Amorphous Carbon Coatings«

Saxon-German-Nanotechnology-Forum, London (GB) 03. Oktober 2005

[T54] A. Leson

»Nanotechnologie - Perspektiven und aktuelle Anwendungen«

Nanoworkshop 2005, Braunschweig (D) 03. November 2005

[T55] A. Leson

»Nanotechnology - Applications and Perspectives for the Automotive Industry«

8th International Automotive Conference - ICA, Sunderland (GB) 05.-06. Oktober 2005

[T56] A. Leson

»Superhard Amorphous Carbon Coatings Applications and Perspectives for the Automotive Industry«

Sächsische Delegationsreise nach Japan, Seminar »Highlights of Automotive Technology in Germany«, Tokio (Japan) 21. Oktober 2005

[T57] A. Leson

»Superhard Amorphous Carbon Coatings Applications and Perspectives for the Automotive Industry«

Sächsische Delegationsreise nach Japan, Seminar »Highlights of Automotive Technology in Germany«, Nagoya (Japan) 24. Oktober 2005

[T58] A. Leson

»Superhard Amorphous Carbon Coatings«

Sächsische Delegationsreise nach Japan , Seminar »Highlights of German Technological Development in Nanotechnology« Kyoto, (Japan) 26. Oktober 2005

[T59] A. Leson

»Entwicklungsstand der Nanotechnologie - Anwendungsgebiete, Visionen, Risiken«

Nanotechnologie in Sachsen - Potenziale - Chancen - Visionen, Dresden (D) 08. November 2005

[T60] A. Mahrle, E. Beyer

»Transient Behaviour of Laser Induced Axisymmetric Melt Pools«

18th Meeting on Mathematival Modelling of Materials Processing with Lasers, Igls/Innsbruck (A) 19.-21. Januar 2005

[T61] S. Martens, V. Weihnacht, L.-M. Berger

»Ceramic Coatings«

Triboscience and Tribotechnology, Superior Friction and Wear Control in Engines and Transmissions - COST 532, Porto (Portugal) 18.-19. Oktober 2005

[T62] E. Marx, W. Grählert

»Insitu FTIR-Spectroscopy for Process Optimization and FDC at Infineon Technology«

Workshop »Advanced Process Control for Future Oriented Manufacturing«, Dresden (D) 22.-23. September 2005

[T63] S. Nowotny

»Rapid Repairing: An Efficient Manufacturing Concept for Reconditioning of Worn Components and Tools«

International User's Conference on Rapid Prototyping & Rapid Tooling & Rapid Manufacturing - Euro-u Rapid 2005, Leipzig (D) 10.-12. Mai 2005

[T64] S. Nowotny

»Precision laser build-up welding using fiber lasers«

1. Workshop »Faserlaser«, Dresden (D) 22. November 2005

[T65] S. Nowotny

»Schnelle Designänderungen und Reparaturen von Werkzeugen durch direkten Metallauftrag mit Laserstrahlung«

Workshop »Laseranwendungen für intelligente Werkzeugtechnik«, Dresden (D) 23. November 2005

[T66] S. Nowotny, T. Naumann, S. Orban, K.-H. Richter

»Laser Beam Cladding in Controlled Atmosphere»

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T67] S. Nowotny, T. Naumann, S. Scharek, F. Kempe, A. Schmidt, E. Beyer

»Technological Solutions for Industrial Applications of Laser Beam Cladding«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T68] T. Sander, J. U. Schmidt, H. Schenk, H. Lakner, S. Braun, T. Foltyn, A. Leson

»Highly Reflective Thin-Film Coatings for High-Power Applications of Micromechanical Scanning Mirrors in the NIR-VIS Spectral Region«

Optical Systems Design 2005 - Advances in Optical Thin Films II, Jena (D) 12.-16. September 2005

[T69] T. Sander, J. U. Schmidt, H. Schenk, H. Lakner, S. Braun, T. Foltyn, A. Leson, A. Gatto, M. Yang, N. Kaiser

»Micromechanical Scanning Mirrors with Highly Reflective NIR Coatings for High Power Applications«

Photonics West 2005: MEOMS, MEMS, Micro and Nanofabrication - MEOMS Display and Imaging Systems III, San Jose (USA) 22.-27. Januar 2005

[T70] T. Sander, J. U. Schmidt, H. Schenk, H. Lakner, A. Gatto, M. Yang, N. Kaiser, S. Braun, T. Foltyn, A. Leson

»Highly Reflective Coatings for Micromechanical Mirror Arrays Operating in the DUV and VUV Spectral Range«

Photonics West 2005: MEOMS, MEMS, Micro and Nanofabrication - MEOMS Display and Imaging Systems III, San Jose (USA) 22.-27. Januar 2005

[T71] H.-J. Scheibe, M. Leonhardt, T. Schülke

»Deposition Technology, Tribological Properties and Applications of Superhard Amorphous (ta-c) Carbon Films«

Functional Coatings and Surface Engineering - FCSE, Montréal (CAN) 05.-09. Juni 2005

[T72] H.-J. Scheibe, M. Leonhardt, T. Schülke, C.-F. Meyer, H. Schulz, B. Schultrich, E. Beyer

»Laser-Arc Process and Technology for Deposition of Amorphous and Nanostructured Carbon Films«

8th International Conference on Applications of Diamond and Related Materials and 1st NanoCarbon Joint Conference, Chicago (USA) 15.-19. Mai 2005

[T73] H.-J. Scheibe, T. Schülke, M. Becker, M. Leonhardt, E. Beyer, C.-F. Meyer, B. Schultrich, H. Schulz, V. Weihnacht

»Laser-Arc-Module System for Industrial Series Deposition of Super Hard Coatings«

International Conference on Metallurgical Coating and Thin Films - ICMCTF 2005, San Diego (USA) 02.-06. Mai 2005

[T74] B. Schultrich

»Nanostructured ceramic and carbon films for wear protection«

NATO-OVT Specialists Meeting AVT-122 »Nanomaterials technology for military vehicle structurral applications«, Granada 03.-04. Oktober. 2005,

[T75] B. Schultrich, V. Weihnacht

»Superharte amorphe Kohlenstoffschichten (ta-C) für Zerspanungs- und Umformwerkzeuge«

Tribologie-Fachtagung, Göttingen, (D) 26.-28. September 2005

[T76] B. Schultrich, W. Grählert

»Von der nanostrukturellen Probenanalyse zur Bauteilprüfung«

5. Dresdner Materialforschungstag, Dresden (D) 11. November 2005

[T77] U. Schwarz, M. Oertel, H. Wust

»Schmalflächenbeschichtung im Brennpunkt des Lasers«

2. Innovationsforum Holz, Lichtenstein (D) Dezember 2005

[T78] F. Sonntag, R. Poll, U. Klotzbach, M. Rabenau

»Technological Plattform for Cell Micro Array Based Biochips«

14th International Conference of Medical Physics (ICMP 2005) & 39th Annual Conference of the German Society for Biomedical Engineering (BMT 2005), Nürnberg (D) 14.-18. November 2005

[T79] J. Standfuß, B. Brenner

»Laser Induction Welding - From Basic Research to Industrial Applications«

Interntional Forum on Project Development, Bologna (I) 28. Februar - 01. März 2005

[T80] J. Standfuß, B. Brenner, A. Jahn, D. Dittrich

»Laserstrahlgeschweißte Leichtbaustrukturen aus Stahl und Aluminium«

16. Weltmesse Schweißen und Schneiden, Essen (D) 12.-17. September 2005

[T81] A. Techel

»Kunststoffprototypen mit Fräsgenauigkeit - pcpro®«

RapidTech 2005, Erfurt (D) 31. Mai - 01. Juni 2005

[T82] A. Techel

»Neue Hard- und Softwarelösungen für das roboterbasierte Laserhärten und Auftragschweißen«

EuroMold 2005, Frankfurt/Main (D) 30. November - 03. Dezember 2005

[T83] A. Techel

»Metal Laminated Tooling im Großwerkzeugbau«

EuroMold 2005, Franfurt/Main (D) 30. November - 03. Dezember 2005

[T84] J. Tuominen, J. Latokartano, J. Vihinen, P. Vuoristo, T. Mäntylä, T. Naumann, S. Scharek, L.-M. Berger, S. Nowotny

»Deposition of Thick Wear and Corrosion Resistant Coatings by High Power Diode Laser«

3rd International WLT-Conference on Lasers in Manufacturing, München (D) 13.-16. Juni 2005

[T85] J. Tuominen, P. Vuoristo, T. Mäntylä, J. Latokartano, J. Vihinen, T. Naumann, S. Scharek, L.-M. Berger

»Deposition of Thick Wear and Corrosion Resistant Coatings by 6 kW High Power Diode Laser«

24th International Congress on ICALEO 2005, Miami (USA) 31. Oktober - 03. November 2005

[T86] S. Völlmar, E. Beyer

»Virtuelle Realität in der Laser-Materialbearbeitung und Oberflächentechnik«

Anwendungen der Virtuellen Realität im Umfeld der Ingenieurwissenschaften, Dresden (D) 22. März 2005

[T87] V. Weihnacht, B. Schultrich

»Superharte Kohlenstoffschichten (ta-C) für Automobilkomponenten«

EFDS-Workshop »Funktionale Oberflächen für den Automobilbau«, Frankfurt (D) 14. November. 2005

[T88] T. Wünsche, W. Grählert

»In-Situ FTIR-Spectroscopy for Process Optimization and FDC at Infineon Technology«

Workshop »Advances Process Controll for Future Oriented Manufacturing«, Dresden (D) 22.-23. September 2005

[T89] H. Wust, P. Haller, G. Wiedemann

»Experimental Study of the Effect of a Laser Beam on the Morphology of Wood Surfaces«

European Conference on Wood Modification 2005, Göttingen (D) 06.-07. Oktober 2005

[T90] R. Zieris, L-M. Berger, I. Schulz, S. Martens, R. Enzl

»Investigation of Ceramic and Hardmetal Coatings in an Oscillating Sliding Wear Test«

International Thermal Spray Conference & Exposition - ITSC 2005, Basel (CH) 02.-04. Mai 2005

[T91] O. Zimmer, B. Schultrich, T. Stucky, I. Endler, R. Schober, J. Vetter

»Beschichtung von Formwerkzeugen - Chance oder Kostenfaktor?«

EFDS-Workshop »Beschichtete Werkzeuge - höhere Wirtschaftlichkeit in der Ur- und Umformtechnik«, Dresden (D) 25. November. 2005

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- ☐ Micro cutting and drilling with ultraviolet light
- ☐ Microstructuring of ceramics with excimer lasers
- ☐ Slip-free modification of natural stone surfaces

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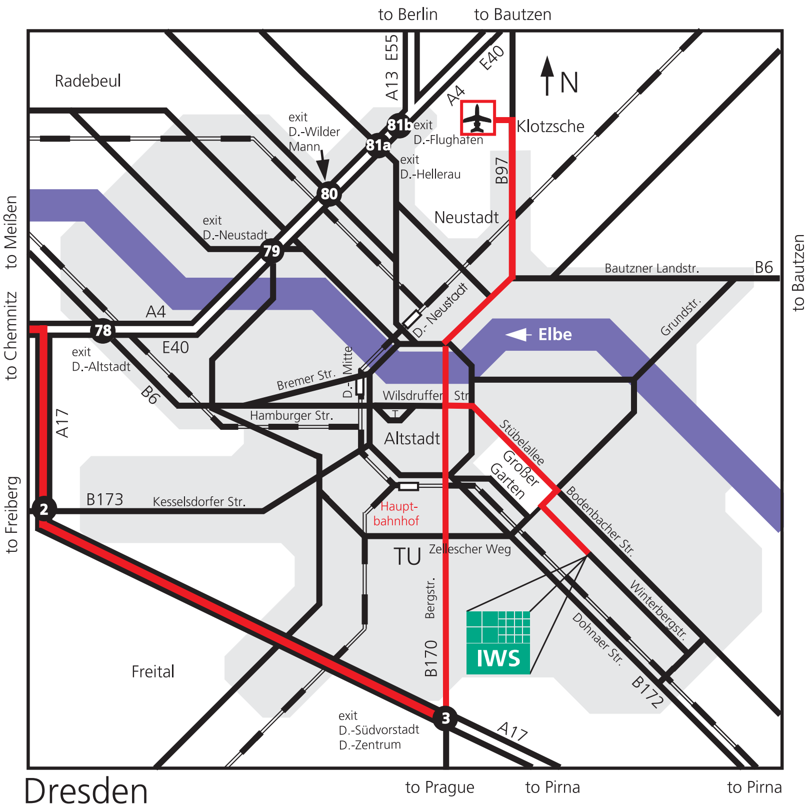

Directions:

by car (from Autobahn / Highway)

- take Autobahn A4 or A13 to intersection Dresden-West, follow new Autobahn A17 to exit Südvorstadt / Zentrum
- follow road B170 in direction Stadtzentrum (city center) to Pirnaischer Platz (about 6 km)
- at Pirnaischer Platz turn right towards »Gruna / VW-Manufaktur«
- continue straight until the end of the »Großer Garten« (Great Garden) and then turn right onto Karcherallee
- at the next traffic light turn left onto Winterbergstraße and continue straight until IWS

by railway and tram

- from Dresden main railway station take line #10 to Straßburger Platz
- change to line #1 or #2 heading out from the city (toward Kleinzschachwitz or Prohlis); exit at Zwinglistraße stop
- 10 minutes to walk from there (in the direction of Grunaer Weg) or one station by bus # 61 (in the direction Löbtau)

by air plane

- from Airport Dresden-Klotzsche with a taxi to Winterbergstraße 28 (distance is approximately 7 miles or 10 km)
- or with public transportation (shuttle train) to the main railway station (Hauptbahnhof), and continue with the tram

Editorial notes

Editorial staff:	Dr. Ralf Jäckel Dipl.-Ing. Karin Juch	
Coordination / editing:	Dipl.-Ing. Karin Juch Dr. Ralf Jäckel	
Photos:	page 6 (right pic.):	Franck Thibault, London
	page 73 (bottom pic.):	Messe München GmbH
	all other pictures:	Fraunhofer IWS Dresden
Quotations:	The quotations are translated faithfully to their meanings.	