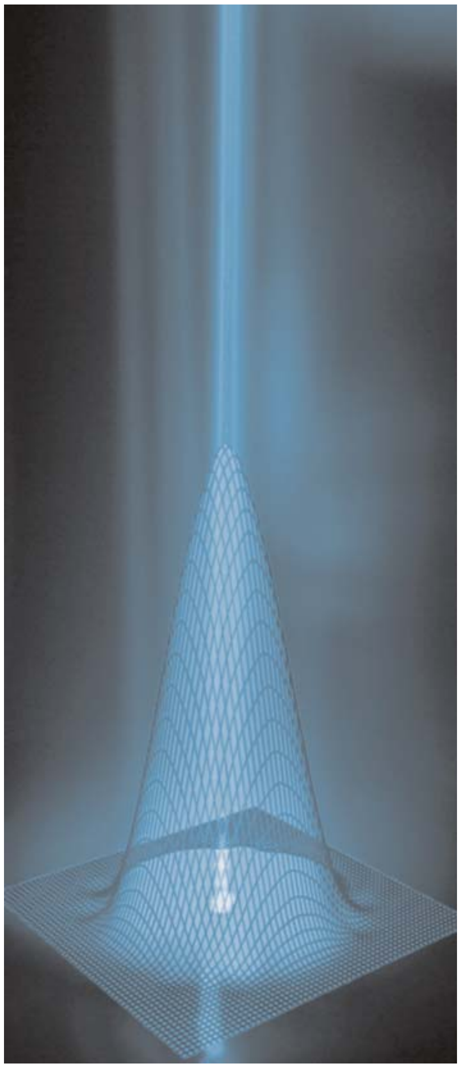
Fraunhofer Institut Werkstoff- und Strahltechnik

IWS - Fraunhofer - Prize 1997 · IWS - Fraunhofer - Prize 1998 · IWS - Fraunhofer - Prize 2000 · IWS - Fraunhofer - Prize 2006

Annual Report 2006



Internet: www.iws.fraunhofer.de

Fraunhofer Institut Werkstoff- und Strahltechnik

Annual Report 2006

CERTIFICATE

ISO 9001:2000

DEKRA Certification

hereby certifies that the company

Fraunhofer Institut Werkstoff- und Strahltechnik

Fraunhofer Institut für Werkstoff- und Strahltechnik

Business field:
Management and Infrastructure, PVD- /Nanotechnology, CVD Thin Film Technology, Thermal Coating, Joining & Surface Treatment, Ablation and Cutting

Location:
Winterbergstraße 28 * D-01277 Dresden

has successfully implemented the above mentioned quality management system according to the standard (12/2000) and applies it effectively. The conformity was inspected during the certification audit documented in audit report no. A0605389. 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 certification:	24.01.2007
This certificate is valid until:	23.01.2010	Certificate registration no.:	91297819/4 duplicate
Last audit day:	12.01.2007		

DEKRA Certification GmbH
Stuttgart, 24.01.2007

QMS-TGA-ZM-05-91-00

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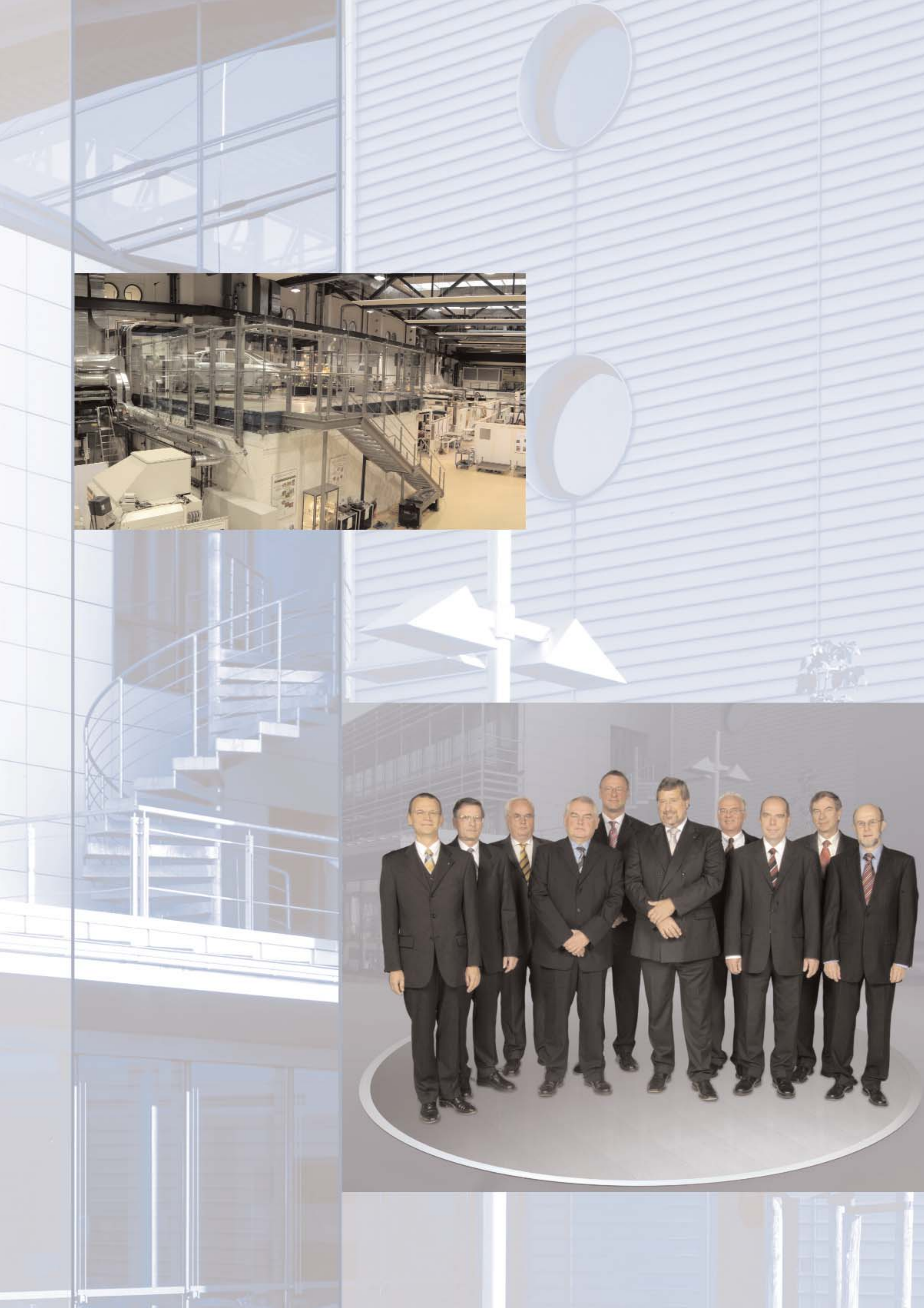


Preface

2006 was a year of economic upswing in the German economy. Through this IWS experienced a strong increase in industrial contracts; a more than 15 % increase. The volume of publicly sponsored projects also increased 10 - 15 % compared to 2005.

Again in 2006 we transferred a number of newly developed processes to industrial production. A distinguished result was the integration of the Laser-Arc process for the manufacturing of diamond-like coatings in a commercial coating machine and its transfer to industry. In addition several laser remote systems for cutting and welding, a laser hardening and a laser induction system have been transferred to industrial utilization.

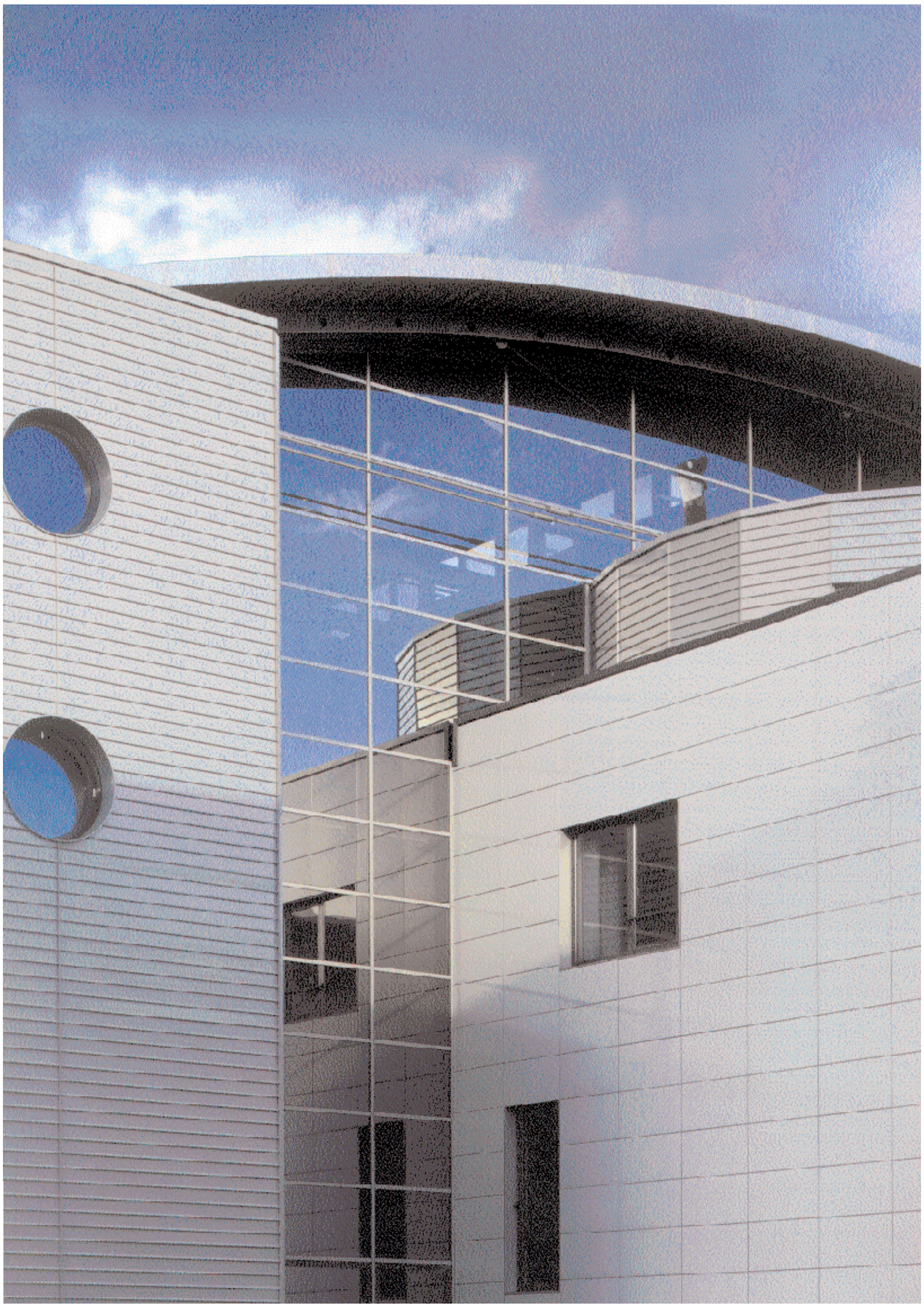
IWS employees received the Fraunhofer-Prize in 2006 for the fourth time in nine years. A process to harden metals through nanodispersed precipitation and its industrial realization was honored.

Another highlight in 2006 was the launching of the innovation cluster "nano for production". This cluster is supported by the state, the BMBF, industry, and FhG. Nanotechnology will therefore be even more important for IWS work in the future.

After an extremely successful year 2006 we are going very optimistically into year 2007.

Die Fähigkeit zur Innovation
entscheidet über unser Schicksal.

The capability to innovate
decides our destiny.
Roman Herzog



Fraunhofer-Institut für
Werkstoff- und Strahltechnik IWS

Fraunhofer Institute for
Material and Beam Technology IWS

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Prof. Dr. Frieder Meyer-Krahmer (State Secretary in the BMBF) during the opening ceremony of the nanotechnology innovation cluster "nano for production"

"Nano for production" Opening of the nanotechnology innovation cluster

On November 27th 2006 the opening ceremony of the nanotechnology innovation cluster "nano for production" took place at the Fraunhofer IWS Dresden. Participating Dignitaries included Prof. Dr. Frieder Meyer-Krahmer, State Secretary in the BMBF and Andrea Fischer, State Secretary in the Saxony State Office. Approximately 100 highly ranked representatives from industry, research organizations, and politics participated as well.

Prof. Dr. Hans-Jörg Bullinger (President of the Fraunhofer Society) during the opening ceremony of the nanotechnology innovation cluster "nano for production"

Participants at the 2nd fiber laser workshop in the Congress Center Dresden

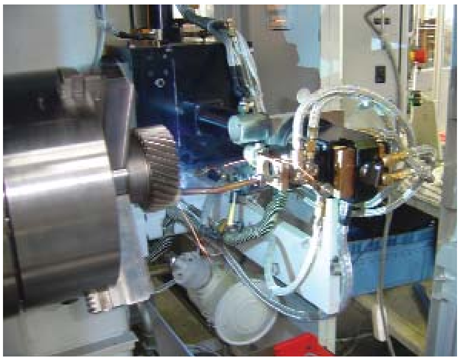
2nd workshop "Fiber Laser"

On July 5th - 6th the second Fraunhofer workshop on fiber lasers was held in the International Congress Center in Dresden. During the short period since the 1st workshop (held on November 22, 2005) research and development in this area has been steadily advancing. The number of fiber laser applications has therefore clearly increased. Approximately 300 participants attended and were informed about the new possibilities.

Fraunhofer-Prize 2006 for Prof. B. Brenner and F. Tietz

Turbine blades experience enormous stress. A new process ensures the increase of the life of a steam turbine. The process survived its "industrial baptism of fire" and has proven successful in 23 large steam turbines in power plants in Germany, Europe and the Near and Far East. For the development of the process "Hardening of the surface near region through localized nanoscale precipitation - a new process for wear protection of precipitation-hardenable steels", Prof. Dr. Berndt Brenner and Dipl.-Ing. Frank Tietz received the Joseph-von-Fraunhofer-Prize 2006.

Award winners Prof. B. Brenner and F. Tietz at the hardening machine



System for laser induction welding of hollow shafts (upper) and a welding process (lower) at GERTRAG Neuenstein (Manufacture EMAG Laser Tec)

Inductively assisted laser beam welding - IWS process development for industrial production

Another laser induction welding system was implemented in industrial production at GETRAG Neuenstein in December 2005. The plant produces hollow shafts for cars using a process developed at Fraunhofer IWS.

TraceScout - multi gas sensor

Laser-Arc module for the industrial deposition of superhard carbon coatings (ta-C)

Superhard amorphous carbon coatings (ta-C) are the new generation of low friction and wear resistant protective coatings for components and tools. The integration of a Laser-Arc module LAM400 in the industrial coater FlexiCoat 1000® of Hauzer Techno Coating (NL), and its handover to a leading automotive supplier, was a decisive step to establish the comprehensive industrial implementation of ta-C coatings based on the Laser-Arc technology.

FlexiCoat® 1000 coating system made by Hauzer Techno Coating with integrated Laser-Arc module LAM400

TraceScout - multi gas sensor for the quality control of ultra pure process gases

The production of integrated circuits requires the use of more than 30 ultra pure process gases for etching, deposition, oxidation, doping, and inertization process steps. Trace contaminations in the ppm and ppb range crucially determine quality and yield of the processed wafers. Quality control of these gases is therefore essential. Within the framework of the European ASSYST project, Intega Hans J. Jehl GmbH and Norsk Elektro Optikk (Norway) developed jointly with IWS a sensor system for the simultaneous detection of gas traces from water vapor, oxygen, and hydrocarbons in ultra pure undiluted specialty gases such as silane, ammonia, and HCl. The system was successfully tested in industrial operation.

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.

Se vogliamo che tutto rimanga come è, bisogna che tutto cambi.

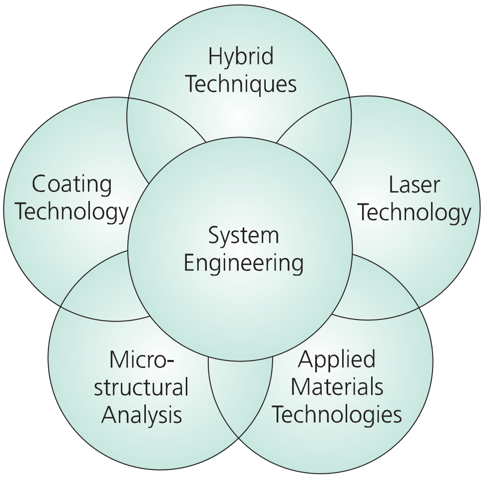
If we wish
that everything remains as it is,
then it is necessary
to change everything.
Giuseppe Tomasi di Lampedusa

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.

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.



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.

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	■	■			■

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Organization and contacts

External Project Groups

CCL - USA
Prof. Asmussen
phone: +1-517-355 4620

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

Infrastructure

Administration
Dr. Techel
ext.: 473

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
- **Carbon Nanotubes** – Dr. Jost, ext.: 477

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. Stehr
ext.: 003

- **Thermal Spraying** – Dr. Berger, ext.: 330
- **Cladding** – Dr. Nowotny, ext.: 241

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. Himmer, ext.: 238
- **Microprocessing/ Cleaning** – Dr. Klotzbach, ext.: 252

Nano particles Generation / Application

Prof. Schultrich, ext.: 403
Dr. Jost, ext.: 447
Mr. Fux ext.: 244

Nano Analysis / Nano Coatings
Dr. Leson, ext.: 317

Simulation
Dr. Lange / Dr. Mahrle, ext.: 328 / 407

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

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 2006, 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: Plasma technique
- Prof. Beyer: Rapid prototyping
- Prof. Beyer: Laser robotic, lasertronic
- Dr. Leson, Prof. Beyer: Surface engineering / nanotechnology
- Prof. Schultrich: Thin film technology

Cooperation Fraunhofer IWS - TU Dresden

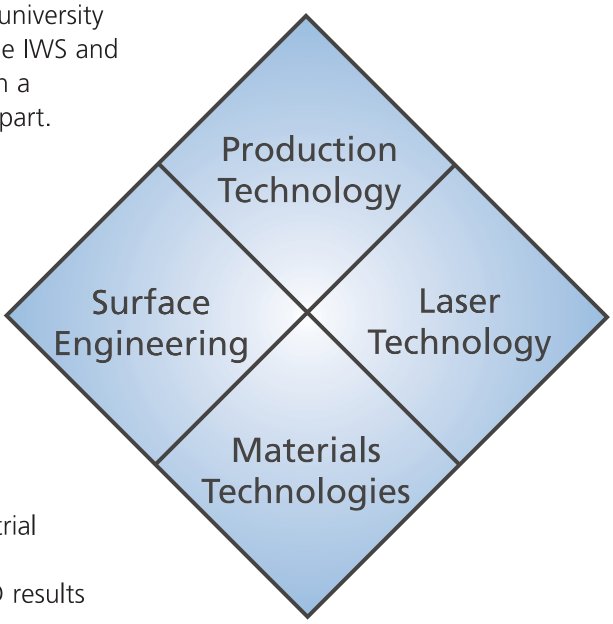
A special agreement regulates the cooperation between the IWS and the TU Dresden. Prof. Beyer works simultaneously as the executive director of the IWS as well as a chairman at the University. The work is distributed as follows: Research and education are performed at the university and applied research 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

Die Forschung lebt
vom Austausch des Wissens.

Research lives
off the exchange of knowledge.
Albert Einstein



CD for laser technology course

CD for manufacturing technology course (II)

Centers and external project groups

Chi più sa, più dubita.

The more one knows
the more one doubts.
Papst Pius II.

Nanotechnology competence center "Ultrathin Functional Films"

Nanotechnology is a key technology of the 21st century. Market ready products already exist: computer harddisks and read / write heads for data storage that are coated with films only a few nanometers thick, or scanning tunneling microscopes which make the world of atoms and molecules visible - these are only two examples. Ultrathin films are key elements in nanotechnology.

The consequential exploitation of industrial applications of ultrathin films is the goal of 51 companies, 10 university institutes, 22 non-university research institutes and 5 associations. In September 1998 they bundled their combined knowledge into a network, which has since been coordinated by the Fraunhofer IWS. The Federal Ministry for Research acknowledged the network as the federal competence center for ultrathin functional films.

Presentation of the state capital Dresden at the Nanofair 2006 in Karlsruhe

Important topics that are addressed include the organization, coordination and execution of events and workshops as well as the recommendation of competence contacts. Other activities include the participation in industrial trade shows, active publicity, as well as education and training.

International symposium Nanofair 2006

The international symposium Nanofair 2006 - new ideas for industry - was held for the 5th time in November 2006 in Karlsruhe. In a short time this event has become one of the leading discussion forums for nanotechnolgy in Europe. A particular focus is on the interface between science and industry and therefore applied research and development.

Due to its importance the event was held under the aegis of Dr. Annette Schavan, Federal Minister for Education and Research. More than 200 participants from science and industry used the opportunity to learn about the latest developments and products in nanotechnology and to participate in exciting discussions. The technology topics were electronics, materials, surfaces, optics, automotive, and biosciences. The symposium was accompanied by a special exhibition in which IWS and the nanotechnology competence center participated. The next Nanofair will be in Dresden on March 11th and 12th in 2008.

The "Year of Germany" in Japan and the "Nanotech 2006" exhibit in Tokyo

The IWS participated in several events of the Free State of Saxony during the German year in Japan (2005 / 2006). On behalf of the Saxony Economic Development Corporation (Wirtschaftsförderung Sachsen GmbH), the nanotechnology competence center organized the exhibition of the Free State at the world's largest nanotechnology fair "Nanotech Tokyo 2006", which was held on February 21 - 23, 2006.

The 45,868 visitors during the three day period marked a new record. A total of 385 exhibitors participated in 3 exhibition halls. This was made up of 120 foreign and 265 domestic exhibitors. Most of the foreign exhibitors were European, with 29 from the UK and 25 from Germany.

Dr. Frank-Walter Steinmeier, Federal Minister of Foreign Affairs, and his delegation of politicians and industry leaders visited the "Nanotech 2006" during the first day. Prof. Dr. Karl Leo from the University of Technology (TU Dresden), who is both the deputy director of the Fraunhofer IPMS Dresden and a member of the nanotechnology competence center, guided the tour. The minister was especially interested in Saxony's exhibit.

Several additional events were held in conjunction with the "Nanotech 2006". In particular the workshop "Germany - Europe's no. 1 nanotechnology market" (organized by Invest in Germany) and the German-Japanese expert meeting "From nanomaterials to innovation" should be mentioned.

Several members of our Nano-CC actively participated with presentations during these events.

Visit of the Germany Minister of Foreign Affairs, Dr. Frank-Walter Steinmeier" at the booth of the Free State of Saxony and the Nanotechnology Competence Center (from left to right: Dr. Andreas Leson, Fraunhofer IWS and Nano-CC, Karin Heidenreich, Saxony Economic Development Corporation, Dr. Frank-Walter Steinmeier, Federal Minister of Foreign Affairs, Prof. Dr. Karl Leo, TU Dresden and Nano-CC)

Australian-German workshop on nanotechnology 2006

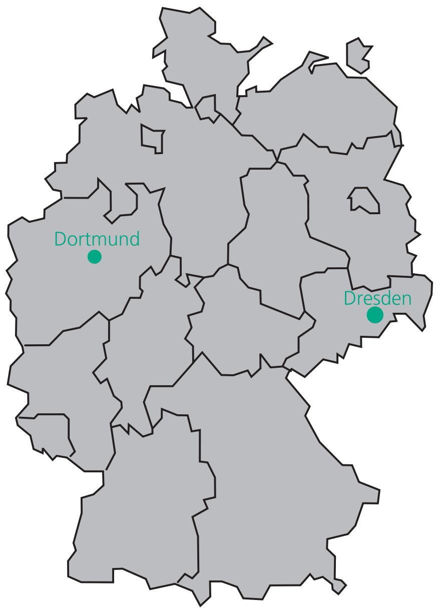
Current research results and new approaches for cooperation were the topics of the bilateral seminar with German and Australian participants on November 23rd and 24th 2006. The Fraunhofer IWS organized and coordinated this event during the Nanofair. Australian and German presentations were given on the current state of research in nanomaterials, nanoparticles, and nanoelectronics. The Australian participants were using the opportunity to also present their results at the Nanofair conference.

The reasonable man
adapts himself to the world.
The unreasonable one persists
in trying to adept the world to himself.
Therefore, all progress
depends on the unreasonable man.
George Bernard Shaw

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
phone:
+49 (0) 231-844-3512

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.

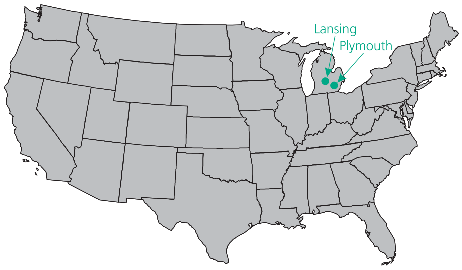
The CCL is comprised of two divisions, the "Coating Technology Division" at Michigan State University in East Lansing managed by Dr. Thomas Schülke, and the "Laser Applications Division" located in the building of Fraunhofer USA Headquarters led by Eric Stiles.

Laser Applications Division
2006 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).

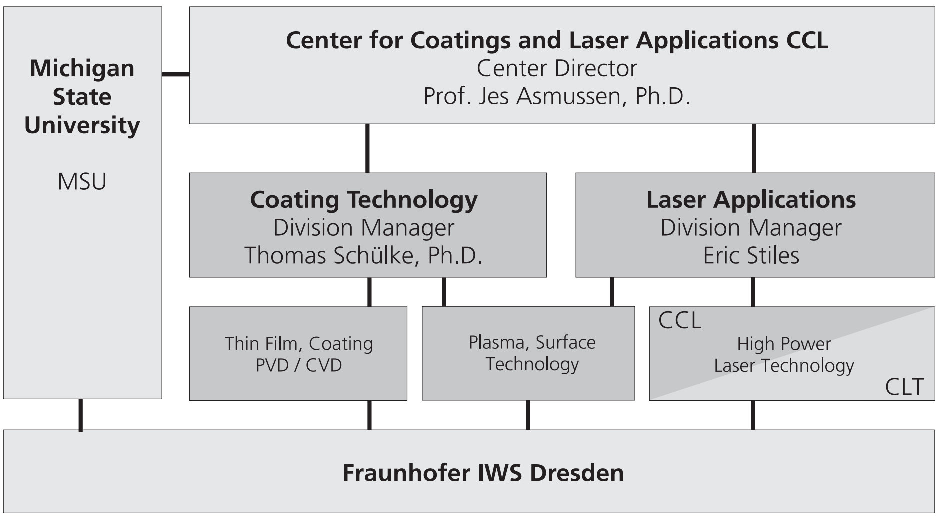
budget 2006	$3.14 million
- personnel costs	$1.50 million
- other expenses	$1.64 million



www.ccl.fraunhofer.org

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

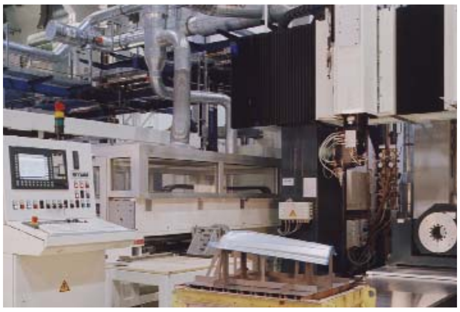
Building of CCL in East Lansing, Michigan



Institute equipment

Facts do not cease to exist because they are ignored.
Aldous Leonard Huxley

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, OPO systems

several high power diode lasers, 1.4 to 6.0 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

Laser machine for simultaneous processing with two cooperating robots, a swivel unit and two fiber-coupled 6 kW diode lasers

cutting machines with linear drives up to 300 m min^{-1} feed with 2.5 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 offline 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 (online / offline 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

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

Only the impossible goal leads to the possible.
Miguel de Unamuno

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 2006 the employees are divided up as follows:

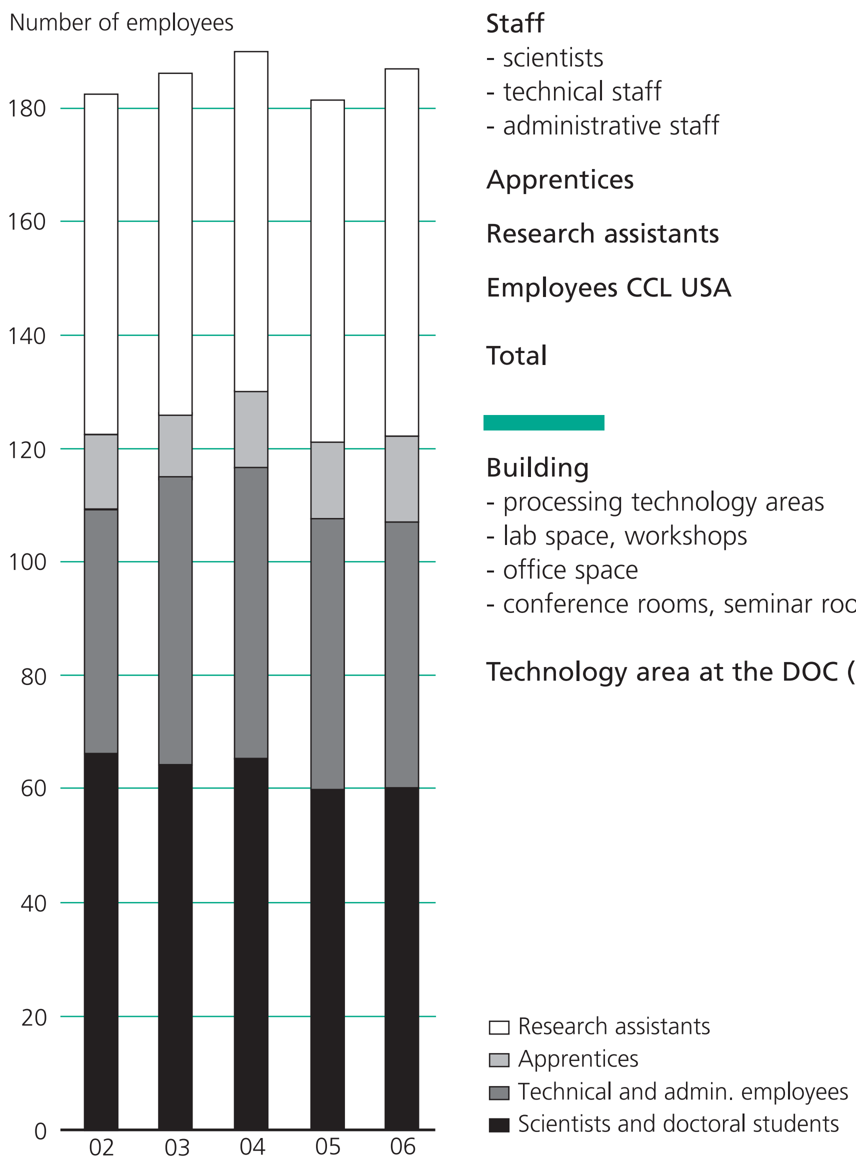
Employees of Fraunhofer IWS

	Number
Staff	**107**
- scientists	60
- technical staff	39
- administrative staff	8
Apprentices	**15**
Research assistants	**65**
Employees CCL USA	**13**
Total	**200**

Employees of Chair for Laser and Surface Technology of TU Dresden

	Number
Staff	**33**
- scientists	20
- technical staff	12
- administrative staff	1
Research assistants	**19**
Total	**52**

Building	**8400 m^2**
- processing technology areas	2000 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 2006 (preliminary*)

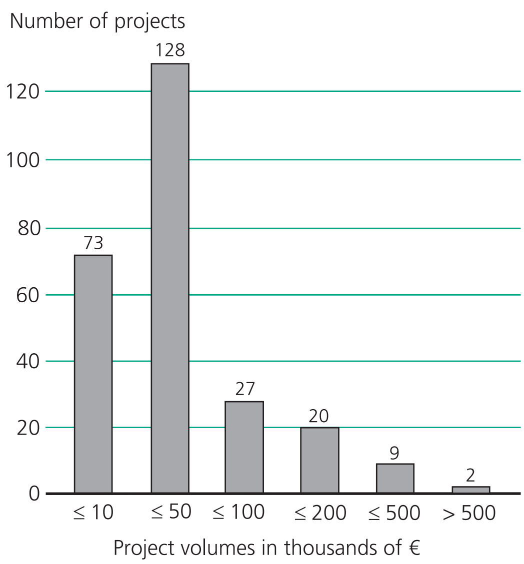
* actual cost determination not yet finalized

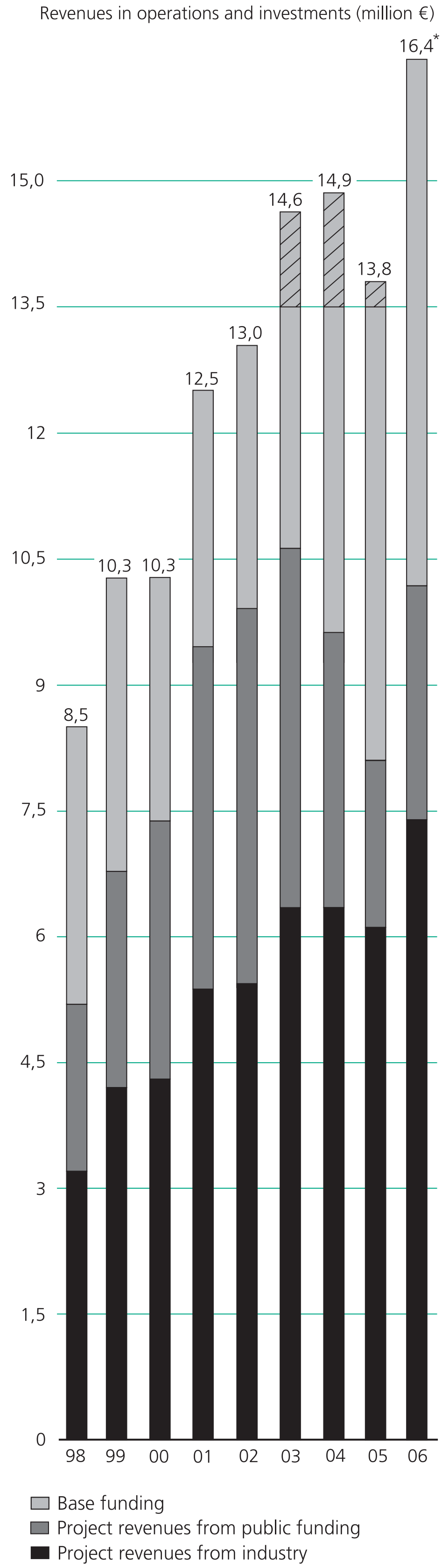
	million €	%
Operational costs and investments 2006	**16.4**	
Budget	**14.2**	
- personnel costs	6.4	
- other expenses	7.8	
Investment	**2.2**	

	million €	%
Revenue 2006	**16.4**	
Revenue operations	**14.2**	
- industrial revenues	7.1	50
- revenues of public funded projects	2.8	20
- base funding IWS	4.3	30
Revenue investment	**2.2**	
- industrial revenues	0.3	
- revenues of public funded projects	0.0	
- base funding IWS	1.3	
- strategic investment	0.6	

Projects

In 2006, IWS handled 259 projects. The distribution of the projects with respect to their volume is shown in the graphic below. One hundred twenty eight of the projects were for 10 to 50 T€ (thousands of euro), for example.





Board of trustees

The advisory committee supports and offers consultation to the Fraunhofer IWS. Members of the advisory committee in 2006:

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

S. Clobes, Ms.
Manager of the production systems and technologies department at the Federal Ministry for Education and Research

D. Fischer, Mr.
General manager EMAG Leipzig Machine Factory GmbH

U. Jaroni, Dr.
Member of the Board of Directors - Automotive Division - ThyssenKrupp Steel AG (curator since July 2006)

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

P. G. Nothnagel, Mr.
Saxony Ministry of Economic Affairs and Labor (curator since July 2006)

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 (curator until April 2006)

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

The 16th committee meeting took place on February 09, 2006, at Fraunhofer IWS in Dresden.

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. A. Techel	Deputy directress Head of administration (since Sept. 2006)
Dr. S. Wilhelm	Head of administration (until August 2006)
Prof. Dr. B. Brenner	Department head
Dr. V. Hopfe	Department head
Dr. L. Morgenthal	Department head
Dr. S. Nowotny	Department head (until June 2006)
Prof. Dr. B. Schultrich	Department head
Dr. G. C. Stehr	Department head (since June 2006)

Guests are:

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

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 2006 were:
- Prof. Dr. E. Beyer
- Dr. S. Bonß

The Fraunhofer-Gesellschaft

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

Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, accelerating technological progress, improving the acceptance of new technologies, and not least by disseminating their knowledge and helping to train the urgently needed future generation of scientists and engineers.

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

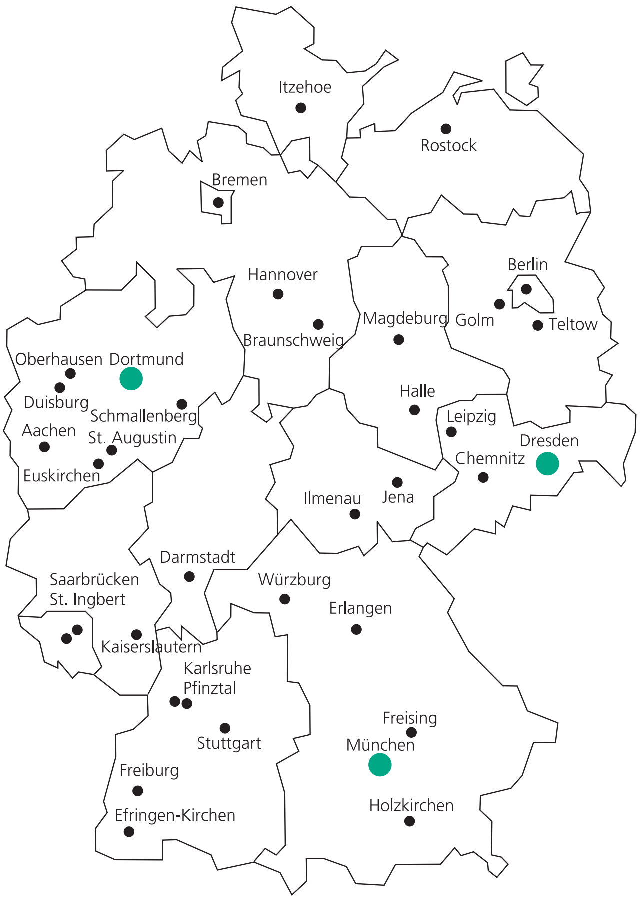
At present, the Fraunhofer-Gesellschaft maintains more than 80 research units, including 56 Fraunhofer Institutes, at 40 different locations in Germany. The majority of the 12,500 staff are qualified scientists and engineers, who work with an annual research budget of €1.2 billion. Of this sum, more than €1 billion is generated through contract research. Two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Only one third is contributed by the German federal and Länder governments in the form of institutional funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

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

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

Wir brauchen etwas Neues.
Wir müssen lernen,
in neuen Situationen
neu nachzudenken.

We need something new.
We need to learn to rethink
in new situations.
Bertolt Brecht



VOP

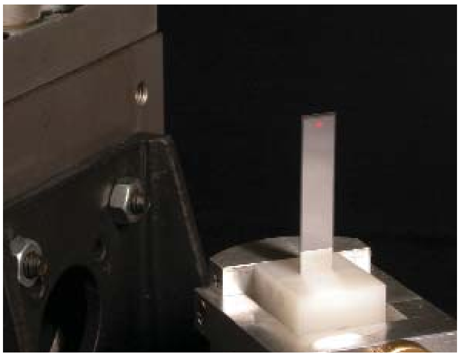
Fraunhofer Verbund Oberflächentechnik und Photonik

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.



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

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.

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

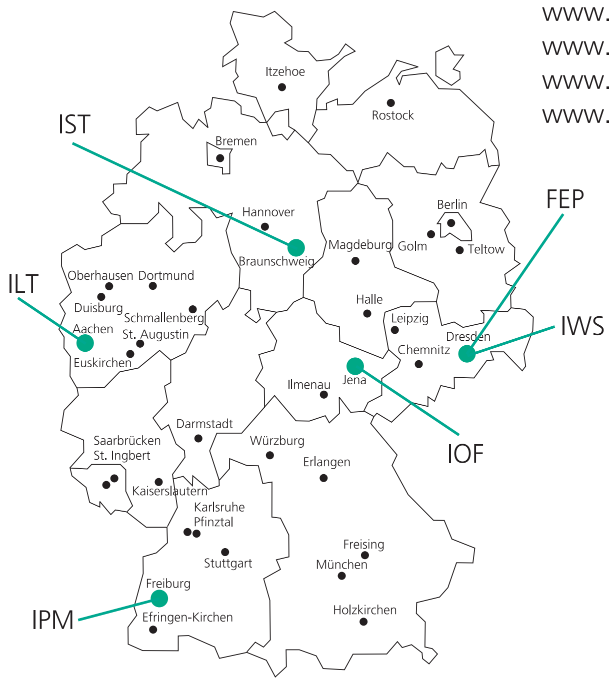
As an industry oriented R&D service centre, the Fraunhofer Institute for Surface Engineering and Thin Films IST is pooling competencies in the areas film deposition, coating application and film characterization. Presently, the institute is operating in the following business fields: mechanical and automotive 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:
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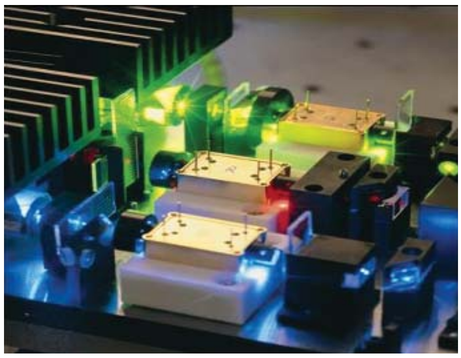
www.ilt.fraunhofer.de
www.ist.fraunhofer.de
www.iof.fraunhofer.de
www.iws.fraunhofer.de



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

R&D-offer: Joining and surface treatment

Rèflèchir, c'est dèranger ses pensèes.

To reflect means
to disorder one's thoughts.
Jean Rostand

Editor: In the middle of 2006 the new technology hall was put in operation. Considering the fact that the IWS just finished a major extension in 2004, why is the new hall necessary?

Prof. Brenner: The area of laser materials processing grew much faster than we expected. Just think about the large XXL laser beam welding machine. We soon realized that we did not have enough space to house new projects, machine concepts, and processing machines. On top of that we are in a development phase where there is no off-the-shelf equipment available. Therefore we have to design and test more prototype equipment, which requires more space as one must have more flexibility.

Editor: Could you please elaborate on this by giving an example?

Prof. Brenner: Certainly. One of the most important competencies in our department is laser beam hardening. The existing systems and the available laboratory space were limiting further development of the technology. We were subsequently able to develop a prototype of a new laser beam hardening machine. This system can selectively harden functional surfaces on complex 3D parts while avoiding tempered zones. This was the first machine that was put in the new technology hall and successfully tested. The machine is very flexible. It is equipped with 12 kW laser power and has a work area of 3.5 m x 2 m x 1.2 m. The main use is to laser harden neighboring areas along 3D edges without generating tempered zones. Examples for use are turbine blades, large tools and dies, special ball bearings and large diameter shafts, machine beds and special crankshafts. In order to derive maximum benefit from the flexibility of the system we are planning on using it for the further process and system development of many other laser based surface technologies such as inductively refining, hardening, remelting, gas alloying, and related hybrid techniques as well as for heat conduction welding.

Editor: Since you mentioned laser welding - what progress has been made here?

Prof. Brenner: Within a publicly funded project titled "Laser Powertrain" we envision developing crack free laser beam welding processes for case hardened components in automotive powertrains without altering the hardened surface. Success in the project would have a major impact on costs and process chain reduction. I am especially glad that we were able to find potential solutions for this complicated challenge.

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Dr. Steffen Bonß
Team leader surface treatment technologies
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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.

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 hardened turbo charger shafts

Laser beam welded transmission component

Dr. Bernd Winderlich
Team leader materials testing and characterization
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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.

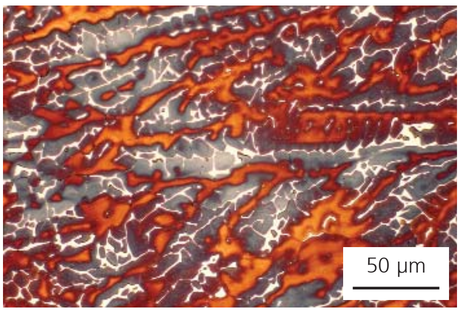
Dr. Irene Jansen
Team leader bonding
(phone: +49 (0) 351-463-35210,
irene.jansen@iws.fraunhofer.de)

Adhesive bonding technology

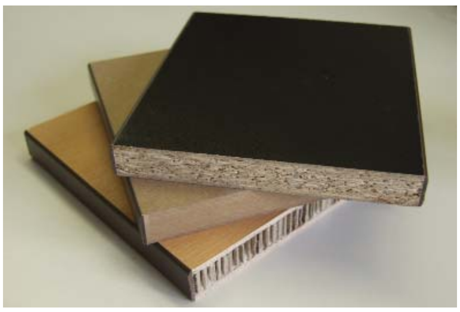
The main working areas of the group are:
- surface preparation through plasma and laser techniques as well as conventional pretreatment methods,
- constructive adhesive bonding of different materials (metals, plastics, glass, wood),
- characterization of surfaces and bonded systems through contact angel, 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.

Example of projects 2006

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



Laser beam welding: microstructure of austenitic steel



Small area bonded plates using lasers to melt the adhesive

Novel robot based laser hardening system for the hardening of complexly shaped workpieces

Task

Over the past years laser beam hardening of steels and cast iron has been established as a complementary laser surface hardening technology. These processes have been known for over twenty years. However, it is the availability of powerful and cost effective high power diode lasers that made this recent success possible. These lasers provide multiple kilowatts and are essential for numerous system technology developments aiming at simplifying laser surface hardening and thus move it from an "expert technology" to the shop floor. New developments included special temperature control units, laser power controls, and beam shaping systems, which are now offered to the market.

As a consequence of the extended application possibilities, there is now a need for universal and flexible machine systems which support this technology. The edges of tools and turbine blades, for example, represent complexly shaped workpieces with defined hardening zones which were exceeding the capabilities of existing machines. In many cases the user requires hardening zone geometries, which cannot be accomplished with one laser spot irradiating from only one side. Unfortunately it is often not possible to treat these parts in a sequence of laser processing steps because it would lead to tempering the previously hardened zone in the overlapping regions. The option to use dual beams in a situation like this, is limited because of the necessary beam splitting optics. The relative position of laser spots is not flexible. The task was to develop a machine system that overcomes these limitations.

Solution

Several system concepts have been studied. The decision was to use a motion system consisting of two buckling arm robots with coupled motion. An additional rotating and swivel system for smaller workpieces adds more access to workpiece areas to be hardened (Fig. 1).

The primary application case is based on each of the robots holding and moving its individual laser optics while the workpiece is set on the floor or held by the rotating swivel unit to additionally move it. Two fiber coupled high power diode lasers with each 6 kW power deliver the laser radiation. Each of the lasers can achieve a track width of 60 mm at common hardening depths of 1 - 1.5 mm if using a special beam shaping optics, which optimizes the laser spot geometry. Two dynamic beam shaping systems "LASSY" are used, which are equipped with scanner mirrors and integrated temperature sensors for process control (Fig. 2).

Hardening applications can utilize laser spot dimensions of 4 mm in diameter up to 18 x 60 mm^2. The temperature reading is done with the camera based temperature measurement system "E-MaqS", which observes along the coaxial direction of the laser beam.

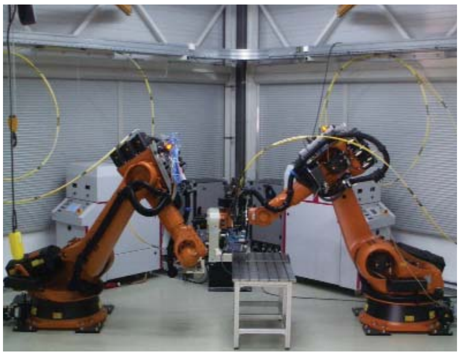


Fig. 1: Inside view of the robot based laser system

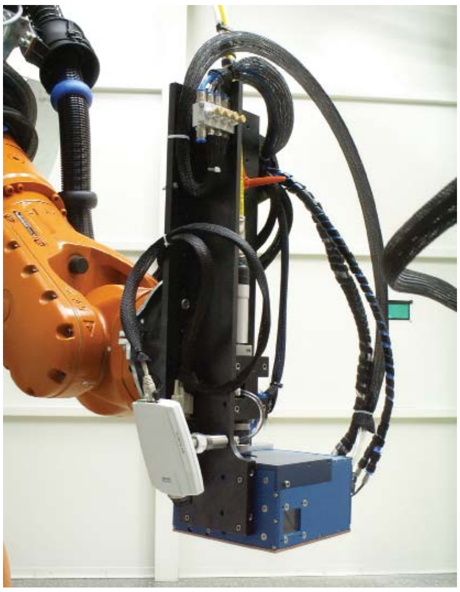


Fig. 2: Laser optics "LASSY", mounted to the robot

Processes are controlled via two coupled laser power control systems "LompocPro". These ensure that the workpiece surface temperatures of overlapping zones remain constant at the desired level by regulating the laser power. This system of coupled controls has been successfully demonstrated for two high power diode lasers in fixed geometric arrangement. By coordinating the geometric robot motion and timing it is possible to generate temperature fields on the workpiece surface, which overlap in areas that should be hardened. It is possible therefore to achieve a time controlled heating and cooling profile in areas that were irradiated by two laser beam spots.

The robot based laser system was in principle designed for industrial applications. A laser proof enclosure ensures that the system belongs to the laser class 1 safety category. Blinds allow daylight to penetrate into the working room for system adjustment. An almost 3 m wide rolling door enables the system to be loaded with parts. Heavy weight workpieces are transported via forklift. For smaller parts there is a 250 kg crane integrated in the work cell. Using a comfortable computer workstation, which controls all systems, the employee operates the machine. Several cameras allow the observation of the work cell and processes.

Results

The system was first used to process the edges of cutting and bending tools as well as steam turbine blades. In the past the hardening of bending tools resulted in a wide hardening track on the one side whereas the other side was only slightly hardened. The newly developed laser system however enables a uniform and in the cross section symmetric hardened zone (Fig. 3). The two robots move timely synchronized but on very different paths. The two laser beam spots generate a common heating zone. The result is a homogeneous hardening zone, which covers the edge (Fig. 4).

Steam turbine blades are exposed to heavy wear. So far it was only possible to harden one side. Using heat conduction it was attempted to harden around the edges, however, the resulting hardening zone geometry was not satisfactory for future turbine designs. The novel laser hardening machine now enables the generation of hardening zones which are suitable for the increasing demands. The process is well controlled so that it works robust and reliably. That guarantees for the user a high product quality, which is in particular important for highly loaded steam turbines and compressor blades.

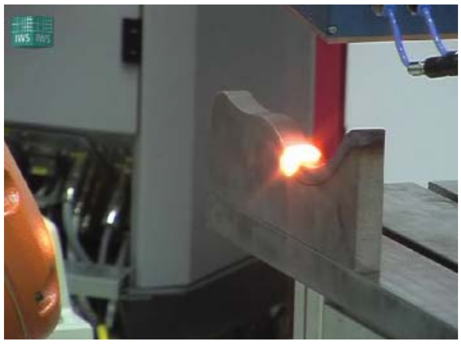


Fig. 3: Simultaneously performed hardening process

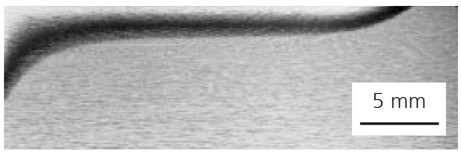


Fig. 4: Example of a simultaneously treated workpiece in cross section

Contact

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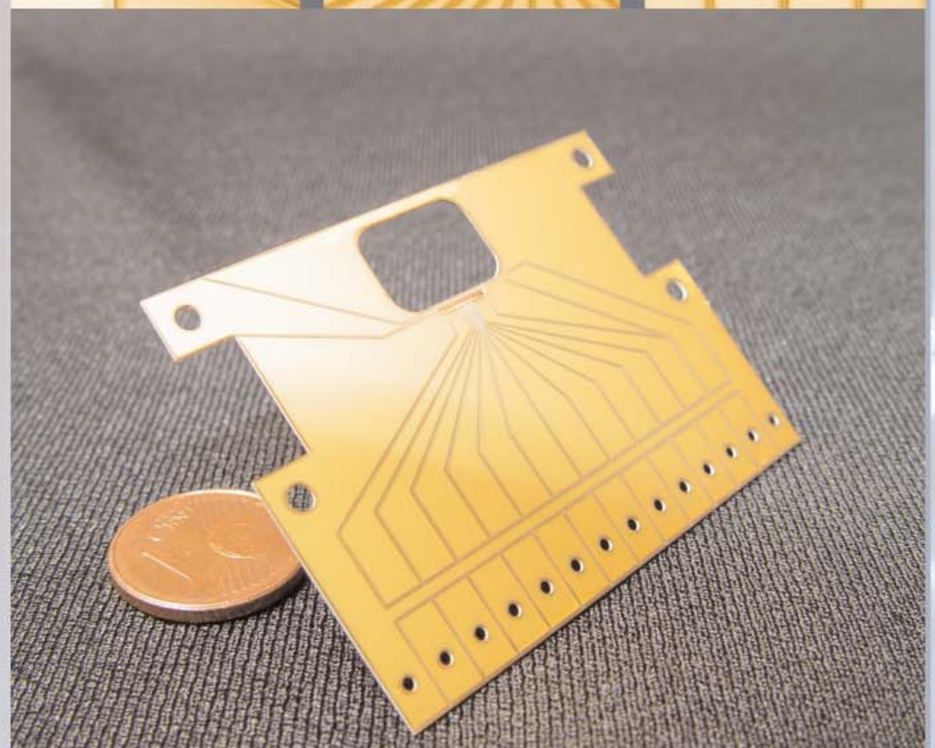
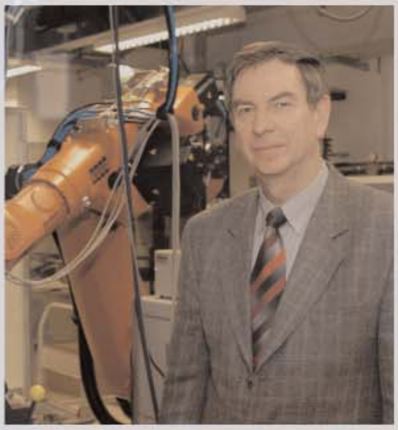


R&D-offer: Laser ablation and cutting, system engineering



Editor: Which perspectives does the fiber laser have for laser beam cutting?

Dr. Morgenthal: Fiber lasers, which appeared in the market over the past years, are an interesting addition for laser cutting applications. For cutting we usually desire laser sources with high beam quality to be able to focus the beam very accurately. So far these sources were CO_2 lasers if laser powers in the range of several kilowatts were required. Solid state lasers, which were in particular interesting for 3D processing due to the possibility to guide the radiation in optical fibers, are not comparable in beam quality and efficiency.

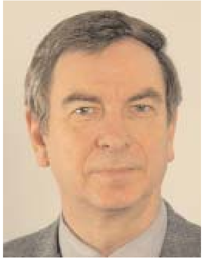
This situation is thoroughly changed with the advent of fiber lasers. These lasers offer highest beam quality at high powers, and high electrical efficiency in a compact design. Therefore it is our task to make this opportunity available to our customers for specific applications.

Editor: Which effects do new lasers such as fiber lasers have on laser system technology?

Dr. Morgenthal: The typically excellent beam quality at high power levels enables high processing speeds for many applications. This becomes evident in particular in laser cutting. However, this opportunity also raises the bar for the laser processing system to realize the higher speeds. These are demands that have already been challenging to classic mechanical engineering in the past. Technologies such as remote processing are particularly useful since they are benefiting from a special property of the laser tool - no inertia. The Fraunhofer IWS has a number of system and process technologies available in this area. If the concept is implemented in a specifically adapted process solution, it can significantly increase the manufacturing productivity in many cases.

Es ist besser,
hohe Grundsätze zu haben,
die man befolgt,
als noch höhere,
die man außer Acht lässt.

It is better to have high principles
which one follows
than having even higher principles
which one ignores.
Albert Schweitzer



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Examples of projects 2006

further information:
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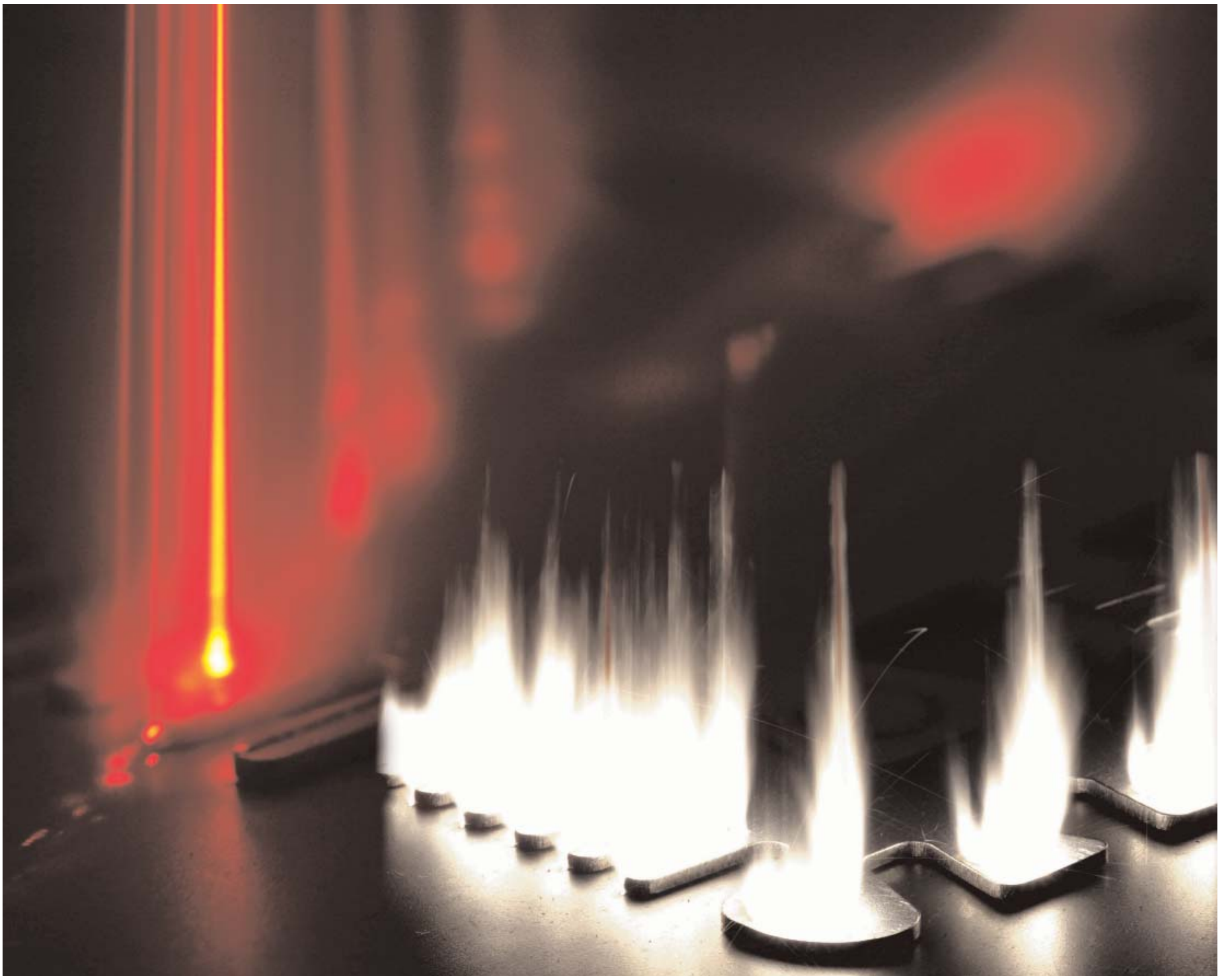
www.iws.fraunhofer.de/projekte/036/e_pro036.html
www.iws.fraunhofer.de/branchen/bra06/e_bra06.html



Dr. Thomas Himmer
Team leader cutting
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Cutting technology

The IWS is equipped with CO_2 and solid-state lasers, and especially fiber lasers, in a wide range of powers and beam qualities, which can be used for cutting of all materials that are used in modern manufacturing.

Research topics include the development of technologies to optimize process and cycle timing. We are using highly dynamic 2D and 3D cutting machines with direct linear drives as well as modern robots. Aside from using commercial processing optics we also apply internally developed scanner systems for remote processing.

We offer:
- technology and system development, testing, and optimization,
- comparison tests,
- feasibility studies with prototype manufacturing.

Dr. Udo Klotzbach
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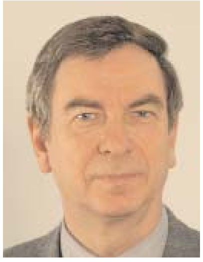
Micro structuring with laser

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.



Dr. Lothar Morgenthal
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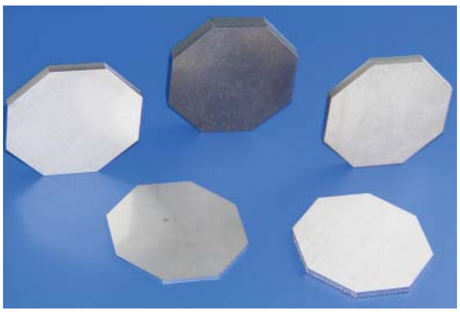
System engineering and laser processing

New or further developed and more powerful technologies in laser materials processing frequently require new system technologies or components in order to optimally use them. In cases where this system technology is not yet commercially available, we offer the development, testing, prototyping, and demonstration of these solutions. For example:
- processing optics with enhance functionality, such as high speed and / or precision beam scanning for remote processing,
- control technology and CAD / CAM tools for remote and on the fly processing,
- system technology and software for online process monitoring and control.



Laser beam cutting with fiber lasers

Mobile system for the anti-slip preparation of natural stones

Scanner optics for fiber laser HF-SAO1.06(2D)

Scanner optics for laser processing with fiber lasers

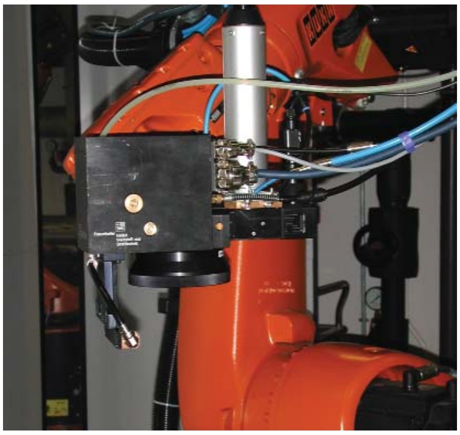


Fig. 1: Large area scanner SAO1.06 FL

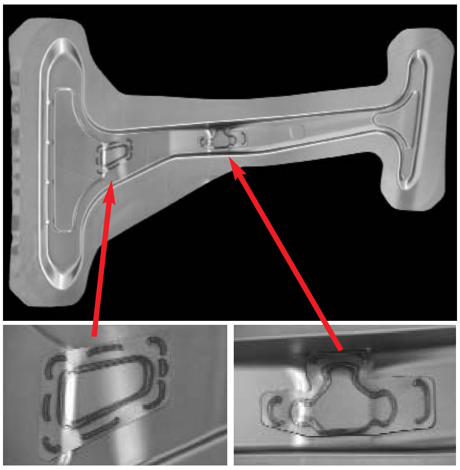


Fig. 2: Typical workpiece for 3D remote processing

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Task

The high power and energy densities of lasers offer ideal conditions for high processing speeds or short cycle times. Remote technology is increasingly used in this application and not only for complex processing contours. The heart of every remote system is the beam deflection or scanner optics, which enables an almost inertia free precise beam scanning over the workpiece surface. Highly desirable are scanner optics, which combine a good beam focus with a large working area. So far that has only been possible with CO_2 lasers. They offer a nearly ideal focus (only limited by diffraction) at high powers. However, the laser radiation cannot be delivered via optical fibers.

Flexible remote systems for 3D contours that have to be processed on the fly are cost effective and can be set up using robots. This requires however, an optical fiber based beam delivery.

Solution

Solid-state laser radiation can be delivered via fibers. But the low beam quality in combination with the need for larger fiber diameters at higher powers was limiting their focus diameter at larger working distances (focal lengths).

Currently the Fraunhofer IWS is using modern fiber lasers for investigations and developments in the area of remote processing. These lasers operate at a base mode of 1 kW (BPP < 0.4 mm mrad) and a 4 kW multi mode (BPP < 2.5 mm mrad).

Results

Flexible scanner optics for fiber laser based remote processing have been developed and tested. One special implementation aims at large and directly with the scanner reachable work areas. Depending on the process requirements with respect to beam projection the work area is approximately 0.5 x 0.5 m^2 or 1 x 1 m^2 (Fig. 1).

Another implementation uses newly developed scanner optics to positively influence critical processes. A high frequency beam motion (up to 1 500 Hz) overlaps with forward feed during processing.

These scanner developments are tailored for high power fiber lasers. They use specific advantages of the fiber laser such as:

- flexible fiber guiding from the laser to the processing optics,
- high degree of absorption of the radiation for metal materials,
- high electrical efficiency,
- compact design and mobility.

These advantages are also useful for remote processing.

New possibilities for laser cutting with fiber lasers

Task

Fiber lasers as modern variations of the solid-state laser offer the advantageous combination of high beam power with highest beam quality.

Important advantages of the fiber laser such as
- depth of focus, capability to focus,
- high absorption for metallic materials,
- possibility to use fiber delivery,
- high electric efficiency,
- compact design and mobility,

are of special interest for laser cutting.

Solution

For investigations and development in laser beam cutting we currently have three fiber lasers available:
- 400 W polarized, BPP < 0.4 mm mrad,
- 1 kW single mode, BPP < 0.4 mm mrad,
- 4 kW multi mode, BPP < 2.5 mm mrad.

All three lasers can be freely combined with 2D and 3D handling systems (portals, robots) and with powerful control technology. Processing optics with a variety of focal lengths and distance sensors have been developed for high pressure cutting. They offer the ability to broadly vary processing parameters. Modern CAD / CAM tools are used to quickly and effectively generate extended cutting programs for complex contours for virtually any part.

Results

The fiber laser outperforms the CO_2 laser at equal material thicknesses for cutting metallic materials (< 5mm, stainless steel, construction steel, aluminum alloys) (Fig. 1). At comparable laser powers the fiber laser achieved twice the cutting speed. If the handling system is the speed limitation for cutting contours, it is even possible to use fiber lasers of less power. For example, it was possible to use a 1 kW fiber laser YLR 1000 SM to achieve the same cutting speeds as a 3 kW CO_2 laser.

Concerning the cutting quality (roughness, burr height) fiber lasers reach the high quality level of CO_2 laser cuts (Fig. 2). An exception is still the cutting of stainless steel with more than 5 mm thickness where the fiber lasers cause a slightly higher roughness and burr than CO_2 lasers.

The excellent cutting performance and quality in combination with the high efficiency make the fiber laser more than an alternative to the so far preferred CO_2 lasers for cutting of metals.

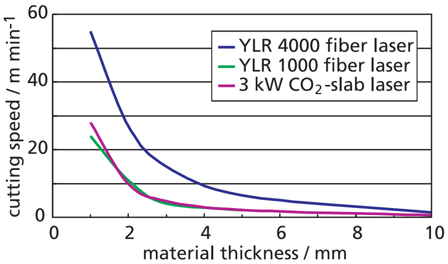

Fig. 1: Cutting of stainless steel, cutting gas N_2

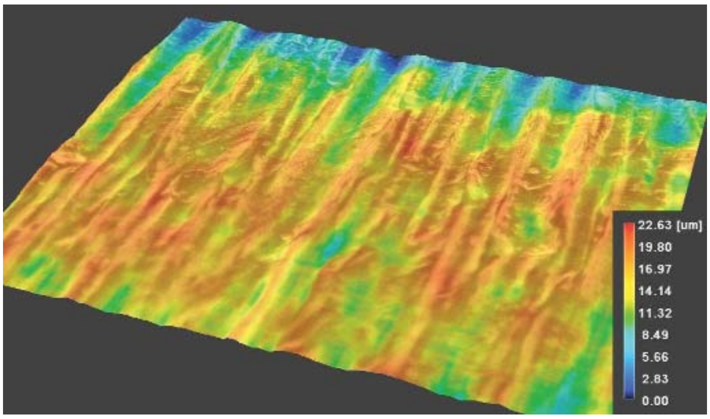

Fig. 2: Surface topography of the cutting area of a 3 mm thick stainless steel band

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R&D-offer: Thermal coating

Editor: The past year was marked by some personnel changes in your department. How do you, as the new head of department, see the strategic orientation for the future of your department?

Dr. Stehr: The previous head of department, Dr. Nowotny, decided for health reasons to step down and exclusively focus on the buildup welding technology. He is now the group leader and therefore remains available as an experienced researcher. In addition we lost our long-term group leader Dr. Techel who became the new head of administration for IWS.

The strategic orientation for our department is characterized as follows:

1. tailored multifunctional property profiles of thermal coatings,
2. nanostructure coating materials and coating systems,
3. novel system technology with complete system integration,
4. new application areas for thermal coatings.

Editor: This list sounds interesting. Can you give us more details?

Dr. Stehr: For each bullet a brief example: One goal of our activities in thermal spraying is to tailor the combination of electrical and mechanical properties of oxide ceramics. We will contribute materials spanning nano technology to the newly founded cluster "nano for production". To use the laser for direction independent coating in complex 3D applications, we not only use powder materials but also wires. To do this we, in conjunction with our industrial partners, develop special beam splitting optics.

In the area of laser buildup welding we managed in the past year to transfer five substantial systems to industry in Spain, Poland, Germany, and Italy. We are not only developing the system technology but also perform the complete system integration into the industrial manufacturing line. Next year we will continue on this successful course.

We are developing new coating systems for high point and line loads, which will open new application areas for thermal coatings. Examples are motor components such as inside high-pressure formed camshafts, which could not be thermally coated in the past. We are also working on the acquisition of new application areas based on buildup welding at a precision level that has not been available so far. That is for example possible with the help of fiber laser systems.

Editor: Are you giving highest priority to the fiber laser as an energy source?

Dr. Stehr: Without a doubt the fiber laser will be an important energy source for thermal coating technology in particular for high precision applications. In parallel I expect that the high power diode laser will further continue to establish itself as the workhorse in coating technology. However, proven solid-state lasers will be used for quite some time because of their installed base.

Wir haben uns immer wieder neu erfunden.

We always reinvented ourselves.
Lothar Späth

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Examples of projects 2006

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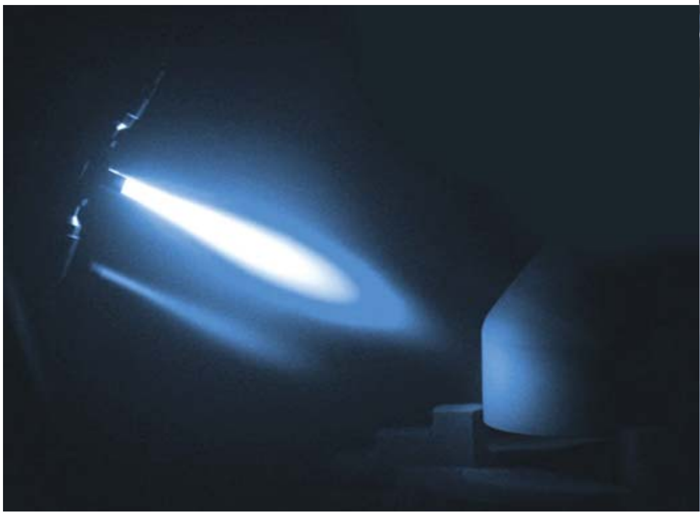
www.iws.fraunhofer.de/branchen/bra09/e_bra09.html
www.iws.fraunhofer.de/projekte/032/e_pro032.html



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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:

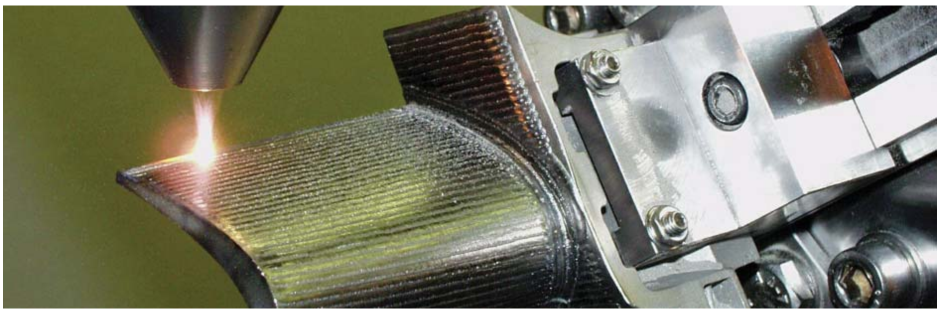
- conception of stress adapted coating systems,
- development of complete coating solutions from the material to the coated part,
- development and manufacturing of system components,
- participation in system integration,
- support of the user with technology introduction.

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

New system technological developments in laser beam buildup welding

Task

The processing heads of the IWS COAXn family contributed with many applications to the industrial acceptance of laser beam buildup welding. The process is more and more getting established in worldwide manufacturing and thus the performance expectations from the technology and its system components are increasing.

Current projects, for example, aim at using the laser process for complex 3D applications and in difficult welding positions with limited access to the parts. An additional challenge is the demand for the directional feeding of wires as an alternative to powders.

Solution

To achieve precision buildup welding two new variations of coaxial powder nozzles have been developed. A segmented powder nozzle guarantees a stable powder stream in tilted and horizontal nozzle position. To better reach difficult welding positions we developed a smaller coaxial powder nozzle, which was designed to work with fiber lasers. Within a BMBF project we are developing as a new production concept a stable wire feed, which is independent from the welding direction. The plan is to feed the wire in the center of the laser beam.

Results

With the *FLEXILAS* project we developed the basics of the new concept "materials in the ring beam". Together with industrial partners we developed beam splitter optical system, which splits the beam in two parts. The wire nozzle is placed along the center axis (Fig. 1). That way the wire can be fed centrally in to the laser focal point and melted, which is formed by the two partial spots. This represents a new quality of laser beam buildup welding, since for the first time wires can be used to build 3D structures independent on the welding direction.

We developed a version of the coaxial powder nozzle based on type COAX 9 which was especially designed for fiber laser applications. The particular features of this nozzle are its compact design for improved accessibility and a smaller powder focus. In a very stable welding process the material can be deposited with a lateral resolution of 200 µm. Fig. 2 shows the processing head of the type COAX12. It is based on known principles of coaxial powder delivery. The powder distribution within the nozzle is segmented into four separate powder streams. Therefore the powder delivery becomes virtually independent of gravity. As a result the nozzle can be used to perform buildup welding in any direction, as is needed for example in CNC machines and robot systems. An application is the repair process of vertically standing surfaces in gas turbine installations without having to remove the functional component from the system.

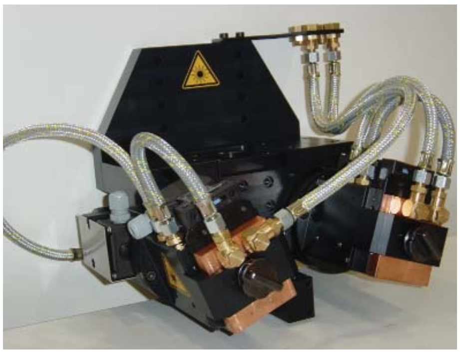


Fig. 1: Beam splitter processing head for buildup welding with centric wire feed

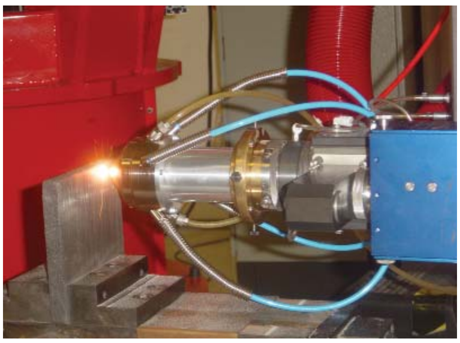


Fig. 2: Segmented powder nozzle for buildup welding in difficult positions

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Parts of the mentioned works have been funded by the federal ministry of education and research (BMBF) within the framework concept "Research for tomorrow's production". They have been supervised by the project leading organization Research Center Karlsruhe, Department of Production and Manufacturing Technologies, Satellite office Dresden.

Tailored oxide ceramic coatings - example: Al_2O_3/Cr_2O_3

Task

The performance requirements for modern surface coatings are frequently very complex. Each application requires a tailored solution with an optimized material and process selection. Aluminum as well chromium oxides have extraordinary properties which make them indispensable materials for thermal spray technologies. The combination of both not only combines their positive properties but also opens up the opportunity to make use of new improved characteristics.

During thermal spray processes the material is extremely rapidly heated and cooled. As a result the materials may solidify in thermodynamically unstable phases. In particular for Al_2O_3 this may cause the formation of its γ-phase, which frequently does not have the desired properties. Disadvantages can be the absorption of water, decreased electrical insulation properties, solubility in strong acids and bases, and decreased mechanical stability. It is known that the addition of Cr_2O_3 may prevent the phase change from α-Al_2O_3 to γ-Al_2O_3.

Solution

There are different possibilities in thermal spraying to combine Al_2O_3 and Cr_2O_3. It is possible to alloy the materials during the fabrication of the powder prior to spraying. This requires a high temperature treatment. However, since the powders are melting during spraying it is also possible to just mechanically mix the powder prior to the spraying process. The alloying then happens during the spraying process.

Results

The analysis of sprayed coatings revealed the essential influence of the spraying process on the phase formation in the coating. This also explains why there are different statements in the literature regarding the stabilization of α-Al_2O_3. High velocity oxygen fuel thermal spraying (HVOF, Fig. 1) and gas stabilized plasma spraying do not show an increase of the a-Al_2O_3 fraction. A substantial increase can be observed, however, for the more energetic water stabilized plasma spraying processes. The fraction of the mixed in chromium oxide is also important.

Fig. 2 shows different colors as they occur for different chromium oxide fractions. For alloyed powders it is possible to utilized this effect also in less energetic processes. However, alloyed powders are not readily commercially available and if so only in limited mixing ratios. Using mechanically mixed powders and alloying them in the spraying processes offers a better flexibility for the end user.

The investigations confirm that Al_2O_3 and Cr_2O_3 are highly suitable for joint thermal spray deposition. The properties of the deposited material system can be tailored to the application based on the premixing ratios of the powders. Fig. 3 shows nano-structured Al_2O_3 powder. In the future this type of powder will also be used for coating systems made from Al_2O_3 and Cr_2O_3.

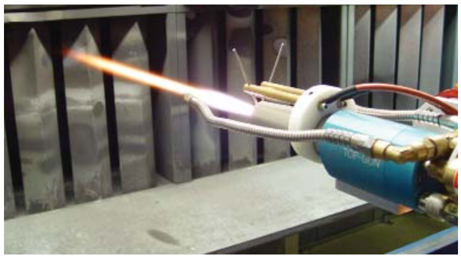

Fig. 1: TopGun® pistol in action

Fig. 2: Coloring due to different Cr_2O_3 fraction

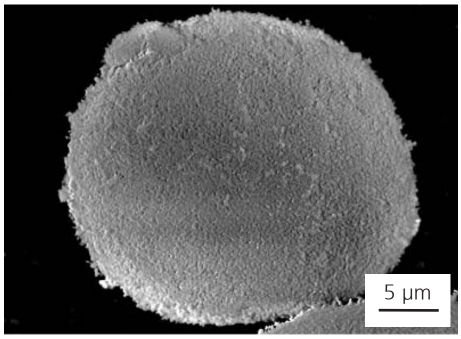

Fig. 3: Nano-structured Al_2O_3 coating powder particle

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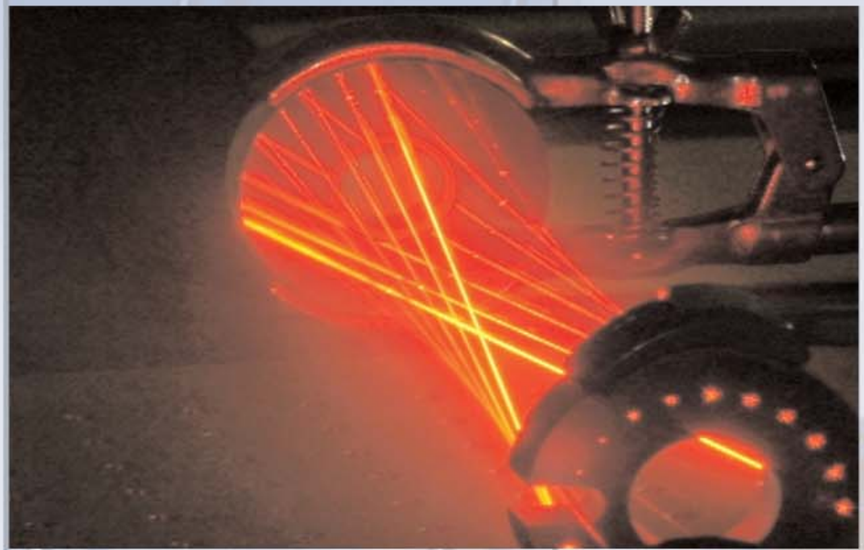
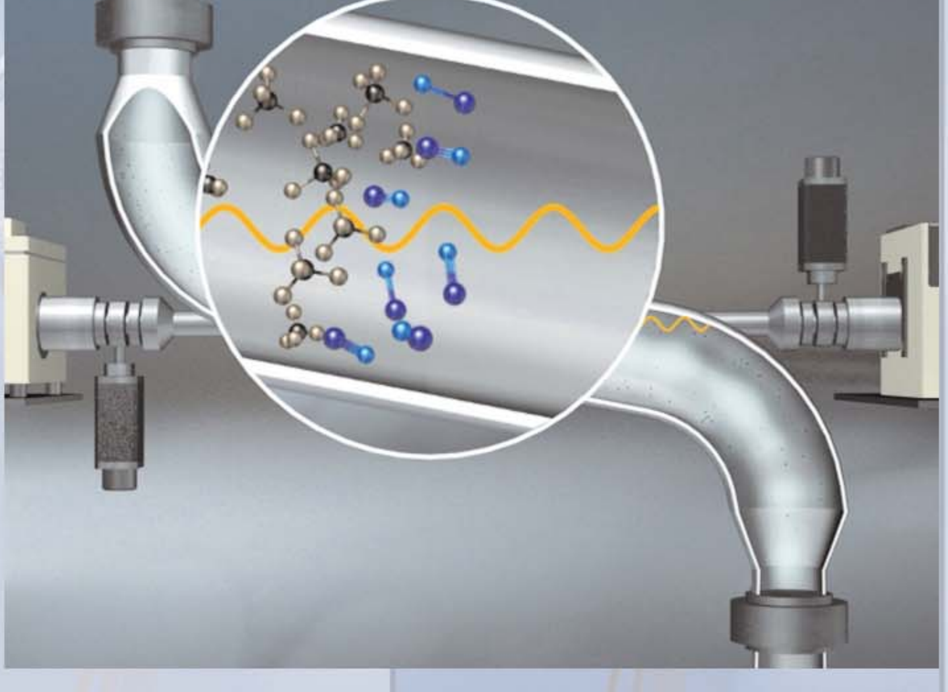
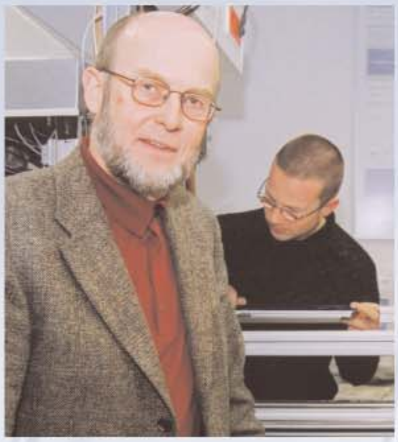




R&D-offer: CVD thin film technology



Editor: A new CVD laboratory has been built during the IWS extension. What systems will be operated there?

Dr. Hopfe: We are glad to finally be able to utilize the new CVD laboratory. We are also very grateful to all who helped us to install the complicated infrastructure. Due to the dynamic growth in atmospheric pressure plasma CVD research over the past two years we were confronted with a bottleneck issue. The available infrastructure was insufficient to operate pre-industrial PECVD prototype machines. Since the end of 2006 the new CVD laboratory is home to two IWS-developed systems to coat and etch solar wafers for silicon photovoltaic applications. It was an exiting showdown at the end of 2006.

Editor: The Fraunhofer innovations cluster "nano for production" was recently founded. Is this relevant to your department?

Dr. Hopfe: Yes, and actually quite significantly. For example, we develop environmentally friendly processes for plasma chemical nano texturing of surfaces. These processes help to increase the efficiency of solar energy production in photovoltaic cells. These technologies can be cost efficiently integrated in continuous manufacturing lines. Another system produces carbon nanotubes…

Editor: …but they are working worldwide on carbon nanotubes! Is there still room for IWS?

Dr. Hopfe: We are concentrating on single-wall nanotubes. The material is very valuable, and I am not referring to the current extreme price. The material has a unique combination of properties. For example, embedded in plastic films a very small amount of carbon nanotubes can increase the electrical conductivity so that automotive windshields can be heated to avoid fogging up. Other potential applications include actuators, which can generate a large displacement in very small voltages. We are working on a cost effective and scaleable production process to produce high quality carbon nanotubes in larger quantities. Many Fraunhofer institutes are cooperating on this task, even here in the Fraunhofer Institutes Center in Dresden. At the IWS we are trying to utilize synergy effects by working on these developments across four departments.

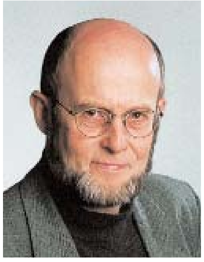
Editor: The second pillar of your department is the development of process sensors to control industrial systems. What is the progress here?

Dr. Hopfe: I would like to particularly mention the new IWS working area of diode laser spectroscopy, which is a very strong detection and highly selective method for gas sensors. The basics have been developed under IWS leadership in a European project with 7 partners from 4 countries. Meanwhile we have tested prototype gas sensors under industrial conditions to monitor the quality of ultra pure special gases as they are used, for example, in microelectronics fabrication. The performance requirements for these sensors are extreme. They are designed to detect traces of water vapor or other contaminations in the ppb range, even in highly corrosive and reactive gas environments such as HCl, silane, or ammonia. The results are so successful that we are meanwhile working with industry partners on products ready for the market.

Wer hohe Türme bauen will,
muss lange beim Fundament verweilen.

He who wants to build tall towers
needs to spend a long time
on the foundation.

Anton Bruckner



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Examples of projects 2006

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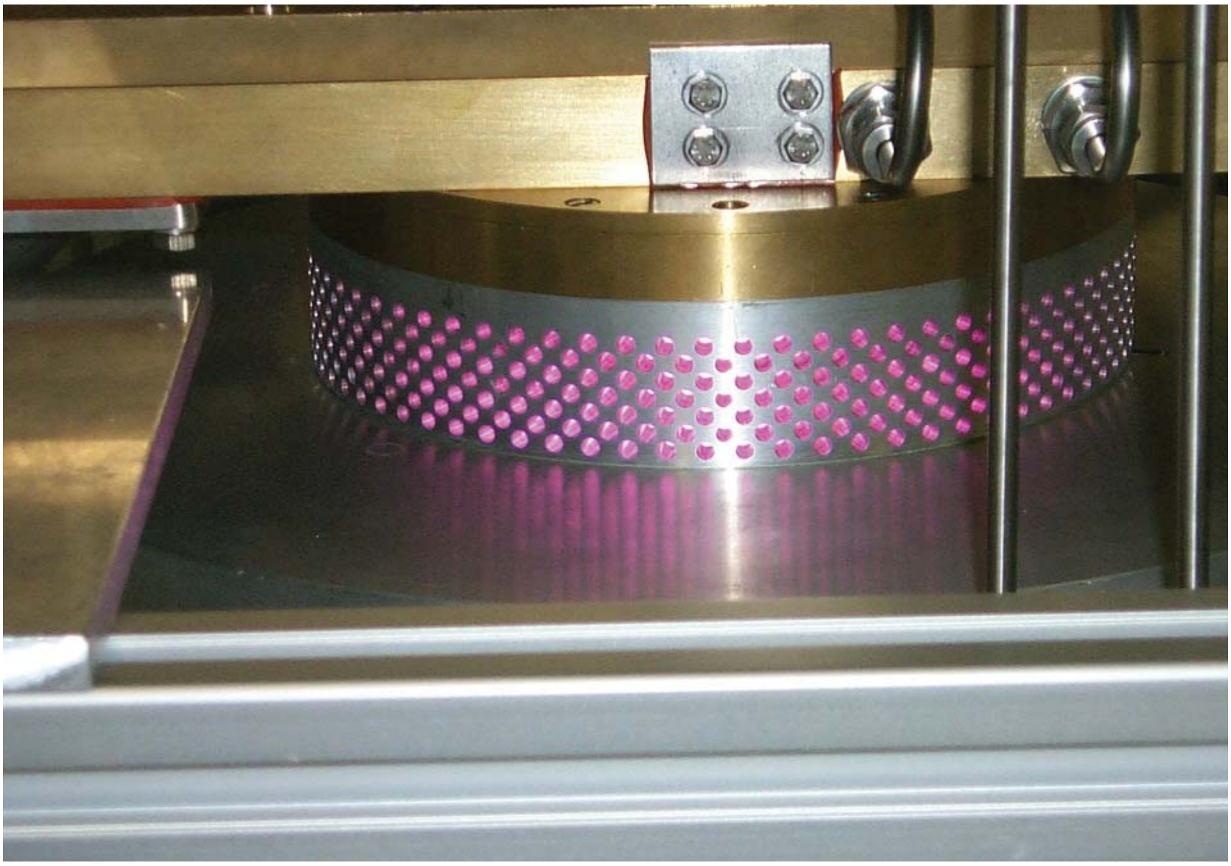

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Plasma activated CVD processes at atmospheric pressure

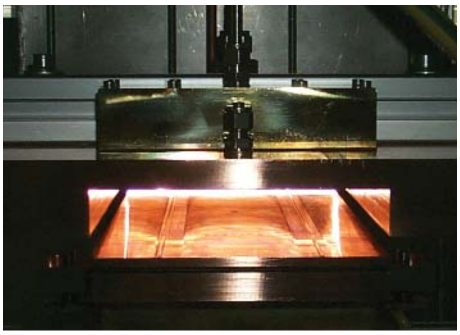
The large area deposition of high quality functional coatings is possible through atmospheric pressure plasma CVD processes (AP-PECVD), avoiding the need for expensive vacuum equipment. It is possible to implement continuous coating processes with high deposition rates on flat and even slightly curved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

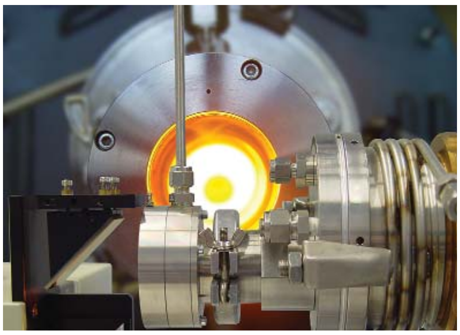
Process monitoring

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

Hydrophobic surfaces through AP-PECVD

Task

Coated surfaces with hydrophobic properties are easy to clean since they have a low affinity to water and oily materials. The development of carbon coatings on steel, glass or plastic is receiving increasing attention in connection with potential applications in medicine and microsystem technology as well in the sanitary and kitchen sectors.

At the Fraunhofer IWS we developed a continuous process for large area deposition of these coatings based on plasma assisted chemical vapor deposition at atmospheric pressure (AP-PECVD). This process is of particular interest for industrial applications since it does not require complex vacuum systems.

To modify the surface energy and therefore the wetting behavior of the carbon coatings, the technology uses a variety of precursor gases for coating. Chemical elements such as fluorine, silicon, or oxygen are built into the carbon network. As a result it is possible to adjust coating properties such as hydrophobicity, hardness, and wear resistance.

Solution

In plasma assisted atmospheric pressure CVD processes, the gaseous precursors are turned into reactive species by plasma activation. The species then are carried by gas flows to the substrate and deposit there in form of a coating. The plasma source for the precursor activation is a scalable linear source based on a linear arc discharge (Fig. 1).

Hydrophobic carbon coatings can be deposited using cost effective precursors such as methane and ethylene as well as hydrogen. The coating process occurs typically at substrate temperature in the range of 100 - 200 °C.

Results

Hydrophobic amorphous carbon coatings have been deposited on polished stainless steel using AP-PECVD. Using methane as the carbon precursor led to transparent coatings with a contact angle of 94° (Fig. 2). The polar fraction of the surface energy is at ≤ 1 mN m^{-1} very small. The total energy (Fig. 3) is 35 - 38 mN m^{-1}. Raman spectra of the amorphous carbon coatings show the planar stretch vibration of sp^2-bonded carbon atoms (graphite band) as well as the center symmetrical vibration of aromatic rings (disordered band) at 1500 - 1630 cm^{-1} and around 1350 cm^{-1}. The hardness of these polymeric coatings is approximately 1 GPa.

Silicon doping by adding a Si-precursor leads to a change of the chemical composition of the coating. FTIR spectroscopy revealed the existence of Si-C, $Si\text{-}CH_3$ and C-H groups. This increased the hardness of the coating to 3 GPa. The surface energy increased slightly to approximately 45 mN m^{-1} compared to pure carbon coatings. The polar fraction of 4 mN m^{-1} indicates that these materials can still be characterized as hydrophobic coatings.

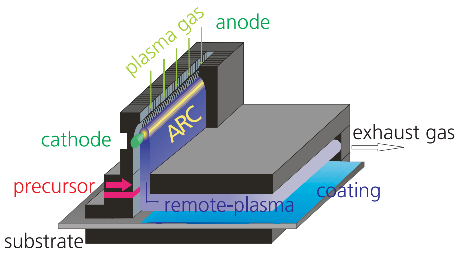


Fig. 1: Schematic representation of atmospheric pressure PECVD technology with dc arc linear source

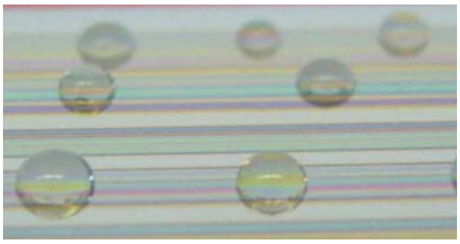


Fig. 2: Water drop formation on hydrophobic surface made from methane and H_2

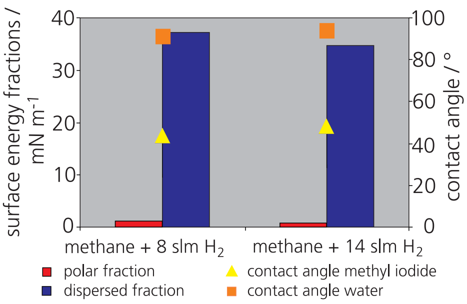


Fig. 3: Surface energies according to Owens and contact angle for coatings from methane and H_2

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Atmospheric pressure plasma process to etch the backside of solar wafers for silicon photovoltaic applications

Task

Currently processes based on crystalline silicon dominate the photovoltaic market. The manufacturing costs for solar cells play a critical role in order for that industry to remain competitive. One possibility to reduce the manufacturing costs is the introduction of cost efficient inline production processes. At Fraunhofer IWS we develop continuous plasma etching processes at atmospheric pressure (AP), which aim at reducing the investment costs for the system as well as a reduction in wafer handling and processing costs. This represents a first step to establish the future of solar cell manufacturing, which will involve inline processes with several linked process steps.

The emitter in a solar cell is fabricating by diffusing phosphorus into silicon. The present doping process is applied all around the wafer. This process causes an electrical short between the front- and backsides of the wafer, which has to be removed in a subsequent step. An atmospheric pressure plasma etching process has been developed to completely remove the backside emitter and to electrically separate front and backsides. This process was evaluated in comparison to the conventional methods of mechanically polishing the wafer edge and vacuum plasma etching of a wafer stack.

Solution

The plasma chemical etching process has some common features with chemical vapor deposition. The principle difference lies in the selection of the precursor. Fluorides are the established industrial precursors for etching silicon since the byproducts (mainly SiF_4) are gaseous and can therefore easily be removed from the surface.

The precursor activation is based on a dc arc discharge in a linear plasma source with a processing width of 120 mm.

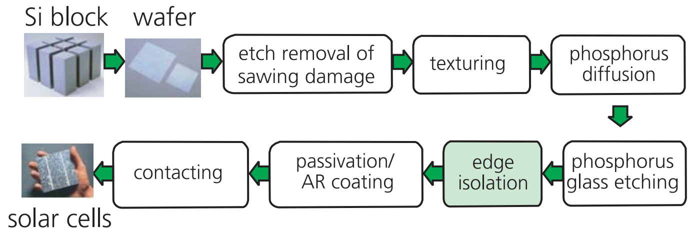

Fig. 1: Schematic representation of the processing steps to fabricate crystalline solar cells. The green colored box represents the process step discussed in this section.

Results

Monocrystalline (100) silicon wafers were processed according to the steps shown in Fig. 1. The edge insulation was performed with the IWS plasma etch process at atmospheric pressure. Etching gases were sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The resulting etch rates were 3 µm / min for SF_6 and 7 µm / min for NF_3.

Solar cell parameters such as efficiency, fill factor, short circuit current, and open circuit voltage have been measured. The data shows that the IWS processed wafers either match or even exceed the data derived from industrial standard cells. The process enables the one-sided etching without any etch effect on the frontside the wafer. This opens new options for the manufacturing process chain. The possibility to deposit anti reflective coatings prior to the edge insulation step is an example of this.

Atmospheric plasma etching is also an attractive option to fabricate future high performance cells that will require smooth emitter-free backsides to increase efficiency. The present manufacturing process is based on wet chemical texturing, which also affects the backside of the wafer. Using atmospheric pressure plasma etching enables the smoothing of the backside and therefore increases the efficiency of the solar cell (Fig. 3).

	mechanical edge isolation	edge isolation caused by low pressure plasma etching
efficiency	103.6±3.3 %	101.8±1.6 %
filling factor	99.4±2.8 %	101.2±1.5 %
I_{SC}	103.2±0.7 %	100.0±0.5 %
U_{OC}	100.9±0.5 %	100.6±0.4 %

Fig. 2: Electrical properties of the wafers processed with the IWS technology (atmospheric plasma etching) in comparison to industrial standard processes. 100 % refers to the values obtained from industrial reference processes applied to the same wafer batch.

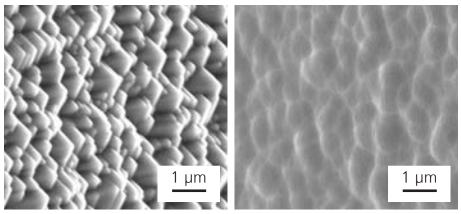

Fig. 3: Backside of solar wafers
left: alkaline textured
right: smooth, after plasma chemical etching process at atmospheric pressure

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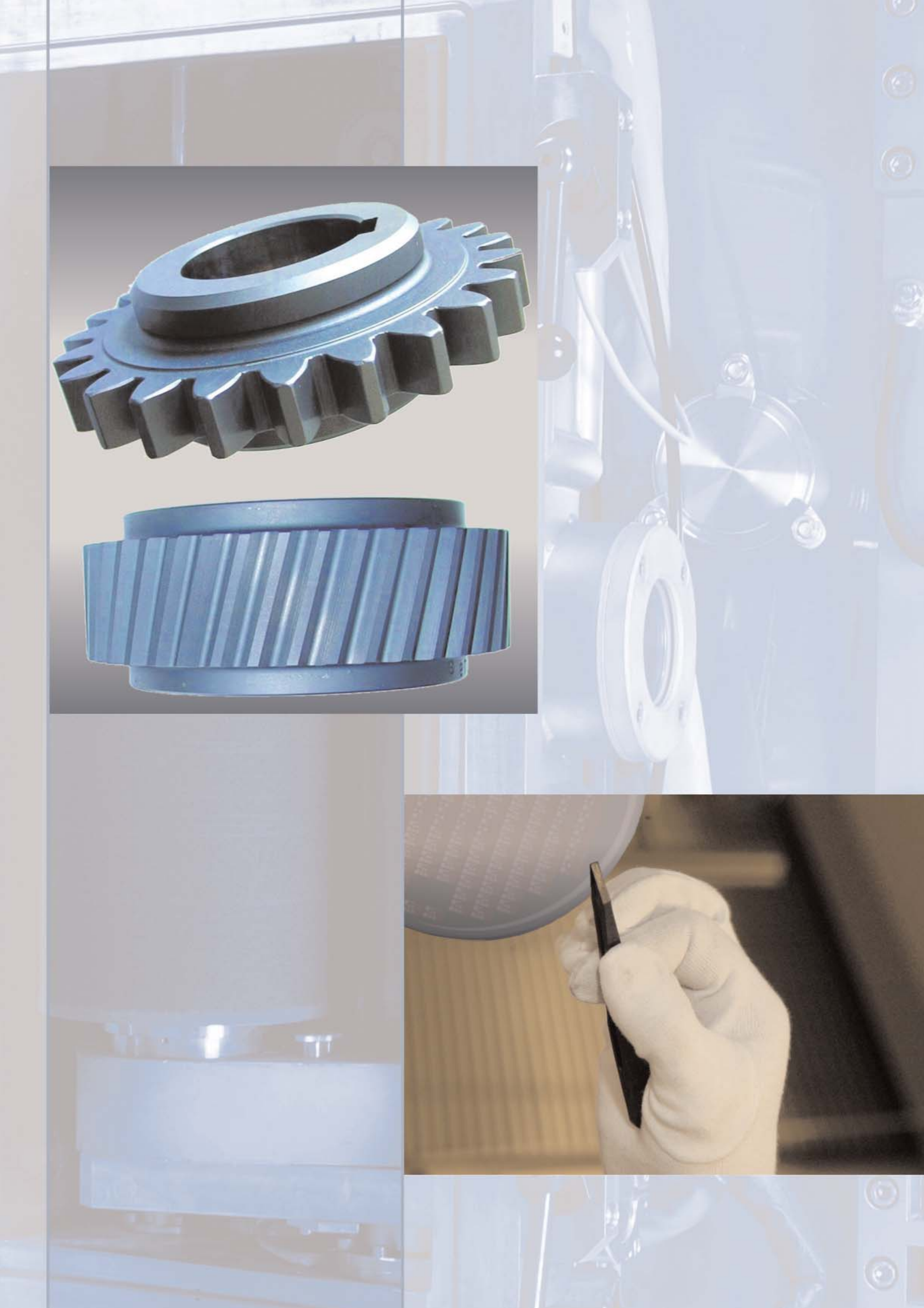

Editor: Since many years your department has been working to commercialize superhard amorphous carbon coatings (ta-C), which are offered by Fraunhofer IWS under the trade name Diamor®.

Prof. Schultrich: I think that we have accomplished a decisive step in commercializing ta-C coatings in 2006. Our laboratory-proven Laser-Arc source LAM400 has been further developed into an industrial component. The company Hauzer Techno Coating from the Netherlands is one of the leading manufactures of PVD equipment. They equipped a Flexicoat1000® system with a Laser-Arc module and installed the coating machine at the facilities of a major automotive supplier. This is worldwide the first system applying ta-C coatings in high volume manufacturing.

Editor: What is the reason for the strongly increasing interest of the automotive industry in superhard ta-C coatings?

Prof. Schultrich: In particular it is the excellent sliding behavior under dry or marginally lubricated conditions in combination with a two- to three-fold increase in hardness (4000 - 5000 HV) in comparison to competing a-C:H coatings. Even under oil lubricated conditions the ta-C coatings show a substantial decrease in friction. This effect is caused by special interactions between coatings and lubricants. Utilizing the interaction between lubricants and coatings is a very promising future technology area, which we are working on in a large research project.

Editor: Considering these excellent properties of the coating, what has been the limiting factor in the past for a broader industrial utilization?

Prof. Schultrich: To commercially use ta-C coatings three challenges had to be overcome. The deposition process had to ensure reliable coating adhesion also for thick coatings in the micrometer range; the system technology had to be designed for industrial application; and the surface quality of the coating had to match industrial performance requirements. The implementation of an innovative smoothing process for the coating surface made it possible to fully exploit tribological potential of ta-C coatings. The smoothed Diamor® coatings have been tested as protective coatings on motor components and demonstrated the benefit of their extraordinary properties.

Editor: Where are other potential application areas of the Diamor® coatings?

Prof. Schultrich: Successful tests have demonstrated the potential for Diamor® coatings in machining of aluminum alloys and other non-ferrous and lightweight metals. As a result of the now excellent surface quality, the Diamor® coating is also becoming interesting for forming tools.

Editor: Do you see applications outside of tribology?

Prof. Schultrich: Carbon coatings in general offer an excellent base for functional applications. Modified a-C:X IWS coatings are, for example, used in special sensors. Doping and nanostructuring increase the application spectrum of amorphous carbon coatings and allow tailoring them to fulfill complex requirements. Here an important tool is simulation. We are also trying to benefit from the experience in developing carbon coatings in other areas such as the production of carbon nanotubes.

Zu neuen Ufern lockt ein neuer Tag.

New day invites me to a newer shore.
Johann Wolfgang von Goethe

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Examples of projects 2006

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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

Extension of the application potential of ta-C coatings through surface smoothing

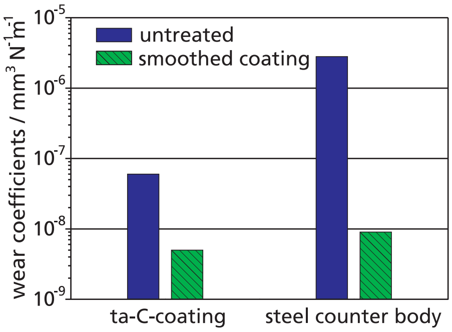

Fig. 1: Wear coefficients of untreated and smoothed coatings (fretting wear)

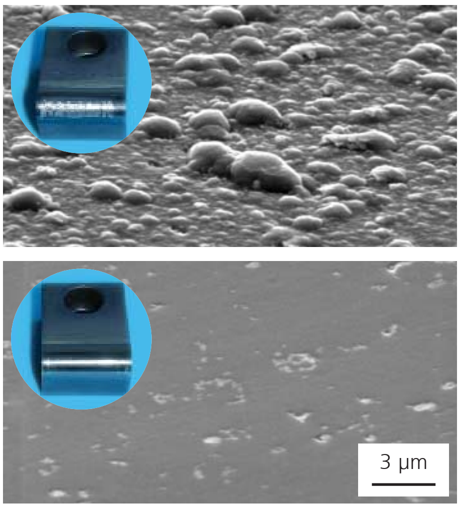

Fig. 2: Surface of a ta-C coating in the SEM as well as pull-bakes after forming of Al metal strips without lubrication: untreated (top) and after smoothing (bottom)

Task

There are many applications where components and tools can only be protected against wear by coatings. Typical wear-resistant coatings are nitrides and carbides such as CrN, TiC, or TiAlN. Increasingly amorphous carbon coatings (DLC) are being used. In addition to wear protection, they offer a low coefficient of friction and they are not sensitive to sticking. Hydrogen free tetrahedral amorphous carbon coatings (ta-C) take the top position with respect to hardness and wear protection.

The efficient deposition of ta-C coatings is presently only possible based on vacuum arc evaporation of graphite. This process however, is connected with the emission of particles which lead to growth defects. These growth defects subsequently cause rough peaks and thus an increased surface roughness (Fig. 2, top). Plasma filtering can minimize the growth defects, but this is still too costly for thick coatings.

Solution

The roughness of ta-C coatings can be mechanically removed after the deposition process. Conventional techniques such as polishing with diamond slurries are possible. However, the application of these techniques is limited for complex shapes and contours. Another disadvantage is that the entire coating would be thinned down, not only the rough peaks. Therefore we developed a process that locally removes the roughness peaks and that can be used for surface contours. A patent application has been submitted (DE 10 2006 010 916.3). The process is efficient and scalable.

Results

The process leads to a ta-C coating surface without roughness peaks (Fig. 2, bottom). Tiny pits remain, which may even function as lubrication pockets for certain applications. Fretting wear tests demonstrated a significant improvement of the already good tribological properties (Fig. 1). The smoothing treatment caused the coating wear to decrease tenfold to $5 \cdot 10^{-9}$ mm^3 / Nm. Even more significant is the reduction of wear on the steel counter body to $9 \cdot 10^{-9}$ mm^3 / Nm.

The smoothening treatment opens other application possibilities for ta-C coatings. This is in particular true for applications with sensitive interactions between coating and counter body such as in the case of dry forming of metal sheets. In particular the critical dry forming of aluminum has been investigated with strip drawing tests at the University of Technology Dresden. Forming tools with the untreated coating showed aluminum sticking to the tool. The smoothed coating, however, only showed minimal sticking (Fig. 2).

The application possibilities for smooth ta-C coatings also extend beyond forming tools to tribologically critical automotive components.

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Industrial ta-C coating through integrated laser arc module (LAM)

Task

Diamond-like amorphous carbon coatings (DLC) are becoming increasingly important as wear protective coatings for tools and components. This trend is a result of the unique combination of hardness, low friction, low sticking tendency to metallic counter bodies and excellent biological compatibility. The currently used hydrogenated DLC coatings (a-C:H) are deposited using a plasma CVD process by decomposing a hydrocarbon gas. This is possible by slightly modifying existing coating systems for the deposition of classic hard coatings (e.g. TiN or CrN).

Hydrogen free ta-C coatings (ta-C is tetrahedrally bonded amorphous carbon) represent a new generation of carbon coatings. The carbon atoms are predominantly bonded with fourfold coordination as they are in diamond. These coatings are therefore significantly harder and more wear resistant. The broad application of the coatings was so far prevented by the fact that there was no system technology available for industrial coating requirements.

Solution

The potential solution is the laser controlled vacuum arc deposition technology (Laser-Arc®) as it was developed at IWS and tested in several industrial PVD machines. The technology is implemented in a separate module that contains the cylindrical carbon cathode (LAM). This module for the ta-C deposition can be attached to commercially available coating machines instead of a conventional rectangular arc or sputter source (Fig. 1).

This solution offers the advantage that the coating technology of the base system can still be used and combined with the Laser-Arc technology. This enables the deposition of novel coating systems based on superhard ta-C coatings while maintaining the productivity of the classic hard coating deposition processes.

Results

The ta-C coating technology based on the Laser-Arc module LAM400 has been integrated into the Hauzer Techno Coating (NL) deposition machine FlexiCoat 1000®. The LAM chamber with the carbon cathode and control laser with scanner and optical system are mounted to the backside of the chamber door in such a way that the coating chamber is freely accessible. The automatic LAM operation is controlled by an independent LAM control system, which communicates with the control system of the base system via a PROFIBUS interface. A special power supply that has been developed for the Laser-Arc technology delivers an average current of 150 A (peak current 1.8 kA, pulse length 130 µs, repetition frequency 800 Hz). The laser coupling window is protected against coating by an automated foil motion handling system. The rotation of the cathode roller in combination with the laser controlled arc spot motion guarantees homogeneous erosion and therefore constant coating conditions over months.

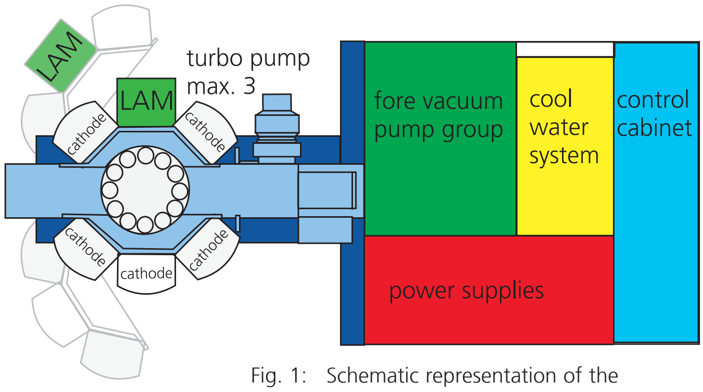

Fig. 1: Schematic representation of the FlexiCoat® 1000 coating machine with LAM

Fig. 2: LAM chamber with carbon cathode

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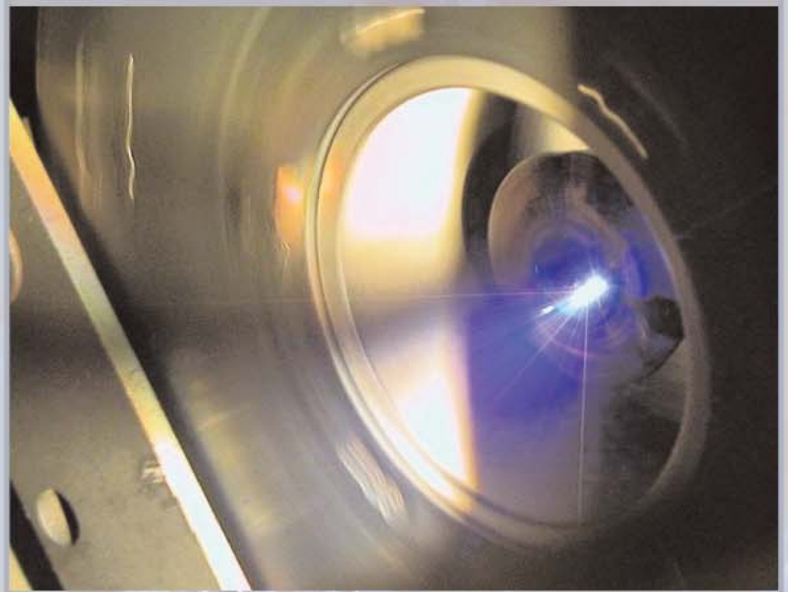

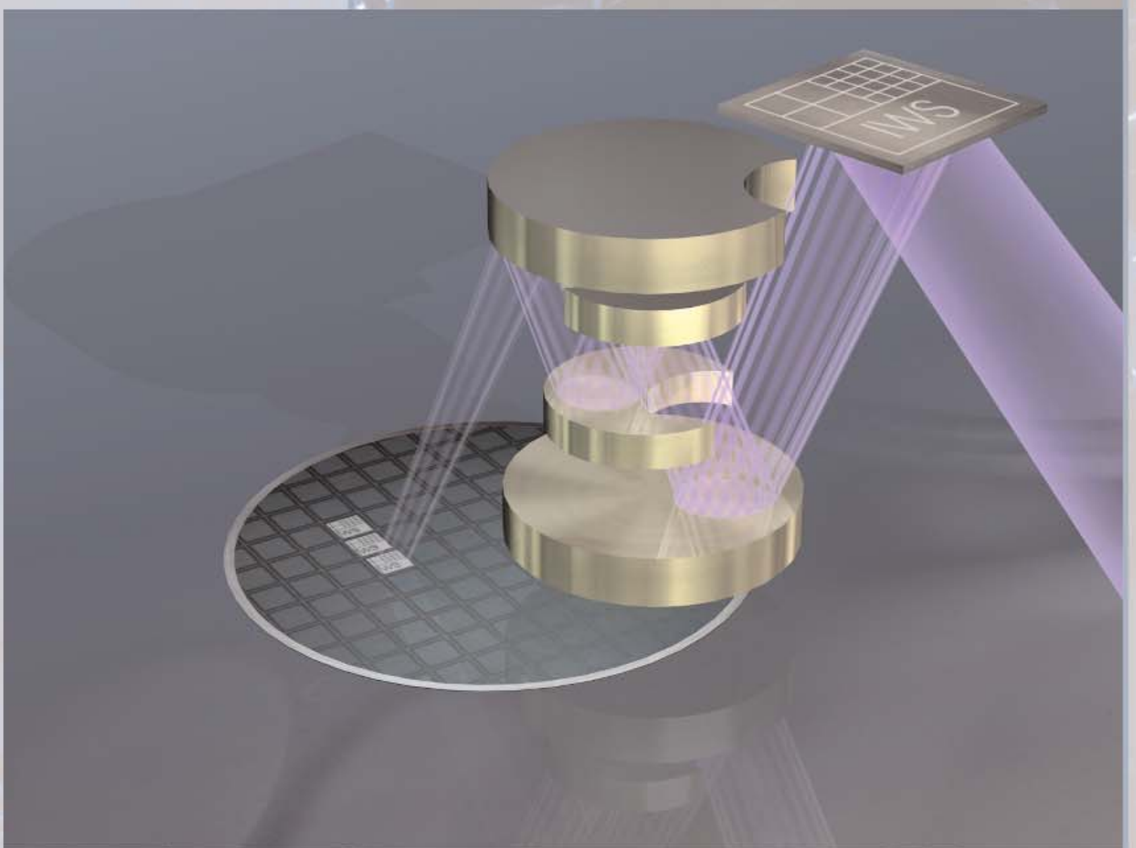
IWS

Editor: Since quite some time your department has been working on the development of ultra precise multilayer coating systems, in particular for X-ray optical applications. What new developments have been accomplished in 2006?

Dr. Leson: We have been focusing on expanding our competences in precision, reliability, and reproducibility of the coating processes which we are using. This is of central importance to our coatings in the EUV range. But we are also benefiting from the improved fabrication possibilities for other applications.

Editor: In addition to pulse laser deposition and magnetron sputtering, you established ion beam sputtering in your department. What advantages does this process have to offer?

Dr. Leson: Ion beam sputtering enables the independent adjustment and control of the parameters that are essential for the quality of the coating. It is therefore possible to deposit a large variety of materials with high precision. Ion beam sputtering is used for the fabrication of multilayers for X-ray optics but also for other applications. An example is the deposition of thin and flexible thermal barrier coatings with excellent performance.

Editor: Besides precision coatings your department is working on so-called carbon nanotubes. How do you distinguish yourself from the many groups that are working on this topic? What are the advantages of your processes?

Dr. Leson: Indeed, there are many groups worldwide that work on the fabrication of carbon nanotubes and their applications, because they have a number of fascinating properties. A central issue however, is the extreme costs since carbon nanotubes can only be produced in limited quantities. We are therefore concentrating on the fabrication processes that allow the cost effective production of larger quantities. Here we benefit from the extensive know-how that we have gained while developing pulsed arc discharges. First results of making single wall carbon nanotubes have been very promising. We are looking forward to an interesting future.

Alles Alte, soweit es Anspruch darauf hat, sollen wir lieben, aber für das Neue sollen wir recht eigentlich leben.

We should love everything old, as long as it deserves it. We should live, however, for the new.
Theodor Fontane

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Examples of projects 2006

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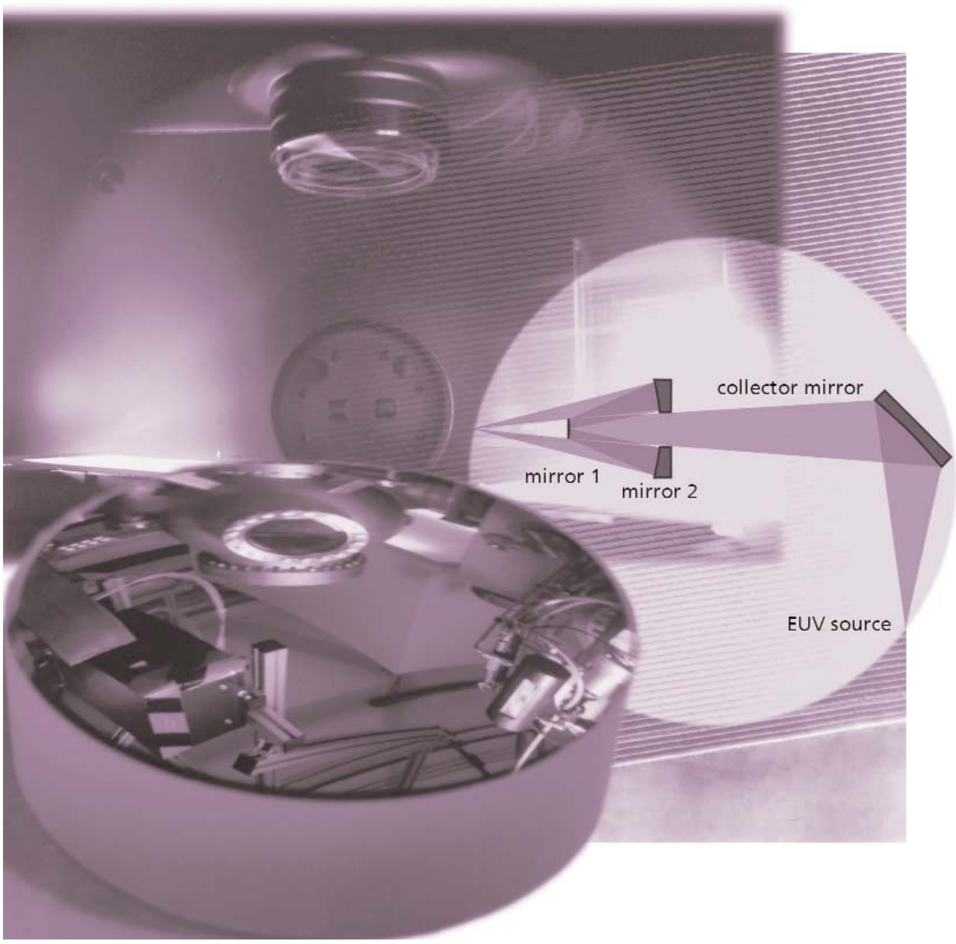

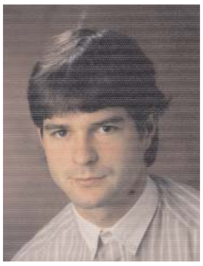

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Fabrication and characterization of nanometer precision coatings

Nanometer single layer and multilayer coatings are used in EUV and X-ray optics for beam shaping and monochromator applications. For the deposition of metallic and dielectric coatings we use magnetron and ion beam sputter deposition as well as pulse laser deposition. The coating systems are characterized by:

- highest thickness precision,
- smallest roughness,
- high chemical purity,
- excellent lateral homogeneity,
- very good reproducibility.

In addition to the development and fabrications of precision coatings, we are offering our long-term experience in characterizing and modeling of nanometer coatings. The following technologies are available in our laboratory:

- X-ray reflectometry,
- EUV reflectometry,
- X-ray diffractometry,
- residual stress measurements.

Mirror with reflective coating

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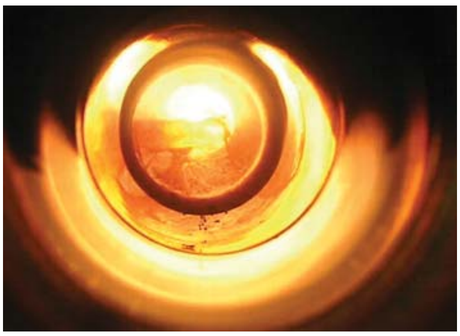
Carbon nanotubes

Carbon nanotubes show a number of interesting properties such as high strength, very good thermal and electrical conductivity, and interesting optical properties. Only small quantities of carbon nanotubes added to composite materials can open completely new functionalities for the matrix material while simultaneously maintaining the conventional matrix properties and keeping established production lines unchanged.

At Fraunhofer IWS we developed a novel process for the synthesis of high-quality single wall carbon nanotubes with a very narrow property spectrum. We are currently up-scaling the process. For the development of composite materials with special properties we are offering carbon nanotubes in different qualities and processing stages. The development of composite materials can be supported by modeling and extensive characterization.



Arc synthesis of filaments made of carbon nanotubes

Production of large quantities of single wall carbon nanotubes

Task

Single wall carbon nanotubes hold world records in physical, mechanical and electrical properties. Therefore these materials are expected to be used for all kinds of different applications in the future. Included are sensors, programmable devices such as conductors, transistors and emitters of electromagnetic radiation as well as composite materials of polymers and other materials. The particular bottleneck, however, in making this vision happen, is the limited amount of material that can be produced (some grams per day). Subsequently the price is high; it is still higher than the costs of diamond. From here, IWS derived the ambitious task to find, as the first manufacturer worldwide, a well scalable process to produce larger quantities of single wall nanotubes while simultaneously keeping their special properties.

Solution

Worldwide research is intensively focusing on CVD processes to fabricate carbon nanotubes. The success however, has been manageable only for producing limited quantities and qualities (defect density). Therefore we selected alternative processes based on laser evaporation and arc discharges. Both methods and even the combination of them (Laser-Arc process) have been established at Fraunhofer IWS for years. We aim at combining the advantages of the laser process (high yield of carbon nanotubes with low defect density) with the advantages of the arc process (large quantities of evaporated material). The available analytical equipment at Fraunhofer IWS (Raman with two laser lines, UV-Vis-NIR spectroscopy, SEM, AFM, LSM, TEM) is very helpful for these optimization efforts.

Results

We could demonstrate significant progress during the current investigations of the arc process. The scientific principal problems have been solved. Today (December 2006) we are able to synthesize 120 mg per minute of carbon nanotubes containing material with a high fraction of nanotubes. This corresponds to a yield of 2 g of pure single wall carbon nanotubes per hour net production time. These can be extracted from the raw material using a robust, soft and scalable purification method. The technology optimization is currently aiming at increasing quantity and yield. The near term goal for 2007 is to produce 100 g per hour of pure single wall carbon nanotubes. However, this can only be a first step. The goal of the development work is a technology that allows the production of carbon nanotubes by tons per year.

Fig. 1: Macroscopic webs consisting of strands of carbon nanotubes

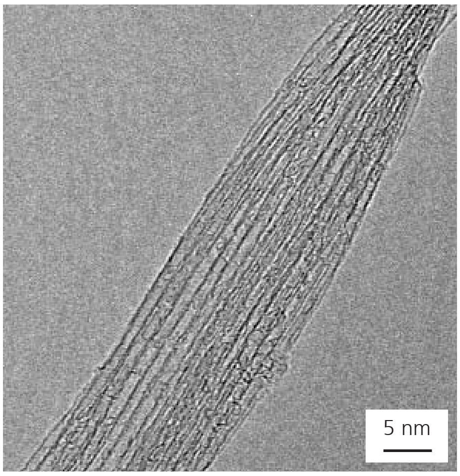


Fig. 2: Carbon nanotube strand (microscopic)

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Improved X-ray optics for reflectometry, diffractometry, and spectroscopy

Task

X-ray optical systems based on nanometer multilayer coatings are used in a variety of applications. Examples include X-ray reflectometry (XRR) and diffraction (XRD) or the X-ray fluorescence analysis (RFA). An advantage of nanometer multilayer coating optics is that the distance of the reflecting planes can be adjusted via the thicknesses of the individual layers. Therefore it is possible to adjust the reflection angle along the surface according to the Bragg equation and to implement beam-shaping functionality (Fig. 3).

To more effectively utilize the radiation from the X-ray source or the reflecting sample, we have been developing over the past years more and more complex optical systems. Examples of this are mirror geometries with multiple curvatures and multilayer coatings with minimal period thickness for high reflection angles. Both measures enable the use of an increased solid angle of the source, which in general emits in all directions.

The combination of curved surfaces and thinnest nanometer coatings with roughness requirements in the angstrom range is a technical challenge, which cannot be controlled with conventional coating processes.

Solution

Ion beam sputtering is characterized by high kinetic energies during the deposition process if compared to alternative vacuum deposition techniques. The process enables the deposition of smooth interfaces and coating stacks, even for materials that have a tendency for island growth and under inconvenient incident angles of condensing particles. The initial roughness of the substrate is also important. In particular it is difficult and expensive to polish curved surfaces. Ion beam sputtering has an increased smoothing effect on the surface, which can lead to good reflectivity even for simpler and rougher substrates.

Results

We used the ion beam sputtering machine "Ion-Sys 1600" to deposit Ni/B_4C multilayer coatings on polished silicon wafers. Fig. 1 shows the results of X-ray reflection measurements on a 170 fold multilayer coating with a linear distribution of the period thickness d_p in the range from 2.0 to 3.5 nm. As expected with decreasing period thickness the degree of reflection reduces. However, even at $d_p = 2.0$ nm ($d_{Ni} = 0.8$ nm) the reflection is still $R_{CuK\alpha} \approx 50$ % (Fig. 2). The interface widths of the layer transitions in the coating stack are in the range from $\sigma = 0.28$ nm ($d_p = 3.2$ nm) to $\sigma = 0.36$ nm ($d_p = 2.0$ nm).

The capability to deposit over 8" substrates lateral gradient multilayer coatings of the Ni/B_4C material system with period thicknesses down to 2 nm opens new qualitative possibilities for the fabrication of beam shaping X-ray optics.

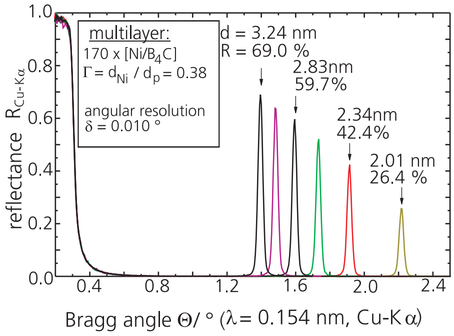

Fig. 1: Cu-Kα reflectograms of a gradient Ni/B_4C multilayer coating

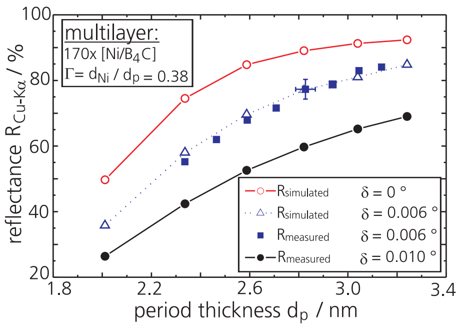

Fig. 2: Degree of reflection of Ni/B_4C multilayer coatings at different period thicknesses, full symbols: measurements
open symbols: calculations with adapted δ values (instrument resolution of reflectometer)

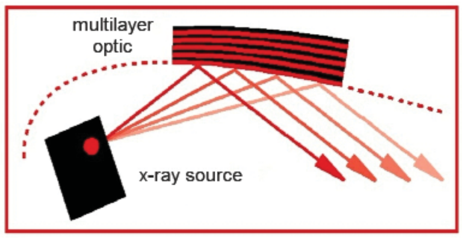

Fig. 3: Principle of beam shaping with multilayer X-ray optics

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Schweißrisse!
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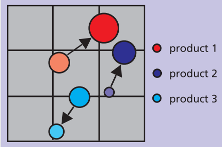

Offer: Marketing

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Dr. Siegfried Völlmar
Team leader media technology
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Examples of projects 2006

further information:
www.iws.fraunhofer.de/e_ausbildung.html

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.

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.

Applied media technology as a service in laser material processing and surface technology

Fig. 1: CD with recorded lectures of the workshop "New Rapid Technologies"

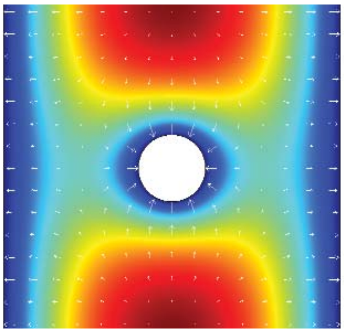

Fig. 2: FEA calculation of a temperature field

Fig. 3: Three-dimensional representation in a virtual installation

Contact
Dipl.-Softwaretechnologe
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Work area

The media technologies group applies modern hard and software in the area of digital media. The spectrum ranges from two-dimensional image processing to complex three-dimensional virtual installations. Our work supports customer projects and is offered as a service to all departments.

Multimedia services

The group's multimedia services include the generation and modification of presentations, data media, and Internet pages. Two- and three-dimensional graphics are provided along with process videos, which are generated with modern recording techniques including the addition of professional sound tracks. A special multimedia workstation equipped for video editing and DVD authoring is used to perform the compilation and processing of media streams.

Available products are CD presentations of project results and industrial solutions. Lectures from workshops and events, which have been organized by other institutions, can be reordered. An example is the event "New Rapid Technologies" (Fig. 1). For educational purposes we developed the software "Laser Safety", which can be used to train the safe operation of lasers. The software "Laser Lexicon" is a reference for laser materials processing. All multimedia products can be ordered via Internet.(www.laser-lexikon.de, www.lasersicherheit.de).

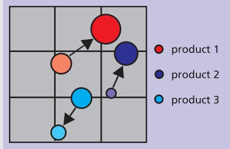
Software development and application

The group works on the systematic creation of software products such as complex three-dimensional simulations of laser material processing and surface technology. Another example is the development of system interfaces for the control of virtual robots and for the content distribution in virtual installations.

The commercial software package "Comsol Multiphysics" (Fig. 2) is used to model complex physical problems requiring finite element code. Many physical processes, which can be described by differential equations, can be simulated with this software package.

Hardware installations

Aside from classic desktop station, we use complex multimedia installations. A virtual installation represents systems and processes in three dimensions (Fig. 3). The 3-page CAVE enables an immersive imaging of real contexts an enables the use to freely interact in three-dimensional space.



"SimCoat" optimization of PVD coating through simulation

Task

Vacuum arc deposition is the leading process to deposit hard protective coatings for tribological applications. An industrial system can be loaded with many parts (Fig. 1). The coating has to meet certain quality requirements such as a uniform thickness distribution. The coating system is therefore designed to move the parts during the coating process so that each surface gets equally coated. The program system "SimCoat" was developed to optimize this coating process under consideration of specific system parameters. The theoretical modeling is done in cooperation with the group carbon coatings.

Solution

During the coating process energetic particles (e.g. carbon ions) from the highly ionized coating plasma hit the surface of the part to be coated. The coating grows layer by layer. This growth and the coating properties mainly depend on the conditions in the coating chamber. It is essential that the simulation accommodates the specific kinematical deposition conditions as realistic as possible. Therefore the simulation can be configured with many parameters. User-friendly dialogs allow the loading of the chamber with a selection of part models. Tools are available to prepare the part models for the simulation, since they may come from a variety of sources.

During the simulation all necessary parameters are recorded. For example, distance and angular relations of source and part are recorded. Possible shadow effects are considered as well. With the dataset it is then possible to analyze the process using physical models (e.g. subplantation as a film growth mechanism).

Results

The analysis enables the review of many problems, which allows an optimization of the coating process. In a first step the thickness distribution on the substrate surface is calculated (Fig. 2). The result is directly correlated to the quality of the coating. In selected areas it is also possible to analyze a multilayer structure and morphology of the coating. It is possible to identify the contribution of a particular plasma source to the simulated thickness distribution (Fig. 2). With the help of a module for temperature field calculation it is possible to determine the increase of temperature as a result of the particle energy impact during the coating process.

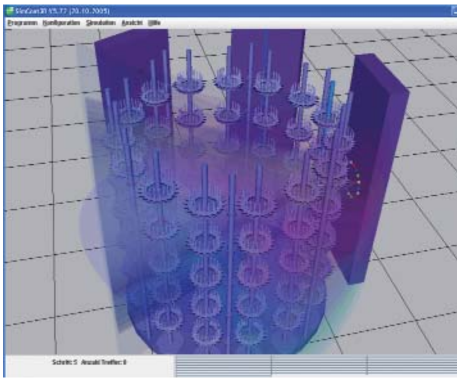


Fig. 1: Virtual representation of the coating system - demonstrator for ta-C coating

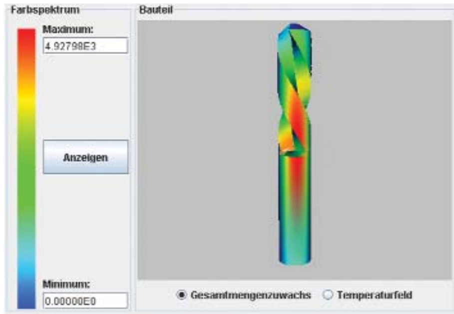


Fig. 2: Thickness distribution in false colors

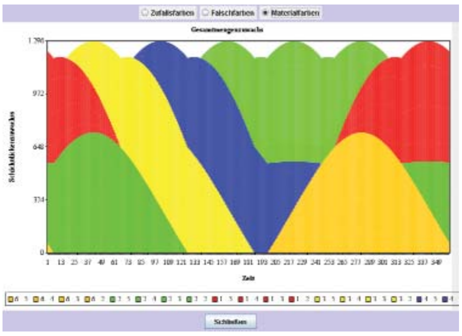


Fig. 3: Timeline of color-coded plasma source contribution

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R&D-offer: Simulation and fundamentals

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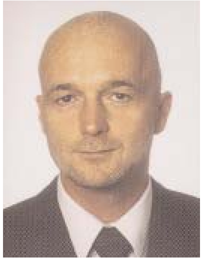

Dr. Achim Mahrle
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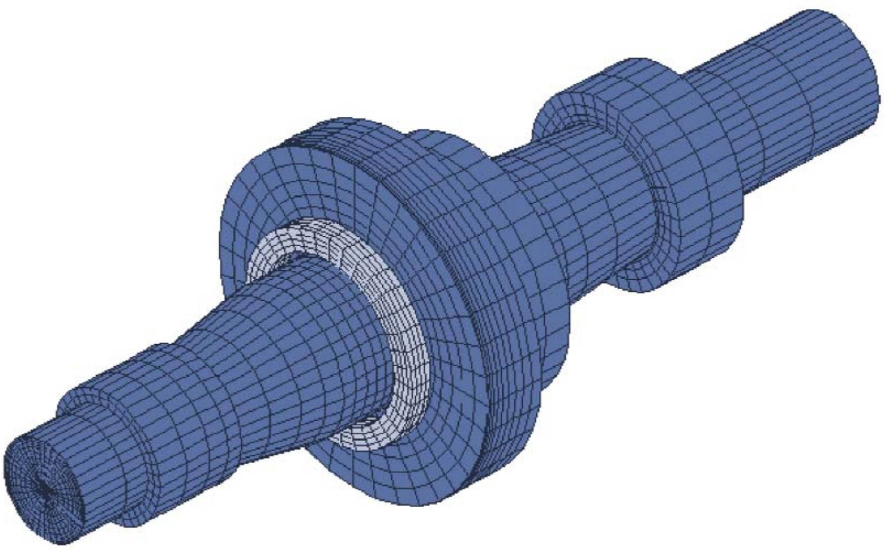
Examples of projects 2006

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 cladding).

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

Calculation of the residual stress distribution in coatings generated through laser cladding

Task

Laser cladding is mainly used to deposit wear and corrosion protective coatings and to generate material volume in rapid prototyping applications. During the process a material is added through a powder nozzle and welded to the substrate with the help of a laser induced melting bath. The deposited layer cools down leading to tensile stresses, which in return can cause cracking and delamination (Fig. 1).

Frequently the tensile stresses are aggravated by phase transformations in the substrate, which cause density changes (martensite). To reduce the formation of cracks, the process needs to be modified to reduce residual stresses and to shift plastic deformation to higher temperatures.

Solution

The calculation of residual stresses during laser cladding is accomplished in three steps:

1. determination of the process parameters to generate an individual track with a given geometry and the related temperature field using the simulation tool LAVA,
2. calculation of the stress development in an individual track (using the previously calculated process parameters) using a commercial FEA code,
3. analysis of the influence of overlapping tracks on the stress distribution in already existing tracks.

Results

In an individual track the thermal contraction of the material, which is deposited in a liquid phase, leads to tensile stresses ($\sigma_{yy} > 0$) in the coating and to compressive stresses in the substrate (Fig. 2).

If the coating is formed by overlapping tracks, the morphology and stress distribution changes as a result of the already with the previous tracks introduced heat, the reheating of the previous tracks, and the mechanical interaction with the already existing tracks. In particular, the interfaces between substrate and coating and between the individual tracks experience high tensile stresses that may result in crack formation.

The goal of this work is to find parameters which reduce these stresses, and to investigate if additional pre- and post-heating (e.g. induction) can be useful.

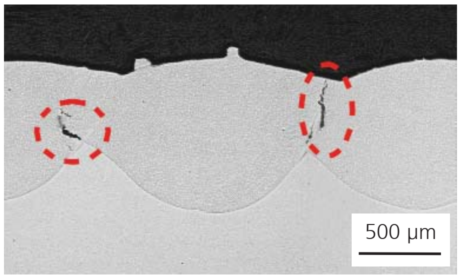


Fig. 1: Crack formation in a buildup welded coating

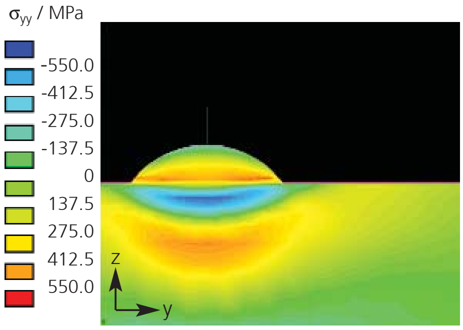


Fig. 2: Horizontal stress distribution σ_{yy} (y, z) in an individual track and its surroundings in cross section (Stellite 21 on steel C45)

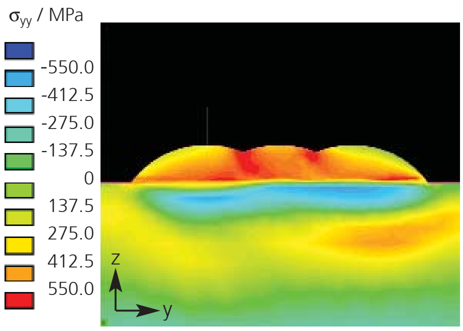


Abb. 3: Horizontal stress distribution σ_{yy} (y, z) in three adjacent tracks (overlapping 40 %)

Contact

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The formation of thermo-electrical currents during laser beam welding

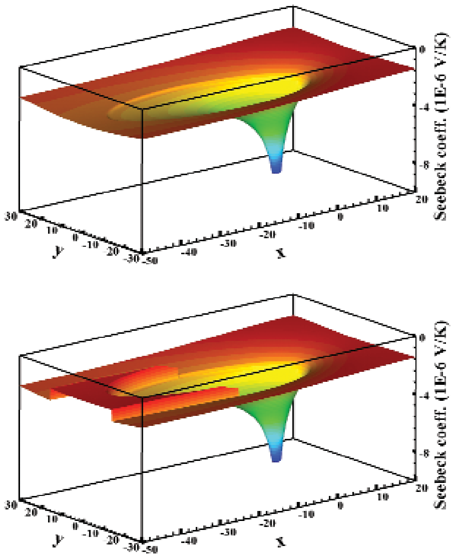

Fig. 1: Seebeck coefficient of aluminum in the melting bath (central region) and in the solid state region (surrounding area), the lower picture show on the left front side the Seebeck coefficient considering the modified welding seam structure

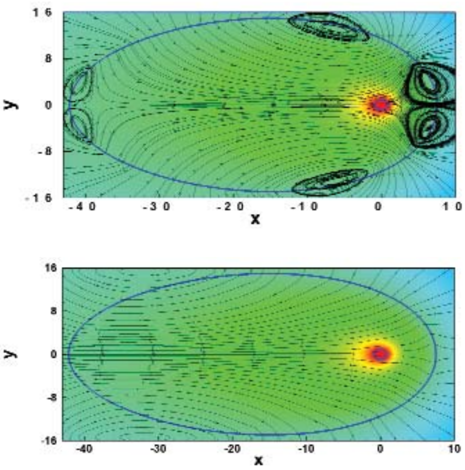

Fig. 2: Temperature field [color and blue isotherms for evaporation (inner) and melting (outer) temperatures] and current density (black current lines) for aluminum at Pe = 0.1 without (upper) and with (lower) consideration of the modified welding seam structure

Contact

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Task

It is possible to increase the welding speed or welding seam quality in laser beam welding processes by using external static magnetic fields. The principle success of this method has been demonstrated in welding experiments using fine grain construction steels and aluminum alloys. The ejection of the melting bath could be suppressed and the quality of the seam surface was improved. This phenomenon was only observed for certain orientations of the magnetic field, which implies the existence of thermo-electric currents. Tailored magnetic fields cause Lorentz forces in the melting bath, which in return influence the convectional flow in the melting bath and thus the geometry of the welding seam. A simulation of the process involving the material in solid and liquid phases as well as the welding seam was performed with the goal to better understand the phenomenon.

Solution

The basic equations of thermo-electricity suggest that gradients in chemical potential and / or temperature can be sources of a thermo-electric current density. The magnitude of this current density depends during laser beam welding primarily on the temperature gradient and the temperature dependent Seebeck coefficient, which is a measure for the electric potential generated by the temperature gradient. There exists an analytical solution for the thermo-electrical current density if the problem is limited to two dimensions (corresponds to the welding of thin metal sheets) and a temperature independent electrical conductivity. The influence of the welding seam texture on the current density distribution has been analyzed for a constant Peclet number, which is the ratio of convective and conductive heat transport in molten metal.

Results

While the Seebeck coefficient is known for solid and liquid aluminum this is not the case for welded aluminum. Therefore we tested several models for the Seebeck coefficient in the welding seam. Fig. 1 shows the Seebeck coefficient of the melting bath surrounded by a solid material without (upper image) and with consideration of the modified welding seam structure (lower image). The current density distribution without a modified welding seam structure (Fig. 2, top) is characterized by three intensive pairs of eddies. They are located directly in front and behind the vapor capillary and at the end of the melting bath. These eddies in current density occur directly at the interface of liquid and solid phases. The current density distribution is clearly different if the modified welding seam structure is considered (Fig. 2, bottom). The thermo-electric current is much more uniformly distributed over the melting bath. There are no eddies. This result has been reproduced for all models. The homogeneous structure makes it easier to generate a tailored Lorentz force over the entire melting bath. This force can be designed so that the resulting flows in the melting bath lead to more narrow and deeper welding seams.

Special events

May 2^{nd}, 2006
Annual meeting of the nanotechnology competence center "Ultrathin Functional Films" at the Fraunhofer IWS

May 12^{th}, 2006
2^{nd} alumni meeting of Fraunhofer IWS Dresden and the LOT department of the TU Dresden.

June 29^{th}, 2006
The "Fraunhofer Board of Directors at Location" at the Institutes Center Dresden

June 30^{th}, 2006
Participation of the Fraunhofer Institutes Center at the "Day of Technology" and the "Long Night of Science" of the state capital Dresden

July 5^{th} - 6^{th}, 2006
2^{nd} international workshop "Fiber Lasers" at the International Congress Center Dresden (organized by Fraunhofer IWS)

November 8^{th} - 9^{th}, 2006
6^{th} workshop "Industrial Applications of High Power Diode Lasers" at Fraunhofer IWS Dresden

November 16^{th}, 2006
Impulse event - Laser based joining and coating processes - BMBF production technology promotion in the frame concept "Research for tomorrow's production" (organized by Fraunhofer IWS Dresden)

November 21^{st} - 22^{nd}, 2006
5^{th} international nanotechnology symposium "Nanofair - New Ideas for the Industry" in Karlsruhe (co-organized by Fraunhofer IWS Dresden)

November 23^{rd} - 24^{th}, 2006
Australian-German workshop on nanotechnology in Karlsruhe (organized by Fraunhofer IWS Dresden)

November 27^{th}, 2006
Opening ceremony of the nanotechnology innovations cluster "nano for production" at the Fraunhofer IWS Dresden

Surface Engineering und Nanotechnologie (SENT)

This term expresses the importance of nanotechnology for the modern thin film technology. IWS collaborated with the TU Dresden and the Fraunhofer Technology Academy to offer lectures on industrial thin film technology. The lectures are offered as general courses in the IWS and as specially tailored courses within companies.

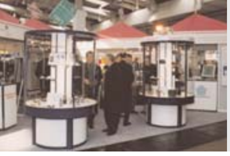
May 16^{th} - 17^{th}, 2006
"Processes to deposit thin films"

December 5^{th} - 7^{th}, 2006
"Industrial characterization of thin films"

Day of Technology at the Fraunhofer Institutes Center Dresden (June 30^{th}, 2006)

Dr. Volkmar Dietz (BMBF) during the 2^{nd} international workshop "Fiber Lasers" in the International Congress Center in Dresden (July 5^{th} - 6^{th}, 2006)

Opening ceremony of the nanotechnology innovations cluster "nano for production" on November 27^{th}, 2006 at the Fraunhofer IWS Dresden



Lecturing

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 engineering / nanotechnology
- Prof. Beyer / Mr. Kötter: Rapid protocoating
- Prof. Beyer: Robotics

Lectures at the Institute for Surface Technology and Production Metrology of the TU Dresden in summer semester 2006:
- Prof. Beyer: Laser basics / laser system technology
- Prof. Beyer: Rapid prototyping
- Prof. Beyer: Laser robotics / lasertronic
- 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 2006 / 2007:
- Prof. Beyer: Manufacturing technology II
- Prof. Beyer: Plasma technics
- Dr. Leson, Prof. Beyer: Surface technology / nanotechnology
- Prof. Schultrich: Thin film technology (special materials)

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:
Chairman 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 Dresden discussion forum of economy and science

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 review committee of the AiF

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

Prof. E. Beyer:
Member of the board of stakeholders of the Technology Platform Photonics21

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 Advisory Board of the magazine "NanoS"

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"

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

Dr. G. C. Stehr:
Member of the scientific counsel

Dr. G. C. Stehr:
DVS Technical Committee 2 "Thermal coating and flame technology"

Dr. G. C. Stehr:
Association of Thermal Sprayers e.V. (GTS)

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 2006

1. Best innovative product ideas

   Annett Klotzbach,
   Dr. Thomas Schwarz,
   Veiko Fleischer,
   Dr. Lothar Morgenthal,
   Michael Leminski,
   Frank Kretzschmar
   "Development of remote laser beam cutting on the fly"

2. Best scientific technical performance

   Michael Leonhardt,
   Dr. Carl-Friedrich Meyer,
   Dr. Hans-Joachim Scheibe
   "Industrial ta-C deposition with Laser-Arc module (LAM) on industrial coating system"

3. Best scientific performance of a junior scientist

   Gunther Göbel
   "Novel thermo-mechanical approach to avoid hot crack formation during laser beam welding"

4. Best scientific student performance

   Julius Roch
   "Construction and test of an experimental setup to evaluate a scaled-up atmospheric pressure microwave plasma source"

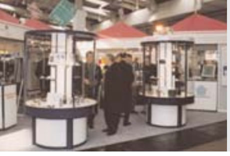
   Georg Dietrich
   "Surface structuring in the nanometer range"

5. Special award

   Dr. Dieter Pollack
   "to especially thank and honor the constantly above average commitment and engagement for the interests of the institute"

Dr. Pollack received a special award for his extraordinary engagement for the interests of the institute

Mr. Göbel during the award ceremony of the institute's prize for the best scientific accomplishment of a junior scientist



Diploma theses

A. Brückner
(Technische Universität Dresden)

"Abscheidung und Charakterisierung kohlenstoffbasierter PVD-Schichten auf Werkzeugen für die schmierstofffreie Aluminium- und Magnesiumblechumformung"

"Deposition and characterization of carbon based PVD coatings on tools for dry forming of aluminum and magnesium sheets"

K. Heinrich
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Untersuchungen zur Innenbeschichtung durch Laser-Auftragschweißen"

"Investigation of using laser buildup welding to coat inner surfaces"

C. Kleemann
(Technische Universität Dresden)

"Laser-Arc deposition of amorphous carbon films and characterization of their mechanical and tribological properties under conditions for biomedical applications"

C. Kündscher
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Potentialanalyse zur großflächigen Anwendung der Laserstrahlreinigung"

"Analysis of the potential for large area application of laser beam cleaning"

R. Münster
(Technische Universität Chemnitz)

"Untersuchungen zum Laser-Auftragschweißen mit Strahlteileroptik"

"Investigations of using beam splitting optics in laser buildup welding"

F. Pfitzner
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Technologische Untersuchungen zum Auftragschweißen mit Faserlaser"

"Technological investigation of buildup welding with fiber lasers"

R. Püschel
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Untersuchung der Möglichkeiten und Grenzen des Faserlasereinsatzes in der Mikrostrukturierung"

"Investigation of the possibilities and limits of fiber laser application in micro structuring"

G. Richter
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Laserstrahlschweißen von Kunststoffen - Untersuchung neuer Strahlquellen und Schweißmechanismen"

"Laser beam welding of plastics - investigation of new beam sources and welding mechanisms"

S. Tschöcke
(Technische Universität Dresden)

"Herstellung von SiO_2-Kratzschutzschichten mittels Mikrowellen-PECVD bei Atmosphärendruck"

"Fabrication of SiO_2 scratch resistant coating using microwave PECVD at atmospheric pressures"

S. Weigelt
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Untersuchungen zum Laserstrahlschweißen von Aluminiumwerkstoffen im T-Stoß für luftfahrtspezifische Strukturen mit dem Faserlaser"

"Investigations of laser beam welding of aluminum materials in T-joint for aerospace specific structures with the fiber laser"

M. Wiener
(Hochschule für Technik und Wirtschaft Dresden (FH))

"Verfahrensoptimierung zur Herstellung thermisch gespritzter Hartmetallschichten an hochbelasteten Bauteilen"

"Process optimization for the fabrication of thermally sprayed hard metal coatings on highly loaded workpieces"

M. Zier
(Berufsakademie Sachsen, Staatliche Studienakademie Dresden (BA))

"Zusammenwirken der Finite Elemente Methode mit virtuellen Umgebungen zur Simulation und Visualisierung von physikalisch-technischen Prozessen"

"Interaction of finite element methods with virtual environments for the simulation and visualization of physical-technical processes"

Doctoral theses

J. Hauptmann
(Technische Universität Dresden)

"Rutschhemmende Ausrüstung polierter Steinfußböden"

"Slip preventive refitting of polished stone floors"

U. Klotzbach
(Technische Universität Wien)

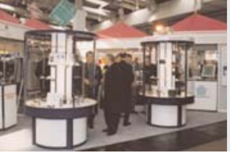
"Untersuchungen zum Trennen von polykristallinen Siliziumwafern mit frequenzvervielfachten Kurzpuls-Nd:YAG-Lasern"

"Investigations to separate polycrystalline silicon wafers with frequency multiplied short pulse Nd:YAG lasers"

H. Schulz
(Technische Universität Dresden)

"Dotierte amorphe Kohlenstoffschichten zur Herstellung superhydrophober Oberflächen"

"Doped amorphous carbon coatings to fabricate super hydrophobic surfaces"



Presentation of the multiple gas sensor system ISPROM® at the semiconductor technology tradeshow SEMICON 2006 in Munich

Visit of Dr. Annette Schavan (center), Federal Minister for Education and Research, at the TU Dresden booth "Research for the future" at the Hannover tradeshow 2006, hall 2

Prof. Berndt Brenner (2nd from right) during the Fraunhofer-Gesellschaft press conference at the central Fraunhofer booth in hall 2 (Hannover fair 2006)

Visit of Andreas Lämmel (center), member of the Federal Parliament, at the LRT booth during the international aerospace exhibition 2006

Participation in fairs and exhibitions

SEMICON 2006 Munich, April 4th - 6th, 2006

SEMICON is the leading European trade show in the areas of semiconductor technology and microelectronics. Jointly with the partner company Sempa Systems GmbH (ultra pure gas systems), IWS presented the multiple gas sensing system ISPROM®. The sensor system is industry-proven and long term stable. It works continuously in-situ and is capable to simultaneously detect almost all process relevant gases. The flexibly designed system enables process monitoring for a variety of industrial processes and its application is not limited to the semiconductor industry.

Hannover Fair 2006, April 24th - 28th, 2006

IWS exhibited at the joint Fraunhofer booth in hall 2. The latest research results in the area of "Integrated lightweight construction" were shown. These results are one of the 12 guiding innovations in the Fraunhofer-Gesellschaft. The presentation introduced laser beam welding of aircraft fuselage structures.

IWS also participated in the second joint booth "Laser Technology" in hall 14. Here the topic was micro technology. The latest applied research results in laser material processing and micro processing were demonstrated on a 40 m² exhibition area. The main focus topics were laser buildup welding (with IWS developed powder nozzle systems, which were shown at the screen "Industrial solutions in laser beam precision buildup welding" with video presentation) and laser beam welding (shown at the screen "Welding cracks! - Your problem?" with video presentation). Another presentation addressed possibilities of fiber laser application in micro processing.

Together with the university institute for laser and surface technology (TU Dresden) the Fraunhofer IWS participated at the joint booth "Research for the future" in hall 2. IWS presented results on preprocessing of surfaces for adhesive bonding and on three-dimensional simulations.

International Aerospace Exhibition, Berlin 2006, May 16th - 21st, 2006

IWS joined for the second time the exhibition booth of the aerospace competence center Saxony / Thuringia e.V. (LRT) at Schoenefeld airport. The IWS exhibition included technology developments in laser beam welding of aircraft fuselage structures, the deposition of heat resistant coatings and the characterization of mechanical, thermal, and tribological properties of laser treated aerospace components.

Rapid.Tech 2006 Erfurt, May 16th - 17th, 2006

IWS participated for the second time at this application conference and exhibition for rapid technologies. The central topics at the IWS booth were industrial solutions for the laser beam precision buildup welding and for rapid tool making through metal sheet packaging (MELATO®).

Euroblech 2006 Hannover, October 24th - 28th, 2006

Euroblech is an international technology exhibition for sheet metal processing. IWS participated for the third time in a Fraunhofer booth in hall 11. The IWS exhibition included three topics:

- transparent scratch resistant coatings through atmospheric pressure plasma technology,
- DIAMOR® - coatings for forming tools,
- MELATO® - fast fabrication of complex tools.

Monument 2006 Leipzig, October 25th - 28th, 2006

"Monument" is a European trade show for the preservation of historical monuments. IWS exhibited the laser beam cleaning process for historic-cultural objects made from metal, wood, and stone. The presentation included a transportable fiber laser (backpack laser) for cleaning in restoration and monument preservation and its first time application to clean 3500-year-old Egypt funerary chambers (under contract by Nefer-hotep e.V.).

Parts2clean 2006 Friedrichshafen, November 7th - 9th, 2006

The IWS participated in the Fraunhofer Alliance booth on cleaning technologies. In particular the institute presented a solution to partially clean parts with laser beams. The special advantage of this process is its integration into automated manufacturing. The process reduces processing time and avoids wet chemical cleaning. An example showed the removal of coolant, lubricant, and preservative residues as joint preparation for laser beam welding.

Euromold 2006, Frankfurt / M., November 29th - December 2nd, 2006

Euromold is a tradeshow for mold and die, model and tool making. The IWS participated for the 11th time. The main attraction was a robot as part of a new machine, which can be used for laser buildup welding (using an IWS developed powder nozzle system), laser hardening and laser welding with fiber and diode lasers. During the past two years IWS transferred the dual function technology involving laser buildup welding and hardening to production at three international customers in Switzerland and Italy.

Fraunhofer IWS presentation at the Fraunhofer booth at Euroblech 2006

Presentation of IWS competency in cleaning technologies; Joint booth at the Fraunhofer Alliance Cleaning Technology exhibition at the Parts2Clean tradeshow. The blue figure in the center carries the backpack fiber laser for mobile applications.

Patent applications

[P1] E. Beyer
"Vorrichtung und Verfahren zur Bearbeitung von Werkstücken mittels Faserlaser"
Anmelde-Az.: DE 10 2006 006 426.7

[P2] E. Beyer
"Verfahren und Vorrichtung zur Bearbeitung von Werkstücken mittels von einem Hochleistungsfaserlaser emittierter elektromagnetischer Strahlung"
Anmelde-Az.: DE 10 2006 428.3

[P3] E. Beyer
"Vorrichtung und Verfahren zur Bearbeitung von Werkstücken mittels statistisch oder unpolarisierter Strahlung eines Faser- oder Scheibenlasers"
Anmelde-Az.: DE 10 2006 006 429.1

[P4] E. Beyer, I. Jansen, A. Klotzbach
"Verfahren zum Fügen von Bauteilen, insbesondere Leichtbaubauteilen, mittels Kleben"
Anmelde-Az.: DE 10 2006 038 868.2

[P5] E. Beyer, C. Krautz, E. Hensel, U. Klotzbach
"Wandelement zum Schutz vor Laserstrahlung"
Anmelde-Az.: DE 10 2006 036 500.3

[P6] E. Beyer, P.-M. Mickel, G. Wunderlich
"Verfahren zur Fügung von Blechkonstruktionen durch Laserstrahlschweißen"
Anmelde-Az.: DE 10 2006 052 827.1

[P7] B. Brenner
"Verfahren und Vorrichtung zum Randschichthärten formkomplizierter Bauteile"
Anmelde-Az.: DE 10 2006 050 799.1

[P8] B. Brenner, G. Göbel
"Verfahren und Vorrichtung zum rissfreien Schweißen, Reparaturschweißen oder Auftragsschweißen heissrissanfälliger Werkstoffe"
Anmelde-Az.: DE 10 2006 048 580.7

[P9] I. Dani, V. Hopfe, B. Dresler
"Vorrichtung und Verfahren zur Ausbildung dünner Schichten auf Substratoberflächen"
Anmelde-Az.: DE 10 2006 042 328.2

[P10] I. Dani, V. Hopfe, E. Lopez
"Verfahren zum selektiven plasmachemischen Trockenätzen von auf Oberflächen von Silicium-Wafern ausgebildetem Phosphorsilikatglas"
Anmelde-Az.: DE 10 2006 042 329.1

[P11] D. Dittrich, J. Hackius, B. Brenner, B. Winderlich, J. Standfuß,
"Metallisches Flugzeugbauteil"
Anmelde-Az.: DE 10 2006 046 080.4

[P12] V. Franke, F. Sonntag, J. Hauptmann
"Technologie zum Fügen von Bauteilen mit Hilfe von elektromagnetischer Strahlung"
Anmelde-Az.: DE 10 2006 040 773.3

[P13] V. Hopfe, I. Dani, M. Rosina, M. Heintze, R. Möller, H. Wanka, E. Lopez
"Verfahren zur Entfernung einer dotierten Oberflächenschicht an Rückseiten von kristallinen Silizium-Solarwafern"
Anmelde-Az.: PCT/DE2006/001058

[P14] A. Klotzbach, V. Fleischer, L. Morgenthal
"Verfahren zur Bearbeitung von Werkstücken mittels Laserstrahlung"
Anmelde-Az.: PCT/EP2006/000055

[P15] C. Meyer
"Anordnung für die Separation von Partikeln aus einem Plasma"
Anmelde-Az.: DE 10 2006 009 106.4

[P16] S. Nowotny, S. Scharek
"Vorrichtung für die Bearbeitung von Werkstücken mit Laserstrahlung"
Anmelde-Az.: DE 10 2006 044 550.3

[P17] M. Rosina, I. Dani, V. Hopfe, B. Dresler, R. Möller
"Vorrichtung und Verfahren zur Ausbildung dünner Siliciumnitridschichten auf Oberflächen von kristallinen Sillicium-Solarwafern"
Anmelde-Az.: DE 10 2006 042 327.5

[P18] B. Schultrich, D. Schneider
"Identifikationselement"
Anmelde-Az.: DE 10 2006 017 155.1

[P19] B. Schultrich, F. Sonntag
"Verfahren zur Herstellung von Oberflächenstrukturen und Element mit Oberflächenstrukturen zur Verwendung für Biosensoren oder die Herstellung von Zellleitstrukturen"
Anmelde-Az.: DE 10 2006 017 153.5

[P20] F. Sonntag
"Mikrofluidische Anordnung zur Detektion von in Proben enthaltenen chemischen, biochemischen Molekülen und / oder Partikeln"
Anmelde-Az.: DE 10 2006 024 355.2

[P21] V. Weihnacht, B. Schultrich
"Verfahren zur Bearbeitung von Oberflächen einer Beschichtung aus hartem Kohlenstoff"
Anmelde-Az.: DE 10 2006 010 916.3

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[P22] E. Beyer, J. Kalich, H. Kötter
"Vorrichtung und Verfahren zum formschlüssigen Verbinden von Werkstücken"
Veröffentlichungs-Nr.: DE 10 2004 062 896 B4

[P23] S. Bonß, J. Standfuß, E. Beyer
"Verfahren und Vorrichtung zum Schweißen mittels Laserstrahlung"
Veröffentlichungs-Nr.: EP 1 007 267 B1

[P24] B. Brenner, B. Winderlich, J. Standfuß, J. Schumacher, H. Brenneis, W. Zink
"Leichtbau-Strukturbauteil insbesondere für Flugzeuge und Verfahren zu seiner Herstellung"
Veröffentlichungs-Nr.: EP 1 439 121 B1

[P25] I. Dani, W. Grählert, G. Mäder, V. Hopfe,
"Vorrichtung und Verfahren zur optischen Detektion von in Abgasen chemischer Prozesse enthaltenen Stoffen"
Veröffentlichungs-Nr.: DE 10 2004 028 420 B3

[P26] G. Mäder, D. Rogler, V. Hopfe,
"Modul und Verfahren für die Modifizierung von Substratoberflächen bei Atmosphärenbedingungen"
Veröffentlichungs-Nr.: DE 10 2004 015 216 B4

[P27] L. Morgenthal, A. Klotzbach, T. Schwarz, J. Hauptmann, R. Gnann
"Vorrichtung und Verfahren für eine Bearbeitung großflächiger Bearbeitungsbereiche von Werkstücken mittels Laserstrahlung"
Veröffentlichungs-Nr.: DE 10 2004 007 541 B4

[P28] R. Neugebauer, R. Lang, M. Seifert, E. Trageser, R. Wolf, R. Zieris, L.-M. Berger, S. Nowotny
"Verfahren zur Herstellung einer Einrichtung zur Umsetzung einer rotatorischen in eine translatorische Bewegung und damit hergestellte Einrichtung"
Veröffentlichungs-Nr.: EP 1 556 585 B1

[P29] D. Rogler, V. Hopfe, G. Mäder
"Verfahren zur Ausbildung dünner Schichten aus Silizium auf Substratoberflächen"
Veröffentlichungs-Nr.: DE 10 2004 015 217 B4

[L01] F. Atchison, B. Blau, M. Daum, P. Fierlinger, P. Geltenbort, R. Henneck, S. Heule, M. Kasprzak, K. Kirch, K. Kohlik, M. Kuzniak, M. Meier, C.-F. Meyer, A. Pichlmaier, C. Plonka, P. Schmidt-Wellenburg, B. Schultrich, T. Stucky, V. Weihnacht, O. Zimmer

"Storage of Ultracold Neutrons in a Volume Coated with Diamondlike Carbon"

Physical Review C 74, (2006)

[L02] H. Beese, W. Grählert, V. Hopfe, F. Petzold, P. Kaspersen, A. Bohman, P. Mackrodt

"In-line Monitoring von Feuchtespuren und weiteren kritischen Verunreinigungen in Bulk- und Korrosivgasen der Mikroelektronik"

VDI-Berichte1959 (2006), S. 57-62

[L03] L.-M. Berger

"Hardmetal Bulk Materials and Coatings - Commonalities and Differences"

Powder Metallurgy Congress & Exhibition Euro PM2006, (2006) S. 289-297 (ISBN 1-899072-32-2), Strewsburg, U.K.: European Powder Metallurgy Association, Vol.1

[L04] L.-M. Berger, J. Hauptmann, S. Nowotny, V. Weihnacht, J. Ziemer

"Herstellung von harten Schichten und Bearbeitung von Hartstoffen"

Industrie Diamanten Rundschau 40 (2006) 3, S. 24-30

[L05] L.-M. Berger, S. Saaro, M. Woydt

"Influence of Oxidation on the Dry Sliding Properties of HVOF-Sprayed Hardmetal Coatings"

Powder Metallurgy Congress & Exhibition Euro PM2006 (2006) S. 225-232

[L06] E. Beyer

"Fiber Laser Welding"

Industrial Laser Solutions 21 (2006) 7, S. 13-14

[L07] E. Beyer

"Schweißen und Schneiden mit Faserlasern - ein Entwicklungssprung in der Lasertechnik aus Anwendersicht"

7th European Conference and Exhibition European Automotive Laser Application EALA (2006) S. 109 - 118

[L08] E. Beyer

"High Power Laser Applications"

14th Annual Automotive Laser Application Workshop ALAW (2006)

[L09] E. Beyer

"Polarisierte Faserlaser und optische Rückwirkungen"

2. Internationaler Workshop "Faserlaser" (2006) Tagungsband

[L10] E. Beyer

"Neue Entwicklungen und Trends in der Lasermaterialbearbeitung und die Anforderungen an die Strahlquellen und Strahlführung"

PRIMES Workshop (2006) Tagungs-CD

[L11] E. Beyer, B. Brenner, A. Klotzbach, S. Nowotny

"Laser Macro Processing - Today and Tomorrow"

4th International Congress on Laser Advanced Materials Processing LAMP 2006, Published online by JLPS-Japan Laser Processing Society, #06-1, Tu1-2 #35

[L12] E. Beyer, B. Brenner, L. Morgenthal

"Laser Beam Applications with High Power Fiber Laser"

XVI International Symposium on Gas Flow and Chemical Lasers & High Power Lasers Conference GCL / HPL 2006 (2006) Tagungsband erscheint im Frühjahr 2007

[L13] E. Beyer, B. Brenner, L. Morgenthal

"Faserlaseranwendung"

5. Jenaer Lasertagung (2006) S. 197 - 210

[L14] E. Beyer, W. Danzer

"Einfluss von Plasma und Schutzgas auf Schweißprozesse"

2. Internationaler Workshop "Faserlaser" (2006) Tagungsband

[L15] I. Bialuch, H.-J. Scheibe, W. Augustin

"Anitihaft- und Antifouling-Effekte durch modifizierte amorphe Kohlenwasserstoffe"

EFDS Workshop "Kohlenstoffschichten - tribologische Eigenschaften und Verfahren zu ihrer Herstellung" (2006) Tagungsband

[L16] S. Bonß

"Der Strahl, der hart macht"

Werkstatt und Betrieb (2006) 5, S. 18-20

[L17] S. Bonß

"Integrierte Härterei - Laserstrahlhärten im Großwerkzeugbau"

Härtereitechnische Mitteilungen, 61 (2006) 5, S. 254 - 259

[L18] S. Bonß, J. Hannweber, U. Karsunke, M. Seifert, B. Brenner, E. Beyer

"Integrated Heat Treatment - System for Precise Hardening Journal of Unique Tools or Parts"

4th International Congress on Laser Advanced Materials Processing LAMP 2006, Published online by JLPS-Japan Laser Processing Society, 2006 ,#06-165 Th4-3 #140

[L19] S. Bonß, J. Hannweber, S. Kühn, M. Seifert, B. Brenner, E. Beyer

"LASSY - Laserstrahlhärten mit variabler Spurbreite"

9. WTK Chemnitz, Tagungsband, TU Chemnitz, Eigenverlag, Schriftenreihe Werkstoffe und Werkstoffverbunde, 24 (2006) S. 161-166

[L20] S. Bonß, J. Hannweber, S. Kühn, M. Seifert, B. Brenner, E. Beyer

"Variable Bearbeitungsoptik zum Laserstrahlhärten"

DVS-Berichte, 241 (2006), S. 95-100, DVS-Verlag, Düsseldorf

[L21] S. Bonß, J. Hannweber, M. Seifert, U. Karsunke, E. Beyer

"Integrated Heat Treatment - System for Precise Hardening of Unique Tools or Parts"

2nd Pacific International Conference on Applications of Lasers and Optics PICALO 2006, LIA Pub. #401, Vol. 2, ISBN #0-912035-84-6

[L22] S. Braun, T. Foltyn, M. Menzel, A. Leson, F. Schäfers, M. Mertin

"Multilayer Monochromators for the Wavelength-Dispersive X-ray Fluorescence Spectrometry"

BESSY-Jahresbericht (2005) S. 451-453

[L23] S. Braun, P. Gawlitza, M. Menzel, A. Leson, M. Mertin, F. Schäfers

"Reflectance and Resolution of Multilayer Monochromators for Photon Energies from 400 - 6000 eV"

The 9th International Conference on Synchrotron Radiation Instruments (SRI) (2006) D3-013

[L24] S. Braun, P. Gawlitza, M. Menzel, S. Schädlich, A. Leson

"High-Precision Multilayer Coatings and Reflectometry for EUVL Optics"

The 9th International Conference on Synchrotron Radiation Instruments (SRI) (2006) K3-014

[L25] S. Braun, H. Mai

"Multilayer and Single-Surface Reflectors for X-ray Optics"

"Metal Based Thin Films for Electronics", K. Wetzig, C. M. Schneider, WILEY-VCH (2006), S. 103-119

[L26] S. Braun, H. Mai

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[L27] S. Braun, H. Mai

"X-Ray Optical Systems"

"Metal Based Thin Films for Electronics", K. Wetzig, C. M. Schneider, WILEY-VCH (2006), S. 373-383

[L28] B. Brenner, G. Göbel, U. Stamm, J. Standfuß, S. Schrauber

"Influence of Beam Quality on Crack Formation in hard-to-weld Materials"

2. Internationaler Workshop "Faserlaser" (2006) Tagungs-CD

[L29] B. Brenner, G. Göbel, J. Standfuß, U. Stamm

"Neuere Ergebnisse zum Schweißen von Eisenbasiswerkstoffen mit Faserlasern"

5. Laser-Anwenderforum, in: F. Vollertsen, T. Seefeld (Hrsg.): "Laserstrahlfügen: Prozesse, Systeme, Anwendungen, Trends", Strahltechnik Band 28, Bremer Institut für angewandte Strahltechnik, (2006) ISBN: 3-933762-18-9, S. 139-148

[L30] B. Brenner, A. Jahn, G. Göbel, A. Klotzbach, J. Standfuß, L. Morgenthal

"Neue Möglichkeiten des Laserstrahlschweißens für den Karosseriebau"

Internationaler Rohbauexpertenkreis, 30. Fachtagung "Prozesskette Karosserie®" (2006) Tagungs-CD

[L31] F. Brückner, D. Lepski, E. Beyer

"Finite Element Studies of Stress Evolution in Induction Assisted Laser Cladding"

XVI International Symposium on Gas Flow and Chemical Lasers & High Power Lasers Conference, Tagungsband erscheint im Frühjahr 2007

[L32] I. Dani, V. Hopfe, L. Kotte, D. Linaschke, D. Rogler, S. Tschöcke

"Transparente Kratzschutzschichten mittels Plasma-CVD bei Atmosphärendruck"

Werkstoffe in der Fertigung (2006) 5, S. 40-41

[L33] I. Dani, V. Hopfe, D. Rogler, E. Lopez, G. Mäder

"Plasmachemische Gasphasenabscheidung und Plasmaätzen bei Atmosphärendruck mittels einer linear ausgedehnten DC-Bogenplasmaquelle"

Vakuum in Forschung und Praxis, 18 (2006) 4, S. 30-33

[L34] T. Dekorsy, F. Hudert, R. Cerna, H. Schäfer, C. Janke, A. Bartels, K. Köhler, S. Braun, M. Wiemer, S. Mantl

"Coherent Acoustic Phonons in Nano-Structures Investigated by Asynchronous Optical Sampling"

Proc. of the SPIE 63930H (2006)

[L35] D. Dittrich

"Gewichtsreduzierung: schweißbares Magnesiumblech im Karosseriebau"

Photonik 38 (2006) 3, S. 16

[L36] V. Franke, F. Sonntag, G. Richter, U. Klotzbach

"Fügen von LTCC und Kunststoff mittels Laserstrahlung"

18. Internationale Wissenschaftliche Konferenz Mittweida (2006) Tagungsband

[L37] V. Franke, F. Sonntag, G. Richter, U. Klotzbach

"New Technology for Joining of LTCC and Polymer Assemblies"

1st Electronics Systemintegration Technology Conference, ESTC2006 Dresden (2006) Tagungsband

[L38] P. Gawlitza, S. Braun, S. Lipfert, A. Leson

"Ion-Beam Sputter Deposition of X-Ray Multilayer Optics on Large Areas"

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[L39] W. Grählert, I. Dani, G. Mäder, O. Throl, V. Hopfe, K. Pietsch, T. Wünsche, Th. Dreyer

"ISPROM, ein in-situ-Multigasanalysator für CVD- und Ätzprozesse"

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[L40] J. Hannweber, S. Bonß, B. Brenner, E. Beyer

"Practical Applications of Camera Based Systems for Laser Material processing"

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[L41] J. Hannweber, S. Kühn, S. Bonss, B. Brenner, E. Beyer

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[L42] G. Hardtke, A. Schumann, I. Hopfe, I. Jansen

"Graffitischutz auf textilen Trägerstoffen durch präventive Oberflächenbeschichtung"

Technische Textilien - Technical Textiles 49 (2006) 1, S. 53-56

[L43] B. Hommel, J. Heikenwälder, O. Zimmer

"Wachstumspotential des Rapid Tooling durch Prototypwerkzeuge für Kunststoffteile mit Miniaturstrukturen"

Die Maschine (dima) (2006) 1, S. 53-55

[L44] I. Jansen

"Partieller Schichtabtrag an faserverstärkten Kunststoffen"

Kunststoffverarbeitung Deutschland (2006) 9, S. 30-31

[L45] I. Jansen, E. Beyer

"Surface Pretreatment of Magnesium with Nd:YAG Laser"

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[L46] I. Jansen, R. Böhme

"Laserstrahlbehandlung von faserverstärkten Kunststoffen vor dem Kleben"

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[L47] I. Jansen, H. Wust, E. Beyer

"Welchen Einfluss hat Laserstrahlung auf Magnesium"

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[L48] J. Kaspar, J. Bretschneider, S. Jacob, S. Bonß, B. Winderlich, B. Brenner

"Microstructure, Hardness and Cavitation Erosion Behavior of Ti 6Al 4V Laser Nitrided under Different Gas Atmospheres"

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[L49] J. Kaspar, A. Luft, S. Nolte, M. Will, E. Beyer

"Laser Helical Drilling of Silicon Wafers with ns to fs Pulses: Scanning Electron Microscopy and Transmission Electron Microscopy Characterization of Drilled Through-Holes"

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[L50] D. Klaffke, B. Schultrich, V. Weihnacht

"Tribological Behaviour of ta-C Coatings under Water Lubricated Conditions"

The Annals of University of Galati 8 (2005), S. 24-28

[L51] D. Klaffke, B. Schultrich, V. Weihnacht

"Tribological Characterisation of ta-C Coatings under Lubricated Conditions"

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[L52] K. Klotz, U. Bahr, W. Brückner, H.-A. Bahr, H. Balke, G. Kirchhoff, H.-J. Weiss, T. Göbel, S. Menzel, K. Wetzig

"Coatings with Intrinsic Stress Profile: Refined Creep Analysis of (Ti,Al)N and Cracking Due to Cyclic Laser Heating"

Thin Solid Films 496 (2006), S. 469-474

[L53] A. Leson

"Nanoscaled Multilayer Systems for X-Ray Analytics and EUV Lithography"

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[L54] K. Lipp, L.-M. Berger, U. May, M. Wiener

"Rolling Contact Fatigue of the Hardmetal Coating WC-17%Co"

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[L55] A. Mahrle, E. Beyer

"Hybrid Laser Beam Welding - Classification, Characteristics, and Applications"

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[L56] S. Martens, V. Weihnacht, L.-M. Berger, I. Schulz, D. Lehmann, B. Schlecht

"Ölfreie Getriebe"

Tribologie-Fachtagung, Moers: Gesellschaft für Tribologie (2006) CD, 11 p., ISBN 3-00-015053-6

[L57] S. Nowotny

"Laserstrahl-Auftragschweißen: Präzisionstechnologie für Oberflächenschutz und Reparaturen"

Schriftenreihe Thermisches Spritzen, Hrsg. Alexander Schwenk, (2006), S. 74-82, ISSN 1610-0530

[L58] T. Sandner, J. U. Schmidt, H. Schenk, H. Lakner, M. Yang, A. Gatto, N. Kaiser, S. Braun, T. Foltyn, A. Leson

"Highly Reflective Optical Coatings for High-Power Applications of Micro Scanning Mirrors in the UV-VIS-NIR Spectral Region"

Proc. of the SPIE 61140H (2006)

[L59] P. Schaaf, M. Shinn, E. Carpene, J. Kaspar

"Direct Laser Synthesis of Functional Coatings by FEL Treatments"

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[L60] B. Schultrich

"Nanostructural Ceramic and Carbon Films for Wear Protection"

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Anwendungen und Trends in der Optischen Analysenmesstechnik
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University of Sherbrooke, Québec (Canada) 12. Mai 2006

[T03] L.-M. Berger

"Hardmetal Bulk Materials and Coatings - Commonalities and Differences"

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[T04] L.-M. Berger

"Magnéli Phases in Thermal Spray Coatings"

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[T05] L.-M. Berger, S. Saaro, M. Woydt

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[T06] L.-M. Berger, S. Saaro, M. Woydt

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[T07] E. Beyer

"Schweißen und Schneiden mit Faserlasern - ein Entwicklungssprung in der Lasertechnik aus Anwendersicht"

7th European Conference and Exhibition European Automotive Laser Application EALA 2006, Bad Nauheim (D) 26.-27. Januar 2006

[T08] E. Beyer

"Fibre Laser Applications in Germany"

AILU Workshop "Fibre Lasers - the Future of Laser Materials Processing Technology?", Bedfordshire (Großbritannien) 08. März 2006

[T09] E. Beyer

"Fraunhofer in Germany and the Fraunhofer Surface Technology and Photonics Alliance"

Fraunhofer Pre-Conference, Plymouth (USA) 28. März 2006

[T10] E. Beyer

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"High Power Laser Applications"

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[T12] E. Beyer

"High Power Fiber Lasers and Potential Applications"

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[T13] E. Beyer

"Reibungs- und Verschleißminderung durch Nanotechnologie"

TKA Workshop "Nanotechnologie", Dortmund (D) 20. Juni 2006

[T14] E. Beyer

"Polarisierte Faserlaser und optische Rückwirkungen"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.-06. Juli 2006

[T15] E. Beyer

"Fiber Laser Technology for Industry"

GE Symposium "Light and matter: Advanced Laser Applications in Europe" Garching (D) 19. Juli 2006

[T16] E. Beyer

"Neue Entwicklungen und Trends in der Lasermaterialbearbeitung und die Anforderungen an die Strahlquellen und Strahlführung"

2. PRIMES Workshop, Pfungstadt (D) 12.-13. September 2006

[T17] E. Beyer, B. Brenner, A. Klotzbach, S. Nowotny

"Laser Macro Processing - Today and Tomorrow"

4th International Congress on Laser Advanced Materials Processing LAMP 2006 Kyoto (Japan) 16.-19. Mai 2006

[T18] E. Beyer, B. Brenner, L. Morgenthal

"Laser Beam Applications with High Power Fiber Laser"

XVI International Symposium on Gas Flow and Chemical Lasers & High Power Lasers Conference GCL/HPL 2006 Gmunden (Österreich) 04.-08. September 2006

[T19] E. Beyer, B. Brenner, L. Morgenthal

"Faserlaseranwendung"

5. Jenaer Lasertagung (D) 23.-24. November 2006

[T20] E. Beyer, B. Brenner, J. Standfuß

"Laser Beam Welding with High Power Fiber Lasers"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006 Scottsdale (AZ, USA) 30. Oktober - 02. November 2006

[T21] E. Beyer, W. Danzer

"Einfluss von Plasma und Schutzgas auf Schweißprozesse"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.-06. Juli 2006

[T22] E. Beyer, A. Klotzbach, L. Morgenthal

"Working with a Polarized Fiber Laser for Welding and Cutting"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006 Scottsdale (USA) 30. Oktober - 02. November 2006

[T23] I. Bialuch, H.-J. Scheibe, W. Augustin

"Anitihaft- und Antifouling-Effekte durch modifizierte amorphe Kohlenwasserstoffe"

EFDS Workshop "Kohlenstoffschichten - tribologische Eigenschaften und Verfahren zu ihrer Herstellung", Dortmund (D) 08. Juni 2006

[T24] S. Bonß

BMBF-Projekt "Integrierte Härterei - Neue Möglichkeiten des Laserstrahlhärtens im Werkzeugbau"

Härtereikolloquium 2006, Wiesbaden (D) 11.-13. Oktober 2006

[T25] S. Bonß, J. Hannweber, U. Karsunke, M. Seifert, B. Brenner, E. Beyer

"Integrated Heat Treatment - System for Precise Hardening Journal of Unique Tools or Parts"

4th International Congress on Laser Advanced Materials Processing LAMP 2006, Kyoto (Japan) 16.-19. Mai 2006

[T26] S. Bonß, J. Hannweber, U. Karsunke, M. Seifert, B. Brenner, E. Beyer

"Integrated Heat Treatment - Comparison of Different Machine Concepts"

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[T27] S. Bonß, J. Hannweber, S. Kühn, M. Seifert, B. Brenner, E. Beyer

"LASSY - Laserstrahlhärten mit variabler Spurbreite"

9. Werkstofftechnisches Kolloquium (WTK) Chemnitz (D) 07.-08. September 2006

[T28] S. Bonß, J. Hannweber, S. Kühn, M. Seifert, B. Brenner, E. Beyer

"Variable Bearbeitungsoptik zum Laserstrahlhärten"

5. Jenaer Lasertagung, Jena (D) 23.-24. November 2006

[T29] S. Bonß, J. Hannweber, M. Seifert, U. Karsunke, E. Beyer

"Integrated Heat Treatment - System for Precise Hardening of Unique Tools or Parts"

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[T30] S. Bonß, M. Seifert, J. Hannweber

"LASSY - dynamisch adaptierbare Härteoptik"

6. Workshop "Industrielle Anwendungen von Hochleistungs-Diodenlasern", Dresden (D) 08.-09. November 2006

[T31] S. Braun, W. Friedrich, P. Gawlitza, S. Lipfert, M. Menzel, S. Schädlich, J. Schmidt, A. Leson

"Herstellung und Charakterisierung von Mo/Si-Multischichten für Anwendungen im extrem ultravioletten Spektralbereich"

XIII Erfahrungsaustausch "Oberflächentechnologien mit Plasma- und Ionenstrahlprozessen"
Mühlleithen (D) 14.-16. März 2006

[T32] S. Braun, P. Gawlitza, S. Lipfert, M. Menzel, S. Schädlich, A. Leson

"Sputter Deposition of Nanometer MultiLayer Coatings for High-Reflection Optics in the Extreme Ultraviolet (EUV) Spectral Region"

10th International Conference on Plasma Surface Engineering PSE 2006 Garmisch-Partenkirchen (D)
10.-13. September 2006

[T33] S. Braun, P. Gawlitza, M. Menzel, A. Leson, M. Mertin, F. Schäfers

"Reflectance and Resolution of Multilayer Monochromators for Photon Energies from 400 - 6000 eV"

The 9th International Conference on Synchrotron Radiation Instruments (SRI) Daegu (Südkorea) 28. Mai-02. Juni 2006

[T34] S. Braun, P. Gawlitza, M. Menzel, S. Schädlich, A. Leson

"High-Precision Multilayer Coatings and Reflectometry for EUVL Optics"

The 9th International Conference on Synchrotron Radiation Instruments (SRI) Daegu (Südkorea) 28. Mai-02. Juni 2006

[T35] B. Brenner, J. Standfuß, B. Winderlich, A. Junk, G. Göbel

"Das Verbundvorhaben LaserPowerTrain (Laserschweißen im Getriebebau) unter dem Simulationsaspekt"

24th CADFEM-User's Meeting, Stuttgart (D) 25.-27. Oktober 2006

[T36] B. Brenner, S. Bonß, F. Tietz, J. Hannweber, M. Seifert, S. Kühn, U. Karsunke

"HLDL - Anlage zum beidseitig-gleichzeitigen Laserstrahlhärten formkomplizierter Bauteile"

6. Workshop "Industrielle Anwendungen von Hochleistungs-Diodenlasern", Dresden (D) 08.-09. November 2006

[T37] B. Brenner, G. Göbel, D. Dittrich, J. Standfuß, E. Beyer

"Use of Fiber Lasers with Highest Beam Quality for Welding of Steel and Light Weight Alloys"

4th International Congress on Laser Advanced Materials Processing LAMP 2006, Kyoto (Japan) 16.-19. Mai 2006

[T38] B. Brenner, G. Göbel, U. Stamm, J. Standfuß, S. Schrauber

"Influence of Beam Quality on Crack Formation in hard-to-weld Materials"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.-06. Juli 2006

[T39] B. Brenner, G. Göbel, J. Standfuß, U. Stamm

"Neuere Ergebnisse zum Schweißen von Eisenbasiswerkstoffen mit Faserlasern"

5. Laser-Anwenderforum, Bremen (D) 13.-14. September 2006

[T40] B. Brenner, A. Jahn, G. Göbel, A. Klotzbach, J. Standfuß, L. Morgenthal

"Neue Möglichkeiten des Laserstrahlschweißens für den Karosseriebau"

Internationaler Rohbauexpertenkreis, 30. Fachtagung "Prozesskette Karosserie®", Leipzig (D) 09.-11. Mai 2006

[T41] F. Brückner, D. Lepski, E. Beyer

"Calculation of the Influence of Additional Heat Sources on Residual Stresses in Laser Cladding"

19th Meeting on Mathematical Modelling of Materials Processing with Lasers, Igls (A) 18.-20. Januar 2006

[T42] F. Brückner, D. Lepski, E. Beyer

"Modellrechnungen zur Reduktion der Spannungen beim Laser-Pulver-Auftragschweißen mittels zusätzlicher Wärmequellen"

WLT-Summerschool, Hannover (D) 28.-30. Juni 2006

[T43] F. Brückner, D. Lepski, E. Beyer

"Finite Element Studies of Stress Evolution in Induction Assisted Laser Cladding"

XVI International Symposium on Gas Flow and Chemical Lasers & High Power Lasers Conference, Gmunden (A), 04.-08. September 2006

[T44] I. Dani, D. Linaschke, V. Hopfe

"Atmosphärendruck-PECVD-Prozesse zur Abscheidung kohlenstoffbasierter Schichten"

2. Workshop "Kohlenstoffschichten - tribologische Eigenschaften und Verfahren zu ihrer Herstellung" Dortmund (D) 08. Juni 2006

[T45] F. Dausinger, J. Weberpals, B. Brenner, G. Göbel

"The Role of Strong Focusability on the Welding Process"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006, Scottsdale (AZ, USA)
30. Oktober - 02. November 2006

[T46] D. Dittrich, B. Winderlich, B. Brenner, J. Standfuß, J. Hackius

"Current Status of Laser Beam Welding of Skin-Skin-Joints for Aircraft Al-Fuselages"

International Conference on Aluminium, Essen (D) 21.-22. September 2006

[T47] V. Franke, F. Sonntag, G. Richter, U. Klotzbach

"Fügen von LTCC und Kunststoff mittels Laserstrahlung"

18th International Scientific Conference Mittweida (D) 09.-11. November 2006

[T48] V. Franke, F. Sonntag, G. Richter, U. Klotzbach

"New Technology for Joining of LTCC and Polymer Assemblies"

1st Electronics Systemintegration Technology Conference ESTC2006, Dresden (D) 05.-07. September 2006

[T49] P. Gawlitza

"Der Einsatz der Ionenstrahlsputtertechnik zur Abscheidung von hochpräzisen Nanometer-Multischichten"

XIII. Erfahrungsaustausch "Oberflächentechnologien mit Plasma- und Ionenstrahlprozessen" Mühlleithen (D)
14.-16. März 2006

[T50] P. Gawlitza, S. Braun, A. Leson

"Ion-Beam Sputter Deposition of X-Ray Multilayer Optics on Large Areas"

Advances in X-Ray/EUV Optics, Components, and Applications - Optics & Photonics, Annual meeting of SPI, San Diego (USA) 13.-17. August 2006

[T51] P. Gawlitza, S. Braun, S. Lipfert, S. Schädlich, A. Leson

"Dual Ion-Beam Sputter Deposited Mo/Si Multilayers with Sub-Nanometer Barrier Layers"

Advances in X-Ray/EUV Optics, Components, and Applications - Optics & Photonics, Annual meeting of SPIE San Diego (USA) 13.-17. August 2006

[T52] G. Göbel, B. Brenner

"Avoiding Hot Cracking by Induction based Change of Thermal Strains during Laser Welding"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006, Scottsdale (AZ, USA)
30. Oktober - 02. November 2006

[T53] W. Grählert

"Forschungs- und Entwicklungsaktivitäten des FhG Institutes für Werkstoff- und Strahltechnik auf dem Gebiet der Halbleiterfertigung"

1. Silicon Saxony Tag, Dresden (D)
02. März 2006

[T54] W. Grählert, I. Dani, G. Mäder, O. Throl, V. Hopfe, K. Pietsch, T. Wünsche, T. Dreyer

"ISPROM, ein in-situ-Multigasanalysator für CVD- und Ätzprozesse"

Anwendungen und Trends in der Optischen Analysenmesstechnik
5. Konferenz über Optische Analysenmesstechnik in Industrie und Umwelt Mannheim (D) 26.-27. September 2006

[T55] J. Hannweber, S. Bonß, B. Brenner, E. Beyer

"Practical Applications of Camera Based Systems for Laser Material processing"

4th International Congress on Laser Advanced Materials Processing LAMP 2006, Kyoto (Japan) 16.-19. Mai 2006

[T56] J. Hannweber, S. Kühn, S. Bonss, B. Brenner, E. Beyer

"Camera Based System for Online Laser Beam Monitoring"

2nd Pacific International Conference on Applications of Lasers and Optics PICALO 2006, Melbourne (Australien) 03.-05. April 2006

[T57] J. Hauptmann, U. Klotzbach, V. Franke

"Überblick der Laseranwendungsmöglichkeiten"

Messe Interpack Innovationparc Packaging, Düsseldorf (D) 26. September 2006

[T58] J. Hauptmann, U. Klotzbach, V. Franke

"Innovative Laserbearbeitung für die Kunststofftechnik"

50. Sitzung der Regionalgruppe Sachsen des GKV, Fachverband Technische Teile, Fa. Pentacon, Dresden (D)
14. November 2006

[T59] J. Hauptmann, A. Klotzbach, G. Wiedemann

"Reinigen mit Lasern: Chancen und Grenzen"

6. PhotonicNet Arbeitskreis "Oberflächenbearbeitung", Braunschweig (D)
21. September 2006

[T60] J. Hauptmann, A. Klotzbach, G. Wiedemann

"Grundlagen des Laserstrahlreinigens und technische Anwendungsmöglichkeiten"

Oberflächentage des Zentralverbandes Oberflächentechnik e. V., Bonn (D)
28. September 2006

[T61] J. Hauptmann, A. Klotzbach, G. Wiedemann

"Partielle Bauteilreinigung mit Lasern"

Messe Parts2Clean Anwenderforum, Friedrichshafen (D) 09. November 2006

[T62] M. Heintze, A. Hauser, R. Möller, H. Wanka, E. López, I. Dani, V. Hopfe, J. W. Müller, A. Huwe

"In-line Plasma Etching at Atmospheric Pressure for Edge Isolation in Crystalline Si Solar Cells"

4th World Conference on Photovoltaic Energy Conversion IEEE , Waikoloa (Hawaii) 07.-12. Mai 2006

[T63] V. Hopfe

"Atmospheric Pressure PECVD Coating and Plasma Chemical Etching for Continuous Processing"

The 33rd IEEE International Conference on Plasma Science, Traverse City (Michigan, USA) 04.-08. Juni 2006

[T64] V. Hopfe

"Atmospheric Pressure CVD",

Mini Course The 33rd IEEE International Conference on Plasma Science, Traverse City (Michigan, USA) 04.-08. Juni 2006

[T65] V. Hopfe

"New Developments (AP plasma CVD) and In-situ Monitoring"

Short Course International Conference on Coatings on Glass and Plastics, Dresden (D) 18.-22. Juni 2006

[T66] V. Hopfe

"AD-Plasma-CVD und Plasmaätzen mittels linearer DC-Arc-Jet-Quelle"

OTTI-Forum Reinigen, Aktivieren und Beschichten mit Atmosphärendruck (AD)-Plasma - Geräte, Verfahren, Anwendungen, Würzburg (D) 26.-27. Juni 2006

[T67] V. Hopfe

"Atmospheric Pressure Plasmas for Continuous Thin Film Deposition and Etching"

4th Technological Plasma Workshop Manchester (UK) 14.-15. Dezember 2006

[T68] V. Hopfe, I. Dani, E. López, M. Rosina, G. Mäder, R. Möller, H. Wanka, M. Heintze

"Atmospheric Pressure PECVD and Atmospheric Pressure Plasma Chemical Etching for Continuous Processing of Crystalline Silicon Wafers"

21st European Photovoltaic Solar Energy Conference and Exhibition, Dresden (D) 04.-08. September 2006

[T69] V. Hopfe, D. W. Sheel

"Atmospheric Pressure Plasmas for Continuous Thin Film Deposition and Etching"

10th International Conference on Plasma Surface Engineering PSE 2006 Garmisch-Partenkirchen (D) 10.-15. September 2006

[T70] A. Jahn, B. Brenner, E. Beyer

"Induction Assisted Laser Welding of Advanced High Strength Steels to Increase the Formability of Welded Automotive Body Structures"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006, Scottsdale (AZ, USA) 30. Oktober - 02. November 2006

[T71] I. Jansen

"Dauerhafte Klebverbindungen durch physikalische Oberflächenbehandlung"

Forum auf der Hannovermesse 2006, Hannover (D) 26. April 2006

[T72] I. Jansen

"Klebtechnik im Fraunhofer IWS in Dresden"

Kolloquium Sika-AG, Widen (CH) 15. Mai 2006

[T73] I. Jansen

"Oberflächenvorbehandlung von Glas und Metallen"

Innovationsforum Glas, Landsberg (D) 27.-28. September 2006

[T74] I. Jansen, R. Böhme

"Vorbehandlung von faserverstärkten Kunststoffen vor dem Kleben"

EFDS Workshop Vorbehandlung von Kunststoffen vor dem Beschichten, Bedrucken und Bekleben, Frankfurt/Main (D) 07. April 2006

[T75] O. Jost, O. Zimmer, I. Dani

"Cheap Carbon Nanotubes - Very Recent Synthesis Successes Open New Opportunities for Nanotube-Based Applications"

Nanofair 2006, Karlsruhe (D) 21.-22. November 2006

[T76] D. Klaffke, B. Schultrich, V. Weihnacht

"Tribological Characterisation of ta-C Coatings under Lubricated Conditions"

15th International Colloquium Tribology, Stuttgart (D) 17.-19. Januar 2006

[T77] C. Kleemann, H.-J. Scheibe, T. Schuelke

"Tribological Study of the Friction and Wear Behavior of Amorphous Hard Carbon (ta-C) Coatings under Different Lubrication Conditions"

49th Annual SVC Technical Conference Washington (DC, USA) 22.-27.April 2006

[T78] C. Kleemann, H.-J. Scheibe, T. Schuelke

"Friction and Wear Behavior of Amorphous Hard Carbon (ta-C) Coatings under Different Lubrication Conditions"

International Conference on Metallurgical Coatings and Thin Films (ICMCTF) San Diego (Ca, USA) 01.-05. Mai 2006

[T79] A. Klotzbach

"Remote System for High Beam Quality Solid State Lasers"

ALAW 2006, Fraunhofer Pre-Conference, Plymouth (MI, USA) 28. März 2006

[T80] A. Klotzbach, E. Beyer

"Variable Bearbeitungsoptik zum Laserstrahlhärten"

5. Jenaer Lasertagung, Jena (D) 23.-24. November 2006

[T81] A. Klotzbach, A. Mahrle, P. Pfohl, E. Beyer

"High Dynamic Beam Deflection Optics for Remote Welding with Fiber Laser"

25th International Congress on Applications of Lasers & Electro-Optics ICALEO 2006, Scottsdale (AZ, USA) 30. Oktober - 02. November 2006

[T82] A. Klotzbach, P. Pfohl

"Remote Processing with Fiber Lasers"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.-06. Juli 2006

[T83] U. Klotzbach, M. Panzner, V. Franke, F. Sonntag, J. Hauptmann

"Chances for Small Medium-Sized Enterprises Relating Laser-Micro-Fabrication"

R&D days International Forum on project development Bologna (I) September 2006

[T84] U. Klotzbach, M. Panzner, V. Franke, F. Sonntag, J. Hauptmann

"Potentialities of Laser in Micro Fabrication"

Laser Anwedungsseminar Budapest (H) Oktober 2006

[T85] U. Klotzbach, M. Panzner, G. Wiedemann

"Möglichkeiten und Grenzen der Lasertechnik für die Restaurierung von metallischen Kunst- Kulturgut"

GfKORR-Jahrestagung, Frankfurt am Main (D) 07.-08. November 2006

[T86] A. Lange

"Formation of Thermoelectric Currents in Weld Pools"

Seminar "Nichtlinearität und Unordnung in komplexen Systemen", Universität Magdeburg (D) 16. Januar 2006

[T87] A. Lange, E. Beyer

"Thermoelectric Currents in Laser Melted Pools"

19th Meeting on Mathematical Modelling of Materials Processing with Lasers, Igls (A) 18.-20. Januar 2006

[T88] A. Lange, E. Beyer

"Thermoelectric Currents in Laser-induced Weld Pools"

WLT-Summerschool, Hannover (D) 28.-30. Juni 2006

[T89] A. Leson

"Nanoscience and Nanotechnology in Germany - Highlights and Examples of Cooperation with Japan"

Luncheon Panel Presentation im Rahmen des "Seeds&Needs" Seminares Tokio (Japan) 22. Februar 2006

[T90] *A. Leson*

"Nanoscaled Multilayers for Electronics and X-Ray Analytical Purposes"

Workshop "Functional nanostructures an nanomaterials", Wellington (Neuseeland) 10. März 2006

[T91] A. Leson

"Nanotechnologie in Sachsen"

Sächsisches Technologieforum Dresden (D) 18. Mai 2006

[T92] A. Leson

"Nanoscaled Multilayer Systems for X-Ray Analytics and EUV Lithography"

3rd Korea-Germany Joint Seminar on Nanostructured Materials, Ulsan (Südkorea) 22. September 2006

[T93] A. Leson

"Nanometermultischichtsysteme und deren Anwendungen in der Elektronik und Analytik"

vaQum 2006, Magdeburg (D) 27. September 2006

[T94] A. Leson

"Problemlösungen für industrielle Fragestellungen"

NanoDE 2006
Berlin (D) 06.-07. Dezember 2006

[T95] A. Leson, S. Braun, P. Gawlitza, M. Nestler

"Large Area Ion Beam Sputter Deposition of Nanometer Multilayers"

7th Symposium of European Vacuum Coaters, Anzio (Italien) 02.-04. Oktober 2006

[T96] S. Lipfert

"Einsatz der Puls-Laser-Deposition (PLD) zur Beschichtung von Innenflächen"

LambdaPhysik-Kolloquium zur "Oberflächenbearbeitung mit dem Laser" Mittweida (D) 28. März 2006

[T97] S. Lipfert, P. Gawlitza, A. Leson

"Verbesserung der Haftfestigkeit superharter amorpher Kohlenstoffschichten (DLC) auf Innenflächen"

WLT-Summerschool, Hannover (D) 28.-30. Juni 2006

[T98] K. Lipp, L.-M. Berger, U. May, M. Wiener

"Rolling Contact Fatigue of the Hardmetal Coating WC-17%Co"

Powder Metallurgy Congress & Exhibition Euro PM2006, Ghent (Belgium) 23.-25. Oktober 2006

[T99] E. López, I. Dani, V. Hopfe, M. Heintze, A. Hauser, R. Möller, H. Wanka

"Plasma Etching at Atmospheric Pressure for rear Emitter Removal in Crystalline Si Solar Cells"

21st European Photovoltaic Solar Energy Conference and Exhibition, Dresden (D) 04.-08. September 2006

[T100] E. López, I. Dani, V. Hopfe, H. Wanka, M. Heintze, R. Möller, A. Hauser

"Plasma Enhanced Chemical Etching at Atmospheric Pressure for Silicon Wafer Processing"

21st European Photovoltaic Solar Energy Conference and Exhibition, Dresden (D) 04.-08. September 2006

[T101] E. López, I. Dani, V. Hopfe, H. Wanka, R. Möller, M. Heintze, A. Hauser

"Atmospheric Pressure Plasma Chemical Etching for Continous c-Si Solar Wafer Processing"

Marie Curie Conference, Manchester (UK) 10.-12. April 2006

[T102] A. Mahrle, E. Beyer

"Transiente Simulation laserinduzierter Schmelzbäder beim Wärmeleitungsschweißen"

WLT-Summerschool, Hannover (D) 28.-30. Juni 2006

[T103] S. Martens, V. Weihnacht, L.-M. Berger, I. Schulz, D. Lehmann, B. Schlecht

"Ölfreie Getriebe"

Tribologie-Fachtagung 2006, Göttingen (D) September 2006

[T104] M. Menzel, S. Braun, A. Leson, F. Schäfers

"Nanometer Multilayers as Monochromators for X-ray Spectrometry"

European Conference on X-ray spectrometry (EXRS), Paris (F) 19.-23. Juni 2006

[T105] S. Nowotny

"Laserstrahl-Auftragschweißen in der industriellen Fertigung"

VDI-Workshop Rapid Innovation, HTW Dresden (D) 15. November 2006

[T106] S. Nowotny

"Laserstrahl-Auftragschweißen: Präzisionstechnologie für Oberflächenschutz und Reparaturen"

3. GTV-Kolloquium Thermisches Spritzen, Luckenbach (D) 9. Juni 2006

[T107] S. Nowotny

"Flexible 3D-Bearbeitung durch laserbasierte Fügeverfahren mit integrierter Werkstoffzufuhr"

1. BMBF-Koordinatorentreffen Fügen, DVS-Forschungsvereinigung, Düsseldorf (D) 30. Mai 2006

[T108] S. Nowotny

"Beschichten, Reparieren und Generieren durch Laserstrahl-Präzisionsauftragschweißen"

BMBF-Impulsveranstaltung "Laserbasierte Füge- und Beschichtungsverfahren", Fraunhofer IWS Dresden (D) 16. November 2006

[T109] S. Nowotny, S. Scharek, A. Schmidt, F. Kempe

"Innovative Systemtechnik zum Rapid Repairing von hochwertigen Bauteilen und Werkzeugen"

Euro-uRapid2006, Frankfurt (D) 27.-28. November 2006

[T110] M. Oertel, U. Schwarz, H. Wust

"Schmalflächenbeschichtung im Brennpunkt des Lasers"

VVD 2006 Verarbeitungsmaschinen und Verpackungstechnik - Vorsprung aus Tradition, Dresden (D), 23.-24. März 2006

[T111] M. Panzner, U. Klotzbach, E. Beyer

"THz-Technik: Neue Möglichkeiten für Tomographie und Spektroskopie"

EFDS Workshop "Imaging und Bildverarbeitung für die Qualitätssicherung in der Oberflächentechnik"Dresden (D) 26. April 2006

[T112] M. Panzner, W. Köhler, S. Winnerl, M. Helm, F. Rutz, Ch. Jördens, M. Koch, H. Leitner, U. Klotzbach, E. Beyer

"Non-Destructive Investigations of Paintings with THz- Radiation"

ECNDT, Berlin (D) 25.-29. September 2006

[T113] M. Panzner, G. Wiedemann, U. Klotzbach

"Lasereinsatz in der Denkmalpflege"

Bauakademie Sachsen zum Tag des offenen Denkmals, Dresden (D) 09. September 2006

[T114] M. Panzner, G. Wiedemann, U. Klotzbach, E. Beyer

"Einsatz mobiler Lasertechnik zur Reinigung in der Restaurierung"

5. Kolloquium "Laserstrahl-Handbearbeitung" 2006, Halle (D) 29.-30. September 2006

[T115] S. Scharek

"Werkstoff-im-Ringstrahl - ein neues fertigungstechnisches Konzept zum Auftragschweißen und Fügen mit Zusatzwerkstoff"

BMBF-Impulsveranstaltung "Laserbasierte Füge- und Beschichtungsverfahren", Fraunhofer IWS Dresden (D) 16. November 2006

[T116] H.-J. Scheibe, C. Kleemann, L. Haubold, T. Schuelke

"Industrial Deposition Technology and Tribological Properties of Superhard Amorphous (ta-C) Carbon Films"

International Conference on Superhard Coatings (ICSC), Ein-Gedi (Israel) 27. Februar - 1. März 2006

[T117] E**.** Schmalz, O. Zimmer

"Coating of Textiles for Filter with Advance Performance"

International Conference on Plasma Surface Engineering PSE, Garmisch-Partenkirchen (D) 11.-15. September 2006

[T118] D. Schneider, B. Schultrich

"Testing Films and Coatings with a Wide Range of Properties by Laser-Acoustics"

International Conference on Plasma Surface Engineering PSE, Garmisch-Partenkirchen (D) 11.-15. September 2006

[T119] B. Schultrich

"Nanolayered Tribological and Functional Coatings"

Trilateral Conference on Vacuum and Plasma Surface Engineering, Hejnice (CZ) 26. September 2006

[T120] B. Schultrich

"Carbon-Based Hard Coatings"

Tutorial "Fundamentals and Trends of Plasma Surface Processing" in Connection with 10th International Conference on Plasma Surface Engineering (PSE2006), Garmisch-Partenkirchen (D) 09.-10. September 2006

[T121] B. Schultrich

"Vakuumbogenbeschichtung"

OTTI Fachforum "Die Vielfalt von Beschichtungen", Regensburg (D) 13.-14. März 2006

[T122] B. Schultrich

"Vakuumbogenbeschichtung"

4th MSTI Nanotechnology and Business Congress & Exhibition Nanotrends, Potsdam (D) 11. Mai 2006

[T123] B. Schultrich, K. Bewilogua

"Tribologisches Verhalten von amorphen Kohlenstoffschichten"

EFDS Workshop "Kohlenstoffschichten - tribologische Eigenschaften und Verfahren zu ihrer Herstellung", Dortmund (D) 08. Juni 2006

[T124] B. Schultrich, T. Stucky, V. Weihnacht

"Potential amorpher Kohlenstoffschichten für die Lebensmittelindustrie"

Messe Innovationparc Packaging, Düsseldorf (D) 26. September 2006

[T125] B. Schultrich, V. Weihnacht

"Industrial Potential of Tetrahedrally Bonded Amorphous Carbon Films"

ATV-SEMAPP Seminar, Aarhus, 29. März 2006

[T126] B. Schultrich, V. Weihnacht

"Superharte amorphe Kohlenstoffschichten für Zerspanungs-Werkzeuge"

Arbeitskreis Diamant-Werkzeuge, Braunschweig (D) 9. März 2006

[T127] B. Schultrich, V. Weihnacht, H.-J. Scheibe, T. Stucky

"Superhard Amorphous Carbon Films (ta-C) for Machining and Forming Tools"

International Conference on Metallurgical Coatings and Thin Films, San Diego (USA) 01.-05. Mai 2006

[T128] B. Schultrich, V. Weihnacht, H.-J. Scheibe, T. Stucky

"Superhard Amorphous Carbon Films (ta-C) for Machining and Forming Tools"

49th Annual SVC Technical Conference, Washington (DC, USA) 22.-27. April 2006,

[T129] C.C. Stahr, S. Saaro, L.-M. Berger, J. Dubsky, K. Neufuss

"Über die Abhängigkeit der Stabilisierung von Korund vom Spritzprozess"

9. Werkstofftechnisches Kolloquium (WTK), Chemnitz (D) 07.-08. September 2006

[T130] J. Standfuß

"Laser Beam Welding - Application- and Material Adapted Solutions"

ALAW 2006, Fraunhofer Pre-Conference, Plymouth (MI, USA) 28. März 2006

[T131] J. Standfuß

"Laser Beam Welding of Light Metals for Automotive Applications"

Symposium on Laser Applications to Materials Joining, Modification and Diagnostics, Quebec (Kanada) 8. Juni 2006

[T132] J. Standfuß, U. Stamm, G. Göbel, S. Schrauber

"Laser Beam Welding with Fiber Lasers in Power Train"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.- 06. Juli 2006

[T133] A. Techel, L.-M. Berger, J. Bretschneider, S. Thiele

"Laser and PTA Surfacing with TiC-Based Materials"

Building on 100 Years of Success: Proceedings of the 2006 International Thermal Spray Conference CD, Ed.: B.R. Marple, M.M. Hyland, Y.-C. Lau, R.S. Lima, J. Voyer, Materials Park/Ohio: ASM International (2006)

[T134] A. Techel, S. Nowotny

"Erzeugung von hochpräzisen Metallschichten und -strukturen durch neue Varianten des Auftragschweißens"

2. Internationaler Workshop "Faserlaser" Dresden (D) 05.-06. Juli 2006

[T135] S. Tschöcke, V. Hopfe, I. Dani, L. Kotte

"Abscheidung von kratzfesten SiO_2-Schichten mittels PECVD bei Atmosphärendruck"

Thüringer Grenz- und Oberflächentage, Oberhof (D) 13.-14.September 2006,

[T136] 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"

International Thermal Spray Conference, Seattle, Washington (USA) 15.-18. Mai 2006

[T137] V. Weihnacht, J. Berthold, B. Schultrich, D. Klaffke

"Superhard Amorphous Carbon Films for Critical Lubrication Conditions"

15th International Colloquium Tribology Automotive and Industrial Lubrication, Stuttgart (D) 17.-19. Januar 2006

[T138] V. Weihnacht, B. Schultrich, O. Zimmer

"Reibungs- und Verschleißeigenschaften modifizierter ta-C-Schichten"

Werkstofftechnisches Kolloqium (WTK), Chemnitz (D) 07.-08. September 2006

[T139] V. Weihnacht, T. Stucky, B. Schultrich

"Eigenschaften und Anwendungen von superharten ta-C-Schichten"

EFDS Workshop "Kohlenstoffschichten - tribologische Eigenschaften und Verfahren zu ihrer Herstellung", Dortmund (D) 08. Juni 2006

[T140] R. Wiese, H. Kersten, L. Kotte, S. Krause, I. Dani, V. Hopfe

"Energieeinstrommessungen an einem atmosphärischen Mikrowellenplasma"

XIII. Erfahrungsaustausch Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen Mühlleithen (D) 14.-16. März 2006

[T141] R. Wolf, F. Trageser, C. Hochmuth, R. Neugebauer, S. Ortmann, L.-M. Berger, M. Wiener, T. Naumann, S. Rein, T. Schumann

"Verschleißschutz von Nockenfunktionsflächen durch Beschichtung und Oberflächenbehandlung"

18th International Scientific Conference Mittweida (D) 09.-11. November 2006

[T142] H. Wust, P. Haller

"Die Veränderung der Struktur von Holz durch Laserstrahlung und die Auswirkung auf physikalische Eigenschaften der Holzoberfläche"

Forschungskolloquium Holzbau "Forschung und Praxis", Stuttgart (D) 23.-24. Februar 2006

[T143] H. Wust, P. Haller, G. Wiedemann

"Schmelzen von Holz durch Laserstrahlung"

Grosse Schweißtechnische Tagung, Aachen (D) 20.-22. September 2006

[T144] H. Wust, I. Jansen, R. Rechner, E. Beyer

"Lasergestütztes Fügeverfahren am Beispiel der Kantenleimung"

WLT Laser Summer School, Hannover (D) 28.-30. Juni 2006

[T145] H. Wust, I. Jansen, M. Oertel, U. Schwarz, A. Wagenführ, E. Beyer

"Lasergestütztes Fügeverfahren am Beispiel der Kantenleimung"

6. Kolloquium Gemeinsame Forschung in der Klebtechnik, Frankfurt am Main (D) 21.-22. Februar 2006

[T146] H. Wust, U. Schwarz, M. Oertel

"Schmalflächenbeschichtung im Fokus des Lasers"

Internationale Möbeltage 2006, Dresden (D) 09.-11. Mai 2006

[T147] O. Zimmer

"Vakuumbogenbeschichtung mit Partikelfilterung"

Werkstofftechnisches Kolloqium (WTK), Chemnitz (D) 07.-08. September 2006

[T148] O. Zimmer, B. Schultrich, T. Stucky, I. Endler, R. Schober, J. Vetter

"Beschichtete Werkzeuge - Chance oder Kostenfaktor?"

EFDS-Workshop "Beschichtete Werkzeuge - höhere Wirtschaftlichkeit in der Ur- und Umformtechnik" Dresden (D) 25. November 2006

[T149] U. Zschenderlein, B. Kämpfe, B. Schultrich

"Application of Energy-Dispersive X-Ray Diffraction for the Efficient Investigation of Internal Stresses in Thin Films"

Conference on Applied Crystallography, Wisla (Polen) 11.-14. September 2006

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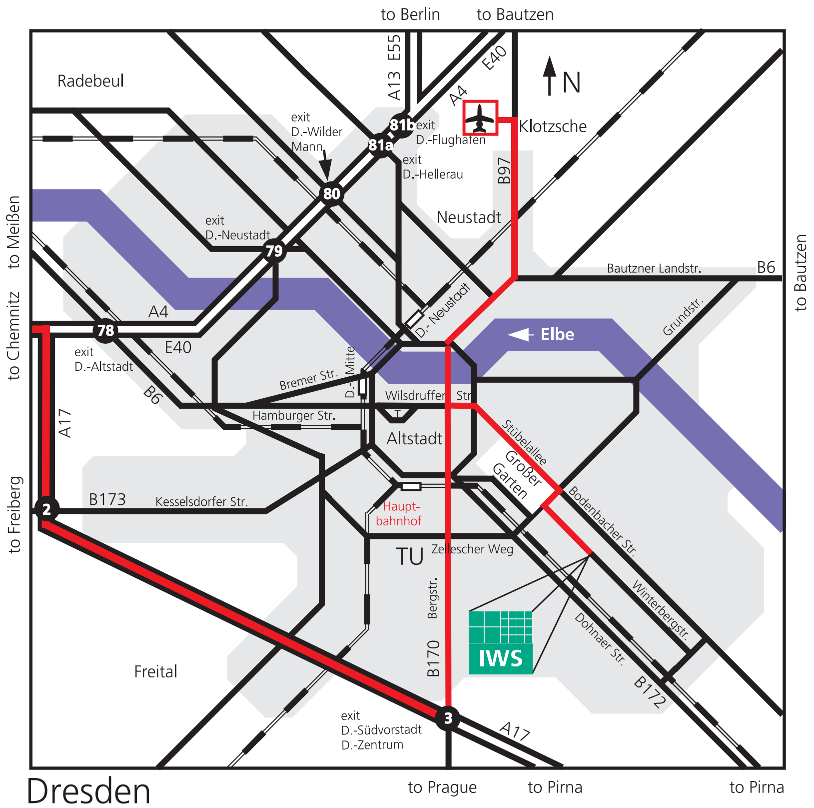

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- take Autobahn A4 or A13 to intersection Dresden-West, follow new Autobahn A17 to exit Südvorstadt / Zentrum
- follow road B170 in direction Stadtzentrum (city center) to Pirnaischer Platz (about 6 km)
- at Pirnaischer Platz turn right towards »Gruna / 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

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	page 7 (bottom pic.):	Hauzer Techno Coating
	page 12:	state capital Dresden
	page 36 (top pic.):	MTU Aero Engines
	page 39 (lower r. pic.):	ALSTOM
	page 41 (fig. 1):	IPP Prag
	all other pictures:	Fraunhofer IWS Dresden
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