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FRAUNHOFER INSTITUTE FOR MATERIAL AND BEAM TECHNOLOGY IWS

DRESDEN

ANNUAL REPORT

2010

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FRAUNHOFER INSTITUTE FOR MATERIAL AND BEAM TECHNOLOGY IWS

ANNUAL REPORT 2010

CERTIFICATE

ISO 9001:2008

hereby certifies that the company

Fraunhofer IWS

Fraunhofer Institut für Werkstoff- und Strahltechnik

Business field:

Thermal Coating, Joining & Surface Treatment, Ablation and Cutting

Location:

This certificate is valid from:

This certificate is valid until:

Last audit day: 18.01.2010

Date of the first certification:

Certificate registration no.

DEKRA

IAF

PREFACE

Today's technology is tomorrow's bread –
today's science is tomorrow's technology.
Richard von Weizsäcker

The economic crisis still shaped the beginning of 2010. A significant improvement of the economic climate during the second half of the year, however, led to record industrial revenues for the Fraunhofer IWS. A 10 % growth was achieved with about 8.5 million euros. The simultaneously increased acquisition of publicly funded projects contributed to an extraordinarily successful 2010 business year.

A production technology project addressing the fabrication of lithium ion batteries presents an outstanding example of IWS efforts, which are shared by several departments. Another interesting challenge being addressed in the field of energy production is a project to break up natural gas into hydrogen and carbon by using solar power. The country of Qatar and the State of Saxony are co-sponsoring this project. Her royal highness, Sheikha Mozah Bint Nasser Al Missned, personally signed the agreement during a visit in Germany.

Since 2009, the Fraunhofer IWS has performed several larger projects in the field of energy research. One of the very successful efforts addresses energy efficiency improvements by reducing friction losses. In this project the IWS is partnering with the University of Technology (TU Dresden) under the coordination of BMW.

The institute has clearly increased its engagement in energy relevant research; however 2010 also saw plenty of traditional IWS strengths in commercializing in-house developed technologies. A successful industrial implementation always marks a highlight for the IWS as well as the Fraunhofer-Gesellschaft. This report will present some examples.

In 2010 the IWS further strengthened its scientific collaboration with the TU Dresden and additional research institutions in Dresden such as the Leibniz and Helmholtz institutes. These efforts are coordinated within the DRESDEN-concept initiative.

It appears that the economic crisis is resolving. Industry inquiries for R&D services are increasing and government project solicitations are on the rise as well. The Fraunhofer IWS is well positioned. We expect a substantial growth for 2011 and are starting the year positively.

Eckhard Beyer

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NEWS FROM BUSINESS FIELDS

NETWORKS, NAMES, DATES

HIGHLIGHTS OF 2010

ENERGY RESEARCH AT THE FRAUNHOFER IWS

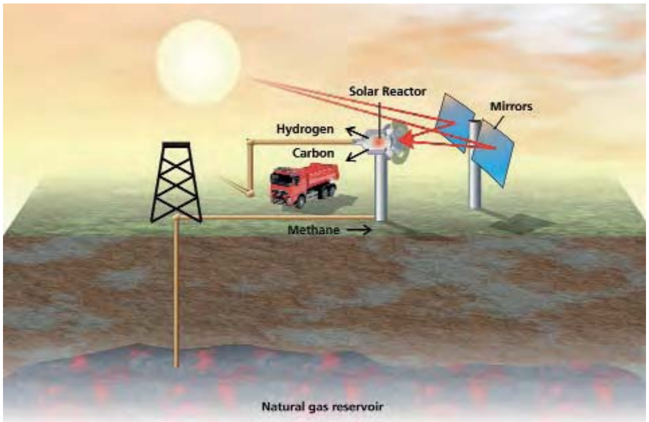
Innovations in energy research are more important than ever to secure the future for the economy and society. The Fraunhofer IWS considers it a priority to work on the implementation of modern energy technologies. In 2010 the IWS acquired energy related research projects from industrial and government funding sources worth 5 million euros. These projects aim at improving energy conversion, storage and efficiency. In addition, the institute invested 1 million euros of internal funds in basic energy research and technology development. Two particularly important projects will be discussed here. Another article describing the DRESDEN-concept initiated DIZE^{eff} project follows on pages 104 / 105.

PRODUCTION TECHNOLOGY DEMONSTRATION CENTER FOR LITHIUM ION BATTERY CELL FABRICATION – DELIZ

The collaborative research project **DeLIZ** (project funding identifier 02P02640) was started in 2010. The collaboration includes researchers from Fraunhofer IWS, TU Dresden and TU Munich. The team researches the process chain of manufacturing lithium ion battery cells. Novel solutions are sought to enable cost efficient high volume manufacturing, efficient quality control systems and innovative fabrication methods with the goal to rapidly transfer the technologies to production. Research foci include the energy efficient coating of electrodes in roll-to-roll processes, the cost efficient manufacturing, the automation of handling and cell fabrication, the setting of individual foils and the joining of foil packages with minimal contact resistance as well as the fabrication of stable Al-Cu contacts for the packaging of individual cells. All areas require the development of concepts, technologies and systems. First results are presented on pages 78 / 79.

RESEARCH COOPERATION WITH QATAR FOR SOLAR THERMAL HYDROGEN PRODUCTION

The first joint research project between the Fraunhofer-Gesellschaft and the Qatar Science & Technology Park (QSTP) began on September 30th 2010. The project's objective is to develop a climate neutral process producing hydrogen and carbon particles using solar energy. QSTP and Fraunhofer IWS are jointly developing a novel solar reactor that applies concentrated sunlight to break up methane into hydrogen and carbon particles. This process substantially contributes to reduce CO_2 emissions.



DRESDEN'S CONFERENCE "FUTURE ENERGY"

The conference "Future Energy" will be held in Dresden from May 11th - 13th 2011. The Fraunhofer IWS and the TU Dresden will jointly present research results which will include those projects discussed above. Representatives from politics, science and industry are invited and they will be presenting their results, products and experiences in energy conversion, storage and efficient utilization. Additional information can be found at:

http://www.zukunftenergie-dresden.de

HIGHLIGHTS OF 2010

2

THE FIFTH LASER-BASED CUTTING MACHINE FOR AIRBAGS WAS TRANSFERRED TO INDUSTRY

Fraunhofer IWS engineers in collaboration with the company Held Systems Deutschland GmbH have developed a compact system for the flexible laser cutting of airbag material. In 2010 another unit was transferred to an industrial customer for production duty. The company Autoliv Poland Restraint Systems is the largest manufacturer for automotive safety components in the world. The advantage of the highly productive system is the constant quality of the insert cut, which is cut out from an up to 3 m wide material strip, and its higher throughput compared to the conventional multilayer cutting process.

HANDOVER OF A ROBOT BASED LASER SYSTEM FOR HARDENING AND BUILDUP WELDING OF TOOLS

In 2010 a robot based laser system to process cutting and forming tools was implemented at Audi AG in Ingolstadt (Fig. 1). The laser hardening and buildup welding system was developed jointly with KUKA Roboter GmbH. The machine is especially adapted to build new, and repair existing, tools for car body making. The Fraunhofer IWS delivered special system components for beam shaping, process control and powder feed as well as modules for the assembly of the robot hand. The engineers also determined process parameters for the different applications and coordinated the startup of the process control systems.

1

FLEXIBLE REPAIR OF JET ENGINE COMPONENTS BY LASER POWDER BUILDUP WELDING USING IWS COMPONENTS

Together with the machine manufacturer Arnold, IWS engineers implemented a new automated precision laser buildup welding system for the repair of engine components (Fig. 2). The customer is MTU Aero Engines in Munich. The system contains an optical geometry detection unit that determines the location and given surface conditions of the damaged part. Based on the data, special software calculates the optimal buildup welding strategy. Immediately after calculation the buildup welding process is performed with an accuracy of a tenth of a millimeter using IWS COAXn series powder nozzles. An IWS developed process control system provides an important contribution to quality control. The system has been used in high volume production since September of 2010. An application example is the repair of blade tips, which is performed at 30 % reduce processing time.

SECOND SYSTEM IMPLEMENTED IN INDUSTRY FOR THE LARGE AREA PRECISION COATING OF X-RAY OPTICAL COMPONENTS

The refraction and reflection of EUV or x-ray radiation requires specially coated surfaces. IWS engineers worked very closely with Saxony's Roth & Rau Micro-Systems GmbH to develop and implement an appropriate system design tailored to the special requirements of an industrial customer (Fig. 3). The system includes 6 coating sources, which makes it especially productive. Substrates of up to 680 mm can be handled. The system is used for the coating of EUV or x-ray optical components in analytical tools for medical application. A future use in lithographic systems for microelectronics manufacturing is also planned.

3

4

LASER-ARC MODULE FOR COATING TESTS AT VAKUUMTECHNIK DRESDEN GMBH

Fraunhofer IWS and VTD Vakuumtechnik Dresden GmbH jointly developed and implemented the PVD hard coating machine DREVA 600-LAM (Fig. 4). The centerpiece of the system is a novel Laser-Arc-Module (LAM 500) for the deposition of superhard amorphous carbon coatings (Diamor®) on tools and components. The coatings proved excellent wear protection in extreme conditions. The Laser-Arc technology is now also available to VTD Vakuumtechnik Dresden GmbH so that the company can provide demonstration coatings as well as coating service to interested customers. In collaboration with Fraunhofer IWS, VTD Vakuumtechnik Dresden GmbH also offers DREVA 600-LAM systems as well as LAM 500 Laser-Arc modules for retrofitting existing coating machines.

FAST TESTING SYSTEM FOR POROUS MATERIALS AVAILABLE

Novel porous materials are a hot research topic worldwide. Time consuming and costly BET measurements are often used to determine the inner surface area of such materials. However, the increasingly popular application of combined high throughput synthesis results in large sample quantities, which require fast characterization.

The measurement system *infraSORB* uses the heat released by adsorption on inner surfaces to estimate the storage capacity of porous materials. The unit was developed in collaboration with Rubotherm. It can simultaneously measure up to 12 samples to identify the material with the highest application potential within a few minutes. Rubotherm licensed the rights to market the IWS technology. A commercial system is near to release.

RELIABLE DETERMINATION OF PERMEABILITY OF BARRIER MATERIALS

A laser beam is the key to reliably and fast determine the permeability of high performance barrier materials. The measurement principle is based on laser diode spectroscopy. IWS engineers developed this method in close collaboration with Sempa Systems GmbH to detect miniscule amounts of permeated water vapor. A European research project funded the development of a commercial *HiBarSens* system using this measurement principle. The sensitivity of the system is better than 100 µg of water vapor per day and square meter of barrier material. Even 10^{-6} g water vapor per day and square meter are feasible in the near future.

One of these systems is available at the Fraunhofer IWS. This machine is available to customers for measurement services (Fig. 5). It is especially suitable for the characterization and quality control of ultra barrier coatings on foils. The high performance barrier foils are increasingly important for applications in photovoltaic components, vacuum insulation panels (VIP) and organic light emitting diodes (OLED). Together with Sempa Systems GmbH, Fraunhofer IWS is working on commercializing the system for endusers.

5

NEWS FROM THE BOARD OF TRUSTEES

The advisory committee supports and offers consultation to the Fraunhofer IWS. The 20th committee meeting took place on March 5, 2010, at Fraunhofer IWS in Dresden. Members of the advisory committee in 2010:

We all experienced an exciting 2010 with many hopes and expectations. At the beginning of the year the economy was still shaken by the financial crisis. Later in the year, however, the situation improved to a degree that no one would have predicted. Many areas, in particular the mechanical engineering sector, gained traction. Exports and investments improved. Production output increased and more jobs became available. Currently we are experiencing a shortage of highly qualified workers. Industry is releasing funds for research and development and adjusts priorities to the requirements. We also observed a positive trend in freshmen university registrations in mechanical engineering. This is very good for the future. We need a knowledge market in Germany and qualified scientists and engineers. Currently there is a substantial gap of engineers and highly qualified technical personnel.

The Fraunhofer-Gesellschaft has shown an excellent development even in times of economic and financial crisis, which is well demonstrated by revenue and personnel trends. The Fraunhofer Institute for Materials and Beam Technologies IWS follows this trend.

The institute's focus on surface and coating technologies as well as laser materials processing is also internationally an important scientific area. The IWS masters the challenge to develop new and innovative solutions and to transfer them rapidly to processes and products. The many results in the areas of

- laser materials processing,
- plasma,
- nanotechnology,
- systems engineering and
- process simulation

are also well aligned with the general requirements driven by current resource shortages and simultaneous increases in energy consumption, mobility and climate change. Thus the IWS is facing the research challenges of society. It is also important for the competitiveness of the State of Saxony and its scientific resources that the research organizations and institutions collaborate and network. Here the IWS is well networked with other Fraunhofer Institutes, the Helmholtz Society, the Leibniz Scientific Community and the Max Planck Society.

The excellent collaboration with the University of Technology Dresden is essential to develop a new generation of scientists. It is self-evident that the IWS is also well prepared for the future with its international satellite laboratories in the USA and Poland. The Board of Trustees are competently supporting IWS' scientific and development efforts with connections to politics, science and industry. Taking on responsibilities is not a question of voiced commitment; it requires the personal and physical contributions of the individuals.

The Board of Trustees thanks the colleagues, the institute's management and all partners for their work and contributions during this past year.

Dr. Frank Junker

CORE COMPETENCES

The business fields of the Fraunhofer Institute for Material and Beam Technology IWS are in the areas of joining, cutting and surface technology. The research and development work is based on a substantial materials and nanotechnology know-how in combination with comprehensive materials and components characterization. In the following areas we developed and continuously expanded core competences:

LASER MATERIALS PROCESSING

- high speed cutting of thick metal sheets
- cutting and welding of plastics and other non-metals
- development of welding processes for hard-to-weld materials
- laser hybrid technologies such as
  · laser induction welding
  · laser induction remelting
  · plasma TIG or MIG assisted laser welding
- laser and plasma powder buildup welding
- laser surface layer hardening, alloying, and remelting as well as short-term heat treatment
- removal and cleaning
- process monitoring and control

PLASMA COATING PROCESSES

- plasma, flame, and HVOF spraying
- atmospheric pressure plasma assisted CVD (microwave and arc jet plasmas)
- plasma etching
- development and adaptation of plasma sources
- vacuum arc processes
- precision coating processes (magnetron and ion beam sputtering)
- laser arc processes as hybrid technology

MATERIALS SCIENCE, NANOTECHNOLOGY

- properties analysis of surface treated, coated and welded materials and parts
- failure and damage analysis
- optical spectroscopic characterization of surfaces and coatings down to the nanometer
- mechanical tribological characterization
- thermoshock testing of high temperature materials
- coating thickness and E-modulus measurements of nm to µm coatings

CHEMICAL SURFACE TECHNOLOGY

- chemical vapor depostion (CVD)
- CVD system manufacturing
- chemical etching processes
- chemical surface functionalization
- gas-phase pyrolysis

SYSTEMS TECHNOLOGY

- utilization of the process know-how to develop, design and build components, equipment and systems that can be integrated in manufacturing lines including software components
- laser system solutions for cutting, welding, coating and surface refinement
- development of process monitoring and control systems
- process focused prototype development of coating systems or their core modules
- components for PVD and CVD systems
- atmospheric pressure plasma assisted CVD sources
- measurement systems for the characterization of coatings and the nondestructive part testing using laser acoustic and spectroscopic methods
- systems for the spectroscopic monitoring of gas mixtures
- software and control techniques
- remote technology

PROCESS SIMULATION

The IWS develops complete modules for the simulation of processes and materials properties. Examples are:

- hardening, laser hardening and laser buildup welding,
- laser welding,
- laser cutting,
- vacuum arc coating,
- gas and plasma flow dynamics in CVD reactors,
- optical properties of nano layer systems.

The results directly flow into process optimization. Additional commercially available simulation modules are deployed.

Business fields / Core services	Laser materials processing	Plasma coating processes	Materials / Nanotechnology	System technology	Process simulation
Removal / Cutting	■		▫	■	▫
Joining	■		■	□	□
Surface technologies					
Surface layer technologies	□	▫	□	■	□
Thermal coating	□	■	□	□	□
PVD vacuum coating technology		■	■	□	▫
CVD atmospheric pressure coating technology		■	□	▫	□

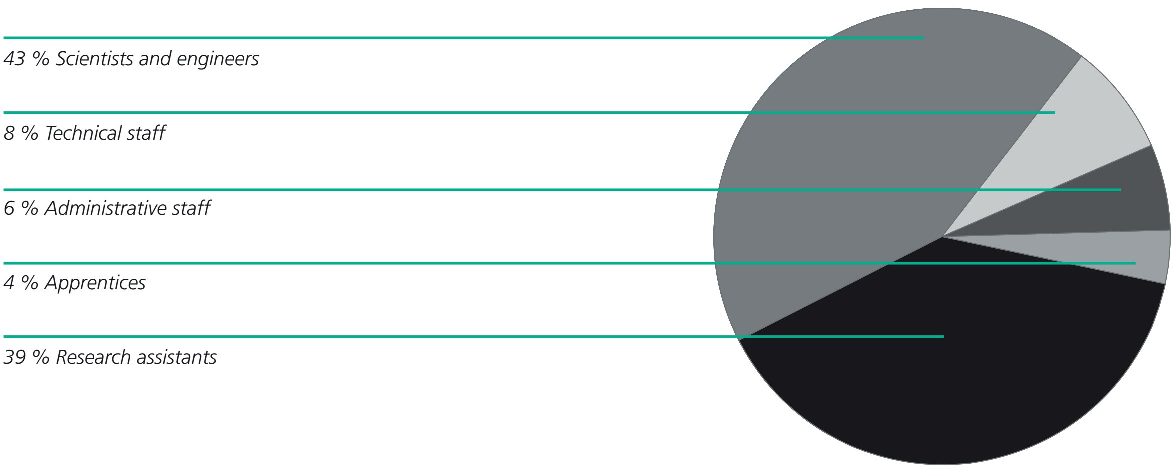
Internet: www.iws.fraunhofer.de

INSTITUTE IN NUMBERS

EMPLOYEES OF FRAUNHOFER IWS 2010

	Number
PERMANENT STAFF	**147**
- scientists	110
- technical staff	21
- administrative staff	16
ANOTHER STAFF	**121**
- apprentices	9
- research assistants	98
- employees CCL USA	14
EMPLOYEES OF FRAUNHOFER IWS (TOTAL)	**268**

EMPLOYEES 2010

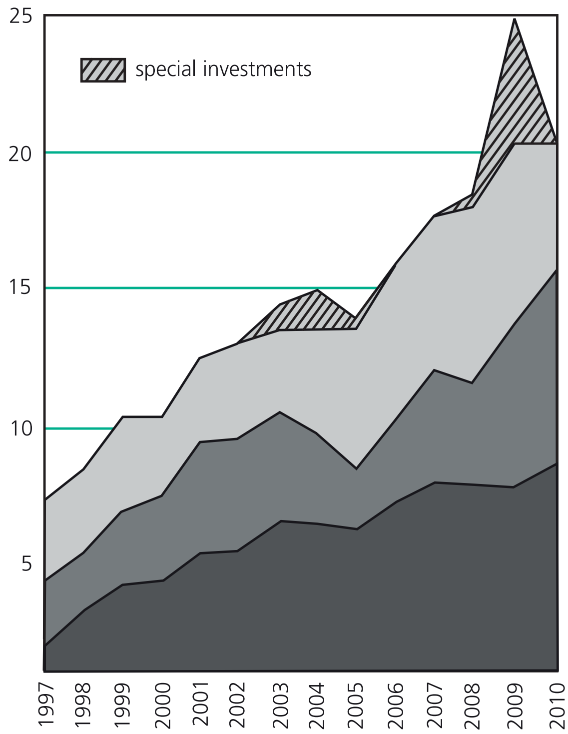


He who ceases to improve
ceased to be good.
Philip Rosenthal

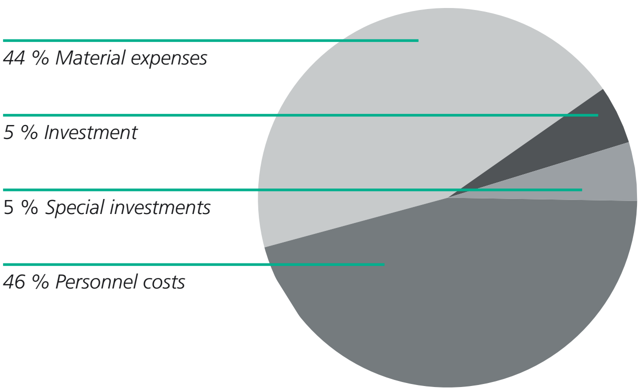
BUDGET AND REVENUE 2010 (JANUARY 2011)

OPERATIONAL COSTS AND INVESTMENTS (Mio. €)	**20.2**
Budget	18.2
- personnel costs	9.2
- other expenses	9.0
Investment	2.0
REVENUE 2010 (Mio. €)	**20.2**
Revenue operations	18.2
- industrial revenues	8.3
- revenues of public funded projects	5.9
- Fraunhofer internal programs	0.9
- base funding IWS	3.1
Revenue investment	2.0
- industrial revenues	0.1
- base funding IWS	0.6
- strategic investment	0.3
- special investments FhG / federal government	1.0

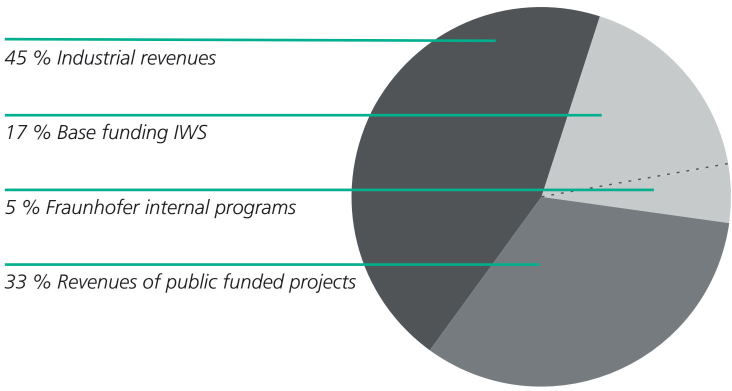
REVENUES (TOTAL)



BUDGET (TOTAL) 2010



REVENUES 2010



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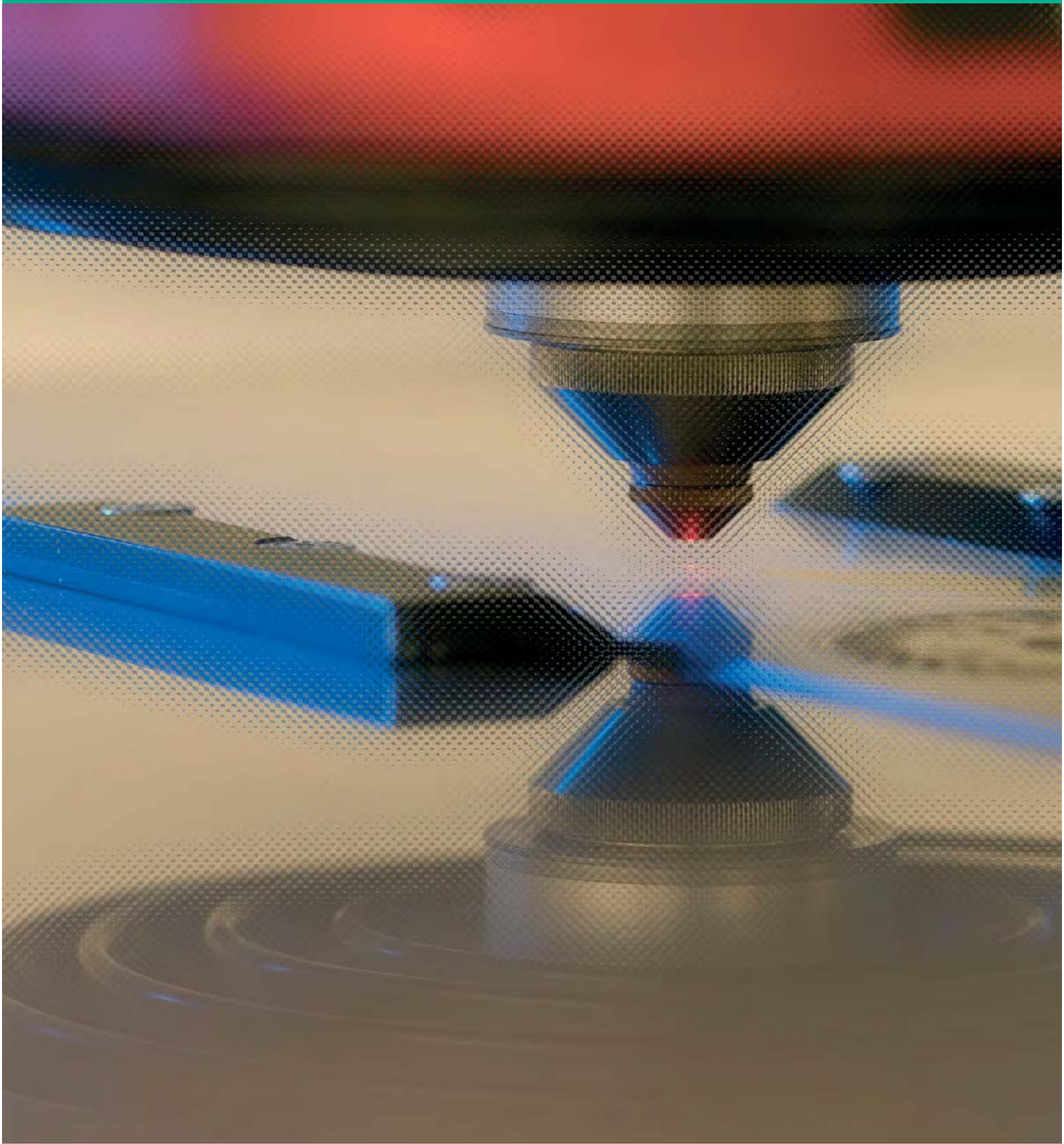


The tendency of people to take small things as important has resulted in many great things.
Georg Christoph Lichtenberg

BUSINESS FIELD ABLATION AND CUTTING

Editor: Laser beam cutting is the most known and established laser application in industry. How much research and development services do your partners, system providers and end-users need?

Dr. Wetzig: Most of the current research and development work is driven by the availability of brilliant beam sources such as fiber and disk lasers. Meanwhile it is possible to reach cutting speeds of up to 100 m / min for thin sheet metal. However, it is not straightforward to utilize these speeds for cutting contours without further development work. The highly brilliant beam source also opens entirely new possibilities for materials processing such as the remote cutting. There are also potential disadvantages of these sources when cutting thicker materials. An example is stainless steel when it gets thicker than some millimeters.

Editor: What are the corresponding research topics in your department?

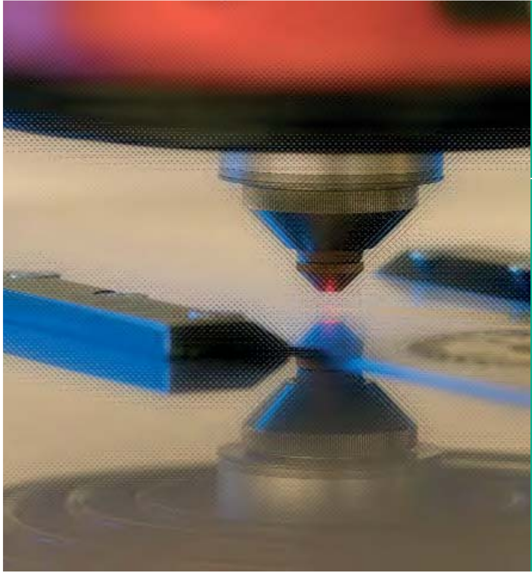
Dr. Wetzig: To address the latter topic for example, we perform basic investigations in collaboration with the Politecnico di Bari. The goal is to develop an improved understanding of the process, which can then be used to adopt strategies for better thick sheet cutting. This topic finds enormous interest at laser manufacturers as well as users. We currently work on a remote laser cutting process for metals and composite materials, which will be implemented at our industry partner's manufacturing line.

Last but not least, we also research alternative concepts to increase the dynamics of the classical 2D cutting. One of the results of this research was the development of a functional prototype of a fast form cutter, which was shown at the International Sheet Metal Working Technology Exhibition (EuroBLECH 2010). This machine is especially suited for the highly dynamic cutting of small contours under limited space conditions.

Editor: Well, that's it for laser cutting. How about micro materials processing?

Dr. Wetzig: The increasing availability of novel laser sources is also important for this area. Of particular importance are ultra short pulse lasers with pulse durations down to femtoseconds. We are trying to bring to our customers an optimized development offer. Therefore we are currently investing in the associated laser and system technologies. Details will be available next year.

First successful applications were developed using direct laser interference structuring to functionalize surfaces. Here we managed last year to attract first customers from the automotive and photovoltaic industry sectors. Thus the method proves a useful addition to our previous activities in micro materials processing.



COMPETENCES

FIBER LASER AND SCANNER TECHNOLOGY

Frequently new system technology is required to fully exploit the technical and economical potential of new or further developed techniques in laser materials processing and more powerful and higher quality laser beam sources. We develop customer tailored solutions if these system components are not yet commercially available. Examples include processing optics with enhanced functionality and hard- and software components for online process monitoring and control.

LASER CUTTING

Laser beam cutting research topics include the development of technologies such as the process throughput optimization for components made from all materials that are used in modern manufacturing. At the IWS for these developments we use highly dynamic 2D and 3D cutting machines with direct linear drives and modern robots as well as laser of various power and beam quality levels. In addition to commercially processing optics for beam focusing we develop and use our own special solutions such as scanner systems for remote processing.

MICROPROCESSING

IWS engineers utilize substantial equipment and facility installations and solid know-how to perform applied research projects in the field of micro and fine processing with laser beams. Targeted applications are the miniaturization of functional elements in machines, systems, vehicles, instruments and medical devices. Examples include the fabrication of 3D structures of sub-millimeter dimensions and areal structures on polymers, metals, ceramics and quartzite and biocompatible materials as well as cleaning with laser technology.

SURFACE FUNCTIONALIZATION

New methods are developed to fabricate 2- and 3-dimensional micro- and nanostructures on surfaces of polymers, metals, ceramics and coatings. Thus it is possible to generate macroscopically large surface areas that exhibit properties that are typical on the micro- and nanoscopic scale. In addition to these topological modifications it is also possible to periodically vary electrical, chemical and / or mechanical surface properties. These structure surfaces are useful for biotech, photonic and tribology applications.

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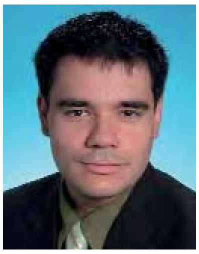

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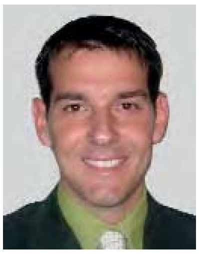


EXAMPLES OF PROJECTS 2010

FURTHER INFORMATION:

www.iws.fraunhofer.de/projekte/006/e_pro006.html

www.iws.fraunhofer.de/projekte/036/e_pro036.html

www.iws.fraunhofer.de/branchen/bra06/e_bra06.html

1

HIGHLY DYNAMIC FORM CUTTER $HDFC_{6060}$ FOR PROCESSING COMPLEX PARTS

THE TASK

At comparable power levels the new generation of highly brilliant solid-state lasers significantly improves cutting speeds in sheet metal applications compared to conventional CO_2 lasers. The utilization of these cutting speeds for higher productivities in industrial environments, however, requires extended dynamic limits of the associated machinery. In particular the high speed cutting of complex shapes with frequent directional changes leads to enormous requirements for the acceleration and jerking capabilities of the machine axes. Jerking refers to the change of acceleration with time and is therefore a significant parameter to increase the average processing time.

OUR SOLUTION

Currently there is a discrepancy between the technically possible, and practically achievable, contour cutting speed. Fraunhofer IWS engineers systematically analyzed cutting geometries and developed a quantitative measure to describe their complexity with respect to the laser cutting process. This measure is introduced as the "agility" of the geometry and captures the ratio of the directional change along the cutting edge to the cutting distance. Therefore the physical unit of the agility is degrees per millimeter.

A software package was developed to read NC codes of individual parts or entire cutting plans and determine the agility. The results make it possible to determine the optimal machine type for the NC program. It is also possible to relate the agility to an average cutting speed and thus estimate cutting and cycle times.

A highly dynamic form cutter $HDFC_{6060}$ was developed based on an entirely new concept to combine motions and beam guiding. This machine expands the traditional limitations of machine dynamics. A parallel kinematic axes structure reduces moving mass requirements and increases the three-dimensional dynamics of the system.

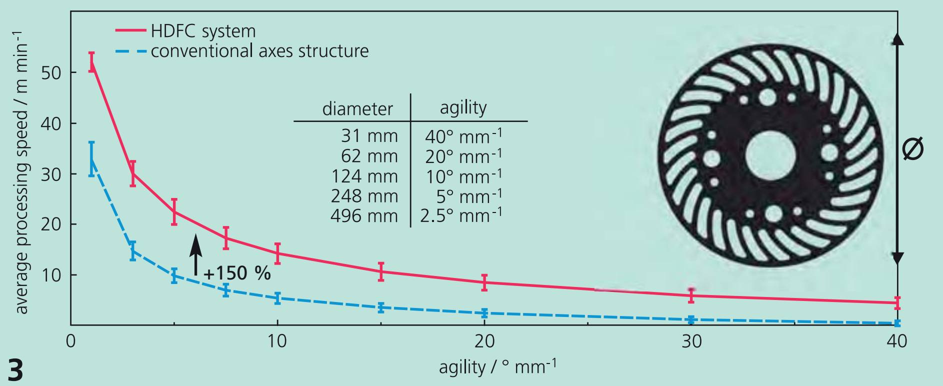
The $HDFC_{6060}$ was developed in cooperation with Held Systems and represents by itself a fully functional guiding machine. The integrated z-axis combination with a capacitive distance sensor is key for reliable process control in particular at high speeds. The consequent use of standard interfaces ensures the trouble free integration of HDFC systems into existing machine control systems.

2

RESULTS

The main application field is highly productive cutting of complex workpiece shapes in high volume production. Sheet material rolling off a coil can be stepwise followed or processed on the fly. Productivity increases in the industrial environment is given by reduced cycle times and lower machine costs. Fig. 2 shows a workpiece (agility of 35° / mm) that can be fabricated in less than 16 seconds using the HDFC system. A conventional axes structure would require at least twice the time. There are additional advantages of the system including its compact form factor, flexibility and high level of integration capability. The use of highly brilliant beam sources and high value optical components leads to laser spot sizes of 15 µm, which can precisely process geometry details of 30 µm.

Correlation of agility and average processing speed



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1 Process photo

2 Geometry generated using $HDFC_{6060}$

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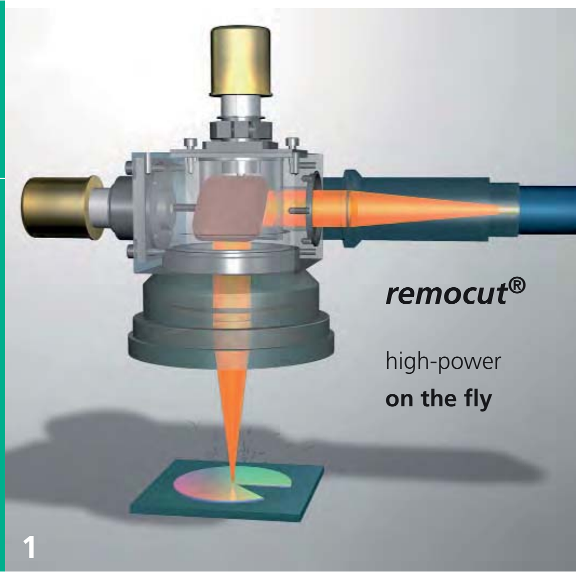
BUSINESS FIELD
ABLATION AND CUTTING



REMOTE PROCESSING OF CARBON FIBER REINFORCED POLYMERS WITH BRILLIANT BEAM SOURCES

THE TASK

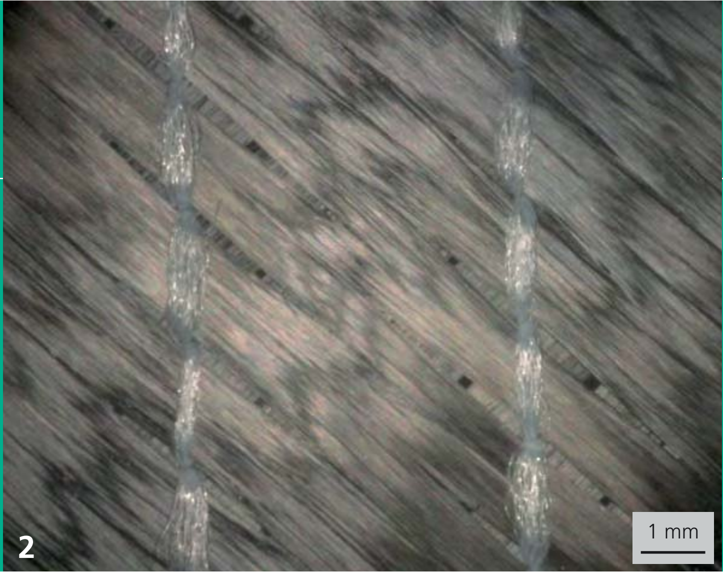
The development of new technologies for energy efficient transportation of people and goods increasingly requires manufacturing solutions for high performance construction materials. Carbon fiber reinforced materials (CFC) combine high specific tensile strengths with low densities, which leads to a great application potential. Since many years these materials have been used in the aerospace and other specialized industries. However, the high volume processing of CFC based parts as required for the automotive industry is barely developed. One of the limiting factors is the currently used forming process, which is based on a duroplastic matrix. This process requires long hardening times and special consolidation strategies to optimize the carbon fiber / matrix bonding. An additional problem is that the individual fibers have strongly anisotropic strength properties. A part that is stressed in multiple directions requires careful construction considering the specific alignment of unidirectional fiber polymer layers.

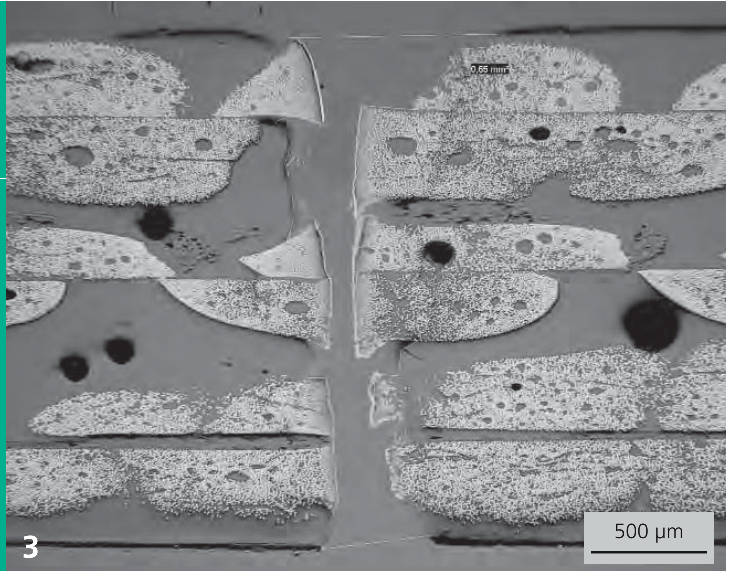
Besides forming, there are other time consuming manufacturing steps such as cutting and the fabrication of openings or bores. The material properties lead to additional difficulties during mechanical processing. Issues include large material damage in the processing zone and low removal rates with high tool wear. The use of water jet cutting is limited due to layer delamination and accessibility limitations in strongly curved surfaces.

Lasers are already industrially used to structure and ablate CFC materials. However, these processes are insufficient to address the needs of flexible mass production due since they are using pulsed beam sources of medium power levels. Based on these considerations it is evident that new flexible and more process efficient technologies are needed.

OUR SOLUTION

Fraunhofer IWS engineers developed a highly dynamic beam deflection system to significantly improve the efficiency of laser processes to treat high performance polymer based fiber reinforced composite materials. A fast mirror system based on galvanometer scanners is used to rapidly project the laser beam onto the material. The mirrors operate very precisely even at very high path velocities. Accelerations of several 10 g are achievable. The high processing speeds reduce the interaction time between laser beam and material. Compared to the classic gas supported cutting, the new method significantly reduces thermal damage of the matrix material. In addition to beam motion it is also necessary to carefully select the processing wavelength to minimize absorption in matrix and fiber materials.

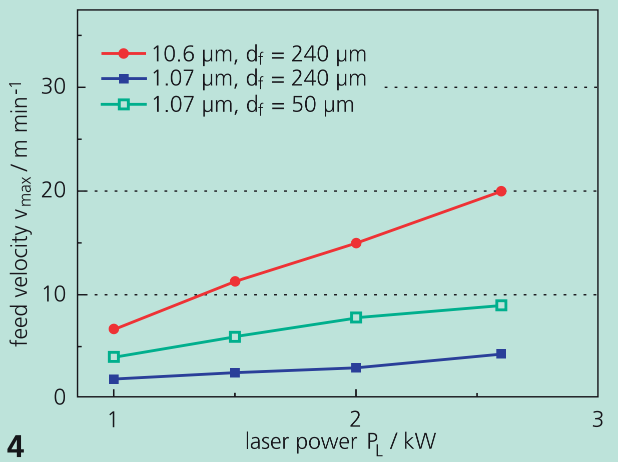




RESULTS

The shortened laser interaction with the composite material reduces the thermal decomposition of the matrix material leading to better ablation and cutting results. High power CO_2 and brilliant solid state lasers such as fiber and disk lasers are used depending on the matrix type. CO_2 laser radiation is sufficiently absorbed by almost all polymer materials. On the other hand solid-state lasers can be better focused and thus may offer efficiency improvements.

Correlation of feed velocity and laser power for various processing wavelengths and power densities
material: bidiagonal carbon netting + VE resin, 2.4 mm thick, fiber fraction 50 wt%



Despite the availability of lasers with continuous wave powers in the kW range it is necessary for the typical thicknesses to ablate the material in cycles. Typically a cycle ablates 100 µm. The number of required cycles to cut through the material depends on:

- material composition,
- laser radiation absorption in matrix and fiber material,
- power density in the processing spot,
- ablation velocity.

The diagram shows possible processing speeds on a carbon fiber duromer composite. The galvanometer scanners have almost no inertia, which allows the achievement of these velocities also for nonlinear cutting contours or small holes and structures. Subsequently the cutting quality remains constant. On the fly processing is possible by actively coupling the handling systems motion with the processing optics.

1 *Principle of high speed beam deflection*

2 *Bi-diagonal carbon netting (topview)*

3 *Cutting kerf of a carbon fiber reinforced duromer (cross section)*

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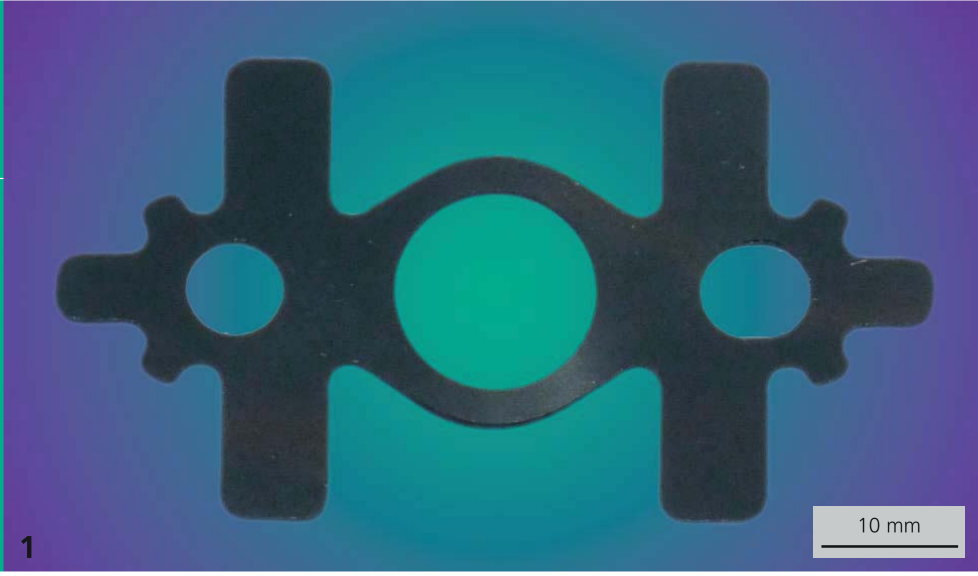

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FROM THE DRAWING TO THE COMPONENT – HIGHEST PRECISION REMOTE CUTTING

THE TASK

Highly dynamic mirror scanners for remote processing are not only used for laser beam welding, they are increasingly applied to laser beam cutting. Purposely avoiding a cutting gas nozzle makes it possible to scan the laser beam also for cutting processes over the entire working field of the optics. A working distance exceeding 200 mm leads to processing speeds of 800 m / min on the part surface.

These unusually high cutting speeds allow the fabrication of any part shape with a few milliseconds. However, the process is also very demanding for the mirror systems. Despite the low inertia of these systems the high processing speeds lead to imprecise cuts in the generated parts. Corners may appear slightly rounded or contours do not always meet the tolerances. These problems also do occur during conventional gas supported cutting at much lower speeds. To meet the tolerances anyway, the processes are usually slowed down.

This procedure, however, is limited for remote cutting metallic materials. Since there is no cutting gas, the material has to not only be cut but also partially evaporated. This requires shortest interaction times between laser beam and work piece and thus highest cutting speeds.

OUR SOLUTION

Fraunhofer IWS engineers develop software tools correcting the cutting path to improve the accuracy of the parts. The research and development efforts focus on the purposeful manipulation of the original motion path of the scanner mirrors. The actual manipulation occurs prior to the cutting process without using the laser beam. It is also not necessary to create sample parts.

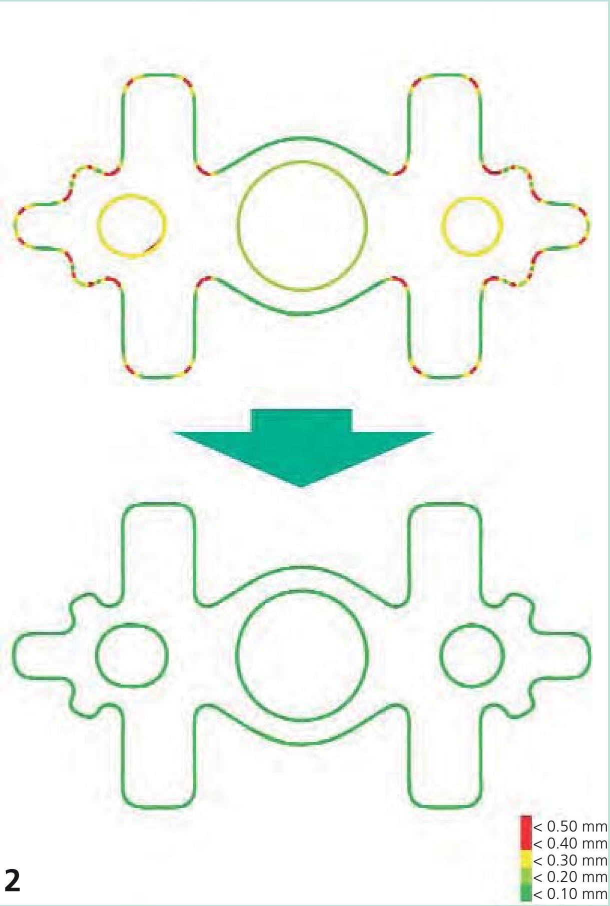
First the software requires the planned motion path of the system. Then the actual mirror motion path is acquired. Comparing both paths helps to identify potential deviations, which ultimately lead to the undesired inaccuracies. It is possible to iteractively approximate the actual path to the planned path. When both paths match within the tolerances the laser beam is turned on and the part is cut.

RESULTS

The described algorithm was implemented in laser scanner software developed at the Fraunhofer IWS. The program is named *PathControl* and controls laser and beam scanning system. The program automatically determines planned and actual motion paths, compares them and calculates differences. The manipulation of the motion path occurs in full or semi-automatic modes. *PathControl* substantially reduces the discrepancies between planned and actual motion and thus enables the system to meet the tolerances.

Fig. 1 shows a part, which is 0.1 mm thick and made from stainless steel 1.4301. Using 1.2 kW laser power it can be remote cut in less than 0.2 s. Considering the cut length the average cutting speed is v_{av} = 100 m / min. Despite such high speeds the part tolerance is below 0.1mm using *PathControl*. The software is under development to become capable of learning, which will then require less and less iteration to find the correct motion path.

Path accuracy before (top) and after (bottom) automated correction with PathControl



2

1 Part geometry made from stainless steel 1.4301, thickness 0.1 mm, 1.2 kW laser power, cutting time < 0.2 s

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1a

1b

NOVEL UNIVERSAL FIBER LASER SYSTEM FOR MOBILE OPERATIONS

THE TASK

Laser tools in mechanical engineering and production technology provide significant improvements of quality and quantity while simultaneously reducing costs. Selected examples of well-established applications include the surface structuring, cleaning or labeling.

Typically laser systems are used as separate processing stations or they are integrated into existing manufacturing lines. However, there are many potential applications which do not conform to well-defined machine setups or which need easy and quick options to move the laser from one machine to another. Examples are the processing of very large parts or immovable objects such as ornaments or statues. Here it is absolutely necessary to have a mobile laser machine concept. Such mobile laser systems have a certain set of requirements including a very broadly applicable parameter spectrum, compactness, flexibility and manageability. These requirements are valid for all system components. Fiber laser systems provide excellent beam quality, a high parameter stability and low weight. Thus they are predestined for the integration in mobile systems.

OUR SOLUTION

Fraunhofer IWS systems have two components: the supply unit and the handpiece for processing. The supply unit houses all operationally relevant components such as power supplies, the laser head and the control system. The heart piece of the control system is a stand-alone controller card. An additional external memory may hold additional application parameters for the mobile operation. The handpiece integrates the laser isolator and the optical beam guidance and shaping components.

The handpiece is designed using a modular concept and well-established mechanical and optical interfaces. It is quick and simple to configure a mobile laser system for various applications with different fiber lasers. Established electrical interfaces make sure that the lasers are easily connected to the controller.

A special adjustment unit and an easily replaceable beam broadening unit were developed to ensure the uncomplicated integration of the laser and the handpiece. The overall system concept is very flexible in terms of optimization for specific applications. All components are within an ergonomically shaped shell, which protects them from mechanical impact and dirt. The interfaces allow the easy adaptation of spacers and laser protection components. For transportation the handpiece and the laser head are stored in the supply unit.

2

3

The parameter space of the system is vast. To simplify operation, Fraunhofer IWS engineers developed a new user concept which is based on a two level approach. The first step is a parameter screening under laboratory conditions, which depends on the materials. Here it is possible to freely vary the parameters and test their effect. Relevant parameter sets are stored in the controller memory. On site the system is operated via a touch panel that allows only minimal adaptation of the predetermined parameter sets to further adapt the process to the local conditions.

RESULTS

The discussed system concept was implemented and installed as a mobile laser system at the Fraunhofer IWS using a MOPA-M-HP 20 fiber laser (Fig. 2). The system offers the possibility to use pulse durations from 10 to 200 ns at repetition rates from 1 Hz to 500 kHz. The pulse peak power can be up to 12 kW and is adjustable to the specific labeling, cleaning or structuring tasks (Fig. 3).

Initially the system test focused on the performance for the various desired applications. For labeling various materials such as steel, copper and polymers were tested. Under laboratory conditions a parameter matrix was developed. The datasets were stored in the controller memory, which reduced the time to find optimal processing conditions on site by several hours to a few minutes.

Cleaning and restoration was another application of interest. First tasks were performed with the system. Of particular interest to these applications is the capability of using self-limiting effects during processing. It proved adequately possible with the new system even though its pulse energy is lower than that of established systems.

1 *Application example of the laser being used in restoration and cleaning*

2 *Complete system, consisting of handpiece and supply unit*

3 *Effect matrix on steel to show cleaning and labeling possibilities*

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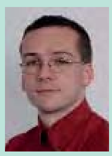
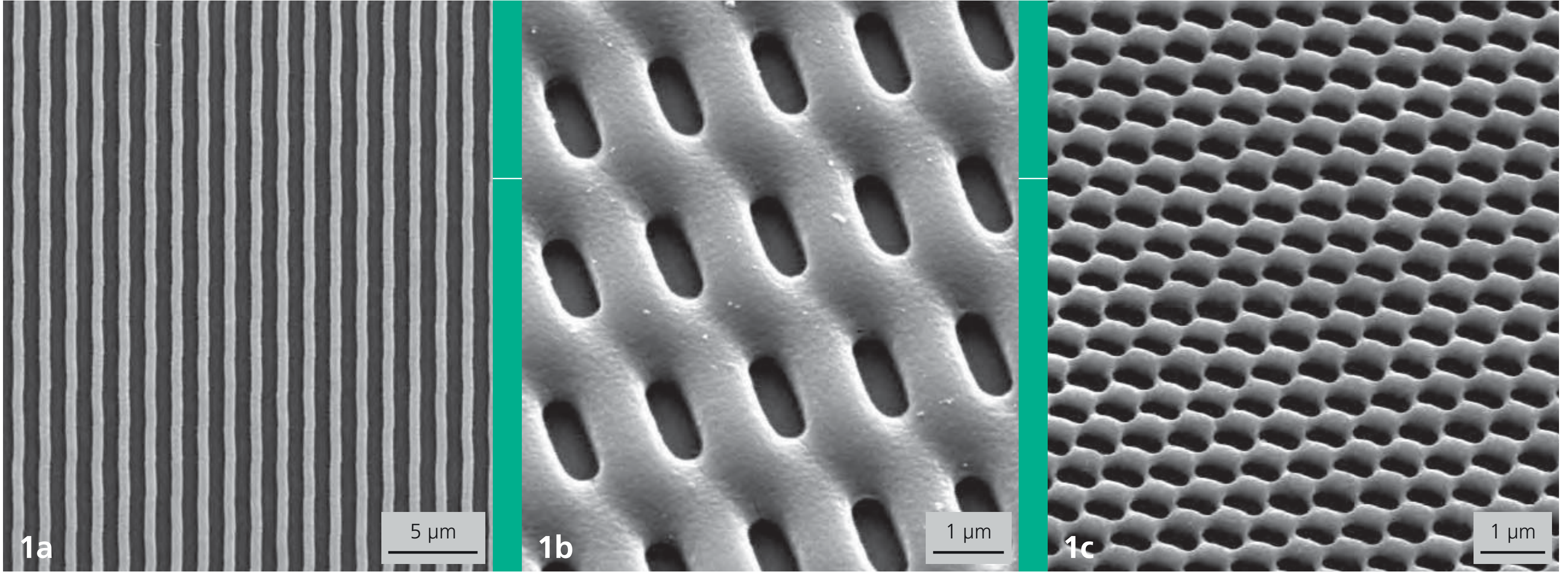




BIOMIMETIC STRUCTURING BY LASER INTERFERENCE LITHOGRAPHY

THE TASK

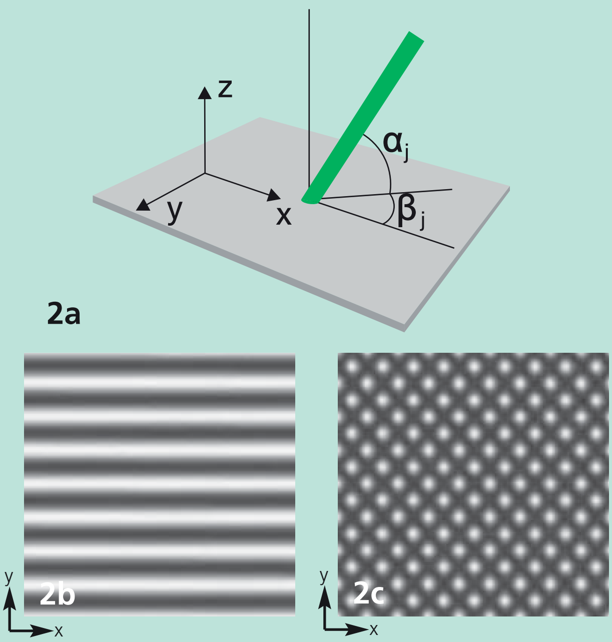
Biomimetic materials mimic the structures and functions of living organisms. Their fabrication is a key technology in materials science. It becomes increasingly important for various innovative technologies.

The surface of biomimetic materials mostly consists of complex one- or two-dimensional structures, which are frequently hierarchically ordered. Over recent years several technological approaches have been pursued to design and synthesize such complex surfaces. However, many of the developed techniques require masks or stamps to generate specific structures which render them useless for making hierarchical patterns. On theother hand, the treatment of larger areas without masks is only possible in a sequential and therefore time consuming way (up to several hours).

The Fraunhofer IWS offers a powerful and competitive technology to fabricate such surface structures. The method is applicable for the fabrication of a wide spectrum of topographically complex patterns on almost any geometry.

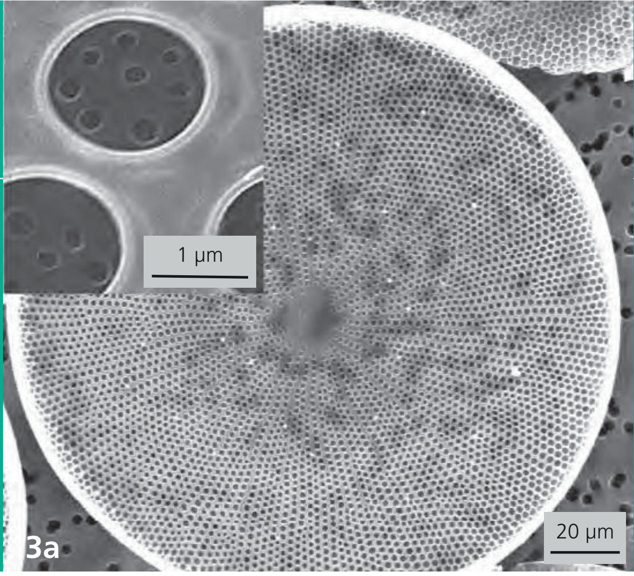
OUR SOLUTION

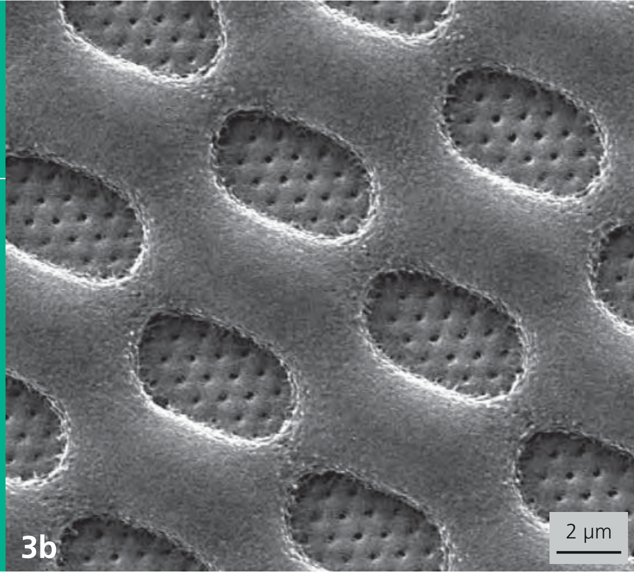
The laser interference lithography method allows the periodic micro- and nanostructured patterning of large planar and non-planar surface areas (Fig. 1). A number of *N* collimated and coherent laser beams are projected onto the surface of the photoresist in order generate the interference pattern. After exposure the photoresist is developed. The porous structure forms due to the spatially varying exposure depending solubility of the photoresist. A great advantage of the method is that the form and size of the periodic structure of the interference pattern only depends on the number of laser beams and their geometric configuration (Fig. 2a). A dual beam setup generates a line shaped periodic structure (Fig. 2b). Four beams with identical azimuthal angles lead to a grid-like array (Fig. 2c).



2a Incoming laser beam labeled with geometric configuration (polar angle α, azimuthal angle β)
2b Periodic line structure due to dual beam intensity distribution
2c Grid array due to four beam intensity distribution

By overlapping arrays with varying periodicity it is also possible to fabricate hierarchical surface structures. The method is capable of treating several square centimeters per second of various technically relevant materials.





RESULTS

A spin coater was used to deposit thin films of the negative photoresist SU-8 onto silicon substrates. Then a line shaped pattern was fabricated by using the dual beam setup (Fig. 1a). Two laser beams with wavelengths in the UV range (355 nm) were brought to interference using an angel of $2\alpha = 13.6°$. The resulting period was 1.5 µm.

Two different approaches can be applied to form grid-like structures. The first method used four laser beams to fabricate the desired structure. However, this approach requires a very precise adjustment of the azimuthal angle since already slight misalignments lead to linear defects.

The second method consists of a process with double exposure. The sample is being rotated by a defined angle between exposures. The choice of the rotational angle defines the shape of the cross-like structures (Fig. 1b-c). Several parameters are critical to form a stable polymeric structure. The structure period, the thickness of the photoresist, the width of the photo polymerized regions and the temperature during annealing steps prior to and after the exposure have to be precisely adjusted. In the case of grid-like structures it is possible to improve the mechanical stability by generating stabilizing junction points using double exposures.

The fabrication of bio inspired surfaces with hierarchical structures is based on a layer-by-layer buildup process. The here presented example shows the fabrication of the Diatomee C. Walesii (Fig. 3a). This diatom consists of complex hierarchical structures consisting of hexagonal patterns (areolae) with a grid distance of 3 – 5 µm and periodically arranged cavities with a diameter from 100 to 250 nm within these patterns. The synthetic fabrication of this structure involved as a first step a thin photoresist film with hexagonal submicron patterns, which were achieved by double exposure with a period of 500 nm and a rotation of 60°. Then a second photoresist layer was deposited onto the already existing pattern and exposed with a line shaped interference pattern with a period of 5 µm. The generated structure has a high degree of geometric uniformity (Fig. 3b).

The here presented simple process sequence demonstrates the potential of laser interference technology to fabricate complex periodic arrays.

1a Line structure with a period of 1.5 µm
1b Grid structure with 1.5 µm period and 60° rotation
1c Grid structure with 0.5 µm period and 60° rotation
3a Diatomee C. Walesii and
3b its synthetic bio inspired structure

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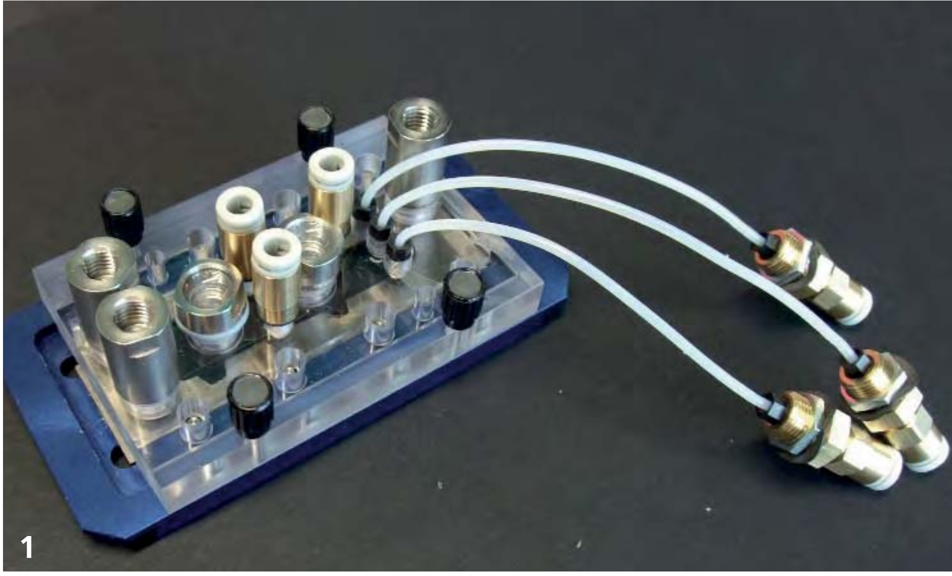
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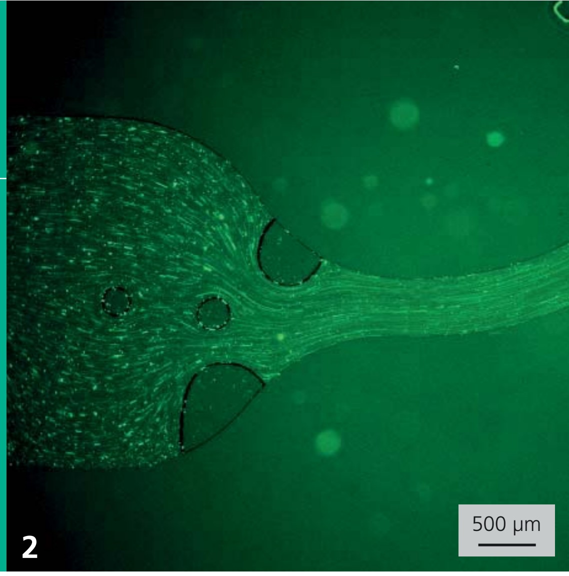

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CELL BASED BIOCHIPS WITH INTEGRATED MICROCYCLES FOR SUBSTANCE EVALUATION WITHOUT ANIMAL TESTING

THE TASK

Over recent years it has become evident that there is a lack of adequate methods to predict the effects of complex interactions in the human body. Examples of wrong prognoses include the significant increase of allergies within the population, the worldwide failure to predict the general toxicity of chemicals and the partially catastrophic misjudgment of potential risks related to medical drugs and nano dusts. This shortcoming is particularly true for predicting the influence of consumer relevant synthetic and natural substances on the human organism in its typical environment and its genotypical individuality. The biological and biochemical processes of such interactions are mostly understood. Missing are technical solutions capable of modeling the interactions between human organism and the substances it is exposed to in a realistic environment.

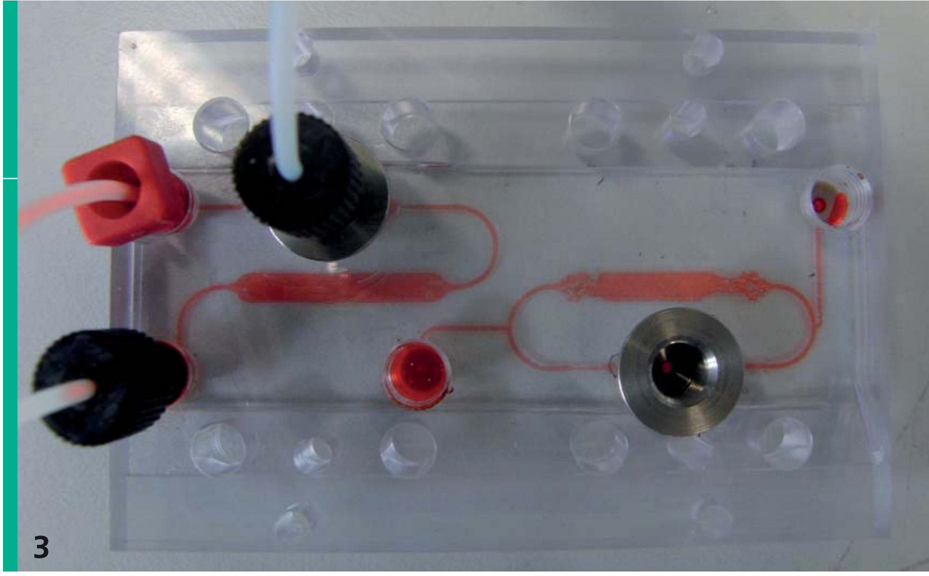
Predicative substance testing requires the assimilative interaction of different cells or tissues within a common cycle in analogy to the human body. Engineers at the Fraunhofer IWS Dresden developed a biochip platform that implements microcycle systems, which consist of several cell culture segments, reservoirs and micropumps. The development and implementation of the system was accomplished in collaboration with the Technical University in Berlin during a project associated with the BMBF founder offensive "Biotechnology" (GO-Bio). The company TissUse GmbH commercializes the cell-based biochips.

OUR SOLUTION

To develop the miniaturized microcycle systems the engineers extended an established modular biochip platform by pneumatically driven nozzle-diffusor or peristaltic micropumps. The peristaltic pumps consist of three sequentially connected pump chambers. The nozzle-diffusor pumps have one pump chamber and two directional flow limiters. By applying positive or negative pressure to the dry side of membranes they pneumatically actuate the volume of the pump chambers. An independent microcontroller based system operates the micropumps, controls temperatures, collects and stores data, monitors threshold values and performs data exchange operations with a central control computer.

The microcycle system connects a polydimethylsiloxane flow cell with a polycarbonate connector plate. The unit is sealed with a cap plate. Connector and cap plates integrate connectors for fluidic, sensors (electrodes, microlenses) and actors (heaters, electromagnets, piezo vibrators). The flow cell houses the microfluidic system, which includes channels, cell structure segments, pump membranes, nozzle-diffusor structures and optional sensors and actors.

The cell is molded from a master die. The die is manufactured using laser processing or lithographic technologies at the Fraunhofer IWS Dresden. The thickness of the pump membranes is adjusted via the penetration depth of the die screws. Typical values are between 300 and 700 µm.



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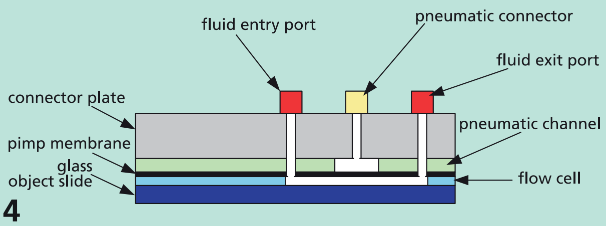
Schematic representation of the biochip design with integrated pneumatic micropump



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RESULTS

Open and closed microcycle systems were implemented using nozzle-diffusor and peristaltic micropumps. The pumps were added to an established biochip platform. The systems were tested using flow sensors and by recording the motion of fluorescence marked nanoparticles.

Appropriate process parameters were developed for both pumping principles. The developed pneumatic micropumps are very well suited for the active transport of liquids in cell based biochip applications because they
- do not emit electric or magnetic fields,
- are small and can be integrated in any biochip,
- can be fully autoclaved and sterilized,
- can be cost effectively manufactured in large quantities,
- allow the implementation of closed cycle systems in combination with additional microfluidic structures.

The developed microcycle systems were successfully used to cultivated human cells over a period of several days. The systems form the basis for the implementation of biochips to study the assimilative interaction of different cells or tissues in analogy to the human organism. Therefore they are providing the means to develop complex substance testing system avoiding animal testing.

1 *Biochip mounted in microscopy holder with microcycle system, driven by peristaltic pump*

2 *Fluorescence image of flowing fluorescing nanoparticles in the microcycle system*

5 *Biochip with one open and one closed microcycle system, driven by nozzle-diffusor pump, both filled with dye*

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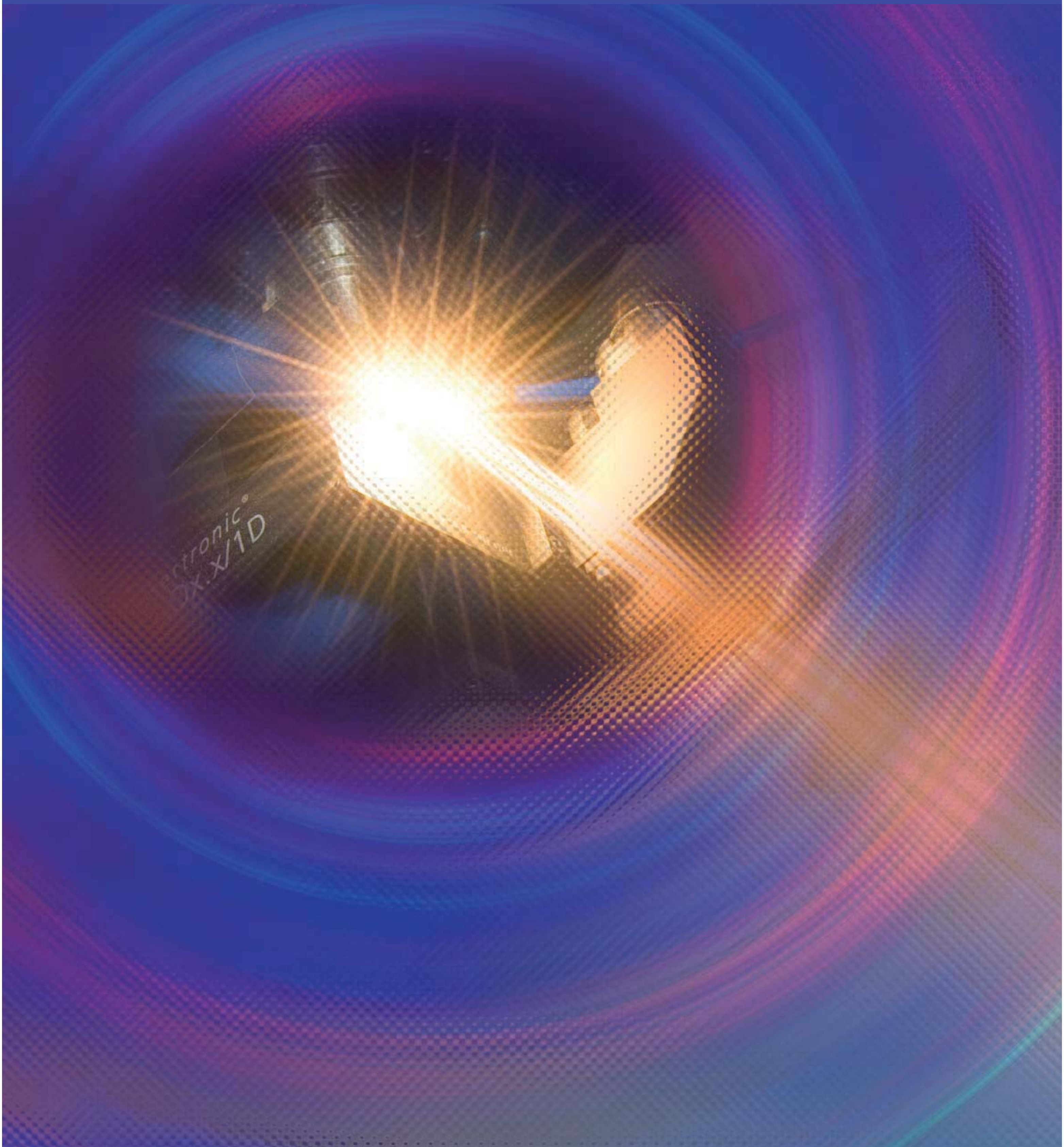

To a pessimist each task is a problem,
to an optimist each problem is a task.
Anonymous

BUSINESS FIELD JOINING

Editor: The term "Electromobility" seems to be a catchword. The German automotive industry, including suppliers, is intensely focusing resources on this topic. New companies such as battery manufactures are emerging. How do you face this change?

Prof. Brenner: We are well prepared for this challenge in particular due to our long-term strategic focus on joining materials that are hard to weld and on material combinations that cannot be welded by conventional melting. On top of that we have been spending the last three years increasing our development efforts to address two of the central joining technology challenges in electromobility – the efficient joining of copper and aluminum and the consequent implementation of lightweight construction concepts.

For example, today we are able to offer the following six new and different joining processes to our industrial partners, which can join copper and aluminum for various applications:

- laser beam welding with highest beam quality and extremely fast beam oscillation,
- laser induction roll plating,
- laser beam soldering,
- adhesive bonding with laser or plasma based bonding area surface preparation,
- friction stir welding
- and electromagnetic pulse joining.

These processes meet application requirements such as mechanical and thermal stability, low electric contact resistance, adapted joining geometries, high joining speeds and efficient process performance.

Editor: Which solutions do you propose to address the second challenge – the need for advanced lightweight construction?

Prof. Brenner: The energy density in electrical energy storage solutions needed for electromobility applications is lower than that in chemical energy storage. System specific components additionally increase the weight. Thus electromobility applications require the consequent application of lightweight construction approaches. This challenge requires the use of multi-material designs. Therefore efficient joining processes are needed to fabricate high strength joints.

We think of cycle time compatible bonding methods as well as EMP joining and the development of efficient processes for making transition joints with material combinations such as Al / steel and Al / Mg of variable geometry. These joints can then be further processed with welding processes already proven in series manufacturing. We think that these transition joints can be best produced using laser induction roll plating methods.

COMPETENCES

WELDING OF HARD TO WELD MATERIALS

The modern laser beam welding process is broadly employed in particular in industrial high volume manufacturing environments. The integration of laser beam welding with short-term heat treatment and adapted filler materials provides a new approach to crack free welding of tough materials such as hardenable and high strength steels, cast iron, aluminum and special alloys as well as parts of high stiffness. Based on a comprehensive background in metal physical processes and system technologies we offer the development of welding technologies, pro totype welds, processes and system optimizations as well as the development of welding instructions.

SURFACE PRETREATMENT AND CONSTRUCTIVE ADHESIVE BONDING

During adhesive bonding process flows it is common to prepare the surfaces of the parts to be bonded. The treatment improves the wetting of the surfaces with the adhesive and ultimately the mechanical strength of the bond. At the IWS we focus on the development of pretreatment processes based on laser and plasma techniques. The pretreated surfaces as well as the bonded compounds are characterized by contact angle measurements, light microscopy, SEM / EDX and spectroscopic methods. A new direction aims at the integration of carbon nanotubes into the adhesives. This may improve the bonding strength and / or the manufacturing of electrically conductive compounds. Our offered services include pretreatment processes, surface characterization, constructive adhesive bonding of various materials and the determination bonding strength and aging.

SPECIAL JOINING TECHNOLOGIES

Conventional melting based welding processes are frequently insufficient to join modern functional materials. In the case of metals, this is for example true for many high strength aluminum alloys. The problem is even more difficult in the case of joining different metals such as aluminum and copper. Typically the melt forms intermetallic phases that drastically reduce the strength. Therefore at the IWS we develop new processes that avoid melt formation and the associated issues. Our primary focus is on friction stir welding, laser beam soldering and the electromagnetic pulse welding. We offer process development and prototyping services in these areas.

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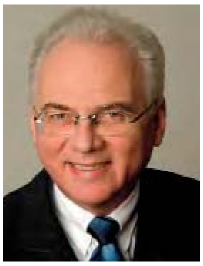

EXAMPLES OF PROJECTS 2010

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FURTHER INFORMATION:

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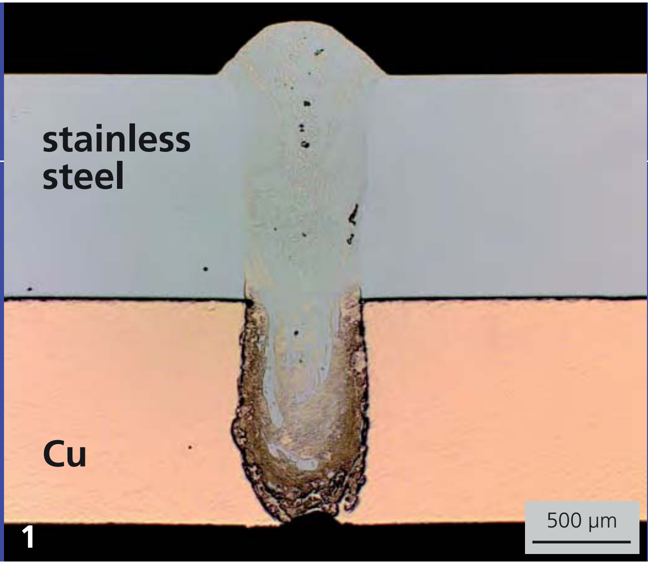
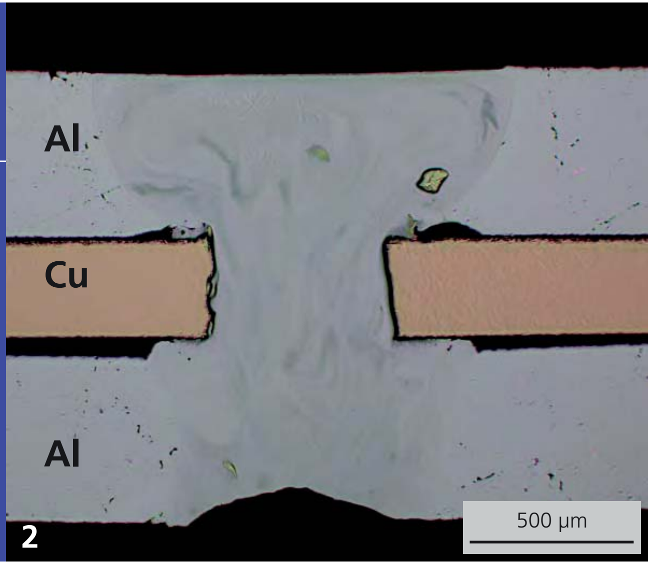




LASER BEAM WELDING OF MIXED MATERIAL JOINTS

THE TASK

It is a general requirement to manufacture components with optimized weight and performance properties. Consequently, the formation of mixed material joints are established as a bonding technology for many applications. The capability to weld combinations of different materials is used to benefit from the specific properties of these materials. Such welded parts include components made from materials matching their specific mechanical loads. This approach offers a better functional integration and a highly optimized overall weight.

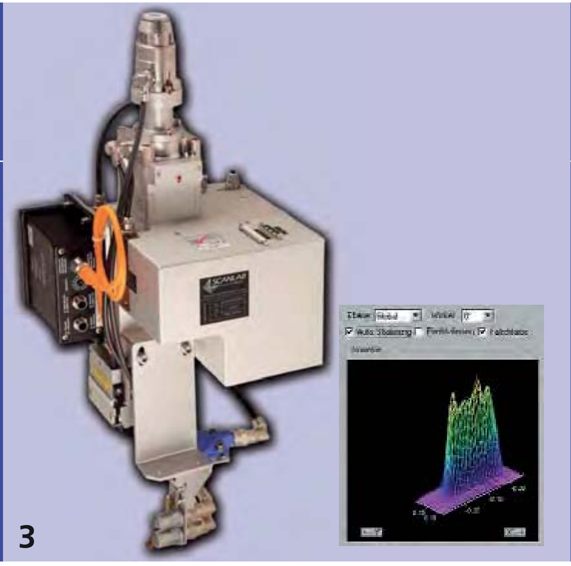
Unfortunately, it is often difficult to weld mixed material joints. The individual components typically vary in thermo-physical and other material properties. Significantly, differences in melting temperatures, thermal conductivities and thermal coefficients of expansion lead to problems melting both welding partners and also cause melt turbulences. The resulting solidifying melt contains new mixed crystals and alloyed phases with extreme hardness and brittleness such as for example intermetallic phases. These form due to diffusion processes at heat treatment temperatures exceeding the material specific processing temperature range. Thus these processes significantly affect the metallurgical compatibility of a material combination.

However, overall beam based welding processes are comparatively well suited to cost effectively fabricate mixed material joints. Laser processes are used to very efficiently weld the material combinations Al / steel, HSS / heat treatable steel and cast iron / case hardening steel. Electron beam welding further increases the palette of available mixed material joints. However, electron beam welding equipment is substantially more expensive and also complicates the process integration into the manufacturing line due the vacuum system requirements. Consequently new flexible and process efficient technologies are sought.

OUR SOLUTION

Engineers at the Fraunhofer IWS used a highly dynamic beam scanning unit to significantly improve the quality of laser welded mixed material joints from Al / Cu, stainless steel / Cu and Al / Mg. A brilliant laser beam is rapidly scanned along and across the welding joint using tilting mirrors. The effort is funded through a collaborative project WELDIMA and focuses on the development of a highly dynamic 2D scanner with scanning frequencies of up to 2.5 kHz (Fig. 3).

During the process the laser beam power is manipulated, which improves the degree of material mixing and also affects melt turbulences. In addition the controlled laser processes affects the melting behavior of both materials. Laser beams of high brilliance are very well focusable. This affords the fabrication of very narrow weld seams with high aspect ratios and extremely shortened melt lifetimes. Consequently the energy deposition into the part is drastically reduced, which limits the formation of brittle intermetallic phases.



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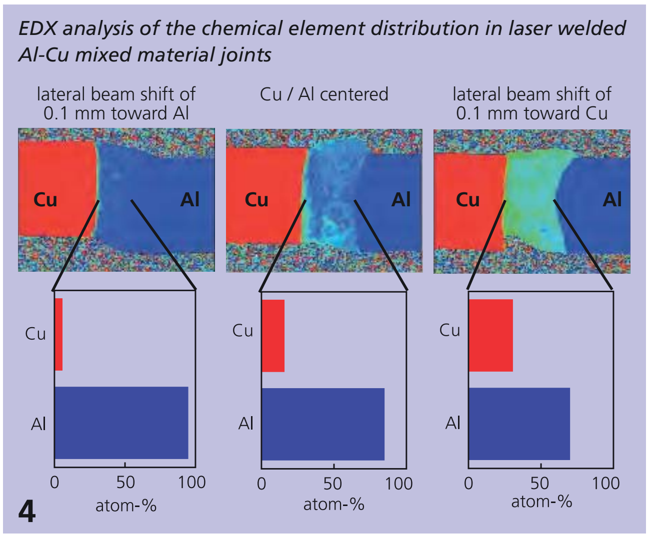
RESULTS

Key to the welding process performance is the control of the mixing ratio of both material partners, which is achieved via the lateral beam shifting in the welding joint region at high beam oscillation frequencies. This approach leads to a reproducible and tailored control of the width of the intermetallic phase seam. Fig. 4 shows a resulting laser welded mixed material joint of the system Al / Cu.

The utilization of brilliant lasers in the kW power range makes it possible to achieve phase seam widths of less than 10 µm for Al / Cu depending on the beam shift. For millimeter thick welded mixed material joints the process results in achievable tensile strengths on the order of 70 % of the weaker and non-affected partner. The tensile strength is similar to that of a same-material joint of the weaker partner.



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The laser power modulation is superimposed over the high frequency 2D beam scanning and shifts the resulting weld properties close to the metal physical limits. So far these regions were not accessible by laser welding processes. The new technology offers further possibilities to cost effectively manufacture mixed material joints from Cu / steel, Cu / austenitic steel, Cu / Al or Ni / curable carbon steel.

The presented results were developed within a BMBF funded project WELDIMA (funding identification 13N 10197).

1 Cross section of a laser beam welded mixed material joint stainless steel / Cu

2 Cross section of a laser beam welded mixed material joint Al / Cu

4 Laser beam weld head WSS intelliscan 20 FC for the highly dynamic beam scanning

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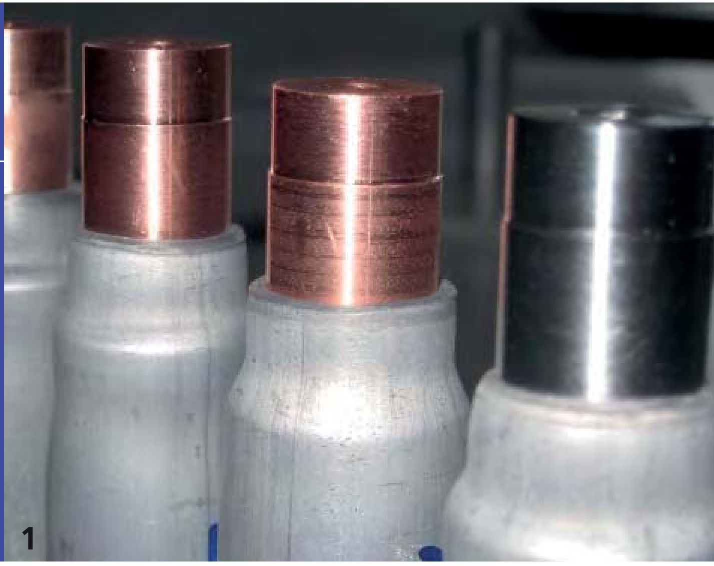

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ELECTROMAGNETIC PULSE WELDING TO FABRICATE MIXED MATERIAL JOINTS

THE TASK

Today it is unimaginable to not have melt-based welding processes in modern manufacturing environments. In particular, laser beam welding processes are the method of choice to efficiently join materials with high quality. However, melt-based processes face difficulties if the materials to be connected are significantly different such as aluminum and copper. Such materials form intermetallic phases in melt conditions, which can limit the achievable strength of the joint. Similar challenges occur when welding alloys are prone to hot cracking. Here the sequential melting and solidification steps lead to a crack-laden material structure, substantially weakening the resulting joint.

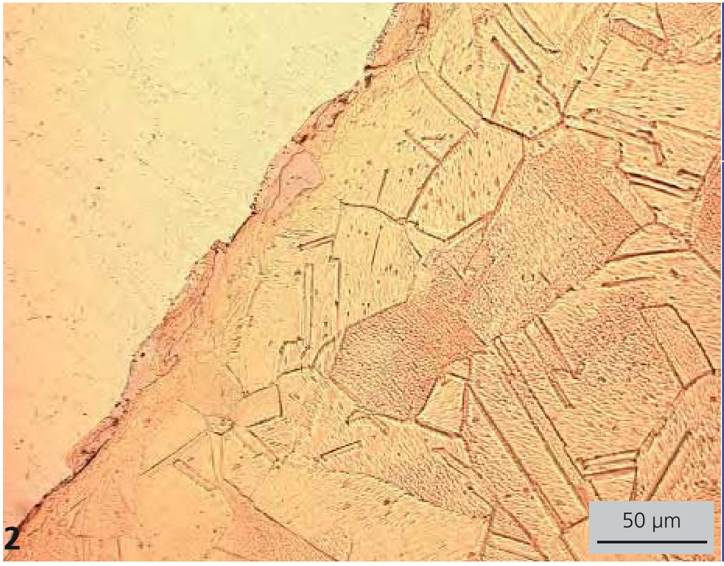
The goal is to establish alternative processes for manufacturing critical mixed material joints in industrial applications, which connect materials without generating localized melts and achieving high strength seams.

OUR SOLUTION

It is known from explosion welding that extreme localized pressures may lead to quasi melt-free welding of virtually any metallic material combination. This process has disadvantages such as high costs and time consumption as well as limited application in terms of geometry. However, the same physical principle is applied during the so-called electromagnetic pulse welding. The localized pressure pulse is generated in the part itself through the interaction with a contactless magnetic field pulse. The technology is mostly known as a contactless forming and form fitting process for metals. However, when selecting the appropriate process parameters it is also possible to generate an atomic level weld connection (electro magnetic pulse welding, EMPW).

The IWS process uses a current carrying tool coil, which couples via its magnetic field to the workpiece (i.e. the end of a pipe) and induces eddy currents. The interaction of the externally applied magnetic field and the generated eddy currents causes Lorentz forces, which suddenly compress the pipe. When the inner surface of the collapsing pipe hits, for example, a shaft at sufficient velocity, it is possible to achieve a material bond with extremely low heat input and without generating a heat influence zone.

The implementation of the processes requires special systems engineering, which was developed in cooperation with the "Dresden High Magnetic Field Laboratory" at the Helmholtz-Zentrum Dresden Rossendorf. IWS engineers use the equipment to perform research on the basic process itself as well as process development and optimization work to address industrial tasks such as the welding of mixed materials. Of particular interest during such investigations is the interface between the different materials, since this region is key to the strength of the joint. The investigations help to improve the process and also to adapt and optimize it to achieve the desired properties.



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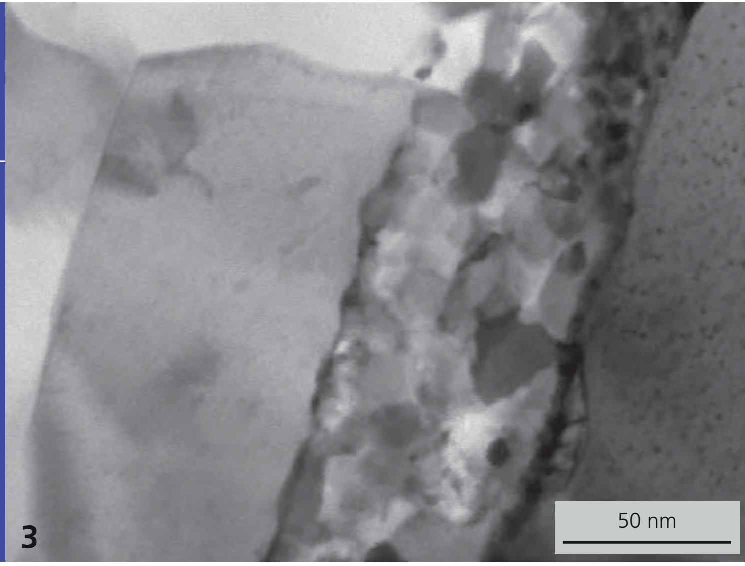

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RESULTS

Mixed material joints of different combinations (Fig. 1) were analyzed with respect to their properties over a broad parameter range. It was confirmed that the process is capable of atomically welding drastically different metals. Metallographic analysis (Fig. 2) in combination with SEM and TEM studies (Fig. 3) demonstrated welded mixed material joints in Al / Cu and Al / steel interfaces made of nanoscale intermetallic phases seemingly free of transition zones. Both the phase seam thickness as well as the phase type depended on the coupled pulse energy. High resolution TEM analysis confirmed that such seams occur everywhere along the connection with thicknesses as thin as 50 nm – 200 nm. If the seams get as thick as 5 µm cracks may occur.

Optimizing the process parameters and in particular minimizing the pulse energy showed good results for all of the studied material combinations. The formation of intermetallic phases was reduced and the seam quality of the axial symmetric joint was high. It is also important to study the material in close proximity to the interface region and to identify potential changes. In copper-aluminum seams there appeared a pressure or forming induced recrystallization zone. This zone consists of an ultra fine-grained material structure in the direct vicinity of the interface. This structure formation is a side effect of the physical principle and improves the joint strength.

1 Pipe-tap joint, mixed material joints from aluminum / copper and aluminum / steel

2 Detailed optical microscopic image of atomically welded aluminum-copper interface

3 Transmission electron micrograph of an interface between aluminum and copper with nanoscale fine grain structure

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1

ROLL PLATED COPPER ALUMINUM CONNECTOR

THE TASK

New developments in the area of electromobility increasingly demand new types of joints that are adapted to specific tasks and combine the properties of various materials. Such material combinations can be clamped or screwed. However, such connections are inferior in terms of productivity, material utilization and the long-term stability of the contract resistance. Classically welded joints often form intermetallic phase seams at the material transitions. These also increase the contact resistance in the connections.

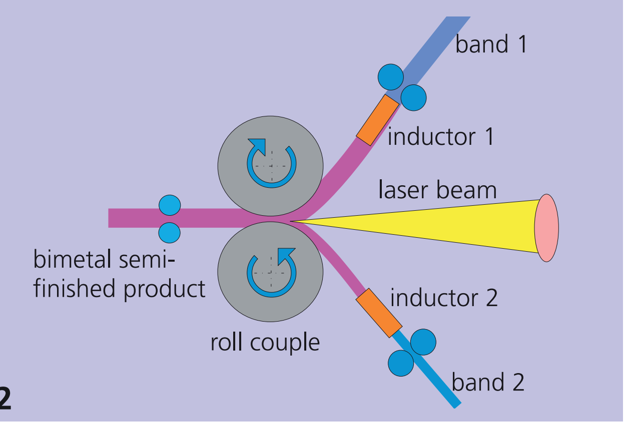
Semi-finished connector products made, for example, from copper and aluminum, would offer new possibilities to implement compact and lightweight powertrain components. Thus it is the objective of a BMBF project "DeLIZ" to develop effective manufacturing processes for long-term stable joints between copper and aluminum parts.

OUR SOLUTION

The idea is to use roll plated bimetal transition joints from aluminum and copper with the goal to generate metallurgically bonded current carrying connections with low contact resistance. Fraunhofer IWS engineers developed a special roll plating process, which is the so-called laser induction roll plating (LIRP, Fig. 3). The specialty of the process is a very limited overall deformation (< 11 %) of the components. The process also consists of only a single forming step with only a very brief peak temperature exposure in the welding zone. This process uses inductive preheating of the semi-finished components in combination with a line shaped laser beam that introduces energy only in the area of the roll plating gap. The welding zone is formed based on metallurgical reactions, caused by the deformation and the simultaneous temperature regime.

Since there is only one processing step and the energy input is very localized, the overall process is flexible in terms of welding various semi-finished parts. For example, the two components to be welded do not have to be geometrically identical. It is possible to join two metals in overlapping configurations to save materials. Thus the joints can be made from materials of almost any thickness and their widths can be adapted to the application as well.

Principle representation of the laser induction roll plating process



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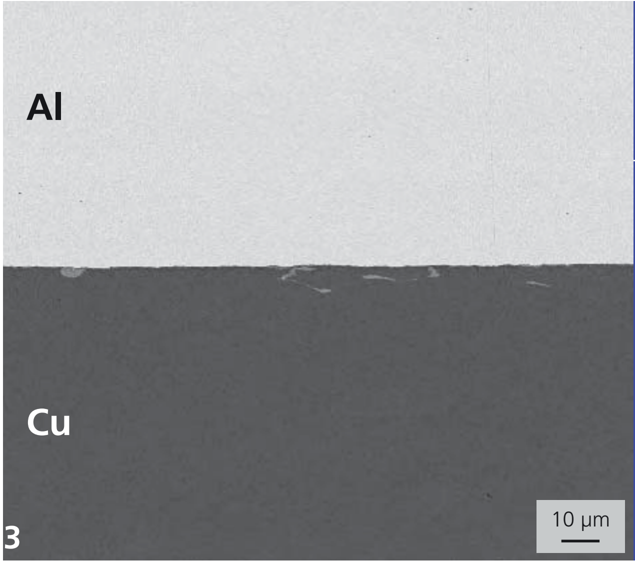

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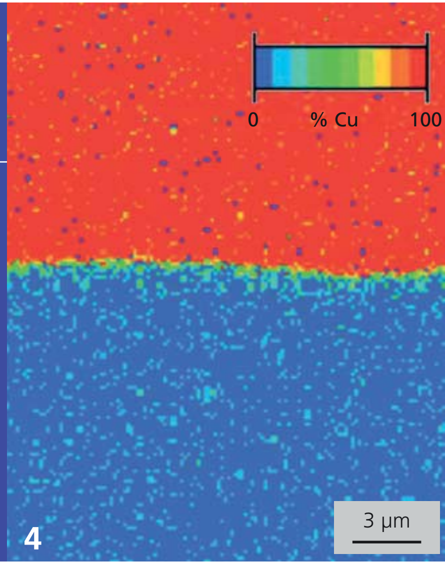

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RESULTS

The laser induction roll plating (Fig. 2) is well suited to fabricated material joints from combinations such as different steels, steel and aluminum / aluminum alloys and steel and copper / copper alloys. It is also possible to make connections between copper / copper alloys and aluminum / aluminum alloys (Fig. 1). Typical metal band geometries are 12 or 22 mm wide and the thickness is between 1 and 2 mm. The resulting plating speeds are up to 8 m / min with lasers of up to 10 kW and 45 kW induction power. Generally the roll plating process runs more stable at higher speeds. However, the achievable throughput depends greatly on the type of semi-finished feedstock (dimensions, materials) and the available power of laser and induction units.

Research focused on achieving excellent electrical parameters for the bimetal transition joints of copper and aluminum. There are also requirements in terms of their mechanical strength and formability. In particular the welding zone is of interest when evaluating the mechanical performance. For most of the fabricated parts it was not possible to determine adhesion values in the welding zone. The separation typically occurs outside of the welding zone in aluminum. Tensile shearing experiments showed the same failure mode. But for a few exceptions, the material separates with the heat influenced zone inside the aluminum band. The measure shearing strengths were on the order of 32 to 52 MPa depending on the applied parameter field.

During the process the laser beam heats the inner surfaces of the metal bands to significant temperatures even exceeding the melting point. However, the formation of an extended intermetallic phase seam can be suppressed (Fig. 3 and 4). Therefore the welding zone has little defects, which is a condition for achieving good electrical performance. Current activities aim at determining the electrical performance as well as the cyclic mechanical loading stability of the formed transition joints.

1 *Plated band made from copper and aluminum*

3 *SEM micrograph: welding zone of a roll plated copper aluminum band, copper light, scattered copper is found within the aluminum*

4 *EDX analysis of the welding zone, quantitative distribution of the copper content*

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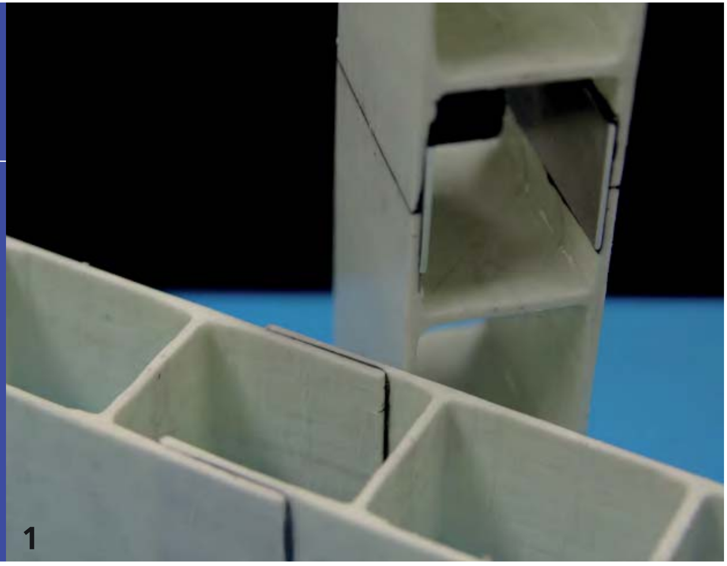

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ADHESIVE BONDING OF TEXTILE REINFORCED LIGHTWEIGHT CONSTRUCTION MATERIALS

THE TASK

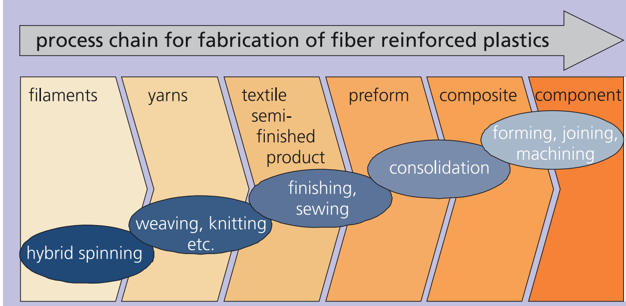
The overall aim of the SFB 639 project is to better utilize the vast potential of lightweight construction concepts. The effort addresses the entire development and manufacturing chain. Within the project the Fraunhofer IWS and the TU Dresden work on a specific subproject titled “Bonding techniques for multi-material design with textile-reinforced composites”.

Glass fiber reinforced thermoplastic materials possess great mechanical strength and can be made in complex shapes. However, the manufacturing of these materials is so far not satisfactory. The injection molding of short glass fiber reinforced thermoplastic materials provide the capability to make complex geometries. Due to the utilization of short glass fibers the so fabricated components do not possess the full level of mechanical strength. Multilayered pressed glass textile reinforced thermoplastic materials (several layers of glass textiles and thermoplastic foils stacked on top of each other) provide excellent mechanical properties but have limitations in terms of the shapes that can be manufactured. There are other liquid processes that disperse the fiber material in a low viscosity monomer or oligomer melt and start the polymerization process post-injection. But such processes are only possible with a limited selection of thermoplastics such as PA.

OUR SOLUTION

Fiber reinforced thermoplastics were fabricated using hybrid yarns made, for example, from polypropylene and glass fibers. Such processes are used to manufacture 2D as well as complex 3D structures (spacer fabrics, Fig. 1). A variety of bonding techniques such as weaving, sewing and knitting are used to fabricate such spacer structures with optimized flux. The technique is flexible and holds the promise of making complex structure in short cycle times (Fig. 2).

Interlinked process chain in SFB639 from filament to component



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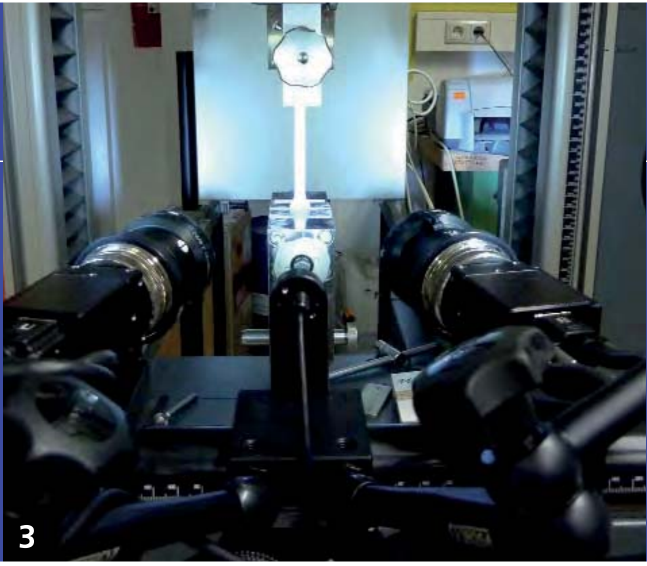
The potential of this hybrid yarn textile thermoplastic composite (HYTC) technology for lightweight construction applications requires appropriate joining techniques. Adhesive bonding processes appear to be particularly well suited. They offer a larger connection area with uniform load transfer. However, polyolefin materials such as polyethylene, polypropylene and polytetrafluorethylene have low energy surfaces and thus tend to show low affinity to adhesives. Therefore the surfaces of these materials need to be effectively pretreated to improve adhesion. The scientific literature discusses various processes addressing the increase of polarity, wetting behavior and surface energy as well as structural changes of the surfaces.



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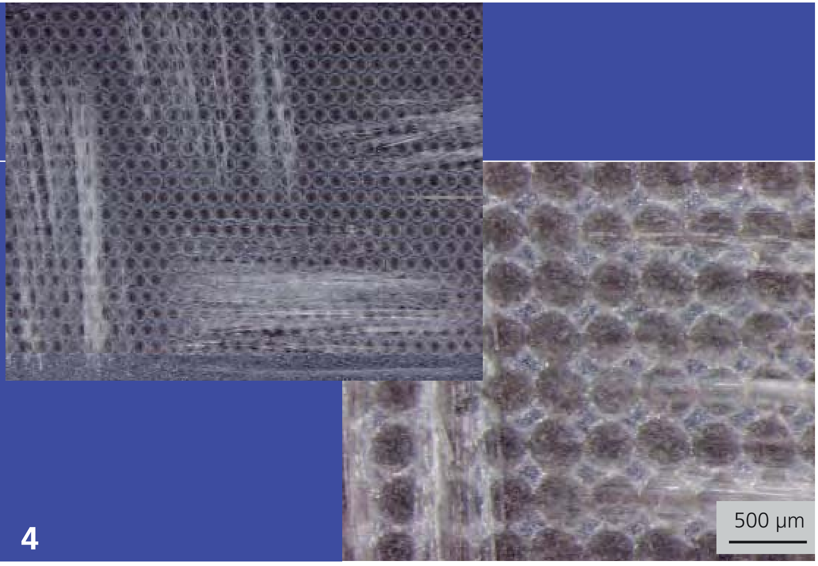

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Polypropylene surfaces require surface modifications to improve their suitability for adhesive bonding. Fraunhofer IWS engineers researched two physical methods to achieve this goal. One approach was to apply atmospheric pressure plasma treatments, which attach chemically functional groups to the surfaces. The second approach involves using an Nd:YAG solid-state laser to remove the upper contaminated surface layers and to structure the surface and thus increase the surface area. Both processes are suitable for inline application as well as robotic automation. To judge the effect of the processes, reference samples were degreased with ethanol for comparison.

RESULTS

The test material was glass fiber textile reinforced propylene, which was fabricated in the form of plates. The adhesive was a commercial epoxy resin. An optical strain measurement system (Fig. 3) was used to determine pure adhesive data and to judged adhesive bonds.

The atmospheric pressure plasma pretreatment improved wetting the polypropylene surface, which was demonstrated by measuring the contact angle. The processing distance was kept sufficiently large to avoid thermal surface damage.

The Nd:YAG laser was used to generate specific surface structures, which depend on processing parameters such as spot size and track overlap (Fig. 4). Surface damage and a partial fiber exposure was also observed and attributed to the specific wavelength of the laser. The construction of the tested HYTC thermoplastic employs a varying thickness of polypropylene cover layers, which led to the undesired fiber exposure.

Subsequently the HYTC plates were tested in adhesive bonding experiments. Atmospheric pressure plasma and laser processing significantly increase the performance of the adhesively bonded joints in comparison the ethanol cleaned samples. An artificial climate change test also showed an improved ageing resistance for the samples that were laser treated.

DRESDEN concept

1 Implementing double overlapped adhesive joints from spacer fabrics without and with metallic joining partner

3 Parameter measurements with optical strain measurement system

4 Scanning electron micrograph of HYTC material after laser preprocessing

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Not the wind
but the sails determine the course.
Unknown Chinese author

BUSINESS FIELD SURFACE TREATMENT

Editor: A recent development focus in the area of laser surface hardening was in process related systems engineering. What progress was made last year?

Prof. Brenner: We continued the development of laser surface hardening system components. They are now part of a system tool set "temperature control of fast and localized heat treatment and liquid phase processes". Typical examples for this development are the industrial implementation of the fast temperature control system "EFAqS" for the laser soldering of solar cells in numerous machines and the qualification of the temperature control system for fast induction hardening processes.

In this context I should mention the development and industrial implementation of a new control concept for laser buildup welding. The control variable is the surface area in which the temperature exceeds the melting point of the buildup material. This parameter proved to be a well controllable quantity that correlates with the melting of the substrate material, which has to be kept within tight tolerances.

A joint project with the department "Thermal Coating Processes" led to the development of a laser hardening and buildup welding module, which is used in a machine for hardening and buildup welding of large dies in the tool making section of a German automotive manufacturer.

We also further developed a laser hardening unit, which uses rotating mirror optics and allows the temperature controlled heat treatment of the inner surfaces of semi spheres. This system overcomes geometrical limitations when hardening concave functional surfaces of rotational symmetry.

Editor: Since the middle of the year a new electron microscope have been started up. How will this machine be used?

Prof. Brenner: We are very glad to have access to an analytical TEM JEM-2100 for high resolution structural analysis. This unit really affords us a new quality level. Materials, microstructures and coatings systems become increasingly complex. It is essential that we can characterize them on the structural level, which is responsible for their properties.

Modern construction materials reach their final application properties after a delicately tailored sequence of thermal processing steps. There is always the risk that a subsequent temperature exposure (e.g. due to joining, surface refinement, coating and cutting processes) irreversibly destroys the microstructure. It is one of the essential tasks for the TEM to help to identify microstructural damage, to minimize or even completely avoid it.

COMPETENCES

OPTIMIZED TECHNOLOGIES FOR THE HARDENING OF STEEL COMPONENTS USING LASER AND INDUCTION

The laser hardening technology offers new approaches to create wear resistant surfaces, where conventional hardening technologies fail due to limitations with respect to part geometries, failure modes and materials. This is in particular true for the selective hardening of parts with multi dimensional curved and inner surfaces that are difficult to access, for bores and notches, and for parts that easily warp. Based on many years of experience and interdisciplinary know-how we offer services from analyzing the failure mode to implement hardening technology:

- development of surface hardening technologies with high power diode lasers, CO_2 lasers, Nd:YAG lasers or induction or both,
- surface refinement of development and prototype samples.

COMPLEX MATERIALS AND COMPONENT CHARACTERIZATION

Mastering modern joining and surface processes requires knowledge about the occurring structural changes in the material and about the resulting part properties. Based on experience and an excellently equipped mircoanalytical and materials characterization laboratory we offer:

- metallographic, electron microscopic (SEM, TEM) and microanalytic (EDX) characterization of the material structure of metals, ceramics and composites,
- determination of material parameters for part dimensioning and quality assurance,
- property evaluation of surface treated and welded parts,
- strategies for the material and loading adapted part design,
- failure analysis.

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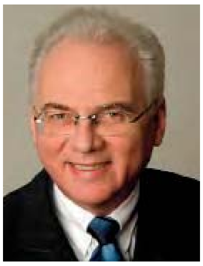

EXAMPLES OF PROJECTS 2010

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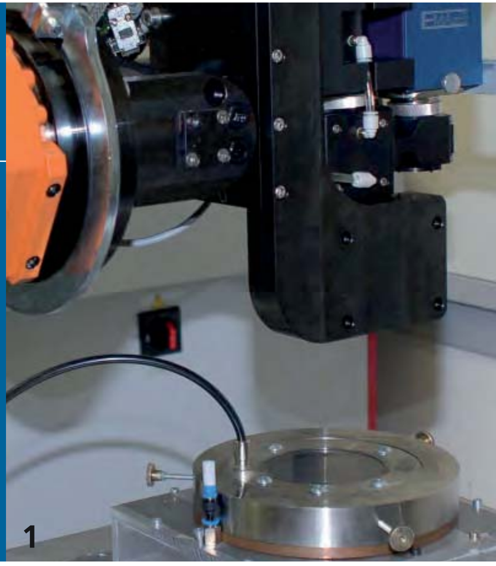
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SYSTEMS ENGINEERING FOR LASER PROCESSING IN PROCESS GAS ATMOSPHERES

THE TASK

Laser surface refinement processes frequently require their application in special gas atmospheres. For example, laser hardening processes need to avoid the oxidation of the treated parts. Laser beam processing of titanium materials on the other hand, often requires a bit of nitrogen in an otherwise inert atmosphere. An important task for industrial applications is to allow the precise adjustment of the gas atmosphere composition while simultaneously avoiding the need for a complicated process chamber such as it is needed in vacuum processes. One of the important requirements is sufficient flexibility and safe control of oxygen content and gas composition.

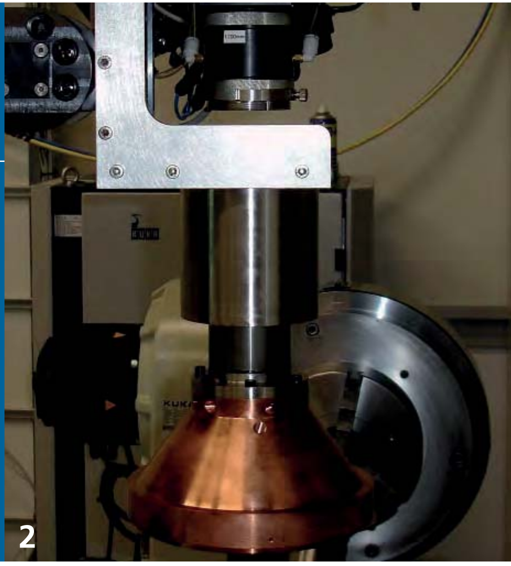
OUR SOLUTION

The applied principle is a slight positive gas pressure, which is maintained within a bell shaped processing volume screen that floats off the workpiece fixture or on the workpiece itself. The bell can be mechanically coupled or completely separated from the laser optics. The gas streams out at the floating surface, which reduces friction at the surface. A special process chamber for large workpieces was developed that is sealed by a glass bell. The part can still be rotated and swiveled. The oxygen content is monitored using a Lambda sensor. The gas mixtures are regulated via a four-channel flow controller.

RESULTS

A simple process bell was developed for the treatment of planar workpieces. The laser beam enters the bell via a quartz glass window. A simple telescope construction couples to the short focal lengths of the laser optics. The bell is easily mounted directly to the laser optics. During processing it is then moved jointly with the optics. Due to the telescope construction it is possible to use gravity to keep the bell on the workpiece or the fixture to seal the process volume even when the laser optics moves vertically. It is no necessary to move the bell when processing smaller parts. In that case it is sufficient to insert a large protection window of 100 mm diameter (Fig. 1). The process bell is simply placed on top. The laser optics performs the necessary movements so that the laser beam always enters the process zone through the entry window. This simple arrangement was successfully used for a multitude of hardening, welding and remelting processes.

A special process gas chamber was developed to treat large workpieces that also have to be moved (Fig. 4). The chamber contains a swiveling yoke, which integrates the clamping fixtures. The clamping fixtures are built so that the contour to be processed is close to the rotational axis. This procedure minimized radial linear motions. A crane with a support frame is used for the placement and extraction of heavy clamping fixtures though a sidewall. The box-shaped chamber is sealed by two pull type metal blinds along one direction and with movable metal sheets at the sides. The intersection contains the holder, which is closed by the robot-mounted protection bell.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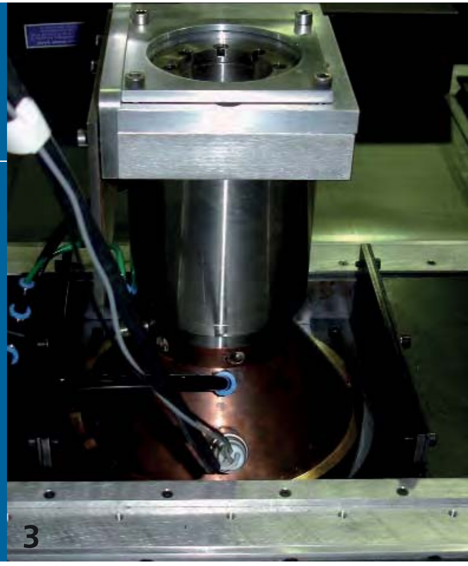
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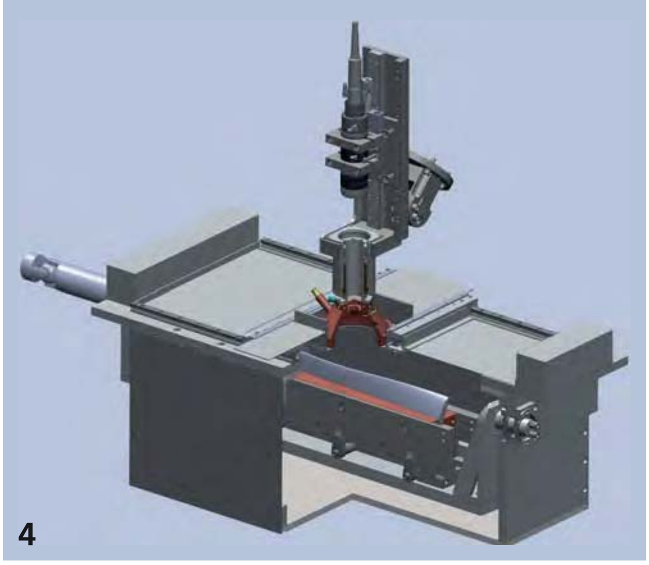
The bell is connected with the machine axis or a robot hand using a stable sleeve bearing (Fig. 2). The laser optics is also mounted there. In this way the bell is fixed in two directions with respect to the optics and simultaneously pulls the metal blinds with it during processing. The sealing of the process chamber during laser processing is again ensured by the weight of the bell (Fig. 3). In the case of the large process chamber, the process gases are not exclusively flowed in through the bell. Additional gas ports in the sidewalls are used to reduce the time to flush the chamber.

The effectiveness of the protection bell was demonstrated by producing wear resistant surface coatings on titanium. Laser gas alloying with nitrogen was performed under the bell on titanium surfaces. Due to the low oxygen partial pressure during the process, the oxygen concentration in the treated material region was further reduced.

Principle representation of the process chamber with an integrated rotating or swiveling clamping fixture and mounted process gas bell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1 *Simple process gas bell with large protective glass window during protection gas welding*

2 *Process gas bell with stable sleeve bearing mounted to be mounted on robot arm*

3 *Process chamber, sealed by process gas bell*

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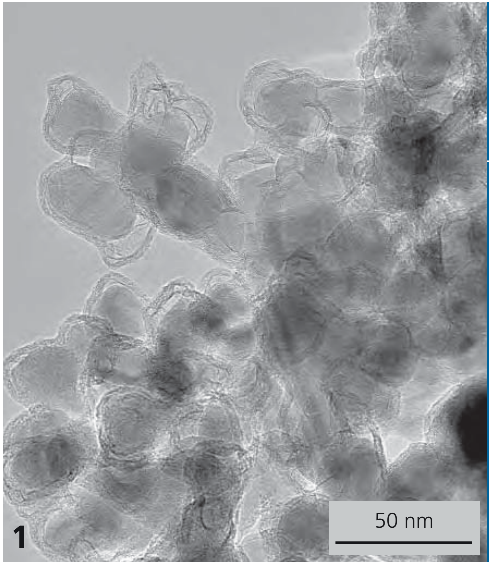
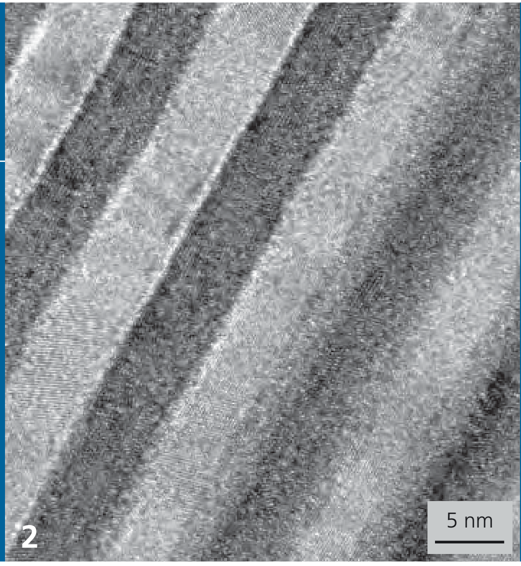
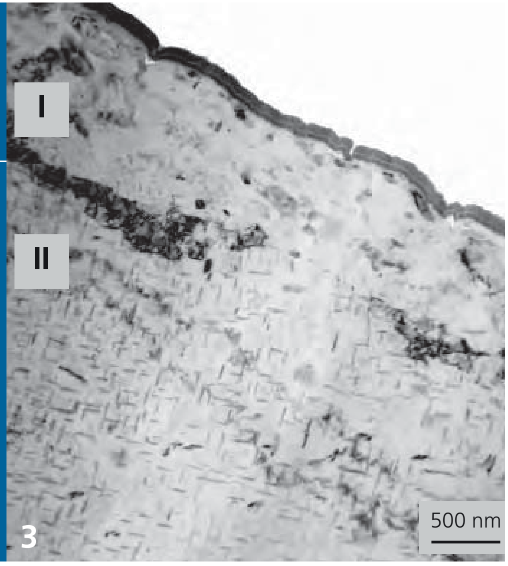






ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY FOR PRODUCT RELATED MATERIALS DEVELOPMENT

THE TASK

Materials and material aspects form the foundation for many technological innovations. The desired material properties depend, to a large degree, on their microscopic structure. Microanalytical tools are therefore a necessity. Analytical transmission electron microscopy (TEM) plays a central role, since it is the only method that provides complete structural characterization down to the atomic level. Transmission electron microscopy combines the three fundamental analytical methods of imaging, diffraction and spectroscopy in one and the same analytical tool, which aid its comprehensive analytical capabilities.

The analytical transmission electron microscopy has decisively contributed to tailor the structure of materials with respect to their application relevant properties. The method is not only advantageous to address basic research questions but also

- to use for improving product related material properties (e.g. surface near region related technologies),
- to further develop material depending manufacturing processes (e.g. joining),
- for failure analysis and
- to evaluate the quality of manufacturing processes.

Thus it is the goal of Fraunhofer IWS engineers to utilize the technique for the product related materials development and also to offer this capability as a service to our customers.

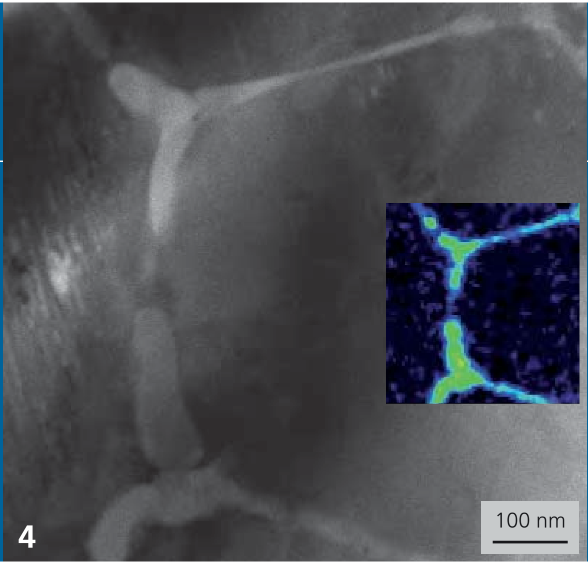
OUR SOLUTION

At Fraunhofer IWS laboratories the analytical transmission electron microscopy is combined with powerful metallography, scanning electron microscopy and materials testing capabilities. The successful application of the technique requires not only broad materials knowledge and methodical experience, but also modern and efficient laboratory equipment. The unit, installed at the IWS, is a TEM JEM-2100. This machine includes a high-resolution pole-piece, a scanning unit, an EDX system for element analysis, two mutually completing camera systems and a very precisely adjustable piezo controlled sample holder. Fabrication methods are available to prepare electron beam transparent samples from many materials and components.

The following results present an overview of Fraunhofer IWS research efforts to develop product related materials.

RESULTS

Current research is devoted to the synthesis of silicon carbon nanoparticles in a so-called "core & shell" arrangement. This material is planned as an electrode material in lithium ion batteries (Fig. 1). TEM investigations provide information such as the structure, size and distribution of the nanoparticles as a function of the synthesis conditions. This information in return provides the opportunity to optimize synthesis parameters.



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Another research topic at Fraunhofer IWS is the development of reactive multilayer coatings (RMC), which are applied in low heat impact joining processes for various material combinations (see pages 86 / 87). An important aspect of this development is to avoid diffusion within the coating stack during the fabrication. TEM analysis demonstrated that specific barrier coatings help to avoid this undesired diffusion effect (Fig. 2).

New materials and material combination require efficient methods for the fabrication of mixed material joints. Promising IWS technologies are the electromagnetic pulse welding and the laser induction roll plating. Transmission electron microscopy analysis is very helpful to study undesired phase seams, which may form at the interface between two materials during such joining processes. The TEM results provide hints as to how to reduce the formation of these phase seams, which are used to improve the quality and strength of the joints (see pages 40 / 41, 42 / 43).

High performance car engines face enormous wear challenges. Piston and cylinder materials need to be optimized, which requires a thorough understanding of the actual wear mechanisms, when the engine is in operation. For example, during the engine's operation the surface region of the cylinder liners undergoes structural change. Conventional metallography and scanning electron microscopy proved insufficient to capture these effects. The analytical challenge was resolved by applying additional TEM investigations. The study clearly demonstrated a correlation between the surface quality of the final manufacturing step and the resulting operational wear (Fig. 3).

Tool steels are in general hard to weld due to high carbon content. This is also true for modern processes such as laser beam welding. Comprehensive TEM studies provide information on the structure formation in the weld material, which contributes to improving the weldability of high speed steel (Fig. 4).

1 SiC nanoparticles, encapsulated with amorphous and graphitic carbon (TEM)

2 Zr/Al RMC with (upper left) and without (upper right) diffusion barrier

3 Proof of a machining related deformation layer on a cylinder liner surface made from ALUSIL:
I recrystallized,
II Al/Cu particle deformed

4 Solidified structure in the weld material of high speed steel (TEM, EDX): increased molybdenum concentration at grain boundaries

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CAMERA BASED PROCESS CONTROL SYSTEM "E-MAQS" – NOW ALSO AVAILABLE FOR LASER BUILDUP WELDING

THE TASK

Laser buildup welding processes are widely used to repair, for example, large tools and to protect expensive wear parts. Compared to other processes laser buildup welding achieves better properties. A key reason for this performance is the minimal but very constant melting of the substrate material. To maintain this melting zone proves difficult since the local heat sinking conditions at the substrate surface may frequently change. For example, small workpiece generally heat up during the process. To maintain optimal deposition conditions it is therefore necessary to constantly adjust the process parameters. The goal was to develop a suitable process control system.

OUR SOLUTION

The solution was to use a camera based temperature control system, which was originally developed for controlled laser hardening applications. The system consists of a CCD camera, which is sufficiently sensitive in the near infrared spectrum. Narrow bandpass filters are applied to correlate temperatures with the gray scale values in the image of the surface. The system achieves a lower temperature threshold of 600 °C.

The system is installed in a dustproof and robust case to deploy it in the industrial environment (Fig. 1). The casing houses a pneumatic linear motion unit, which places the filters in front of the optics, when it receives commands via CNC or control software user interface actions. Without filters the camera can be used in the visible spectrum, which is used for adjustments of processes. The system can be attached to the laser optics via a coupling cube for coaxial process observation. To capture the heat radiation from the process it is separately mounted to observe the process from the side.

The calibration of the system is performed using a blackbody radiator. The software stores nonlinear characteristic curves, which help to achieve a very wide detection range from 600 °C to the melting temperatures of metals. Experiments showed that it is not necessary to keep the temperature of the melt constant during laser buildup welding. A constant size of the melt pool proves more important for achieving reproducible process result. This control variable depends on a number of process parameters such as the powder mass stream, the laser spot dimension, the powder material etc. It has to be determined for each specific application. During operation the laser power is regulated to accommodate for the locally differing thermal conditions and to maintain the melt pool size at all locations.

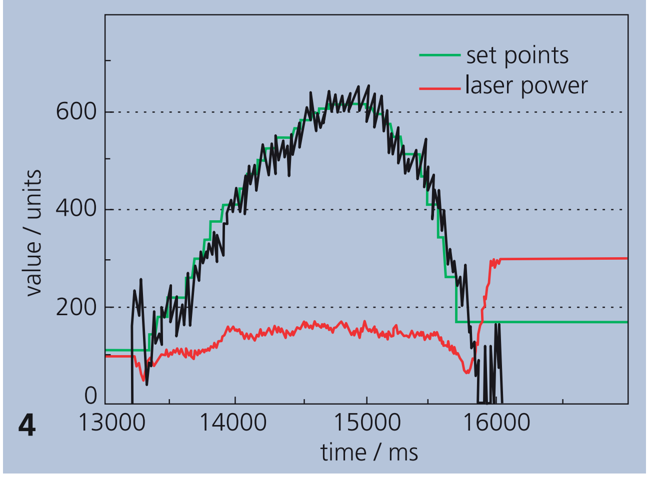

3

APPLICATIONS

Among the several existing applications for laser buildup welding is the repair of jet engine components. The particular difficulties of this application are the need for very fine buildup welds and the dynamic requirement for the control variable due to the shape of the component (Fig. 3). First, the camera optic is adapted so that it captures a smaller sized area to make finer welds clearly visible. Secondly, the NC based change of the size related control variable is integrated into the control software. The data are transmitted via Profibus from the machine controller. The control variable itself is calculated by an offline programming system, which determines the values based on the measure workpiece contour dimensions and integrates it into the NC code.

Another application lies in the area of large tools for car body making. Since mid 2010 Audi AG in Ingolstadt has been using such a system to process forming tools (Fig. 2, 3).

Process behavior of "LompocPro" controlled cyclical laser buildup welding with variable set points, green: set points, black: actual value, red: control variable laser power



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1 System "E-MAqS" with robust aluminum case

2 Operator panel of a laser buildup welding system with integrated process controller "LompocPro"

3 "E-MAqS" integrated in a laser buildup welding module in the tool making section at Audi AG Ingolstadt during startup

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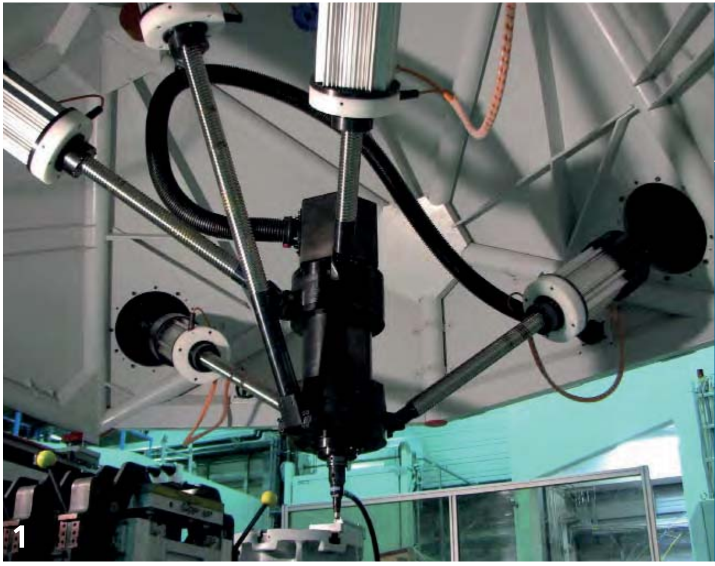

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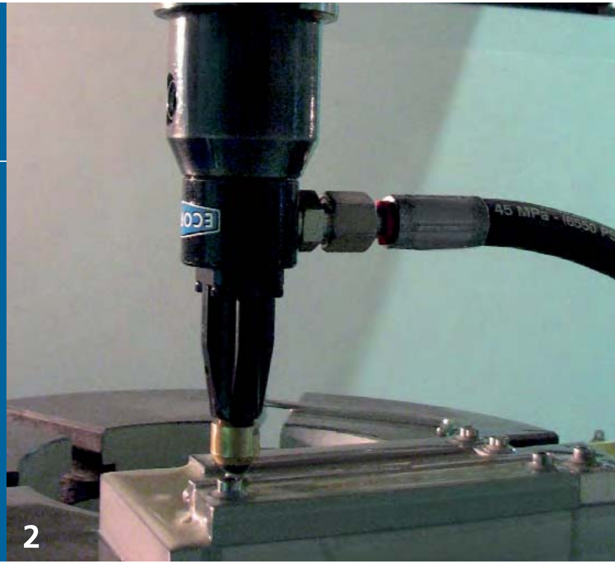


2

DEEP ROLLING OF 3D FREEFORM SURFACES

THE TASK

Lifetime and safety considerations for cyclically loaded components are increasingly important in mechanical engineering and system manufacturing. In particular a cyclic bending load leads to critical crack formation on the outer surfaces of the parts. The following strategies are known as counter measures to increase part life and safety:
- introduce localized compressive stresses: increases the strength of critical strain loaded components since the strain has to overcome the compressive stresses first to lead to cracking,
- reducing the surface roughness: this reduces the notch effect and makes crack formation more difficult,
- increasing the dislocation density in the material: this increases safety from crack formation.

Mechanical compacting of the surface region provides a solution to this problem. The method significantly improves fatigue resistance and strain corrosion resistance. Deep rolling offers an effective solution. Compared to competing processes such as shot peening, deep rolling offers the following advantages:
- outstanding surface quality,
- relatively large depth effect,
- a precisely localized treatment is possible,
- moderate investment costs.

Often it proves difficult to integrate the process into modern machine tools.

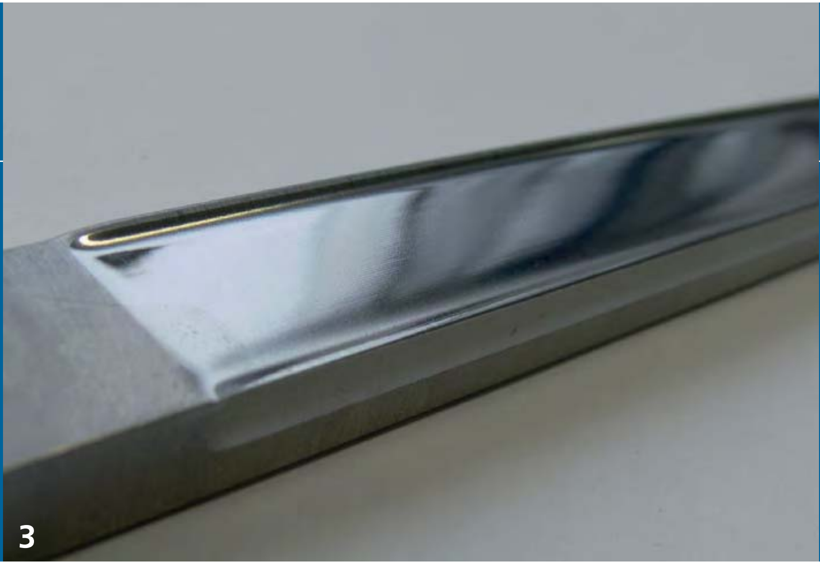
The technique represents a state-of-the-art approach treating parts of rotational symmetry in turning machines. However, it remains a challenge to apply the process in 3D machine tools to machine freeform surfaces.

OUR SOLUTION

Fraunhofer IWS engineers worked in collaboration with the Network Initiative Mechanical Engineering Saxony and the Metrom GmbH on the integration of deep rolling tools and the associated force controlled process using a 3D milling machine. The project was funded by Saxony's State Department for Economy, Labor and Traffic. The technical advantages of this approach are:
- force control adjusts the affected material depth,
- complete 3D capability: the rolling path can be freely programmed via CNC, it is technically easy to locally adapt the applied force,
- machining and surface treatment can be done in the same setting.

Systems Engineering

The tests were performed on Metrom's 3D capable milling center using parallel kinematics – a so-called Pentapod (Fig. 2). Jointly with the machine builder Fraunhofer IWS engineers modified the system to implement fast pressure force measurement and adjustment capabilities for the working-spindle. This is an advantage for deep rolling processes when treating parts of complex shapes and varying tolerances and deformations. Maintaining a constant pressure force is key to achieving constant surface quality.



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RESULTS

Successful integrated deep rolling was demonstrated using the proposed system and control concepts. Parts of uniform surface quality were reproducibly manufactured (Fig. 3). The surface roughness was reduced by up to 78 %. Depending on the material it is also possible to increase the hardness. Some of the tested materials were hardened up to 10 %.

The effective penetration depth of the process also becomes evident in terms of hardness. Increased hardness values were measured down to a depth of 1.5 mm below the surface. Fatigue tests revealed the need to avoid sharp contour transitions (edges, chamfers). Such features may promote crack initiation during cyclical loading.

Application areas

There are many examples for workpieces with challenging geometries:

- energy production:
    - shafts, blade foot mounting and blade feet of modern gas and steam turbines
    - compressors, pump wheels
- automotive manufacturing:
    - car suspension components, e.g. suspension wishbones and trailing arms formed from sheet metal cast aluminum materials
- machinery and system construction:
    - load bearing points and bearing surfaces in transmission and motor casings
- aerospace:
    - deep rolling of laser beam welded structural elements to compensate for weld seam undermatching

1 3D machine tool (Pentapod) with integrated force control

2 Hydraulic roll tool in test configuration

3 Locally rolled sample with smoothened surface

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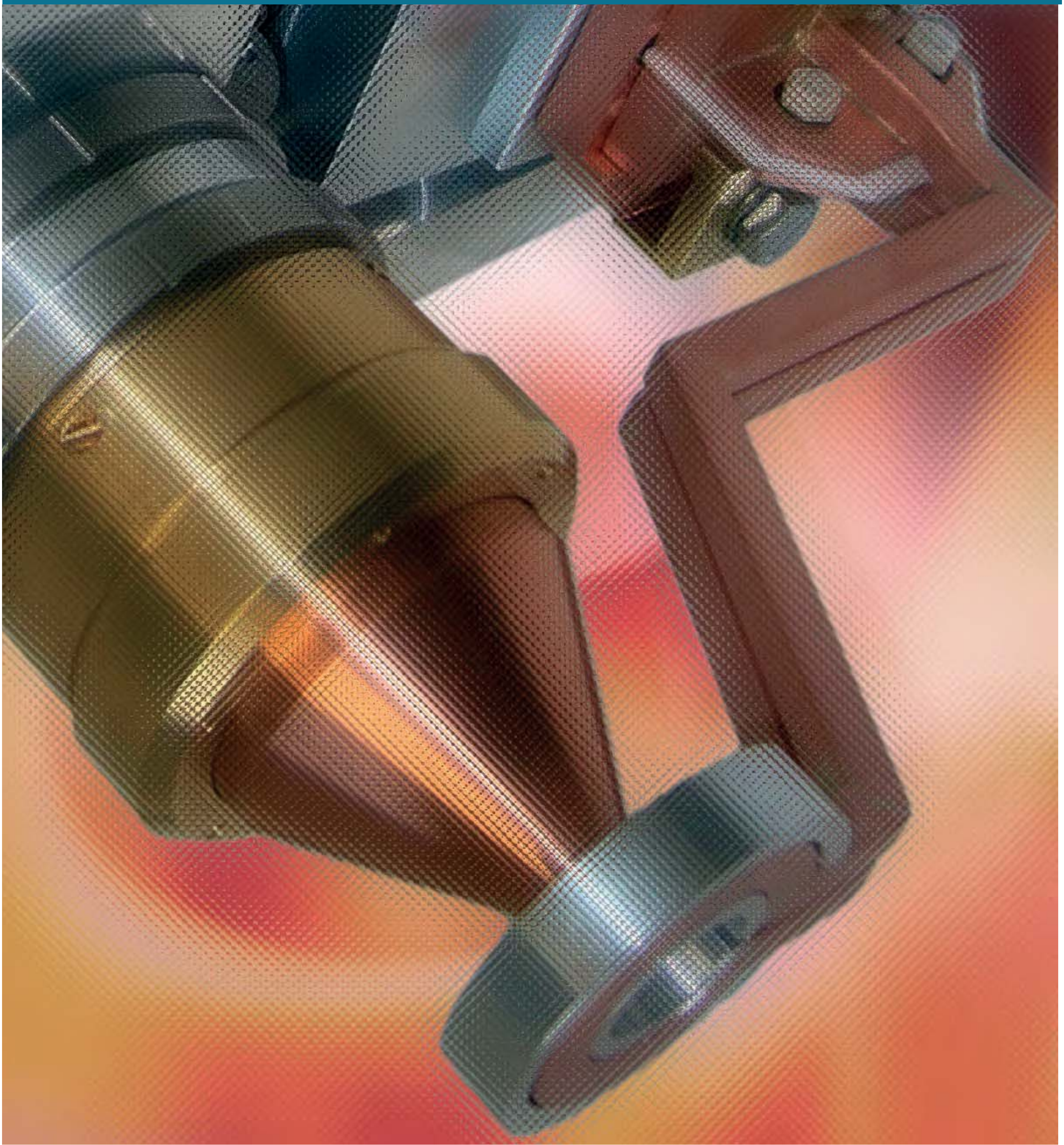

Vision without action is a daydream,
action without vision is a nightmare.
Japanese proverb

BUSINESS FIELD THERMAL COATING

Editor: You have been responsible for the IWS business field Thermal Coatings for about a year now. Can you give us a summary?

Prof. Leyens: Despite the economically tense situation we had a successful business year. With many of our customers we are maintaining a long-term relationship based on trust and active collaboration. Even in economically tough times our expertise is required. In some cases the "quiet times" proved to be advantageous since they freed up room for further development. But not only long-term customers stayed true to us. We were also able to generate new business relations.

Editor: What are the development emphases in this business field?

Prof. Leyens: Much progress has been made in suspension spraying. It becomes more and more evident that this technique has the potential to fill the gap between classical thin film technology and conventional thermal powder spraying. The process uses fine powder particles dissolved in a suspension so that it is possible to fabricate thin films. These films are not only dense and homogeneous but also surprisingly smooth. Suspension spraying is a high rate deposition process that is suitable for new applications in combination with corresponding coating materials.

In laser buildup welding we put emphases on the precision of the generated geometries and on the process productivity. Our latest powder nozzle development in the COAX family is COAX-powerline. The concept is based on the combination of energy sources and in particular on supporting lasers with inductive heating, which tremendously improves the efficiency of the powder buildup. Highest precision is needed for making fine structures with widths of less than 100 µm. New powder nozzles with further reduced powder foci are under development. These nozzles simultaneously improve powder utilization.

Editor: Thus system engineering remains an important topic?

Prof. Leyens: Definitely. Our customers do not only profit from our materials and process know-how. We are offering systems engineering and integration services, which are specific to their applications. We support the industrial implementation at our customers until equipment and processes are running in series manufacturing. A one-stop-solution – so to speak.

Editor: You mentioned materials know-how. Can you be more specific?

Prof. Leyens: The different materials possess specific properties and therefore their processing benefits from optimized parameters to yield best results. On the other hand the process is also influencing the properties of the material. This results in a close interaction between material, process and final part properties. We need to understand this coupling very well. Then we can apply hard-to-weld materials such as nickel base alloys or titanium aluminides to form laser coatings or structures or thermal spray coatings in the desired qualities.

COMPETENCES

THERMAL SPRAYING

At the Fraunhofer IWS we have available atmospheric plasma spraying (APS) and high velocity oxy-fuel (HVOF and HVAF) spraying technology with powders and suspensions to coat parts made from steel, lightweight metals or other materials with metals, hardmetals and ceramics.

Our offer, in cooperation with other Fraunhofer Institutes in the Dresden region, includes:
- design of application specific coating systems,
- development of complete coating solutions from the material to the coated part,
- development and fabrication of system technical components,
- support of system integrations,
- support of the customer during technology transfer.

CLADDING AND BUILDUP WELDING

The available technologies are laser beam and plasma powder buildup welding as well as hybrid technologies combining lasers, plasma and induction heating. The processes are applied to repair and coat parts, forms and tools. Metal alloys, hard materials and ceramics are applied as thick coatings and 3D structures through deposition, alloying or dispersing. All technologies make use of a closed process chain including digitizing, data preparation and final processing.

For these applications we offer:
- simulation of buildup welding processes,
- coating and shape forming laser buildup welding with highest precision and productivity,
- processing heads and CAM software for industrial use of laser technology,
- on-site support of the technology transfer.

EXAMPLES OF PROJECTS 2010

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FURTHER INFORMATION:

www.iws.fraunhofer.de/technologien/laserauftragschweissen/e_tech01.html

www.iws.fraunhofer.de/technologien/thermisches_spritzen/e_tech02.html

www.iws.fraunhofer.de/branchen/bra02/e_bra02.html

INCREASED EFFICIENCY DURING LASER BUILDUP WELDING BY COMBINING ENERGY SOURCES

THE TASK

Excellent precision, highest mechanical strength and tailored properties of surface coatings and generated 3D structures: these characteristics led to the industrial breakthrough of laser buildup welding processes in series manufacturing. However, low deposition rates and limited energy efficiency set barriers for the technology – in particular for simply shaped parts. Examples include long hydraulic cylinders in offshore applications, oil production and mining tools as well as large screw-conveyors, which require high strength surfaces. In terms of the coating properties required for these applications, there are no alternatives to laser buildup welding. However, the comparatively high coating costs have been limiting the use of this technology for these applications.

Laser buildup welding, just like any buildup welding process, suffers from energy losses. These are principally connected to the welding process and affect its efficiency. Heat conduction into the base material assumes a key role. On the one hand this cooling process enables the solidification of the laser-induced melt. It also represents the major loss component of the expensively generated and precisely applied laser energy. Up to 90 % of the absorbed energy drains into the workpiece. The fast heat conduction in combination with the laser beam tool leads to especially high cooling rates and spatial temperature gradients, which may become critical for crack prone coating materials.

OUR SOLUTION

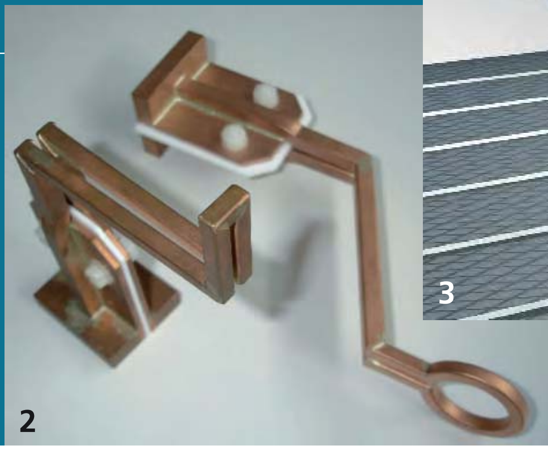
The here presented solution implements a simultaneous support of the laser beam by local inductive heating. The basic principle of this single stage hybrid technology is the combination of two energy sources with very different power densities. This approach allows the superposition of two independent temperature-time regimes, which cannot be achieved by laser beam buildup welding on its own.

The technical implementation occurs in the form of a modular coaxial laser coating head of a new generation. The head integrates an induction module for localized and directionally independent application (Fig. 1). The new COAXpowerline processing head is part of the IWS-COAXn series.

RESULTS

The powder delivery principle is coaxial. All media (powder, gas, cooling water) are fed through an internally and protected medial line. The weld track width is CNC controlled by moving the z-axis during the running process. The inductive heating module is integrated into the processing head. Inductors are selected from an assortment depending on the processing task (Fig. 2). Inductors, which run in front of the laser, help to maximize the deposition rate. Laser trailing inductors reduce the temperature gradients and minimize crack formation in the coatings. A ring shaped inductor in coaxial arrangement with laser and powder jet axes provides direction independent processing capability.

1



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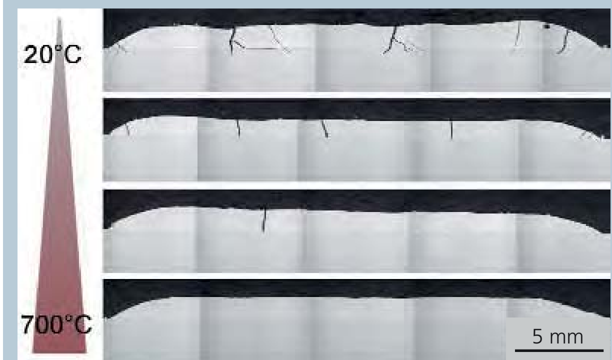
The first application of the new processing head was the fabrication of corrosion protective coatings from INCONEL 625 on large cylindrical steel parts (Fig. 3). A 4 kW diode laser was combined with 12 kW induction power. The deposition rate was 8 kg / h and the welding speeds reached 3 m / min. This means that smaller and less expensive lasers achieve welding performance in the order of plasma powder buildup welding. A record deposition rate of 21.5 kg / h for INCONEL 625 was achieved with 10 kW diode laser and 14 kW induction powers.

Crack prevention due to localized process simultaneous additional heating: cross section of an area coating from Stellite 20, 62 HRC



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To judge the economic impact of this technology, it needs to be considered that the investment costs drop by 50 % per kilowatt total power while the energy efficiency doubles.

In addition to efficiency and productivity, the combination of energy sources is also beneficial to expand the available material spectrum. As a consequence of the increased local heating the $t_{8/5}$ cooling time extends. The reduced temperature gradients make the process accessible in terms of crack prevention to hard and wear resistant metal alloys. An example is a defect-free wear protective coating made from Stellite 20 with a hardness of 62 HRC (Fig. 4).

1 COAXpowerline: coaxial laser processing head with integrated induction module

2 Easy to change inductors, which are mostly independent from the part geometry and were optimized via simulations

3 Process of large area buildup welding on cylindrical parts with inductive preheating

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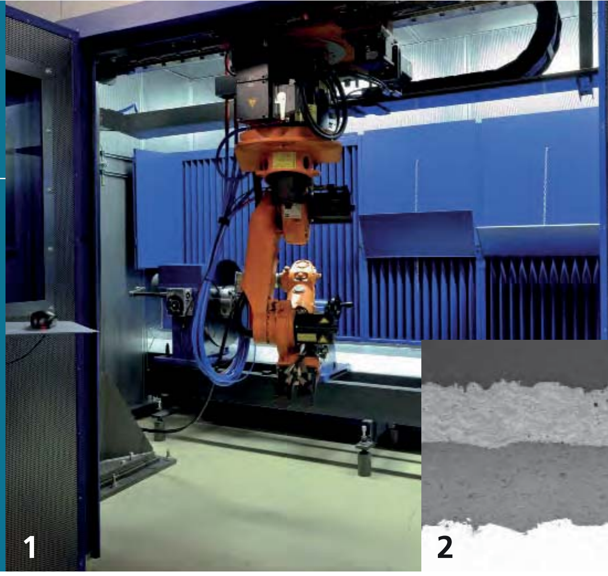
BUSINESS FIELD
THERMAL COATING



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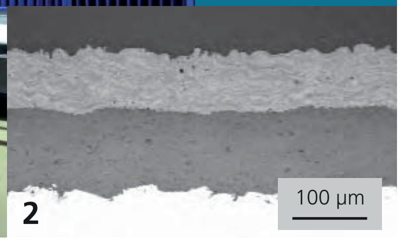

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CERAMIC COATING HEATER ELEMENTS – THERMALLY SPRAYED

THE TASK

Thermal spray processes and in particular atmospheric plasma spraying (APS) and high velocity oxygen fuel spraying (HVOF) are flexible and industrially established coating technologies. Single layered coating systems are made from ceramics, metals or hard metals. Multilayers have an especially high application potential.

For example, by combining conductive and nonconductive coatings it is possible to apply heater elements of nearly any geometry directly to a part that requires heating. There are several advantages including the low profile of the heater elements, the possibility to cover a large area, and their direct contact to the part, which minimizes heat losses.

To generate heat from electrical energy the conductive coatings should have a defined and temperature stable resistance. Previously metallic materials were tried. However, the approach failed due to the thermal and oxidative damage, which limited the lifetime of the coatings.

A fully ceramic heater element was developed in cooperation with Fraunhofer Institute for Ceramic Technologies and Systems (IKTS). The DKG / AiF funded the project.

OUR SOLUTION

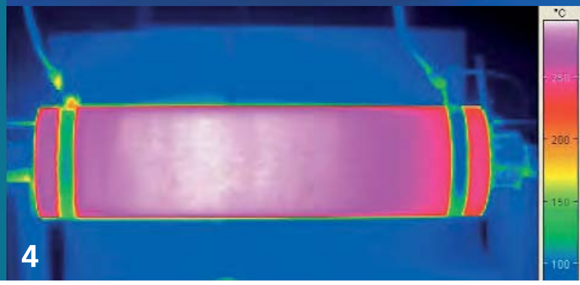
Current state-of-the-art ceramic technology uses aluminum oxide (Al_2O_3) materials for electrically insulating coatings. Conventional APS and HVOF processes fabricate insulating coatings from spinel ($MgAl_2O_4$), which do not suffer the known disadvantages of thermally sprayed Al_2O_3 coatings such as phase changes during the spraying process and the reduction of insulating properties in high humidity.

Electrically conductive ceramic coatings offer a so far rarely used alternative. The material selection depends on the application temperature. The material titanium dioxide (TiO_2) plays an important role. Coating formation in thermal spray processes often occurs under reducing conditions. Here it is possible to form a sub-stoichiometric titanium sub-oxide (TiO_x). The temperature stability can be improved by adding Cr_2O_3. Other materials are available for even higher temperatures.

During the project conductive and insulating ceramic coatings were analyzed with respect to the microstructure, phase composition and electrical properties. Optimal coating composites were selected for different working temperatures.

DRESDEN concept

3



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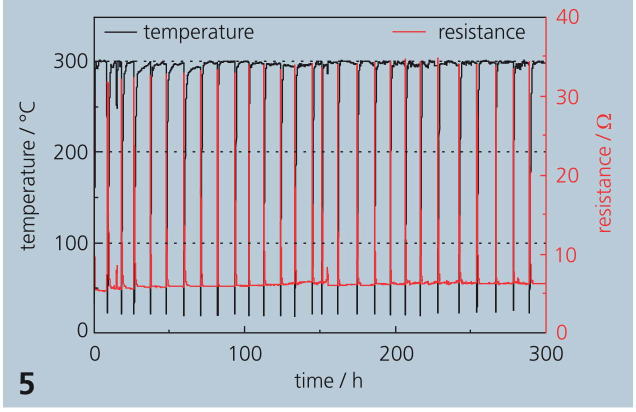
RESULTS

Spinel coatings offer the best insulating properties at high humidity (>70 % RH). These coatings do not suffer from phase changes during the spraying process and the electrical breakdown strength exceeds that of Al_2O_3 coatings.

Insulating coating, conductive heater and cover coating can be freely selected, which provides numerous opportunities for heating and tempering applications. A roll with applied heater was used as a technology demonstrator. During the successful test the roll was heated at 300 °C for more than 300 h (Fig. 3 and 4). Long-term thermo-cycling experiments proved the stability of the coated heater elements for different temperature ranges (Fig. 5). The so far developed coating heater elements can be combined with a selection of appropriate cover coatings to offer application-optimized solutions.

Thermo-cycling to demonstrate temperature stability of TiO_2 / Cr_2O_3 using a directly heated roll at 300 °C over 300 h



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1 *Spraying system at the Fraunhofer IWS*

2 *Coating design of the thermally sprayed heating conductor structure made from ceramic materials*

3 *Roll with areal heating conductor coating*

4 *Thermographic image of a directly heated roll at 300 °C*

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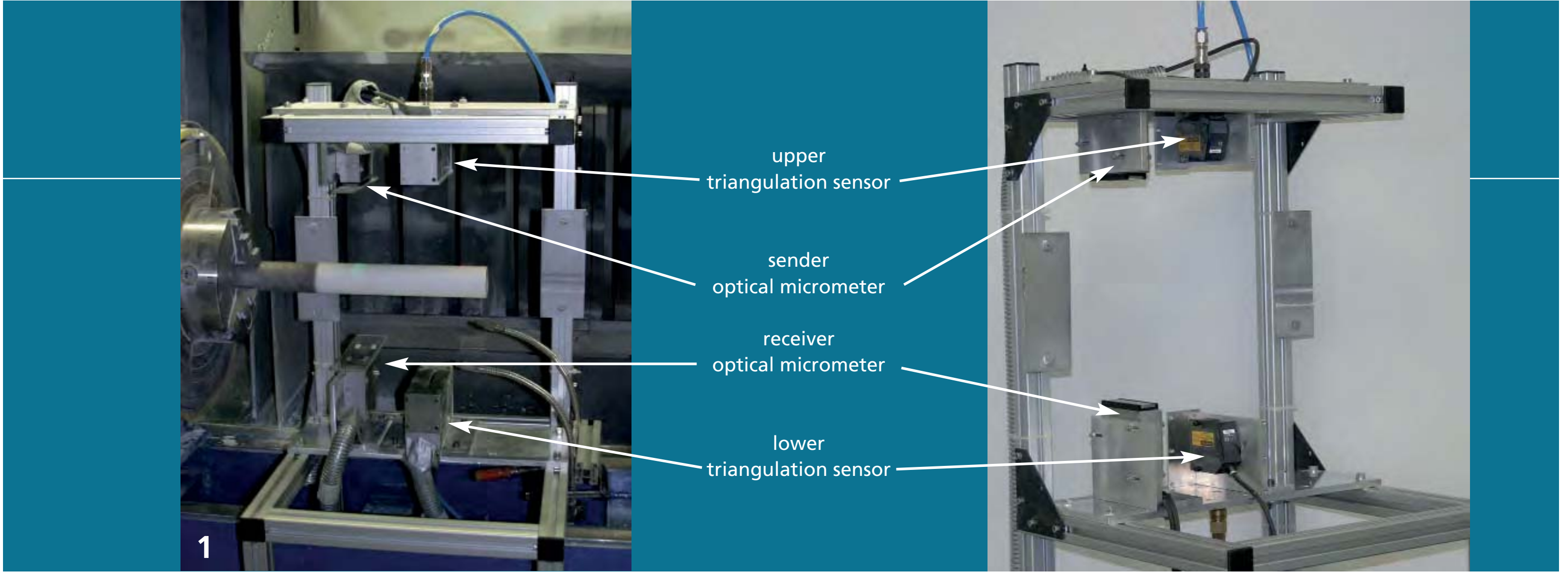


POSSIBILITIES FOR ONLINE COATING THICKNESS MEASUREMENT DURING THERMAL SPRAYING

THE TASK

There are several important economic factors related to thermal spraying, including the selection of the right spraying material and the desired coating thickness. For the latter it is critical to actually achieve targeted thickness as precisely as possible. Putting down too much material and exceeding the specified thickness can substantially increase costs.

Typical methods to determine the coating thickness rely on offline measurements, which either involve the interruption of the coating process, or the utilization of test samples that run in parallel to the actual part coating. Some of these methods only work for particular substrate and coating materials. Therefore concepts to measure the coating thickness during the process without the need for physical contact are of critical importance to the cost effectiveness of thermal spraying solutions.

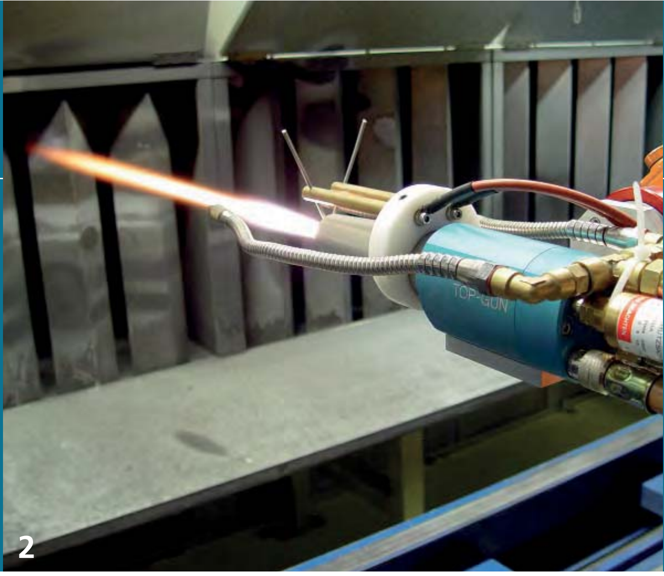
Fraunhofer IWS engineers evaluated the technical possibilities for simple contactless optoelectronic measurement techniques to determine the coating thickness online during the thermal spray process such as atmospheric plasma spraying (APS) and high velocity oxygen fuel spraying (HVOF). The most important task was to determine the reliability of the various methods including the data spread and possible disturbances.

OUR SOLUTION

Two different optical methods were tested for online monitoring. An optical micrometer determines geometric changes of the measured object. A laser triangulation sensor on the other hand, determines the coating thickness via the change of a defined distance between measurement object and sensor. By integrating the measurement systems into the spraying system the data can be collected during the spraying process.

A solid steel roll was used for the evaluation of the measurement techniques. The thermal spray process used about 30 passes of the spray gun to deposit an aluminum oxide coating of 450 µm. The online systems collected data after each pass. After every 10 passes the thickness was measured offline using caliper and magnetic inductive thickness measurements. Afterward the data sets were compared.

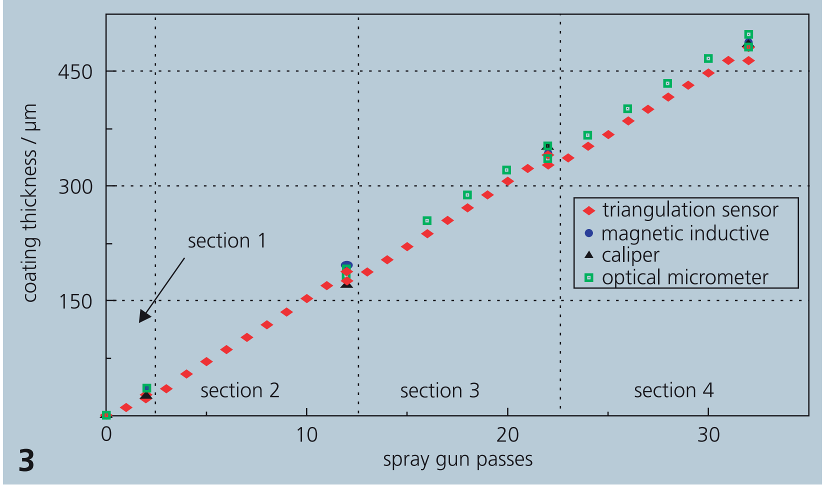
The influence of additional factors was investigated that may disturb the online measurements. Examples are the thermal expansion of the workpieces, the surface roughness of the coating, the radiation of flame or plasmas and mechanical influence form the spraying machine such as vibrations of the rotational axis.



RESULTS

The optical micrometer as well as the triangulation sensor proved suitable for online thickness measurements during thermal spray processes. Both datasets clearly show the stepwise increase in coating thickness, which corresponds to a measurement after each pass. The deviations in comparison to the offline data are minor.

Increasing coating thickness during the APS experiment with four coating sections and comparison of online measurement systems with offline measurement methods



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A direct comparison reveals that the optical micrometer provides higher accuracy and stability (Fig. 3). However, the triangulation sensor is more flexible in terms of part geometry.

The roll's thermal expansion substantially contributed to distorting the online measured coating thickness values. Thus it will be required to correct this influence by simultaneously measuring the temperature of the part and correcting for the expansion in the software system. The accuracy of the data points with compensation was ± 5 to ± 10 µm for the optical micrometer and ± 10 to ± 20 µm for the triangulation sensor.

1 *Measurement setup*
2 *HVOF gun during operation*

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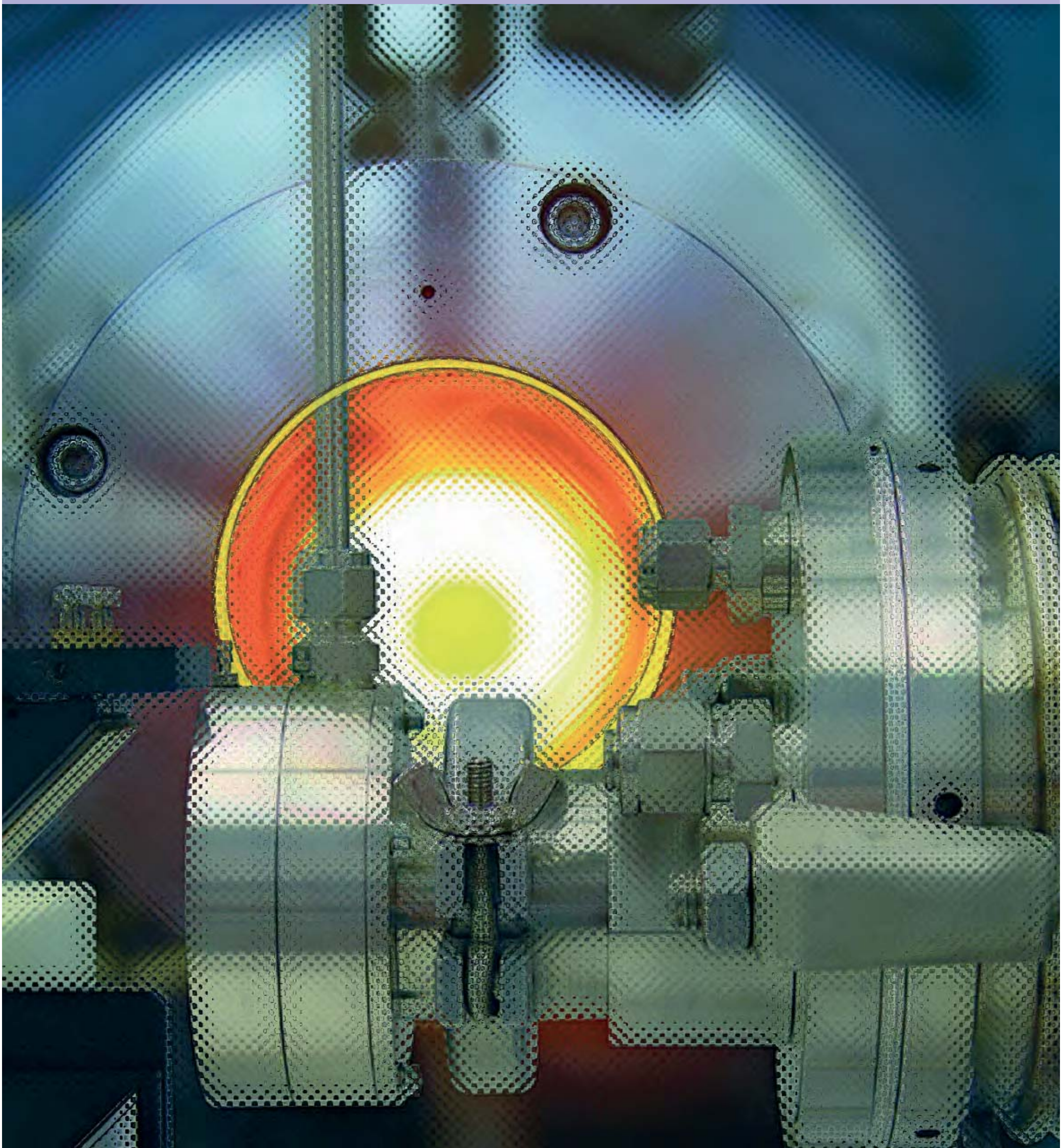


Man will build ships without rudders
so that the largest can be steered by an individual person,
and incredibly fast carts that will need no animal to pull,
and flying machines,
and also those that can dive without harm
to the floors of the oceans and streams.
Roger Bacon (1214 - 1294)

BUSINESS FIELD ATMOSPHERIC PRESSURE CVD COATING TECHNOLOGY

Editor: For many years your department has focused on the development of materials for energy technology. The photovoltaic industry is now facing significant cuts due to the change in feed-in regulations. In addition this industry is facing stiff cost competition from Asian suppliers. Will the German photovoltaic industry be competitive in the medium term? Where do you see chances and risks?

Prof. Kaskel: One of our central tasks is to provide research services to industry that provide them with innovative and more economical production processes. We closely collaborate with equipment manufacturers, which are in Germany frequently the source for decisive innovations to more cost-effectively produce solar cells with improved efficiencies. We focus on the optimization of material flows and recycling. The economic exploitation of PV industry byproducts holds a cost savings potential of 30 %. Also consider the potential export product of environmentally friendly high technology in the form of a more efficient disposal process for exhaust gases and the application of process gases that do not contribute to global warming.

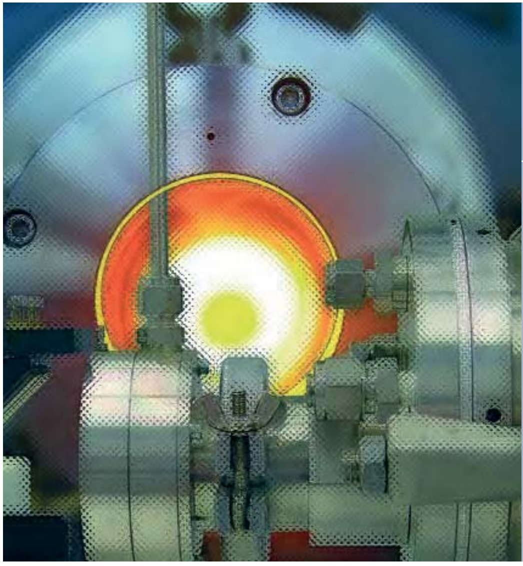
Editor: Isn't it true that the current energy problems are more related to energy storage than transformation?

Prof. Kaskel: I agree with you. Last year we followed this trend and established our own battery laboratory. Here we cover the entire production flow from developing new electrode materials to coating technology and packaging including the testing of individual cells. At the Fraunhofer IWS we focus on high power density systems, which, for example, use supercaps. These are double layer capacitors, which can be very rapidly charged and discharged and provide a good addition to the battery. In demand are also electrode materials for lithium sulfur batteries. Here we were able to demonstrate significant improvements over the state-of-the-art by using our nanostructured carbon electrodes.

Editor: In the news we heard about a large project with the country of Qatar. What is behind this?

Prof. Kaskel: A completely new energy research area at the IWS is the use of highly concentrated solar radiation for chemical reactions. The research centers on the solar thermal decomposition of gases to produce higher value products. By the way, Tschirnhaus already used concentrated solar radiation generating high temperatures when porcelain was discovered in Meissen. We are following good Dresden traditions – so to speak.

Our first project aims at the production of carbon nanoparticles, which can be used as an additive in polymers and in lithium ion batteries. A nice perk of this process is also the byproduct, which is hydrogen – a clean energy source or chemical resource. Since no oxygen is used, no CO_2 is generated. It is a completely CO_2 free process.



COMPETENCES

ATMOSPHERIC PRESSURE CVD TECHNOLOGIES

Plasma assisted chemical vapor deposition processes at atmospheric pressure allow a large area deposition of high quality functional coatings with the need for cost intensive vacuum equipment. The technology is used for continuous and high rate deposition processes on temperature sensitive materials and on slightly curved substrates of various thicknesses. At the Fraunhofer IWS we develop prototype pass through reactors with gas locks for deposition of oxide and non-oxide coatings and for plasma chemical etching at atmospheric pressure. The optimization of the reactor design is based on experimental results and thermo fluid dynamic simulations. The reactor design is modular, which makes it easily adaptable to the requirements of new applications and coating materials.

PROCESS MONITORING

The optimal function of industrial systems and product quality are frequently directly related to the composition of the gas atmosphere inside the reactor. An industry grade in-situ gas analytics is essential for quality assurance of chemical coating, etching and sintering processes and for the monitoring of emissions from industrial systems. The Fraunhofer IWS offers sensors that are based either on NIR diode laser or FTIR spectroscopy. They can be deployed in custom tailored solutions to continuously monitor the chemical composition and concentrations of gas mixtures. In addition, we characterize surfaces and coatings with methods such as FTIR spectroscopy, spectroscopic ellipsometry and Raman microscopy.

CHEMICAL SURFACE TECHNOLOGY

Many applications depend especially on the surface properties of materials. Functional thin films add properties such as conductivity, scratch resistance or self-cleaning behavior to surfaces. The development of nanostructured materials with defined surface chemistry is a condition for a significant performance increase of next generation double layer capacitors and batteries. The group Chemical Surface Technology develops chemical vapor and liquid phase processes for the uniform deposition of new materials over large surface areas. The work focuses on transparent functional thin films and porous carbon coatings for electric energy storage.

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EXAMPLES OF PROJECTS 2010

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CONDUCTIVE IN ONE STEP – INTEGRATION OF CARBON NANOTUBES IN POLYMER SURFACES

THE TASK

The largest fraction of technically important polymers is made from electrically insulating materials. However, the market for electrically conductive polymers is large and continues to grow with manifold applications. Conductive polymers are mainly used for:

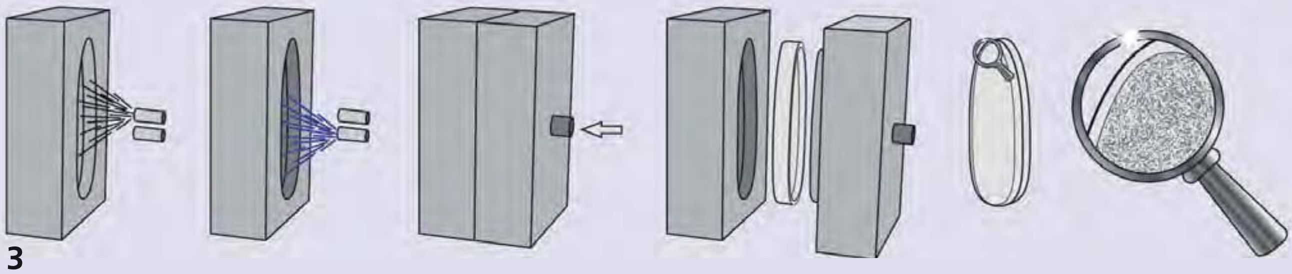
- antistatic application to avoid electrostatic charging,
- cases with electromagnetic shielding,
- electrostatic painting,
- printed electronics,
- electrodes for displays / lighting,
- photovoltaic electrodes.

Various technical solutions are used to make polymers electrically conductive. The approach is to introduce during the polymer melting conductive additives such as conductive carbon particles, carbon fibers, metal powders or fibers. However, a high volume percentage of additives is required which changes the mechanical, physical and chemical properties of the polymer. In the case of transparent polymers the light transmission may suffer significantly. Another approach is coating the plastics with conductive films. Low temperature deposition processes are required. Disadvantages include potential adhesion issues and high costs due to elaborate processing steps. Intrinsically conductive polymers are expensive and not very stable. They are only used for special applications. An alternative offers the here-introduced process, which renders polymer surfaces electrically conductive by introducing carbon nanotubes (CNT).

OUR SOLUTION

During the fabrication process of a polymer part, a CNT film is integrated into the surface which is only a few nanometers thin. Fig. 3 shows the process for fabricating a 3D preform using injection molding. A aqueous dispersion holds the tenside-stabilized CNTs, is sprayed onto the form tool and dried. Afterward the tenside is washed out and a porous CNT thin film remains on the surface of the form tool (Fig. 4).

Fabrication process for a 3D preform using injection molding



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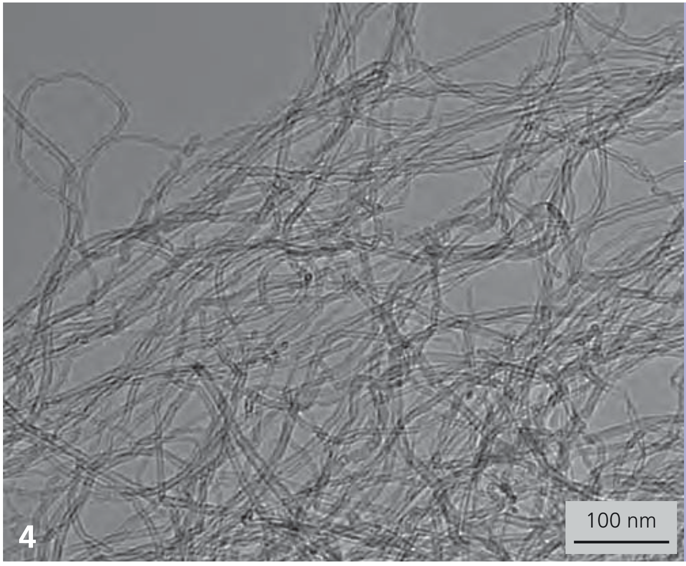

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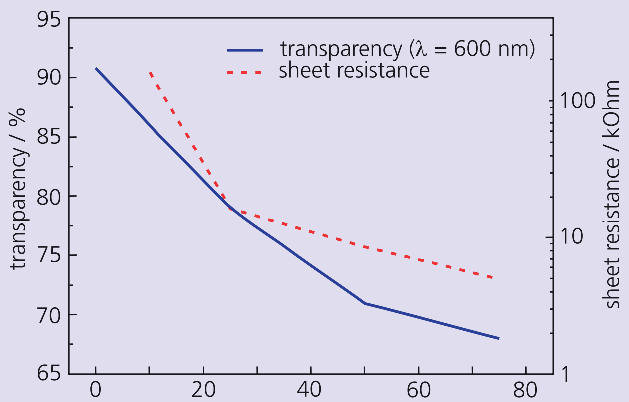
When the polymer melt is injected it infiltrates the CNT network and embeds it into the surface during cooling. The process can be adapted to other thermoplastic processes, which embed the material via the polymer melt (i.e. foil extrusion). Thus the process can be applied to many different polymer materials. Due to the small CNT film thickness it is especially well suited for transparent components. The material costs are very low and the properties of the base material remain almost completely unchanged.

RESULTS

The practicability and functionality of this process were demonstrated for different manufacturing processes. Fig. 1 shows a PMMA-plate (plexiglass) with a transparency of 82 % and a sheet resistance of up to 1 kOhm. Sheet resistance and transparency decrease with increasing film thickness of the embedded network (Fig. 6).

Transparency and sheet resistance of a CNT coated plate versus the thickness of the embedded network



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The process is also suitable for the fabrication of foils (Fig. 2). The CNT network is highly flexible and maintains electrically conductive paths under mechanical deformations (bending, folding). Fig. 4 shows injection molded lamp covers. The CNT films are less than 30 nm thin and have a sheet resistance of 10 kOhm. These parts are used in explosion safe environments and should not charge up for safety reasons. The antistatic guidelines require a sheet resistance of less than 1 GOhm. This process provides lower numbers by orders of magnitudes.

Current work addresses the optimization and automation of process technology, the improvement of CNT network properties and the optimization of the CNT dispersion.

1 PMMA disk with integrated CNT film

2 PET foil with high flexibility

4 TEM image of a CNT network

5 Antistatic PC injection molded preforms

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INFRASORB: HIGH THROUGHPUT SCREENING OF POROUS MATERIALS

THE TASK

High throughput synthesis processes are more frequently used to develop porous materials such as zeolites, activated carbon or novel metal-organic frameworks (MOF). Numerous synthesis parameters are varied to identify the sometimes only very small process window for product fabrication or to optimize existing synthesis routes.

The fabricated products are volumetrically or via x-ray diffractometry analyzed to determine their specific surface areas. These characterization techniques are time consuming and relatively expensive. The analysis of an individual sample may take several hours. Often only a small fraction of the high throughput synthesis output possesses the desired properties. Nevertheless, the large amount of potentially negative samples has to be analyzed as well.

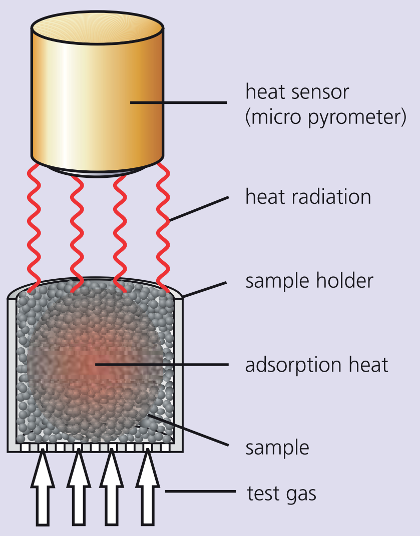
The bottleneck in developing high throughput synthesis therefore lies in finding the few but promising highly porous samples. An enormous cost- and timesaving potential would be accessible by a significantly accelerated but simultaneously equally reliable screening of the entire synthesized product.

OUR SOLUTION

Porous materials are frequently used in absorptive gas cleaning processes. The undesired gas components cover the large surface area of the porous material, get adsorbed and thus separated from the gas flow. During this process each adsorbed molecule releases a certain amount of energy, the adsorption heat.

Fraunhofer IWS engineers developed a measurement technique, which determines the adsorption capability of a material based on the released heat. The sample is exposed to a gas flow, which contains the gas to be adsorbed. When the material adsorbs, the adsorption heat is released and detected with a contactless optical temperature sensor (Fig. 2). The analysis time to measure a sample is on the order of a few minutes. The measurement principle is simple and scalable to enable parallel analysis.

Measurement principle



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RESULTS

The current device generation (Fig. 3) measures up to 12 samples in parallel. Easy to use software supports the user performing the measurements, analyzing and handling the data. Device operation requires a PC and gas supply for the selected test gas and a freely selectable inert gas.

View of the data curves in the device software

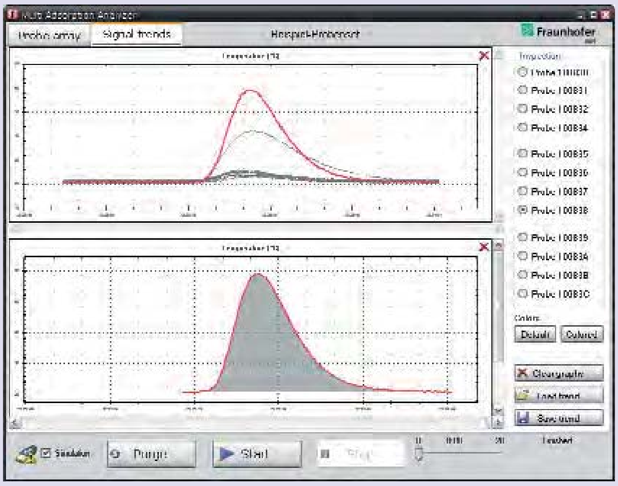

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Fig. 4 shows typical temperature data plots versus time during the adsorption of a gas on the samples. The measurement result is the integral of these curves. To be useful in high throughput synthesis, it is already sufficient to provide a qualitative interpretation: if there is a signal, the synthesis was successful (adsorption occurs). A quantitative interpretation is also possible. The integral data are proportional to the amount of adsorbed gases. The results were confirmed via gravimetric measurements of the adsorption capacity for different model samples.

This simple and fast measurement technique saves time and costs when synthesizing new materials. It can also be deployed for quality control duty in existing manufacturing processes.

1 *Samples of novel metal-organic frameworks (MOF)*

3 *Prototype of the fast adsorption tester*

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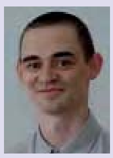
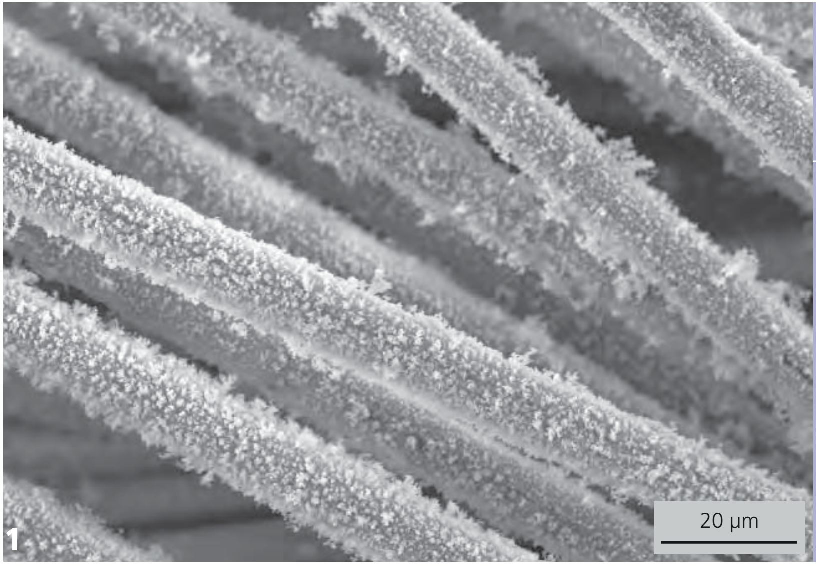
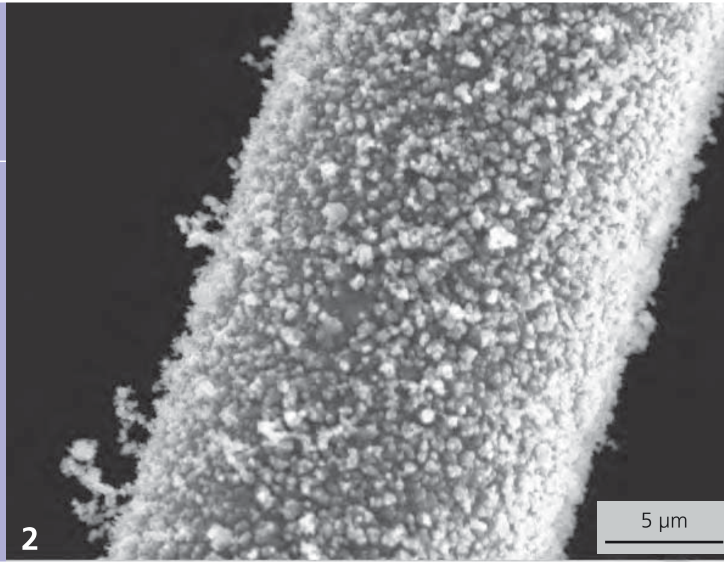






PARTICLE COATED GLASS FIBERS FOR REDUCED THERMAL CONDUCTIVITIES IN VACUUM INSULATION PANELS

THE TASK

The principle of vacuum based heat insulation has been known since more than 100 years in the form of the thermos bottle. Recent years have seen an increasing utilization of this insulation principle in technical equipment such as refrigerators and also for the thermal insulation of houses by using vacuum insulation panels (VIP). However, if a hollow volume is evacuated its outside surface faces a pressure of 1 bar. The cylindrical shape of the thermos bottle withstands this pressure. Planar vacuum insulation panels require a filler material to withstand the high pressures that has a low thermal conductivity. Flat evacuated vacuum insulation panels consist of nanoporous filler materials, which are enveloped in high barrier foils. These VIPs achieve the same insulation performance as conventional materials at one tenth to one fifth of the thickness.

The filler material (i.e. glass fibers) and the enclosed gas determine the thermal conductivity of the VIPs. One possibility to improve the heat insulation of the panels is to reduce the thermal conductivity in the filler material. Pyrogenic silicic acid has a thermal conductivity of 18 mW m^{-1} K^{-1} at atmospheric pressure. Foamed polyurethane (PU) and polystyrene (PS) with about 32 mW m^{-1} K^{-1} and glass fibers with 35 mW m^{-1} K^{-1} are state-of-the-art filler materials.

To reduce the gas contribution to the heat conduction, the internal pressure in the panel is reduced to 50 or even 1 mbar. However, the heat insulation performance varies substantially for different filler materials at different pressures. VIPs filled with agglomerated SiO_2 particles (pyrogenic silicic acid) of pore sizes from 100 to 200 nm, achieve minimal thermal conductivities of 2 mW m^{-1} K^{-1} at a pressure of 10 mbar [1]. The pressure inside of the VIP inevitably increases over its lifespan and thus its heat insulation performance declines over time. The task was to develop a filler material that shows a stable thermal conductivity over the broadest possible pressure range.

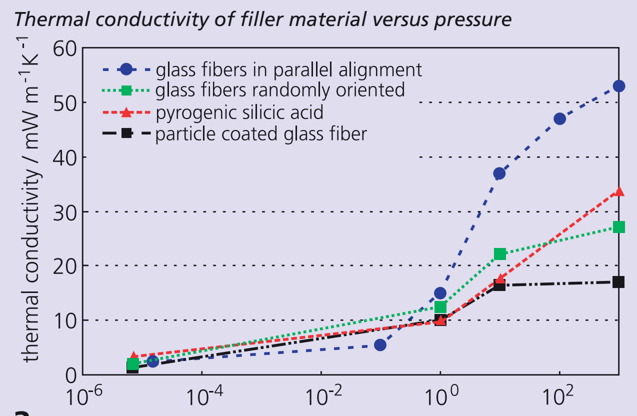
OUR SOLUTION

Fraunhofer IWS engineers in cooperation with Fraunhofer CCL (USA) and the Mackinac Technology Company developed a particle coated glass fiber material with low thermal conductivity over a broad pressure range. Glass fibers were used with a diameter of approximately 15 µm. The deposition of SiO_2 particles was performed in a microwave plasma assisted chemical vapor deposition process (PECVD) at atmospheric pressure. The activation of the argon-nitrogen gas mixture occurred in a 6″ CYRANNUS plasma source. After passing through the plasma source the activated plasma species flow through a nozzle array to the coating zone. In the nozzle array the precursor gases tetra-ethoxy-silane (TEOS) and oxygen are added to the flow. The glass fibers are coated in a roll-to-roll process with a speed of 50 mm s^{-1}.

[1] J. Fricke et al., Nanotecture 2006

RESULTS

The coated glass fibers were initially investigated in the scanning electron microscope (SEM). The fibers were coated from two sides, which led to a uniform surface coverage with particles. The particle diameter is about 400 nm. Smaller particles form agglomerates. The thermal conductivity as a function of the pressure was measured for several materials (Fig. 3). Different samples of particle coated glass fibers show reproducible thermal conductivities.



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At pressures of 10^{-5} mbar all investigated materials show the same thermal conductivity from 2 to 4 mW m^{-1} K^{-1}. The differences in thermal conductivities remain marginal up to 1 mbar (10 to 16 mW m^{-1} K^{-1}). Uncoated glass fibers in parallel alignment show the highest increase in thermal conductivity with rising pressure. The particles improve the situation significantly by reducing the contact area between fibers and limiting gas flow heat conduction. They show the lowest values of 18 mW m^{-1} K^{-1} at atmospheric pressure.

Thus on the laboratory scale it was shown that the particle coating significantly improves the heat insulation properties of an established standard insulation material. The applied system technology is based on a continuous coating process, which enables high volume coating of glass fibers in a roll-to-roll process at atmospheric pressure.

1/2 SEM micrographs of particle coated glass fibers

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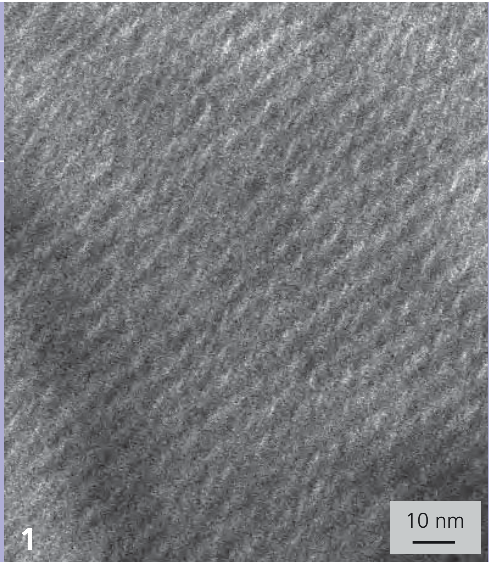
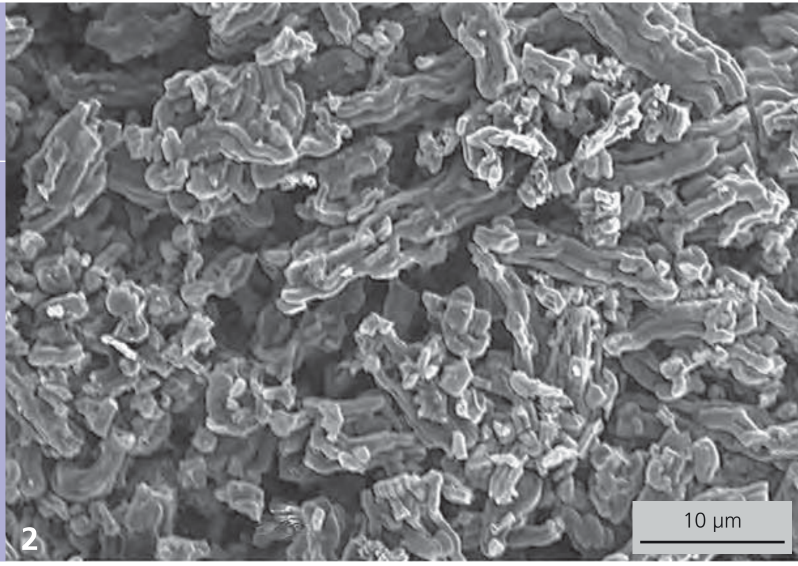




NEW MATERIALS AND PROCESSES FOR ELECTRICAL ENERGY STORAGE

THE TASK

The storage of electrical energy is simultaneously key and bottleneck for many future technology fields including electric and hybrid vehicles. Electric double layer capacitors (EDLC) are, in addition to the battery, a key component for electro-mobility.

EDLCs offer high power densities and lifetimes (cycle stability) and thus ideally meet the power requirements during starting, acceleration and energy recovery during braking in electric and hybrid vehicles. EDLCs can be combined with batteries and provide relief by handling power peak loads. This extends the lifetime of the battery and also offers the option to use smaller battery units.

However, further development is necessary to increase the power density of EDLC cells and modules. A significant increase in power densities in energy storage is only possible via principally new material concepts. For example, EDLCs can be substantially improved by a special pore design in the highly porous carbon materials that is used to build these devices.

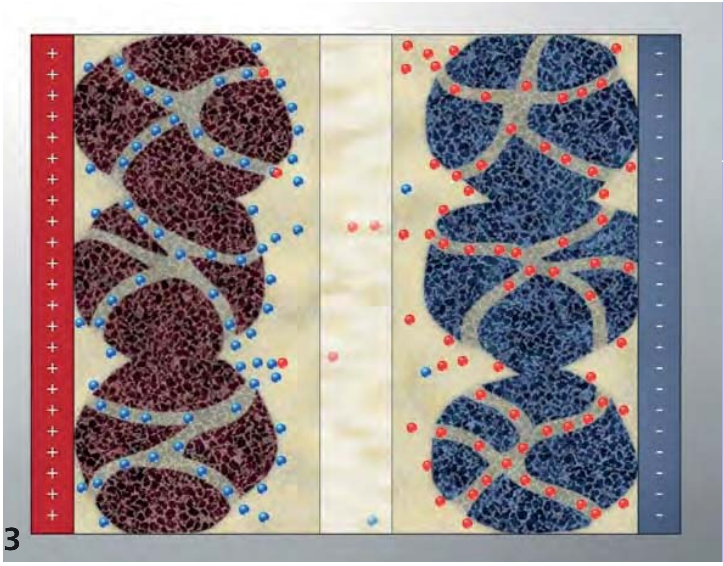
More efficient production technologies primarily aim at cost reduction. Fraunhofer IWS engineers address these challenges by developing solutions in material design and process development for electrical energy storage applications. A particular example will be discussed in the following paragraphs.

OUR SOLUTION

The specific surface area and pore geometry of carbon materials significantly determine the performance parameters of electric double layer capacitors. These devices use electrodes made from porous carbon materials that are coated onto metal foils (current collector). A spacer wetted with an electrolyte separates every pair of electrodes. During the charging process electrolyte ions accumulate in the electrochemical double layer at the surface of the electrodes (anions at the positively charged electrode, cations at the negatively charged electrode). Large surface areas yield high capacitances. Open pores with diameters > 2 nm aid a fast transport of charged particles. The transport of electrolyte ions in the pore system determines the inner resistance of the capacitor and thus the maximal possible power.

Mesoporous ordered carbon materials (OM-CDC), which are synthesized from carbides, have excellent properties for this application. CDCs are chlorinated from carbides (i.e. silicon carbide) at temperatures > 600 °C. The silicon is extracted as $SiCl_4$, which leaves a highly porous carbon material with micropores diameters < 1 nm and surface areas > 1000 m^2 / g.

A template synthesis process produces silicon carbide with hexagonally ordered mesopores. Chlorinating this material leads to OM-CDCs and also to carbon materials that have ordered mesopores in addition to high micropore volumes. This synthesis route yields specific surfaces of up to 2800 m^2 / g. This class of materials provides a perfect test bed to study the influence of different pore geometries for electrode applications in supercaps. In comparison to conventional materials OM-CDCs are expected to provide significant performance increases.



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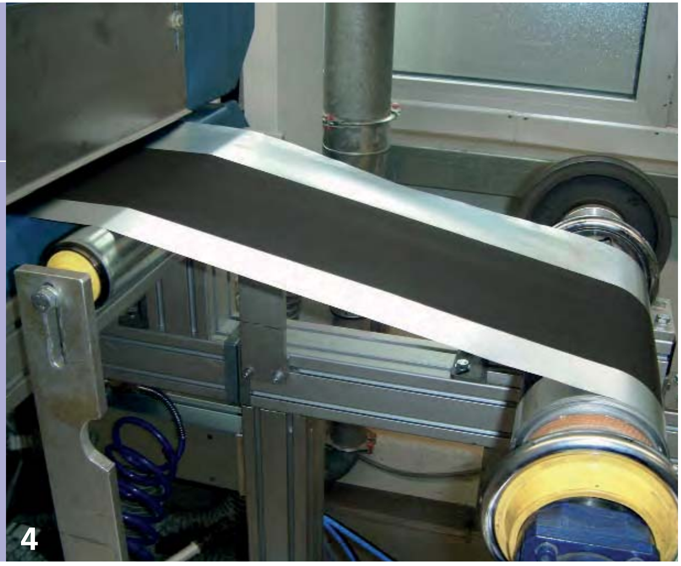

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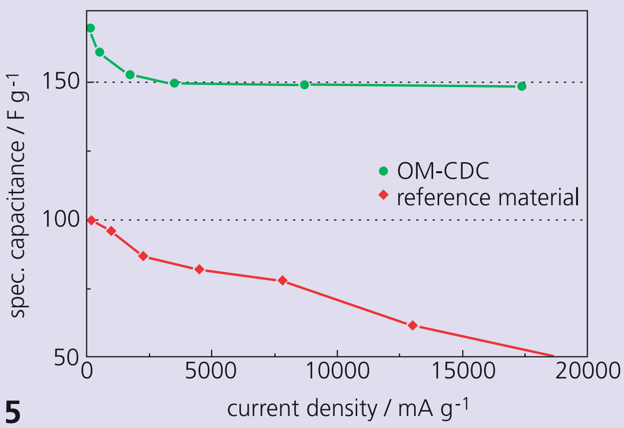
RESULTS

The carbon materials were electrochemically studied using a two-electrode configuration and an organic electrolyte. OM-CDC materials indeed show a significantly improved power performance compared to the porous carbon materials that are conventionally used in supercaps. Conventional materials have specific capacitances of up to 100 F / g. Measurements on OM-CDCs yielded values exceeding 150 F / g. The high surface area of the OM-CDC primarily explains the difference. The advantage of the mesoporous structure becomes evident when testing with higher charging current densities. Conventional materials clearly reduce their capacitance with increasing charging current densities. The capacitance of OM-CDC materials remains nearly constant up to current densities of 20 A / g.

Specific capacitance versus current density



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This behavior is explained by the fast kinetics of the charge carrier transport in the electrolyte. The ordered mesopores enable a fast transport and good accessibility of the material for the electrolyte ions. For double layer capacitor applications OM-CDC materials simultaneously increase the energy density (proportional to the capacitance) and the power density.

This is just one example of electrode and electrical energy storage development activities at the Fraunhofer IWS. It focuses on innovative materials. Another emphasis is the development of scalable manufacturing processes to facilitate the possibility of a midterm industrial implementation. A new IWS laboratory has been set up to fabricate electrodes in a roll-to-roll process. All necessary equipment is installed to produce the materials and to characterize the results.

1 *Transmission electron microscopy image (nano-structure) of the meso-porous CDC material*

2 *Scanning electron micro-scopy image (microstruc-ture) of the mesoporous CDC material*

3 *Schematic design of a double layer capacitor*

4 *Roll-to-roll coater to pro-duce supercap electrodes*

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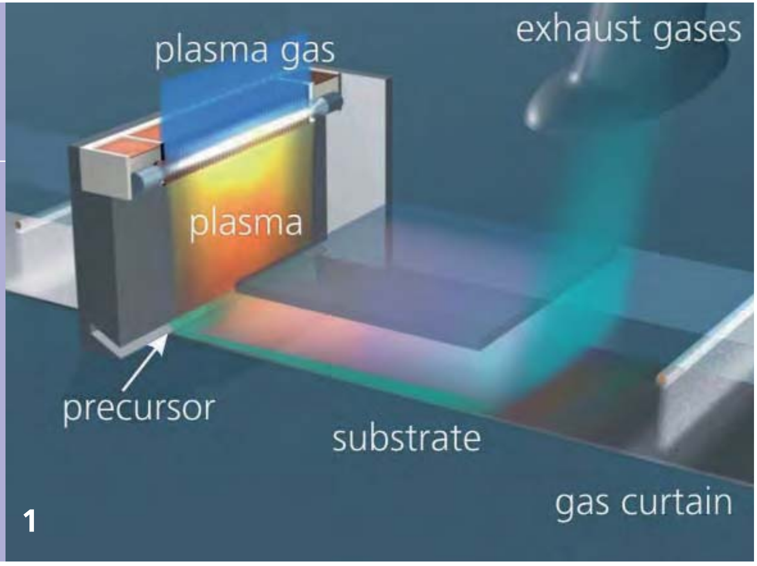


HOMOGENEOUS B-DOPED SILICON OXIDE COATINGS FOR PHOTOVOLTAICS

THE TASK

Today's solar cell production uses either tube furnaces or inline diffusion processes to fabricate pn junctions. The tube furnace process involves the vapor deposition of a thin glass film that contains the dopant ("emitter", e.g. borosilicate glass – BSG). Afterwards the same film is driven into the wafer by diffusion at high temperatures in the same furnace. The inline diffusion process, on the other hand, adds the dopant via a liquid film, which is sprayed or fogged onto the wafer prior to the transport through diffusion furnace.

Both techniques cause emitter uniformity issues, in particular when the wafers have highly structured surfaces. The emitter may collect in recessed features and leave protrusions with less dopant. These localized variations lead to resistive losses after contact fabrication.

OUR SOLUTION

Fraunhofer IWS engineers developed atmospheric pressure CVD technologies to deposit homogeneous and uniformly thick emitter coatings on textured surfaces. These coatings ensure uniform dopant distribution in the wafer after the diffusion process. Two different atmospheric pressure CVD processes were qualified for industrial applications to deposit boron-doped SiO_2 as well as pure boron oxide coatings onto Si wafers.

Thermally activated atmospheric pressure CVD

An atmospheric pressure CVD laboratory reactor is used for thermally activated oxide deposition. The reactants are tetraethyl orthosilicate (TEOS), trimethyl borate (TMB) and ozone. The liquid metal-organic precursors are vaporized and, together with the ozone, flowed into the coating reactor. The solar wafers are heated to about 400 °C, which thermally initiates the coating deposition reaction.

Plasma activated atmospheric pressure CVD

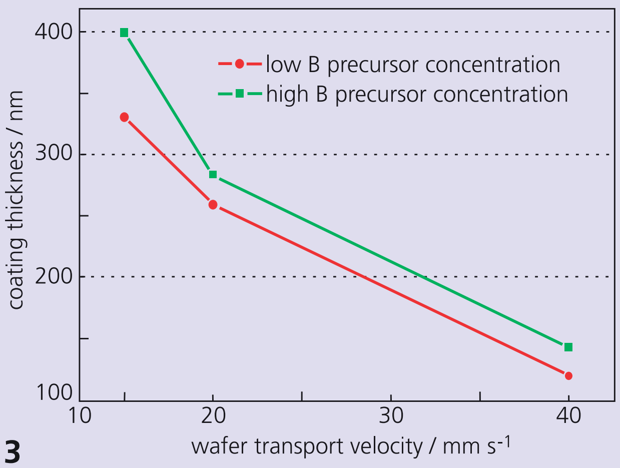
The atmospheric pressure plasma source is a linear dc arc discharge with a working width of 150 mm. The plasma gas perpendicularly flows through the arc discharge and transports excited species from the source toward the substrate. Similar to the thermally activated coating, trimethyl borate (TMB) is used as a boron precursor. It is mixed with hexamethyl disiloxane (HMDSO) and oxygen and flowed in the reaction zone toward the afterglow plasma. As a consequence of the plasma excitation no ozone is required. The wafer temperature can be reduced to 250 °C.

RESULTS

Both processes deposit coatings that are excellent dopant carriers for the synthesis of pn junctions in solar cells. Homogeneously boron-doped silicon oxide coatings were deposited onto Si wafer with different thicknesses and boron concentrations. The deposition rate depends for both processes on the substrate temperature, the precursor concentrations and the O_2 and O_3 concentrations. Fig. 3 plots the coating thickness versus the wafer transport velocity for two different B precursor concentrations. FTIR analysis revealed differences for the coatings depending on the deposition process. The plasma CVD coatings contain significantly more hydrogen, which is partially directly bonded to the boron (Fig. 4).

The developed processes yield doped coating materials of high chemical stability. The coating thickness and thus the amount of dopants are efficiently adjusted via process parameters and wafer transport velocity. Both processes operate at atmospheric pressure and can be trouble-free and economically integrated into the solar cell manufacturing process chain.

Coating thickness versus wafer transport velocity and concentration of B precursors



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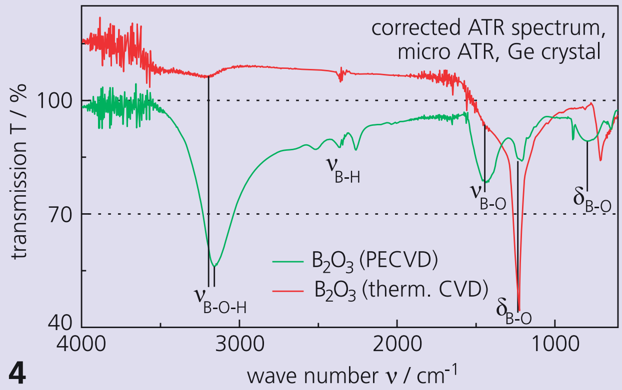
An additional advantage of these CVD processes becomes evident when several doping steps have to be combined, as it is the case in solar cell manufacturing. The coating only occurs on one side of the wafer per step. Two sequential steps can be used to deposit different emitter coatings onto both sides of the wafer. Then a single diffusion step generates two differently doped areas on the front and backside.

FTIR spectra of B_2O_3 coatings, deposited by different processes



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1 *Principle function of the plasma activated AP-CVD process*

2 *Homogeneous SiO_2 coating, deposited by thermally activated AP-CVD process*

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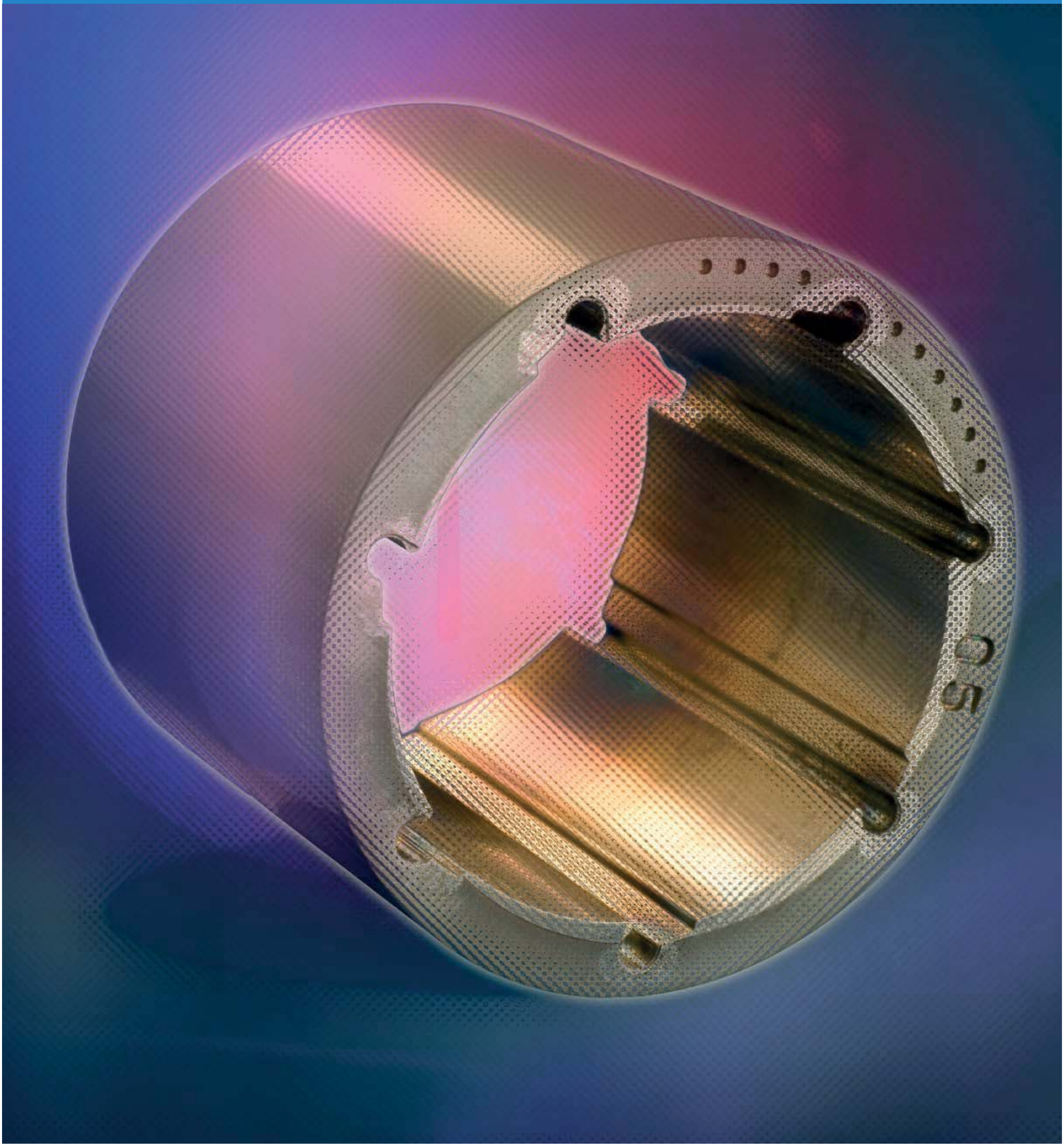


The way to get good ideas is to get lots of ideas, and throw the bad ones away.

Linus Pauling

BUSINESS FIELD PVD VACUUM COATING TECHNOLOGY

Editor: The coating of automotive motor and powertrain components with superhard ta-C carbon coatings doesn't just provide wear protection, it also reduces friction and thus has great potential to increase efficiency and reduce CO_2 emissions. Your department is very active in this field. Is there any news to report?

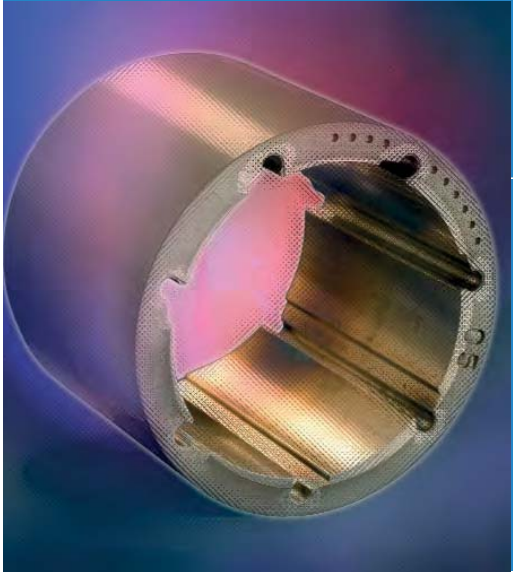
Dr. Leson: In 2010 we made significant progress to commercialize our technology. In a large BMWi project we are collaborating with automakers, suppliers and system builders. In parallel we are qualifying with an industrial partner a high rate deposition process for filtered Diamond® coatings. These films are especially smooth and do not require any post-processing. There is an increasing industrial interest in our R&D services due to the significant advantages of ta-C versus classical DLC coatings. The market for ta-C coatings is growing. We are very well prepared with our Laser-Arc process. In terms of productivity of ta-C deposition there is no competition.

Editor: One of your department's central core competences with longstanding tradition is the fabrication of high precision multilayer coating stacks for x-ray optical components in the hard and soft x-ray ranges. How did this field develop?

Dr. Leson: We are pleased to find that customer's interest in this field is also increasing. Cooperating with a system manufacturer, we equipped a large machine with our technology and installed it at the customer site in industry. We also began to use the multilayer coating technology know-how to develop reactive multilayer coatings. These are beneficially applied for high precision welding applications and have a huge potential. We haven't worked very long on this topic, but already have several industrial customers with whom we are testing these reactive multilayer coatings.

Editor: For several years your department has been intensively working on carbon nanotubes. These materials have spectacular properties and thus there is the promise of interesting applications in many different fields. Are there any applications in reach for these highly interesting materials?

Dr. Leson: Carbon nanotubes (CNT) occur in single-wall and multi-wall varieties. Many of the interesting properties are found only in single-wall tubes. However, these are harder to synthesize. We were able to further optimize and scale our fabrication process for high quality single-wall CNTs. For example, we used these materials to produce flexible transparent electrodes, which retain good electrical properties at very large strain loads, while still exceeding the performance of multi-wall CNTs by orders of magnitudes.



COMPETENCES

X-RAY AND EUV OPTICS

Magnetron and ion sputtering as well as pulsed laser deposition are processes that we utilize to synthesize nanometer single and multilayer coatings. These coating systems fulfill highest demands with respect to thickness precision, smoothness, chemical purity, lateral uniformity and reproducibility. In addition to developing and manufacturing these coatings we also offer our experience in characterizing and modeling nanometer coating systems.

NANOTUBES AND -PARTICLES

Fraunhofer IWS engineers develop processes to synthesize single-wall carbon nanotubes and non-oxide core-shell nanoparticles with special properties in technically relevant quantities. Both material classes can be added to composites. Already minimal quantities lead to entirely new functionalities of the matrix material. We offer these materials in various qualities and processing stages. The development of composites is supported by modeling and substantial characterization.

CARBON COATINGS

The IWS developed amorphous carbon coatings (Diamor®) are exceptionally useful as protective coatings. Films of a wide thickness range are deposited achieving excellent adhesion and performance. The synthesis process operates at low temperatures in a vacuum environment with a special pulsed arc process. IWS engineers collaborate with industrial partners to commercialize Diamor® coatings and the associated coating machine technology. As part of this portfolio we have developed the unique thin film testing technique LAwave®, which is applied for coating optimization and quality control.

PVD COATINGS

Physical vapor deposition (PVD) processes are employed to synthesize high value adding tribological and functional coatings. Thicknesses range from a few nanometers to tens of micrometers. IWS facilities include various processes such as high rate evaporation and highly activated plasma techniques as well as their combinations. A special focus is placed on using arc discharges as the most efficient source of energetic vapor jets.

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EXAMPLES OF PROJECTS 2010

FURTHER INFORMATION:

www.iws.fraunhofer.de/branchen/bra07/e_bra07.html
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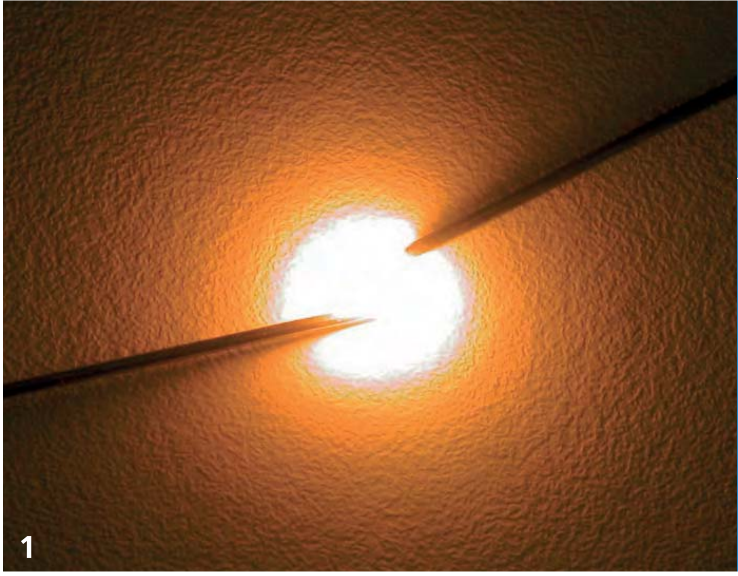

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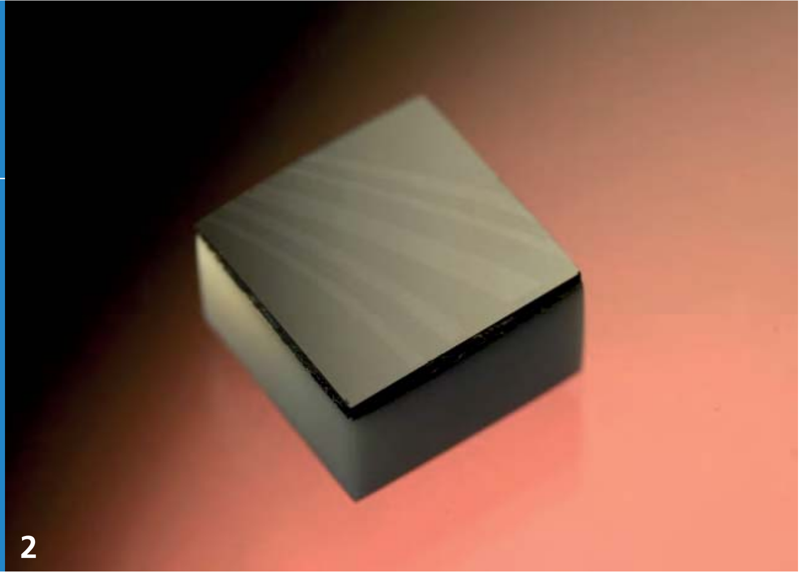

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REACTIVE NANOMETER MULTILAYER SYSTEMS: TAILORED HEAT SOURCES FOR LOW STRAIN JOINING

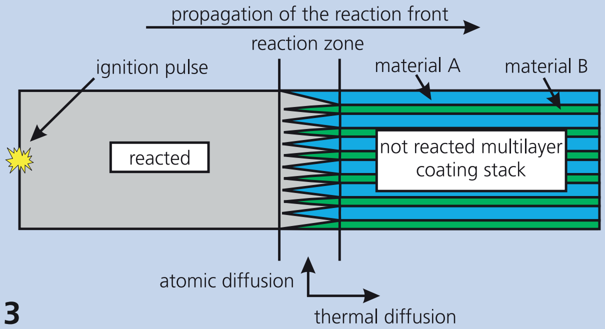
THE TASK

Typical joining processes such as soldering and welding usually require heating of larger regions in the vicinity of the contact zone. This heat input may lead to thermal modification of the material properties or the introduction of stresses in the joint. Such issues could be avoided with a precise heat source that provides heat only to the contact zone of the two material pieces to be joined. If this heat is provided only for a short period of time it could melt the solder without heating the base materials.

OUR SOLUTION

Reactive multilayer systems (RMS) can deliver heat energy precisely and reproducibly to the contact zone. RMSs consist of nanometer multilayers with hundreds or thousands of individual films in their initial state. These films can exothermally react with each other if activation energy is introduced. Then the originally separate films start to atomically diffuse at the interfaces. Given an appropriate material selection, the atomic inter diffusion leads to an exothermal chemical reaction (i.e. $5\ Ti + 3\ Si \rightarrow Ti_5Si_3$). This reactions progresses along the entire RMS and provides heat energy for melting the solder. By tailoring the coating stack design, it is possible to configure special heat sources, that are adapted to a particular joining task. Reactive multilayer coatings can be produced on parts and also in from of freestanding foils. It is also possible to deposit the solder.

Setup and principle of reactive multilayer systems (RMS)



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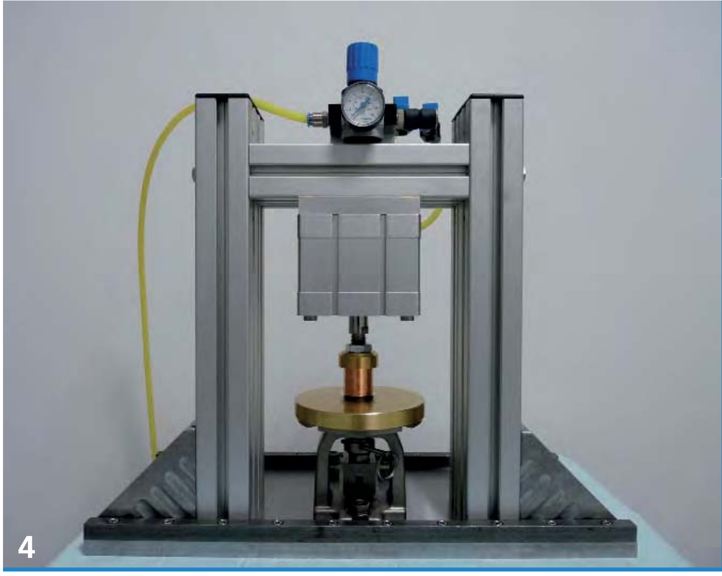
RESULTS

Fraunhofer IWS engineers develop reactive multilayer coatings of various material combinations. Experiments determined the temperature maxima after igniting the RMSs. They ranged from 900 °C to 1400 °C. The released energy was measured using differential thermo analysis (DTA). Typical values are 1.4 to 1.6 kJ g^{-1}. The total released heat directly correlates with the total RMS thickness, which can be between 10 µm and currently 60 µm.

Another important parameter is the velocity of the reaction front, which can also be influence by the detailed design of the RMS. The period thickness of the RMS determines the diffusion length. A smaller period thickness leads to shorter diffusion lengths and faster propagation velocities of the thermal wave and thus to higher reaction velocities.



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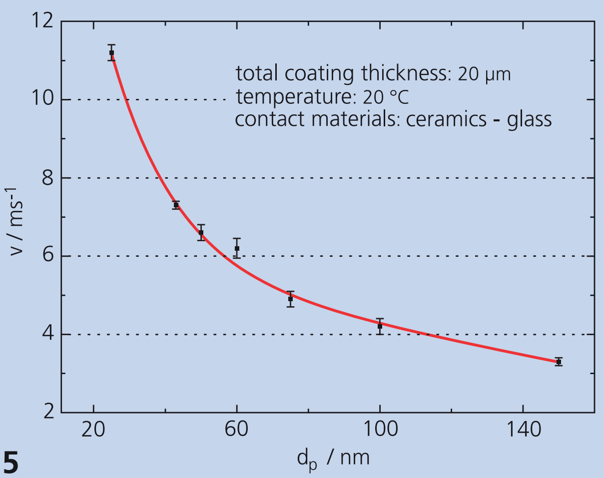
From differential thermal analysis (DTA) it is known that changing the period thickness does not change the energy content of the reactive multilayer coatings. Thus RMS can be exactly tailored to a joining problem.

Reaction front propagation velocity versus reactive multilayer period thickness



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There are numerous advantages when using reactive multilayer coatings. The released heat energy can be precisely portioned because it is possible to calculate the chemical reaction of the RMS due to its well-defined structure. The process times are very short, typically less than a second. There is no significant heating of the components that are being soldered together. The heat is deployed directly in the soldering zone where it briefly acts on the solder. Thus it is possible to join thermodynamically very different materials such as metals and ceramics. Based on the well-defined RMS design the joining process is very reproducible. Compared to adhesive bonding, the joining with reactive multilayer coatings provides the advantage of fabricating electrically and thermally well conductive metallic joints. No outgassing and aging is expected from the joint. The exothermal reaction of the reactive multilayer coating does not require oxygen. This enables special applications such as joining under vacuum conditions, in protective gas or immersed in water.

1 *Electrical ignition of a reactive multilayer system (RMS)*

2 *Joining of a Si wafer with Marcor glass ceramics using reactive multilayer systems*

4 *Setup for pressure ignited joining with reactive multilayer systems*

The following material combinations were successfully tested at IWS: brass - brass, ceramics - silicon, invar - silicon, silicon - silicon and ceramics - stainless steel. In principle it can be assumed that RMS joining works with any material combination.

RMS joining should be considered when conventional joining techniques fail. The special advantages of RMS joining processes benefit the precision joining of microsystems technology, optics and precision mechanics, mechanical and plant engineering and automotive and aircraft technology.

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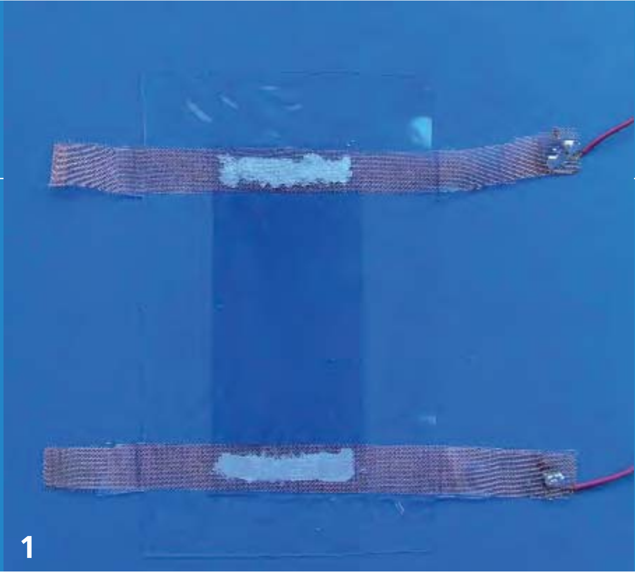

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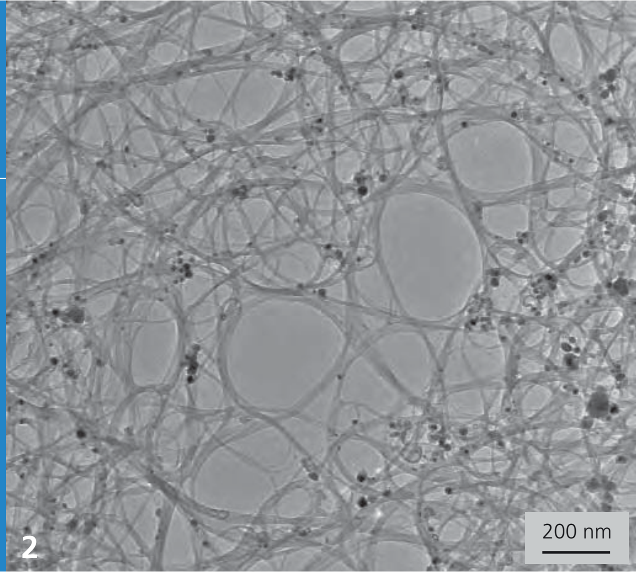

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HIGHLY FLEXIBLE AND HIGHLY TRANSPARENT POLYMER FOILS BASED ON CNTS

THE TASK

Flexible as well as transparent electrodes are said to have great market potential. This is specially valid if both – flexibility and sufficient transparency – are combined. Examples are tactile displays in consumer and automotive applications. The current standard for transparent electrodes is based on ceramic indium tin oxide (ITO). Due to its ceramic nature this material is hard to integrate with polymers and offers limited flexibility.

Flexible electrodes are mostly made from very thin and nontransparent metallic films, graphite filled silicone oil or polymers with a high content (often more than 30 %) of conductive particles (silver particles, conductive carbon particles, fine metal wires). These materials cannot simultaneously achieve good and stable conductivity and good and stable flexibility. Mostly the compromised solution leads to either low conductivities or short lifetimes.

Carbon nanotubes are known for their especially high electrical conductivity. Thus they may offer an interesting alternative.

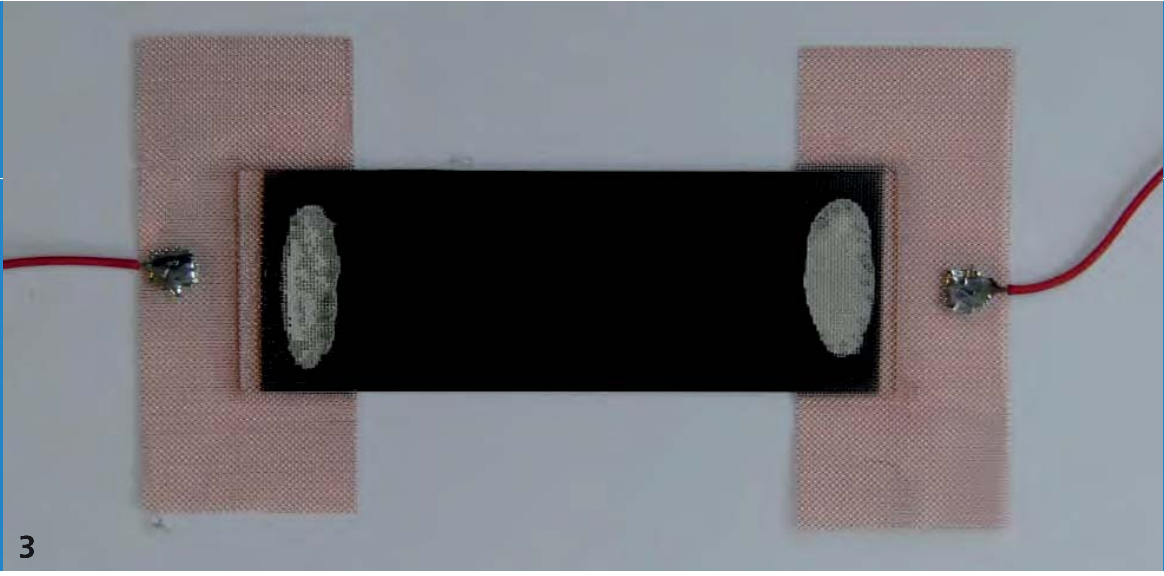
OUR SOLUTION

Our Fraunhofer IWS team developed a large scale manufacturing technology to synthesize and modify tailored single-wall carbon nanotubes (SWCNT). Currently the institute is in the worldwide unique position to fabricate mostly metallic SWCNTs at a rate of 500 g per day. The SWCNTs are purified and functionalized. Semiconducting SWCNTs are p-doped to improve the conductivity. The manufacturing process yields little defects and the gentle handling retains the original SWCNT lengths during all post-processing steps. On average the SWCNTs are 10 µm long. This is an ideal length for a low percolation threshold in polymers as well as for the formation especially well conducting percolating networks.

Fraunhofer IWS SWCNTs were sprayed onto a 100 µm thick silicone foil over an active area of 50 mm x 25 mm. The experiment was performed to prove the compatibility of the tubes with flexible transparent polymer foils. In some experiments the SWCNT coated surface was further infiltrated with another silicone layer. The material was then cured to form a SWCNT / silicone composite layer sandwiched between two pure silicone films (Fig. 1 and 2).

RESULTS

Fig. 4 shows the sheet resistance of doped and undoped IWS-SWCNTs versus the transparency of the films. Antistatic behavior is achieved when exceeding the percolation threshold. This occurs for IWS SWCNTs at a deposition of 0.15 µg SWCNTs / cm^2 (transparency > 98 %). At a SWCNT film thickness of about 20 nm the transparency drops to 90 % and the films have a sheet resistance $R_{\square}$ of 2000 - 3000 Ω / sq (ITO: $R_{\square} \approx$ 100 Ω / sq). The fabrication of such thin SWCNT



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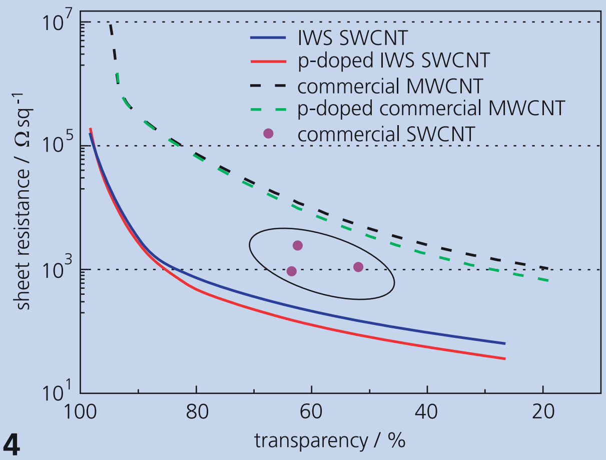
films is not complicated and requires minimal material. Thus they can already be considered a serious alternative to ITO. In particular at very thin films (and high transparency) the IWS solution is remarkably superior compared to carbon nanotubes (single-wall and multi-wall) from other manufacturers (Fig. 4).

Sheet resistance (at = 550 nm) of CNT films versus transparency



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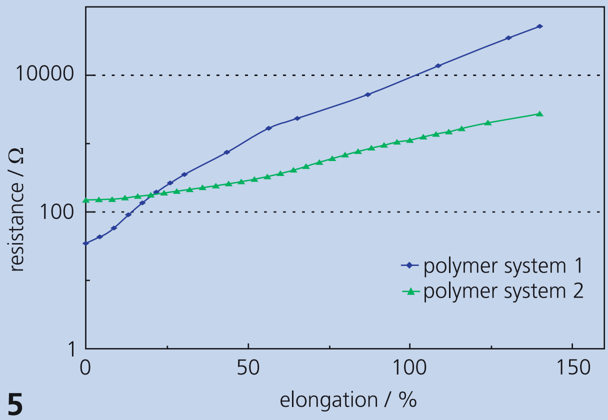
Electrical resistance versus elastic elongation for flexible SWCNT electrodes



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The excellent mechanical integration capability of SWCNT films thinner than 5 µm is advantageous for flexible electrodes. Doped SWCNT films of that thickness (Fig. 3) achieve specific conductivities of > 5000 S / cm. They survive elongations of up to 250 % without delaminating or cracking, which is reflected in a continuous change of the resistance (Fig. 5). Elongations up to 70 % cause reversible resistance changes. Initial conductivities and resistance changes with elongation depend on the polymer system (Fig. 5). Thus the conductivities of the polymer infiltrated films need to be optimized for each polymer system.

1 80 nm thick silicone / SWCNT composite film sandwiched between two pure silicone films with 66 % transparency

2 Sprayed SWCNT film in electron microscope

3 800 nm thick silicone / SWCNT composite film

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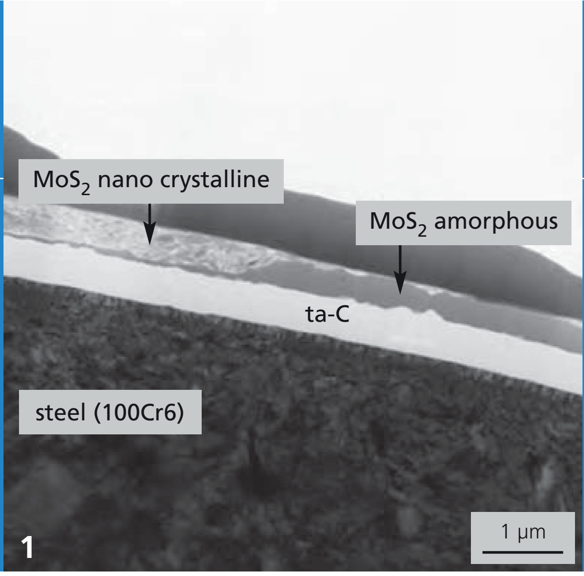
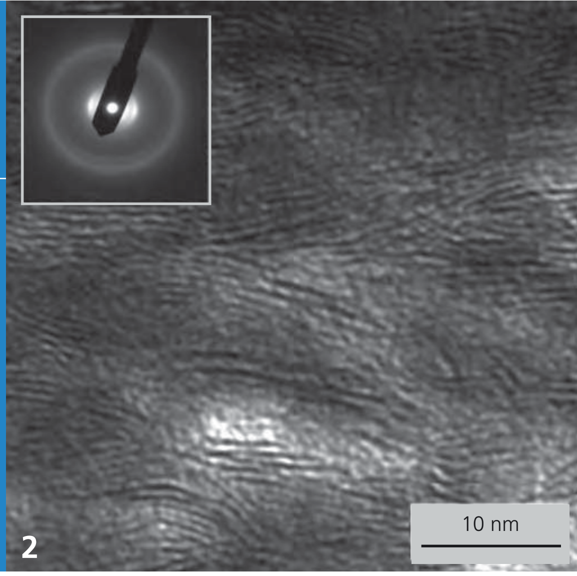




FRICTION AND WEAR REDUCING COATING SYSTEMS FOR VACUUM APPLICATIONS

THE TASK

Compared to conventional conditions, using mechanical components such as gears, bearings or sliding rails in vacuum presents entirely new lubrication challenges for friction and wear reduction. Such components are used in satellites, space stations and (micro-) mechanical systems in technical vacuum conditions. These applications cannot rely on liquid lubrication. Under vacuum there is also no formation of natural protection layers from air oxygen and water. Tribological wear couples in vacuum tend to cold weld and fret already under low loads.

Solutions to this problem are primarily based on solid lubricants such as MoS_2. High quality MoS_2 coatings can be sputtered. These coatings show extraordinarily low friction coefficients in vacuum. Their wear resistance is, however, limited and the coatings fail relatively quickly under atmospheric conditions. Diamond-like carbon coatings (DLC or a-C:H and ta-C based coatings) perform excellently under dry atmospheric conditions but they lose their properties in vacuum. Coatings based on a-C:H with a large fraction of hydrogen are an exception but also have limited wear resistance. There is a continuous need for coating solutions that offer both low friction and high wear resistance in vacuum and atmospheric environments.

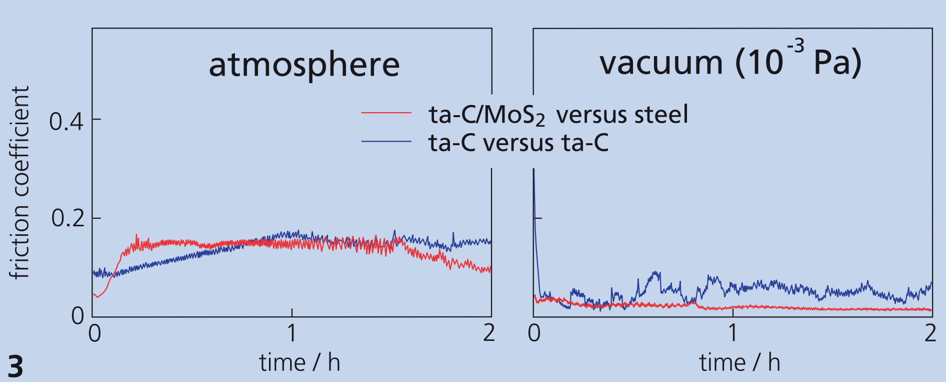
OUR SOLUTION

Fraunhofer IWS engineers systematically studied several variations of ta-C and MoS_2 coatings in individual and combined structures. The BMWi funded this IGF project. Project partners were the Federal Institute for Materials Research and Testing (BAM) and the Fraunhofer Institute for Production Technology and Automation (IPA). The Laser-Arc technology was applied to deposit pure ta-C coatings, mixed ta-C/MoS_2 coatings and various stacks of ta-C and MoS_2 coatings. The coating systems were tested using a vacuum tribometer at BAM.

RESULTS

The first step was the Laser-Arc deposition of pure ta-C coatings. The tribology tests were performed in ball-on-disk arrangement in air and high vacuum. Maxima 1000 MPa load were applied. In contradiction to literature reports, the results showed better friction coefficients in high vacuum than in air when both partners of the wear couple were ta-C coated (Fig. 3). Low friction coefficients lead to low wear.

Friction coefficient of a pure ta-C coating and a ta-C/MoS_2 combination coating in comparison



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In addition to pure ta-C and MoS_2 coatings, several mixed ta-C/MoS_2 and multilayer coatings were produced using the Laser-Arc process. The films were also tested with the tribometer in air and vacuum. A very promising combination was a simple stack made from a base layer of ta-C and a top coating of MoS_2.

The measured friction coefficients for the optimized ta-C/MoS_2 combination coating are convincing in air and high vacuum. Under high vacuum conditions the friction coefficient ranges from 0.008 to 0.02, which is extraordinarily low. These friction coefficients remained stable in 24-hour tests even under increased loads of 1250 MPa. The ta-C base layer provides an abrasion resistant reserve to the coating stack. The MoS_2 top layer provides low friction coefficients in vacuum. TEM investigations showed the initially amorphous structure of the MoS_2 coatings, which then partially convert to nanocrystalline sections under mechanical loads.

1 *TEM cross-section of a ta-C/MoS_2 combination coating. A localized crystallization of the otherwise amorphous MoS_2 layer occurs in the area of the mechanical tribo-contact.*

2 *TEM high resolution image of the nanocrystalline MoS_2 section and a fine area diffraction image (small section). The (0002) basal plane of MoS_2 is oriented parallel to the surface.*

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1

LASER-ARC MODULE WITH NOVEL FILTER TO DEPOSIT SMOOTH TA-C COATINGS (DIAMOR®) WITH LOW DEFECT DENSITY

THE TASK

The classical approach to friction reduction is sufficient lubrication. When lubrication fails or is inapplicable, friction and wear depend exclusively on the surface properties of the materials. Hard and carbon-based coatings in combination with modified lubricants (additives) have made great progress. Here hydrogen free ta-C coatings have the highest potential to reduce friction and wear.

Classical DLC coatings (a-C:H, Me-C:H) were quickly commercialized since the coating could be deposited using only slightly modified system technology, which was conventionally used to deposit hard coatings such as TiN/CrN. So far it proved difficult to respond to the increasing industrial interest in ta-C coatings due to the limited availability of novel plasma sources, which only existed on the laboratory scale.

Hydrogen free ta-C coatings form under vacuum conditions at low temperatures when energetic carbon ions impinge on the surface. The coatings have a high content of diamond bonds. High energetic laser pulses or pulsed arc discharges generate the required carbon ions from a graphite target. The Fraunhofer IWS laser controlled pulsed arc discharge technology (Laser-Arc) proved to be suitable for industrial ta-C manufacturing.

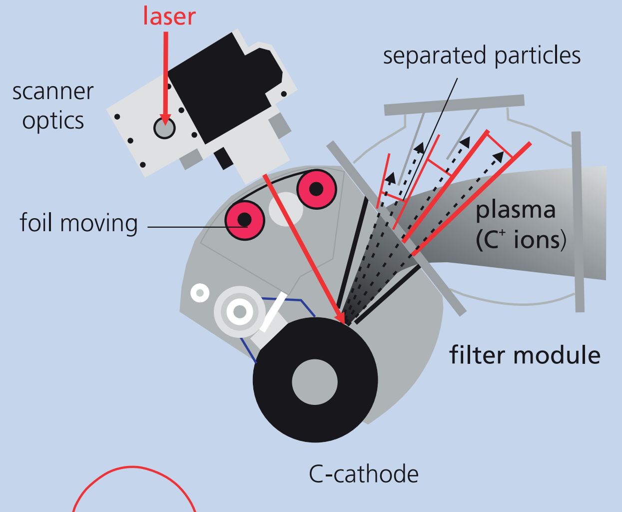
OUR SOLUTION

The Laser-Arc uses short laser pulses (about 120 ns pulse duration) focused on a rotating graphite cylinder to ignite arc discharges (Fig. 2). These discharges are 130 - 330 µs in duration and have peak currents of about 1.5 kA. The graphite is uniformly evaporated from the cylinder due to the rotation in combination with the linear scanning of the laser beam along the cylinder surface. This principle yields excellent target utilization and reproducible coating conditions. Under industrial conditions the substrates are held by a two- or three-fold rotating planetary to achieve uniform coating thicknesses in front of the Laser-Arc source. The necessarily high deposition rates are achieved thanks to the high repetition frequency of the arc discharges (about 600 Hz). The rotating graphite cylinder (cathode) and an anode are placed in a separate vacuum chamber, which is flanged onto the main coating system. Thus the Laser-Arc can be used with any conventional commercial coating system chamber. Linear scanner optics is used to control the laser motion along the entire cathode length. The laser beam entrance window is protected from getting coated by a transparent foil. An automated transport mechanism moves the foil whenever it gets coated. Thus the source can be operated in uninterrupted duty.

RESULTS

SAB funded a project (FZK (PT) 0030/007) to develop the Laser-Arc module LAM 500, which provides uniform deposition over a height of 500 mm. The industrial project partner was Vakuumtechnik Dresden GmbH (VTD). The LAM 500 source chamber was designed to fit an adapter flange mounted to a standard coating system DREVA 600. In this configuration ta-C coatings of up to 10 µm in thickness can be deposited under industrial conditions. The surface roughness of such thick coatings, which is caused by particles originating from the graphite cathode, may be too high for many applications. For such applications it is necessary to smooth down the coatings after the deposition.

Schematic view of a laser controlled pulse high performance source to produce carbon plasmas with particle filter



2 Laser-Arco **LAM 500 F**

This additional process step can be saved when using an IWS patented technology that separates the emitted particles from the deposition plasma before it reaches the substrates. The so-called plasma filtering process was demonstrated on the laboratory scale. The filter module replaces the adapter flange between source chamber and coating machine (Fig. 1, 2).

Using the filter provides smooth ta-C coatings with low defect density. The surface quality conforms to the application requirements. The deposition rate is reduced by 40 %.

The filter unit does not affect the LAM 500 operation. All functions and components (control laser, pule power supply, control unit) can be used without alteration and limitation. The capability to run a fully automated deposition process remains intact.

1 *Coating system DREVA 600 with integrated LAM 500 plasma source with filter module at the Fraunhofer IWS Dresden*

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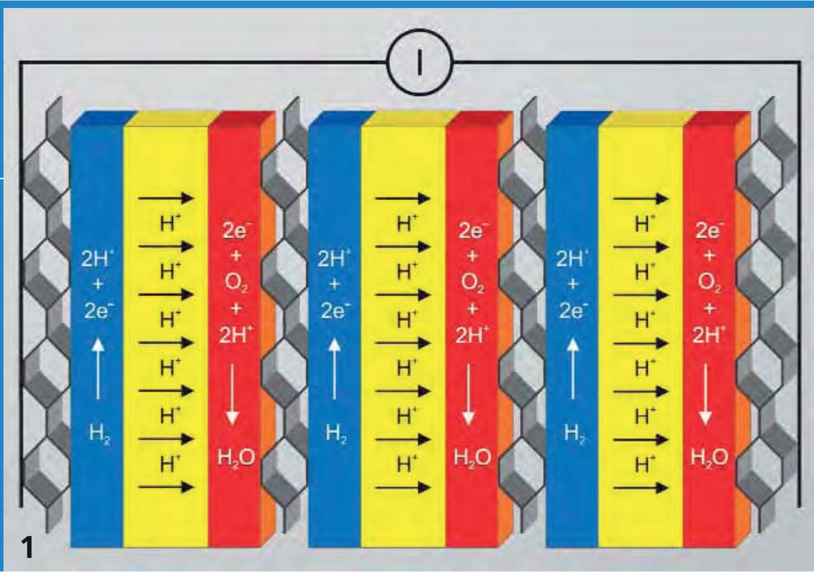

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THE APPLICATION OF CARBON COATINGS IN ENERGY TECHNOLOGY

THE TASK

One of large technology topics for the future is energy – its sustainable generation, distribution, storage and utilization. On the one hand there are more than 6 billion people on this planet with increasing needs. On the other hand there is our natural environment with limited resources and a finite capacity for CO_2. This conflict demands intelligent solutions. This is in particular true for individual transportation: Of the almost 10 tons of CO_2 that on average every German "generates" per year (2008), 2.6 tons are car emissions.

Experts agree that the future belongs to electric motor. It is unclear however where the electric energy should come from. Options include generators coupled with combustion engines, batteries, supercaps or fuel cells. All of these technologies still have disadvantages compared to the combustion engines. Thus today's commercially available electric vehicles are mostly combinations of several of these technologies (hybrid vehicles). The combustion engine has been optimized for more than a hundred years. To match its capabilities still requires an enormous development effort.

OUR SOLUTION

Modern combustion engines lose 25 % of their power due to friction. Fraunhofer IWS engineers applied their materials competency and developed a coating made from pure carbon that combines hardness and wear resistance with a low coefficient of friction: Diamor®. The filtered Laser-Arc process is especially well suited to deposit very smooth and friction reducing coatings. Currently we are testing powertrain components jointly with leading automotive manufacturers and suppliers. The goal is to reduce friction by using Diamor® coatings and to realize the CO_2 savings potential.

Thin metal foils are used as electrically conductive components in fuel cells and batteries. However, these foils form passivation surface layers (Cr_2O_3 on stainless steel, Al_2O_3 on aluminum) that have low conductivity. The high contact resistance causes losses and reduces the efficiency of the unit. IWS laboratories develop a modified Diamor® deposition process, which produces carbon coatings with a majority of graphite bonds. Instead of being hard and diamond-like, these coatings are soft and have a high electrical conductivity (GLC: graphite-like carbon). Applying these coatings to metal foils combines the advantages of metals (low costs, good workability, and mechanical stability) with those of graphite (high conductivity and corrosion resistance). This innovative materials solution will lead to smaller, lighter and more efficient fuel cells stacks with longer lifetime.

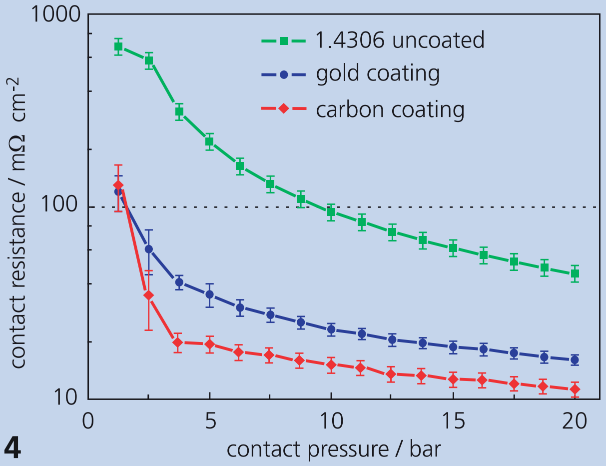
2

3

RESULTS

Coating 0.1 mm thick stainless steel foils with GLC significantly reduces the contact resistance compared to the uncoated material. It is even lower than that of a gold coating (Fig. 4). The coated stainless steel foils can be used to manufacture bipolar plates for fuel cell stacks, which are smaller, lighter and more efficient.

Contact resistance versus mechanical contact pressure for uncoated, gold coated and GLC coated stainless steel 1.4306



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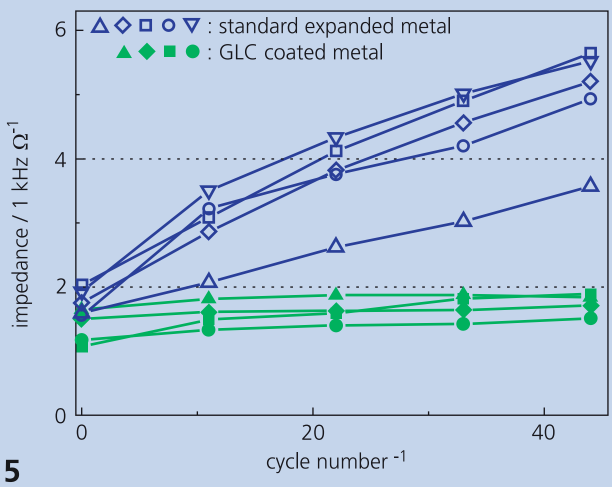
The same principle can also be used for batteries. Anode and cathode use expanded copper foils to provide electricity to the battery during charging and to discharge it during driving. Just like in fuel cells the native oxide layer of the metals reduces the efficiency of the battery.

First experiments with GLC coated expanded metals showed low contact resistance and good stability over several charging / discharging cycles, which was not the case for uncoated expanded metal (Fig. 5). Thus further development could yield high power batteries with improved performance and longer lifetime.

Impedance versus charging / discharging cycle number for Nokia form bicells (3.2 x 5.6 cm^2), with uncoated (standard) and GLC coated expanded aluminum connectors



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1 *Schematic view of a fuel cell stack consisting of three cells*

2 *Coating machine*

3 *View into the opened coating chamber with coated test sheets*

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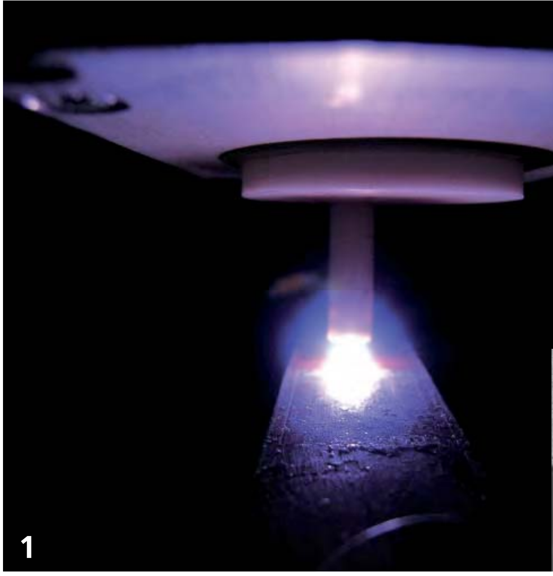

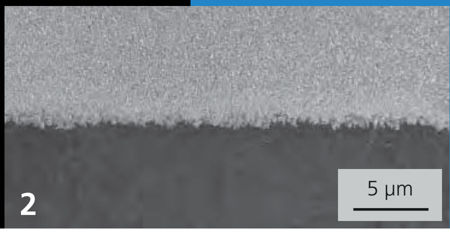

CLEANING OF METAL SURFACES WITH ELECTRICAL DISCHARGES AT ATMOSPHERIC PRESSURE OR IN VACUUM

THE TASK

The cleaning or conditioning of metal surfaces is a frequent task in many technical fields. This is in particular important in joining and coating technologies but also is often needed for forming and other metal processing operations, which require pre-cleaning. There are numerous cleaning processes available depending on the type of contamination.

What cleaning process can be applied depends strongly on the detailed cleaning task and the existing setting. Mechanical cleaning processes are useful when there are a few parts that have to be cleaned from rough dirt. Continuously running chemical processes are often applied for large area surface cleaning. However, due to increasing environmental and economic demands the use of classical cleaning processes gets more restrictive. Mechanical cleaning processes suffer wear (brushes) or require additional effort to handle support materials (i.e. media for sandblasting). Chemical processes require copious preparation and safety technology to conform to environmental regulations. Thus, there is the need for cleaning processes that can be applied to various cleaning tasks but also work without the need for supporting materials and do not generate waste products.

OUR SOLUTION

Electrical arc discharges are equally suitable for localized and large area surface removal operations. The can be used at atmospheric pressure as well as in vacuum.

Localized cleaning at atmospheric pressure:

Pulsed high voltage discharges can selectively clean surface areas at atmospheric pressure conditions. The setup consists of the workpiece to be cleaned and an electrode, which is placed at a distance of several millimeters from the workpiece surface. A generator creates voltage pulses that cause a brief electrical discharge between electrode and workpiece. The discharge removes a limited amount of material from the workpiece surface at a selective processing zone. The electrode is then moved across the workpiece and the discharges are repeated. Discharge by discharge it is possible to clean larger areas. The discharge current, frequency and the speed of the electrode motion can be adjusted. It is also possible to add process gases to the processing zone. These gases support the cleaning process by forcing reaction products out of the processing zone or prevent the formation of new surface deposits.

Large area cleaning in vacuum:

The dc arc discharge is known from coating technologies. It is also an effective tool to remove material from surfaces over large areas. In vacuum, metallic surfaces can be cleaned at high processing speeds. The setup consists of the metal to be cleaned and a counter electrode in the processing chamber. A generator is also needed that provides continuous power to


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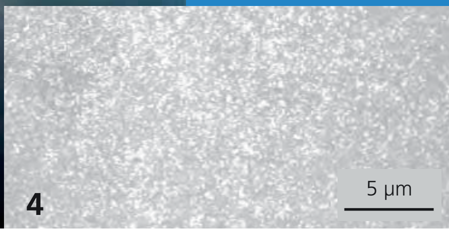

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operate the discharge. The discharge generates microscopically small arc spots on the metal surface, which move at high speed across the surface. Within the arc spots the material abruptly evaporates, which removes only a few micrometer thin layer. The heat input into the workpiece is moderate. Due to the fast motion of the arc spots the material removal occurs in the form of lines, which can be overlapped to clean larger areas. The arc spot motion is controlled by the geometric design of the electrode and by externally applied magnetic fields. The parallel operation of several electrodes increases the processing area.

RESULTS

Both processes were used to clean metal surfaces. They were in particular developed to remove solid contaminations such as scale. The processes also proved to successfully remove fats and oils. The spatially selective process at atmospheric pressure is well suited for situations where a limited surface area needs to be prepared for further processing. That is, for example, the preparation of parts to be joined (welding, adhesive bonding). Fig. 2 shows a metal surface, which was partially cleaned with pulsed discharges. The cleaning is completely based on electrical power. No additional support materials are needed. The processing gas is typically air. In some case nitrogen or argon are used.

Fig. 4 shows a metal surface that was cleaned with a highly productive process in vacuum. The cleaning was performed in fine vacuum. The processing speed depends on the characteristics of the applied discharge and the setup. It can be varied over a wide range. Areal removal rates of several square meters per second are technically controllable. The cleaning process causes a slight roughening of the surface, which is in particular useful for the preparation of joining processes such as adhesive bonding.

1 Cleaning of metal surface with electrical discharge at atmospheric pressure

2 Partially cleaned metal surface

3 Vacuum arc discharge to remove contaminations from metal surfaces

4 Large area cleaned metal surface

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PRICES AND HONOURS 2010

2010's "Young Professionals" in the welding arena come from Fraunhofer IWS.

At the scientific conference "Youth researches and welds" Mr. **Florian Woelke** presented on his topic "Basic experiments in friction stir welding of aluminum materials using 5-axes kinematics". He won 1st place from the DVS initiative "Young Professionals". His research is based on the work of the Fraunhofer IWS group "Special Joining Processes".

At the same conference the award for "Best Poster" went to Mr. **Tilo Witt's** contribution. His poster "Laser powder buildup welding with rectangular spot for high deposition rates" impressed the jury with its technical content as well as its presentation.

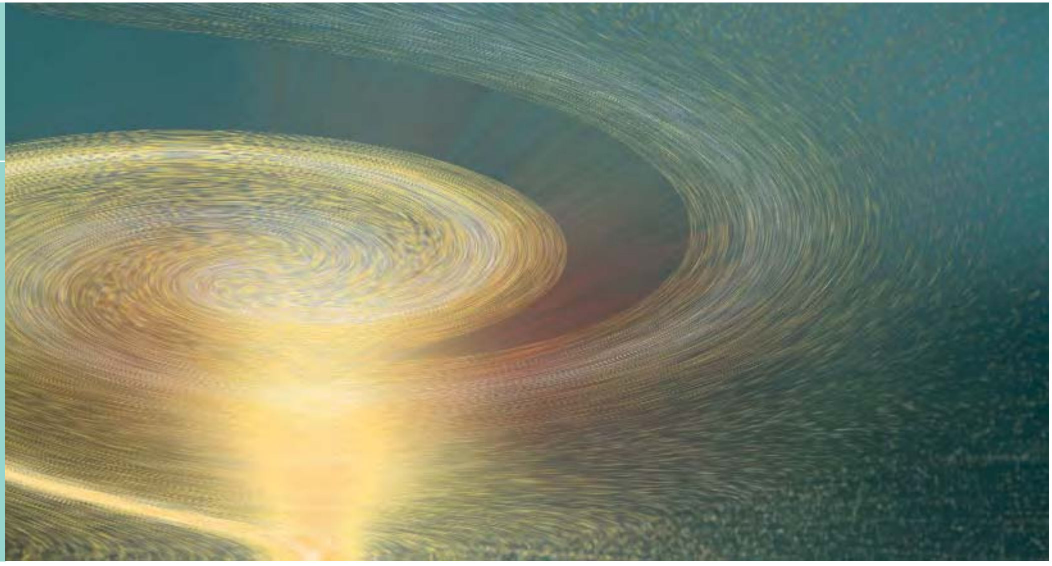
IWS prize winners of the year 2010 were honored on December 17th.

The award for the best innovative product idea to open a new business field was issued twice this year. Within only a few months, Mr. **Oliver Throl** and Mr. **Matthias Leistner** developed a measurement system for the high throughput screening of porous materials. The technique and system are described on pages 74 / 75 of the annual report. The company Rubotherm acquired the license right to market the system.

Drs. Gunther Goebel (front left) and **Jens Standfuss** (front middle) and Mr. **Andreas Grimm** (front right) received an award for the efforts on expanding the application possibilities of the Pentapod machine. This parallel kinematic system was

acquired in 2009. Meanwhile it is used at Fraunhofer IWS for machining operations, laser beam welding and hardening, friction stir welding and deep rolling. The system is fully 3D capable. It can be easily converted and is very flexible to use. Within the first year of its use it supported the generation of 600 kEuros in project revenues.

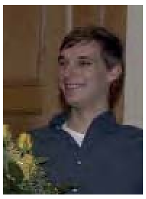
The award for best scientific-technical contribution was handed to **Dr. Frank Sonntag**. He developed and implemented microfluidic concepts to increase the sensitivity of lab-on-chip systems. Modularly built simulation models describe physical and flow technical processes in the reaction zone. They also help to characterize the influence of numerous parameters and provide approaches to increase the sensitivity. Last but not least they lead to less costly and efficient microfluidic systems.



Ms. **Esther Roch Talens** (2. from left) and Mr. **Aljoscha Roch** (3. from left) received the award for the best scientific performance from a junior scientist. Both awardees jointly achieved the dispersing of Fraunhofer IWS SWCNTs in solvents and subsequently pursued coating process development with these materials. By doping and optimizing the contact resistance they improved the conductivity of IWS-SWCNTs by one order of magnitude. Based on these results it is possible to fabricate flexible, transparent and conductive electrodes for photovoltaic, adaptronic, sensor and electronic applications (also see pages 72 / 73 and 88 / 89).

Outstanding student contributions were honored in the area of nanotechnologies. The award recipients were Ms. **Claudia Richter** and Mr. **Martin Kroll**. Ms. Richter optimized the

synthesis parameters for the selective fabrication of semiconductive and metallic nanotubes. She developed a semi-quantitative characterization method to determine the fractions of semiconductive and metallic nanotubes in a batch. The method is based on



adsorption spectroscopy. Mr. Kroll performed a technology analysis addressing the topic "Development trends and applications of single-wall carbon nanotubes". His study was well received and acknowledged within the innovation alliance Carbon Nanotubes – CNT of the Federal Ministry for Education and Research. The document is available for download on Fraunhofer IWS websites.

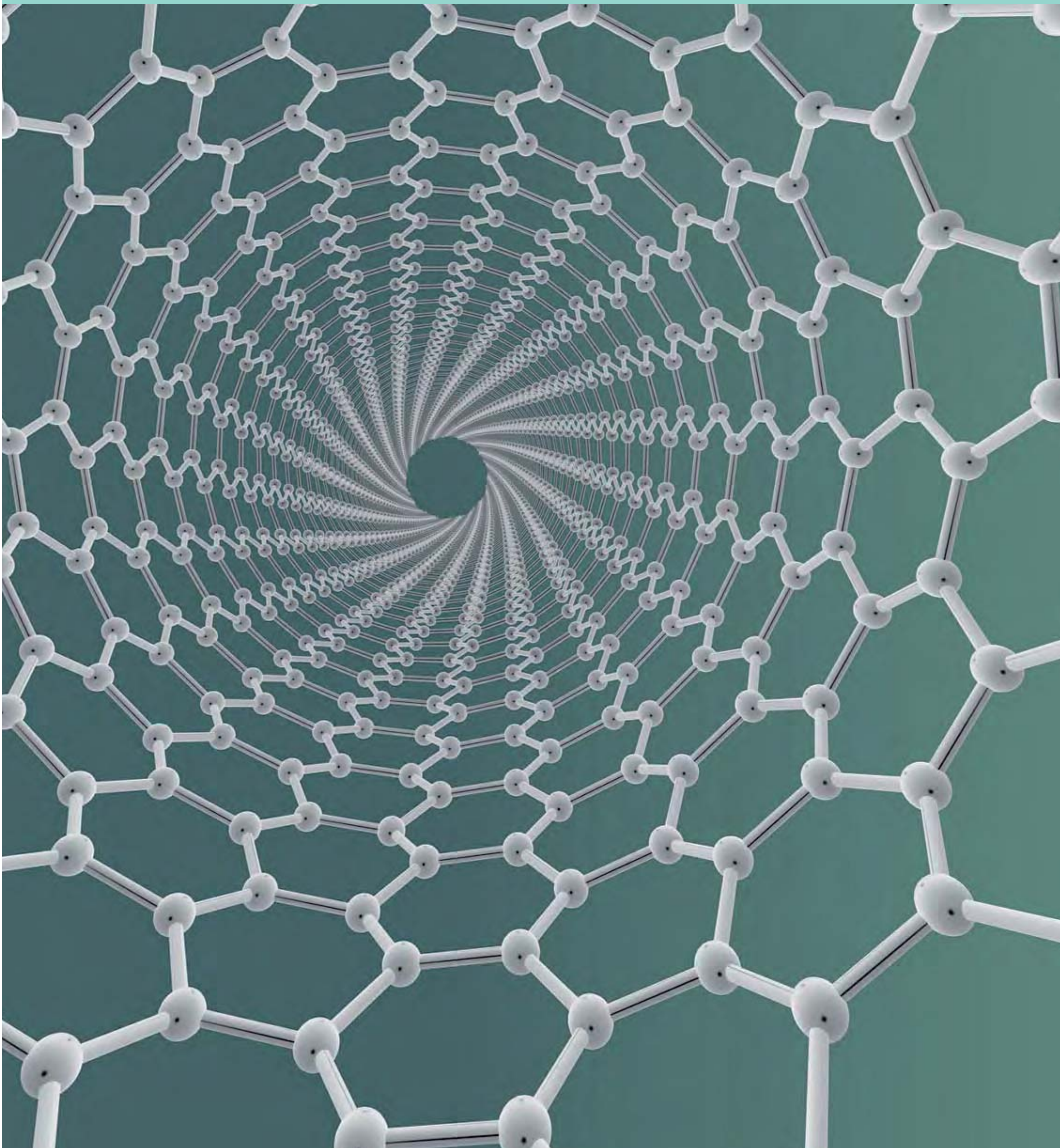
The works of Mr. **Markus Hauser** and Mr. **Ronny Wappler** were equally honored with an award of an outstanding student contribution. Mr. Hauser performed experiments to

study the ablation and cutting of fiber reinforces polymers. The results provided the information for the annual report article on pages 24 / 25. They led to the launch of a new IWS business field addressing the high efficiency remote processing of fiber reinforced

composite materials. Mr. Wappler delivered a decisive contribution to the development of a novel technical system for laser beam buildup welding. A coaxial powder nozzle was equipped with an inductive preheating module and numerous other improvements. A patent application was submitted and the nozzle is already being successfully marketed using the brand name COAXpowerline (see pages 62 / 63).

The special institutes award went to Ms. **Birgit Schaub** (2. from left) for her crucial contributions preparing and executing the Nanofair 2010.

NETWORKS



THE FRAUNHOFER-GESELLSCHAFT

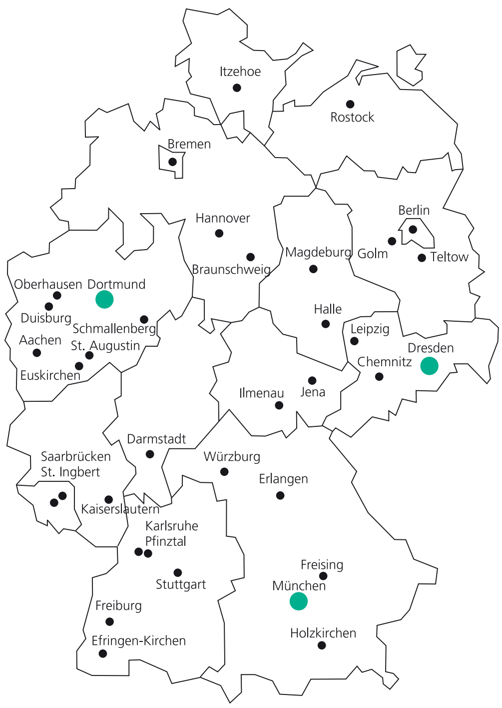
Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual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

At present, the Fraunhofer-Gesellschaft maintains more than 80 research units in Germany, including 60 Fraunhofer Institutes. The majority of the more than 18,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.65 billion. Of this sum, more than €1.40 billion is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development.

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

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



Economic power
determines the present of a country;
its youth determines its future.
Unknown author

CONNECTION TO THE UNIVERSITY OF TECHNOLOGY (TU DRESDEN)

COOPERATION FRAUNHOFER IWS – TU DRESDEN

A cooperation agreement regulates the collaboration between IWS and TU Dresden. Based on a joint appointment, Prof. Beyer simultaneously holds the positions of Fraunhofer IWS director and a chaired professorship at the TU Dresden. This arrangement is based on the following concept: The emphasis at the university chair is on research and teaching, and applied research and development occur at the IWS. IWS employees are involved in university activities, and vice versa, university employees join IWS efforts. Ultimately, IWS and university chair form a unit with different emphases.

advantages for IWS:
- cost effective basic research
- education of junior scientists for IWS
- access to scientific assistants

advantages for the TU:
- R&D participation in industrial projects
- integration of latest R&D results in education
- education of students using latest equipment

PROF. DR.-ING. HABIL. E. BEYER
CHAIR OF LASER AND SURFACE TECHNOLOGY

topics:
- laser systems engineering
- laser processing methods
- plasma in manufacturing technology
- surface, micro and nanotechnology

Following professors of the TU Dresden work as department heads at the Fraunhofer IWS:

PROF. DR. RER. NAT. HABIL. S. KASKEL
CHAIR OF INORGANIC CHEMISTRY

topics:
- synthesis, characterization and application of porous materials
- inorganic nanoparticles
- nanocomposites and hybrid materials

PROF. DR.-ING. C. LEYENS
CHAIR OF MATERIALS SCIENCES

topics:
- metallic and intermetallic lightweight construction materials
- high temperature materials
- thin film systems
- materials testing

PROF. DR.-ING. U. GÜNTHER
CHAIR OF PRODUCTION TECHNOLOGY STEINBEIS UNIVERSITY

topics:
- chipping surface processing technology
- production design

DRESDEN concept

"DRESDEN-CONCEPT"

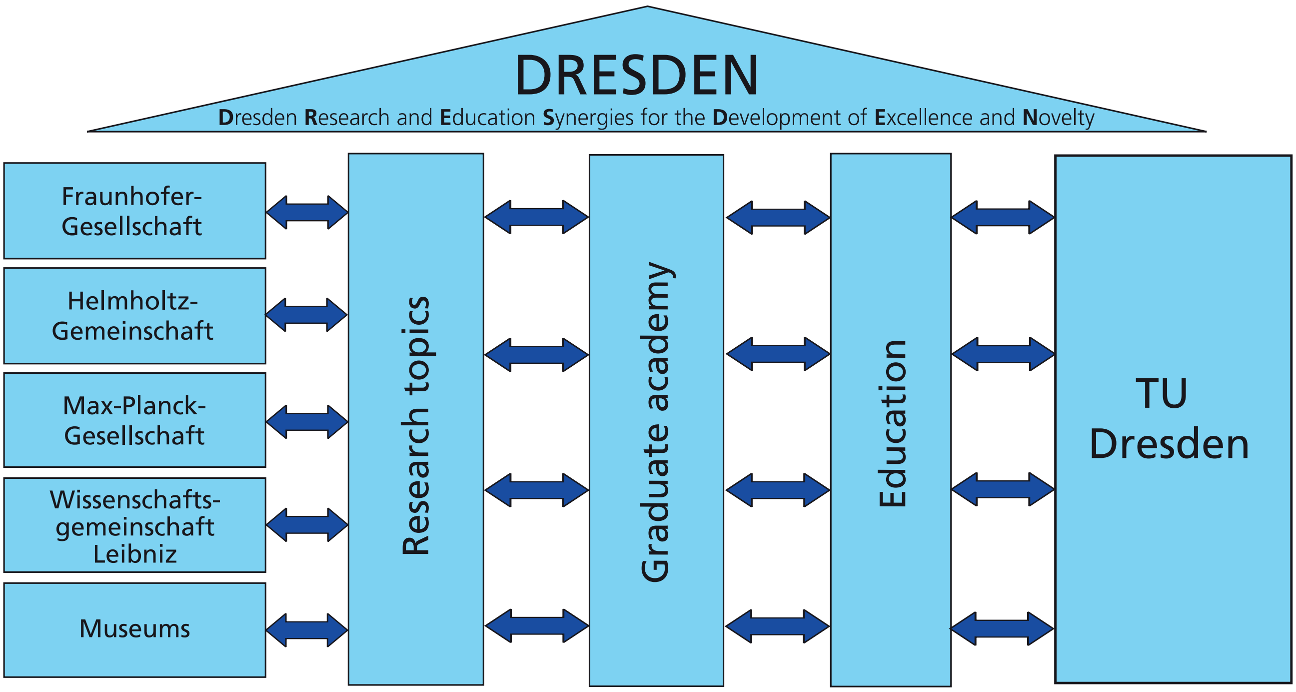
Dresden is among the leading research locations in Germany with a high concentration of scientific institutions: ten universities including the TU Dresden, the university of technology and economy Dresden (HTW), 12 Fraunhofer institutions, three institutes of the Max Planck-Gesellschaft, three institutes of the Leibniz-Gemeinschaft and the Helmholtz-Zentrum Dresden-Rossendorf.

Strong networking activities are pursued in Dresden's scientific landscape to further build on this advantage and to form an excellent research and education region. Since February 2009 the TU Dresden has been forming an elite research alliance with Dresden's research institutions and the museums in the state capital. Such an alliance is unique not only for Germany, but also globally.

The name of the alliance is its program: DRESDEN-concept (**D**resden **R**esearch and **E**ducation **S**ynergies for the **D**evelopment of **E**xcellence and **N**ovelty). The collaboration of non-university and university research and education institutions with the TU Dresden creates synergies benefiting research, graduate education and scientific infrastructure.

The concrete goals of the DRESDEN-concept are:

- definition of joint research emphases,
- establishment of graduate schools in these areas,
- collaboration to attract excellent scientist from all over the world,
- utilization of synergies of existing infrastructure (laboratories, equipment) as well as student education.



"DRESDEN INNOVATION CENTER ENERGY EFFICIENCY (DIZE^{EFF})"

The Dresden Innovation Center Energy Efficiency originates from the very successful cooperation between the University of Technology Dresden and the Fraunhofer-Gesellschaft with the DRESDEN-concept.

The goal of the innovation center is to strengthen academic education, research and innovation competency of both institutions through close scientific collaboration. The results shall benefit the Dresden research region.

The competences of 4 Fraunhofer and 8 university institutes are bundled to collaborate on research relevant to energy efficiency:

- high performance solar cells,
- fuel cells,
- high temperature energy technology,
- lightweight construction and energy efficient manufacturing,
- energy saving displays.

These topics are of substantial interest to industry in terms of research and development services and education of scientists and engineers.

Within this innovation center the TU Dresden and Fraunhofer-Gesellschaft particularly focus on the promotion and support of the next generation of scientists and engineers. They offer attractive working conditions to junior researchers.

	Fraunhofer institutes			
TU institutes	Material and beam technology	Electron beam and plasma technology	Ceramic technologies and systems	Photonic microsystems
Surface and manufacturing technology	☐			
Inorganic chemistry	☐		☐	
Applied physics		☐	☐	☐
Materials science			☐	
Lightweight construction and polymer technology	☐			
Semiconductor and microsystems technology				☐
Electronic packaging laboratory				☐
Solid-state electronics		☐		
Power engineering		☐	☐	

The Dresden Innovation Center Energy Efficiency achieves a high performance level because it tightly connects basic research at the University of Technology Dresden with Fraunhofer's competences to transfer technologies and innovations to industry. Thus the implementation speed for industrial innovation increases. The university and Fraunhofer strengthen Germany's economy.

The Fraunhofer-Gesellschaft provides 6 million Euros and the Free State of Saxony commits 4 million Euros to support the innovation center. These funds support numerous highly qualified scientific jobs in the region from 2009 through 2013. Additional industrial financial commitments generate more scientist jobs in the subsequent years.

www.innovation-energieeffizienz.de
www.iws.fraunhofer.de

The Fraunhofer IWS coordinates the project and is the authorized contact partner.

SPEAKER

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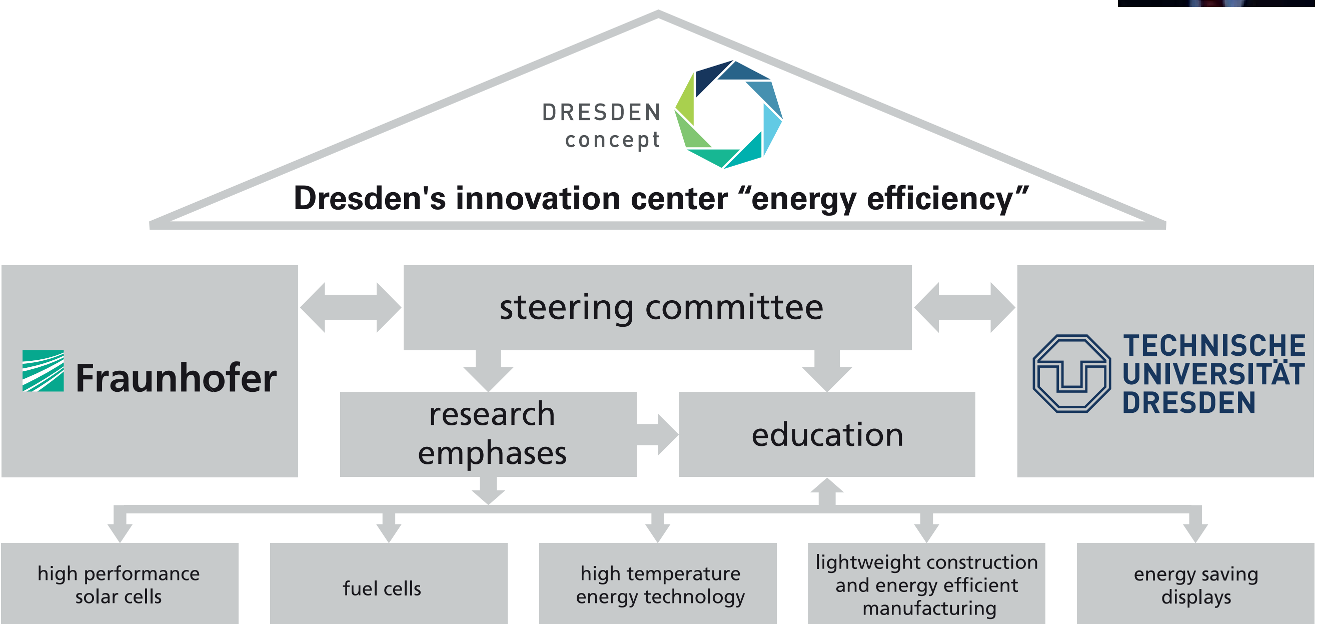

PROJECT GROUP AT THE DORTMUNDER OBER-FLÄCHENCENTRUM (DOC)

The DOC Dortmunder Oberflächencentrum develops tailored coatings using continuous processing of steel band. Development goals include the further development of functions such as corrosion resistance, scratch resistance, electric conductivity and cleaning properties.

The Fraunhofer IWS is a partner at the DOC and has a project group operating on site. This group develops coating processes based on PVD, PACVD and spraying techniques as well as focuses on laser materials processing.

Novel zinc alloy coatings (ZE-Mg) present an outstanding result of this collaboration. At half the thickness of convention zinc coatings these new coatings offer the same corrosion protection combined with significantly improved laser weldability. Hybrid and combination processes were developed and in particular the hybrid welding of high strength steel components. It is also possible to combine cleaning and welding or welding and post galvanizing processes.

In its 1100 m^2 facility the Fraunhofer group offers a number of complementary process for surface refinement. State-of-the-art equipment is used to generate nearly pore free and extremely adhering plasma spray coatings. Highly stressed areas of parts and tools are protected with millimeter thick wear protective cladding using laser buildup welding. The vacuum coating capabilities include machines that handle meter sized and ton heavy parts, which are coated with nano- and micrometer thick high performance coatings such as Diamor®. These coatings provide outstanding hardness and excellent sliding properties. Coating materials are under development offering additional corrosion protection capability.

It is frequently possible to combine these various state-of-the-art processes. The resulting broad technology spectrum in combination with the Fraunhofer IWS know-how provides confidence to TKS or other customers that they will receive a technically and economically optimal solution. Compact and mobile new solid-state lasers of high beam quality and up to 8 kW laser power are used for process development but can also be deployed for trouble shooting missions directly at the customer's plant.

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PROJECT CENTER (PCW) LASER INTEGRATED MANUFACTURING IN WROCŁAW

The Fraunhofer project center was established in 2008. It works actively on establishing the Fraunhofer model in the Polish research market. In 2010 Wrocław's University received substantial funding from a Polish investment project "Optolas" to expand its technical equipment base. New laser technology and analyzing equipment was acquired. The investment project finished with a seminar titled "Opto-mechatronics and laser technologies for industrial and medical applications". The seminar primarily addressed interested parties from industry but also research institutions.

The workshop "Optical technologies for energy efficiency in manufacturing and product design" was held at the ITM 2010 fair in Poznan. Application oriented contributions were primarily aimed at the Polish and Eastern European industries. Both events lead to the expansion of existing networks and to new contacts and will be continued in 2011. Two current projects intensify the collaboration between Polish and German scientists.

The project "BioReactor" aims at the generating fabrication of a biocompatible reactor. The goal is to create materials and process knowledge to fabricate scaffold structures. Fraunhofer IWS contributes the in-house developed scaffold printer and the Polish colleagues possess extensive know-how in the areas of rapid prototyping and generative fabrication. Both institutions bundle their strengths, gain new knowledge and purse new developments.

www.iws.fraunhofer.de/polen.html

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The project "RemCoVis" addresses the development of new visualization and monitoring solutions to overcome obstacles in CO_2 laser based remote processes. Tools are created, which contribute to process understanding and accelerated process development. Fraunhofer IWS engineers provide experience and knowledge of laser remote applications and Wrocław University complements the effort with extensive competences in the areas of optical inspection and image processing.

FRAUNHOFER CENTER FOR COATINGS AND LASER APPLICATIONS (CCL)

The US market is one of the most important international benchmarks and innovation driving forces for applied research and development. Since 1997 the Fraunhofer IWS Dresden has been concentrating its USA activities within the "Fraunhofer Center for Coatings and Laser Applications" (CCL).

The Fraunhofer Center for Coatings and Laser Applications mirrors the main activities of the IWS in laser and coating technologies. With an annual turnover of $4.2 Mio the center is one of the strongest Fraunhofer centers in the USA. Since 2003, Dr. Jes Asmussen heads the CCL. He is a professor at Michigan State University and his previous work in diamond coatings and synthesis ideally complement the know-how of the Fraunhofer IWS in the area of Diamor® coatings.

The CCL consists of two divisions,
the "Coating Technology Division" at the Michigan State University in East Lansing and the "Laser Applications Division", which is situated at the Fraunhofer USA Headquarters location in Plymouth, Michigan.

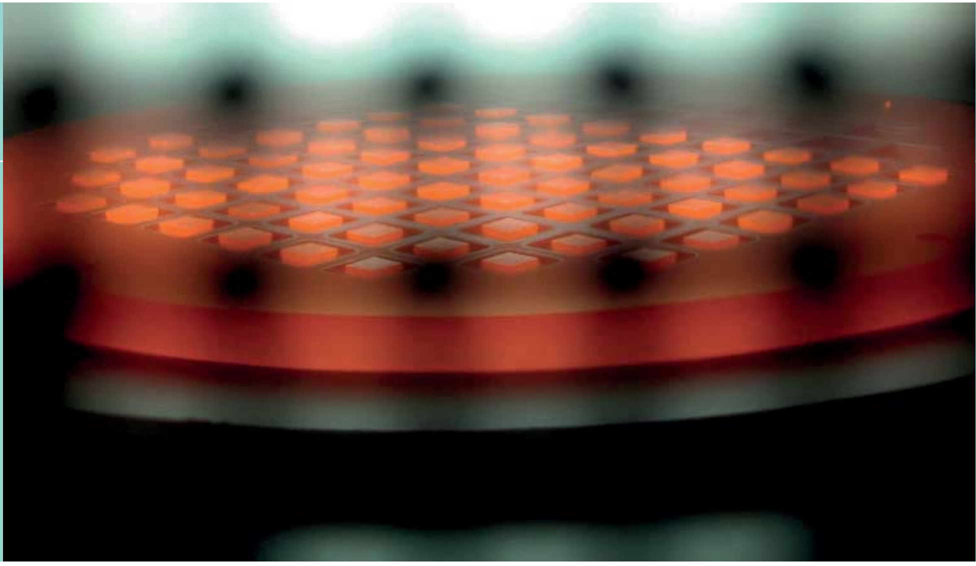
COATING TECHNOLOGY DIVISION

Prof. Jes Asmussen and Dr. Thomas Schuelke lead a group of experienced Fraunhofer researchers and German students in collaboration with faculty members and students of the Michigan State University. The team works in the following research areas:

- technologies involving amorphous diamond-like carbon coatings,
- chemical vapor deposition of ultranano-, poly- and single crystalline diamond materials,
- doping of diamond materials,
- physical vapor deposition technologies.

The amorphous diamond-like carbon coating research program utilizes the Laserarc® process, which was developed at the IWS Dresden. For several years CCL engineers have been applying this technology to coat tools for the machining and processing of aluminum materials. The amorphous diamond-like carbon coating significantly improves the lifetime of these tools. The Coating Technology Division collaborates closely with Michigan State University's Formula Racing Team. High performance wear resistant coatings are tested on various racecar components under race conditions. The collaboration provides the racing team with a competitive advantage and also returns critical information to CCL engineers for improving coating performance.

In recent years the Coating Technology Division have focused on research in the area of microwave plasma assisted chemical vapor deposition of diamond materials and in particular on the synthesis of doped and undoped single crystalline diamond. Here the team established an international reputation.



LASER APPLICATIONS DIVISION

The laser group of the CCL is located in Plymouth (Michigan), which is "next door" to the American automotive industry in Detroit. The group performs numerous laser beam welding projects of power train components such as differential gear sets, transmissions and drive shafts. In 2007 the CCL was presented with the Henry Ford Technology Award in recognition for the development of a laser beam welding process to improve the roof strength of Super Trucks.

A highlight of the research work is the development, patenting and licensing of a laser buildup welding process to generate highly abrasion resistant coatings. The coating consists of nearly mm-sized synthetic diamond particles, which are embedded in a metallic matrix. The technology is applied to drilling equipment for the oil production in the USA and Canada.

The close connection to the Fraunhofer CCL offers several advantages to the IWS. The awareness of the supply and demand situation helps to quickly recognize trends in the United States, which influence the technology development efforts at the IWS.

The research and development work performed in the United States generates additional know-how and competencies, which benefit the project acquisition in German and European markets. An exchange program offers IWS researchers the opportunity to work in the United States, which provides them with experiences that are beneficial for their entire career.

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NANO TECHNOLOGY ACTIVITIES

All industry branches from automotive to medical technology benefit from nanotechnologies. Entrepreneurs and researchers are collaborating to quickly and effectively commercialize the research results of this strategic technology for Germany. Dresden is a very successful nanotechnology location. Since November 2006, companies and research institutions collaborate in the **nanotechnology innovation cluster "nano for production"**. The objective of this collaboration is to move nanotechnology forward from basic research to the threshold of industrial implementation, which would create a necessary condition for a wide range commercial utilization of the technology. Essential elements of nano production technology are being developed, tested and made available to a broad user range.

In September 1998, 51 companies, 10 university institutes, 22 extramural research institutions and 5 associations formed the **nanotechnology competence center "Ultrathin Functional Films"** to consequently explore possibilities for industrial applications. The Center was recognized by the BMBF (Federal Ministry for Education and Research) as Germany's leading competence in ultra thin functional films. Work at the competence center includes participating in exhibitions, supporting and performing events and the issuing of requests for proposals and funding of feasibility studies.

In the nanotechnology field the IWS was organizer of the "Nanofair – International Nanotechnology Symposium", which was held on May 6th - 7th for the 8th time. Currently the 9th Nanofair is in preparation. The event will be held on June 12th - 13th 2012 at the International Congress center in Dresden under the joint sponsorship of the state capital, the Office for Economic Development and the Fraunhofer IWS.

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LASER INTEGRATION IN PRODUCTION TECHNOLOGY - INITIATIVE LIFT

The **LiFt initiative** aims at applying laser technologies to secure and expand the competitiveness of Saxony's machine and plant engineering and building industries. The initiative was launched in 2007 when the concept won the innovation competition "Industry meets Science", which was sponsored by the Federal Ministry of Transportation, Building and Urban Affairs (BMVBS).

Within the LiFt initiative the Fraunhofer IWS Dresden cooperates with the University of Applied Sciences in Mittweida and the Institute for Innovative Technologies, Education and Continuing Education (ITW) e.V. in Chemnitz. The institutions aim at commercializing innovations in the area of laser materials processing.

The goal of this network is to point out potential opportunities and offer services to machine builders and manufacturers. The potential advantages are:

- time and cost savings by shortening process chains,
- increase efficiency of manufacturing processes and products,
- unique selling features at the highest technology level.

As developers of technologies and educators, the LiFt project partners offer their services to small and medium sized companies not only in Saxony but also in other regions.

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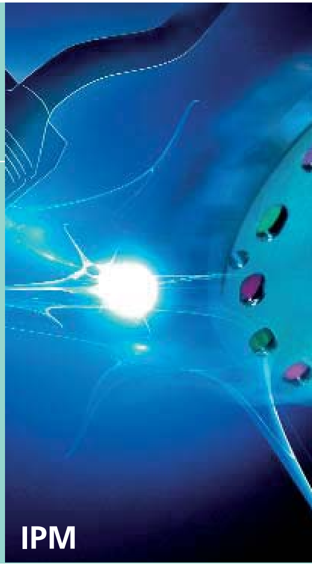
The demand for laser applications is increasing. The core networking activities in 2010 were again consultations at the Fraunhofer IWS and on-site at the interested parties. These activities belong to the key tasks of the project. Together with industrial partners, European contacts are strengthened.

The project is funded by the Federal Ministry for Transport, Building and Urban Affairs (contract number 03WWSN019).



FRAUNHOFER GROUP ”LIGHT & SURFACES”

COMPETENCE BY NETWORKING

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

CORE COMPETENCES OF THE GROUP

- surface and coating technologies
- beam sources
- micro- and nanotechnology
- materials treating
- opto-mechanical precision systems
- optical measuring systems

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FRAUNHOFER INSTITUTE FOR ELECTRON BEAM AND PLASMA TECHNOLOGY FEP

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

www.fep.fraunhofer.de

FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

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

www.ilt.fraunhofer.de

FRAUNHOFER INSTITUTE FOR APPLIED OPTICS AND PRECISION ENGINEERING IOF

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

www.iof.fraunhofer.de

FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

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

www.ipm.fraunhofer.de

FRAUNHOFER INSTITUTE FOR SURFACE ENGINEERING AND THIN FILMS IST

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

www.ist.fraunhofer.de

FRAUNHOFER INSTITUTE FOR MATERIAL AND BEAM TECHNOLOGY IWS

The Fraunhofer IWS is the leading innovative institution in the areas of laser and surface technologies. The institute offers customer tailored solutions for joining, cutting, buildup, removal, surface treatment and coating with lasers as well as PVD and CVD processes. Substantial materials and nanotechnology know-how is the base of numerous research and development efforts. System engineering and process simulation add to the central competences in the areas of laser materials processing and plasma coating processes. The IWS offers one-stop solutions. These include researching and developing new processes and systems, integrating them into manufacturing environments and troubleshooting all types of potential problems and errors.

www.iws.fraunhofer.de

SPECIAL EVENTS

January 15th 2010
"Fraunhofer kick-off" – Year's opening event with the president of the Fraunhofer-Gesellschaft Prof. Bullinger at the Fraunhofer Institutes Center in Dresden

March 2nd - 3rd 2010
8th workshop "Industrial applications of high power diode lasers" (organizer: Fraunhofer IWS Dresden)

March 4th 2010
Colloquium "50 years laser" in honor of the chairman of the board of trustees Dr. Peter Wirth

March 17th - 18th 2010
TAW symposium "Thermal coatings with laser based manufacturing processes" of the Technical Academy Wuppertal e.V. in collaboration with the Fraunhofer IWS Dresden

March 19th 2010
Saxony's minister president Stanislav Tilich visits the Fraunhofer IWS

April 15th 2010
EFDS workshop "Gas management for atmospheric pressure plasma processes"

April 22nd 2010
Fraunhofer IWS participation in the federal "Girls Day 2010"

May 6th 2010
Workshop "Supercapacitors: materials, processes and applications" (organizer: Fraunhofer IWS Dresden)

May 7th 2010
"Technology Day Dresden" – 6th alumni meeting of the Fraunhofer IWS Dresden and the TU Dresden LOT department

June 18th 2010
Fraunhofer Institutes Center participation in the state capital Dresden's "Long night of the sciences"

June 25th 2010
Workshop "Hard metal coatings of a new generation" (organizer: Fraunhofer IWS Dresden)

July 5th 2010
"4th Nanofair Junior Scientists Forum" – an event during the "Nanofair 2010" (organizer: Fraunhofer IWS Dresden)

July 6th - 7th 2010
8th International nanotechnology symposium "Nanofair – New ideas for industry", held at the International Congress Center Dresden (organizer: Fraunhofer IWS Dresden and state capital Dresden)

July 8th 2010
Workshop "Commercializing future technologies for energy and energy efficiency" – an event during the "Nanofair 2010" (organizer: Fraunhofer IWS Dresden)

August 17th - September 3rd 2010
"Youth researches" (practicum supervision: Fraunhofer project group at the DOC)

September 7th - 9th 2010
"SMT 24 – International Conference on Surface Modification Technologies" at the International Congress Center Dresden (organizer: Fraunhofer IWS Dresden)

September 28th 2010
Convention of expert circles "Control and automation technologies" and "Production and process technologies"

September 30th 2010
Undersigning of the first bilateral research cooperation between Qatar and Germany in Berlin: Project for the environmentally neutral generation of energy sources from natural gas through solar energy

October 5th - 6th 2010
"FiSC 2010 – International laser symposium fiber & disk" at the International Congress Center Dresden (organizer: Fraunhofer IWS Dresden)

November 25th 2010
"MOF synthesis and structure", workshop in London, (Organizer: TU Dresden, Institute for Inorganic Chemistry, co-organizer: Fraunhofer IWS Dresden)

PUBLICATIONS

[L01]
H.-A. Bahr, H.-J. Weiß, U. Bahr, M. Hofmann, G. Fischer, S. Lampenscherf, H. Balke

»Scaling Behavior of Thermal Shock Crack Patterns and Tunneling Cracks Driven by Cooling or Drying«

Journal of the Mechanics and Physics of Solids 58 (2010) 9, S. 1411-1421

[L02]
F. Bartels

»Ruck Zuck zum Bauteil - hochdynamische Achssysteme zum Laserstrahlschneiden mit Festkörperlasern hoher Strahlbrillanz«

International Laser Symposium Fiber & Disc, 5. - 6. Oktober 2010, Dresden,Tagungs-CD, ISBN 978-3-8396-0197-6

[L03]
F. Bartels, B. Süss, J. Hauptmann, A. Wetzig, E. Beyer

»Ruck Zuck zum Bauteil – Hochdynamischer Form-Cutter erweitert Möglichkeiten von Laserschneid- und -schweißanwendungen«

Laser Technik Journal (2010) 3, S. 40-43, ISSN: 1613-7728

[L04]
J. Berger, M. G. Holthaus, N. Pistillo, K. Rezwan, A. Lasagni

»Ultraviolet Laser Interference Patterning of Hydroxyapatite Surfaces«

Applied Surface Science (2010), DOI: 10.1016/j.apsusc. 2010.10.120

[L05]
L.-M. Berger, S. Saaro, T. Naumann, M. Kašparova, F. Zahálka

»Influence of Feedstock Powder Characteristics and Spray Processes on Microstructure and Properties of WC-(W,Cr)$_2$C-Ni Hardmetal Coatings«

Surface and Coatings Technology 205 (2010) 4, S. 1080-1087, ISSN 0257-8972

[L06]
L.-M. Berger, M. Woydt, S. Saaro, C.C. Stahr, S. Thiele

»High-Temperature Sliding Wear of APS-Sprayed Coatings of the Cr_2O_3-TiO_2 System«

Proceedings of the 14th Nordic Symposium on Tribology, Nordtrib 2010, Luleå and Storforsen, Schweden, 7. – 10. Juni 2010 Luleå, Luleå University of Technology (2010), ISBN 978-91-7439-124-4

[L07]
M. Bieda, E. Beyer, A.-F. Lasagni

»Direct Fabrication of Hierarchical Microstructures on Metals by Means of Direct Laser Interference Patterning«

Journal of Engineering Materials and Technology 132 (2010) 3, Art.031015/1-6, ISSN: 0094-4289

[L08]
M. Bieda, A.-F. Lasagni, E. Beyer,

»Fabrication of Hierarchical Microstructures on Metals by Means of Direct Laser Interference Patterning«

29th International Congress on Applications of Lasers and Electro Optics ICALEO, Proceedings, paper M504 (2010) S. 900-907, ISBN: 978-0-912035-61-1

[L09]
R. Böhme, I. Jansen, L. Girdauskaite

»Verbundkunststoffe - Reproduzierbare Preformfertigung für textilverstärkte Kunststoffe«

Lightweight Design (2010) 1, S. 55-60

[L10]
S. Bonß

»Der Laser in der Produktion«

Heat Treatm. Mat. 65 (2010) 3, S. A8

[L11]
S. Bonß

»Laser Transformation Hardening of Steel«

In Jonathan Lawrence, David KY Low, Juan Pou and Ehsan Toyserkani: Advances in Laser Materials Processing - Technology, Research and Applications, Woodhead Publishing Ltd. (2010), S. 291-326

[L12]
S. Bonß

»Laserstrahlhärten zum Härten lokal beanspruchter Bauteile – Integration in die Fertigung ermöglicht schlanke Prozesse«

Gießerei-Erfahrungsaustausch (2010) 5 / 6, S. 8-10

[L13]
S. Bonß, J. Hannweber, U. Karsunke, S. Kuehn, M. Seifert, E. Beyer

»Local Laser Heat Treatment of Stainless Steel at Very High Speed«

29th International Congress on Applications of Lasers and Electro Optics ICALEO, Proceedings, paper 1702 (2010) S. 249-258, ISBN: 978-0-912035-61-1

[L14]
T. Börner, L.-M. Berger, S. Saaro, S. Thiele

»Rollkontaktermüdung von HVOF gespritzten Hartmetallschichten auf ungehärteten Substraten«

Schriftenreihe »Werkstoffe und werkstofftechnische Anwendungen«, Band 37, Herausgeber: B. Wielage, TU Chemnitz (2010) S. 178-187, ISBN: 978-3-00-032471-0, ISSN: 1439-1597

[L15]
S. Braun, P. Gawlitza, M. Menzel, A. Leson, F. Allenstein, M. Nestler, D. Rost, A. Seifert, M. Zeuner

»Large Area Sputter Deposition for High-Precision Nanometer Films«

PSE (2010), S. 306

[L16]
B. Brenner, J. Standfuß, U. Stamm, G. Göbel, S. Schrauber

»Neue Perspektiven für das rissfreie Fügen von schwer schweißbaren Werkstoffen im Bereich Powertrain«

European Automotive Laser Applications (2010), Tagungsband (Hrsg: Automotive Circle International), S. 17-32

[L17]
F. Brückner, S. Nowotny, M. Riede, D. Lepski, E. Beyer

»Generation of high-precision metallic 3D structures with brilliant lasers«

International Laser Symposium Fiber & Disc, 5. - 6. Oktober 2010, Dresden,Tagungs-CD, ISBN 978-3-8396-0197-6

[L18]
E. Büchter, I. Jansen, R. Rechner

»Lasereinsatz in der Klebvorbehandlung«

10. Kolloquium Gemeinsame Forschung in der Klebtechnik (2010), S. 68-70

[L19]
A. Cramer, S. Landgraf, E. Beyer, G. Gerbeth

»Marangoni Convection in Molten Salts: Physical Modeling Toward Lower Prandtl Numbers«

Springer-Verlag (2010), DOI: 10.1007/s00348-010-0951-8, http://www.springerlink.com/content/u8234640387946w1/

[L20]
I. Dani, L. Kotte, P. Grabau, B. Leupolt, S. Kaskel, E. Beyer

»Atmosphärendruck-Plasmabehandlung von Polypropylen zur Haftungsverbesserung«

Workshop »Haftverbesserung durch Oberflächenfunktionalisierung mittels Atmosphärendruckplasma« (2010), Tagungsband

[L21]
I. Dani, E. Lopez, D. Linaschke, S. Kaskel, E. Beyer

»Großflächiges plasmachemisches Ätzen bei Atmosphärendruck«

Workshop »Gasmanagement für Atmosphärendruck-Plasmatechnologien«, 15. April 2010, Tagungsband, S. 1-9

[L22]
N. Danz, F. Sonntag, A. Kick, B. Höfer, U. Klotzbach, M. Mertig

»SPR Plattformtechnologie zur Multi-Parameter-Analyse auf polymeren Chips«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

[L23]
G. Dietrich, S. Braun, M. Rühl, A. Leson

»Reactive Nanoscaled Multilayers for High Precision Joining«

PSE (2010), S. 313

[L24]
D. Dittrich, B. Brenner, G. Kirchhoff, J. Hackius

»New Stiffener Designs and Al-Alloys for Laser Welded Integral Structures to Sustain Higher Load at Reduced Weight«

European Conference on Materials and Structures in Aerospace (2010), Tagungs-CD

[L25]
D. Dittrich, B. Winderlich, G. Kirchhoff, B. Brenner, J. Hackius

»Verbesserung der Bewertung von laserstrahlgeschweißten Flugzeugrumpf-Strukturen und deren Belastbarkeit anhand von Tests an Kleinproben«

DGM-Tagung »Werkstoffprüfung« (2010), Tagungsband

[L26]
K. Florschütz, A. Schröter, M. Körner, S. Schmieder, F. Sonntag, U. Klotzbach, G. Kunze

»Detection of Phytopathogenic RNA-Viruses«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

[L27]
F.-U. Gast, M. Bürger, T. Gehring, S. Howitz, K. Meißner, J. Steidl, U. Klotzbach, F. Sonntag

»Der Nano-Plotter, eine flexible Robotikplattform zur Herstellung von 2D- und 3D-Strukturen für die Zellbiologie und die regenerative Medizin«

Regenerative Medizin (2010)

[L28]
P. Gawlitza, S. Braun, A. Leson, W. Soer, M. Jak, V. Banine

»DLC/Si Multilayer Mirrors for EUV Radiation«

Society of Photo-Optical Instrumentation Engineers -SPIE-, Bellingham/Wash: Advances in X-Ray/EUV Optics and Components V: San Diego, CA, USA, 02.-03. August 2010, Bellingham, WA: SPIE (2010), Paper 78020A

[L29]
L. Girdauskaite, S. Krzywinski, H. Rödel, A. Wildasin-Werner, R. Böhme, I. Jansen

»Local Structure Fixation in the Composite Manufacturing Chain«

Appl. Compos. Mater. 17 (2010), S. 597-608, DOI: 10.1007/s10443-010-9130-6

[L30]
G. Göbel, J. Kaspar, T. Herrmannsdörfer, B. Brenner, E. Beyer

»Insights into Intermetallic Phases on Pulse Welded Dissimilar Metal Joints«

4th International Conference on High Speed Forming ICHSF 2010 Online-Proceedings Columbus/USA (2010), S. 127-136

[L31]
W. Grählert, H. Beese, S. Kaskel, J. Grübler, K. Pietsch

»HiBarSens - ein neuartiges Messsystem zur Bestimmung der Permeationsrate flexibler Ultrabarrierematerialien«

Workshop »Anforderungen an Schichten auf flexiblen Substraten für Barriereschutz und weitergehende Eigenschaften« (2010), Tagungsband

[L32]
W. Grählert, C. Jakschik, V. Türschmann

»Ressourcen schonen - Innovative Absaugtechnik für Laserbearbeitung von Wafern senkt Kosten«

EuroLaser (2010) 1

[L33]
M. Gruchow, U. Marx, S. Hoffmann, N. Schilling, S. Schmieder, U. Klotzbach, S. Howitz, F. Sonntag

»Pneumatisch betriebene Mikropumpen für Lab-on-a-Chip Anwendungen«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

[L34]
H. Gutzmann, J.-O. Kliemann, R. Albrecht, F. Gärtner, T. Klassen, F.-L. Toma, L.-M. Berger, B. Leupolt

»Evaluation of the Photocatalytic Activity of TiO_2-Coatings Prepared by Different Thermal Spray Techniques«

DVS Media GmbH (2010) CD, S. 182-186, ISBN: 978-3-87155-590-9

[L35]
L. Haubold, T. Schülke, M. Becker, G. Woodrough

»The Influence of the Surface Texture of Hydrogen-Free Tetrahedral Amorphous Carbon Films on their Wear Performance«

Diamond and Related Materials 19 (2010) 2/3, S. 225-228

[L36]
J. Hauptmann, A. Klotzbach, T. Himmer, A. Wetzig, E. Beyer,

»Domain Refinement of Grain Oriented Silicon Steel«

Inductica Technical Conference 22-24 Juni 2010, Berlin, Tagungsband

[L37]
A. Henseleit, S. Schmieder, T. Bley, F. Sonntag, N. Schilling, P. Weber, U. Klotzbach, E. Boschke

»An Advanced Low-Cost Bench-Top SPR-Based Aptasensor«

Journal Sensors, ISSN 1424-8220

[L38]
C. Hinüber, C. Kleemann, R.-J. Friederichs, L. Haubold, H.-J. Scheibe, T. Schuelke, C. Boehlert, M.-J. Baumann

»Biocompatibility and Mechanical Properties of Diamond-Like Coatings on Cobalt-Chromium-Molybdenum Steel and Titanium-Aluminum-Vanadium Biomedical Alloys«

Journal of Biomedical Materials Research. Part A 95 (2010) 2, S. 388-400

[L39]
A. Jahn, M. Heitmanek, J. Standfuß, B. Brenner, B. Donat, G. Wunderlich, P. Mickel, T. Vogel

»Lokale Laserbehandlung zur Steigerung der Crash-Belastbarkeit von Karosseriebauteilen«

DVS-Berichte 267 (2010), S. 306-311

[L40]
F. Kaulfuß, O. Zimmer

»Unterdrückung des Defektwachstums. Neue Perspektiven bei der Arc-Abscheidung von Hartstoffschichten«

Vakuum in Forschung und Praxis 22 (2010) 2, S. 39-42

[L41]
S. Kaskel, H. Althues, I. Dani, V. Hopfe, E. Beyer

»Chemical Vapour Deposition at Atmospheric Pressure«

PSE (2010), Tagungsband

[L42]
A. Kick, M. Bönsch, B. Katzschner, J. Voigt, A. Herr, W. Brabetz, M. Jung, F. Sonntag, U. Klotzbach, N. Danz, S. Howitz, M. Mertig

»DNA Microarrays for Hybridization Detection by Surface Plasmon Resonance Spectroscopy«

Biosensors and Bioelectronics (2010) DOI: 10.1016/j.bios.2010.07.108

[L43]
A. Klausch, H. Althues, C. Schrage, P. Simon, A. Szatkowski, M. Bredol, D. Adam, S. Kaskel

»Preparation of Luminescent ZnS:Cu Nanoparticles for the Functionalization of Transparent Acrylate Polymers«

Journal of luminescence 130 (2010) 4, S. 692-697

[L44]
A. Klotzbach

»Lasereinsatz für flexible Verbindungen«

Fachtagung High-Tech-Textilien (2010), Tagungsband

[L45]
A. Klotzbach

»Schnelles Trennen von Faserverbundwerkstoffen«

Photonik (2010) 6

[L46]
A. Klotzbach, M. Hauser, E. Beyer

»Remote Processing of Fiber Reinforced Plastics«

29th International Congress on Applications of Lasers and Electro Optics (2010), Tagungs-CD, ISBN: 978-0-912035-61-1

[L47]
U. Klotzbach

»LIFT Leadership in Fibre Laser Technology Perspectives of fibre lasers - Challenges and Potential«

High Power Diode Lasers & Systems Congress, Photonex November 2010, Telford UK, Tagungsband

[L48]
S. Kozerski, F.-L. Toma, L. Pawlowski, B. Leupolt, L. Latka, L.-M. Berger

»Suspension Plasma Sprayed TiO_2 Coatings Using Different Injectors and Their Photocatalytic Properties«

Surface and Coatings Technology 205 (2010) 4, S. 980-986, ISSN 0257-8972

[L49]
S. Kühn

»Dynamisches Strahlformungssystem zur Erzeugung ringförmiger Härtezonen«

8. Workshop »Industrielle Anwendungen von Hochleistungsdiodenlasern« (2010), Tagungs-CD

[L50]
D. Langheinrich, O. Paetzold, L. Raabe, M. Stelter

»VGF Growth of Germanium Single Crystals without Crucible Contact«

Journal of Crystal Growth 312 (2010) 16/17, S. 2291-2296

[L51]
A.F. Lasagni, C. Holzapfel, M. Engstler, F. Mücklich

»3D-Mikrostrukturuntersuchung an einer $AlSi_8Mg_5$-Legierung mit der FIB-Tomographie«

Praktische Metallographie 47 (2010) 9, S. 487-499

[L52]
A.F. Lasagni, B.S. Menendez-Ormaza

»Two- and Three-Dimensional Micro- and Sub-Micrometer Periodic Structures Using Two-Beam Laser Interference Lithography«

Advanced Engineering Materials 12 (2010) 1/2, S. 54-60

[L53]
A.-F. Lasagni, P. Shao, J. Hendricks, C.-M. Shaw, D.-C. Martin, S. Das

»Direct Fabrication of Periodic Patterns with Hierarchical Sub-Wavelength Structures on Poly (3,4-Ethylene Dioxythiophene) -Poly (Styrene Sulfonate) Thin Films Using Femtosecond Laser Interference Patterning«

Applied Surface Science 256 (2010) 6, S. 1708-1713

[L54]
A. Leson

»Nanotechnologie - Risiko oder Chance?«

Vakuum in Forschung und Praxis Vol. 22 (2010) 2

[L55]
A. Leson

»Umsetzung in industrielle Prozesse und Produkte«

Nano-Energie, Newsletter (2010) 1, CeNIDE, S. 6

[L56]
J. Liebich, H. Althues, S. Kaskel

»Leitfähige CNT-Dünnschichten in Polymeroberflächen«

Kunststoffe (2010) 12

[L57]
M. Lütke, T. Himmer, A. Wetzig

»From Drawing to the Device – Requirements and Approaches in Remote Cutting«

Fraunhofer IWS International Laser Symposium Fiber & Disc (FiSC), (2010), Tagungs-CD, ISBN 978-3-8396-0197-6

[L58]
M. Lütke, T. Himmer, A. Wetzig, E. Beyer

»Enlarging the Application Area for Remote Cutting«

International Sheet Metal Review (ISMR) (2010) 2/3, S. 18-19

[L59]
A. Mahrle, M. Lütke, E. Beyer

»Fibre Laser Cutting: Beam Absorption Characteristics and Gas-Free Remote Cutting«

Journal of Mechanical Engineering Science: Special Issue on Laser Engineering, Proceedings of the Institution of Mechanical Engineers, Part C (2010) 224, No. C5, S. 1007-1018, ISSN: 0954-4062

[L60]
K. Meißner, F. Sonntag, J. Steidl, M. Bürger, S. Howitz, U. Klotzbach

»Entwicklung eines Mehrkanalplotters zur Herstellung von Multi-Komponenten-Scaffolds mit definierten Versorgungskanälen«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

[L61]
S. Nowotny

»3D-Laserauftragschweißen bei erschwerter Zugänglichkeit«

Photonik 42 (2010) 3, S. 18

[L62]
S. Nowotny, F. Brückner, F. Kubisch, R. Wappler, S. Scharek, E. Beyer

»Increased Productivity of Laser Surface Cladding by Simultaneously Assisting Energy Sources«

24th International Conference on Surface Modification Technologies SMT24, 7. - 9. September 2010, Dresden, Tagungsband

[L63]
S. Nowotny, R. Münster, S. Scharek, E. Beyer

»Integrated Laser Cell for Combined Laser Cladding and Milling«

Emerald´s Assembly Automation 30 (2010) 1, S. 36-38, ISSN: 0144-5154

[L64]
J.-S. Pap, I. Jansen

»Adhesive Bonding of Hybrid Yarn Textile Thermoplastic Composites«

14th European Conference on Composite Materials (2010), Paper ID: 067-ECCM14

[L65]
J.-S. Pap, I. Jansen

»Techniques for Adhesion Improvement – Adhesive Bonding of a Glass Fibre / Polypropylene Composite«

4th World Congress on Adhesion and Related Phenomena (2010), Tagungsband, S. 103

[L66]
J.-S. Pap, M. Kästner, I. Jansen

»An Approach to Experimentally Characterise the Mechanical Behaviour of an Epoxy-Based Adhesive«

4th World Congress on Adhesion and Related Phenomena (2010), Tagungsband, S. 215

[L67]
M. Panzner, U. Klotzbach, W. Köhler, A. Schmid, E. Beyer

»Untersuchung von Kunstobjekten mit Terahertz-Zeitdomänenspektroskopie - Chancen und Herausforderungen eines neuen Messverfahrens«

Restauro Callwey Verlag (2010)

[L68]
R. Rechner, I. Jansen, E. Beyer

»Effect of Laser Pretreatment on Aluminium Oxide Surfaces«

4th World Congress on Adhesion and Related Phenomena (2010), Tagungsband, S. 177

[L69]
R. Rechner, I. Jansen, E. Beyer

»Laser- und Plasmaverfahren im wirtschaftlichen Vergleich: Vorbehandlung von Aluminiumoberflächen«

Adhäsion. Kleben und Dichten 54 (2010) 1/2, S.36-38, S. 40-43, ISSN: 0943-1454

[L70]
R. Rechner, I. Jansen, E. Beyer

»Influence on the Strength and Aging Resistance of Aluminium Joints by Laser Pre-Treatment and Surface Modification«

International Journal of Adhesion and Adhesives 30 (2010) 7, S. 595-601

[L71]
T. Roch, M. Bieda, A. Lasagni

»Innovative Methode für die direkte Herstellung periodischer Oberflächenstrukturen auf Metallen und Beschichtungen«

Laser Magazine 4, S. 30-31

[L72]
T. Roch, A. Lasagni

»Direct Laser Interference Patterning of Tetrahedral Amorphous Carbon Thin Films«

8th International Nanotechnology Symposium »Nanofair 2010, New Ideas for the Industry«, Dresden, 6. – 7. Juli 2010, Tagungsband

[L73]
T. Roch, A. Lasagni, E. Beyer

»Surface Modification of Thin Tetrahedral Amorphous Carbon Films by Means of UV Direct Laser Interference Patterning«

Diamond Related Materials (2010) 19, Issue 12, S. 1472-1477
DOI: 10.1016/j.diamond.2010.10.003

[L74]
T. Roch, A. Lasagni, E. Beyer

»Nanosecond UV Laser Modification of Thin Tetrahedral Amorphous Carbon Films with Different sp^3/sp^2 Content«

Thin Solid Films, im Druck
DOI: 10.1016/J.tsf.2011.01.338

[L75]
D. Rost, M. Zeuner, A. Seifert, M. Nestler, S. Braun, A. Leson, P. Gawlitza, M. Menzel

»Deposition of Large Area Multilayer Coatings for High End Optics«

PSE (2010), S. 518

[L76]
N. Schilling, S. Schmieder, M. Gruchow, U. Marx, S. Hoffmann, U. Klotzbach, F. Sonntag

»Prägetechnologie zur Umsetzung von fluidischen Strukturen in Gel für die 3D-Zellkulturtechnik«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

[L77]
W. Schork

»Reibungsminderung an Antriebs- und Motorkomponenten durch Beschichtungen mit diamantähnlichem amorphen Kohlenstoff«

Fraunhofer Verlag (2010), ISBN 3-8396-0101-0

[L78]
W. Schork, B. Schultrich, V. Weihnacht

»A New Kind of Oscillating Dynamic Load Test for Tribological Coatings«

Wear 268 (2010) 7-8, S. 955-959

[L79]
C. Schrage, H. Althues, A. Klausch, D. Adam, S. Kaskel

»ZnS:Cu Polymer Nanocomposites for Thin Film Electroluminescent Devices«

Journal of Nanoscience and Nanotechnology 10 (2010) 7, S. 4335-4340

[L80]
B. Schultrich

»Lexikon der Dünnschichttechnologie«

Sonderausgabe der Zeitschrift Vakuum in Forschung und Praxis (2010)

[L81]
B. Schultrich

»Reibungs- und verschleißmindernde Schichten«

In G. Blasek, G. Bräuer (Herausg.): Vakuum-Plasma-Technologien, Leuze-Verlag, Bad Saulgau, 2010, S. 901-982

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B. Schumm, H. Althues, S. Kaskel

»CdTe Nanoparticles for the Deposition of CdTe Films Using Close Spaced Sublimation«

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»A Comparative Study on Fusion Cutting with Disk and CO_2 Lasers«

29th International Congress on Applications of Lasers and Electro Optics ICALEO, Anaheim/USA Proceedings, paper 702 (2010), S. 249-258,
ISBN: 978-0-912035-61-1

[L84]
L.-D. Scintilla, L. Tricarico, A. Wetzig, T. Himmer, E. Beyer

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»Steigerung der Sensitivität von Lab-on-a-Chip-Systemen durch magnetophoretische Fokussierung paramagnetischer Analyte«

15. Heiligenstädter Kolloquium »Technische Systeme für die Lebenswissenschaften«, Tagungsband

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7. Jenaer Lasertagung (2010), Tagungsband

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»Laserstrahlschweißen mit hochfrequenter Strahloszillation: Untersuchungen zum Schweißen von Mischverbindungen mit brillanten Strahlquellen«

International Laser Symposium Fiber & Disc (FiSC), (2010) Tagungs-CD, ISBN 978-3-8396-0197-6

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Schriftenreihe »Werkstoffe und werkstofftechnische Anwendungen« Band 37, Herausgeber: B. Wielage, TU Chemnitz (2010) S. 13-24, ISBN: 978-3-00-032471-0, ISSN: 1439-1597

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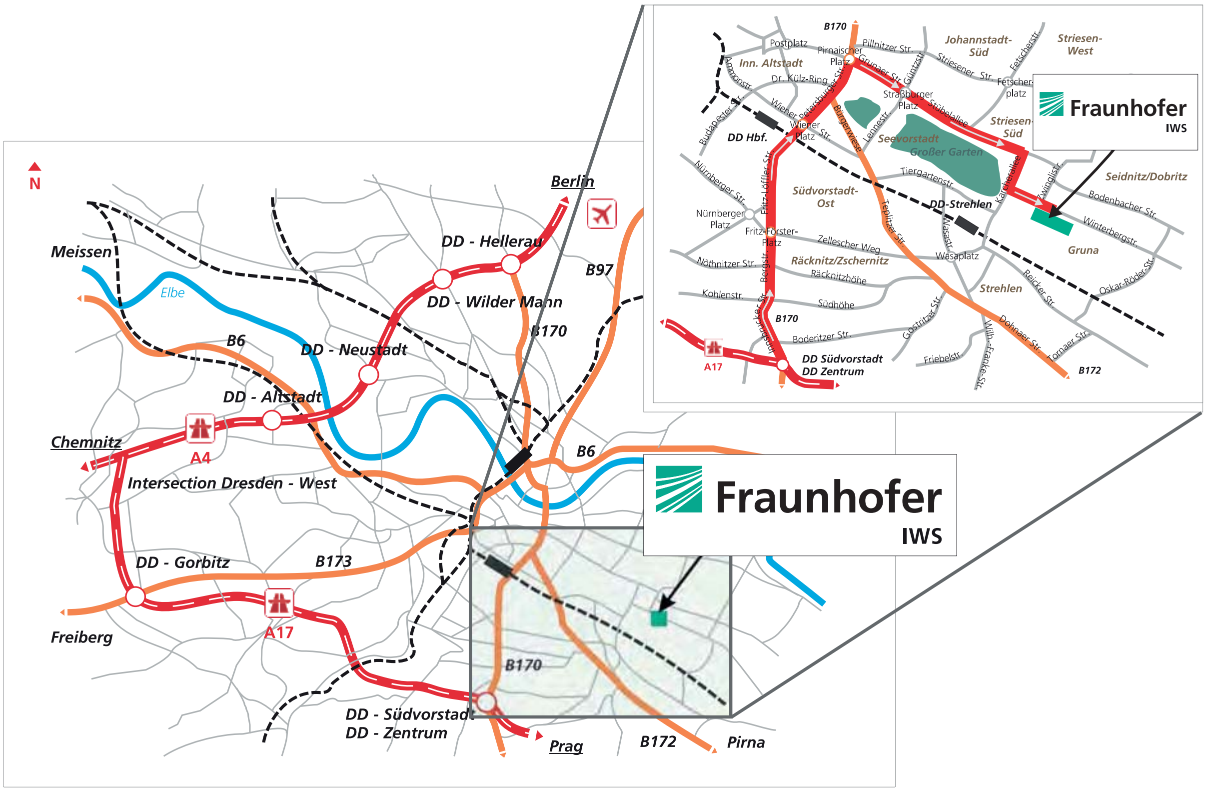

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