Fraunhofer
IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

ANNUAL REPORT 2010/2011

ANNUAL REPORT

2010/2011

PREFACE

Dear
ladies and gentlemen,
business associates and research partners,
patrons of Fraunhofer IFAM,

The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM is an R&D service provider acting as a company for industry and public authorities. It is especially remarkable that, even during the difficult economic times, the demand for our products and services remained as strong as ever with satisfied customers convinced by our R&D accomplishments. The result is a positive overall balance – and so we can once again present a gratifying summary for the past business year. The institute continued to expand in 2010, expressed for example by another increase in personnel.

A decrease in industrial contracts was a tangible consequence of the economic situation in 2010. However, this was more than compensated for through publically funded research projects. The upturn in the German economy in the course of the last six months of 2010 then made itself apparent with an increase in industrial investments in research and development. It is our declared aim to once again intensify the industry balance in the institute's financing mix.

Holding a leading position in the market of research services requires hard, intensive work every day – because stagnation is a step backwards. Fraunhofer IFAM has developed rapidly over the past years and is continually confronted with new challenges. Against this background success can only function with a skilled team of enthusiastic and highly motivated employees. The typical Fraunhofer recipe, based on excellent know-how in the respective specialist disciplines whilst keeping the bigger picture in mind, paired with engagement and enthusiasm, is our key to success. The positive development at Fraunhofer IFAM is due to the extraordinary dedication and motivation of all our employees. Our very special thanks go to all of them at this point.

Our strong growth has lately led to a shortage of space. But relief is on the way as another stage of construction will be started in summer 2012 for the institute's building on Wiener Strasse in Bremen. Additional offices, laboratories and technology zones covering a total of 2400 square meters underline our continuing expansion.

We are delighted that Prof. Dr. rer. nat. Bernd Mayer took over the management of the Adhesive Bonding Technology and Surfaces Division on August 1, 2010 from his predecessor Priv.-Doz. Dr. Andreas Hartwig. As a member of the general management, he will actively shape the future-oriented development of Fraunhofer IFAM. As he joined us directly from industry, he will use his technical competence and knowledge of the needs of international customers to strengthen as well as further enhance the institute's position as the largest independent European research establishment in the adhesive bonding technology and surface technology sector.

At the same time, Bernd Mayer has followed the call to take up the professorship for "Polymeric Materials" in the Production Technology Department at the University of Bremen. Prof. Dr.-Ing. Matthias Busse also teaches "Near Net Shape Manufacturing Technologies" in this department. Both university lecturers do not just pass on their knowledge to students; they can also directly spark future scientists' interest in the specific fields of work at Fraunhofer IFAM. The close relations to the University of Bremen are exemplified by the central scientific unit "Integrated Solutions in Sensorial Structure Engineering" (ISIS), which is involved in the integration of sensor technology in technological structures under the auspices of Fraunhofer IFAM.

In consequence of past strategic decisions, the institute now has a broad technological foundation; we are a coveted partner in a range of industrial sectors. Our activities support Germany's technology leadership, which is extremely important in the global competition. In addition, we are active in new future-oriented fields with our application-based research and development work, for instance in energy storage, new drive systems and light-weight construction, where we are developing solutions for current social challenges. Two fields of our diverse activities became particularly prominent in 2010: electromobility and carbon-fiber reinforced plastic (CFRP) technology.

Electromobility has rapidly become a significant topic in Germany. 33 Fraunhofer Institutes coordinate all stages of this value chain in the Fraunhofer project "Electromobility System Research"; numerous threads link these institutes on the technological side to the IFAM "Shaping

1 *Directors Prof. Dr.-Ing. Matthias Busse and Prof. Dr. rer. nat. Bernd Mayer (left to right).*

and Functional Materials" division. Bremen is also working on e-mobility prototypes, amongst other things. The institute is the main initiator of numerous activities in Northern Germany. The Fraunhofer IFAM performed very successfully in 2010 as the coordinator of the "Northwest Bremen/Oldenburg E-Mobility Model Region". This model region is one of eight regions selected from 130 applications by the Federal Ministry of Transport, Building and Urban Development. The urban-rural structure present between the cities of Bremerhaven, Bremen and Oldenburg, the surrounding towns and communities, and the proximity to wind energy as a regenerative source of energy, all make this region ideal testing grounds for an integration of electromobility into everyday life. The division has also built a test shop for the drive trains of electric vehicles: the research results flow directly into the further development of these vehicles. A Fraunhofer IFAM Working Group on the topic of energy stores was also successfully set up in 2010 in Oldenburg, and is already working very successful in cooperation with the local project partners.

The inauguration of the Europewide unique large research center for carbon-fiber reinforced plastic, "CFK Nord" in the city of Stade, was one of the main milestones in 2010 for the "Adhesive Bonding Technology and Surfaces" division. With its Project Group Joining and Assembly FFM, Fraunhofer IFAM is one of the two main actors in the center utilizing more than half of the 7000 square meters and 24 meters high hall of the CFK Nord. Together with industry partners, machining work and subsequent adhesive bonding assembly are implemented here to realize in a 1:1 scale large CFRP structures such as aircraft fuselages and wings, huge wind turbine rotors or large-scale components for shipping, rail transport and the transport industry. The task is to transfer existing joining and assembly processes, including those still undergoing development, into an error-free, automated and cost-effective mass production of XXL structures. This is implemented in close cooperation with the existing Working Groups in Bremen who are working on many other material engineering and process-oriented aspects of CFRP materials.

We promoted numerous other projects and collaborative activities in 2010. They included the extremely successful work carried out by the innovation cluster "Multifunctional Materials and Technologies" (MultiMaT) which, under the management of Fraunhofer IFAM, has strategically converted the latest results from material research into market-mature products. The institute is a key contributor in a variety of projects within the "Clean Sky" research program, aimed at sustainable promotion of the environmental compatibility and competitiveness of the European aerospace industry.

The institute division "Adhesive Bonding Technology and Surfaces" was also delighted to receive several awards, underlining the excellent scientific competence of Fraunhofer IFAM. It is particularly worth mentioning here that a scientific team in our institute won the Joseph von Fraunhofer research prize awarded by the Fraunhofer-Gesellschaft for the first time in over 40 years of IFAM history. The ongoing and extremely successful work carried out by our Powder Metallurgy and Composite Materials division in Dresden is also noteworthy.

Many of the activities, endeavors and developments mentioned here are portrayed at in more depth below in selected project and trend reports. They provide a detailed look at the work of our dedicated employees.

We hope you will enjoy reading our annual report

Matthias Busse   Bernd Mayer

CONTENTS

PREFACE 2

THE INSTITUTE IN PROFILE

The institute in profile 8
Brief portrait and organigram 10
The institute in figures 11
Investments 12
Operation and investment budget 13
Operation budget income 13
Personnel development 14
The advisory board of the institute 15
The Fraunhofer-Gesellschaft 16

SHAPING AND FUNCTIONAL MATERIALS

Competencies and know-how 19
Fields of activity and contacts 22
Equipment/facilities 24

RESULTS FROM RESEARCH AND DEVELOPMENT

New drive concepts and components for electric vehicles 27
Electrical energy storage systems for mobile applications 31
Materials and technologies for sustainable energy storage 34
The electromobility model region Bremen/Oldenburg: Initial aims achieved 37
Durable, stable and perfectly shaped – new bio-compatible materials for implants and prosthetics 42
A powerful bond: Metal/carbon nanotube composite materials 46

ADHESIVE BONDING TECHNOLOGY AND SURFACES

Expertise and know-how 51
Fields of activity and contacts 54
Equipment/facilities 57

RESULTS FROM RESEARCH AND DEVELOPMENT

Bernd Mayer: New institute director of the Fraunhofer IFAM – Adhesive Bonding Technology and Surfaces – and professor in the Department of Production Technology at the University of Bremen 60
CFRP North in operation: The Fraunhofer Project Group Joining and Assembly FFM has started its work 64
Fraunhofer IFAM in the spotlight after successful R&D work on functional coatings 70
Plasma hybrid process offers new opportunities for applying thin functional layers 76
Light rotor blade connection – adhesive bonding of metal inserts 80
Instead of soldering and laser welding: Adhesive bonding of cutting segments in situ 84

PEOPLE AND MOMENTS

Premiere for Fraunhofer IFAM: Joseph von Fraunhofer Prize 2010 awarded to Volkmar Stenzel, Yvonne Wilke, and Manfred Peschka 90
Skaupy Prize 2010 for Prof. Dr.-Ing. Bernd Kieback 91
Heat storage project receives E.ON research award 2010 92
Volkmar Stenzel rewarded with CoSi Prize 2010 for "sharkskin" riblet coatings 93
Anja Zockoll and Andreas Brinkmann awarded FARBE UND LACK Prize 2010 94
"Adhesive bonding for lightweight structures for moving masses" – Kai Brune receives FTK Young Scientist Prize 2010 95

GROUPS | ALLIANCES | ACADEMY

NETWORKED AT FRAUNHOFER

Fraunhofer Group for Materials and Components – MATERIALS 97
Fraunhofer Adaptronics Alliance 99
Fraunhofer Automobile Production Alliance 100
Fraunhofer Building Innovation Alliance 101
Fraunhofer Additive Manufacturing Alliance 101
Fraunhofer Lightweight Construction Alliance 102
Fraunhofer Nanotechnology Alliance 102
Fraunhofer Photocatalysis Alliance 103
Fraunhofer Polymer Surfaces Alliance (POLO) 103
Fraunhofer Cleaning Technology Alliance 104
Fraunhofer Numerical Simulation of Products, Processes Alliance 104
Fraunhofer Traffic and Transportation Alliance 105
Fraunhofer Academy – research know-how for your success 105

NAMES | DATES | EVENTS

CONTENTS 107
Conferences | Congresses | Workshops 108
Scientific publications 109
Patents 131
Honors and awards 132

EDITORIAL NOTES 133

THE INSTITUTE IN PROFILE

The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM conducts proactive research and development in the following areas.

Shaping and Functional Materials

The institute's Shaping and Functional Materials division concentrates on developing customized material solutions with optimized production methods and processes at its facilities in Bremen, Dresden and Oldenburg.

The research and development activities range from the materials themselves and shaping to the functionalization of components and systems. We develop customer-specific solutions requested by such diverse sectors as the automotive industry, medical engineering, aerospace, machine and system engineering, environmental and energy technology, and the electronics industry.

Fraunhofer IFAM follows an integrated concept with three main core areas in the area of electromobility. Our work focuses on the areas of energy storage and electrical drive technology, as well as the testing, verification, evaluation and optimization of complete systems. The Electromobility Model Region Bremen/Oldenburg is currently laying the foundation for new vehicle and traffic concepts.

Our focus in the shaping sector lies in the development of economic and resource-conserving production processes for increasingly complex high-precision and standard components. We are working here to increase the functional density in components using cutting edge powder and casting technologies. Our range of services includes component design and shaping process simulation, production engineering implementation and the appropriate training of company personnel.

The focus in the functional materials sector is on advancements in improving or extending material properties and material processing. The functional materials can either be integrated directly in the component during the production process or applied to surfaces. They provide the component with additional or completely new properties, for example electronic or sensory functions.

By exploiting the specific properties of cellular materials, hybrid materials, fiber composites and biomaterials it is possible to realize a broad variety of applications.

Adhesive Bonding Technology and Surfaces

The department of Adhesive Bonding Technology and Surfaces provides industry with qualified products and processes in the area of adhesive bonding technology, plasma technology, and paint/lacquer technology at Bremen and Stade.

The R&D services of the department are sought after by a large number of partners in diverse sectors of industry. At present the main markets and customers are the whole transport sector – manufacturers of aircraft, cars, rail vehicles, ships – and their suppliers, machine and plant construction, energy technology, construction industry, packaging sector, textile industry, electronics industry, microsystem engineering, and medical technology.

The work of the Adhesive Bonding Technology business unit is subdivided into adhesives and polymer chemistry (adhesive formulation, composite materials, bio-inspired materials),

adhesive bonding technology (bonding in microsystem engineering and medical technology, adhesives and analysis, process development and simulation, application methods), materials science and mechanical engineering (structural calculations and numerical simulation, mechanical joining technology), joining and assembly of large fiber reinforced plastic structures on a 1:1 scale (joining technologies, precision processing, assembly and plant technology, measurement technology and robotics), and the Certification Body of the Federal Railway Authority in accordance with DIN 6701.

The Surfaces business unit covers plasma technology with its working groups low pressure plasma technology, atmospheric pressure plasma technology, and plant technology/plant construction and also paint/lacquer technology with the activity fields development of coating materials and functional coatings, as well as application technology and process engineering.

These two business units are complemented by Adhesion and Interface Research with the work groups surface analysis and nanostructure analysis, applied computational chemistry, electrochemistry/corrosion protection, and quality assurance of surfaces.

Certifying training courses in adhesive bonding technology complement the R&D work and are of interest for all sectors of industry. Following the successful workforce training courses introduced by the Center for Adhesive Bonding Technology in German-speaking countries and in other European countries, the courses are now being offered worldwide to global multinational companies. Other workforce training courses in fiber composite technology are given by the Plastics Competence Center.

Competence network at Fraunhofer IFAM

Shaping and Functional Materials

- Biomaterials Technology
- Electrical Energy Storage
- Electrical Systems
- Functional Structures
- Casting Technology and Component Development
- Materialography and Analytics
- Powder Technology
- Sinter and Composite Materials
- Cellular Metallic Materials

Adhesive Bonding Technology and Surfaces

- Certification Body of the Federal Railway Authority in accordance with DIN 6701
- Adhesion and Interface Research
- Adhesive Bonding Technology
- Adhesives and Polymer Chemistry
- Business Field Development
- Fraunhofer Project Group Joining and Assembly FFM
- Materials Science and Mechanical Engineering
- Paint/Lacquer Technology
- Plasma Technology and Surfaces PLATO
- Process Reviews
- Workforce Qualification and Technology Transfer

BRIEF PORTRAIT AND ORGANIGRAM

The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM was set up in 1968 as a working group on Applied Material Research and incorporated as an institute in the Fraunhofer-Gesellschaft in 1974.

The institute collaborates closely with the University of Bremen as a contract research institute with new focal points and systematic expansion. The Institute directors are appointed to chairs in the department of production technology at the University of Bremen. The institute has sites in Bremen and Dresden, as well as Fraunhofer Project Groups in Oldenburg and Stade.

Prof. Dr.-Ing. Matthias Busse has been managing the Shaping and Functional Materials division since 2003 as the director (executive) of the institute.

Priv.-Doz. Dr. Andreas Hartwig, who manages the Adhesive Bonding Technology and Surfaces division, held the post of director (acting) from June 2009 up to the end of July 2010.

Prof. Dr. rer. nat. Bernd Mayer, member of the management board, became director of the Adhesive Bonding Technology and Surfaces division on August 1, 2010.

The institute, as a neutral and independent facility, is regarded as one of the best in Europe in the sectors of Shaping and Functional Materials, as well as Adhesive Bonding Technology and Surfaces. The total Fraunhofer IFAM budget in 2010 was approximatley 35.3 million euros. The institute employed 478 people, among them 93 percent active in the scientific engineering department.

<table>
<tr><td colspan="2">Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM</td></tr>
<tr><td colspan="2">Institute directors
Prof. Dr.-Ing. Matthias Busse (executive)
Prof. Dr. rer. nat. Bernd Mayer</td></tr>
<tr><td>Division
Shaping and Functional Materials
Prof. Dr.-Ing. Matthias Busse
Dr.-Ing. Frank Petzoldt
Deputy director
Prof. Dr.-Ing. Bernd Kieback
Head of Dresden branch</td><td>Division
Adhesive Bonding Technology and Surfaces
Prof. Dr. rer. nat. Bernd Mayer
Priv.-Doz. Dr. Andreas Hartwig
Deputy director</td></tr>
<tr><td colspan="2">Head of administration
Dipl.-Oec. Alexander Busk</td></tr>
</table>

THE INSTITUTE IN FIGURES

The overall Fraunhofer IFAM budget (costs and investments) for 2010 comprises the budgets of both divisions (Shaping and Functional Materials/Adhesive Bonding Technology and Surfaces). The results of the Fraunhofer Project Group Joining and Assembly FFM in Stade were also included for the first time in 2010.

Budget

The preliminary budget result totaled 35.3 million euros. The individual institute division results were:

Shaping and Functional Materials, Bremen

Operating budget (OB)	8.7 million euros
Own income	6.9 million euros
Including	
Business income	2.1 million euros
Federal/State/EU/Other	4.8 million euros
Investment budget (IB)	3.1 million euros

Shaping and Functional Materials, Dresden

Operating budget (OB)	4.2 million euros
Own income	3.2 million euros
Including	
Business income	0.9 million euros
Federal/State/EU/Other	2.3 million euros
Investment budget (IB)	0.8 million euros

Adhesive Bonding Technology and Surfaces, Bremen

Operating budget (OB)	15.8 million euros
Own income	12.9 million euros
Including	
Business income	7.5 million euros
Federal/State/EU/Other	5.4 million euros
Investment budget (IB)	1.6 million euros

Fraunhofer Project Group Joining and Assembly FFM, Stade

Operating budget (OB)	1.1 million euros
Own income	0.8 million euros
Including	
Business income	0.2 million euros
Federal/State/EU/Other	0.6 million euros

INVESTMENTS

Investments worth 5.5 million euros were made in 2010 by Fraunhofer IFAM. These investments are divided between the various divisions as listed below with the main acquisitions specified.

Shaping and Functional Materials, Bremen
IB (3.1 million euros)

- Raman spectrometer/AFM
- TGA/DSC/MS analysis
- Battery measuring stands (Maccor, Basytec and Solatron)
- Impedance analyzer (Novocontrol)
- Injection molding machine (Boy XS)
- Sensor test bench in form of a hydraulic fatigue testing machine
- ProboStat measuring head (Novocontrol)
- (Bi-)potentiostat
- 3-roller mill (paste homogenization)
- Electric vehicles for fleet testing in the model region Bremen/Oldenburg

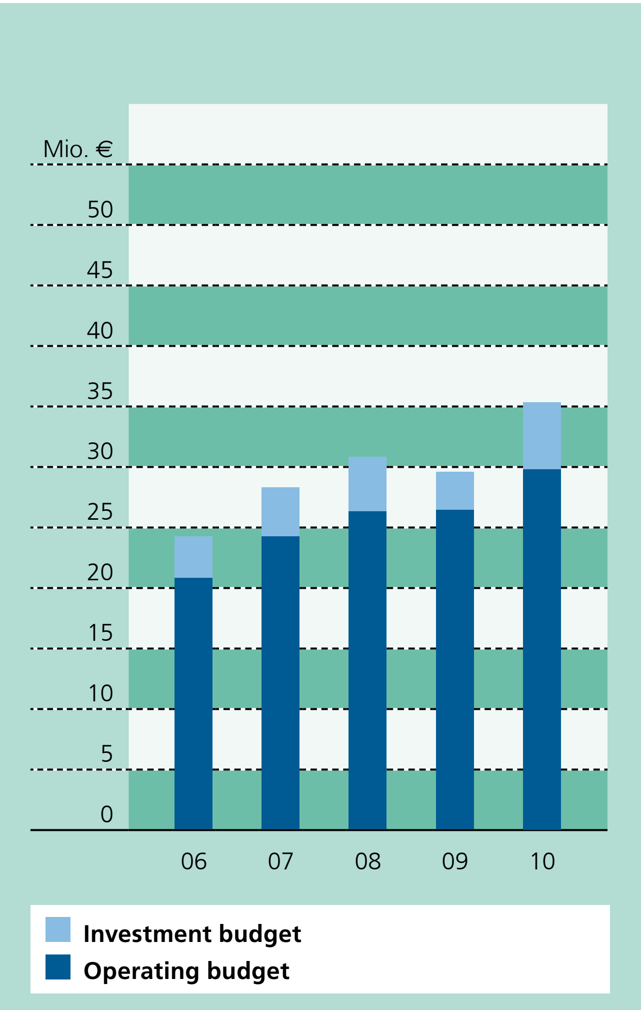
Shaping and Functional Materials, Dresden
IB (0.8 million euros)

- Dynamic high-pressure heat flow differential scanning calorimeter
- Gas analysis unit (Sieverts apparatus)
- Laser confocal microscope

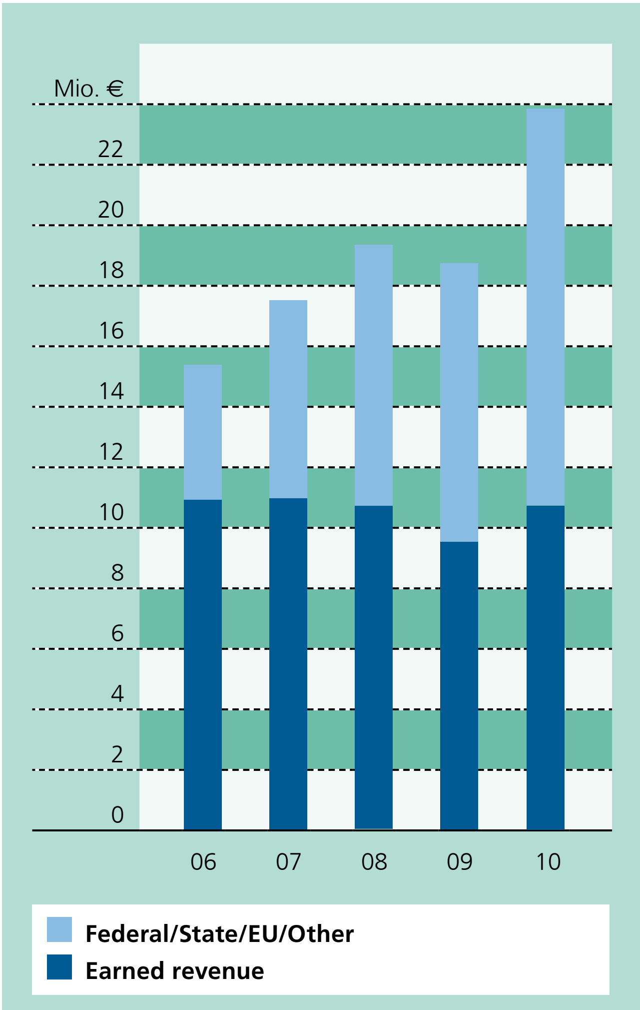
Adhesive Bonding Technology and Surfaces, Bremen
IB (1.6 million euros)

- Multi-use tribometer with module for nano-indentation
- Ion chromatography
- Galvanic system
- Hand-held device for nuclear magnetic resonance spectroscopy
- Twin screw extruder

OPERATION AND INVESTMENT BUDGET



OPERATION BUDGET INCOME



PERSONNEL DEVELOPMENT

A total of 478 persons (93 percent active in the scientific engineering sector) were employed as of December 31, 2010 by Fraunhofer IFAM at the Bremen and Dresden locations, and by the Fraunhofer Project Groups at Oldenburg and Stade. In comparison to the previous year, the institute saw an increase of 13 percent in permanently employed personnel.

Personnel structure 2010

Scientists	175
Technical personnel	108
Administration/Internal Services/Apprentices	45
PhD students/Trainees/Assistants	150
Total	478

THE ADVISORY BOARD OF THE INSTITUTE

Members

Prof. Dr. Jürgen Klenner
Chair of the advisory board
Airbus Deutschland GmbH
Bremen

Dr. Ramon Bacardit
Henkel AG & Co. KGaA
Düsseldorf

Dr. Klaus Dröder
Volkswagen AG
Wolfsburg

Prof. Dr. Michael Dröscher
EVONIK Degussa GmbH
Essen

Prof. Dr. Reinhard X. Fischer
University of Bremen
Bremen

Michael Grau
Mankiewicz Gebr. & Co.
Hamburg

Dr. Stefan Kienzle
Daimler AG
Ulm

Dr. Johannes Kurth
KUKA Roboter GmbH
Augsburg

Carsten Meyer-Rackewitz
tesa SE
Hamburg

Dr. Matthias Müller
Robert Bosch GmbH
Stuttgart

Reinhard Nowak
Glatt GmbH
Binzen

Staatsrat Carl Othmer
Senator for Education and Science of the Free and Hanseatic City of Bremen
Bremen

Dr. Ralf-Jürgen Peters
TÜV Rheinland Consulting GmbH
Köln

Dr. Rainer Rauh
Airbus Deutschland GmbH
Bremen

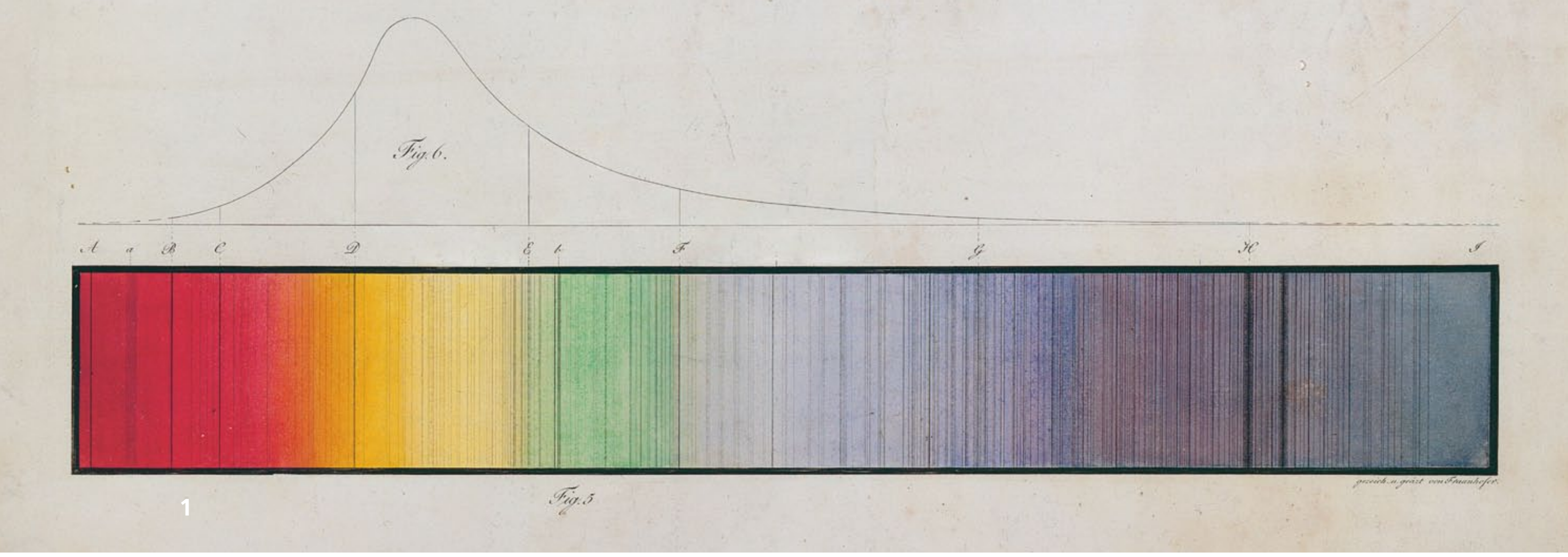
Jan Tengzelius M. Sc.
Höganäs AB
Höganäs, Sweden

Christoph Weiss
BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG
Bremen

Min.-Rat Dr. R. Zimmermann
Saxon State Ministry for Science and the Arts
Dresden

Guest

Johann Wolf
BMW AG
Landshut



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.

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

1 *Fraunhofer's drawing of the solar spectrum.*

Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

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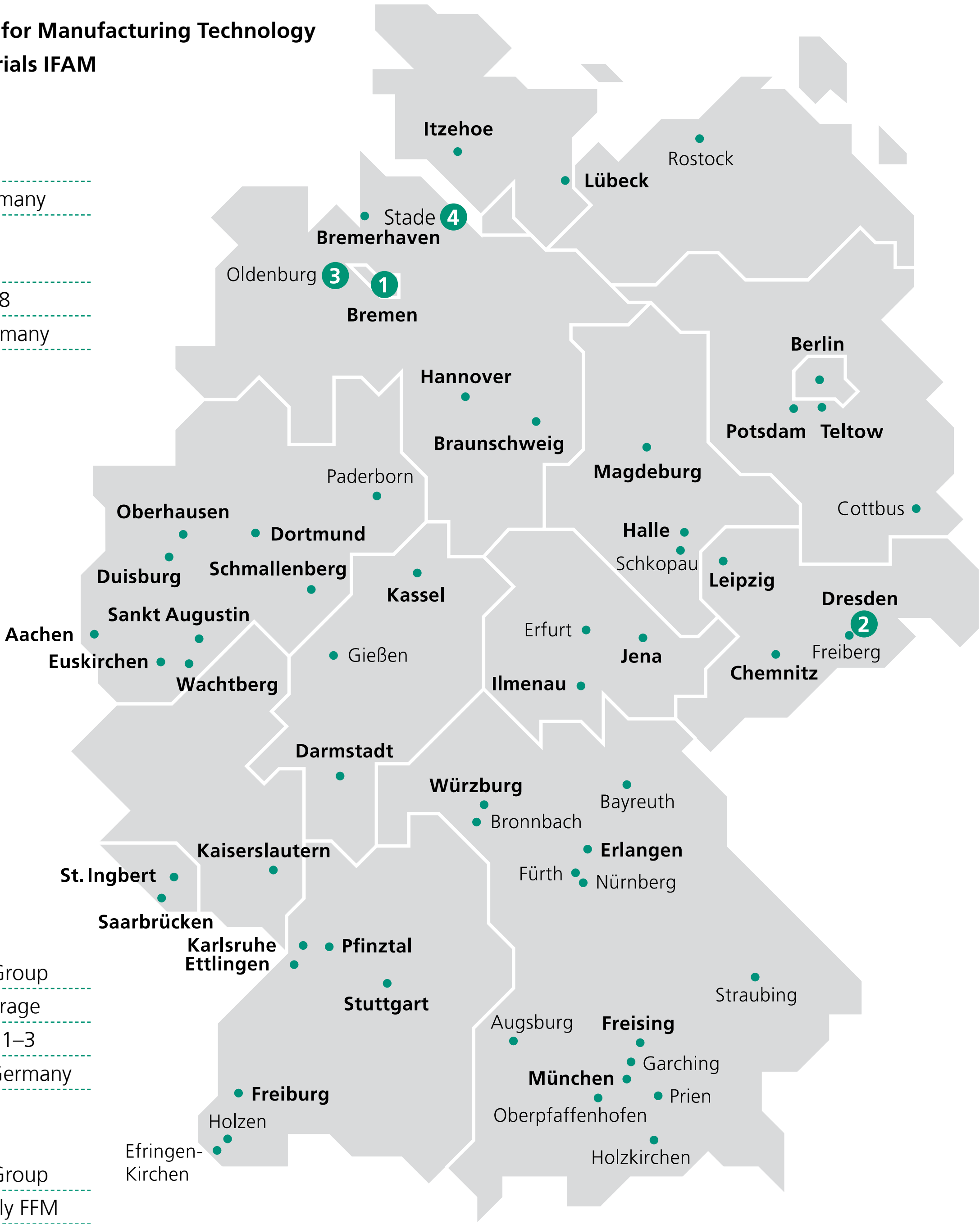
28359 Bremen, Germany

2
Winterbergstrasse 28
01277 Dresden, Germany



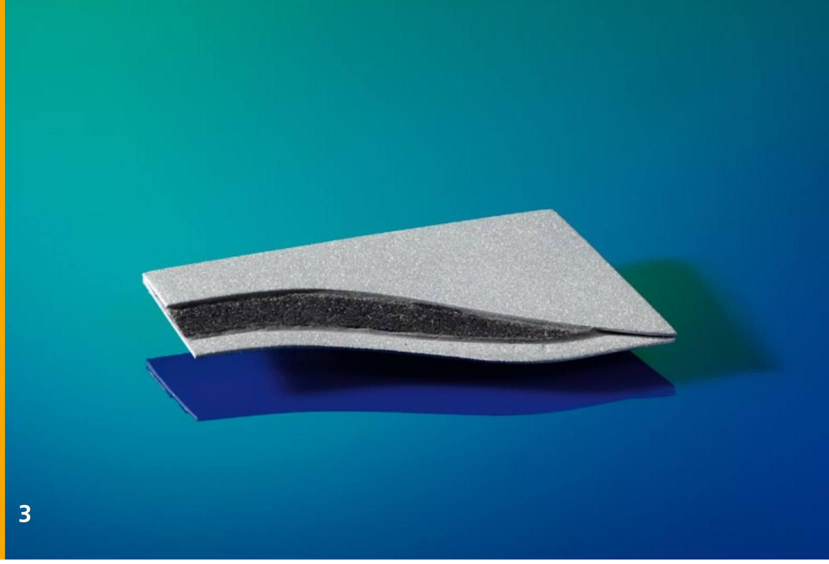
3
Fraunhofer Project Group
Electrical Energy Storage
Marie-Curie-Strasse 1–3
26129 Oldenburg, Germany

4
Fraunhofer Project Group
Joining and Assembly FFM
Research center CFK Nord
Ottenbecker Damm 12
21684 Stade, Germany

Institutes and Facilities
Other sites

SHAPING AND FUNCTIONAL MATERIALS

2



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COMPETENCIES AND KNOW-HOW

Networks of business partners and research facilities play a decisive role in the development of complex system solutions. Methodological competence and excellent specialist knowledge are essential, in particular wherever the various fields interface. At Fraunhofer IFAM employee competence and our network with industry and science partners is the guarantee for the development of innovative solutions for the economy.

Transferring basic application-oriented research to implementable production solutions or component development is a task that requires constant advancement of knowledge bases and methodological competencies. The continuous expansion of specific competencies and know-how has a very high priority at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials – Shaping and Functional Materials division.

Our research and development work ranges from basic application-oriented research to the implementation of new products and production launch support.

Multifunctional components with integrated sensor functions set specific requirements for the materials involved. Properties can be precisely customized by combining various materials within a component. A major task in enhancing competence is to refine and control such material combinations in production processes. The material combination spectrum ranges here from metal-metal, metal-ceramic all the way to combinations with CFRP.

Manufacturing processes such as injection molding are now used for the production of geometrically demanding components made from numerous metal alloys and ceramic materials. It has now become possible to specifically apply the different properties of materials to different parts of components. This allows, for instance, hard-soft, dense-porous material property combinations, or even materials with sensory properties, to be custom-integrated in components. Such developments are of particular interest in microcomponent production where these integrated production solutions mean that microassembly work can be omitted.

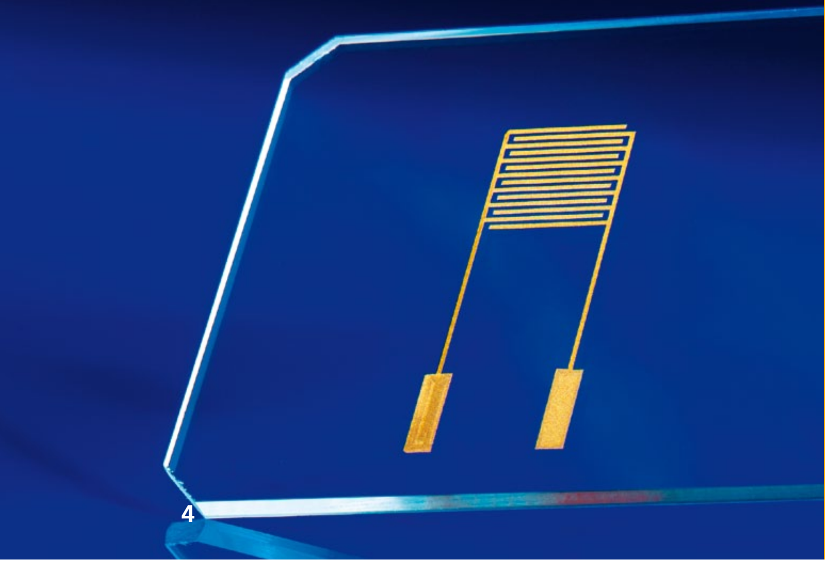
Functional ink and paste formulations, and the relevant experience in applying them to components, have also been elaborated, especially for the development of the "INKtelligent printing®" process. This makes it possible to equip components with sensors for recording operating or ambient conditions, for example.

Fraunhofer IFAM is well positioned in the market with cutting edge casting and analytical equipment, plus comprehensive know-how on diecasting processes for aluminum and magnesium alloys. In addition to optimizing permanent mold casting processes, we have continuously advanced our com-

1 *Future energy supplies: Fraunhofer IFAM has developed new storage technologies for greater ranges (Photo: Dr. Hermann Pleteit).*

2 *Functional thin layers created with magnetron sputtering.*

3 *Composite material laminated into a sandwich component for component monitoring.*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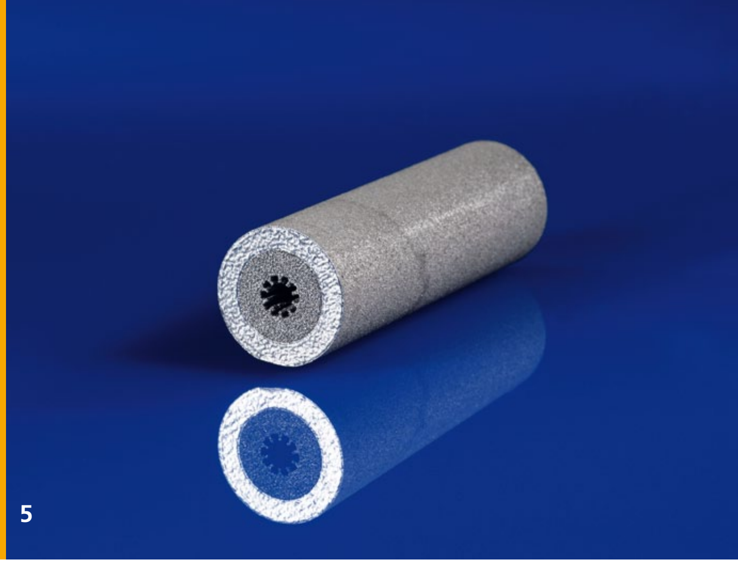
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petence in lost-foam casting. A process engineering approach has led to the development of “CASTtronics® technology”, which provides casting shops with the ability to integrate functional components directly in their casting process.

The implementation of cellular metallic materials into products is now at a high level of expertise, which allows us to develop special solutions for markets, such as diesel particulate filters, while thereby extending our process knowledge on a continual basis. Our subject portfolio is continuously synchronized thus specifications, resulting in new technological challenges. Questions regarding product innovation under strict economic constraints play an essential role here, as do the contributions of research results for improving quality of life and sustainable developments for the sectors of transport, energy, medicine and the environment.

A significant success factor in all product innovations continues to be materials and their processing. This is particularly relevant for primary forming methods, as both material properties and component geometry can be influenced during the production process. The resulting market continues to grow due to the increasing product complexity involved.

Material properties and technologies are customized and characterized for structural and functional applications. High-performance materials, composite materials, gradient materials and smart materials are all being refined for this purpose, while production technologies aimed at integrating their properties into components are also being developed.

Our customers gain new opportunities for product developments through this enhancement of material competence in the special fields of functional materials, such as magnets, thermal management materials, thermoelectric and magneto-caloric materials and nano-composites.

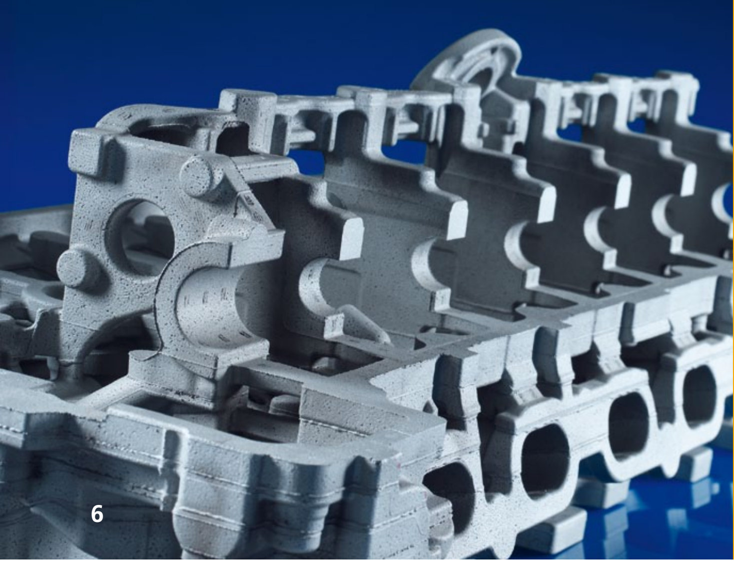
A highly dynamic area under development is the field of electromobility with emphasis on energy storage systems, drive technology and system testing. New battery systems are being worked on together with partners in the Northwest metropolitan region. The activities carried out by Fraunhofer IFAM in the Fraunhofer-Gesellschaft project “Electromobility System Research” are concentrating on the development of magnetic materials for wheel hub motors and the construction of an electrically driven vehicle as a prototype for integrating new components. An evaluation center has already been set up for measuring the complete electrical drive technology. The services here include the specific investigation and evaluation of electric motors, power converters, control systems and traction batteries. They also include battery aging tests and the characterization of continuous operation properties for electrical drive systems based on real and specially designed driving cycles.

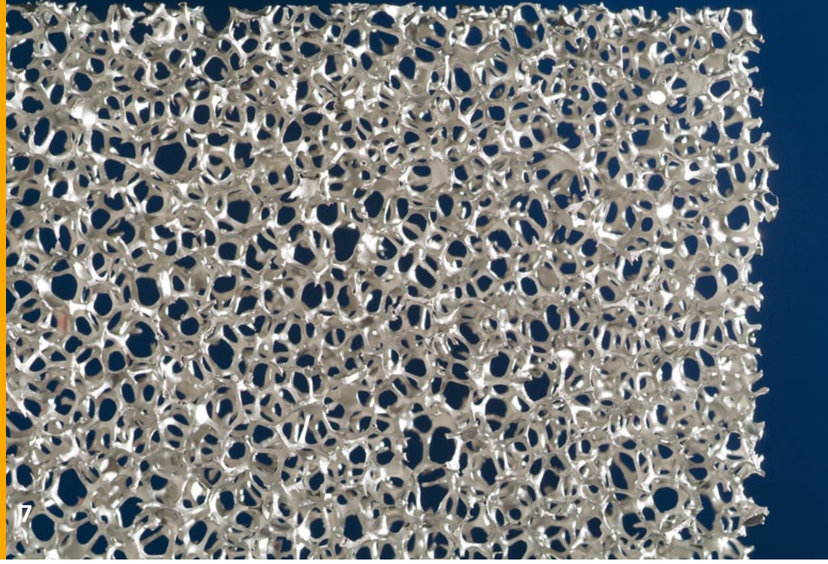
Outlook

The test setup for the electric drive train is to be supplemented by so-called vehicle models, which allow vehicle-specific data (vehicle weight, driving resistance, etc.) to be integrated in the test. This will make it possible to evaluate the tested batteries and motors within the context of different vehicle models.

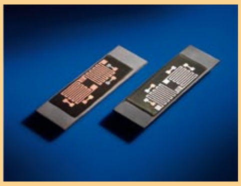
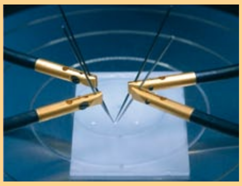
The development of new production engineering options for the cost-effective production of components in electric vehicle drive trains is economically very attractive and presents a new set of challenges.

The creation of a production cell for the functionalization of components and surfaces is the next step in the implementation and introduction of sensor integration using printing techniques in existing industrial production lines.





FROM MATERIAL TO RELIABLE APPLICATION

MATERIAL	SHAPING	FUNCTION	TESTING	APPLICATION
				
· Metals · Ceramics · Polymers · Structural Materials · Functional Materials · Composite Materials	· Powder Metallurgy · Casting · Freeform Fabrication · Nano- and Microstructuring	Integration of function during the manufacturing process · Sensors · Actors · Functional Coatings Energy Storage	· Material Analysis · Mechanical Testing · Performance tests · System checks · Expert reports	· Machine and Equipment Construction · Automotive · Electromobility · Environmental and Energy Technologies · Aerospace · Medical technology · Microsystems Technology

Competencies.

Additive production processes must be expanded and integrated in digital production process chains with a view to a production based on recyclable/renewable materials.

This is also being evaluated with respect to recycling concepts, particularly for strategic metals such as rare earths.

4 *Printed gold interdigital structure for production of selective sensors.*
5 *Study for a heat exchanger: Solid cladding – porous core, steel 1.4542, laser-generated.*
6 *Complex lost-foam cast component (cylinder head – BMW).*
7 *Open-cell metal foam structure.*

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Casting technologies: Aluminum, magnesium and zinc die casting; Cast iron and cast steel; Function-integrated cast components (CAST*TRONICS®*); Lost-foam processes; Simulation; Rapid prototyping. Component development: Design, production and testing of electrical machines.

Materialography and Analytics

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High-temperature materials; Nanocrystalline materials; Materials for tribological loading; Sputter targets; Materials for hydrogen storage.

EQUIPMENT/FACILITIES

Component manufacturing

- Metal powder injection molding units (clamping force 20 t and 40 t)
- 2-component injection molding machine
- Single cavity injection molding
- Hot press (vacuum, inert gas, 1800 °C)
- Uniaxial powder presses (up to 1000 t)
- Powder press for thermal compaction (125 t)
- Extrusion press (5 MN)
- Rapid prototyping systems for laser sintering of metals; Conceptual models via 3-D printing, including colors
- Cold chamber diecasting machine (real-time control, clamping force 660 t)
- Hot chamber diecasting machine (real-time control, clamping force 315 t)
- Sand casting
- Pilot systems for production of metal foam components
- Microwave sintering machine
- Screen printing machine
- Polystyrene miller
- Hot wire cutting system
- Model production for lost-foam processes
- Casting system for lost-foam processes
- Spark-plasma sintering unit (up to 300 mm part diameter)

Micro- and nanostructuring

- Inkjet printing technologies
- Aerosol-Jet® technology
- Micromanufacturing cell
- Four-point-bend station
- Ink test bench – drop on demand
- Sputtering technology
- Glove box system

Thermal/chemical treatment of formed pieces

- Chemical dewaxing units for injection molded parts
- Diverse sintering furnaces (up to 2000 °C, inert gas, hydrogen, vacuum)

Material synthesis and processing

- Gradient material production systems (sedimentation, wet powder injection)
- Metallic nanopowder and nanosuspension production systems
- Test bench for characterization of functional inks for inkjet printing processes
- Melt extraction unit (metal fibers)
- Rapid solidification system for producing nanocrystalline or amorphous slivers or flakes
- High-speed mixer and shear roll extruder for MIM feedstock production
- Twin-screw extruder
- Compounding of biopolymers and composites
- Granulator

Instrumental analytics

- Rheometry
- Micro-tensile testing machine
- Tensiometer

- 2-D/3-D laser surface profilometry
- Thermal conductivity measurements of molding materials
- IR laser for translucent material density determination
- Magnetic measurement technology
- Electrical characterization
- Dynamic sensor characterization
- FIB – Focus Ion Beam

Certified to DIN 9001:2008

- FE scanning electron microscopy with EDX
- X-ray fine structure analysis
- Thermal analysis with DSC, DTA, TGA
- Sinter/Alpha-dilatometry (accredited lab)
- Powder measurement equipment with BET and laser granulometry (particle size analysis)
- Trace element analysis (C, N, O, S)
- Materialography
- Emission spectrometer
- X-ray tomograph (160 kV)
- Gas permeability determination

Electric energy storage

- Battery and cell test benches (cycling unit)
- Impedance spectroscopy
- Raman spectrometer with integrated AFM
- Thermal analysis with integrated MS/IR
- Inert gas system with integrated PVD unit for electrode coating and cell production

Electromobility

- Two motor test benches up to 120 kW
- Battery test bench up to 50 kWh

Computers

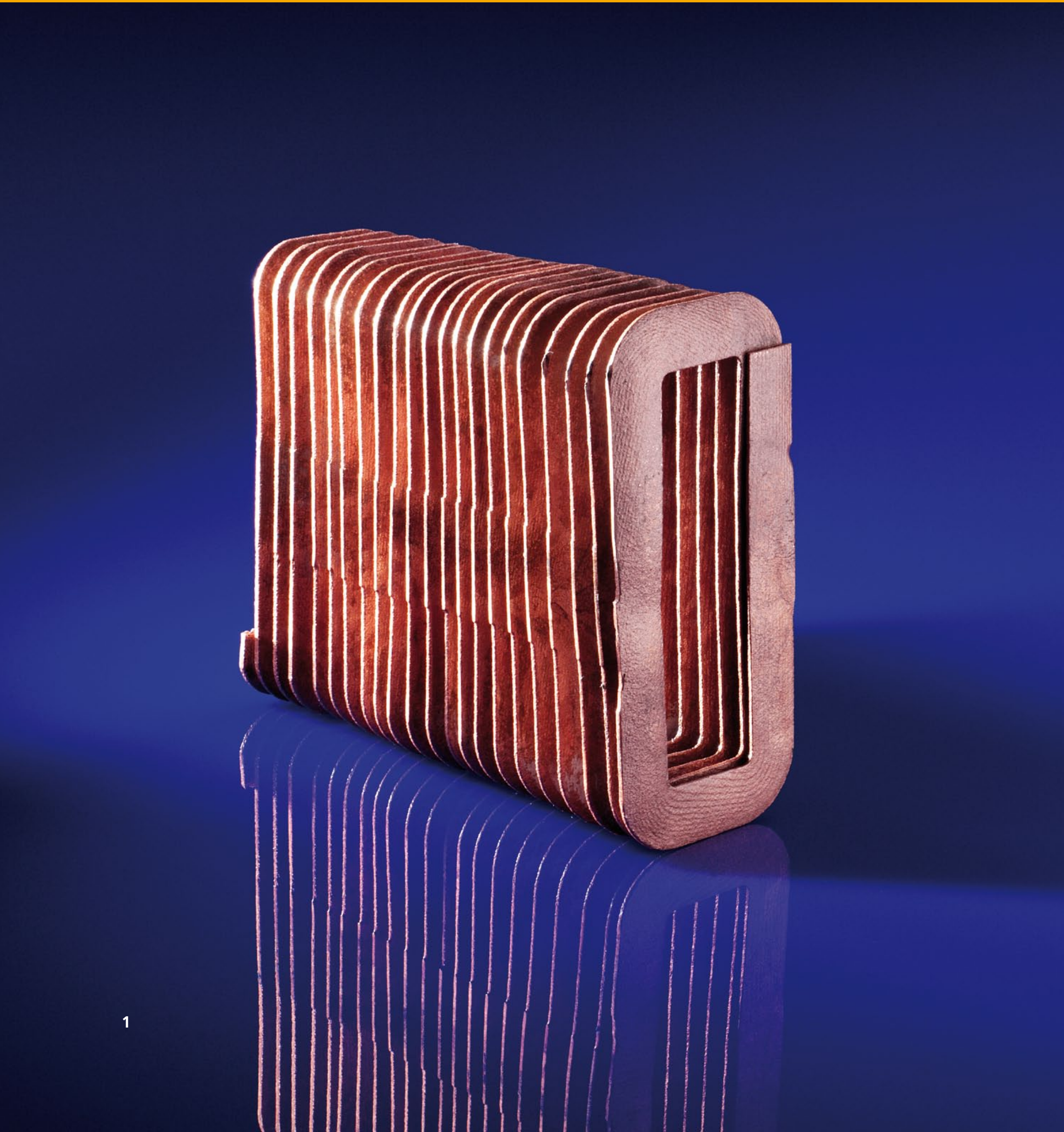
- High-performance workstations with software for non-linear FE analysis, mold filling and solidification simulation, and component optimization

1 *Motor test bench for shaft alignment.*

2 *Universal testing machine for dynamic characterization of printed sensors.*

SHAPING AND FUNCTIONAL MATERIALS

RESULTS FROM RESEARCH AND DEVELOPMENT



NEW DRIVE CONCEPTS AND COMPONENTS FOR ELECTRIC VEHICLES

New vehicle concepts and components are necessary to make electric vehicles more suitable for daily use. Battery systems, charging devices and motors – what will the components of future vehicles look like and how will their different functionalities interact? Fraunhofer researchers are developing components for electric vehicles and testing them in the demonstrator vehicle "Frecc0". The Casting Technology division at IFAM participating in the project "Fraunhofer System Research on Electromobility – FSEM" has developed wheel hub motors with high torque density. They have a good chance of taking a lead as a drive concept for electric vehicles.

Electromobility – Effects on future fields of action and products in casting technology

The ongoing electrification of the drive train - starting with the successful market introduction of hybrid vehicles in the past – has become an irreversible process. This is due to constantly increasing fuel prices, limited oil reserves and the effects of private motor transport on the environment and climate, which is also giving rise to increasingly stricter emission laws. Even though the combustion engine will continue to be used and optimized as a vehicle propulsion system over the coming years and decades, its significance as the only solution for drive energy generation will lessen. This is also a crucial necessity if air pollution, in accordance with climate aims, is not to increase any further in mega-cities and agglomerations around the world; especially when regarding the increasing levels of private mobility in the highly populated and dynamic Asia-Pacific economic region. A disruptive change in technology is not expected to take place, instead conventional and hybrid drive technologies will coexist with electric traction drives for several decades.

This general change in drive technology necessitates a change in the product portfolio and consequently in production and manufacturing technology, especially in casting technology: Over time, the variety and quantity of traditionally cast vehicle components on the market (i.e. cylinder heads, transmission housings, manifolds, injection pumps, etc.) will decrease. Even though the replacement parts market promises to ensure significant turnover for many years, the automotive industry and its suppliers must gear up in time at all levels for a change in products, and a corresponding change in essential production and manufacturing technologies.

The hybridization of vehicles means that both drive technologies will have to coexist with each other for some time. This opens up the opportunity to continue offering "classic" products to current customers and, at the same time, evolving a new orientation with components for electromobility. The increasing electrification of the drive train and the use of energy storage systems (batteries) changes the portfolio of products likely to be made using casting processes. Examples are components in electric traction motors or battery cases where new application areas in casting technology are being developed.

1 *Coil for electric machines produced by casting.*

Continuing development of mass-production capable manufacturing methods in casting technology

Within the context of electromobility, Fraunhofer IFAM is looking at numerous questions regarding specific component development and the necessary advancements in production and manufacturing processes for the mass production of electric vehicles and their primary components. Casting technology is the key word here, as it can provide a significant contribution to cost reduction and mass-production capability of electric vehicle components. The work and development priorities at Fraunhofer IFAM in this field include advancing die casting processes, e.g. towards a stronger functional integration of cast components ($\text{CAST}^{\text{TRONICS®}}$), and the use of lost-foam processes for creating complex component geometries. Other areas also cover material and process development, with the aim of improving material properties, and casting methods to meet the requirements of industrial manufacturing. The focus in the "Component development" working field is on the design and development of electric machines and control equipment, as well as on the ongoing development of mass-production capable manufacturing methods for electric vehicle components.

Sustainable and holistic evaluation – Fraunhofer System Research on Electromobility

Questions regarding electromobility from a system perspective are being evaluated within the framework of the "Fraunhofer System Research on Electromobility – FSEM" project, which is funded by the Federal Ministry of Education and Research. The strategic aim of the Fraunhofer-Gesellschaft is to continue developing competence and expand the research portfolio in the electromobility sector. Research work is focusing on the primary components of electric vehicles and their optimal integration in the energy supply network. Socio-political questions, such as the availability of resources, are also being examined in detail. Setting up demonstrator vehicles as scientific integration platforms not only advances further development at component level, it also aims to integrate and apply the jointly developed components within the complete vehicle.

Fraunhofer IFAM is contributing significantly to three areas in the FSEM project. These are the provision of optimal joining techniques for efficient manufacturing of battery systems, the electromagnetic planning, design and manufacturing of a compact wheel hub motor with a very high torque density, and the design and integration of Fraunhofer components in the demonstrator vehicle "Fraunhofer e-concept car type 0 – Frecc0" (Fig. 1 and 2).

Consistent utilization of the advantages in casting production processes

Casting technology can contribute significantly to cost reduction and mass-production capability of electric vehicles. Ways are being identified as to how casting manufacturing methods can provide important impulses for essential greater functional integration in complex components as well as potentials for necessary substantial cost reductions based on the wheel hub motor (Fig. 4 and 5) developed in the "Fraunhofer Electromobility System Research – FSEM" project.

The motor is designed as a permanent-magnet synchronous motor with external rotor. The rotor bell, which transfers the generated drive torque to the wheels, is structurally designed as an aluminum die cast component. It holds a soft magnetic sheet metal ring into which the permanent-magnets are glued. The actual stator is mounted with the coil windings as a laminated core on the stator housing. The component is designed as a cast component using lost-foam casting. The

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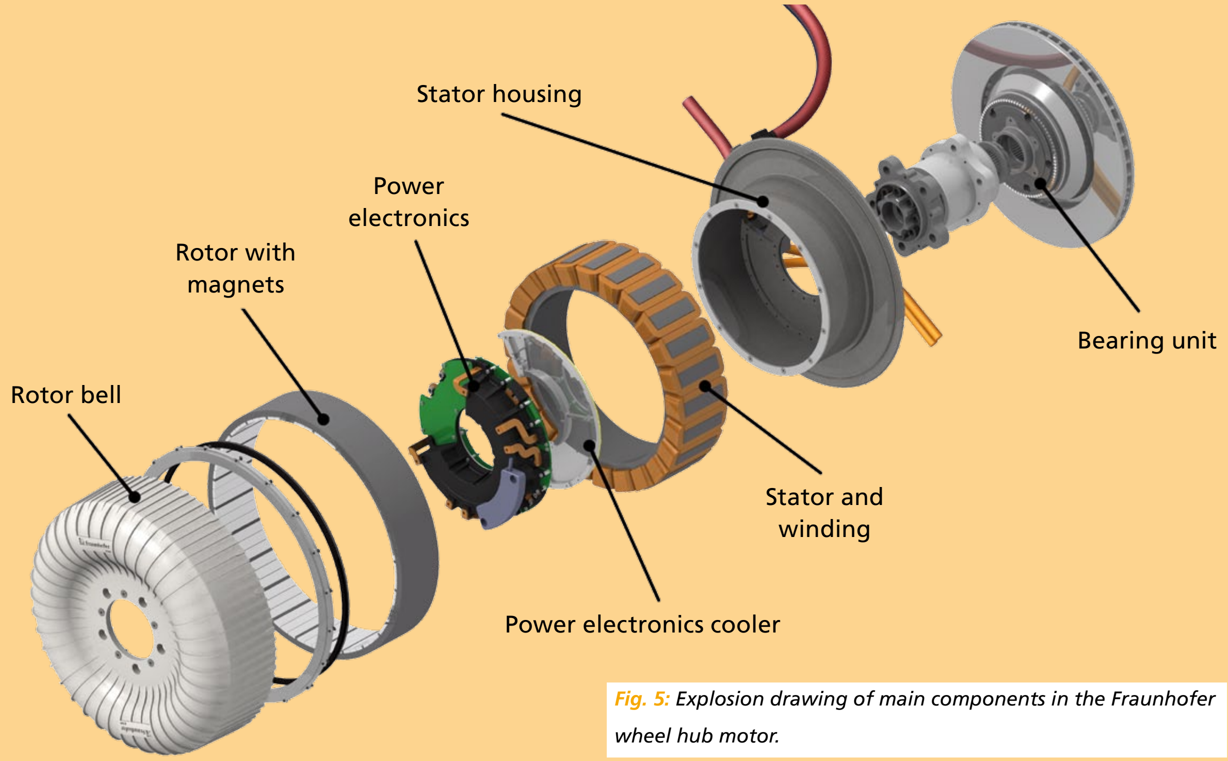

Fig. 5: Explosion drawing of main components in the Fraunhofer wheel hub motor.

process advantages with regards to geometric design are used here to realize integrated channels for liquid cooling of the stator laminated core and for the power electronics which are also integrated in the motor installation space. Consistent utilization of the advantages in casting production processes means that a rapid transition to possible mass-production can be achieved following the FSEM project. All main mechanical components of the wheel hub motor will then be produced as cast parts.

Fraunhofer IFAM is following a completely new approach (Fig. 6) with their method for "making coils for electric machines with casting technology" in order to contribute to increasing the mass-production capability of electric motors as drive systems in vehicles. The aim of this work lies in demonstrating a production method for a drive motor coil using casting and in characterizing the properties with regards to the achievable performance and the resulting losses. In addition, a maximization of the slot fill factor should be achieved by utilizing the process technology advantages inherent in investment casting, for example. The improved use of the available installation space makes it possible to either achieve greater power and

2 *The "Fraunhofer e-concept car type 0-Frecc0« based on the Artega GT.*

3 *The Federal Minister of Education and Research Prof. Dr. Annette Schavan and the President of the Fraunhofer-Gesellschaft Prof. Dr. Hans-Jörg Bullinger testing the Artega GT, which is being used as the platform for the integration of the Fraunhofer components.*

4 *Wheel hub motor.*

degree of efficiency whilst maintaining the same geometry or reduce the required installation space, saving weight, whilst maintaining the same power. It is also feasible to use aluminum as an alternative conductor material to realize further weight savings and significantly reduce raw material costs.

Another development direction lies in the powder-metallurgical production of soft magnetic components in the electric motor. This applies mainly to the stator laminator core where segments should be replaced by sintered components. The advantage here is that the soft magnetic material enables a three-dimensional flux guide and therefore the development of novel machine concepts. The performance capability of various materials and process flows is currently being investigated through simulations and experiments.

Casting manufacturing methods can not only contribute to cost savings in the drive system, other vehicle components can also benefit, for instance, battery systems or structure components (e.g. casting knots in frame constructions). The functional integration of sensors, for example, also plays an important role in the sense of "Structural Health Monitoring" with regards to safety considerations.

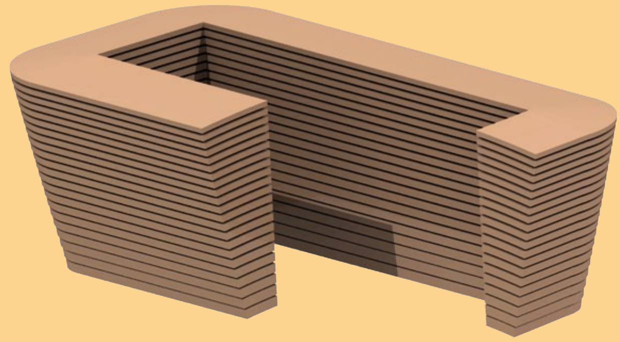

Fig. 6: Sectional view of a cast coil with maximum exploitation of the hub area.

Project funding

Funded by the Federal Minister of Education and Research.

Bundesministerium
für Bildung
und Forschung

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ELECTRICAL ENERGY STORAGE SYSTEMS FOR MOBILE APPLICATIONS

Electrical energy storage systems are key elements of most electrically-operated mobile products. They must meet a variety of specific requirement profiles. In particular, a broad market introduction of modern electric vehicles depend crucially on the availability of efficient energy storage technologies. Materials science and production engineering solutions are needed for the development of next generation battery components and systems – one aim set by the Fraunhofer IFAM project group "Electrical Energy Storage".

2010: The combustion engine still holds pole position

Mobile applications with electronic components and/or electric drives require a safe and powerful energy supply. These tasks can be implemented by chemical (fuels), electrochemical (batteries) or purely electrical storage systems (capacitors). The balancing act between high energy and power density, high operating safety and low costs has to be re-evaluated for each application. Electromobility is of particular significance here, with its use being closely coupled with the on-board generation of electric energy from primary energy carriers (fuel cells) or with the availability of electrochemical energy storage systems (batteries) with a high energy and power density and high cycle numbers (more than 2000 full cycles). With existing material concepts for batteries, purely electric-based driving ranges, similar to those known from cars with combustion engines, cannot be realized under the combined aspects of safety, costs and service life.

Multiple development opportunities with new material concepts

The development of electromobility and many other mobile applications is closely coupled to a further increase in the energy and power density of electrical or electrochemical storage systems. This is the only way allowing further miniaturization of storage systems (at identical energy content) or larger operating duration/driving range (at identical storage volume). Theoretical estimates indicate that developments regarding lithium-ion batteries will soon reach their limits regarding energy and power density. In contrast, rechargeable metal/air-, lithium/sulphur- and other storage concepts demonstrate a high development potential, especially with regards to their energy density, with an expected 300–1000 Wh/kg, which is significantly higher than that of lithium-ion technology (Fig. 2). However, new routes must be taken in material and process engineering for the components of these high energy cells, the so-called "4th generation storage systems".

1 *Assembly of test cells in inert gas conditions.*

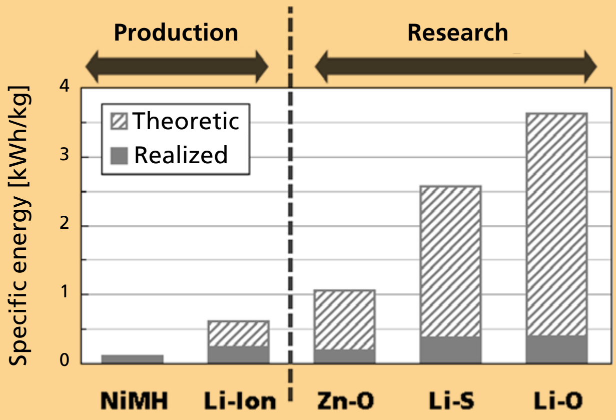

Fig. 2: Energy density of various types of rechargeable batteries at single cell level. The theoretical energy density is based on the active materials including the reaction product in the case of air batteries. NiMH: Nickel-metal hydride, Li-Ion: Lithium-ions, Zn-O: Zinc-air, Li-S: Lithium-sulphur, Li-O: Lithium-air.

Significant differences from currently used energy storage concepts are also expected regarding cell chemistry and cell design. Modified concepts derived from fuel cell technology could however be used for the structure of cell stacks.

Overall, this will give rise to numerous opportunities for developing cycle-stable and operationally-secure metal/oxygen energy storage systems for mobile applications.

2020 already in mind: “post-lithium-ion technologies”

The global developments in lithium-ion technologies in the consumer batteries sector have already led to mature products in billions of pieces (especially in Asia). Lithium-ion technology also has an obvious development and implementation potential for electrical traction. This potential will probably be all but exhausted during this decade. Probably by 2020, the requirements for purely electrically operated vehicles (EVs) will be successfully achieved regarding power density by using novel nano-structured active materials. However, the theoretically predicted energy densities would still lie well below the required values. Here, radically new research approaches and routes must be taken for long-term advancements in battery technologies. Consequently there is consensus within the “National Platform for Electromobility” that research into “Post-lithium-ion technologies” must be intensified and supported by an appropriate materials-orientated support program, focusing on metal/air-, lithium/sulphur- and solid-state batteries.

Current research work

The following topics are most important and are prioritized with regards to the development of rechargeable metal/air batteries:

- Increasing energy efficiency (reducing the overpotential during charging/discharging) via suitable mixed catalysts in gas diffusion electrodes (GDE) – ensuring the bi-functionality of the GDE, i.e. oxygen reduction reaction during discharging (ORR) and oxygen evolution reaction during charging (OER)
- The influence of atmospheric trace gases (H_2O, CO_2, SO_2) on cycle life and suitable protective measures


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- Cycle-stable silicon-based negative electrodes with special morphology allowing "non-destructive" uptake/release of lithium
- Cell design and new stack concepts for metal/air batteries

Component manufacture and development of relevant methods are accompanied by special test methods and in-situ analyses.

Implementation and outlook

IFAM has been running the project group "Electrical Energy Storage" since January 2010. Laboratories and offices were rented in the Technology and Start-Up Center in Oldenburg (TGO) and equipped with technical infrastructure and the required large-scale equipment. The TGO is located close to the EWE research center "Next Energy" and the University of Oldenburg, which has an excellent reputation in physics and chemistry, particularly in the sectors of energy research and electrochemistry. Important questions imposed by the extremely broad application area for electrochemical energy storage can be efficiently investigated via shared developments. Further, existing competencies at IFAM form another important basis for new developments in this application field: Nano-particle technologies and electrochemical corrosion phenomena, modeling of metal/polymer interfaces and transport processes are sectors, in which IFAM has developed comprehensive competencies that can be adopted for material and process developments for new energy storage systems.

The project group will expand to a staff of 30 and is financially supported by the German state of Lower Saxony. The aim is to focus on important (sub-) areas, to sharpen the research profile and to network with project groups in the region, the Fraunhofer-Gesellschaft and within international cooperations.

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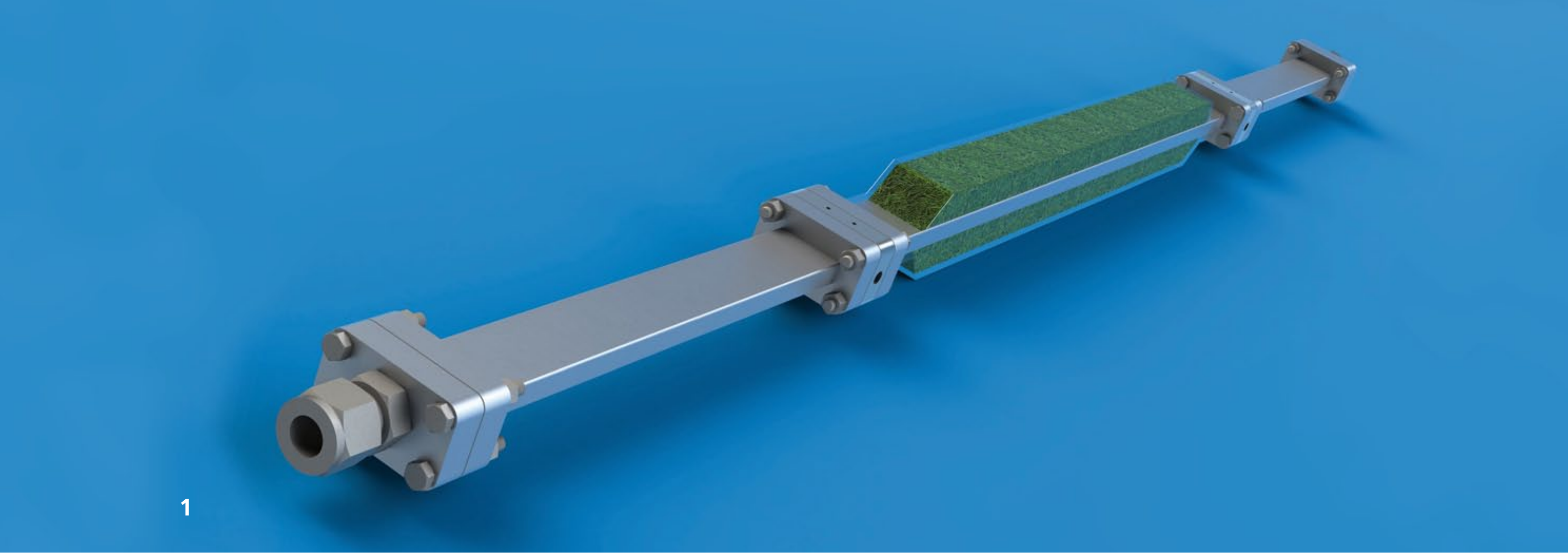
3 *Cycling unit for battery and cell tests with temperature-controlled measuring chambers (-20...+100 °C) and 96 test channels (max. ± 50V).*

4 *Examination of cell components using FTIR spectroscopy.*



MATERIALS AND TECHNOLOGIES FOR SUSTAINABLE ENERGY STORAGE

Energy is required in ever increasing quantities in all areas of life. The primary focus is on climate-friendly production and storage of energy. Fraunhofer IFAM is contributing to the evolution of sustainable energy storage technologies with approaches such as metal hybrid and thermal storage systems.

Motivation and aims

Starting situation

A sustainable reduction of climate-damaging CO_2 emissions means reducing primary use of carbon-based fuels in all sectors of technology. This can be implemented by increasing the use of regenerative energy sources. However, due to fluctuating availability these sources will have to be balanced out by innovative storage technologies. Electrical energy storage systems are required for photovoltaic and wind energy plants, while solar thermal systems require heat reservoirs. Heat reservoirs can also be used to exploit energy saving potentials most commonly derived from waste heat. General requirements for energy storage systems are:

1. High energy and power density (volumetric and gravimetric)
2. Charging and discharging time scenarios matched to existing constraints
3. High energetic and economic efficiency
4. High service life / cycle stability
5. High security
6. Low maintenance requirement
7. Simple and cost-efficient recycling

As the storage of energy is generally coupled with energy conversion processes, it is possible to use the same type of storage systems for different starting energy forms. Figure 2 shows an overview of the volume-based storage densities of various CO_2 neutral storage technologies achievable for thermal, electric and chemical energy.

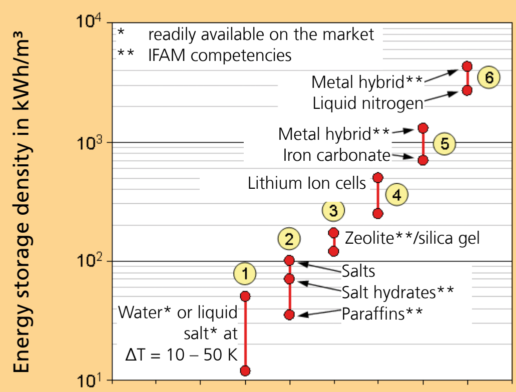
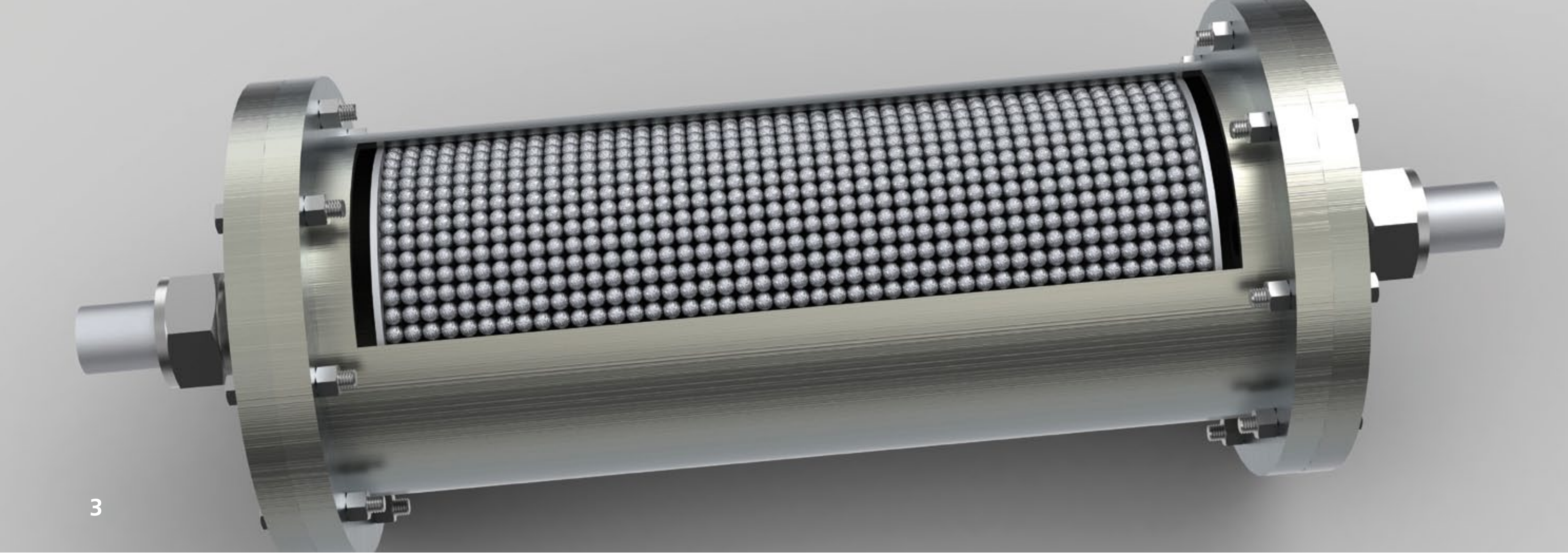


Fig. 2: Volume-based energy storage densities of various technologies – thermal [sensitive (1), latent (2), sorptive (3), thermochemical (5)], electric (4) and chemical storage systems (6).



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Challenge and competence

As demonstrated, currently available materials and material systems provide a great variety of energy storage systems with different storage densities (Requirement 1). Significant deficits, which will be the challenge for future technological developments, lie in the sector of storage dynamics and the efficiency of storage.

Storage systems with high energy densities enable more compact constructions, less material utilization and minimization of losses – thereby creating essential requirements for efficient storage operation. The kinetics of a storage system crucially depends on how fast energy and material transfer processes occur within the storage material. Fraunhofer IFAM in Dresden has the best prerequisites for targeted designing of sustainable energy storage technologies, due to the combination of expertise in material and production technology and heat and flow engineering know-how.

Research potential and current work

Thermal storage systems – compact and fast

Storage systems for thermal energy – referred to as heat or cold depending on the temperature level – only achieve acceptable storage densities if phase change (latent heat), addition reaction (adsorption) or thermochemical effects are exploited. Typical phase change materials (PCM) are paraffins and salt hydrates. Storage kinetics can only be improved in this case by improving heat transfer. Typical material systems are zeolite/steam for adsorption storage systems and metal/hydrogen for thermochemical storage systems. Both material and heat transfer processes affect storage kinetics here.

Optimization of heat transfer in latent thermal storage systems can be achieved by either "shorter routes" through small-scale PCM capsules or by realizing heat-conducting structures in larger storage units. Metallic hollow spheres developed by Fraunhofer IFAM, with diameters of just several millimeters, are an excellent basis for minute PCM capsules as they can be infiltrated with liquid PCM through the porous shell and then surface-sealed. Heat storage systems are provided with peak power density by the arrangement of such PCM-filled spheres as a packed bed with internal flow or directly added as "floating" heat capacity to a heat transfer medium.

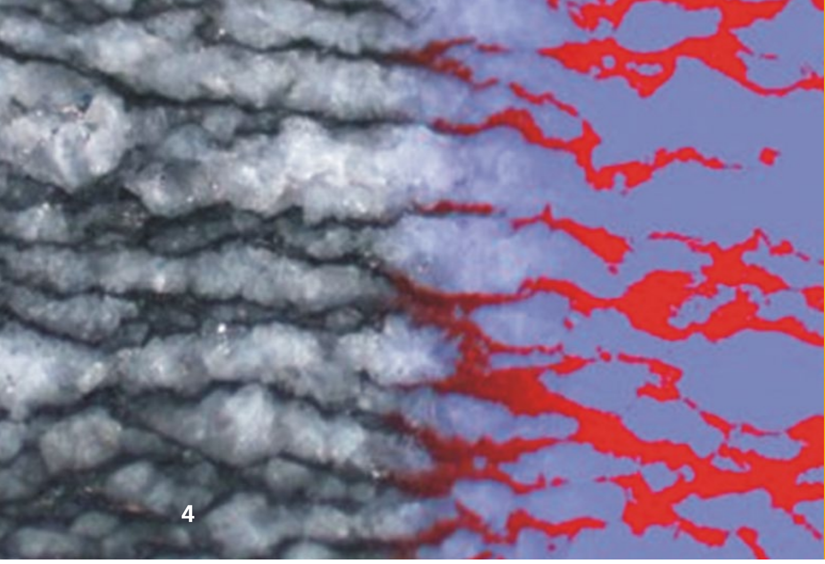
Alternatively, the use of open-cell metallic sinter, foam, fiber or wire structures with variable PCM porosity leads to an increase in thermal conductivity by one to two orders of magnitude. This principle can also be transferred to thermochemical storage materials. Metallic heat transfer structures can also be soldered to the wall of the storage element forming thermally conductive connections. Metal fiber structures also represent an optimal heat transfer framework with an extremely high volume-based interior surface area (up to several tens of thousand m^2/m^3) available for coating with substances for adsorption processes (zeolites).

Multitalented metal hydride storage system

The storage of hydrogen by chemically bonding it to a metal offers numerous possibilities for use as an energy store. The interpretation as a chemical store is justified when the hydrogen is subsequently oxidized (combustion engine, fuel cell).

1 *High-performance latent thermal storage module based on a rectangular channel and a PCM-metal fiber composite.*

3 *Prototypical thermal compact storage unit packed with PCM-filled metallic spheres.*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The utilization of significant amounts of reaction heat, generated during the hydration of special metal alloys, gives rise to heat reservoirs. If the energy carrier hydrogen is produced through water electrolysis using excess energy (e.g. from wind power) and then turned again into electrical energy, the end result is an electricity storage system.

Both material and heat transfer in the storage medium must be optimized to achieve the necessary storage kinetics. The powder-metallurgical competence at Fraunhofer IFAM in Dresden forms the foundation for this process (preparation of nanostructured storage materials and their combination with metallic or graphite structures). The development chain leads all the way to complete storage tank systems in which storage materials can be tested and evaluated under realistic conditions.

Outlook

Current research projects in the field of energy storage are not just focused on the preparation and characterization of materials used. They are also looking into the numerical simulation of impulse, heat and material transport phenomena in the storage medium and the energy engineering design of complete storage systems. This comprehensive know-how, bundled with the excellent equipment in the thermal engineering and hydrogen laboratories, permit Fraunhofer IFAM to make an important contribution to the development of energy storage technologies, which will withstand the test of time.

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4 *Microscopic view of an MgH_2-ENG composite (blue-red).*

5 *H_2 car (Source: MEV).*

THE ELECTROMOBILITY MODEL REGION BREMEN/OLDENBURG: INITIAL AIMS ACHIEVED

Electromobility is a very popular topic nowadays. Hardly a day passes without the media reporting on new electric vehicles and related technologies. And public interest also appears to be constant. The vision of new means of transport is simply too enticing: Quiet, emission-free and environmentally-friendly – driven by energy from renewable energy sources.

Chances and risks of electromobility

The greatest challenge in electromobility is to meet the widely different information requirements of the various interest groups. Naturally, future buyers and users of electric vehicles want to know what these vehicles can offer now and in the future, how suitable they are for daily life and what commercial purposes they can be used for. Above all, there are numerous questions concerning what effects the expected change will have on the automotive industry value chain when the market percentage of electric vehicles increases. Many supplier companies in the automotive sector are confronting this topic and would like to gain first-hand experience of this new technology. And finally, new business ideas are also being developed with respect to electromobility. Starting with intelligent charging stations, this spectrum reaches all the way to new mobility service providers.

The mutual task that the employees at Fraunhofer IFAM, together with their project partners, have set themselves is to meet precisely this need for information and personal experience. The Electromobility Model Region Bremen/Oldenburg has geared itself up to thoroughly test a fleet of more than one hundred vehicles.

Vehicle testing in hard daily use

The Bremen/Oldenburg region has been one of eight Federal Ministry of Transport, Building and Urban Development (BMVBS) "Electromobility Model Regions" since the end of 2009. These model regions are therefore a measure, within the framework of the national electromobility development plan, aimed at turning Germany into a leading market for new mobility technologies. The task of all eight model regions is

1 *"A region discovers (electro)mobility" – Kick-off event for the Electromobility Model Region Bremen/Oldenburg: Enak Ferlemann symbolically handing over the keys in Bremen. From left to right: Enak Ferlemann, Parliamentary State Secretary at the Federal Ministry for Transport, Building and Urban Development, Martin Günthner, Senator for Economic Affairs and Ports, Bremen, Prof. Dr.-Ing. Matthias Busse.*

4

to translate application-oriented research and development topics into demonstration projects and so prepare for future everyday electromobility applications.

Fraunhofer IFAM developed and implemented the idea of the Model Region Bremen/Oldenburg jointly with the German Research Center for Artificial Intelligence (DFKI) GmbH. Employees from both facilities manage the regional project control center for the model region, pulling together all relevant projects here. Coordination with the Ministry and the project management also takes place at this center. Over 30 partners from politics, science and business are now directly or indirectly involved in the model region projects. Results are being processed from a total of 15 projects.

The activities of the model region are delineated within 4 so-called Modules (Fig. 3) and Fraunhofer IFAM is active in all four Modules (partly in a leading role).

The regional project control center carries out the superordinate program coordination at regional level in Module 1 ("Personal Mobility Center" – PMC) and is the direct contact partner of the national coordinating body NOW GmbH authorized by the BMVBS. All administrative processes of the project are managed from this control center. The operative execution of all activities linked to the implementation of the above-mentioned issues takes place in the "Personal Mobility Center". The PMC supervises and coordinates all activities in the region, in consultation with the regional project control center, moderates processes and manages the vehicle fleet. In addition, the PMC is available as a regional service center for all members of the model region. Plans are also underway to turn the PMC into an independent institution in 2011.

Module 2 ("Intelligent Integration of Electromobility") develops software and hardware tools essential for the demonstration projects of the model region. This also includes the development of the data acquisition infrastructure. A large proportion of the electric vehicles in the model region are

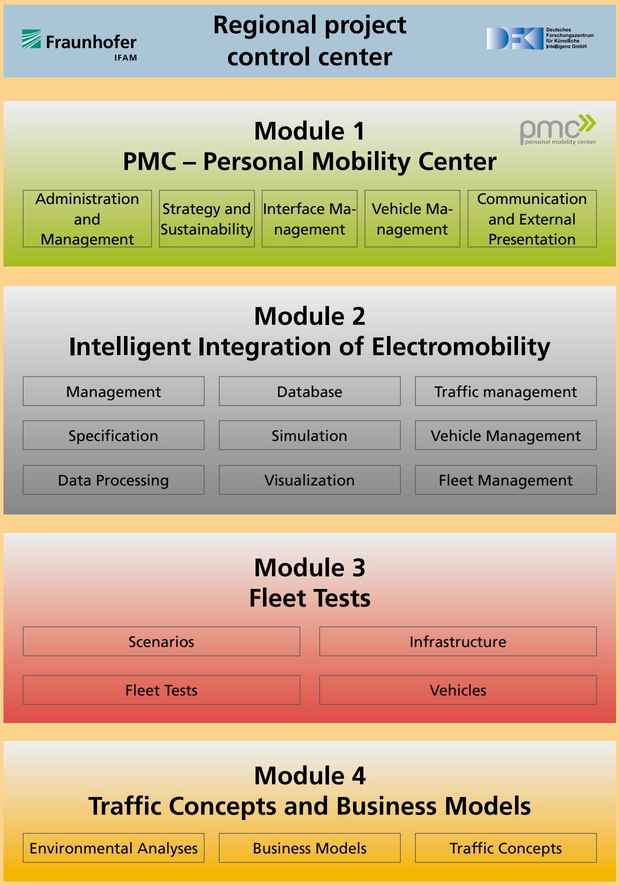

Fig. 3: Activities in the Electromobility Model Region Bremen/Oldenburg.

2 *Delivery of the first vehicle fleet to Fraunhofer IFAM (Photo: Move about GmbH).*

4 *Federal Transport Minister Dr. Peter Ramsauer visiting the Electromobility Model Region Bremen/Oldenburg.*

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equipped with data acquisition systems which transmit their data directly to the central Module 2 data server. The evaluation of this data will in future provide important findings about the technical condition of the vehicle and batteries, and also about the mobility behavior of the vehicle user.

A prerequisite for the successful establishment of electromobility is to demonstrate the suitability for daily use of electric vehicles. In Module 3 ("Fleet tests"), tests are carried out with the vehicle fleet, using various vehicle types and technologies, by both specialists and technological laypersons. The vehicle fleet covers the entire spectrum of electromobility and the needs of potential users, as well as service providers.

Module 4 ("Traffic Concepts and Business Models") brings together all work related to sub-aspects of, and investigations into, the development of business models and traffic concepts in the sector of electromobility. These activities include the analysis of customer behavior (demand, acceptance, driving behavior, sites, etc.), the development of business models (invoicing concepts, tariff models, collective versus individual vehicle utilization, etc.), and the testing of developed concepts through fleet tests.

The electric test fleet at the starting line

A central component of the model region, and therefore of Fraunhofer IFAM activities with regards to the model region, is the operation of the test fleet. Over 30 vehicles are available to IFAM and its project partners. These vehicles are assigned to commercial users for a specific time within the framework of the fleet tests. The application scenarios range from company cars used by a public authority to service vehicles for a technology company. A specific purpose is not the paramount factor in the use of the vehicle. Instead, the aim is to test as many different application scenarios as possible.

But the interest of the Fraunhofer IFAM researchers is not just focused on the commercial use of these vehicles. A total of 14 vehicles are assigned to private users in a special model region project, the "e-car4all". The users commit themselves to share the vehicle with 3–5 other users ("neighbors") in a so-called "Neighbor-carsharing" concept. This concept encompasses several advantages: On the one hand, a maximum number of users can be reached with a limited number of vehicles. On the other, it is also possible to cover a far wider range of mobility scenarios. The first "e-car4all" project vehicles were handed over in the autumn of last year, others followed in January 2011.

The first interim balance of all fleet tests in the model region looks very positive: Even though the first vehicles started operation during wintery climate conditions, there were only a few teething problems in a couple of vehicles.

The model region project partners gave themselves time up until the first quarter of 2011. All vehicles should then be "on the road" in the model region. The next exciting phase of the project – evaluation of the vehicle data – will then be underway.

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Project funding

Funded by the Federal Ministry for Transport, Building and Urban Development (BMVBS).
Coordinated by the NOW GmbH (National Organisation for Hydrogen and Fuel Cell Technology) in Berlin.

Bundesministerium
für Verkehr, Bau
und Stadtentwicklung

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5 *The first private users were delighted to receive their very "own" electric vehicles as part of the "e-car4all" pilot project in the Electromobility Model Region Bremen/Oldenburg. From left to right: Klaus Schinke, Paul Ackermann, Babett Oettken.*

6 *The "EcoCarrier" is part of the vehicle fleet in the Electromobility Model Region Bremen/Oldenburg.*

7 *The "Tazzari ZERO« is also part of the vehicle fleet in the Electromobility Model Region Bremen/Oldenburg.*

1

DURABLE, STABLE AND PERFECTLY SHAPED – NEW BIOCOMPATIBLE MATERIALS FOR IMPLANTS AND PROSTHETICS

Implant materials matching the properties of the human skeleton – a desire not only voiced by older people. Many athletes are afraid of severe injuries that would require surgery involving the placement of implants or even prosthetics. Medical demand for biocompatible implants is increasing, regardless of whether they are needed because of fractures, illnesses or natural aging processes. Specialists in the biomaterials research area are working to optimize the applied materials, develop new materials for special purposes and form these materials into the right shapes for the respective applications.

The challenge: Precise shaping and control of material properties

Biocompatible materials are widely used today, especially as implants or prosthetic components. These technical materials are used whenever the application involves direct contact with the body and takes on important functions, for instance, for stabilizing bone fractures, acting as prosthetic hip or knee joints, in the field of dental replacement or as simple surgical suture material. It quickly becomes obvious that the same material cannot be used in every application area. Even the time such materials need to remain in the body varies immensely. Sutures should dissolve within days or weeks, a prosthetic hip joint should remain unchanged within the body and perform for as long as possible, while artificial teeth should only be used where necessary.

Fraunhofer IFAM is focusing on materials from various material classes and their shaping processes to meet these numerous requirements. Biocompatible metals, such as medical stainless steel and titanium, and bioceramics like calcium phosphate are generating great interest. Composites of biocompatible polymers and bioceramics are now also in the focus of developments (Fig. 1).

One main objective of the current research is shape forming of novel composite materials, including a modified powder injection molding method, and the adjustment of properties in the resulting components – both from the mechanical aspect and with regards to the biological interactions resulting from use as an implant or prosthesis.

The task: Injection molding of composite materials

Composites consist of at least two different materials with specific properties. The combination of materials unites the useful properties of the individual components. The work presented here focuses on the production of so-called particle composites in which bioceramic calcium phosphate powders are embedded in various polymer matrices. The bioceramic particles should lead to higher mechanical strengths and also offer the possibility, due to their biocompatibility, of remaining within the body without causing negative side effects.

The easiest way to produce such composites is to melt a polymer and blend in a bioceramic powder, a process known as compounding. The polymer-filler material ratio depends on numerous factors and cannot be modified arbitrarily. This is why Fraunhofer IFAM uses a method that makes this possible: liquid phase deposition (LPD). The first step in this process is to dissolve the polymer in a suitable solvent. Then the powder is dispersed into the solution. In a final step the solvent is removed to produce a powder, in which the bioceramic particles are surrounded by a thin polymer layer. The layer thickness and therefore the percentage of polymer can be adjusted as required.

One example of a composite produced in this way is calcium phosphate, in its hydroxylapatite (HA) modification, mixed with polymethylmethacrylate (PMMA), where the proportion by volume is 30 percent HA and 70 percent PMMA. Because of the relatively high polymer percentage, this composite is suitable for injection molding and could be used in the sector of dental technology.

The material combination of HA and polylactic acid (PLA) could give rise to composites of interest as a bone replacement material, because the composition is similar to that of human bone. As HA represents the inorganic component of bone and PLA is a resorbable polymer, this composite could be integrated as a bone replacement or fixing component (e.g. an interference screw) within the body and would not have to be removed, as is often the case with classic metal implants.

Bone consists of up to 70 percent of inorganic substances (mainly HA) and up to 30 percent of organic substances (mainly collagen) and water. For this reason bone can also be characterized as a composite. The composite selected for investigation by Fraunhofer IFAM consequently had a HA volume fraction of 70 percent and a PLA volume fraction of 30 percent. Although this composite could be compressed, it cannot be directly injection molded, as the polymer content is too low. A method to produce composite parts was therefore developed on the basis of powder injection molding.

After preparing the composite powder using the LPD method, it was blended with a water-soluble binder based on polyethylene glycol and polyethylene oxide. This mass, which was now suitable for injection molding, was shaped in a conventional injection molding machine. Subsequently the binder was dissolved in water. The remaining composite was then subject to thermal treatment during which the polymer coating of the composite powder particles formed a homogenous matrix with embedded HA particles. The entire process is illustrated schematically in Figure 2. Figure 3 shows interference screws made of the HA-PLA composite.

1 *Interference screws produced by injection molding or powder injection molding and made of polylactic acid (left), hydroxylapatite (middle) and medical stainless steel (right).*

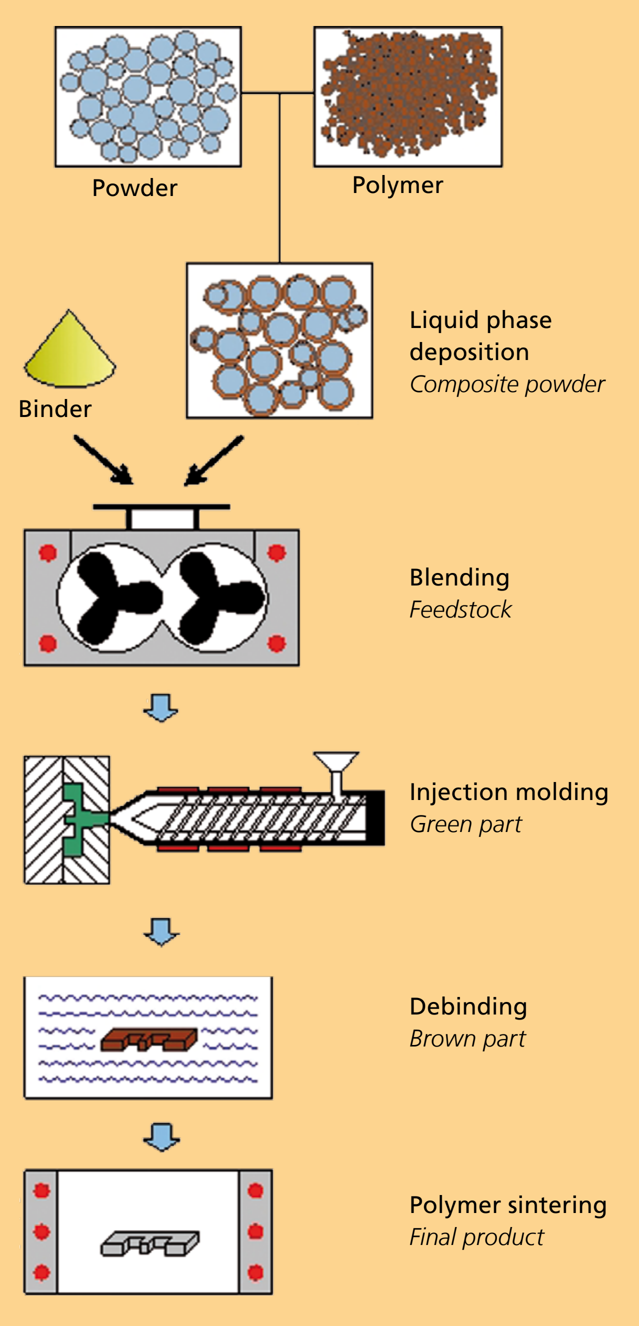


Fig. 2: Schematic process illustration of the preparation and shaping of composite materials.

The result: Mechanically stable composite components with a powder percentage as required

In-house developments saw the successful development of a modified powder injection molding process and various composite materials based on this process. The positive effect of the filler material on the mechanical properties is exemplified by the PMMA-HA composite with a HA volume percentage of 30 percent. The behavior of the compressed and sintered samples in compressive tests, as illustrated in the examples in Figure 4, show that compressive strengths of up to 202 MPa are obtainable. In comparison, the compressive strength of the PMMA used is approximately 120 MPa. The significantly more pressure-resistant materials could therefore be ideally used in areas where higher compressive forces occur, for example as a base material for prostheses.

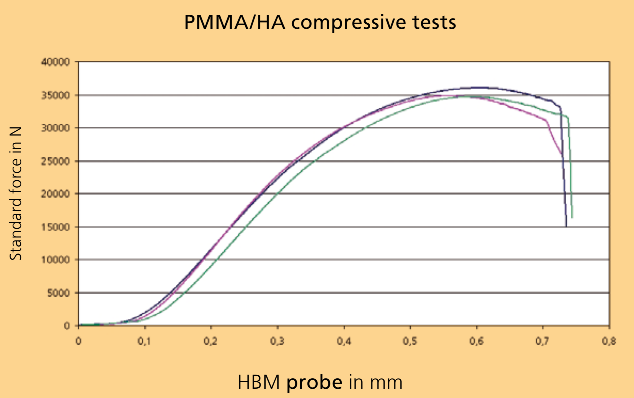
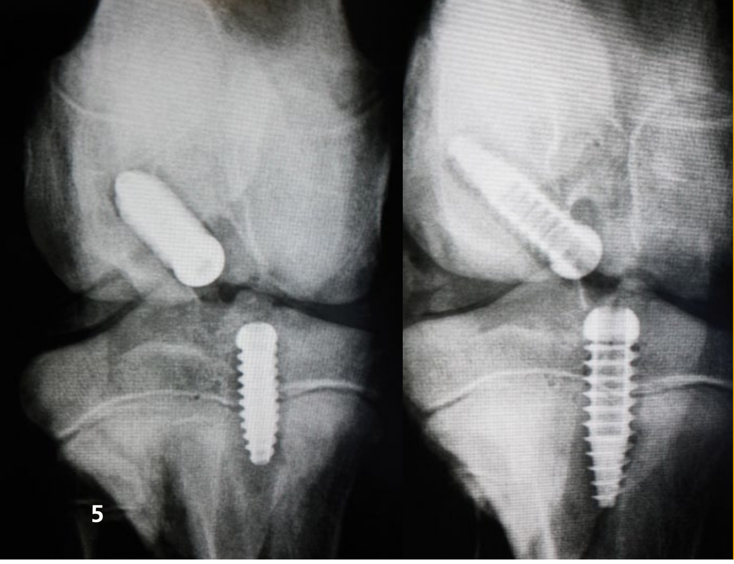


Fig. 4: Plot of a compressive test to determine the compressive strength of a composite consisting of polymethyl methacrylate (PMMA) and hydroxylapatite (HA).

3 *IInterference screws made of a composite based on hydroxylapatite and polylactic acid. Production is based on a modified powder injection molding process (Fig. 2).*



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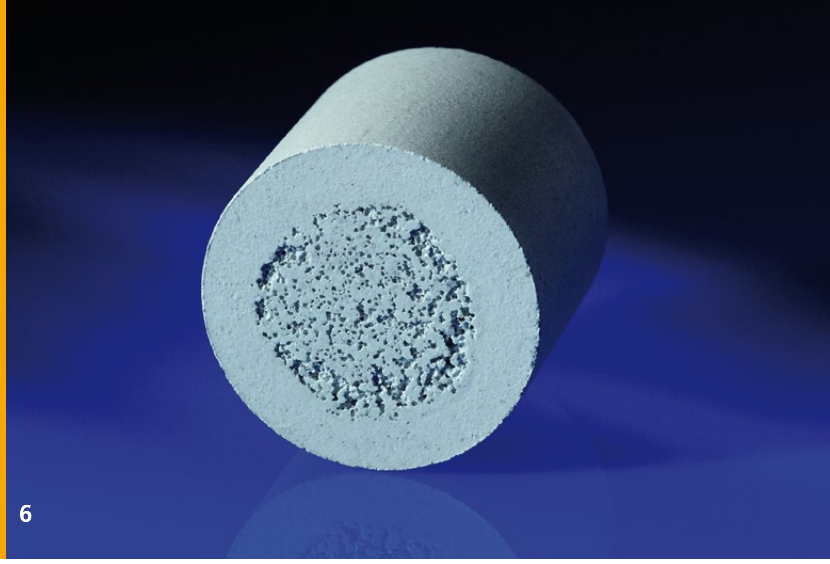

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	HA/PLA samples	Bone
Compressive strength	132 ± 4 MPa	130 - 180 MPa
Elastic modulus	13.1 ± 1.6 GPa	12 - 18 GPa
Density	2.3 g/cm³	1.5 - 3.1 g/cm³
Microhardness	45 ± 3 HV	35 HV

Table 1: Comparison of the mechanical properties of a composite, consisting of hydroxylapatite and polylactic acid, and cortical bone.

Various mechanical properties of HA-PLA composites, formed with a HA volume percentage of 70 percent, are in close agreement with those shown by cortical bone. The properties are given in Table 1. Such similar mechanical behavior would be beneficial, particularly with regards to use as a bone replacement material. If implants and the adhering bone are subject to the same deformation during loading/unloading, then microstresses between the implant and bone could be avoided. Such microstresses can inhibit rapid healing and damage the implant, in the worst case leading to implant failure. In addition to the encouraging mechanical properties, the high ceramic content also has advantages with regards to imaging examinations. Components rich in calcium phosphate enable a significantly better evaluation of the situation as can be seen in Figure 5, showing X-ray images of porcine preparations.

Bone is never uniformly dense, but has a spongy (cancellous) internal structure. The method used by Fraunhofer IFAM also enables the production of porous shapes by introducing space holders before injection molding and subsequently removing these space holders. Such a gradient structure can be seen in Figure 6. Such components offer new possibilities in the field of bone replacement and are difficult to produce via other methods.

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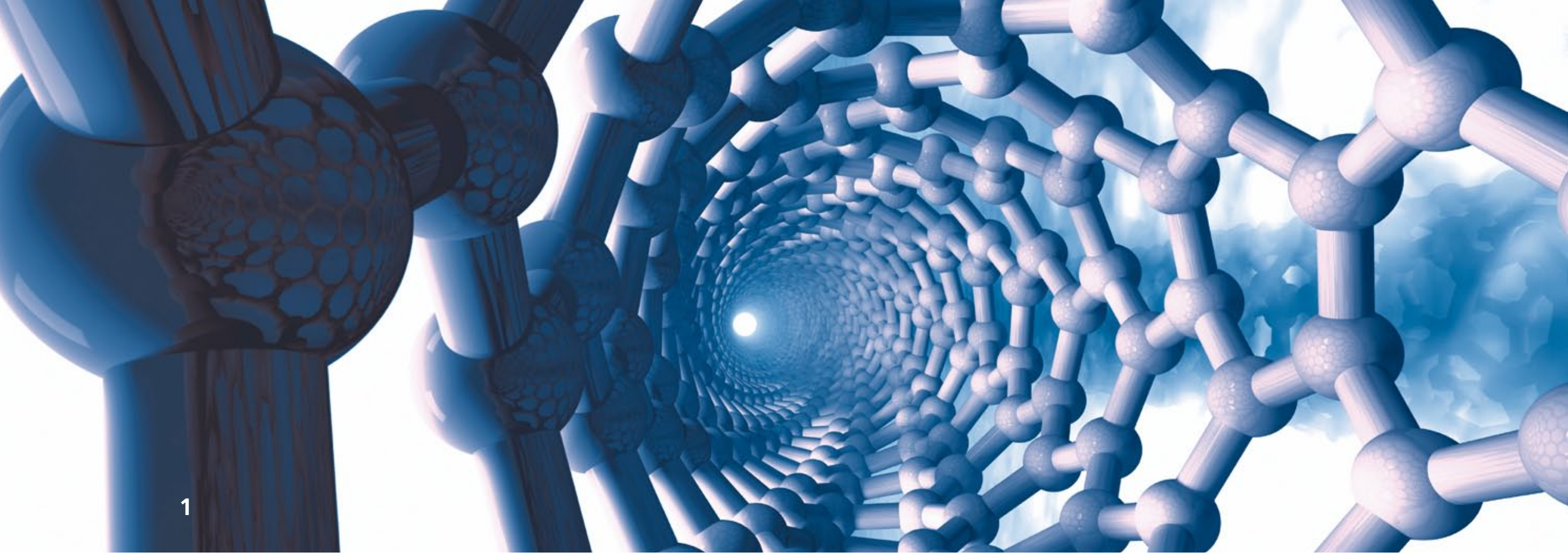
5 *X-ray image of a porcine preparation with titanium screws. The screws are not X-ray permeable (left). X-ray image of a porcine preparation with HA screws. This shows X-ray permeability and a transparency of the screw interior (right) (Source: Prof. Dr. med. Ulrich A. Wagner).*

6 *Bone replicate featuring adense to porous structure gradient. It consists of a resorbable polymer and hydroxylapatite, and can be used as bone replacement scaffold or for resorbable implants.*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A POWERFUL BOND: METAL/CARBON NANOTUBE COMPOSITE MATERIALS

Carbon nanotubes (CNT) evidence unusual properties, above all with regards to their thermal and electrical conductivity, thermal expansion behavior and mechanical loading capacity. The great challenge lies in transferring these properties to a composite material.

Starting point

Due to their high strength and electrical/thermal conductivity, carbon nanotubes (CNT) provide the possibility of producing various types of composite materials with CNT embedded in a metal matrix. In comparison to a pure matrix, these are characterized by increased strength as well as identical or greater electrical/thermal conductivity as based on theoretical considerations. The transfer of this predicted potential is based on the dispersion of CNT when embedded in the composite material without changing the CNT structure. The powder-metallurgical production of metal/CNT composite materials is the subject of current research work at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden. This work is implemented within the framework of the Innovation Alliance CNT in the CarboMetal subproject. Here, metals such as copper, aluminum and their alloys, as well as other materials, serve as matrices.

Project implementation

Carbon nanotubes from various manufacturers are processed to become dispersible CNT (Fig. 2). The subsequent ultrasonic blending of the metal powder with dispersible CNT in liquid media (e.g. water, ethanol, or acetone) offers the possibility of producing homogenous powder mixtures (Fig. 3). These mixtures are compressed by using hot pressing, spark-plasma sintering and hot isostatic pressing to form semi-finished parts with a density greater than 90 percent theoretical density (TD). Further shaping or forming is possible with extrusion and/or wire drawing processes, for example. These semi-finished parts then have densities greater than 96 percent TD. The alignment of the CNT can be influenced by the production process to form three to one-dimensional alignments. The metal/CNT composite materials are comprehensively characterized with regards to their structure and their mechanical and thermophysical properties. The process takes the determined structure-property relationships into account during metal/CNT composite material production and feeds them back into the CNT production process for further process optimization. This permits customized CNT to be embedded homogeneously in a metal matrix with a volume fraction adapted to the application.

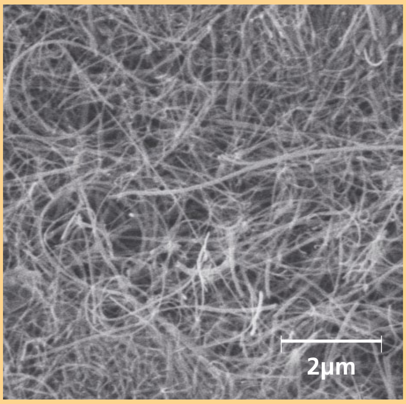

Fig. 2: Dispersible CNT for composite material production.

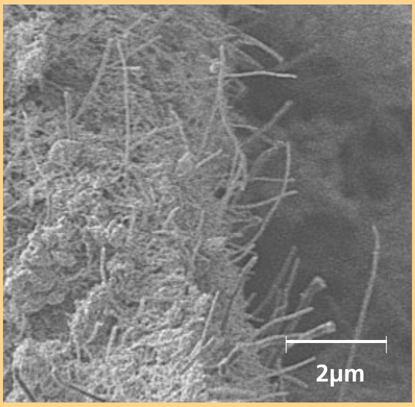

Fig. 3: Powder made of copper and CNT before consolidation.

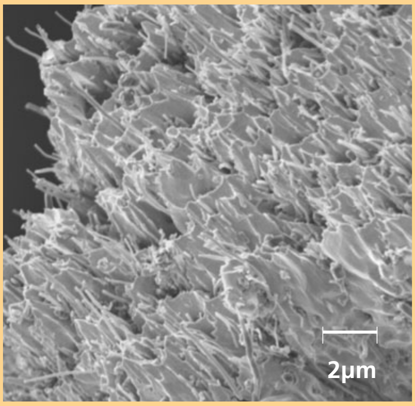

Fig. 4: Alignment of CNT in copper/CNT composite material in the extrusion direction.

Result

Structure

The characterization of the structure is essential in at least two spatial directions, due to the high aspect ratio of the embedded CNT. After extrusion, metallographic microsections parallel and perpendicular to the extrusion direction are prepared. With suitable preparation methods, residual CNT agglomerates can be almost completely removed and the individual CNT fully enveloped by the matrix metal. Figure 4 shows the one-dimensional alignment of the CNT after extrusion.

Mechanical strength

Extruded copper/CNT composite materials show a strength increase parallel to the extrusion direction with an increasing CNT volume content. Figure 5 depicts the stress-strain curves of Cu/CNT composite materials with up to 10 vol% of one CNT type. Tensile strength and breaking strain increase with a rising CNT volume content. This is because the tensile force applied from the outside is transferred via the metal/CNT boundary to the CNT.

As the CNT have a lower breaking strain, they – and therefore the metal/CNT composite material – fail above their fiber breaking strength due to brittle fracture. Figure 6 displays the fracture surface of a copper/CNT composite material with 5 vol% CNT, exposing the CNT broken due to brittle fracture in the honeycomb cells of the matrix. Different strength increases can be achieved with the identical volume content of CNT by varying the CNT type (Fig. 7). Embedding 3.5 vol% CNT in a copper matrix can increase the yield strength Rp0.2 to 200 percent and the tensile strength Rm to 125% compared to pure copper (Rp0.2 = 70 MPa, Rm = 210 MPa).

1 *Carbon nanotubes (Source: istockphoto).*

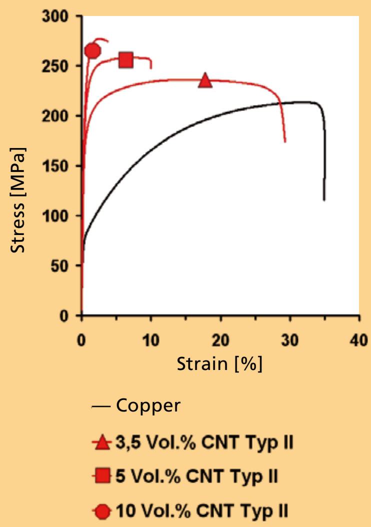

Fig. 5: Stress-strain curves of Cu/CNT composite materials with up to 10 vol% of one CNT type.

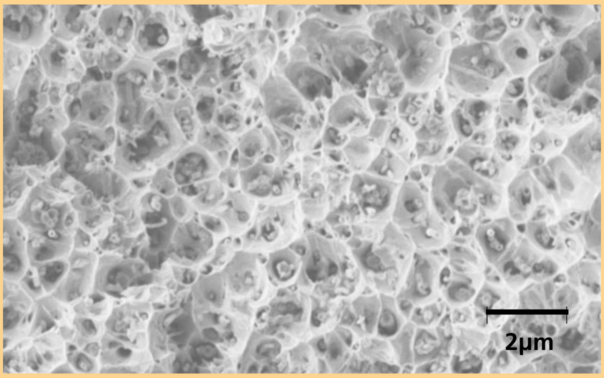

Fig. 6: Fracture surface of a Cu/CNT composite material with 5 vol% CNT.

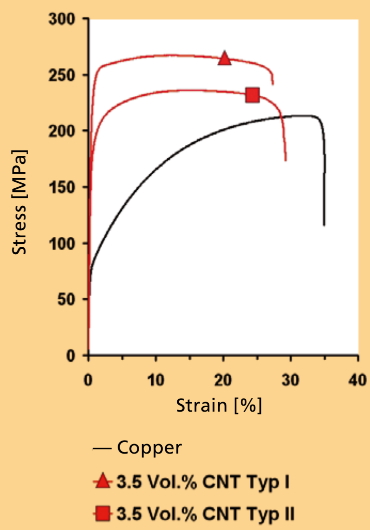

Fig. 7: Stress-strain curves of Cu/CNT composite materials with 3.5 vol% of different CNT types.

Electric conductivity

The anisotropy of the Cu/CNT composite material can be seen when measuring the specific electric conductivity (Fig. 8). The greater conductivity parallel to the extrusion direction is an indicator of the one-dimensional alignment of the CNT. The influence of different CNT types also becomes apparent. With a volume content of 3.5 vol%, a specific electric conductivity equivalent to pure copper can be maintained whilst strength increases to 125 percent.

Outlook

The results show that it is possible to produce composite materials based on metal and CNT using powder-metallurgical processes. The CNT can be dispersed homogeneously in the matrix, their alignment specifically influenced and their intrinsic properties transferred to the composite material. The influence of different CNT types on the resulting composite material properties is verifiable and can be used to optimize the respective CNT production methods in cooperation with CNT manufacturers.

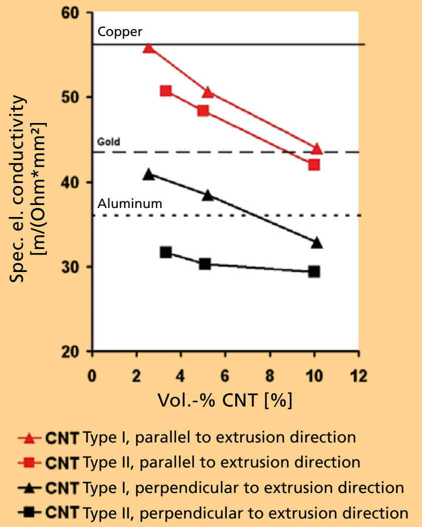

Fig. 8: Specific electric conductivity of copper/CNT composite materials parallel and perpendicular to the extrusion direction compared to reference materials.

In addition, a dispersion method is available at Fraunhofer IFAM in Dresden which makes it possible to produce long-term stable dispersions. Based on these results, influences on the mechanical and thermophysical properties of metal/CNT composite materials with regards to volume content, preparation method and CNT types used will be investigated further to elaborate application-specific optimization of metal/CNT composite materials together with partners in industry and science.

Project funding

The Federal Ministry of Education and Research is supporting this work within the framework of the Innovation Alliance CNT "Inno.CNT" in the CarboMetal project.

Bundesministerium
für Bildung
und Forschung

Project partners

- EADS IW
- FutureCarbon
- EADS Astrium Satellites
- PEAK Werkstoff
- Leibniz IFW Dresden
- Fraunhofer IWS
- Fraunhofer IFAM in Dresden

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ADHESIVE BONDING TECHNOLOGY AND SURFACES

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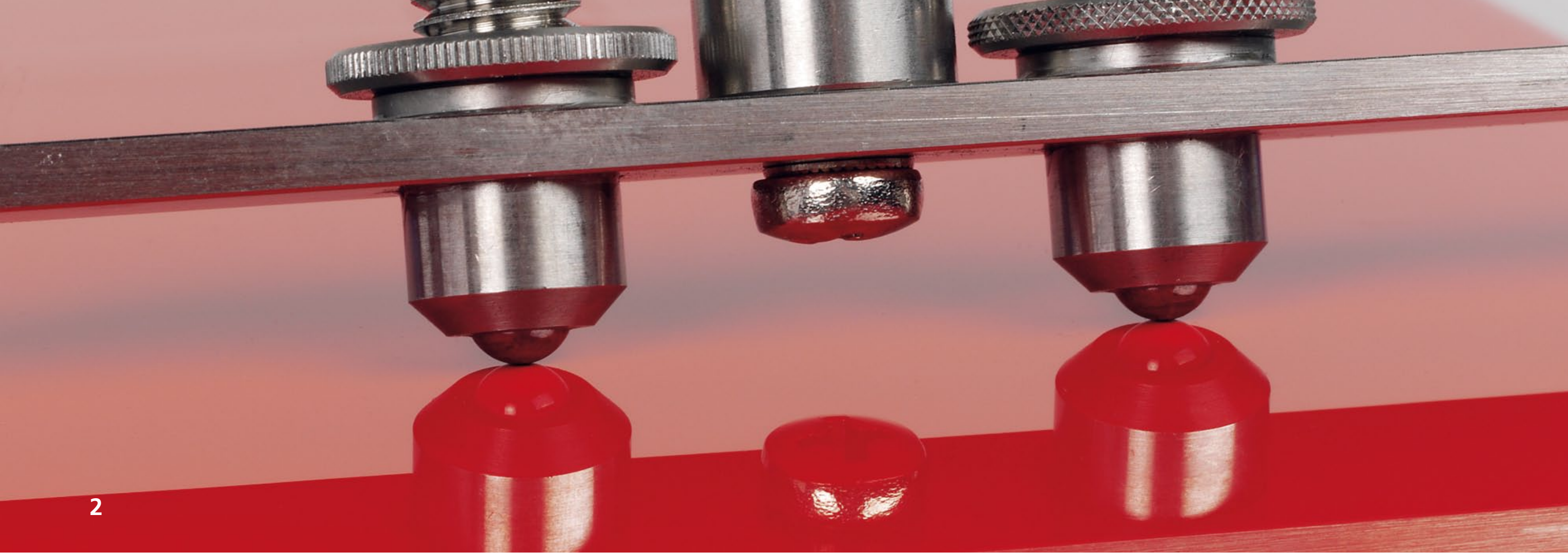

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EXPERTISE AND KNOW-HOW

The Department of Adhesive Bonding Technology and Surfaces at Fraunhofer Institute for Manufacturing Technology and Advanced Materials is the largest independent research group in Europe working in the area of industrial adhesive bonding technology and has more than 270 employees. The R&D activities focus on adhesive bonding technology, as well as plasma technology and paint/lacquer technology. The objective is to provide industry with application-oriented system solutions.

Multifunctional products, lightweight design, and miniaturization – achieved via the intelligent combination of materials and joining techniques – are opening up new opportunities which are being exploited by the Department of Adhesive Bonding Technology and Surface Technology. The activities range from fundamental research through to production and the market introduction of new products. Industrial applications of bonding as well as surface technology are mainly found in the car, rail vehicle, ship, and aircraft manufacturing sectors, and in the areas of machine and plant construction, energy technology, construction industry, packaging, textiles, electronics, microsystem engineering, and medical technology.

The work in the Adhesive Bonding Technology business unit involves the development and characterization of adhesives and matrix resins for fiber reinforced plastics, the design and simulation of bonded, bolted, and hybrid joints, as well as the characterization, testing, and qualification of such joints. Planning and automation of industrial adhesive bonding processes are also undertaken. Other key activities are process reviews and providing certifying training courses in adhesive bonding technology and fiber reinforced plastics materials.

The work of the Surfaces business unit is subdivided into plasma technology and paint/lacquer technology. Customized surface modifications – for example surface pre-treatment and functional coatings – considerably expand the industrial uses of many materials and in some cases are vital for the use of those materials.

The Adhesion and Interface Research business unit is involved, amongst other things, in the early detection of degradation phenomena, the validation of ageing tests, and in-line surface monitoring techniques for quality assurance concepts. The results of this research work provide fundamental knowledge for adhesive bonding technology and also for plasma technology as well as paint/lacquer technology and so contribute to the safety and reliability of bonded joints and coatings.

The Fraunhofer Project Group Joining and Assembly FFM of the Fraunhofer IFAM is carrying out ground-breaking work on large carbon fiber reinforced plastic (CFRP) structures and is able to join, assemble, process, repair, and carry out non-destructive tests on large 1:1 scale CFRP structures, thus closing the gap between the laboratory/small pilot-plant scale and industrial scale in the area of CFRP technology.

The Department of Adhesive Bonding Technology and Surfaces is certified according to DIN EN ISO 9001, and the Materials Testing Laboratory, Corrosion Testing Laboratory, and Paint/Lacquer Technology Testing Laboratory are further accredited according to DIN EN ISO/IEC 17025.

1 *Rotor for an electric motor with bonded magnets (courtesy of SEW Eurodrive GmbH & Co. KG).*

2 *Testing a coating developed at Fraunhofer IFAM.*

The Center for Adhesive Bonding Technology has an international reputation for its training courses in adhesive bonding technology and is accredited via DVS-PersZert® in accordance with DIN EN ISO/IEC 17024. It is also accredited in accordance with the German quality standard for further training, AZWV. The Plastics Competence Center is certified in accordance with AZWV and meets the quality requirements of DIN EN ISO/IEC 17024. The Certification Body for the Manufacture of Adhesive Bonds on Rail Vehicles and Parts of Rail Vehicles is accredited by the Federal Railway Authority (FRA; Eisenbahn-Bundesamt) in accordance with DIN 6701-2 and following DIN EN ISO/IEC 17021.

Perspectives

Industry puts high demands on process reliability when introducing new technologies and modifying existing technologies. These demands are the benchmark for the R&D activities in the Department of Adhesive Bonding Technology and Surfaces. Working with customers, Fraunhofer IFAM develops innovative products which are later successfully introduced into the marketplace by the companies.

In this context manufacturing technologies are playing an ever more important role, because high product quality and the reproducibility of production processes are key requirements for success in the marketplace.

Adhesive bonding technology has been used in vehicle construction for a long time, its potential has, however, not yet been fully utilized. Lightweight construction for vehicles as a means of saving resources, intentional debonding during the recycling process, and the use of nanoscale materials in the development and modification of adhesives are just a few examples of the broad activities of the institute.

In order to interest more sectors of industry in adhesive bonding technology, the motto for all the institute's activities is: Make the bonding process and the bonded product more reliable!

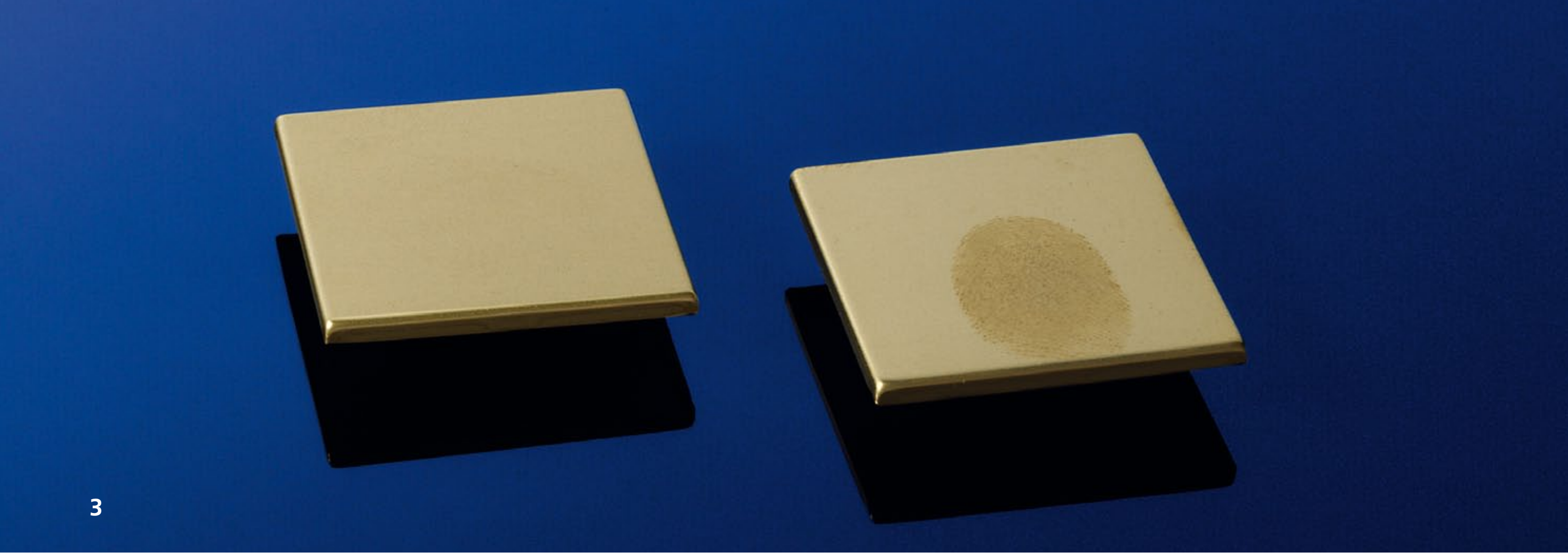
This objective can only be achieved if all the steps in the bonding process chain are considered as an integral whole.

This includes:

- Application-specific adhesive selection and qualification, and if necessary adhesive modification
- Design and dimensioning of structures using numerical methods (e.g. FEM)
- Surface pre-treatment and development of corrosion-protection concepts
- Development of adhesive bonding process steps via simulation, and integration into production processes
- Selection and dimensioning of application units
- Training courses in adhesive bonding technology for all staff involved in the development and manufacture of bonded products
- Training courses in fiber composite technology for production staff

In all areas Fraunhofer IFAM is making increasing use of computer-aided methods, for example the numerical description of flow processes in dosing pumps/valves, multiscale simulation of the molecular dynamics at a molecular level, and macroscopic finite element methods for the numerical description of materials and components.

A variety of spectroscopic, microscopic, and electrochemical methods are employed to give insight into the processes involved in the degradation and corrosion of composite materials. Using these "instrumental methods" and the accompanying simulations, Fraunhofer IFAM acquires information which empirical test methods based on standardized ageing and corrosion procedures cannot provide.



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Other key questions for the future include the following: Where and how is adhesive bonding accomplished in nature? What can we learn from nature for industrial adhesive bonding technology? The experts are already studying how bio-adhesion at a molecular level can be utilized to make medical adhesives with protein components.

However, the requirement to make processes and products more reliable is not only limited to adhesive bonding technology. It also applies to plasma and paint/lacquer technology.

Industries with very stringent requirements on surface technology make use of the in-depth expertise and technological know-how of Fraunhofer IFAM. Considerable customers include leading companies particularly in the aircraft and car manufacturing sectors.

Key activities

- Formulation and testing of new polymers for adhesives, laminating/cast resins, including industrial implementation
- Development of additives (nanofillers, initiators, etc.) for adhesives
- Synthesis of polymers with a superstructure, and biopolymers
- Computer-aided material development using quantum-mechanical and molecular-mechanical methods
- Development and qualification of adhesive bonding production processes
- Development of innovative joining concepts, e.g. for aircraft and car manufacture (bonding, hybrid joints)
- Application of adhesives/sealants, casting compounds (mixing, dosing, application)
- Bonding in microproduction (e.g. electronics, optics, adaptronics)
- Computer-aided production planning
- Economic aspects of bonding/hybrid joining technology
- Design of bonded structures (simulation of the mechanical behavior of bonded joints and components using finite element methods, prototype construction)
- Development of industrially viable and environmentally compatible pre-treatment methods for the bonding and coating of plastics and metals
- Functional coatings using plasma and combined methods
- Testing and qualification of coating materials, raw materials, and lacquering methods
- Development of functional paints/lacquers for special applications
- Development of special test methods (e.g. formation and adhesion of ice on anti-icing coatings)
- Parameter determination, fatigue strength, and alternating fatigue strength of bonded and hybrid joints
- Material models for adhesives and polymers (quasi-static and crash states)
- Evaluation of ageing and degradation processes in composite materials
- Electrochemical analysis
- Evaluation and development of new anti-corrosion systems
- Analysis of development and production processes involving adhesive bonding
- Quality assurance concepts for adhesive and lacquer/paint applications via in-line analysis of component surfaces
- National and international training courses for
  European Adhesive Bonder – EAB,
  European Adhesive Specialist – EAS, and
  European Adhesive Engineer – EAE
- Training courses for Fiber Reinforced Plastic Technician

3 *The invisible nano-coating developed at Fraunhofer IFAM reduces the appearance of fingerprints on matt metal and plastic surfaces.*

FIELDS OF ACTIVITY AND CONTACTS

Institute Director

Priv.-Doz. Dr. Andreas Hartwig – up to July 31, 2010
Prof. Dr. rer. nat. Bernd Mayer – from August 1, 2010
Phone +49 421 2246-419
bernd.mayer@ifam.fraunhofer.de

Adhesive Bonding Technology

Dipl.-Ing. Manfred Peschka
Phone +49 421 2246-524
manfred.peschka@ifam.fraunhofer.de
Production planning; dosing and application technology; automation; hybrid joining; production of prototypes; selection, characterization and qualification of adhesives, sealants and coatings; failure analysis; electrically/optically conductive contacts; adaptive microsystems; dosing ultra small quantities; properties of polymers in thin films; production concepts.

- Microsystem technology and medical technology
- Adhesives and analysis
- Process development and simulation
- Application methods

Plasma Technology and Surfaces PLATO

Dr. Ralph Wilken
Phone +49 421 2246-448
ralph.wilken@ifam.fraunhofer.de
Surface modification (cleaning and activation e.g. for bonding, printing, painting/lacquering) and functional coatings (e.g. adhesion promotion, corrosion protection, scratch protection, antimicrobial effect, easy-to-clean coatings, release coatings, permeation barriers) for 3-D components, bulk products, web materials; plant concepts and pilot plant construction.

- Low pressure plasma technology
- Atmospheric pressure plasma technology
- Plant technology/Plant construction

Adhesives and Polymer Chemistry

Priv.-Doz. Dr. Andreas Hartwig
Phone +49 421 2246-470
andreas.hartwig@ifam.fraunhofer.de
Development and characterization of polymers; nanocomposites; formulation of adhesives, matrix resins, and functional polymers; preapplicable adhesives; conducting adhesives; improvement of the long-term stability; bonding without pre-treatment (polyolefins, light metals, oil-containing sheets with 2-C systems, thermoplastic composites); photocuring; curing at low temperature, but with longer open time; curing on demand, rapid curing; pressure-sensitive adhesives; casting compounds; selection and qualification of adhesives; failure analysis; adhesives based on natural raw materials; peptide-polymer hybrids; bonding in medicine; biofunctionalized and biofunctional surfaces.

- Adhesive formulation
- Composite materials
- Bio-inspired materials

Paint/Lacquer Technology

Dr. Volkmar Stenzel
Phone +49 421 2246-407
volkmar.stenzel@ifam.fraunhofer.de
Development of functional coatings, e.g. anti-icing paints, anti-fouling systems, dirt-repellant systems, self-repairing protective coatings, low-drag coatings; formulation optimization; raw material testing; development of guide formulations; characterization and qualification of paint/lacquer systems and raw materials; release of products; color management; optimization of coating plants; qualification of coating plants (pre-treatment, application, drying); failure analysis; application-related method development; accredited Paint/Lacquer Technology Testing Laboratory.

- Development of coating materials and functional coatings
- Application technology and process engineering

Adhesion and Interface Research

Dr. Stefan Dieckhoff
Phone +49 421 2246-469
stefan.dieckhoff@ifam.fraunhofer.de
Surface, interface and film analysis; analysis of adhesion, release and degradation mechanisms; analysis of reactive interactions at material surfaces; damage analysis; quality assurance via in-line analyses of component surfaces; development of quality assurance concepts for applications in adhesive, paint/lacquer and surface technologies; corrosion on metals, under coatings and in bonded joints; analysis and development of anodizing processes; electrolytic metal deposition; accredited Corrosion Testing Laboratory; modeling of molecular mechanisms of adhesion and degradation; structure formation at interfaces; concentration and transport processes in adhesives and coatings.

- Surface and nanostructure analysis
- Applied computational chemistry
- Electrochemistry/Corrosion protection
- Quality assurance of surfaces

Materials Science and Mechanical Engineering

Dr. Markus Brede
Phone +49 421 2246-476
markus.brede@ifam.fraunhofer.de
Testing materials and components; crash and fatigue behavior of bolted and bonded joints; fiber composite components; lightweight and hybrid constructions; design and dimensioning of bonded joints; qualification of mechanical fasteners; optimization of mechanical joining processes; design and dimensioning of bolted joints; accredited Materials Testing Laboratory.

- Structural calculations and numerical simulation
- Mechanical joining technology

Workforce Qualification and Technology Transfer

Prof. Dr. Andreas Groß
Phone +49 421 2246-437
andreas.gross@ifam.fraunhofer.de
www.bremen-bonding.com
www.kunststoff-in-bremen.de
Training courses for European Adhesive Bonder (EAB), European Adhesive Specialist (EAS), and European Adhesive Engineer (EAE) with Europe-wide certification via DVS®/EWF; in-house courses; consultancy; qualification of production

processes; studies; health, work safety and the environment; training course for Fiber Reinforced Plastic Technician.

- Center for Adhesive Bonding Technology
- Plastics Competence Center

Fraunhofer Project Group Joining and Assembly FFM

Dr. Dirk Niermann
Forschungszentrum CFK Nord
Ottenbecker Damm 12
21684 Stade, Germany
Phone +49 4141 78707-101
dirk.niermann@ifam.fraunhofer.de

Automated assembly of large fiber reinforced plastic (FRP) structures, up to a 1:1 scale: adhesive bonding, combined bonding/bolting; adaptive precision machining; automated measuring and positioning processes; shape and positional correction of flexible large structures in assembly processes.

- Joining technologies
- Precision machining
- Assembly and plant technology
- Measurement technology and robotics

Business Field Development

Dr. Michael Wolf
Phone +49 421 2246-640
michael.wolf@ifam.fraunhofer.de

- Technology Broker
- New research fields

Certification Body of the Federal Railway Authority in accordance with DIN 6701

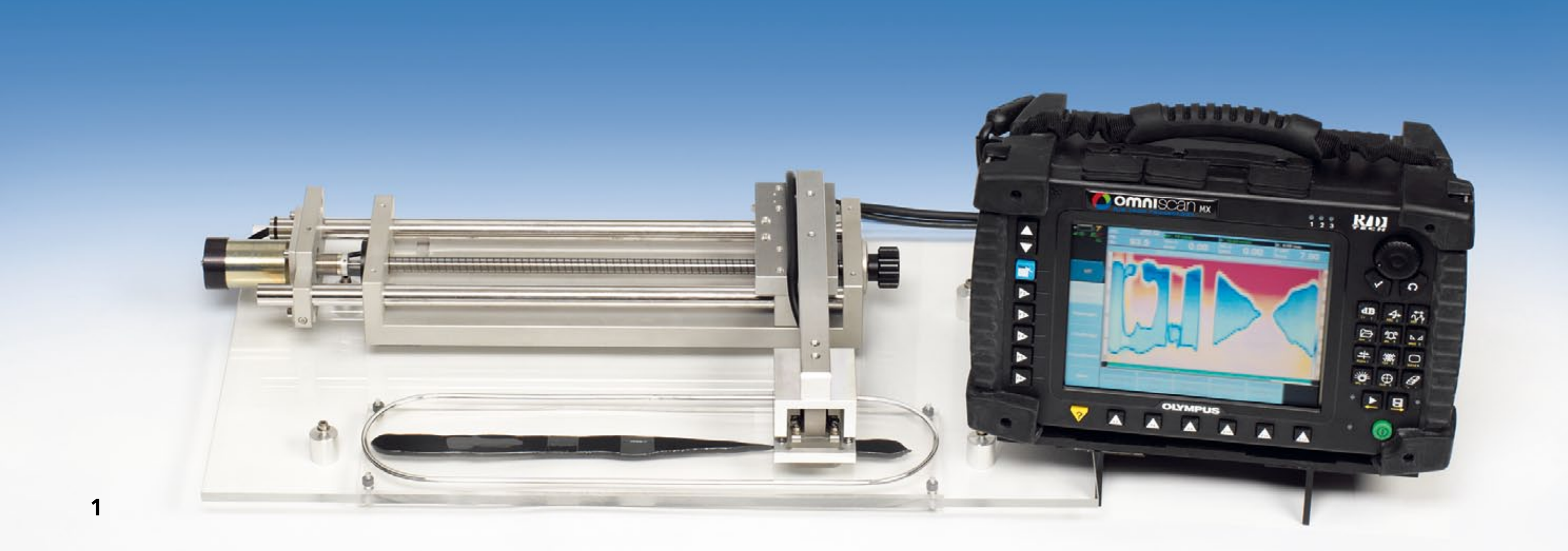
Dipl.-Ing. (FH) Andrea Paul
Phone +49 421 2246-520
andrea.paul@ifam.fraunhofer.de

Consultancy; testing and approval of rail vehicle manufacturing companies and their suppliers with regard to their ability to produce adhesive bonds in accordance with the requirements of DIN 6701.

Process Reviews

Dipl.-Ing. Manfred Peschka
Phone +49 421 2246-524
manfred.peschka@ifam.fraunhofer.de

Analysis of development and/or production processes taking into account adhesive bonding aspects and DVS® 3310; processing steps and interfaces; design; product; proof of usage safety; documentation; production environments.



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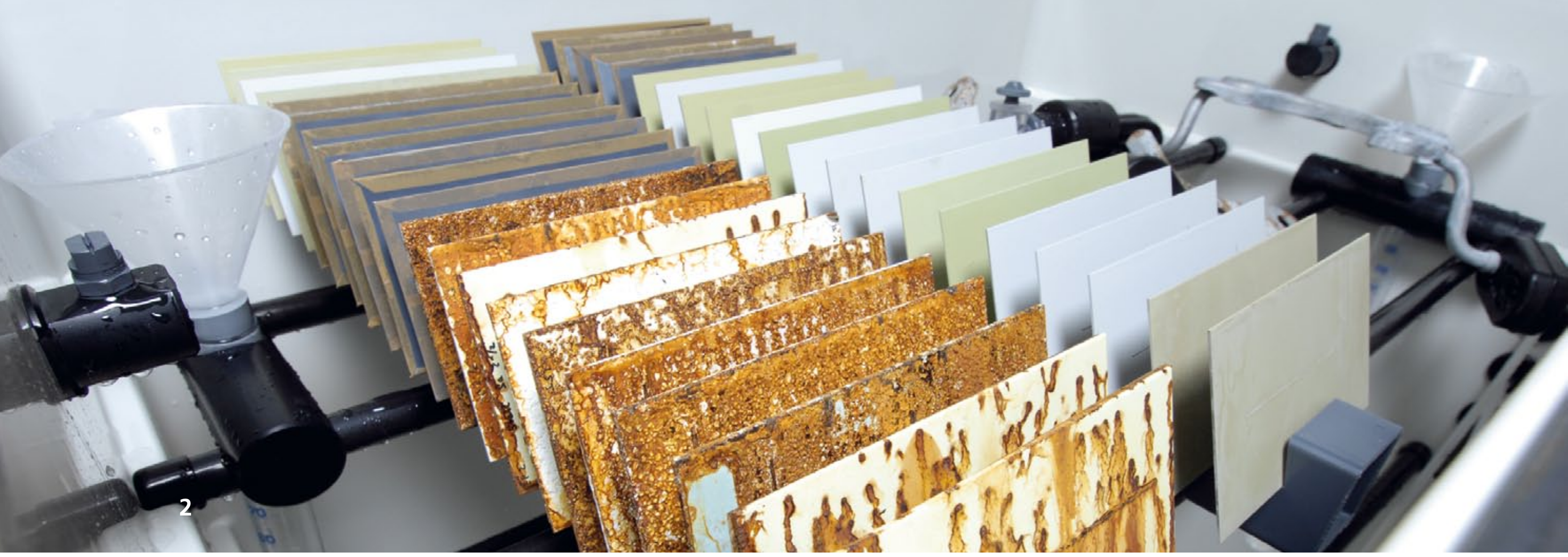
EQUIPMENT/FACILITIES

Adhesive Bonding Technology and Surfaces

- Low pressure plasma plants for 3-D components, bulk products, and web materials up to 3 m³ (RF, MW)
- Atmospheric pressure plasma plants for 3-D components and web materials
- Robot-controlled atmospheric pressure plasma plant (6-axle) for laminar and line surface treatment and coating
- VUV excimer plant for surface treatment and coating
- CO_2 snow jet units
- Mobile laser unit for surface pre-treatment
- Tribometer in combination with nanoindentation
- Laser scanner for 3-D measurement of components up to 3500 mm
- Universal testing machines up to 400 kN
- Units for testing materials and components under high rates of loading and deformation under uniaxial and multiaxial stress conditions
- All-electric laboratory bolting machine with semi-automatic installation of one-piece and two-piece fasteners, C-frame construction with 1.5 m frame depth, maximum compressive force: 70 kN, drill spindle for speeds up to 18,000 rpm and internal lubrication and high speed workplace monitoring
- Laboratory vacuum press with PC control for manufacturing multilayer prototypes
- 200 kV FEG transmission electron microscope with EDX, EELS, EFTEM, and 3-D tomography and cryo and heating options
- Confocal laser microscope
- Laboratory galvanizing unit
- LIF (Laser Induced Fluorescence)
- Thermography
- XRF hand unit (x-ray fluorescence analysis)
- Surface analysis systems and polymer analysis using XPS, UPS, TOF-SIMS, AES, and AFM
- Chromatography (GC-MS, headspace, thermal desorption, HPLC)
- Thermal analysis (DSC, modulated DSC, DMA, TMA, TGA, torsion pendulum)
- MALDI-TOF-MS for polymer and protein characterization
- Automatic equipment for peptide synthesis
- Light scattering for characterizing turbid dispersions
- Spectroscopic ellipsometer
- LIBS (Laser Induced Breakdown Spectroscopy)
- Small-scale pilot plant for organic syntheses
- IR, Raman and UV-VIS spectrometers
- IR-VCD spectrometer (Infrared Vibrational Dichroism)
- Rheology (Rheolyst AR 1000 N, ARES – Advanced Rheometric Expansion System)
- Equipment for measuring heat conductivity
- Dielectrometer
- Electrochemical Impedance Spectroscopy (EIS) and noise analysis (ENA)
- Twin-screw extruder (25/48D) and kneader for incorporating fillers into polymers
- Single-screw extruder (19/25D) for characterizing the processing properties of polymer composites
- 12-axle robot for manufacturing micro bonded joints
- Linux PC cluster with 64 CPUs
- Various dispersion units
- Automatic paint application equipment
- Fully conditioned spraying booth
- Paint dryer with moisture-free air
- UV curing technology
- Mechanical-technological tests
- Color measurement unit MA 68 II
- Optical testing technology
- Test equipment for anti-icing paints

1 *Phased-array ultrasonic measuring device for non-destructive testing, for example on bonded glass.*



- Wave tank simulation chamber
- Test loop for measuring the loads on paints
- Miniature test loop for measuring the loads on paints
- Outdoor weathering at various locations
- Scanning Kelvin probe
- Coatema Deskcoater
- 6-axle industrial robot, 125 kg bearing load, on additional linear axis, 3000 mm
- 1-C piston dosing system SCA SYS 3000/SYS 300 Air
- 1-C/2-C geared dosing system t-s-i, can be adapted to eccentric screw pumps
- Freely configurable 1-C/2-C dosing technology, adaptable to specific tasks, with comprehensive measurement technology (own development)
- Phased-array ultrasonic measuring device (Olympus OmniScan MX PA)
- Fluorescence microscope
- Bohlin Gemini 200 rheometer
- Climate chambers for all standard tests and special tests
- Hall for assembling large structures, 80 x 50 m^2, two 20 tonne cranes, 15 m below crane hooks

Certification and Accreditation

- The Department of Adhesive Bonding Technology and Surfaces is certified according to DIN EN ISO 9001, and the Materials Testing Laboratory, Corrosion Testing Laboratory, and Paint/Lacquer Technology Testing Laboratory are further accredited in accordance with DIN EN ISO/IEC 17025.
- The Center for Adhesive Bonding Technology has an international reputation for its training courses in adhesive bonding technology and is accredited via DVS-PersZert® in accordance with DIN EN ISO/IEC 17024. It is also accredited in accordance with the German quality standard for further training, AZWV.
- The Plastics Competence Center is certified in accordance with AZWV and meets the quality requirements of DIN EN ISO/IEC 17024.
- The Certification Body for the Manufacture of Adhesive Bonds on Rail Vehicles and Parts of Rail Vehicles is accredited by the Federal Railway Authority (FRA; Eisenbahn-Bundesamt) in accordance with DIN 6701-2 and following DIN EN ISO/IEC 17021.

2 *Salt spray chamber in the accredited Corrosion Testing Laboratory of the Fraunhofer IFAM.*

3 *Investigating the wetting properties of surfaces using the aerosol wetting test developed at the Fraunhofer IFAM.*

ADHESIVE BONDING TECHNOLOGY AND SURFACES

RESULTS FROM RESEARCH AND DEVELOPMENT

BERND MAYER: NEW INSTITUTE DIRECTOR OF THE FRAUNHOFER IFAM – ADHESIVE BONDING TECHNOLOGY AND SURFACES – AND PROFESSOR IN THE DEPARTMENT OF PRODUCTION TECHNOLOGY AT THE UNIVERSITY OF BREMEN

A new face leading the Fraunhofer IFAM and a new face in the Department of Production Technology at the University of Bremen: As of August 1, 2010, Prof. Dr. rer. nat. Bernd Mayer became institute director at Fraunhofer Institute for Manufacturing Technology and Advanced Materials with responsibility for the Department of Adhesive Bonding Technology and Surfaces. He was simultaneously appointed Professor of Polymeric Materials at the University of Bremen.

Prof. Dr. rer. nat. Mayer (Fig. 1) replaces Priv.-Doz. Dr. Andreas Hartwig (Fig. 2) as institute director. The latter was appointed acting institute director, following the departure of Dr.-Ing. Helmut Schäfer in 2009, until the arrival of Bernd Mayer. Hartwig is now once again the deputy institute director. This transfer from Andreas Hartwig to Bernd Mayer brings continuity within the leadership. For more than 40 years the R&D work of the Department of Adhesive Bonding Technology and Surfaces has been carried out by a team with in-depth scientific knowledge coupled with very close associations with practice – and hence also customers.

This is very much the case with Bernd Mayer, because the new institute director moves straight from industry to the top of the Fraunhofer IFAM. At Henkel AG & Co. KGaA, the largest adhesive manufacturer in the world, Bernd Mayer lastly led product development in Heidelberg in the area of adhesives and sealants as well as acoustic and structural materials for car applications. Mayer was not only responsible for the development activities in Germany but also throughout Europe. Before taking on this senior position in 2000, Mayer had worked for several years at Henkel in various positions in their central research in Düsseldorf. His work included conversion treatments for metallic surfaces, studies on corrosion protection, adhesion promoting systems, and later the development of functional surface coatings. Bernd Mayer is a chemist who studied and took his doctoral degree at the University of Karlsruhe. Thereafter he undertook post-doctoral work at the University of Pennsylvania, USA.

Fraunhofer IFAM – a reliable partner

Bernd Mayer has just arrived at Fraunhofer IFAM, but he has long known and valued the institute as a reliable R&D partner. During his time at Henkel, Bernd Mayer worked with the Fraunhofer IFAM – and in particular with the Materials Science and Mechanical Engineering field of work. There were joint projects and Bernd Mayer appreciated the informal contact that was possible: "If there was a question or problem and we needed an opinion from outside or simply a tip, then the IFAM experts were always there for us." It was inevitable that Fraunhofer IFAM, Europe's largest independent R&D organization in the area of adhesive bonding technology and surfaces, would be involved: "For those involved in adhesive bonding, the Fraunhofer IFAM is an exceptional research institute."

This will remain so under the new institute director. Bernd Mayer is aware of the needs of customers and project partners and knows the expectations of public funding organizations. Also, he has become familiar in a very short space of time with the structure and daily work of the individual competencies at Fraunhofer IFAM and knows the capability of "his" department. "The reason for me taking this position has been yet further strengthened when looking closer at the essence and work of the 'Department of Adhesive Bonding Technology and Surfaces' at Fraunhofer IFAM. I wanted the challenge of working at a globally renowned research institute which was constantly breaking new technological ground and which transferred innovative ideas into end applications together with partners. Impressive for me was the scope of it all. In industry work is focused on narrow technology fields, whilst here at Fraunhofer IFAM there is greater freedom for creativity." This also results from the very effective multidisciplinary collaboration between individual sections: "The fields of expertise in the Department of Adhesive Bonding Technology and Surfaces at the Fraunhofer IFAM are building blocks which complement one another and which together synergistically form a single closed structure." Naturally the building blocks are constantly adapted and expanded to current requirements: "This keeps us at the forefront of technology and enables us to meet the needs of our customers. We can provide integrated total solutions because we are able to cover all key aspects at IFAM." This is the fascination of the institute for Mayer: When a specific challenge requires questions about a related field, these can be immediately looked at from an interdisciplinary viewpoint. "All aspects of adhesive bonding technology and surfaces are available from one organization. When needed, additional expertise can be quickly called upon from within the large network of other Fraunhofer Institutes."

Objective: Working even closer with customers

The expertise and experience of Bernd Mayer are giving the institute new impulse. One objective is to work even closer with customers and users to transfer new developments and advancements into specific applications: "The Fraunhofer IFAM is already very good at this. But I am very familiar with the 'views of customers' and I know we can make improvements." Mayer also built up many contacts in industry all over the world and now wants to use these for IFAM's benefit. At a technological level the strategy of the new institute director for adhesive is "to successfully develop more solutions than we'll able to utilize them all." Much is possible, but the resources are limited. "We will therefore have to consider carefully what areas we want to focus on in the future. These will certainly

1 *Prof. Dr. rer. nat. Bernd Mayer took up his position in Bremen on August 1, 2010: New institute director of the Fraunhofer IFAM, Department of Adhesive Bonding Technology and Surfaces, and professor in the Department of Production Technology at the University of Bremen.*

2 *Prof. Dr. rer. nat. Bernd Mayer and Priv.-Doz. Dr. Andreas Hartwig (from left to right).*

be R&D fields to meet the technological and social challenges of the future."

Prof. Dr. rer. nat. Bernd Mayer's opinion is in tune with the work of his predecessors. They carefully steered the development of Fraunhofer IFAM to open up new application fields which utilized the varied expertise of the institute. "I will carefully continue this in close consultation with my deputy, Andreas Hartwig, and all employees of the institute." Key areas for the Fraunhofer IFAM have long been the aircraft manufacturing industry, the car, rail vehicle and shipbuilding industries, as well as wind turbine manufacture. "This will remain so. However, our broad expertise is also ideal for new fields and we are becoming increasingly active here. These include, for example, adhesive bonding in the construction sector. Developments here include new solutions for noise protection along railway lines and motorways, for road building, and for the maintenance of infrastructure – for example, maintenance of the many dilapidated sewage systems in Germany. This naturally also applies to the new services being offered by Fraunhofer IFAM at the research center CFK Nord in Stade: The development of processes and plant technology for assembling very large CFRP structures on a 1:1 scale." New concepts for bonding and sealing for innovative energy-generation projects using fuel cells, battery technology, and photovoltaic technology against the challenges of climate change are also topics which the Fraunhofer IFAM under Bernd Mayer will increasingly focus on.

Especially in the area of fiber composites it is currently considered how the work can be organized so that the whole processing chain is covered. "These are the materials of the future. The topic of lightweight construction is of great interest, for example the whole transport sector. The objective of Fraunhofer IFAM for all challenges associated with the industrial application of fiber composites is to contribute towards finding a solution." When production scale manufacture of fiber composite materials eventually starts, for example in the car manufacturing industry, many new questions will arise, "and then we want to be the partner of choice for users."

In recent years the Fraunhofer IFAM has been very successful in the area of Surface Technology and Paint/Lacquer Technology. "Regardless of whether this has concerned the pre-treatment of materials, coatings, or novel paint systems, Fraunhofer IFAM scientists and their partners have always achieved excellent results. Further technology advances and cost optimizations are possible for users in these areas, and this is why we will continue to be very actively involved here", says Bernd Mayer. Amongst other sectors, the aircraft manufacturing sector, the shipbuilding industry, and the wind energy sector should benefit from the new methods for pre-treatment and quality assurance of surfaces. "We are developing and improving complete systems for our customers – including the application and measurement technology", emphasizes Mayer as he outlines the "holistic approach" of the Fraunhofer IFAM. One example of a very interesting new development concerns coatings with so-called riblet structures, which mimic the structure of sharkskin. They reduce the frictional resistance and have potential for lowering the fuel consumption of, for example, aircraft and ships.

Passing knowledge on to younger scientists

The new institute director of the Fraunhofer IFAM will pass on his wide knowledge to undergraduates and doctoral students. His appointment as Professor of Polymeric Materials in the Department of Production Technology at the University of Bremen has deepened the longstanding relationship between the Fraunhofer IFAM and the university.

Taking advantage of his industrial experience, Bernd Mayer will strive to inspire prospective production engineers concerning the issues of Fraunhofer IFAM. "It is no secret that a worldwide competition is fierce for the best students and graduates. I believe it is my task to offer young people an attractive working environment: The University of Bremen is an excellent place to study, and working at the Fraunhofer IFAM is an excellent opportunity to start out on an interesting research career." That the students get to learn about applications at as early a stage as possible makes sense to Bernd Mayer. "I am convinced that understanding the practical relevance as early as possible motivates and drives the young scientists. Our work covers many highly interesting topics which are at the core of present and future high-technology. What could be more exciting for young people?"

Besides teaching, research is naturally very important for Bernd Mayer. His main interests are in ageing processes for polymeric materials, which of course include adhesives. How do such materials react to the various environmental effects? How do these effects change the microscopic and macroscopic structure of materials? What does this mean for the mechanical properties of the material? How can components be optimally designed in order to reduce fatigue due to external influences and so prolong the service life of polymeric materials? Bernd Mayer goes on: "It is necessary to fully understand the ageing mechanisms in order to optimize the design of components. That will be the focus of my research work."

CONTACT

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Institute
Fraunhofer Institute for Manufacturing Technology and
Advanced Materials IFAM,
Department of Adhesive Bonding Technology and Surfaces, Bremen

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CFRP NORTH IN OPERATION: THE FRAUNHOFER PROJECT GROUP JOINING AND ASSEMBLY FFM HAS STARTED ITS WORK

September 21, 2010 was a landmark day for Stade. It saw the opening of a new research center for the processing of carbon fiber reinforced plastics (CFRPs): The Forschungszentrum CFK Nord (Research Center CFRP North; Fig. 1). This new facility is unique in Europe and cost more than 26 million euros. It is an investment in industry's future. The work that is carried out here will pave the way for serial application of CFRP materials in the aircraft manufacturing industry and also in other sectors such as wind energy, shipbuilding, and the car, commercial vehicle, as well as rail vehicle manufacturing industries.

September 21, 2010 was also a historic day for the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM and its project group Joining and Assembly FFM because the 17 strong FFM team headed by Dr. Dirk Niermann will play a leading role in the new research center. As one of the two main lessees, the project group occupies more than half of the circa 7000 square meter area of the 24 meters high hall of CFRP North. The aim is to work together with industrial partners on assembly processes using adhesive bonding technology and on the subsequent precision machining of large CFRP structures in series production (Fig. 2).

Politics, industry and R&D have long been aware that CFRPs with their many advantages are the materials of the future. CFRPs have demonstrated this in numerous products, many of which are nowadays part of everyday life. Nevertheless, in order to transfer the technology economically to very large structures, for example large aircraft or wind turbines, one also requires reliable processes on such a scale. These processes must function seamlessly in series production and under

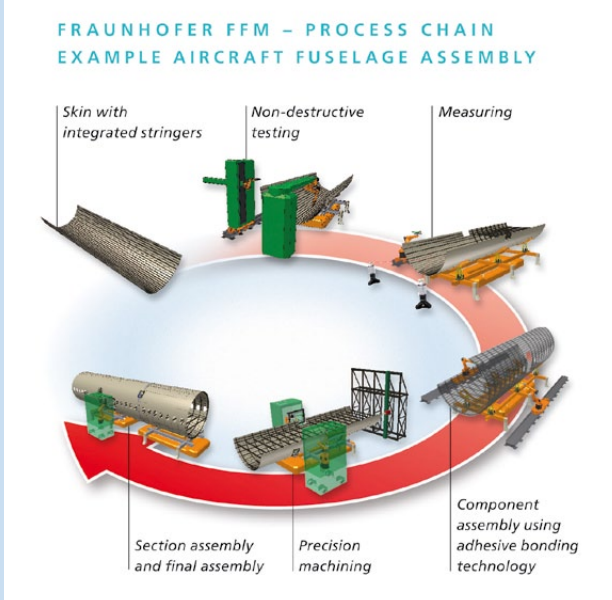

Fig. 2: Activities of the Fraunhofer Project Group FFM on large CFRP structures up to a 1:1 scale for the example of an assembly process for an aircraft fuselage.


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ever increasing production quantities per unit time – because only this scenario will make production actually economically viable in the face of international competition. After many discussions and much preparatory work the state of Lower Saxony decided to financially support CFRP development and fund the new facility in Stade.

The opening of the new research center was attended by representatives from politics and industry and other leading figures involved in carbon fiber reinforced plastics. More than 300 guests came together in the impressive large hall. The celebratory opening was undertaken personally by the Minister President of the state of Lower Saxony, David McAllister (Fig. 3); the Fraunhofer-Gesellschaft was represented by Prof. Dr. rer. nat. Ulrich Buller – Senior Vice President for Research Planning of the Fraunhofer-Gesellschaft –, Prof. Dr. rer. nat. Bernd Mayer – Institute Director of the Fraunhofer IFAM –, and Dr. Dirk Niermann – Head of the Project Group Joining and Assembly FFM – (Fig. 4). The aviation industry journalist Cord Schellenberg presented the opening event in an informative and varied way. The Mayor of Stade, Andreas Rieckhof, pointed out in his opening that he was certain that CFRP North will promote the town to the "Champions League of the CFRP" world.

CFRP North: Research center of short ways

In his speech, David McAllister said the new "research center of short ways" was a prime example of the excellent collaboration between politics, industry, and R&D. "Straight to the point: We are enhancing our leading position in the production of CFRPs and are hence strengthening the aircraft manufacturing industry's sites in the North", explained the Minister President. Indeed, CFRP North is situated directly next to the Airbus plant in Stade. The aircraft manufacturing industry is one of the most important partners of the research center.

McAllister recalled the very short time between making the political decision to sponsor CFRP technology and the completion of the research center, "despite the economic and financial crisis which had impacted public budgets". The Minister President emphasized the good collaboration between all partners and mentioned representatives from the political world, EADS, Airbus, Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), CFRP Valley Stade industrial network, Dow Deutschland, and also Prof. Dr. rer. nat. Ulrich Buller (Fig. 5). As Senior Vice President for Research Planning, Buller represented the Fraunhofer-Gesellschaft, one of the main players involved in the new CFRP North, in many of the discussions. McAllister also mentioned that CFRP North is not solely directed at the aviation industry: "All of the transport industry will eventually benefit from CFRPs. CFRPs are on the advance. For example, the world's first truck trailer made entirely of CFRP has just been built in the Stade area!"

The Minister President is convinced that the two key partners in CFK Nord – Fraunhofer-Gesellschaft and DLR – will focus attention on the research center from far afield. "They not only have many years of experience working with industrial partners, but also in researching fiber composite materials. I am very pleased that they have come together here in Stade for a joint research partnership which will bring lots of developments for the location and the industry."

1 *With its Project Group Joining and Assembly FFM, Fraunhofer IFAM is one of the main lessees of the research center CFRP North in Stade.*

3 *David McAllister (left), Minister President of the state of Lower Saxony, together with Dr. Dirk Niermann (right), Head of the Fraunhofer Project Group FFM, at the official opening of CFRP North on September 21, 2010 in Stade.*

4 *Representatives of the Fraunhofer-Gesellschaft (from left to right): Dr. Dirk Niermann (Head of the Fraunhofer Project Group FFM), Prof. Dr. rer. nat. Ulrich Buller (Senior Vice President for Research Planning of the Fraunhofer-Gesellschaft), and Prof. Dr. rer. nat. Bernd Mayer (Institute Director of the Fraunhofer IFAM).*

The practical work of the new research center was covered in an informative podium discussion in which Prof. Dr. rer. nat. Ulrich Buller was on hand for the Fraunhofer-Gesellschaft (Fig. 6). First of all Prof. Dr.-Ing. Axel Herrmann, the Chairman of CFK-Valley Stade e. V., pointed out that the whole CFRP process chain is now covered in Stade: From training, especially in the area of composite materials, by the local university via the technology center, in which research results are optimized for series production, right through to the new large research center. "CFRP North will forge our future. For example, the second generation of CFRP aircraft will be prepared here, some 10 to 15 years before the start of actual production." Fraunhofer Senior Vice President Buller was asked what the inside of the Fraunhofer part of the hall would look like when the FFM team was carrying out their work: "Here would be adhesive bonding of large aircraft fuselages, and also the ultra-precision machining of large components. Our part of the hall is still empty but will soon be filled with a lot of new research equipment and the large structures", said Buller.

From the Fraunhofer point of view, Buller emphasized, CFRP North brings three key advantages: "Airbus and Dow Deutschland are two of our most important customers and they are close to CFRP North; CFRPs are fascinating, advanced materials and not only the Fraunhofer IFAM but many other institutes of the Fraunhofer-Gesellschaft have built up extensive expertise in this area; and CFRPs are not only of interest for the aircraft manufacturing industry but also for the entire transport sector and for lightweight construction."

Fraunhofer Project Group FFM establishes large structure assembly facilities

The tasks of the Fraunhofer Project Group FFM at the research center CFRP North are carried out using the technical scientific expertise of a multidisciplinary team (Fig. 7). Currently there is a team of 17 experts, comprising production and automation technicians, mechanical engineers, software programmers and chemists. Their work for customers covers the whole process chain involved in the assembly of large CFRP structures on a 1:1 scale. The first projects in Stade have already started, and mainly concern the establishment of the assembly for the production of large aircraft structures. At the start a few project steps were carried out relatively quickly in order to reach the ambitious aims as quickly as possible. This includes changing the assembly technology for large aircraft manufacture from the hitherto widely used manual process to a highly automated process – because automation is a fundamental requirement for faster and lower cost production in the aircraft manufacturing industry. Components, which were realized for car manufacture many years ago, are nowadays the industry norm. Now they must be developed and tested for large structures and ultimately transferred to an error-free series production if possible – even though the product quantities are much lower than in the car industry.

5 *Prof. Dr. rer. nat. Ulrich Buller, Senior Vice President for Research Planning at the Fraunhofer-Gesellschaft.*

6 *Experts taking part in the podium discussion (from left to right): Prof. Dr.-Ing. Johann-Dietrich Wörner (Deutsches Zentrum für Luft- und Raumfahrt e. V.), Dr. Gerald Weber (Airbus Operations GmbH), Reiner Roghmann (DOW Deutschland Anlagengesellschaft mbH), Dr.-Ing. Dieter Meiners (Premium Aerotec GmbH), Prof. Dr.-Ing. Axel Herrmann (Faserinstitut Bremen e. V., Composite Technology Center GmbH), Dr. Claudio Dalle Donne (EADS Deutschland GmbH Innovation Works), Prof. Dr. rer. nat. Ulrich Buller (Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.) and presenter Cord Schellenberg (Luftfahrt-Presse-Club e. V.).*

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Objective: Faster process steps

In the area of assembly, both the aircraft manufacturers and the Fraunhofer experts see opportunities for speeding up the production. Time-consuming tasks, which presently take place one after another, can be combined in automated or partially automated processes. This can be achieved, for example, by using laser-aided measuring systems. The challenge with large structures is that, unlike in the car industry, even the components from the series production are unique products because of the considerable geometric differences between them. This is due to unavoidable component distortion caused by their size. For example, if there is a difference of several millimeters within a component series, then the robots must be informed of the exact dimensions of the component in order, for example, to drill holes at exactly the right position. Another challenge is that CFRP surfaces have been very difficult to measure up until now using conventional measurement technology due to the embedding of carbon fibers in a transparent resin. New developments are also ongoing here.

A further task concerns automated processing sequences for joining large components and for machining large structures. A primary objective here is also acceleration of the relevant steps. In the aircraft manufacturing industry adhesives have up until now been little used for CFRP structures to transfer forces between components, rather they have mainly been used for support and for filling gaps. The term "shim" is generally used for this. The load-bearing components of the aircraft are generally bolted, and the shim material fills the void between components. As these voids are very irregular, the current filling process consumes a lot of time and resources and often multiple measurements as well as modifications are necessary. The strategy of the Fraunhofer IFAM and its Project Group FFM at CFRP North is to measure the components exactly so that the gap widths are known prior to joining, thus allowing the shim mass to be accurately applied in a single processing step. The binding of the adhesives, which still takes several hours, will also be significantly accelerated at selected points and those points will thus provide secure fixation. The next processing steps will then be able to be undertaken faster, because it will not be necessary to wait for curing of all the adhesive. A further development step in the near future will be to replace the shim mass that has been used up until now for sealing with "real" adhesives. This will result in a reduction in the number of very expensive drilled holes and titanium bolts in the aircraft and will also largely eliminate the need for bolts which are not suitable for CFRP materials.

Objective: Versatile, light, and reliable

The precision machining of components is a major challenge. The Fraunhofer Project Group FFM at CFRP North is involved in various areas of work here. One main area concerns development of a versatile processing cell which uses different modules to process large components fully automatically – and also simultaneously at different positions. Whereas at present huge, rigid, steel structures together with heavy duty foundations are necessary to accurately operate end tools such as mills or drills, in the near future light, mobile units will be used. These will move on the floor or can be attached to the structure with suction pads around the component in order to carry out machining tasks faster and better. This requires efficient as well as intelligent measuring and control technology. FFM will develop this with project partners in the years ahead.

An important factor for the advanced development of processing techniques for large structures is the prospective prevention of faults. Machining faults often cause irreparable

7 *The team of the Fraunhofer Project Group Joining and Assembly FFM of Fraunhofer IFAM.*

damage to components, and this would be enormously costly for large structures. For this reason, CFRP North is focusing from the outset on developing processes that are totally reliable and manageable, with the objective being to get as near as possible to zero fault production. This will be achieved by continuous and thorough monitoring of all key parameters as well as optical and sensor-aided checks. This means that before faulty machining can take place the machining process will be able to be corrected or switched off.

Work is also already being undertaken in Stade on designing large plants and on the organization of the individual processes: In what sequence must steps such as milling, drilling, bolting, and bonding be undertaken? Many complex processing sequences must be coordinated, which in some cases must also be carried out simultaneously. To do this requires first of all test stands which are reduced to the key processes. The ideas are tested and optimized on these before being ultimately transferred at lower risk to a large scale. Project partners here include manufacturers of large plants who sell these and then assemble them at the end-user and bring them into operation.

In order to utilize the latest scientific findings in the area of precision machining, the Project Group FFM works closely with experts of the Technical University of Hamburg-Harburg. Prof. Dr.-Ing. Wolfgang Hintze – Institute of Production Management and Technology – (Fig. 8) heads the Precision Machining activity field within the Fraunhofer Project Group FFM, and Priv.-Doz. Dr.-Ing. habil. Jörg Wollnack – also of the Institute of Production Management and Technology – (Fig. 9) supports the FFM in the areas of automated measurement and referencing technology and robotics.

All from a single partner

The FFM team works closely with its parent organization, the Fraunhofer IFAM in Bremen, where the development of technologies and materials takes place on different scales – laboratory up to small pilot plant. The work that is carried out in Stade focuses on planning for industrial implementation, the realization of processes on up to a 1:1 scale, and the associated development of large plant technology and equipment.

The findings can also be transferred to other fields – for example to the construction of wind turbines, commercial and rail vehicles, and shipbuilding, even when glass fiber reinforced plastics (GFRPs) are still used. The use of CFRPs generally means lower weight and higher stiffness. These features have noteworthy benefits for energy consumption, resistance, fatigue behavior, and also for the comfort of means of transport.

The projects at CFRP North are making a considerable contribution to demonstrating the feasibility of series production at acceptable cost – a key prerequisite for the use of CFRPs not only in the aircraft industry but also in other sectors of industry. It is inevitable that the already mentioned industries such as construction of wind turbines, commercial and rail vehicles, and shipbuilding will increasingly turn to lightweight construction using CFRPs with all the associated advantages – and so benefit from the application-oriented R&D work of the Fraunhofer IFAM and the Project Group Joining and Assembly FFM.

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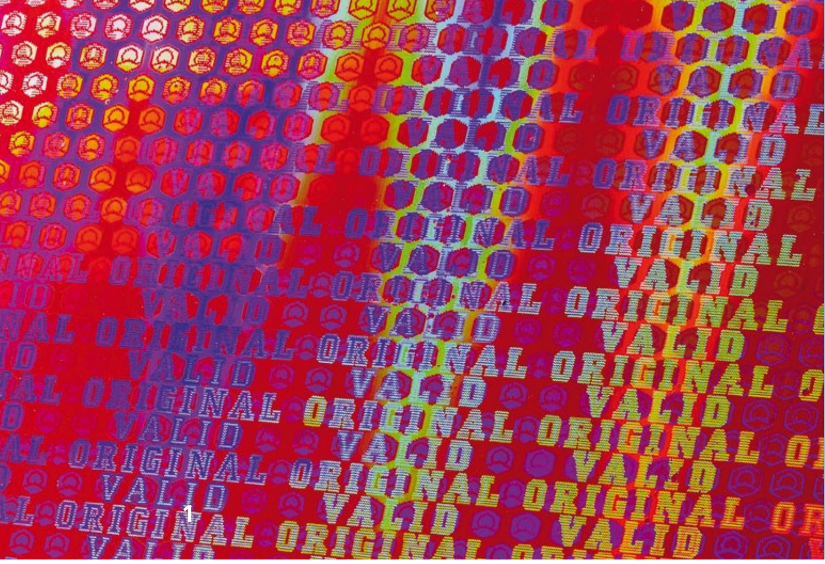
8 *Prof. Dr.-Ing. Wolfgang Hintze, Institute of Production Management and Technology at the Technical University of Hamburg-Harburg, heads the Precision Machining work group within the Fraunhofer Project Group FFM.*

9 *Priv.-Doz. Dr.-Ing. habil. Jörg Wollnack, Institute of Production Management and Technology at the Technical University of Hamburg-Harburg, consults the Fraunhofer Project Group FFM in the areas of automated measurement technology and robotics.*



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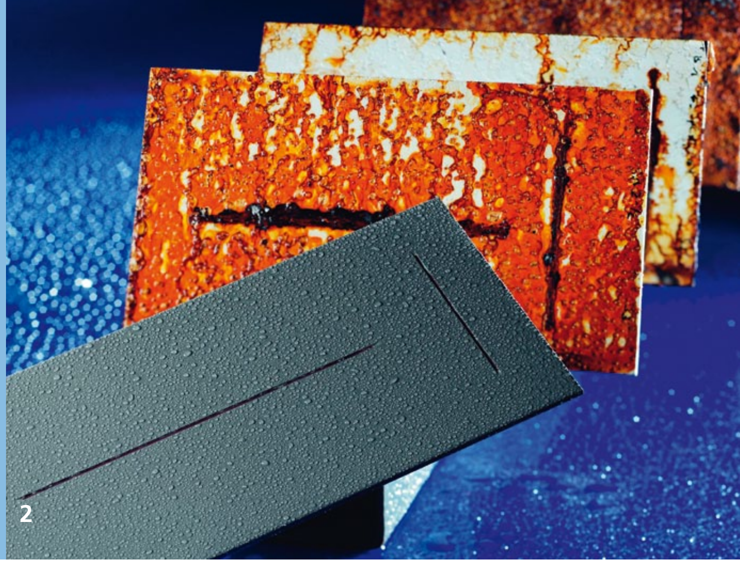

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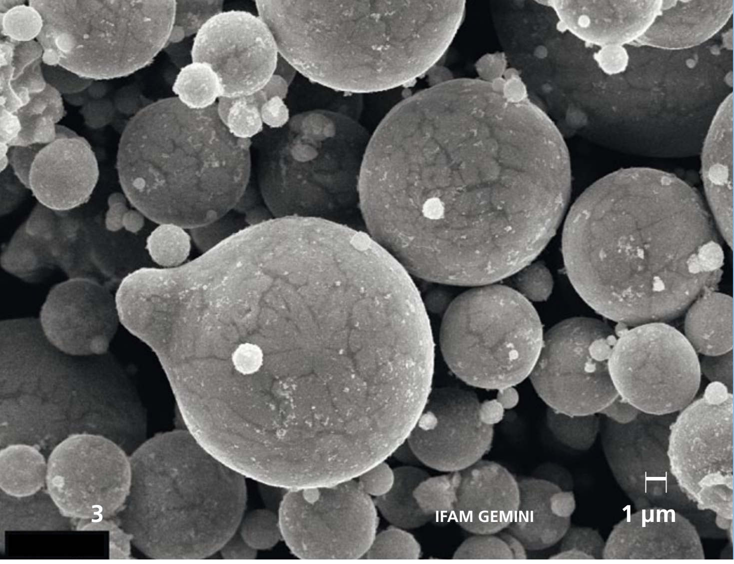
FRAUNHOFER IFAM IN THE SPOTLIGHT AFTER SUCCESSFUL R&D WORK ON FUNCTIONAL COATINGS

They sound futuristic, but are already here: Functional surfaces (Fig. 1). They have a variety of functions, such as reducing the drag of aircraft and ships, and preventing ice adhesion, contamination, erosion, abrasion, as well as corrosion. There are even self-healing coatings which have repairing effects. The Paint/Lacquer Technology section of Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has achieved impressive results in recent years in the field of functional coatings. Its work, in collaboration with other groups of the Fraunhofer IFAM, has made many existing applications for coatings more efficient and has also opened up completely new applications for coatings. Furthermore, the section has extensive knowledge of industrial coating and the latest technologies. The experts at Fraunhofer IFAM in Bremen are a valued partner of the paint and coating industry as a result of their successful development work, huge experience, and synergistic collaboration with other sections in the Adhesive Bonding Technology and Surfaces department of Fraunhofer IFAM.

Regardless of whether the work concerns coatings for aircraft, ships, wind turbines, heat exchangers, or other sensitive components: almost all the work is geared towards extending repair and maintenance intervals, prolonging the service life of components, increasing effectiveness, or saving energy. The industrial services offered by the section are varied and include work that has led to the industry changing over from solvent-based coatings systems to more environmentally friendly water-based systems. Currently the section's experts are helping industry to optimize coating applications, for example the prevention of cavitation and the prevention of dirt inclusion during coating processes. A further focus is on more efficient coating methods, for instance new methods for paint application and improved methods for drying paint.

"Holistic" solutions guaranteed – for example innovative corrosion protection concepts

When carrying out work for customers, the Paint/Lacquer Technology section collaborates closely with other specialists of Fraunhofer IFAM and is thus able to offer "holistic" solutions. On matters relating to defect avoidance during the application of coatings, the expertise of the Adhesion and Interface Research section is called upon. When drawing up concepts for corrosion protection, the researchers of Fraunhofer IFAM also benefit from close internal, interdisciplinary collaboration. For example, collaboration between the Paint/Lacquer Technology section and the Electrochemistry/Corrosion Protection work group (which falls under Adhesion and Interface Research) and the Casting Technology section of Fraunhofer IFAM resulted in the development of a new corrosion protection pigment.



The reason for carrying out this work was the fact that most damage to metal components is caused by corrosion. This is why metal components are often coated with anti-corrosion layers (Fig. 2). In most cases special coatings are used for this purpose. The anti-corrosion coatings often contain pigments which actively suppress corrosion of the component. Chromate-containing pigments were commonly used in the past for this, but these have environmental and health drawbacks. The search for alternatives, in particular for the aluminum alloys used in aircraft manufacture, has long proved difficult.

Within an internal Fraunhofer-project, aimed at assisting small and medium-sized companies (MEF), Fraunhofer IFAM finally succeeded in developing cathodically active metal pigments consisting of intermetallic magnesium-zinc phases which provide effective corrosion protection (Fig. 3). The electrochemical properties of the pigments mean that the corrosion of steel and aluminum alloys is significantly reduced. They also have the major advantage that they are not harmful to health or the environment. Effective, easy-to-apply corrosion protection coatings were then developed using these pigments.

Solvent-containing anti-corrosion primers demonstrated that the pigments developed at Fraunhofer IFAM were very efficient. For example, substrates made of very corrosion-sensitive aluminum alloys showed no corrosion after more than 10,000 hours in the salt spray test in the accredited corrosion testing laboratory of Fraunhofer IFAM – not even when the coating layer which was applied for experimental purposes was seriously damaged.

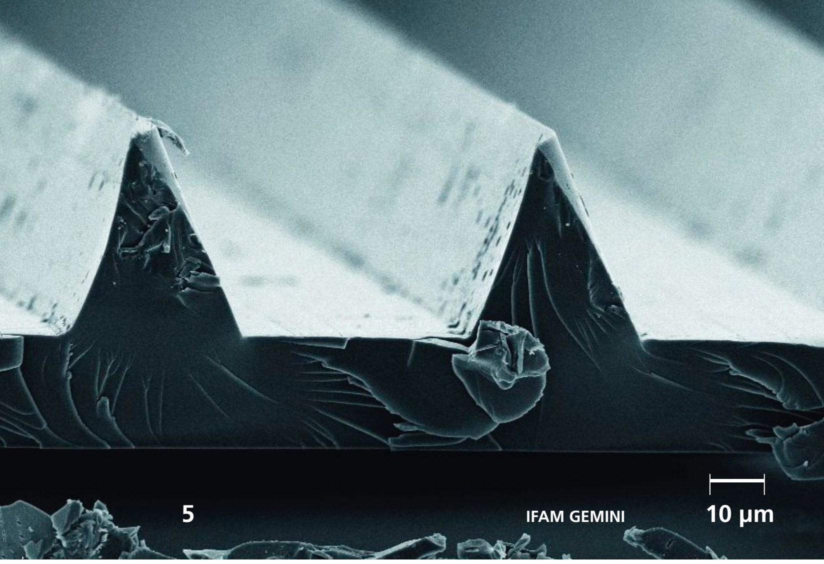
However, the researchers were still not totally satisfied. Further work was undertaken to develop pigments not only for solvent-based systems but also for water-based coatings, and so benefit the environment even further. As these pigments, due to their mechanism of action, are very reactive to water, a special stabilization system had to be developed for water-based coatings (Fig. 4): The stabilization system isolates the pigments in the liquid coating from the surrounding water, but becomes ineffective as soon as the coating is present as a cured layer. The initial corrosion tests showed that good protection was provided by the water-based coating containing stabilized pigments.

The stabilization of corrosion protection pigments in water-based coating systems was the topic of an article written by Anja Zockoll (Electrochemistry/Corrosion Protection) and Andreas Brinkmann (Paint/Lacquer Technology) in the technical magazine FARBE UND LACK. For this article the authors received an award for the best technical article of 2010 (see page 94).

Sharkskin coatings reduce drag

Also worthy of an award in 2010 was a development of the Paint/Lacquer Technology and Adhesive Bonding Technology sections at Fraunhofer IFAM which had been many years in the making: A coating system that significantly reduces the drag of large components. Dr. Volkmar Stenzel and Yvonne Wilke – both members of the Paint/Lacquer Technology section – and Manfred Peschka – a member of the Adhesive Bonding Technology section – received the Joseph von Fraunhofer Award in 2010 for this innovative work (see page 90). Since 1978 the Fraunhofer-Gesellschaft has presented this

1 *Example of functional surfaces: The nanostructuring of the coating, visible as a hologram, is used for product and brand protection.*
2 *Testing corrosion resistance: Coated test specimens after exposure in the salt spray chamber at Fraunhofer IFAM.*
3 *Scanning electron micrograph of magnesium-zinc pigments: Corrosion protection without risk to health or the environment.*
4 *Non-stabilized magnesium-zinc pigment (left) and stabilized magnesium-zinc pigment (right) on contact with water.*



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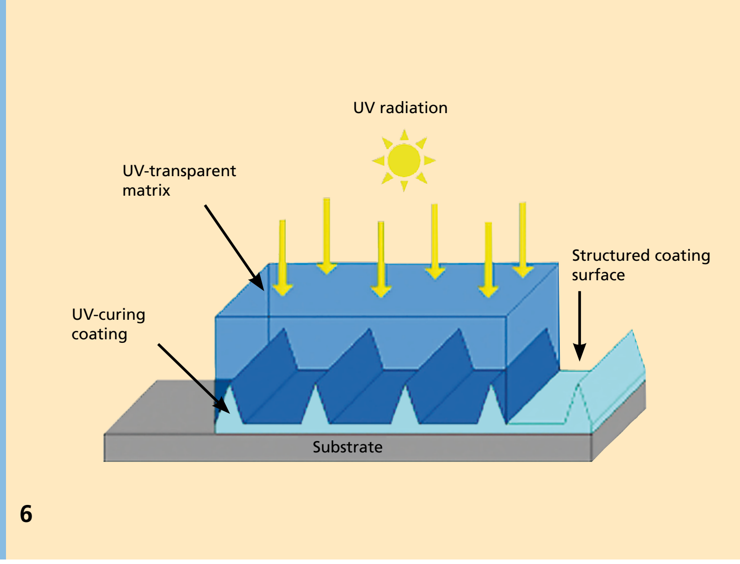

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award in recognition of excellent scientific work to solve application-related problems. The new coating of the Fraunhofer IFAM team helps to meet the demands of the European Commission to perceptibly lower the fuel consumption by aircraft and ships. From 2012 the shipbuilding and aircraft manufacturing industries will be incorporated into the emissions trading scheme. This will bring added pressure to reduce carbon dioxide emissions within the industries.

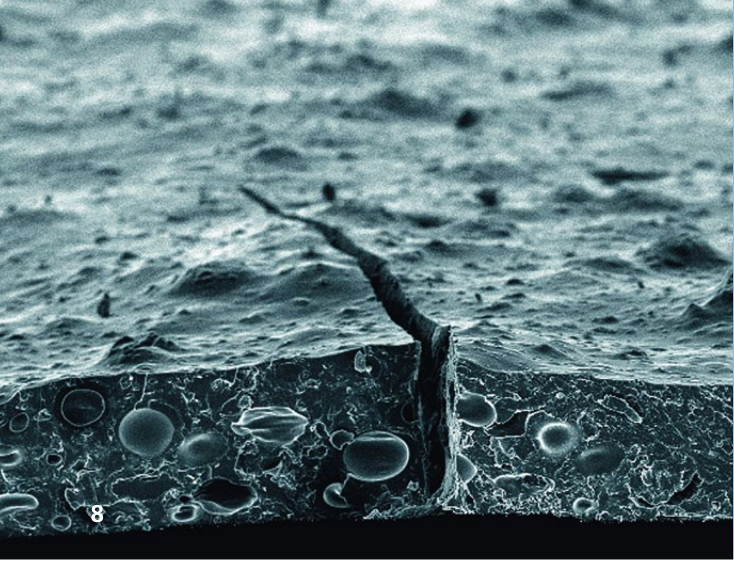
The structure of the coating system developed at Fraunhofer IFAM was based on what is found in nature. The scales of fast-swimming sharks have microscopic grooves, so-called riblets, in the longitudinal direction. These considerably reduce the drag of sharks in water. The Fraunhofer IFAM scientists transferred this concept to a coating (Fig. 5) which met the exacting requirements of the aircraft manufacturing industry – such as resistance to extraordinarily high temperature fluctuations from –55 to +70 degrees Celsius, aggressive ultraviolet radiation, and very high speeds. Nanoparticles are a key component of the riblet coating. They are the reason why the coating can withstand extreme conditions permanently. The advantages of the coating are enormous: In order to make fuel savings of about two percent, the only requirement is investment in the coating technology. Indeed, aircraft and ships always have to be coated and the application of a riblet coating is therefore essentially cost and weight neutral for users. Besides having low-drag, the coating has other advantages: It repels dirt and the nanoparticles make the coating highly resistant to abrasion and erosion.

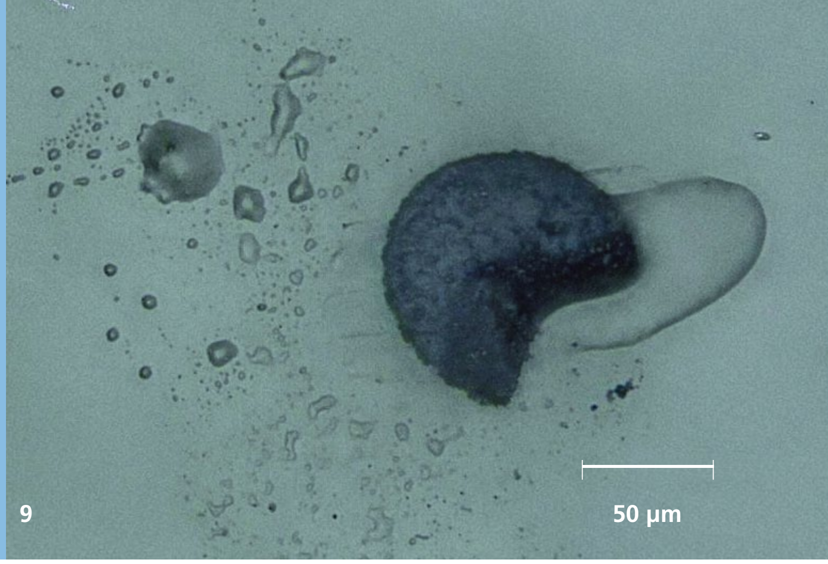
The "sharkskin coating" can be readily applied to three-dimensional curved surfaces, and this was not the case for previously tested systems involving structured foils. Indeed, the researchers of the Fraunhofer IFAM have simultaneously developed a suitable application system. This involves using a patented roller applicator to apply and structure the nanoparticle-containing coating with riblets. The coating is then partially cured by UV light and partially via chemical reactions (Fig. 6 + 7). The process can be operated automatically using a robot.

Cracks which repair themselves

Also of great promise is a development of the Paint/Lacquer Technology section which involves coatings that have self-healing functionality. Coatings are frequently exposed to extreme stresses and this often leads to cracking of coatings. Such cracks ultimately mean a weakening of the component. Wind turbines, for example, are exposed to both environmental influences and very high dynamic loads, and this often gives rise to surface damage. In this sector – and in particular for offshore wind turbines – maintenance work is very expensive, and self-healing coatings would represent major progress. However, such coatings also have benefits for other steel structures such as large bridges and other capital goods which have to withstand high stresses. They are also desirable for "repairing" scratches on decorative coating systems such as car paints.

The self-healing system developed by the Paint/Lacquer Technology section of Fraunhofer IFAM contains microcapsules of active agents which are incorporated into the coating. If the coating is damaged, the microcapsules at this location are broken apart. They contain a healing reagent which immediately closes the cracks (Fig. 8 + 9). Untreated cracks normally quickly become deeper and bigger, soon causing material damage. The microcapsules prevent this. These coating systems would allow longer maintenance intervals and the less frequent repairs would result in perceptible cost savings. This would increase the economic viability of plants in various sectors. Of course, the demands on the microcapsules are very complex: They must be resistant to solvents and must be able to be dispersed, namely they must be able to be incorporated intact into the coatings. Simultaneously, it is vital that the microcapsules remain intact during the coating application with spray guns. Indeed, they must form a composite system with the matrix and must be stable in the coating for a long time. When needed, the microcapsules must effectively break apart and then seal the crack. In order to meet these requirements





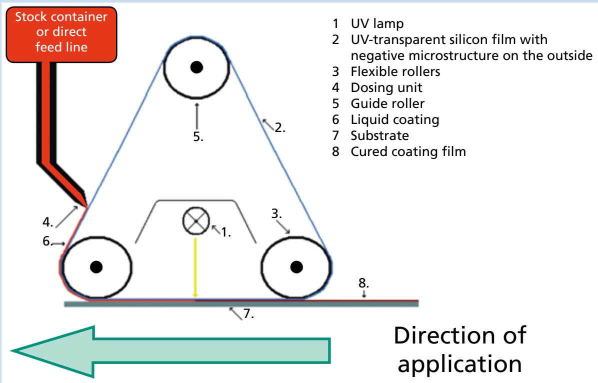


Fig. 7: Riblet coating: Principle of the applicator for continuous application of the coating.

for different applications, the microcapsules are "customized" by the Fraunhofer IFAM for specific coating systems and they are then thoroughly tested for their functionality.

Strategies against icing

The work of the Paint/Lacquer Technology section on anti-icing coatings is also of much interest for commerce and industry. Complete prevention of ice formation on surfaces, or even partial reduction, is attractive for many sectors of industry because ice formation incurs high costs. The best known example is the deicing of aircraft. Passengers only see this when the plane is on the ground but deicing is also carried out during a flight if ice crystals form on the aircraft wings at high altitude. Ice formation on electricity pylons or wind turbines can lead to irreparable damage, and in particular under extreme weather conditions as exemplified in Münsterland in November 2005 when pylons collapsed. Also, ice on wind turbine rotor blades lowers the energy production and falling ice can be a danger. Ice formation is also a huge problem for rail vehicles, ships, cars, refrigerator systems, and roller shutters.

Common to all these areas is that downtimes, maintenance periods, and complex repairs add up to a considerable extra financial impact.

The Paint/Lacquer Technology section of Fraunhofer IFAM is currently working on a variety of strategies for minimizing ice formation. An icing chamber has been developed which can mimic virtually any icing scenario on surfaces and coatings – with different air and substrate temperatures, air humidity, rain and wind simulation, and much more (Fig. 10). In addition, outdoor weathering is carried out under real conditions on an icing test stand located 1141 meters above sea level on the Brocken in the Harz Mountains. The main tests used by researchers at the Fraunhofer IFAM are the rime adhesion test for simulating rime formation (Fig. 11), the ice rain test for simulating ice formation from rainwater, and the so-called runback ice test on models of wing sections (Fig. 12).

The objective of the scientists is to minimize or prevent ice formation using a variety of strategies. Their in-depth knowledge of surface pre-treatment, coating development, and testing are utilized here. The research work includes, for example, extremely water-repellant coatings which effectively prevent adhesion of water – and ice cannot form where there is no water. Another approach is the development of biomimetic anti-icing surfaces based on antifreeze proteins. Nature shows the way here: There are insects, fish, and plants which contain proteins for frost protection. They are able to withstand temperatures as low as –60 degrees Celsius without freezing. The Paint/Lacquer Technology section is working together with the Adhesives and Polymer Chemistry section on functionalizing

5 *Scanning electron micrograph of a riblet-structured coating surface.*

6 *Riblet coating: Principle of the application.*

8 *Damaged coating with microcapsules of healing agents.*

9 *Healing agent is released from a broken microcapsule.*

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technical coating surfaces with synthetic antifreeze proteins. A further approach concerns surfaces with microscopic structures which prevent the adhesion of ice.

The work of the Paint/Lacquer Technology section also involves collaboration with the Adhesion and Interface Research section of Fraunhofer IFAM: Customized studies on the mechanisms of ice formation and ice adhesion on different surfaces and computer-aided simulation work by the Applied Computational Chemistry work group support and accelerate the research work.

Dirt-repellant surfaces

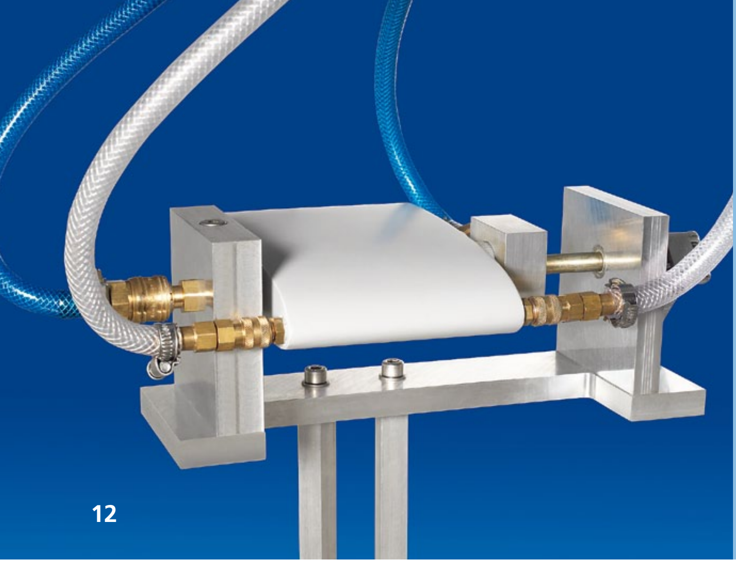
It is not only ice and rime that are problematic to industry. Contamination of surfaces is also often undesired. Indeed, regular cleaning is often required to maintain the full efficiency of plants and this brings with it considerable costs. Wind turbines are used once again as an example: Contamination due to insect residues in the summer months decreases the efficiency by up to five percent, and even more at certain wind speeds. The reason for this is the change in the aerodynamic profile caused by the insect residues. The Paint/Lacquer Technology section is using a variety of strategies to develop coatings which effectively prevent residues sticking to the surfaces.

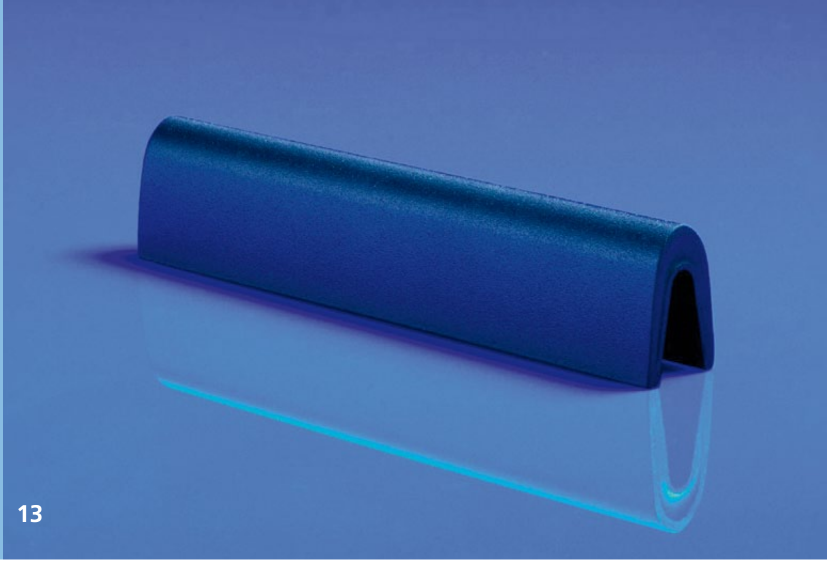
Surfaces becoming more resistant

A further challenge is to develop coatings which are resistant to erosion and abrasion. Over a period of time sand and rain damage the surface of components – the effect is like treating them with sandpaper. The same applies where two component surfaces rub each other – this abrasion shortens the service life of components and increases the maintenance as well as repair times. The Paint/Lacquer Technology section is using various approaches to significantly increase the resistance of surfaces and to develop coatings which provide components with greater resistance to erosion and abrasion (Fig. 13).

The load on surfaces differs widely depending on the application, so tailored solutions need to be developed: Surface protection for aircraft requires a different solution to surface protection for wind turbines. The experts of the Paint/Lacquer Technology are developing novel, highly erosion-resistant coatings containing inorganic and organic reinforcing fillers – for example nanoparticles – and systems already in use are being modified with this functionality (Fig. 14). To combat frictional loads, high-strength coatings having minimum frictional resistance are being developed. These have special slip and antiblocking properties. The Paint/Lacquer Technology section possesses state-of-the-art testing and analytical facilities in order to realize optimum solutions for each specific requirement.

The in-depth knowledge of the section on both everyday coating issues and the very latest technologies makes the Fraunhofer IFAM a valued partner of the paint/lacquer industry. The latter manufactures and processes more than 2.5 million metric tons of paints, lacquers, and printing inks in Germany each year. Its importance to society is considerable, because paints and coatings provide surfaces with customized surface protection. They protect materials worth many billions of euros, which otherwise would go into decline due to corrosion as well as wear and would have to be regularly renewed. And this surface protection is getting ever better. The work of the Paint/Lacquer Technology section in Bremen is making a significant contribution here.





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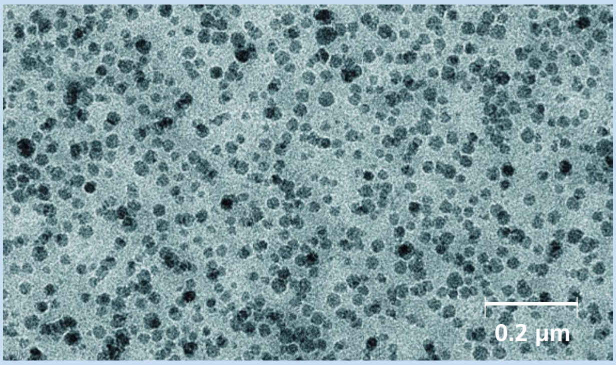


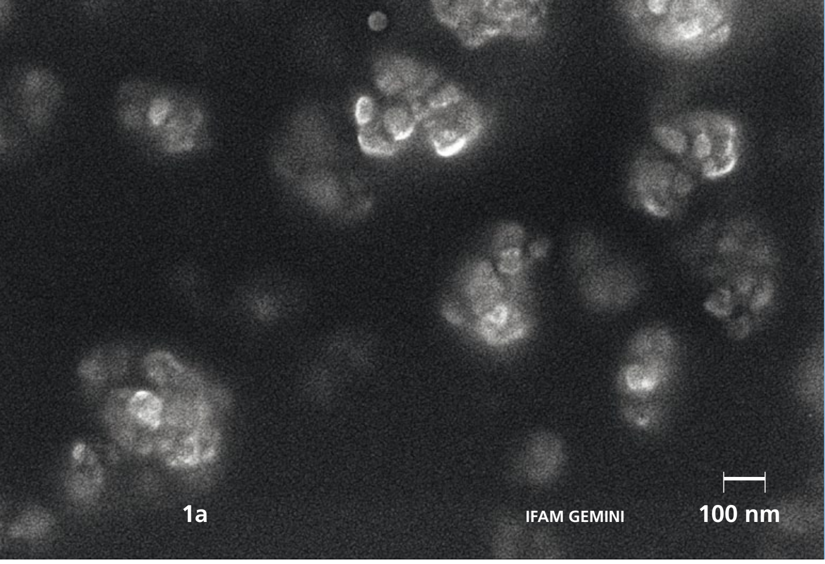
Fig. 14: Silicon nanoparticle in a dual-cure coating to increase the abrasion resistance.

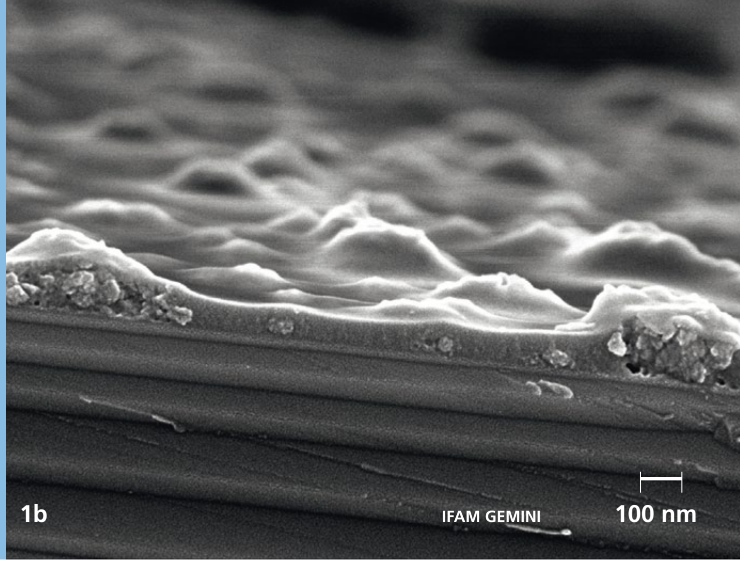
10 *Icing chamber developed at Fraunhofer IFAM for testing anti-icing coatings.*

11 *Evaluation of rime adhesion using the rime adhesion test developed at Fraunhofer IFAM.*

12 *Test device developed at Fraunhofer IFAM for carrying out the runback ice test on wing profiles.*

13 *Erosion-resistant elastomer coating on a front wing profile.*





PLASMA HYBRID PROCESS OFFERS NEW OPPORTUNITIES FOR APPLYING THIN FUNCTIONAL LAYERS

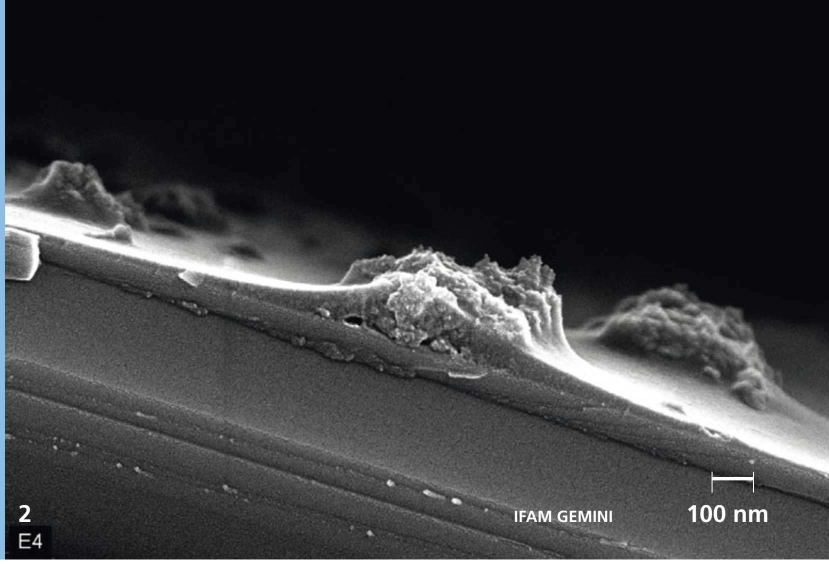
The section Plasma Technology and Surfaces PLATO of Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has developed a new approach for manufacturing thin functional layers on materials. PLATO has been working together with the Adhesives and Polymer Chemistry section of Fraunhofer IFAM and work groups of the University of Greifswald and the University of Bremen since mid 2008 on the so-called plasma hybrid process.

A polymeric liquid is applied to the surfaces to be coated. Particles in the micrometer and nanometer size range can also be incorporated into these liquids, forming dispersions. The polymeric liquid or dispersion is then crosslinked in a plasma and thus cured. The process offers numerous advantages and new opportunities for generating functional layers on different types of materials. The fundamental research project is being funded under the "Innovative Methods for the Manufacturing of Multifunctional Surfaces" initiative of the VolkswagenStiftung (Volkswagen Foundation).

The development involves a new procedure in the area of plasma technology. In classical plasma polymerization the surfaces and components are coated from the gas phase, but in the plasma hybrid process a new approach is adopted: In a first step the liquids are applied to the substrate surface and in the next step there is crosslinking using a plasma. In order to clearly distinguish this from conventional plasma polymerization, the scientists involved in the development work coined the term "plasma crosslinking". As already mentioned, a special feature is the ability to incorporate very small particles in the micrometer and nanometer range into the carrier liquid (Fig. 1a + 1b).

The manufacture and stabilization of these dispersions with a high particle filler content is also part of the project work. After crosslinking, the particles in the thin layer take on special functions. Subsequent exposure of the particles via selective plasma-etching – a sub-project assigned to the University of Greifswald – results, for example, in catalytically active particles being even more effective (Fig. 2). Another advantage over gas phase processes is that rough surfaces can be smoothed by the thin layer and micropores can be filled.

The incorporation of particles into thin layers is in principle not new. Up until now this has been carried out by a combination of physical and chemical gas phase deposition (Physical Vapor Deposition, PVD, and Chemical Vapor Deposition, CVD). The disadvantage here is that the sputtering process used in PVD is very directional. This means that shaded areas of a workpiece cannot be completely coated. Furthermore, some roughness and pores possibly remain on the surface, and this is detrimental, for example, for corrosion protection. Indeed, effective corrosion protection requires a closed coating layer. The new plasma hybrid process allows lasting smoothing of the surface.



Very small particles incorporated into a siloxane matrix

The project team has successfully incorporated microparticles and nanoparticles into a highly crosslinked silicon-organic layer (siloxane matrix): This involved dispersing the particles. Using emulsifiers, for example, hydrophobic silicone oil and hydrophilic anatase (titanium dioxide) were mixed to form a stable, finely dispersed mixture. This development work required the in-depth expertise of the Adhesives and Polymer Chemistry section of Fraunhofer IFAM. Intelligent application methods – ranging from immersion of the substrates respectively components right through to wetting using an aerosol evaporator in a kind of "mist chamber" – guaranteed that the liquids wetted the entire surface of the substrate. The plasma crosslinking was then carried out using low pressure plasma. From a chemical point of view, this process breaks single bonds and then new compounds are formed. Virtually all liquid, silicon-organic compounds can be crosslinked. The thin layers that result from this process have similar chemical and mechanical properties to plasma-polymer layers. They are relatively hard, have excellent adhesion, and are generally transparent. A further advantage over plasma polymerization is that layers up to a thickness of 350 nanometers can be rapidly crosslinked to form mechanically stable layers.

Photocatalytic coatings are a specific example of the huge potential of the plasma hybrid process (Fig. 3). The mineral anatase proved itself to be the most suitable "supplier" for the microparticle. When applying anatase with conventional PVD or CVD methods the substrate must be made very hot (several hundred degrees Celsius). This means there is a risk of distortion or damage to the substrate which proves unsuitable, for example, for the coating of classical plastics. For this reason, photocatalytic layers have up until now been almost exclusively applied to glass.

"Cold" coating – the basis for diverse applications

The advantage of the plasma hybrid process is that the coating process can be carried out cold, namely at room temperatures. This means that numerous other surfaces come into the fray for coating with a highly effective photocatalytic layer – for example aluminum or plastic slats of exterior blinds. The catalyst that is incorporated into the coating "combusts" organic molecules – such as those found in dirt or algae – decomposing them into carbon dioxide and water. The only thing necessary for this is moderate UV light, as is present in abundance in sunlight. The special coating uses the light to decompose organic contaminants and simultaneously promotes the rinsing off of the detached dirt particles by rain. The research project has also indentified other potential future applications for this process.

A further example of the use of photocatalytic coatings concerns photo-microreactors for water purification (Fig. 4). Reactors that work with sunlight are also conceivable: Water containing organic components, for example, bacterial contamination, flows from a feed vessel via microreactors that are exposed to sunlight into a collection vessel and is thus purified. As the coating is "active" but is firmly anchored to the surface, the catalysts do not have to be filtered out of the water after the purification process. As the coating also provides a surface smoothing effect, the flow in the microreactor is also improved.

1a + 1b *Scanning electron micrographs of a plasma-crosslinked dispersion of titanium dioxide nanoparticles in silicone oil (1a: top view; 1b: broken edge).*

2 *Scanning electron micrograph after exposure of the photocatalytic titanium dioxide nanoparticles via plasma-etching at the University of Greifswald.*

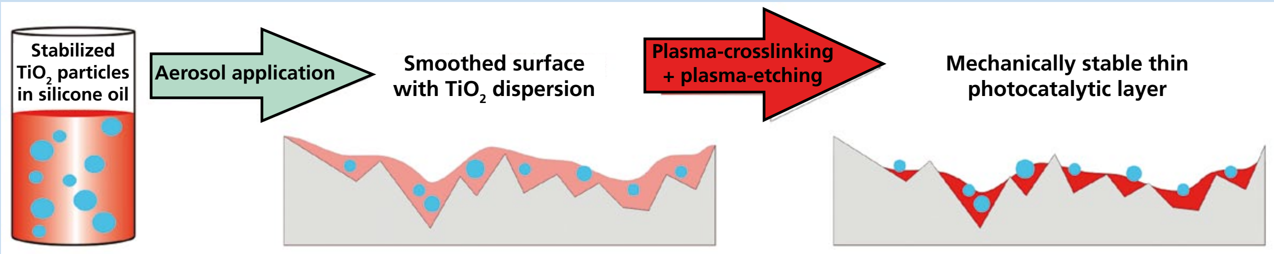


Fig. 3: Plasma hybrid coating for the cold application of a thin photocatalytic layer to technical components.

The incorporation of silver nanoparticles also allows thin antimicrobial layers to be produced. This is of interest for medical technology, as well as other applications. In contrast to antimicrobial layers containing antibiotics that are currently used, the use of silver nanoparticles does not have the drawback of antibiotic resistance, an ever growing problem in medicine. The silver particles that are crosslinked into the thin film can also be used in the human body, for example on implants. This contrasts, for example, with the pure silver coatings that are applied by gas phase deposition and which are rejected by body tissue.

As bacteria often form biofilms on surfaces, antimicrobial coatings have many other potential applications, including in space technology. Biofilms often form in inaccessible areas of a space station such as the ISS and these can become a serious hygiene problem over the course of time.

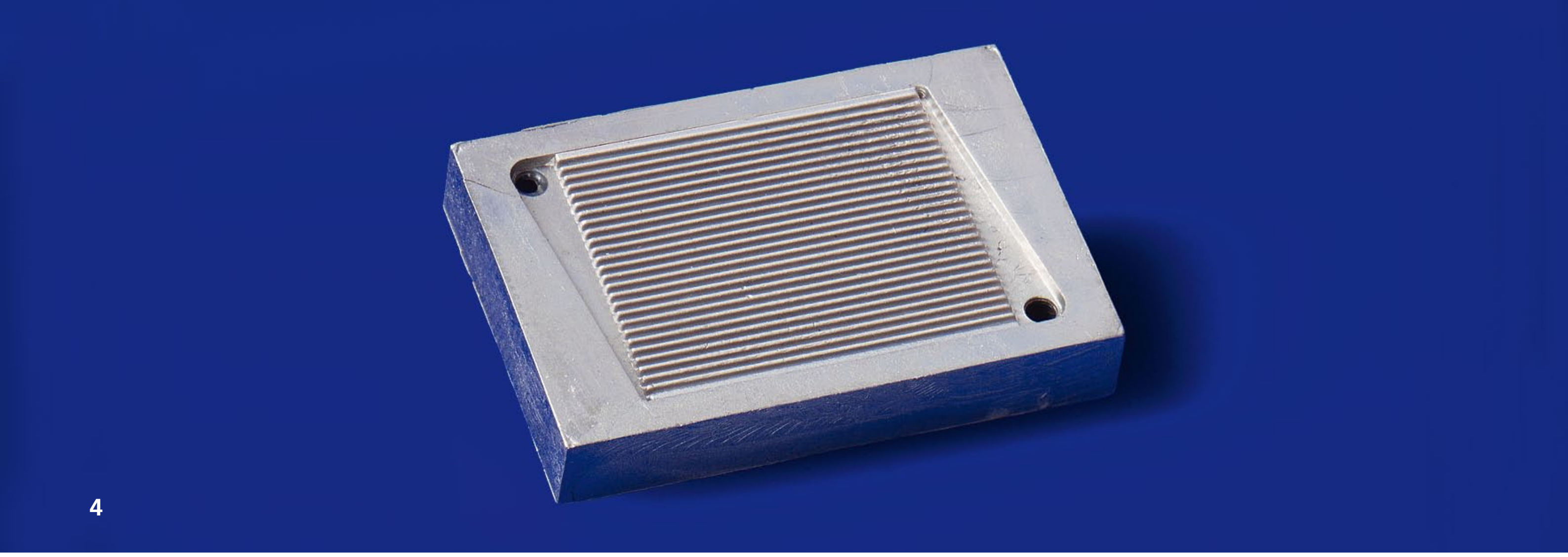
Optimized corrosion protection coatings

Not to be forgotten when considering the potential applications of the plasma hybrid process is the added value of a qualitatively improved corrosion protection coating. Technical surfaces of all types benefit from the filling of micropores and the general smoothing of the surface. This is not only due to the defect-free coating but also due to the gentle process conditions at room temperature.

The array of possible surface functionalities has been significantly enlarged due to the research work that has been described. Despite the many potential applications, the focus here was on successful technical implementation of the concept. The viability and reproducibility of the coating of substrates with highly crosslinked silicon-organic layers using this process has been successfully demonstrated on a laboratory scale. Furthermore, the section Plasma Technology and Surfaces PLATO of Fraunhofer IFAM has already developed concepts for practical implementation of this process in real production lines.

Project funding
This work presented was funded by the Volkswagen Foundation as part of the project “Plasma Hybrid Coating: Functional Surfaces by Plasma Supported Nanotechnology” (funding initiative “Innovative Methods for the Manufacturing of Multifunctional Surfaces”; project term: June 1, 2008 to May 31, 2011).

Project partners
- Ernst Moritz Arndt University of Greifswald, Institute of Physics, Prof. Dr. Jürgen Meichsner
- University of Bremen, Institute of Applied and Physical Chemistry (IAPC), Prof. Dr. Petra Swiderek



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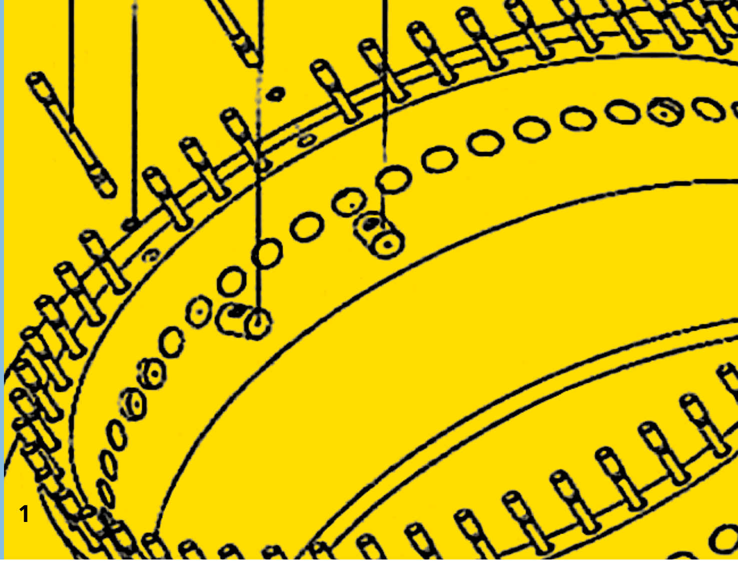
4 *Inside view of a metallic photo-microreactor cold-coated with photocatalytic titanium dioxide particles in a siloxane matrix.*



1

LIGHT ROTOR BLADE CONNECTION – ADHESIVE BONDING OF METAL INSERTS

The optimization potential of lightweight glass fiber reinforced plastics (GFRPs) for wind turbine rotor blades is virtually exhausted. There are, however, still opportunities for optimizing the utilization of materials for the blade connection. In order to optimally utilize the properties of GFRPs in this area, new joining techniques are required.

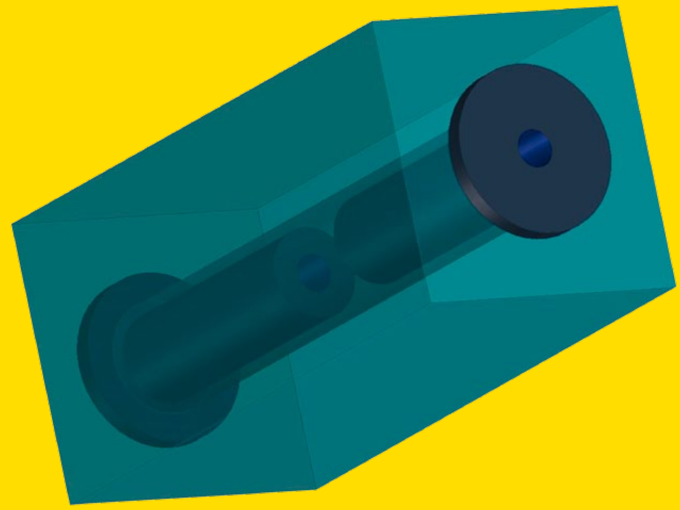
Connectors are currently still used for blade attachment (Fig. 1). The introduction of forces when conventional connectors are used has its disadvantages. These include stresses on hole walls and tensile fracture in the residual cross-section. Such disadvantages can be compensated by using extra materials, but this in turn makes this joining technique complex and expensive. Adhesively bonded metal inserts allow material savings to be realized (Fig. 2). Also, there is no local stress due to hole walls. There are threads in the adhesively bonded inserts for screwing the blade to the hub.

Before adhesively bonded inserts can actually be used, it must be ensured that the bonded joint meets the requirements in operation. Amongst other things, it is necessary to specify the fundamental design of the bonded joint and to select suitable substrate materials as well as the adhesive. Only then can a demonstration of the effectiveness of the bonded system be started.

The project, which was undertaken by the experts of the section Materials Science and Mechanical Engineering of Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, was split into three parts. The first part involved selecting suitable substrate materials and the adhesive. The data needed for the calculation was collected in the second part. The third part of the project estimated the service lives of simple test specimens and test components using a combination of experimental data and finite element simulation. The individual parts of the project are summarized below. Further details can be found in the project report.

Selection of the adhesive | Part 1

Four different cold-curing adhesive systems based on vinyl ester, polyurethane, and methacrylate were proposed for the test component. The adhesives were characterized, amongst other things, for their glass transition temperature, tendency to undergo creep, volume shrinkage, elongation at fracture, and adhesion properties under cyclic load. The adhesive based on vinyl ester and one of the polyurethane adhesives were not used due to their too low elongation at fracture. Another polyurethane adhesive had a glass transition temperature in the upper temperature region of the application. The methacrylate adhesive (MA) showed good adhesion in the non-aged state on primed steel and on GFRP under cyclic load and was hence used for further tests.



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Data collection | Part 2

For the project the material and joint properties were measured under three different sets of climatic conditions: –40 degrees Celsius, room temperature, and +40 degrees Celsius at 80 percent relative humidity. In order to estimate the service life, stress-number curves (S-N curves) were measured on adhesive specimens, on steel-steel lap shear specimens having an adhesive layer thickness of 2 millimeters, and on steel-GFRP lap shear specimens having an adhesive layer thickness of 3 millimeters.

For the component tests, the geometries of the insert, the adhesive layer, the pretensioning device, and the force introduction were estimated in accordance with the subsequent application. The test components for the laboratory tests were smaller in size.

The test components were tested under cyclic load up to six times the operating load. At higher loads the adhesively bonded joint could not be tested in one stage, otherwise the threaded rods of the pretensioning device failed after about 0.3 million load cycles.

Three of the seven test components failed in the tests. In these three cases the failure was clearly due to production effects. In correctly manufactured specimens the inserts were not pulled out in the fatigue tests.

The block load test was used to subject one test component to a representative load spectrum for rotor blade-hub connections in wind turbines under controlled climate conditions (+40 degrees Celsius; 80 percent relative humidity). The highest load corresponded to six times the operating load. The bonded insert-GFRP joint in the test component withstood 100 million load cycles (1000 blocks each with 100,000 load cycles) without damage. With a single operating load, 100 million load cycles would correspond to a service life of about two years. As the highest load amounted to six times the operating load, a higher service life was actually observed.

For the given load spectrum, about 5 percent of the load cycles cause 98 percent of the damage, respectively 95 percent of the load cycles cause only 2 percent of the damage. The load spectrum thus has many components that contribute very little to the damage.

If one neglects all the loads which contribute little to the damage and only test the loads which contribute a lot to the damage, then an operating year is tested with 95 percent fewer load cycles. The load on the component can be increased if the load level of the remaining 5 percent of the load cycles is in each case increased to the highest possible load (six times the operating load, one stage). This corresponds to an one stage test with six times the operating load.

A test component was tested under these conditions. The test was terminated after 75 million load cycles. The specimen showed no damage. For a single operating load, 75 million load cycles correspond to a service life of about 32 years. Therefore, the one stage test gave a service life of about 32 years with a safety factor of six. Wind turbines are designed to operate for 30 years.

1 *Elements for connecting the blade root to the blade flange.*
2 *GFRP test component with bonded inserts.*

Estimation of the service life | Part 3

The estimation of the service life is based on the calculation of the stresses in the adhesively bonded joint using finite element methods. The stress distribution is calculated using linear elastic models for the materials. From the stress distribution, a failure criterion is used to determine a value for an equivalent stress. This value is compared with the S-N curve for the adhesive specimens: The value corresponds to a stress amplitude (y-value in the S-N diagram) whose associated value, the number of load cycles (x-value in the S-N diagram), is determined with the help of the S-N curve respectively its parameters. The resulting number of load cycles is the estimated service life of the adhesively bonded joint for the load assumed in the calculation (Fig. 3).

The failure criterion was determined on steel-steel lap shear specimens in such a way that the service life up to failure of the specimens under cyclic load corresponds to the S-N experiments which were undertaken. The resulting failure criterion was then applied to steel-GFRP lap shear specimens having other geometries. The estimated service life for this specimen

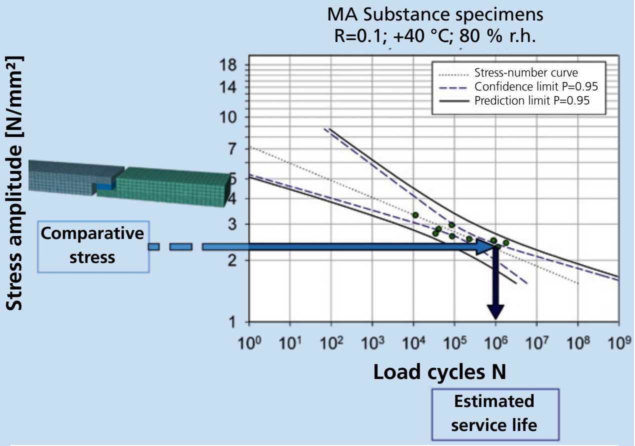

Fig. 3: Stress-number curve (S-N curve) for adhesive specimens at +40 degrees Celsius and 80 percent relative humidity (the service life is estimated from the equivalent stress).

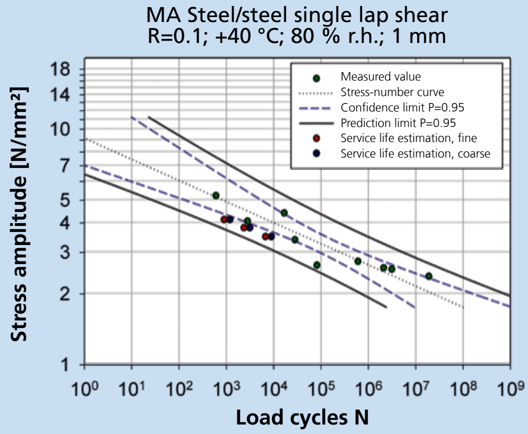

Fig. 4: S-N curve for steel-steel lap shear specimens at +40 degrees Celsius and 80 percent relative humidity (estimated service lives for fine and coarse mesh of the FE models).

type at room temperature was within the 95 percent prediction limit of the measurement. The criterion was also applied to steel-steel lap shear specimens at +40 degrees Celsius and 80 percent relative humidity. The estimated service life here was also within the 95 percent prediction limit of the corresponding measurement (Fig. 4). The defined failure criterion thus provides a good estimated service life for different test specimens and different climatic conditions.

The failure criterion was used to estimate the service life of test components under cyclic load at +40 degrees Celsius and 80 percent relative humidity. For a cyclic one stage load corresponding to the highest possible load, which corresponds to about six times the operating load (see part 2), the calculated service life is about 645 million load cycles. That corresponds to a service life of about 280 years, and that at a six times higher operating load. There would be no practical benefit of tests to validate the estimated service life of these test components which were designed for an operating life of 30 years.

Conclusions

A failure criterion was identified for estimating the service life via calculations. This failure criterion can be applied for cyclic load on different test specimens, and also under different climate conditions. The estimated service life in each case was within the 95 percent prediction limit. In the cyclic load test on the test component with six times higher operating load, a service life of about 32 years was determined without the specimen showing any damage. The tests show that bonded steel inserts are in principle suitable for connecting rotor blades to the hub.

Rust was identified below the adhesive layer on primed steel in the test specimens and test components that were manufactured using the methacrylate adhesive. This rusting even occurred during the project term. For durable systems, the steel surface must be subjected to a different pre-treatment.

Summary

In order to connect wind turbine rotor blades to hubs, it is planned to bond metal inserts into the glass fiber blades using cold-curing, two-component adhesive systems. The service life of bonded GFRP-metal joints under cyclic load was estimated based on the calculated local stress. The concept assumes there is cohesion failure within the adhesive film.
In order to estimate the service life, adhesive specimens and single lap shear specimens with different shape and different substrates were tested in fatigue tests at constant amplitude. The estimated service lives for the lap shear specimens agree well, within the bounds of scatter, with the experimentally determined services lives. A test component with bonded steel insert was tested with a six times higher operating load for up to 75 million load cycles without the specimen showing any damage. According to the load spectrum of a plant manufacturer, 75 million load cycles under an one staged operating load correspond to a service life of about 32 years.

Project funding
The IGF project "Design of structural bonded joints of fiber reinforced plastic with metal for wind turbines" 14.840 N/DVS number 08.040 of the "Forschungsvereinigung Schweißen und verwandte Verfahren des DVS ("DVS; Research Association for Welding and Related Processes"; Aachener Strasse 172, 40223 Düsseldorf, Germany) was funded via the AiF (German Federation of Industrial Research Associations) as part of the program for "Industrielle Gemeinschaftsforschung" (IGF; "Collaborative industrial research and development") of the Federal Ministry of Economics and Technology, following a decision by the German Parliament.

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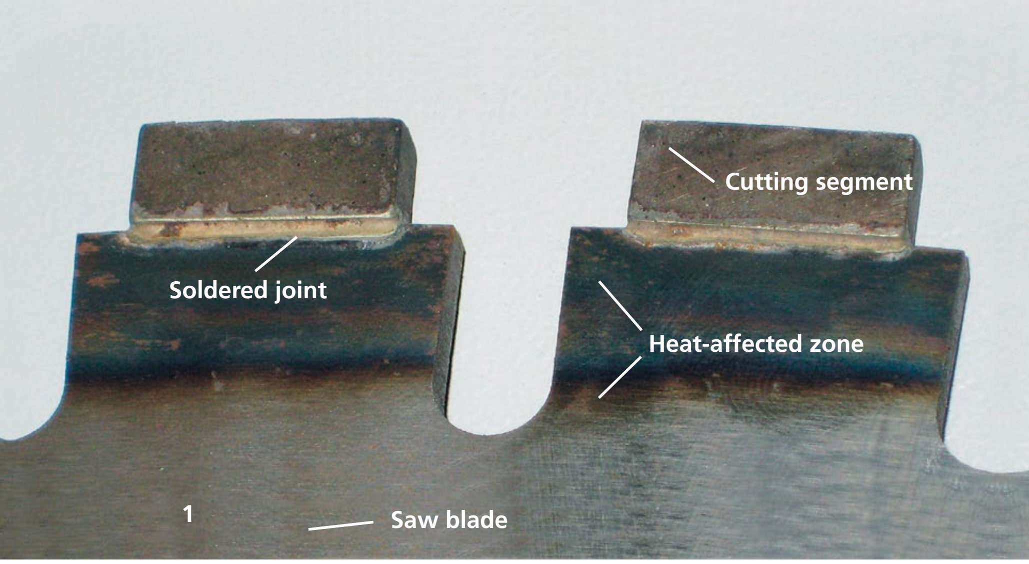


INSTEAD OF SOLDERING AND LASER WELDING: ADHESIVE BONDING OF CUTTING SEGMENTS IN SITU

The first step in producing natural stone slabs from blocks of granite or marble is a separation process, usually using disc-shaped tools. The individual diamond-studded cutting segments of the tools are currently attached to the saw blade, which is slotted at the edge, using thermal joining techniques like soldering and laser welding.

These conventional joining techniques adversely affect the properties of the saw blade and cutting segments in the joining zones due to the high heat input (Fig. 1): Amongst other things, there is distortion of the saw blade due to internal stresses, and this has to be remedied by time-consuming post-treatment processes such as grinding and straightening. The replacement of cutting segments after becoming worn also requires the blade to be removed from the saw each time for the straightening process.

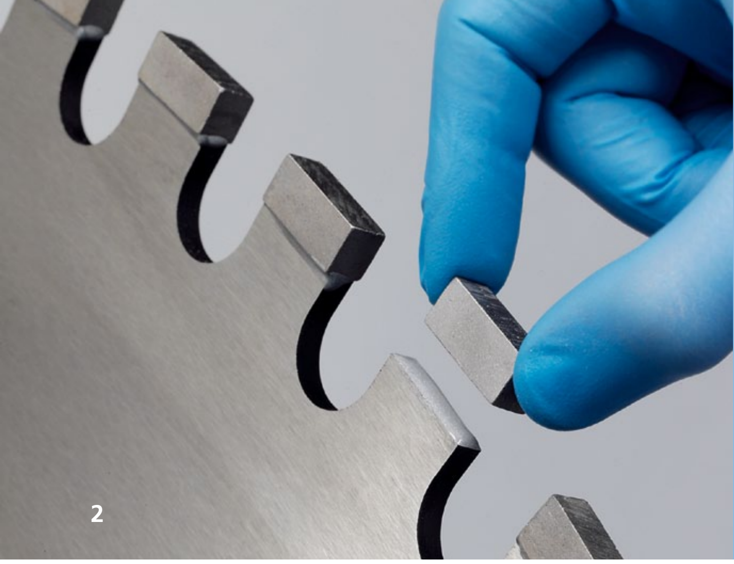
Adhesive bonding technology reduces post-treatment processes and saves time

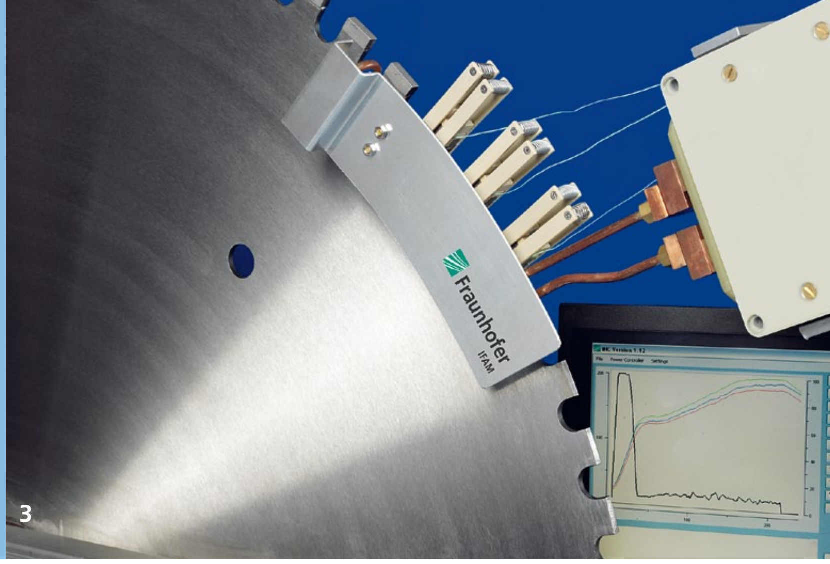
An innovative process developed at Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM is making these disadvantages a thing of the past – because the cutting segments are bonded to the saw blade at much lower temperatures (Fig. 2). Adhesive bonding at a temperature of maximum 200 degrees Celsius causes no change to the internal stress or to the strength of the surrounding material. Adhesive bonding technology thus brings considerable benefits: New saw blades only have to be pretensioned and straightened before first fitting them with the cutting segments. Thereafter the cutting segments can be quickly replaced in situ.

The new adhesive bonding production process

Adhesive selection

In a preceding project, three one-component epoxy resin adhesives made by different manufacturers were selected. They were then tested for their suitability on cutting discs having a diameter of 380 millimeters. The adhesive with the highest strength was selected for further optimization of the production process.





Production module for manufacturing adhesively bonded cutting discs

The adhesive bonding process was developed for saw blades having a diameter from 600 to 1500 millimeters. In principle, however, it can be used for attaching cutting segments to larger blades. The adhesive bonding process can be split into the following steps: preparation, adhesive application, joining, securing, and curing.

Prior to adhesive bonding it is necessary to grind the surfaces to be bonded and to clean those surfaces with solvent. The adhesive is then applied to one side of the cutting segment and this is then joined to the saw blade. Clamps made of heat-resistant plastic, which grab onto the saw blade, have recently been developed at Fraunhofer IFAM and have been proved to be the best way of centrically positioning the cutting segments (Fig. 3). The positioning in the axial direction has been shown to be accurate to circa ± 0.1 millimeter. This value is considerably below the allowable production variation of the cutting segment geometry. The usual processing step after soldering, namely the straightening of the segments in the axial direction, is redundant when this fixing unit is used, assuming the segments have been manufactured with satisfactory precision.

Inductive heating was selected for curing the steel substrates due to the high heating rates that can be achieved. Induction coils were developed in collaboration with a manufacturer. These allow parallel curing of three positioned cutting segments (Fig. 3). The temperature is controlled via thermocouples which record the temperatures of all three cutting segments. Using a control unit developed at Fraunhofer IFAM the power to the coil is controlled via the respective segment with the highest temperature. The induction method is designed so that it can easily be expanded until up to ten cutting segments heated in parallel.

When optimizing the curing time for the selected adhesive it was found that the joint strength significantly decreased when too high heating rates were used. Curing times of 3 minutes were attained. To demonstrate the practical viability of this process, a saw blade in a bridge saw was directly fitted with some new cutting segments under these conditions. This work took place at the project partner, the Institute of Production Engineering and Machine Tools (IFW) at Leibniz University in Hannover. Further potential for shortening the processing time has been demonstrated with a new adhesive developed at Fraunhofer IFAM. For this new development, specially customized hardener components have been used and optimized for rapid curing. This adhesive gives curing times of less than 10 seconds with full maintenance of the strength, which was measured here to be 43 megapascals (MPa = N/mm^2; tangential test direction).

It is hence clear that the newly developed adhesive bonding process holds much economical promise for directly fitting segments to saw blades or repairing saw blades in short processing times.

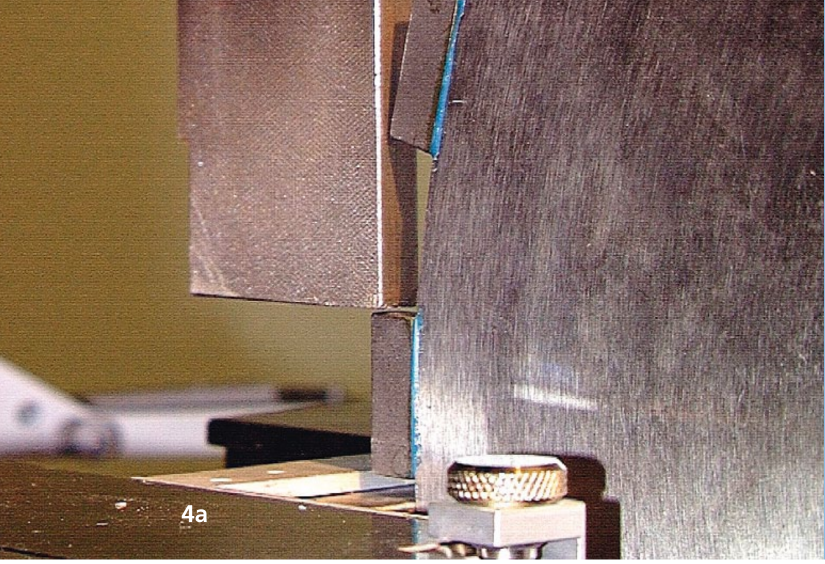
Bond strengths

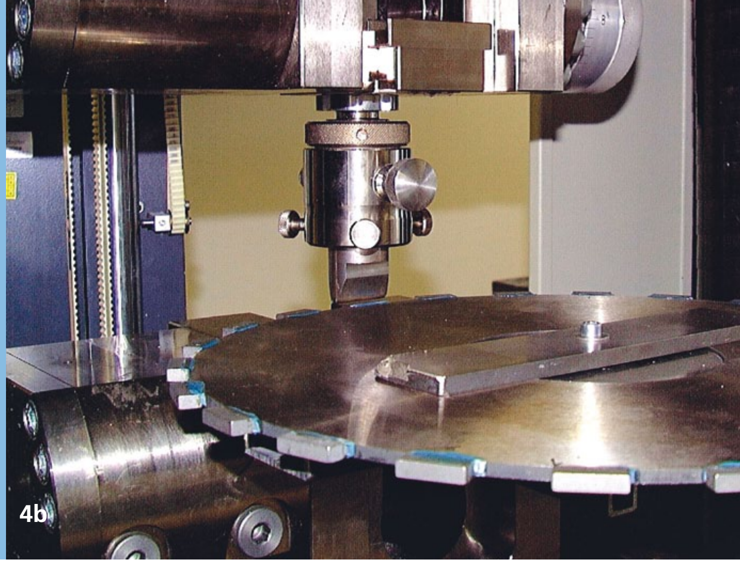
Quasistatic component tests were carried out on saw blades of 1000 millimeter diameter. The adhesively bonded cutting segments were sheared off in a tangential and axial direction in the static material testing machine (Fig. 4a + 4b).

1 *For cutting slabs of natural stone – a saw blade with soldered diamond cutting segments.*

2 *Saw suitable for cutting granite with adhesively bonded cutting segments.*

3 *Induction unit developed at Fraunhofer IFAM for parallel curing of three cutting segments positioned with adhesive bonding technology.*





The critical load case for the adhesively bonded joint is the axial load when storing the cutting disk leaned against a wall (Fig. 5). The shear forces measured in the axial test direction before and after use of the tool are shown in Figure 6. It can be seen that there was no strength loss, within the range of scatter of the measurements, after using the tool for cutting 3 square meters of granite and 0.5 square meters of sandstone.

For the critical load case, the "Principles for the type examination and certification of abrasive tools with diamond and boron nitride" (BGG 932 and 933, formerly ZH 675 and 676) prescribe a minimum axial bending stress (σ_{bB}) of 450 N/mm²:

$$\sigma_{bB} \text{ (target)} = \frac{M_{bmax}}{W} \geq 450 \text{ N/mm}^2$$

M_{bmax} = maximum torsional moment at fracture [Nm]
W = moment of resistance [mm³]

The bending strength determined in the laboratory test was:

$$\sigma_{bB} \text{ (adhesive)} = 541{,}6 \text{ N/mm}^2$$

The measured value lies above the prescribed value of 450 N/mm². Further significant strength increases are expected when applying geometries adapted to adhesive bonding demands.

Cutting tests

By using the new developed production module, cutting tests showed that the tool with the bonded cutting segments was equivalent to a soldered reference tool with regards to its usage and the quality of cut. Tests without water cooling showed that this tool can also be safety operated in extreme situations.

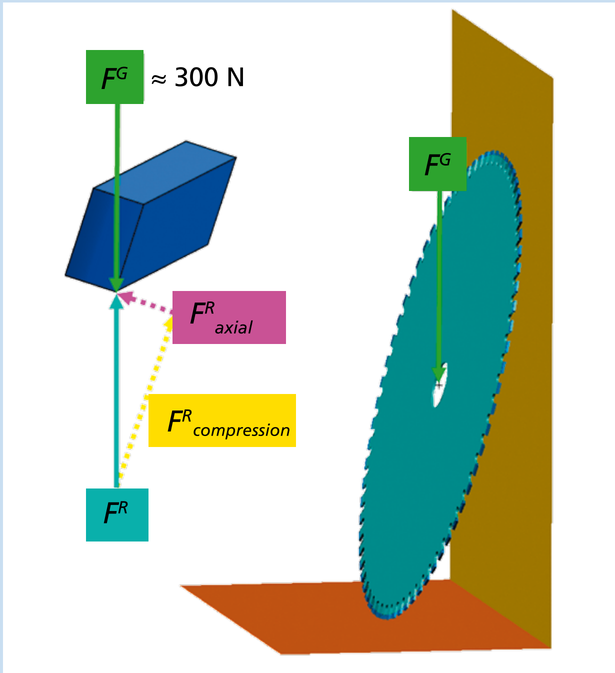


Fig. 5: Representation of the critical load case (F^G: Weight force, F^R: Reaction force, $F^R_{compression}$: Fraction of the reaction force which acts on the adhesively bonded joint as compression, F^R_{axial}: Axial fraction of the reaction force).

Adhesively bonded joint design

Optimization of the design of the contact zone between the saw blade and cutting segment allows stress peaks to be reduced. In an example optimization step, the geometry of saw blade and cutting segment was changed in such a way that the bond area becomes larger, so improving the possibility of force transfer (Fig. 7). By means of a rounded groove in the segments (Fig. 7, c) the maximum stress was roughly halved compared to radially modified variant without the groove (Fig. 8). The strength increases were demonstrated on test specimens of corresponding geometry in quasistatic tests.

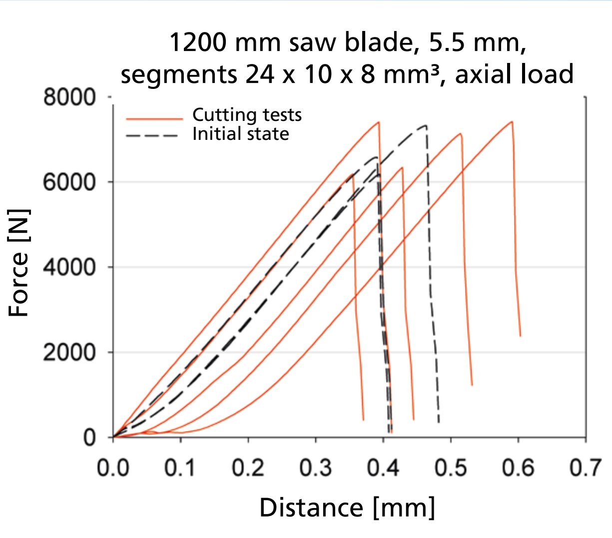


Fig. 6: Testing a 1200 millimeter saw blade; axial load before (black) and after the sawing process (red).

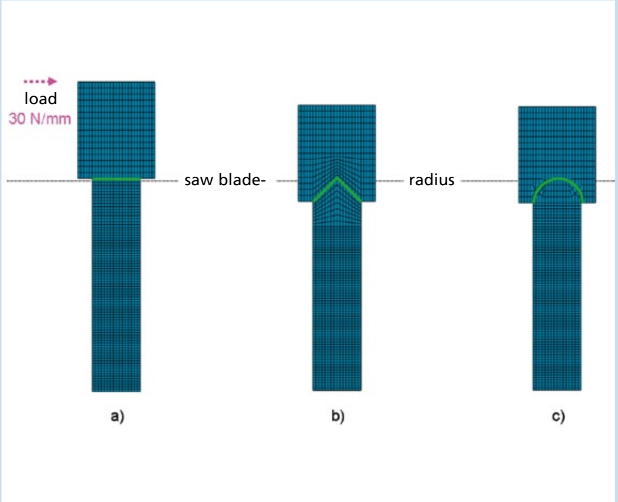


Fig. 7: Magnification of the geometry of the adhesively bonded joint (view in the tangential direction): a) current adhesive bond area, b) linear pointed, and c) rounded saw blade edge.

The new adhesive bonding process in practice – outlook

The new adhesive bonding process can compete with conventional joining methods such as soldering or laser welding and has key advantages for fitting saw blades with cutting segments. Practical tests cutting granite confirmed there was equivalent performance. The strength values in the axial direction determined in static tests were above the value specified in the "Principles for the type examination and certification of abrasive tools with diamond and boron nitride" (BGG 932 and 933, formerly ZH 675 and 676). There is considerable further potential for optimizing the geometry as well as for further shortening of the processing and curing times.

In general, adhesive bonding offers very promising development opportunities. This is particularly so because in some areas there is a trend towards the use of functional elements made of materials which cannot be soldered, for example ceramics. Practical uses for the new adhesive bonding technology hence go far beyond cutting stone and have promise, for example, for the machining of wood and metal.

4 *Shear tests under compressive loads: 4a tangential, 4b axial.*

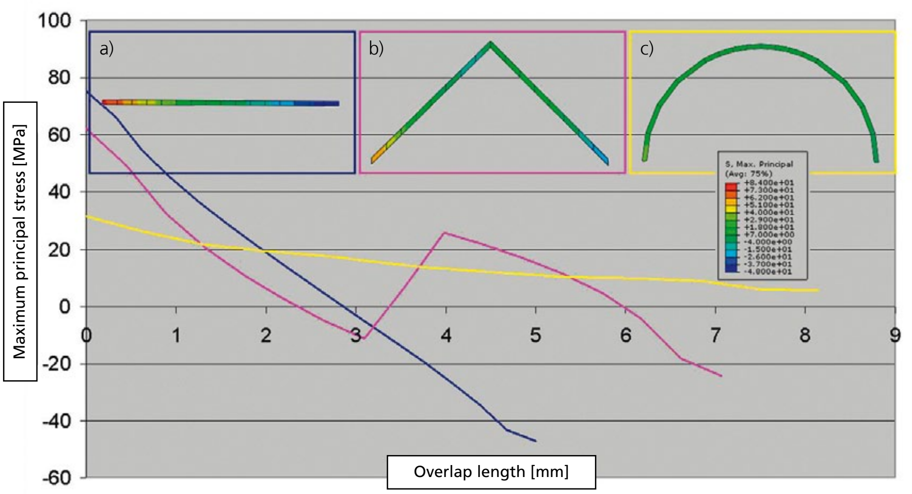


Fig. 8: Stress distribution in the axial direction for the geometries shown in figure 7.

Project funding

The research projects presented here, "Development of a favorable-cost and mobile production and service technology for fitting saw blades with cutting segments" (15028 N) and "Development of a low-heat joining technique for fitting saw blades with cutting segments" (12792 N), were funded by the Federal Ministry of Economics and Technology (BMWi) via the Association of Industrial Research Associations "Otto von Guericke" e. V. (AiF).

Project partners

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- Institute for Tool Research and Materials (IFW), Berghauser Strasse 62, 42859 Remscheid, Germany

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PEOPLE AND MOMENTS

1

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PREMIERE FOR FRAUNHOFER IFAM: JOSEPH VON FRAUNHOFER PRIZE 2010 AWARDED TO VOLKMAR STENZEL, YVONNE WILKE, AND MANFRED PESCHKA

"Research for practice solutions" – The Fraunhofer-Gesellschaft has since 1978 presented awards to its employees for outstanding scientific work that develops brilliant and practical solutions for application-oriented problems.

On May 19, 2010 Dr. Volkmar Stenzel, Yvonne Wilke, and Manfred Peschka of the Fraunhofer IFAM were awarded this prestigious prize at the annual meeting of the Fraunhofer-Gesellschaft in Leipzig. The award was for their development of the innovative "sharkskin" riblet coating system – a premiere in the history of the Bremer institute.

600 invited guests from politics, industry, and science congregated in the Central Theater in Leipzig to, amongst other things, acclaim the Joseph von Fraunhofer prizewinners. The prizewinning projects were presented in a fascinating show by the former ZDF presenter Steffen Seibert. The Minister for Education and Research, Prof. Dr. Annette Schavan, was a guest of honor. She explained the high-tech strategy of the federal government and spoke about activities relating to "the future of energy" year of science. During the award ceremony Prof. Dr. Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft, went on to say: "Those who want to shape the future must act in the present. Scientists and engineers occupy key positions and their work directly affects how we will live in the future."

The challenges not only of tomorrow but also of today include energy-saving, resource-saving, and environmental protection: The riblet coating system developed by Dr. Volkmar Stenzel, Yvonne Wilke, and Manfred Peschka, together with their teams in the Paint/Lacquer Technology and Adhesive Bonding Technology sections of Fraunhofer Institute of Manufacturing Technology and Advanced Materials IFAM, has the potential to lower fuel consumption and CO_2 emissions, and hence to sustainably lower costs in particular for the aviation and shipping industries (see pages 70 and 93).

CONTACT

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1 *The Joseph von Fraunhofer Prize 2010.*

2 *Prof. Dr. Annette Schavan, Federal Minister for Education and Research (middle), and Prof. Dr. Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft (right), together with prizewinners Manfred Peschka, Yvonne Wilke and Dr. Volkmar Stenzel (first row, from right to left next to Dr. Annette Schavan) at the annual meeting of the Fraunhofer-Gesellschaft in Leipzig.*

SKAUPY PRIZE 2010 FOR PROF. DR.-ING. BERND KIEBACK

Prof. Dr.-Ing. Bernd Kieback, director at the Dresden division of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, was awarded the 2010 Skaupy Prize during the 29th Hagen Symposium, which venued on November 25th and 26th, 2010. This prize is the most prestigious award in the field of powder metallurgy in German-speaking countries. The Skaupy Prize was first awarded in 1982 and is named after Prof. Dr. Franz Skaupy (1882–1969), member of the board at OSRAM GmbH and a pioneer of powder metallurgy in Germany. This is the greatest distinction awarded by the "Gemeinschaftsausschuss Pulvermetallurgie", the common board of the German powder metallurgy community, and recognizes special services and excellent technical-scientific work in powder metallurgy.

Prof. Kieback has been involved in a variety of powder metallurgy fields, starting with sintered steel, but mainly with hard metals, ever since his first years in research. He completed his studies under Prof. Geguzin in Charkow, then received his doctorate with Prof. Schatt and followed this up with research at ZFW. Following the reunification of Germany, he seized the opportunity and created the new Fraunhofer IFAM division in Dresden from his powder metallurgy group.

The Fraunhofer IFAM in Dresden has since become renowned in the sector of powder metallurgical special materials. Thanks to his leading positions in research and academia, Prof. Kieback represents an optimal symbiosis between powder metallurgical research and industry-oriented applications.

In addition, the 2010 Skaupy Prize winner participated in various powder metallurgical expert groups, significantly promoting collaborative research and the general perception of powder metallurgy on an international basis. He was, for example, a long-term chair of the Gemeinschaftsausschusses Pulvermetallurgie board, and thus head of the renowned Hagen Symposia for Powder Metallurgy.

Prof. Bernd Kieback regards the 2010 Skaupy Prize award not only as a recognition of his past services, but also as an incentive to continue advancing and furthering the field of powder metallurgy, both in applied research and in academia.

CONTACT

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3 *Prof. Dr.-Ing. Bernd Kieback during his lecture after receiving the 2010 Skaupy Prize (Source: Fachverband Pulvermetallurgie).*

1

HEAT STORAGE PROJECT RECEIVES E.ON RESEARCH AWARD 2010

On "Energy Day", September 25, 2010, the Fraunhofer Dresden division team headed by Dr. Lars Röntzsch together with their cooperation partner, the Fuel Cell Research Center (ZBT) GmbH in Duisburg, Germany, were bestowed with the E.ON Research Award, one of the most highly endowed awards in international energy research. The five laureates from Europe and the USA will receive a total of around five million euros for a project period of three years starting from January 2011.

The project partners were successful in their bid for the globally advertised E.ON Research Award in the field of "Heat Storage for Concentrating Solar Power (CSP)". Their use of novel storage materials means that solar thermal energy can be made available around the clock – even when the sun is not shining. The aim of the project "Metal Hydride Heat Storage System for Continuous Solar Power Generation", developed by Fraunhofer IFAM in Dresden and ZBT, is to use nanostructured hydride-carbon composites for heat storage. The addition of carbon to metal hydrides greatly accelerates a two-stage chemical process, with which thermal energy produced from solar radiation can be stored up during the day and then released for energy generation at night. This gives rise to an energy storage material that provides solar energy when the consumer actually needs it.

The project partners are testing these materials and processes at demonstration scale in order to develop the basis for future industrial applications. In addition to the storage of thermal energy gained from solar energy, these nanostructured hydride-carbon composites are also suitable as storage media for other types of renewable energy that can be converted to heat. They can also be combined with other heat sources, e.g. industrial plants outputting excess heat at high temperatures, to store this energy for subsequent utilization.

CONTACT

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1 *The prizewinners of the E.ON Research Award 2010 during the ceremony on 25.9.2010 in Berlin. The photo includes project partner Dr. Lars Röntzsch (Fraunhofer IFAM, left) and Dipl.-Ing. Bernd Oberschachtsiek (ZBT Duisburg, 2nd from left) © E.ON.*

VOLKMAR STENZEL REWARDED WITH COSI PRIZE 2010 FOR "SHARKSKIN" RIBLET COATINGS

In July 2010 Dr. Volkmar Stenzel was awarded the CoSi Prize 2010 by Prof. Dr. Gijsbertus de With at the 6th Coating Science International Conference in Noordwijk, the Netherlands, for his presentation entitled "Low-drag coatings for reducing the fuel consumption of aircraft and ships". 140 delegates from 27 countries, representing R&D and industry, attended the conference.

The presentation by Dr. Volkmar Stenzel on "sharkskin" riblet coating systems developed at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM was chosen from 160 contributions as the most interesting innovative development at the 6th Coating Science International Conference.

The riblet coating system of the Fraunhofer IFAM

The riblet coating system is based on the scales of fast-swimming sharks which have microscopic grooves, so-called riblets, in the longitudinal direction. It is an UV curing system containing nanoparticles, and is applied with a roller application unit which covers, structures, and cures the coating. This method can be readily used for 3-dimensional, curved surfaces.

With its microstructured surface, the riblet coating system is able to significantly reduce the drag of surfaces to air and water. This is of special interest for large structures such as aircraft and ships. The coating can withstand severe conditions such as extreme temperature fluctuations from –55 to +70 degrees Celsius, aggressive ultraviolet radiation, and very high speeds. If the system is used comprehensively, it is possible to reduce fuel consumption in aircraft and ship fleets by around two percent – a remarkable potential for sustainably reducing fuel consumption, Co_2 emissions and therefore costs – not to mention protecting resources and the environment (see pages 70 and 90).

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2 *Dr. Volkmar Stenzel, Head of the Paint/Lacquer Technology section at the Fraunhofer IFAM, receiving the CoSi Prize 2010 from Prof. Dr. Gijsbertus de With, professor at Technical University of Eindhoven, and co-organizer of the 6th Coating Science International Conference.*

1

2

ANJA ZOCKOLL AND ANDREAS BRINKMANN AWARDED FARBE UND LACK PRIZE 2010

At the 75th annual meeting of the German Chemical Society (Gesellschaft Deutscher Chemiker; GDCh), Paint/ Lacquer Chemistry section, on September 23, 2010 in Wernigerode, the society chairman Prof. Dr. Thomas Brock presented Anja Zockoll and Andreas Brinkmann with the FARBE UND LACK PRIZE 2010 in front of 135 participants from six countries. It was the first time in over 20 years that a panel of experts together with the readers of FARBE UND LACK had decided the prizewinners.

The two researchers were awarded the industry prize for their technical article entitled "Stabilization of corrosion protection pigments – protection of zinc and magnesium pigments in water-based systems", acknowledging also the interdisciplinary work at Fraunhofer IFAM. The article was the result of the collaboration between Anja Zockoll – Electrochemistry and Corrosion Protection – and Andreas Brinkmann – Paint/ Lacquer Technology – on the development of new corrosion protection systems.

Cathodically active metal pigments developed at Fraunhofer IFAM consisting of intermetallic magnesium-zinc phases provide, as proven, effective corrosion protection for steel and aluminum alloys. Unlike chromate-containing pigments these pigments represent no risk to health or the environment. Effective, easy-to-apply solvent-containing corrosion protection coatings were successfully developed with these pigments.

The article by Anja Zockoll and Andreas Brinkmann presents the results of a follow-up research work at Fraunhofer IFAM: The pigments are not only of use for solvent-based coatings but also have potential for water-based systems, so providing an even greater contribution to environmental protection. However, as the pigments are very reactive to water – as required for their mechanism of action – a special way of stabilizing them had to be found for water-based coatings: The stabilization system involves isolating the pigments in the liquid coating from the surrounding water. This then becomes ineffective as soon as the coating is present in the cured state. The first corrosion tests have shown that the water-based systems with stabilized pigments provide good protection against corrosion (see page 70).

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1 *The 2010 FARBE UND LACK Prize 2010.*

2 *Prizewinners Anja Zockoll and Andreas Brinkmann (Source: Vincentz Network).*

"ADHESIVE BONDING FOR LIGHT-WEIGHT STRUCTURES FOR MOVING MASSES" – KAI BRUNE RECEIVES FTK YOUNG SCIENTIST PRIZE 2010

At the "Adhesive Bonding Technology" (Fertigungstechnologie Kleben; FTK) seminar in Stuttgart on October 7, 2010, Kai Brune received an award in the 3rd Young Scientist Competition. His presentation "Monitoring surfaces when using adhesives to repair CFRP components" won over the audience who also acted as the competition jury.

Lightweight structures along with ever increasing requirements and new combinations of materials have resulted in adhesives becoming indispensible in industry. Carbon fiber reinforced plastics (CFRPs) are being increasingly used in industry, and in particular for aircraft manufacture, meaning there is a need for reliable repair procedures. In this regard, adhesive bonding has a number of key advantages over bolting: For example, the aerodynamic properties of a component are retained when adhesives are used and forces are distributed uniformly across the whole bonded joint. However, on aircraft there may be contaminants on the bonded joint area – e.g. hydraulic oil and de-icing fluid – and this can result in much diminished joint strength and can subsequently lead to damage.

Quality assurance of substrate surfaces

The physicist Kai Brune's specialized work at Fraunhofer IFAM involves the quality assurance of surfaces and in particular how surface contamination can affect adhesive bonding repairs. In order to guarantee effective bonded repairs, it is vital to measure contaminant levels on substrates and to monitor the results of pre-treatment procedures using suitable analytical methods. In addition, the effects of various contaminants on the properties of the resulting bonded joints need to be studied.

A variety of suitable repair methods were tested for their applicability for measuring contaminants on and in CFRP components. Everyday contaminants encountered in the aviation sector (hydraulic oil, de-icing fluids, etc.) and from repair processes (fingerprints, hand cream, etc.) were taken into account. X-ray fluorescence analysis was found to be a very effective method for measuring these contaminants.

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3 *Physicist Kai Brune receives the FTK Young Scientist Prize 2010 from Dr. Axel Weiß, BASF (from left to right; source: Redaktion adhäsion).*

GROUPS | ALLIANCES | ACADEMY

NETWORKED AT FRAUNHOFER

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FRAUNHOFER GROUPS

Institutes working in related subject areas cooperate in Fraunhofer Groups and foster a joint presence on the R&D market. They help to define the Fraunhofer-Gesellschaft's business policy and act to implement the organizational and funding principles of the Fraunhofer model.

Fraunhofer Group for Materials and Components – MATERIALS

The Fraunhofer Group for Materials and Components – MATERIALS pools the competencies of the Fraunhofer-Gesellschaft institutes working in the field of materials science.

Materials science and material engineering cover the entire value chain from innovative material advancement and the improvement of existing materials to production technology at industry-level scales. In addition, they encompass the characterization of properties to the evaluation of application behavior. The same applies to the components made from these materials and their behavior in systems. In addition to experimental studies in laboratories and technical centers, numerical simulation and modeling processes are equally implemented in all fields. The Fraunhofer Group for Materials and Components – MATERIALS is responsible for the entire sector of semi-conductor materials and all materials produced using metallic, inorganic-non-metallic, polymeric and renewable raw materials.

The Group focus is on applying their expertise within the business areas of energy and environment, mobility, health, machine and plant engineering, construction and housing, microsystem technology as well as safety. The Group achieves system advances using customized material and component development, in consideration of the evaluation of customer-specific application performance.

Primary topics in the Group include:

- Improving safety and comfort, and reducing resource consumption in the sectors of traffic engineering, machine and plant engineering
- Increasing system efficiency for energy generation, energy conversion and energy storage; improving biocompatibility and the function of materials used in medicine or biotechnology
- Raising integration density and refining usage properties of components in microelectronics and microsystem technology
- Enhancing the use of raw materials and bettering the quality of the products made from these materials

The Group includes the following Fraunhofer institutes:

- Applied Polymer Research IAP
- Building Physics IBP
- Structural Durability and System Reliability LBF
- Chemical Technology ICT
- Manufacturing Technology and Advanced Materials IFAM
- Wood Research, Wilhelm-Klauditz-Institut, WKI
- Ceramic Technologies and Systems IKTS
- High-Speed Dynamics, Ernst-Mach-Institut, EMI
- Silicate Research ISC
- Solar Energy Systems ISE
- Systems and Innovation Research ISI

1 *Networked.*

- Mechanics of Materials IWM
- Non-Destructive Testing IZFP

Actively participating permanent guest member institutes:
- Interfacial Engineering and Biotechnology IGB
- Industrial Mathematics ITWM

www.materials.fraunhofer.de

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FRAUNHOFER ALLIANCES

The Fraunhofer Alliances facilitate customer access to the services and research results of the Fraunhofer-Gesellschaft. Common points of contact for groups of institutes active in related fields provide expert advice on complex issues and coordinate the development of appropriate solutions.

Fraunhofer Adaptronics Alliance

The adaptive structure technology, in short Adaptronics, integrates actuator and sensor functions into structures and links these functions through (often adaptive) control 'intelligence'. This allows structures to recognize their own condition and actively react to it, leading to the realization of adaptive structure systems. With this background, light and compact as well as vibration-free and dimensionally stable modern structures can be designed that optimally adapt to their changing operating environment.

This leads to the conservation of raw materials, reduced environmental pollution such as noise and emissions, reduced system and operating costs, and increased functionality and performance of systems. Adaptronics has a particular application potential in the fields of automotive engineering, machine tool manufacture and plant construction, medicine and space technology, optics, and defense technology.

The mechanical properties, efficiency and performance capability of systems can be improved. These include economic material utilization, function enhancement, increased comfort and safety aspects such as optimization of vehicle crash characteristics or damage monitoring.

www.adaptronik.fraunhofer.de

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Fraunhofer Automobile Production Alliance

Carmakers, their suppliers, and those equipping the automotive industry, represent a decisive economic factor in Germany. Significant changes to the entire concept of mobility are ultimately being driven by global trends, such as dwindling natural resources, an increasing need for mobility, urbanization and megacities. In addition, German carmakers and their suppliers are facing increasingly tough competition as the trend towards low-cost vehicles takes hold.

The Fraunhofer Alliance pools the expertise of 17 institutes, who collectively provide the German automotive industry with a competent single-source partner for its research and development needs. The complementary effect, achieved by combining the individual institutes' key areas of research, makes it possible to generate rapid, integrated and sustainable innovations along the entire process chain of vehicle manufacturing – from the planning stage right through to the finished vehicle.

The Alliance tackles the challenges posed by environmental policies (reducing fuel consumption and CO_2; electromobility; cutting material consumption) while taking full account of commercial imperatives (ongoing pressure to cut costs).

Key tasks performed by the Alliance:
- Consistent use of virtualization, and simulation of the entire process chain
- Reduction in the amount of required materials (use of recyclable materials with long-term availability)
- Use of innovative technologies that save resources
- Low-energy plant technologies

www.automobil.fraunhofer.de

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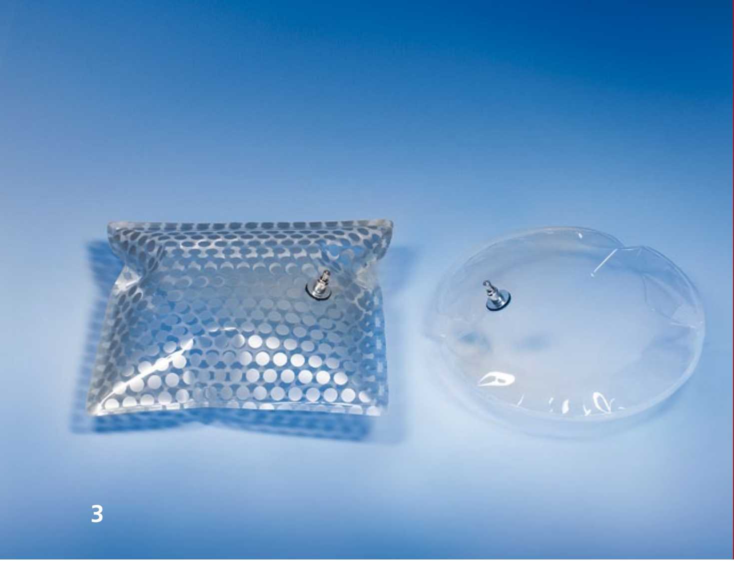
2 *Production and assembly processes.*

3 *Adhesively bonded membrane cushions made of ethylene-tetrafluoro-ethylene film (ETFE film) for use in facade design.*

4 *Replica of a human jaw bone (study for a medical implant, laser-sintered Ti6Al4V).*



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Fraunhofer Building Innovation Alliance

The construction industry has high potential for innovation, and it is with a view to tapping this potential that several Institutes have pooled their resources in the Fraunhofer Building Innovation Alliance. The Alliance offers single-source construction expertise by means of integrated systems solutions. Its portfolio encompasses not only the systematic consideration of buildings, from materials and components to rooms, buildings and entire housing estates, but also the chronological consideration of buildings – that is, their entire life cycle from the initial idea through to final recycling.

Opportunities for rationalization and potential for optimization can be found throughout the construction process chain, starting with the original construction, including building materials and systems, and extending through to the conversion and dismantling of a building. In this era of exploding energy prices, the energy efficiency of buildings is a key issue for both residential and industrial buildings. However, the focus of the alliance goes a great deal deeper than this. It aims to assure sustainability, careful use of resources, and healthy construction methods in building and living, and to address issues such as product, system and process optimization. Construction research shares common ground with Fraunhofer expertise in the areas of energy, information and communication technology, materials and components, life sciences, production, microelectronics, and defense or security research.

www.bau.fraunhofer.de

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Fraunhofer Additive Manufacturing Alliance

The generic term "Additive Manufacturing" describes processes for the manufacturing of models, shapes, tools and functional components. Additive manufacturing offers a high success potential for the rapid and efficient conversion of product innovations for prototypes and small production series.

The Fraunhofer Additive Manufacturing Alliance pools the competencies of nine Fraunhofer institutes, developing innovative concepts for the application of additive production technologies. This Alliance puts the Fraunhofer-Gesellschaft in a position to offer complete solutions in product development through the depiction of the entire process chain. In addition to the additive core processes, it encompasses both up and downstream processes: From process preparation, including the acquisition and preparation of data, to the final development of properties for products ready for use.

Together with national and international partners, the Alliance develops individual concepts, technologies and processes for improving the performance and competitive ability of small and medium-sized businesses. The Fraunhofer Additive Manufacturing Alliance is a member of the management in the EU Rapid Manufacturing platform in Brussels and is responsible for the organization of the "German" working group within this EU platform.

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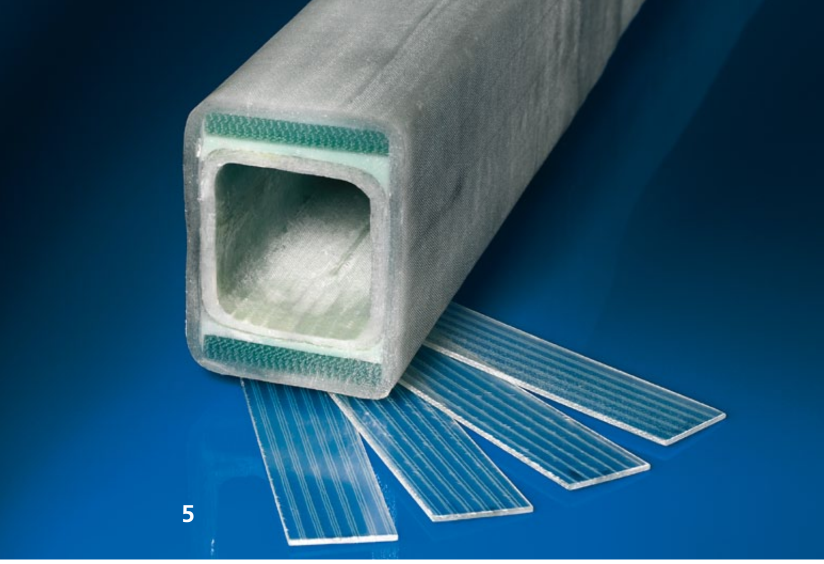

Fraunhofer Lightweight Construction Alliance

Creating lightweight structures means reducing weight whilst retaining sufficient rigidity, dynamic stability and strength. It must be ensured that the components and structures developed here fulfill their objective safely over the period of application.

Lightweight structure quality is primarily dependent on the material properties, the constructive shaping process, the design and production process. It is therefore necessary to examine the entire development chain, from material and product development to approval, mass production and product application.

The institutes collaborating in the Fraunhofer Lightweight Construction Alliance have the necessary expertise in the following areas:

- Materials and material composites for lightweight construction
- Joining and production processes in lightweight construction
- Numerical and experimental simulation in lightweight construction
- Evaluation of components and systems

Main research areas

- New materials and material composites
- Production and joining technologies from a lightweight construction aspect
- Functional integration
- Construction and design
- Non-destructive and destructive test methods

Speaker of the Alliance

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Fraunhofer Nanotechnology Alliance

Nanotechnology, a bundle of crosscutting new technologies for the next years to come, deals with materials, systems and devices where something very small (below 100 nm) determines functions and applications.

Nanotechnology is an integral part of our everyday life: As an example, nanoparticles in suntan lotions protect the skin against UV radiation, nanoparticles are used to reinforce car tires; nanotechnology can help to produce easy-care scratch-resistant surfaces, and ultra-thin coatings are an important element in data storage media. The technology is already in use for a wide variety of applications across all sectors of industry, generating a worldwide sales volume of 80 to 100 billion euros.

Nearly a third of all Fraunhofer Institutes are active in this field. The activities of the Alliance focus on multifunctional coatings for use in such areas as the optical industries, the design of special nanoparticles for use as fillers and functional materials in biomedical applications, and a novel type of actuators based on carbon nanotubes. In national and European research projects the alliance also treats questions regarding toxicology and operational safety while dealing with nanoparticles.

www.nano.fraunhofer.de

Speaker of the Alliance

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Fraunhofer Photocatalysis Alliance

Photocatalytic active coating systems with self-cleaning, antibacterial, foul-resistant or fog-reducing characteristics are the central focus of the R&D work carried out by the Fraunhofer Photocatalysis Alliance.

The aim of the Alliance is the development of new material and coating concepts for higher-performance photocatalysts and their application on various surfaces such as glass, plastics and metals.

The eight participating institutes bring a comprehensive, diverse set of competencies to the Alliance: material, coating and process development, analysis techniques as well as test and measurement systems for assessing biological activity and also ecotoxicological environmental impact.

www.photokatalyse.fraunhofer.de

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Fraunhofer Polymer Surfaces Alliance (POLO)

The Polymeric Surfaces Alliance (POLO) pools the core competences of seven Fraunhofer Institutes in the development of polymer products with functional surfaces, barrier layers or thin films. This strategic and operative collaboration is supported by a joint marketing approach. The Alliance thus broadens significantly the range of activities that can be offered by each individual institute.

The Alliance works to achieve concrete results in preliminary development and secures the relevant industrial property rights for polymer products that have new or significantly enhanced properties. Products already developed in the areas of "flexible ultra-barriers" and "anti-microbial polymer surfaces" are targeted at the optical and optoelectronic industry, the building and construction industry, and the packaging, textile, medical and automobile industry.

www.polo.fraunhofer.de

Speaker of the Alliance
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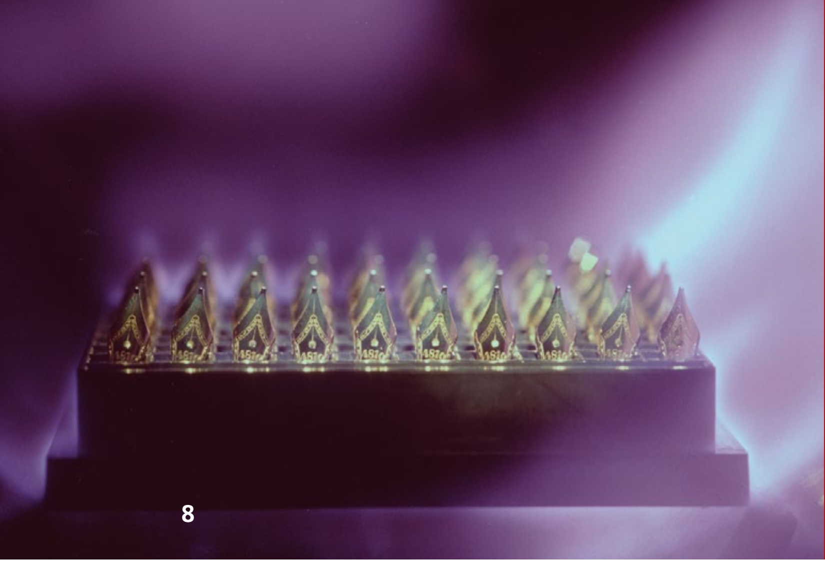
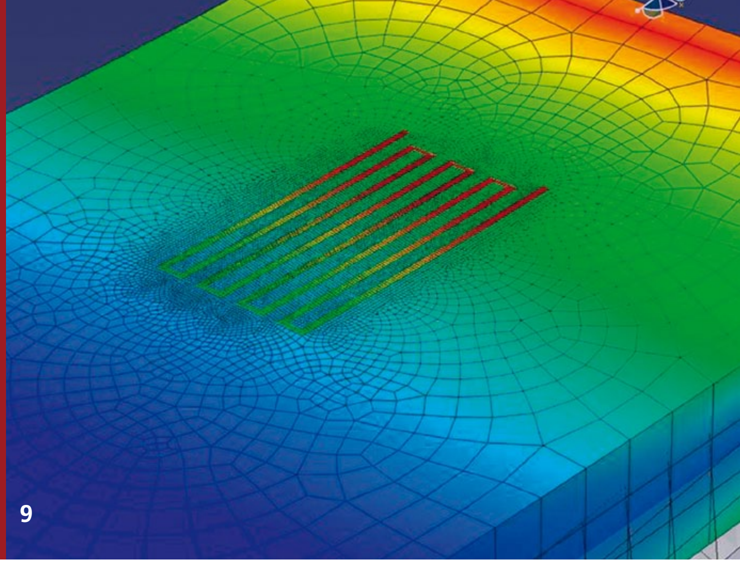
5 *Bonded beam made of glass fiber reinforced plastic (GFRP) for determining the fatigue strength of rotor blade materials.*
6 *Enhanced dispersibility of nanoparticles (color particles) by plasma treatment at atmospheric pressure (plasma-treated right).*
7 *Filter material with improved chemical resistance and increased service life due to an ultra-thin plasma-polymer coating.*





Fraunhofer Cleaning Technology Alliance

The cleaning of surfaces is the subject of research at a number of Fraunhofer Institutes engaged in different spheres of activity. No single institute focuses exclusively on cleaning technology. The capabilities of the individual institutes are pooled in the Alliance, so that the entire process chain relating to cleaning can be addressed. In addition to different cleaning techniques, the chain of activity involved in cleaning technology also encompasses the upstream and downstream processes.

Upstream processes deal with process analysis, where the emphasis lies on preventive measures to avoid contamination and reduce the necessity and cost of cleaning. Downstream processes include quality assurance of the cleaning work, drying technology for wet-chemical cleaning processes, and the environmentally compatible disposal of waste products and used solvents. To cover the entire range of cleaning technologies used in different sectors of industry, the Alliance has defined separate areas of business focusing on the cleaning of buildings and structures, sanitation and hygiene, cleaning in microsystems engineering, surface cleaning prior to coating, and cleaning of electronic components.

www.allianz-reinigungstechnik.de

Speaker of the Alliance
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Fraunhofer Numerical Simulation of Products, Processes Alliance

In the Fraunhofer Alliance for Numerical Simulation of Products and Processes, twenty institutes pool their expertise in the development and improvement of simulation techniques.

The simulation of products and processes today plays a decisive role in all phases of the product life cycle, from model-based materials development and simulation of manufacturing processes to operating characteristics and product placement on the market.

The object of the Alliance is to address institute-overarching issues and to represent the interests of the member institutes as a central point of contact for public sector and industrial customers. In particular, the pooling of expertise from the I&C sector with materials and components know-how as well as with surface technology, production and microelectronic engineering promises to yield innovative results.

www.simulation.fraunhofer.de

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8 *Fine cleaning of nibs.*
9 *Numerical stress simulation of a strain gauge.*

Fraunhofer Traffic and Transportation Alliance

The Fraunhofer Traffic and Transportation Alliance develops technical and conceptual solutions for public sector and industrial customers and translates them into practical applications. It does this by identifying future developments and guiding the focus of sponsored research programs.

The Alliance analyzes market requirements and develops system solutions in multi-institute collaborative projects. It also draws together and markets the expertise of its members in the field of traffic and transportation. Work groups such as FVV-Automotive, FVV-Rail, FVV-Aviation and FVV-Waterborne help to assure a close relationship with the sector. International research programs and contracts from around the world ensure that the member institutes maintain links to companies and research organizations involved in traffic and transportation worldwide. The Alliance's central office brings together suitable partners.

www.verkehr.fraunhofer.de

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Fraunhofer Academy – research know-how for your success

The Fraunhofer Academy consolidates all advanced training courses offered by the Fraunhofer-Gesellschaft under one roof, offering excellent further education options for technical and business staff. Cutting-edge science and research results are integrated immediately in course teaching materials – a genuine pact for research and innovation.

First-class training is a foundation for future careers – continuous advanced training is an absolute necessity for staying on top.

Industrial adhesive bonding technology – Workforce qualification at the Center for Adhesive Bonding Technology, Bremen

Adhesive bonding has become the main bonding technology of the 21st century. The transfer of the entire potential inherent in adhesive bonding technology into commercial applications is ensured through specific, customized advanced training courses in the Center for Adhesive Bonding Technology, Bremen. The "Fiber-Reinforced Plastic Technician" training course, which has been awarded the Training Course Innovation Prize 2009, is highly relevant for future multi-functional products and lightweight constructions, particularly for the transportation sector and manufactures of wind turbines.

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NAMES | DATES | EVENTS

1

CONTENTS

CONFERENCES | CONGRESSES | WORKSHOPS

Conferences, congresses and workshops 108

SCIENTIFIC PUBLICATIONS

PhD theses 109
Lectures 109
Publications 111
Presentations and posters 119

PATENTS

Applications 131

HONORS AND AWARDS

Honors and awards 132

1 *Fraunhofer IFAM, Bremen.*

Conferences | congresses | workshops

Workshop
2. Workshop Oberflächen und Grenzflächen
Fraunhofer IFAM, Bremen
12.2.2010

Workshop
Nano Materials: Perspectives and Risks
Hanse-Wissenschaftskolleg, Delmenhorst
18./19.2.2010

Congress
4. FIMRO Symposium "Druckguss 2010"
Fraunhofer IFAM, Bremen
17./18.3.2010

Official event
Besuch des Bundesverkehrsministers Dr. Peter Ramsauer
Fraunhofer IFAM, Bremen
14.4.2010

Cooperation forum
Kleben im Automobilbau
Nuremberg
14.4.2010

Workshop
Anwendung des Spark-Plasma-Sinterverfahrens
Dresden
15.4.2010

Congress
Rapid-Prototyping-Fachtag für Unternehmen
BBZ "Dr. Jürgen Ulderup"
Diepholz
15.4.2010

Workshop
Möglichkeiten der Pulvermetallurgie zur Herstellung von Aluminiumbauteilen
Dresden
6.5.2010

Industry symposium
Biomaterialien 2010
Fraunhofer IFAM, Bremen
20.5.2010

Symposium
Next Generation Battery Materials
Hanse-Wissenschaftskolleg, Delmenhorst
17.–19.6.2010

Official event
Eine Region wird (elektro-) mobil
World Trade Center, Bremen
21.6.2010

Workshop
9. Bremer Klebtage Klebtechnische Fortbildung im Rahmen der DVS®/EWF-Personalqualifizierung
Fraunhofer IFAM, Bremen
22./23.6.2010

Workshop
12. FTK-Fachtagung Fertigungstechnologie Kleben
Stuttgart
7./8.10.2010

Talent School Bremen
Bremen
11.–13.10.2010

Conference
CELLMAT 2010
Dresden
27.–29.10.2010

Workshop
Functional Printing – Impulse für die gedruckte Sensorik
Fraunhofer IFAM, Bremen
2./3.11.2010

Workshop
3. Workshop Innovationscluster "MultiMaT"
Fraunhofer IFAM, Bremen
7.12.2010

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PhD theses

M. Burchardt
Fabrication and Characterisation of Micropatterned Functional Surfaces (Herstellung und Charakterisierung mikrostrukturierter funktionaler Oberflächen)
Carl von Ossietzky Universität Oldenburg

Experts:
Prof. Dr. Katharina Al-Shamery
Prof. Dr. Lorenz Walder
Date of exam: 11.5.2010

S. H. Marzi
Ein ratenabhängiges, elastoplastisches Kohäsivzonenmodell zur Berechnung struktureller Klebverbindungen unter Crashbeanspruchung
RWTH Aachen

Experts:
Univ.-Prof. Dr.-Ing. Jürgen Güldenpfennig
Univ.-Prof. Dr.-Ing. Markus Feldmann
Prof. Dr.-Ing. Horst-Erich Rikeit
Prof. Dr.-Ing. Rüdiger Schmidt
Date of exam: 9.6.2010

C. Merten
Untersuchung der molekularen Konformation und der intermolekularen Wechselwirkung chiraler Verbindungen mittels VCD-Spektroskopie
Universität Bremen

Experts:
Priv.-Doz. Dr. Andreas Hartwig
Prof. Dr. Marcus Bäumer
Prof. Dr. Wulff Possart
Date of exam: 27.8.2010

M. Maiwald
Untersuchungen zum Einfluss der Mikrostruktur auf die Eigenschaften aerosolgedruckter Sensorstrukturen
Universität Bremen

Experts:
Prof. Dr.-Ing. Matthias Busse
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Date of exam: 11.11.2010

M. Necke
Zersetzungsverhalten neuartiger, kohlenstofffreier Gold-Precursoren für den Einsatz in elektronenstrahlgestützten additiven Strukturierungsverfahren zur direkten Abscheidung von Metallen
Carl von Ossietzky Universität Oldenburg

Experts:
Prof. Dr. Katharina Al-Shamery
Prof. Dr. Mathias Wickleder
Prof. Dr. Thorsten Klüner
Date of exam: 10.12.2010

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Biologie/Chemie und Fachbereich Geowissenschaften
Universität Bremen
WS 2010/2011

A. Burblies
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Hochschule Bremerhaven
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Hochschule Bremerhaven
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S. Dieckhoff
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H. Fricke
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Einführung in die Chromatographie
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B. H. Günther, M. Busse
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Universität Bremen
Fachbereich Produktionstechnik
SS 2010

B. Kieback
Pulvermetallurgie und Sinterwerkstoffe II
Technische Universität Dresden, Institut für Werkstoffwissenschaft
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U. Meyer
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F. Petzoldt
Produktorientierte medizinische Prozessketten
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B. Kieback
Skaupy-Preis 2010
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