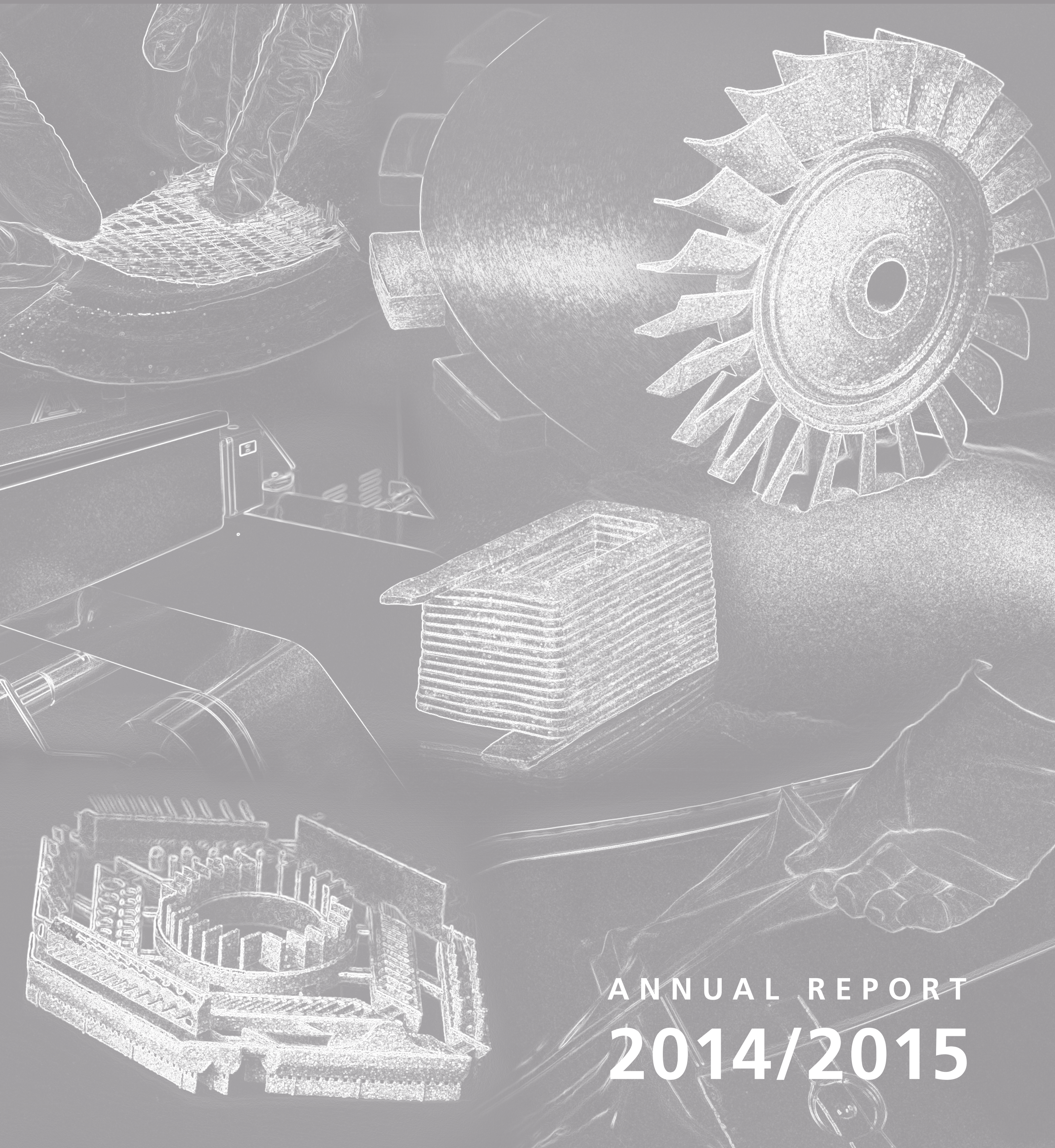
Fraunhofer
IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM



ANNUAL REPORT
2014/2015

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FOREWORD

Dear Reader,

Fraunhofer IFAM once again had a very active and successful year in 2014. The strengthening of our technological and scientific expertise in our seven core competencies enabled us to maintain the high income of previous years and to further enhance the institute's position in the R&D marketplace. Highlights of the year were major awards, many new and promising research results, and the start of several interesting projects. Special thanks go to all those who have played a part in this success: To our customers in the private and public sectors, to our R&D partners, and in particular to all the employees of Fraunhofer IFAM.

The focus of all the R&D activities in 2014 was as ever to provide customers with effective, application-oriented solutions. Most of the products, processes, and technologies we develop are for sectors where sustainability is particularly important, namely energy and the environment, the automotive sector, the aviation industry, medical technology, and the life sciences. Fraunhofer IFAM has a highly qualified workforce of 589 people, organized into project teams and business segments covering specific topics.

A key factor for the success of the institute is investing for the future. In order to carry out anti-icing tests for our customers under near-real icing conditions, a 90 cubic meter icing laboratory with wind tunnel has been constructed at Fraunhofer IFAM. The institute thus reached a further milestone for testing anti-icing coatings and novel de-icing technologies. The Materials and Mechanical Engineering department also expanded their facilities: The new servo-hydraulic rapid tensile testing machine is suitable for testing bonded joints, materials, and structural elements at high rates of loading and is of interest for the car and aircraft manufacturing industries. The installation of an advanced 3D screen printing plant and a versatile production line for functional printing extends the facilities for additive manufacturing. The plants are designed for the rapid production of complex and functionalized components for a wide range of industrial uses.

There were further strategically important developments in our main business segments. The Electric Energy Storage project group in Oldenburg now forms part of the Energy and Environment business segment. After a pilot phase lasting five years it now has recognition for its excellent work. Distinguished experts evaluated the work of the project group praising the approaches adopted for the development of novel batteries. The project group has accordingly become a permanent part of Fraunhofer IFAM.

This research area is supported by a junior group, established in 2014 under the Excellence Initiative, involving the University of Bremen and Fraunhofer IFAM. The research team aims to develop new functional materials for solid state batteries. The results of this fundamental scientific research can thus be directly implemented in practice.

The newly formed Electrical Drive Systems department will form an interface to the Automotive business segment. The team is involved with the whole development chain for prototype drives – from the conception through to the manufacture and testing. Its work complements the work on electromobility at the institute. The research activities in the Fraunhofer flagship project "Criticality of rare earths" also involve electric motors. The aim is to reduce the use of dysprosium in magnetic materials by 50 percent with maintenance of motor performance. Fraunhofer IFAM is working here on topics such as net-shape production of anisotropic high-remanence NdFeB magnets and magnetic simulation of different motor concepts.

The newly established Fraunhofer Project Center in Wolfsburg sees three Fraunhofer institutes, under the leadership of Fraunhofer IFAM, working closely with R&D organizations and

1 *Prof. Dr.-Ing. habil. Matthias Busse (left) and Prof. Dr. Bernd Mayer (right).*

companies in the region. The objective is to develop sustainable material and drive concepts for future road vehicles. The partners are pooling their expertise here to enable rapid transfer of sustainable, favorable-cost lightweight components to industrial production. The research results will also be able to be utilized for wind turbines, aircraft, and other means of transport.

The Aviation business segment received excellent news in 2014: Within the framework of the "CleanSky" project of the European aviation industry, Fraunhofer IFAM has carried out successful development work in recent years on topics such as the repair of CFRP components and special coatings for reducing aerodynamic drag. In 2014, the European Commission decided to continue this major project. "CleanSky II" will see us working with the aircraft manufacturing industry and their suppliers on new challenges for future aircraft. Building on existing work, surface technologies will be further developed to commercial readiness. Our expertise in automated joining will enable us to make an important contribution to future aircraft assembly processes.

A real breakthrough has been made by the Medical Technology and Life Sciences business segment. Within the "mediNiK" project a biocompatible medical adhesive for removing kidney stone residues was developed for endoscopy treatments. The advantage of the "mediNiK" technology: The adhesive application can be integrated into existing endoscope procedures without new instruments or additional procedural steps. The selective adhesion of the adhesive bonds stone fragments which would otherwise remain in the kidneys, without adhering to the kidney tissue or endoscope. For the first time this allows all stone fragments to be safely removed. The project work involved close collaboration with the Urology Clinic of the University Medical Center Freiburg. The new product will be ready for market introduction within four to five years. The project is being funded by the Federal Ministry of Education and Research (BMBF) under the Biotechnology GO-Bio program.

Besides the emphasis on practical applications, with much of the work involving collaborative projects with partners from a wide range of industries, scientific excellence in our core competencies is also vital for the institute. The R&D results and the dedication of our workforce are reflected in the large number of publications and best paper and poster awards. It pleases us enormously that their efforts and ideas are rewarded each year by prestigious national and international prizes. We mention here the recently received Joseph von Fraunhofer Prize for pre-applicable adhesives and the "Academic R&D Award" for printed thermogenerators.

This annual report gives you an overview of selected R&D activities at Fraunhofer IFAM. We very much hope you enjoy reading about our work and we are looking forward to a suspenseful exchange as well as a continuing successful cooperation.

Matthias Busse

Bernd Mayer

CONTENTS

1 *Fraunhofer IFAM, Dresden.*

BRIEF PORTRAIT AND ORGANIGRAM

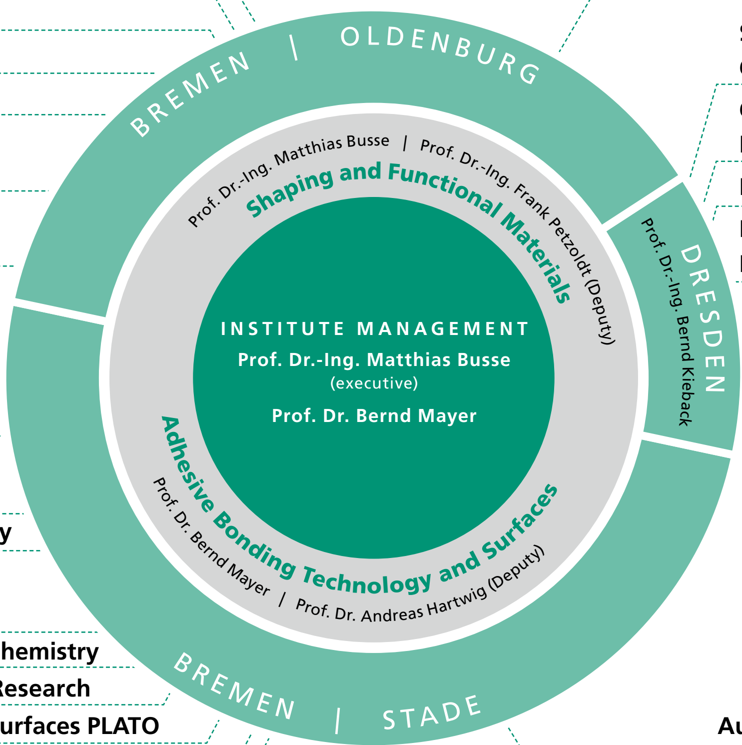
The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM was founded in 1968 as a work group in applied materials research. It was incorporated into the Fraunhofer-Gesellschaft as an institute in 1974. As a contract research institute with new thematic focal points and systematic an expansion, Fraunhofer IFAM is cooperating closely with the University of Bremen, since the institute directors are also professors in the Production Technology department. The institute has major sites in Bremen and Dresden, Oldenburg and Stade.

Prof. Dr.-Ing. Matthias Busse has acted as executive institute director since 2003, leading the Shaping and Functional Materials division. Prof. Dr. Bernd Mayer has been an institute director since 2010 and heads the Adhesive Bonding Technology and Surfaces division. In both its divisions, Fraunhofer IFAM as a neutral and independent body counts among the largest R&D establishments in Europe.

In 2014 Fraunhofer IFAM employed 589 people and had an overall budget of 45 million euros.

Powder Technology
Casting Technology
Functional Printing
Energy System Analysis
Electrical Drive Systems
Technical Qualification and Consultancy
Materialography and Analytics

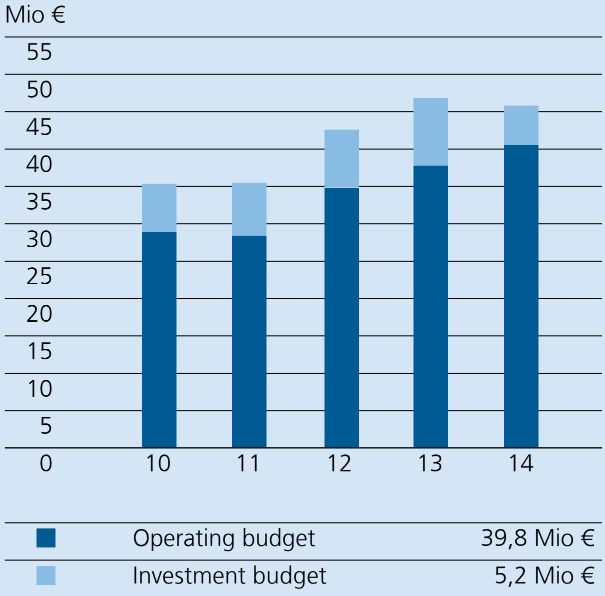
Electrical Energy Storage
Sintered and Composite Materials
Cellular Metallic Materials
Hydrogen Technology
Energy and Thermal Management



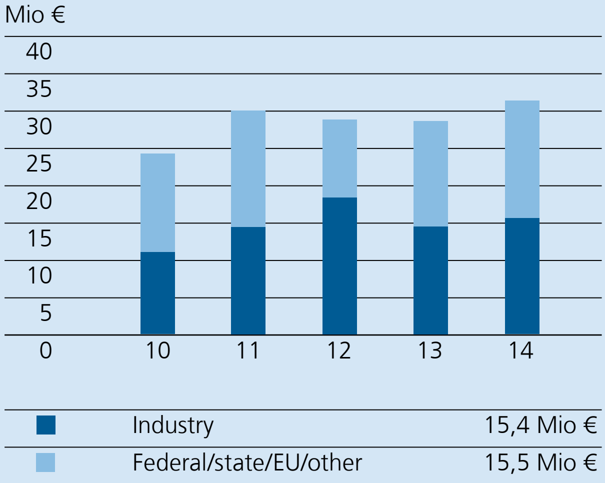
Business Development
Adhesive Bonding Technology
Chemistry of Fiber Reinforced Plastics
Paint/Lacquer Technology
Materials Science and Mechanical Engineering
Adhesives and Polymer Chemistry
Adhesion and Interface Research
Plasma Technology and Surfaces PLATO
Certification Body of the Federal Railway Authority in accordance with DIN 6701
Workforce Training and Technology Transfer

Automation and Production Technology

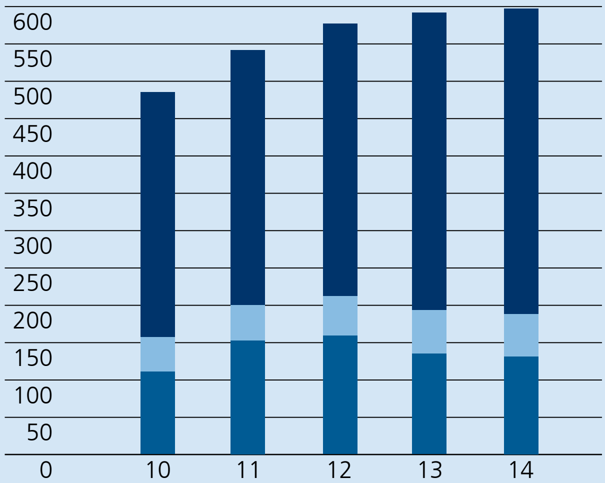
Operating and investment budget 2010–2014



Project revenues 2010–2014



Personnel development 2010–2014

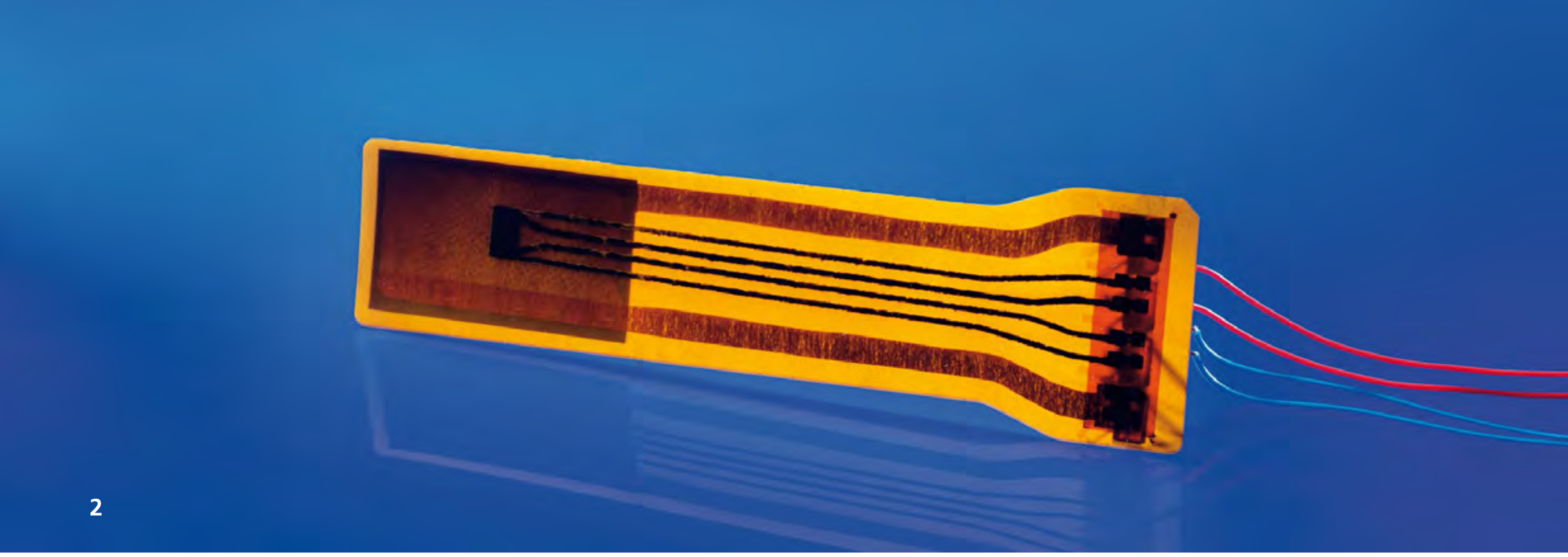


Personnel structure 2014

On December 31, 2014 a total of 589 staff were employed by Fraunhofer IFAM in Bremen, Dresden, Oldenburg and Stade.

Scientific-technical staff	404
Administration/IT/Service	56
Student assistants/Students	129
Total	589

PROFILE OF FRAUNHOFER IFAM



SHAPING AND FUNCTIONAL MATERIALS

The networking of industry and R&D organizations is vital for developing complex system solutions. Expertise and know-how at the interfaces of the various disciplines is particularly important. The expertise of Fraunhofer IFAM's personnel and our network of partners from industry and research establishments mean that we are in an excellent position to develop innovative solutions for industry.

Transferring application-oriented research into viable solutions for the industry or for component-specific developments is a task that requires the continuous expansion of knowledge and expertise. This is why the ongoing expansion of specific competencies and know-how is given high priority by the Shaping and Functional Materials division at Fraunhofer IFAM.

The spectrum of our R&D activities ranges from application-oriented research to the realization of products, assistance with industrial implementation, and support with short-term solutions.

One key area of work concerns state-of-the-art powder-based production processes such as metal injection molding and additive manufacturing. These processes are being increasingly used by industry to manufacture components of complex shape from various metal alloys. Especially for additive manufacturing Fraunhofer IFAM possesses a wide range of equipment for binder-free processes, such as selective laser melting and electron beam melting, as well as for binder-based 3D printing.

Multifunctional components with integrated sensor functions make great demands on material specifications. Combining various materials in a single component allows localized customization of properties. Designing these material combinations and controlling the production processes are key aspects of our R&D activities. The range of material combinations here includes metal-metal, metal-ceramic, and combinations with CFRP.

With regard to "Functional Printing", our expertise includes the formulation of functional inks and pastes as well as their application to components. This process enables components to be equipped with sensor systems, e.g. for recording their own operating and ambient conditions.

The robot-based production line for the functionalization of components and surfaces represents a further key step for sensor integration via printing techniques into automated industrial production processes.

State-of-the-art casting equipment, analytical facilities, and in-depth know-how regarding the casting of metal alloys using various processes puts Fraunhofer IFAM in an excellent position to serve the future needs of industry. The pilot plant facilities cover die casting, low pressure casting, investment casting and – unique in Europe – a complete lost foam plant.

1 *Extruded section made of an electrically and thermally conducting polymer composite.*

2 *Temperature sensor printed on a fibrous web integrated into a composite material (in collaboration with INVENT GmbH).*

The main scope of work includes hybrid casting for combining different materials or structures via casting. The integration of fiber and wire structures via casting processes enables customization and optimization of the mechanical properties and crash behavior of cast components. *CAST*$^{TRONICS®}$ technology allows the direct casting of electronic functional elements, for example sensors and RFID transponders for component identification. Our latest development are casting coils for electric motors – which allows not only the implementation of the coils' highly complex geometry but also offers vast opportunities for performance and efficiency improvement.

Innovative products are being made from cellular metallic materials. Specific solutions are being developed for a variety of applications, enabling our process knowledge to be continuously expanded. Our R&D activities are constantly adapted to the needs of the market and new technological challenges are continually identified. Matters such as product innovation under strict commercial conditions are just as important as the contribution of our R&D results to improving the quality of life and to ensuring sustainable developments in the area of transport, energy, medicine, and the environment. Material properties and technologies for structural and functional applications are being customized and characterized. High-performance materials, composite materials, gradient materials, and smart materials are being developed, as are production technologies for the integration of properties into components.

Our ever increasing expertise in special functional materials such as magnets, thermal management materials, thermoelectric and magnetocaloric materials, and nanocomposites is opening new opportunities for our customers to develop new products.

Regarding the development, assembly, and testing of components for electric vehicles and their integration into systems, the services of Fraunhofer IFAM cover the customized testing and evaluation of electric motors, power converters, control systems, and traction batteries. For example, studies are carried out on battery aging and the characterization of the endurance properties of electric drive systems using standardized and real driving cycles. The development and testing of novel hydrogen storage systems and their integration into fuel cell based energy and drive systems complete our range of work.

Also being addressed are renewable energies, cogeneration of heat and power, energy-efficient buildings, as well as heating networks and electricity grids.

Technical training courses, consultancy activities, and company-specific training programs are being continuously expanded.

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Perspectives

An important factor for industrial competitiveness is advancement in materials and production technologies. Fraunhofer IFAM is making its contribution here by following various strategies on a range of topics. For example, within the framework of the flagship Fraunhofer project "Criticality of rare earths" it is being demonstrated, by means of two case studies on permanent magnets in electric motors, how the primary requirement for heavy rare earth elements can be halved or subsequently completely replaced. For medical technology applications, materials are being developed for load-bearing, degradable implants.

As part of the "Harvest" project of the Fraunhofer-Zukunftsstiftung, work is being undertaken in collaboration with Fraunhofer ISE on the development and optimization of metallic heat transfer structures based on cellular metallic materials and metallic fiber structures.

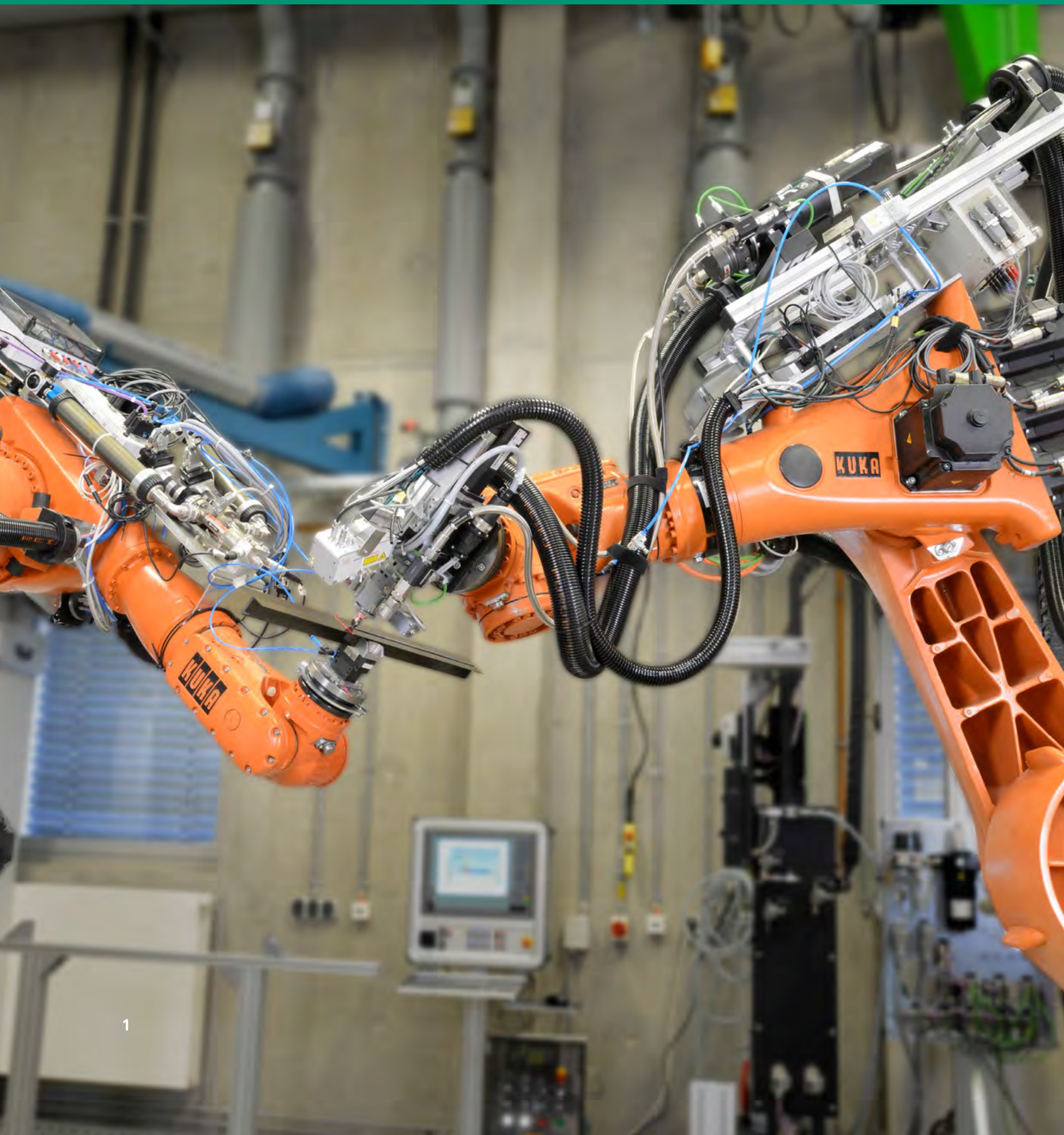
Fraunhofer IFAM is also responding to the growing industrial interest in additive manufacturing technologies. Over the next two years the pilot plant facilities will be expanded to allow the qualification of additive manufacturing processes, especially for applications in the aviation and aerospace industries.

Key areas of work

- Development and modification of materials: metallic materials, structural materials, functional materials, composite materials, cellular materials, thermal management, thermo-electric systems, composite materials, and magnetic materials
- Powder-metallurgical technologies: special sinter processes, metal injection molding, additive manufacturing processes
- Casting technologies: Die casting, investment casting, lost foam casting
- Functionalization of components: Sensors, actuators, nanostructuring and microstructuring
- Materials analysis and materialography
- Development of electrical components and their integration into systems, testing components for the drive trains of electric motors
- Material and process development for novel energy storage systems: nanostructured electrodes, manufacture of cell components, battery testing technology, electrochemical analysis
- Hydrogen technology
- Testing and evaluating charging of infrastructures for electromobility, training courses/technical seminars – national and international
- Energy-efficient buildings, heating networks and electricity grids
- Combined heat and power systems

3 *Prototype suture anchor for the shoulder made of iron tricalcium phosphate (FE-TCP).*

PROFILE OF FRAUNHOFER IFAM



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ADHESIVE BONDING TECHNOLOGY AND SURFACES

The Adhesive Bonding Technology and Surfaces division at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has more than 300 employees and is the largest independent research group working in the area of industrial adhesive bonding technology. The R&D activities focus on adhesive bonding technology, surface technology, and fiber composites. The objective is to supply 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 Adhesive Bonding Technology and Surfaces division. The activities range from fundamental research through production technologies right up to the market introduction of new products with partners. Industrial applications mainly occur in the transport sector – manufacturers of aircraft, cars, rail vehicles, ships – and their suppliers, energy technology, the construction industry, the packaging sector, textile industry, electronics industry, microsystem engineering, and medical technology.

“Adhesive bonding technology”, a core competence, involves the development and characterization of adhesives, the design and simulation of bonded and hybrid joints, as well as the characterization, testing, and qualification of such joints. The planning and automation of industrial production as well as process reviews and certified training courses in adhesive bonding technology and fiber composite technology are additional provided services.

The core competence “Surface technology” covers plasma technology, paint/lacquer technology, as well as adhesion and interface research. Customized surface modifications – for example surface pre-treatment and functional coatings – considerably expand the industrial uses of many materials and in some cases are essential for the use of those materials. The focus here is on the optimization and long-term stability of bonded joints and coatings, including early detection of degradation and corrosion phenomena, the validation of aging tests, and inline surface monitoring. The research results in the area of aging and surface pre-treatment provide important fundamental knowledge for both adhesive bonding and coating technology, thus contributing to the safety and reliability of bonded joints and coating.

The Automation and Production Technology department of Fraunhofer IFAM at Forschungszentrum CFK NORD (Research Center CFRP NORTH) in Stade is carrying out groundbreaking work on large fiber reinforced plastic structures and is able to join, assemble, process, repair, and carry out non-destructive tests on large 1:1 scale structures. The core competence of fiber reinforced plastic technology thus closes the gap between the laboratory/small pilot-plant scale and industrial scale FRP applications. The aspects mentioned above concerning adhesive bonding technology, plasma technology, paint/lacquer

1 *Adhesive application using cooperating robots.*

2 *Outside view of the icing laboratory with integrated wind tunnel.*

technology, as well as adhesion and interface research are also key aspects of this core competence. Expertise in matrix resin development, fiber-matrix adhesion, and the sizing of joints completes this work field.

The entire Adhesive Bonding Technology and Surfaces division is certified according to DIN EN ISO 9001. The laboratories for material testing, corrosion testing, and paint/lacquer technology 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 accredited in accordance with the German Regulation for employment promotion, AZAV. The Plastics Competence Center is also accredited in accordance with AZAV 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" in accordance with DIN 6701-2 has been accredited by the Federal Railway Authority (FRA, Eisenbahn-Bundesamt) since 2006.

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 Adhesive Bonding Technology and Surfaces division. Working with our customers, we develop innovative products which are later successfully introduced into the marketplace by the companies. Manufacturing technologies are playing an ever more important role here, 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, yet its potential has not nearly been fully utilized. Lightweight construction for vehicles as a means of saving resources, adhesive bonding in medicine and medical technology, as well as the use of nanostructured 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 our activities is: Make the bonding process and the bonded product even safer as they already are! This objective can only be achieved if all the steps in the bonding process chain are considered as an integral whole.

In all areas, Fraunhofer IFAM is making increasing use of computer-aided methodologies. 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 used in order to provide 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 aging and corrosion procedures cannot provide. Industries with very stringent requirements on surface technology make use of the in-depth expertise and technological know-how of Fraunhofer IFAM. Notable customers include leading companies – particularly in the aircraft and car manufacturing sectors.

Key activities

- Synthesis, formulation, and testing of new polymers for adhesives, laminating/casting resins
- Development of additives (nanofillers, initiators, etc.) for adhesives and coatings
- Biomimetic concepts in adhesive bonding and surface technology, including bonding in medicine
- Development and qualification of adhesive bonding production processes; computer-aided production planning
- Application of adhesives/sealants, casting compounds (mixing, dosing, application)
- Development of innovative joining concepts (bonding, hybrid joints)
- Design of bonded structures (simulation of the mechanical behavior of bonded joints and components using finite element methods, prototype construction)
- Parameter determination, fatigue strength and alternating fatigue strength of bonded and hybrid joints; material models for adhesives and polymers
- Development of environmentally compatible pre-treatment and corrosion protection systems for the long-term stable bonding and coating of plastics and metals
- Functional coating systems using plasma processes and combined methods
- Development of special test methods (e.g. formation and adhesion of ice on surfaces, resistance to aging)
- Evaluation of aging and degradation processes in composite materials; electrochemical analysis
- Computer-aided material development using quantum-mechanical and molecular-mechanical methods
- Automation and parallelization of processes in FRP technology
- Processing FRP materials
- 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 Manufacturer, Fiber Reinforced Plastic Specialist, Fiber Reinforced Plastic Remanufacturer and Fiber Reinforced Plastic Expert

3 *Specimens after peel test. Left: Cohesive failure in the adhesive film; right: Adhesive failure due to a release layer at the surface.*

PROFILE OF FRAUNHOFER IFAM

FIELDS OF ACTIVITY AND CONTACTS

INSTITUTE DIRECTORS

- **Prof. Dr.-Ing. habil. Matthias Busse** (executive)
- **Prof. Dr. Bernd Mayer**

SHAPING AND FUNCTIONAL MATERIALS DIVISION

- **Prof. Dr.-Ing. habil. Matthias Busse**
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  matthias.busse@ifam.fraunhofer.de

DRESDEN BRANCH

- **Prof. Dr.-Ing. Bernd Kieback**
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  bernd.kieback@ifam-dd.fraunhofer.de

ADHESIVE BONDING TECHNOLOGY AND SURFACES DIVISION

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ADHESION AND INTERFACE RESEARCH

Dr. Stefan Dieckhoff
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- Surface and nanostructure analysis
- Corrosion protection and electrochemistry
- Numerical simulation of materials
- Quality assurance – monitoring surface properties
- Wet chemical pre-treatment
- Analysis of damage/failure

CERTIFICATION BODY OF THE FEDERAL RAILWAY AUTHORITY IN ACCORDANCE WITH DIN 6701-2

Dipl.-Ing. (FH) Frank Stein
Phone +49 421 2246-655
frank.stein@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/DIN6701

- Information relating to company certification in accordance with DIN 6701 ("Manufacture of adhesive bonds on rail vehicles and parts of rail vehicles")
- Company audits and certifications in accordance with DIN 6701
- Member of the work group on adhesive bonding in accordance with DIN 6701

AUTOMATION AND PRODUCTION TECHNOLOGY

Dr. Dirk Niermann
Phone +49 4141 78707-101
dirk.niermann@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/Stade

- Automated assembly of large structures up to a 1:1 scale
- Joining techniques (adhesives, shims, sealants)
- Processing technologies (milling, drilling, waterjet cutting)
- Automated component handling
- Shape and positional correction for large components
- Sensor-controlled robots with high positioning accuracy
- Release agent free manufacture of fiber composite components
- Manufacture of prototype components and structures
- Development of plants and components

BUSINESS DEVELOPMENT

Prof. Dr. Bernd Mayer
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bernd.mayer@ifam.fraunhofer.de

- Contact for European research projects, including project conception and applications
- Participation in regional, national, and international industry networks
- Coordination of major projects
- Focal point for large companies

CHEMISTRY OF FIBER REINFORCED PLASTICS

Dr. Katharina Koschek
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→ www.ifam.fraunhofer.de/en/durocycle

- Controlled polymerization reactions
- Interfacial reactions
- Novel matrix systems
- Bio-based fiber reinforced plastics

ELECTRICAL DRIVE SYSTEMS

Dipl.-Ing. Felix Horch
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felix.horch@ifam.fraunhofer.de

- Development, design, and simulation of electrical drive systems
- Development of control systems, control units, and software
- Prototype manufacture for electrical drive systems
- Testing of components and drive systems
- Integration into vehicles

ELECTRICAL ENERGY STORAGE

Dr. Julian Schwenzel
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julian.schwenzel@ifam.fraunhofer.de
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- Cell chemistry
- Metal-air batteries
- Paste development and electrode manufacture
- Cell assembly
- Electrocatalysis
- Battery testing stands
- In-situ analytics
- Service life and aging mechanisms

ENERGY AND THERMAL MANAGEMENT

Prof. Dr.-Ing. Jens Meinert
Phone +49 152 56608698
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- Efficient storage of heat and cold
- Development of high-performance latent-heat storage systems
- Optimization of heat transport processes
- Cellular metals in compact heat exchangers
- Structuring of evaporator surfaces
- Thermal management of heat-generating components
- Mathematical modeling of heat transport
- Simulation of melting and solidification processes
- Measurement of thermal material and transport parameters
- Testing of technical energy-related components

ENERGY SYSTEM ANALYSIS

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→ www.ifam.fraunhofer.de/en/esa

Analyses, expert studies, and consulting service regarding

- Energy supply and climate protection
- Energy-efficient buildings and districts
- Combined heat and power systems
- Integrated heat and power supply
- Digital mapping of heat demand
- Energy efficiency in material/process technologies
- Economic/political framework conditions for energy supply
- Residential living and electric mobility
- Integration of energy storage systems

FUNCTIONAL PRINTING

Dr. Volker Zöllmer
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volker.zoellmer@ifam.fraunhofer.de
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- Printed electronics
- Assembly and joining technology
- Sensor integration
- Printable inks and pastes
- (Nano) composites and functional materials
- Energy harvesting
- Integration of functionalities
- Digital manufacturing
- Semi-automated production

CASTING TECHNOLOGY

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- Cold-chamber die casting (aluminum, magnesium, zinc)
- Lost foam casting
- Low pressure casting
- Investment casting
- Sand casting
- Salt cores/Lost cores, complex geometries
- Function integration/*CAST*TRONICS®
- Component identification/component labeling
- Composite casting/hybrid casting

ADHESIVES AND POLYMER CHEMISTRY

Prof. Dr. Andreas Hartwig
Phone +49 421 2246-470
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- Formulation of adhesives
- Matrix resins for fiber reinforced plastics
- Characterization of adhesives/bonded joints
- Novel additives, polymers, and other raw materials
- Morphology of adhesives and other thermosets, e.g. nanocomposites
- Biofunctional surfaces and bioanalysis
- Adhesives for medicine and medical technology
- Improved reliability and productivity of bonding processes
- Market advice for adhesives and raw materials

ADHESIVE BONDING TECHNOLOGY

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- Production concepts for bonded joints
- Selection and characterization of adhesives and sealants
- Production planning, process design, and automation
- Dosing, mixing and application systems
- Production of bonded prototypes
- Simulation of dosing and production processes
- Process analysis and fault analysis for industrial processes
- Long-term stability of bonded joints and seals
- Adhesive application on high-area substrates
- Bonding electrically/optically conductive contacts
- Adhesive bonding in microsystem technology
- Adhesives in the construction industry

PAINT/LACQUER TECHNOLOGY

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→ www.ifam.fraunhofer.de/paint

- Processing and application technologies for paints and coatings
- Qualification of materials and processes
- Functional paints and coatings (e.g. anti-icing, anti-fouling, self-healing, and dirt-repelling coatings, electrically insulating layers)
- Analysis of raw materials for coatings
- Coating formulation
- Test methods
- Analysis of damage/failure
- Training seminars

MATERIALOGRAPHY AND ANALYTICS

Dr.-Ing. Andrea Berg
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- Thermal analyses: melting point, phase changes
- Powder analysis: Specific surface area (BET method), particle size distribution
- Metallography: microsections, hardness measurements, image analysis
- Scanning electron microscopy
- Focused ion beam
- Trace analysis
- X-ray phase analysis
- Training course for material tester

FRAUNHOFER PROJECT CENTER WOLFSBURG

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- Lightweight automotive design with integrated functions
- Textile manufacturing chain
- Hybrid materials with metallic matrix
- Components for electric vehicles

PLASMA TECHNOLOGY AND SURFACES PLATO

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- Low pressure plasma technology
- Atmospheric pressure plasma technology
- VUV excimer technology
- Plant technology and construction
- New surface technologies
- CVD processes
- Tribology
- Functional coatings
- Web materials/film technologies
- Pre-treatment, cleaning, and activation

POWDER TECHNOLOGY

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- Pressing and sintering
- Additive manufacturing
- Magnetic materials
- Composite materials
- Metal foams

SINTERED AND COMPOSITE MATERIALS

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- Additive manufacturing (electron beam melting, dispensing technology)
- Composite materials, multimaterial composites
- Light metals
- Materials for tribological applications
- Materials for energy conversion (thermoelectric materials) and storage (supercaps)
- High temperature materials
- Sputter targets

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- R&D Inside – knowledge and technology transfer
- Knowledge update – management workshop
- Foresights – technology screening
- Intercultural training and coaching

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- Electrochemical characterization of electrodes
- Development and testing of electrolysis cells
- Metal hydrides for reversible H_2 storage, H_2 cleaning, and H_2/D_2 isotope separation
- Techniques for the production of metal hydrides
- Development and testing of hydride reactors
- Integration of hydride reactors in H_2 energy systems
- Hydrolysis reactions for H_2 generation for H_2-on-demand solutions
- Hydrogen embrittlement for powder manufacture
- Comprehensive analysis of H_2-solid reactions

WORKFORCE TRAINING AND TECHNOLOGY TRANSFER

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- Training courses in adhesive bonding technology
- Training courses in fiber composite technology
- Quality assurance for adhesive bonding technology
- Quality assurance for fiber composite technology
- Promotion of young scientists and engineers (MINT)

MATERIALS SCIENCE AND MECHANICAL ENGINEERING

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- Qualification of bonded structures
- Bonded and riveted joints: design, sizing, crash/fatigue behavior
- Combination and optimization of mechanical joining processes
- Qualification of mechanical fasteners
- Fiber composite components, lightweight and hybrid constructions
- Accredited Material Testing Laboratory

CELLULAR METALLIC MATERIALS

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- Additive manufacturing via 3D screen printing
- Open-celled fiber structures and foams
- Hollow sphere structures and precision hollow spheres
- Reinforcement of cast components with 3D wire structures
- High-performance vibration damping
- High-performance heat storage systems
- Degradable metallic implant materials
- Jewelry and design
- Catalysis and filtration

1

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1 *Fraunhofer IFAM, Oldenburg.*

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 66 institutes and research units. The majority of the nearly 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, around 1.7 billion euros 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.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the 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.

→ **www.fraunhofer.de/en.html**

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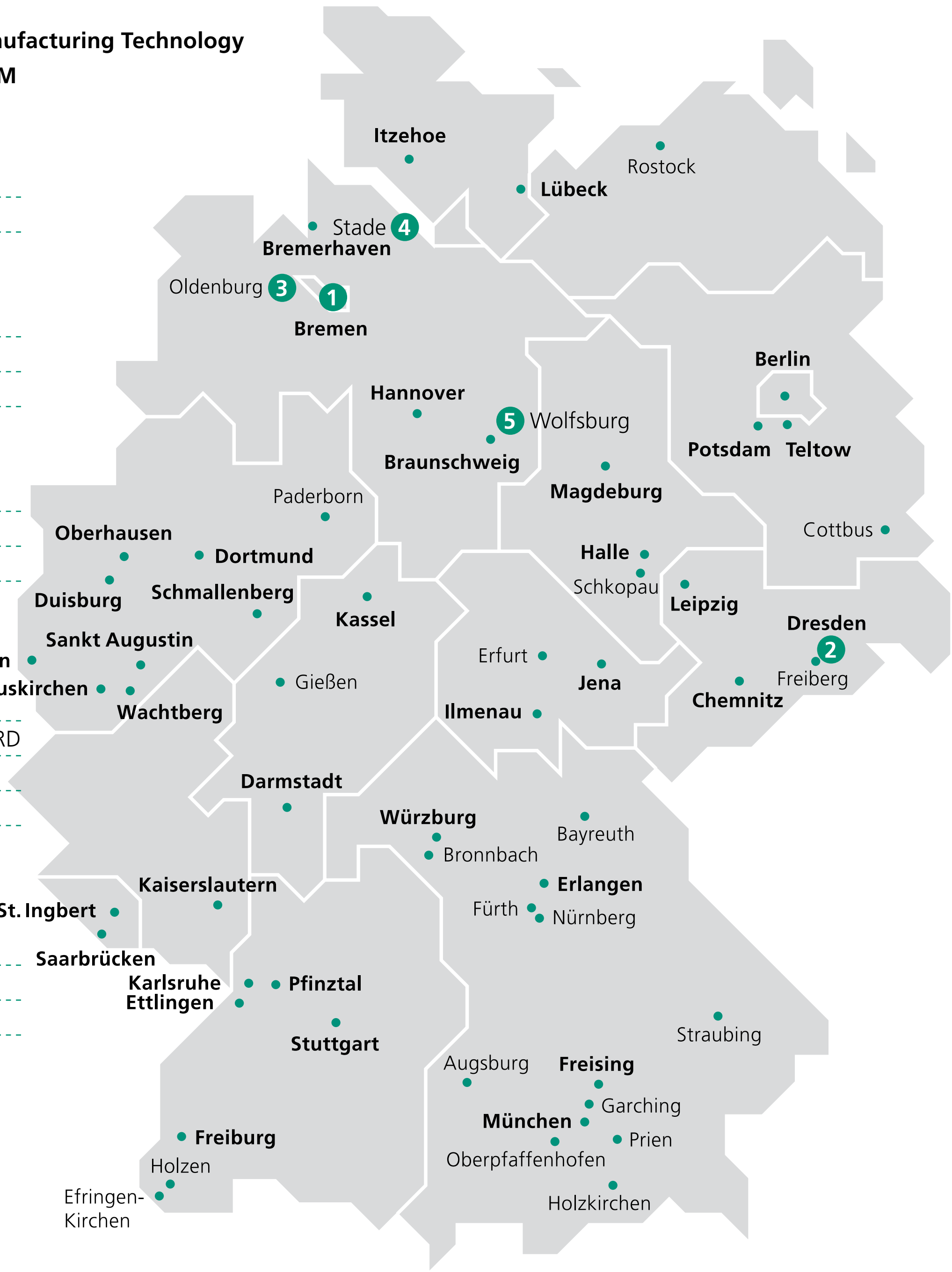

Fraunhofer Institutes and facilities
Other sites

GROUPS | ALLIANCES | ACADEMY

NETWORKS AT FRAUNHOFER

FRAUNHOFER GROUP FOR MATERIALS AND COMPONENTS – MATERIALS

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

The Fraunhofer Group for Materials and Components – MATERIALS pools the expertise of the Fraunhofer Institutes that work in the field of materials science.

Materials science research within the Fraunhofer-Gesellschaft covers the entire value-creation chain from the development of new materials and improvement of existing materials through to manufacturing technology on an industry scale, characterization of properties, and evaluation of applications. The same applies for components and systems made from these materials. In addition to experimental studies in laboratories and pilot plants, numerical simulation and modeling methods are also employed. The Fraunhofer Group for Materials and Components – MATERIALS covers metals, inorganics/non-metals, polymers, renewable raw materials, and semiconductors.

The Group applies its expertise within a range of business areas including energy and environment, mobility, health, machine and plant engineering, construction and housing, microsystem engineering, and safety.

Key work areas of the Group include:

- Improving safety/comfort and reducing resource usage in transport technology as well as machine and plant engineering
- Increasing the efficiency of systems for energy generation, energy conversion, and energy storage
- Improving biocompatibility and the functionality of materials used in medicine and biotechnology
- Enhancing integration density and usage properties of components in microelectronics and microsystem engineering
- Improved usage of raw materials and improved product quality

→ **www.materials.fraunhofer.de/fhg/vwb_en/index.isp**

Chairman of the Group
Prof. Dr.-Ing. Peter Elsner
Deputy Chairman of the Group
Prof. Dr. Peter Gumbsch
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1 *Networking. (Image: © Gerhard Bergmann)*

FRAUNHOFER ALLIANCES

Fraunhofer Institutes or divisions of institutes having differing expertise collaborate in Fraunhofer Alliances in order to jointly develop and market a specific field of business.

FRAUNHOFER AUTOMOBILE PRODUCTION ALLIANCE

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FRAUNHOFER ACADEMY

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PROFILE OF FRAUNHOFER IFAM

1

QUALITY MANAGEMENT

Certified in accordance with DIN EN ISO 9001

Fraunhofer IFAM has been certified in accordance with DIN EN ISO 9001 since 1995. Certified areas at Bremen and Stade include:

- Product-oriented development of materials, mechanical engineering, processes and production technologies for adhesive bonding technology, surface technology, and paint/lacquer technology
- Characterization and simulation of materials and technologies
- Adhesive development
- Training courses in adhesive bonding technology, fiber reinforced plastics, and electromobility
- Casting technology
- Metallography, thermal analysis, powder measurement technology, and trace analysis
- Laboratories for material testing, paint/lacquer technology, corrosion testing, materialography and analysis

Accreditation in accordance with DIN EN ISO/IEC 17025

The laboratory in Bremen has also been accredited in accordance with DIN EN ISO/IEC 17025 since 1996.

The Fraunhofer IFAM's Dresden test laboratory is certified in accordance with DIN EN ISO/IEC 17025 for powder metallurgy, special tests for characterizing inorganic powders and sintered materials, and for material tests on metallic materials.

Certification in accordance with DIN EN ISO/IEC 17024 and accreditation in accordance with AZAV

The Center for Adhesive Bonding Technology has an international reputation for its training courses and since 1998 has been accredited via DVS-PersZert® in accordance with DIN EN ISO/IEC 17024. Since 2009 it has been accredited in accordance with the German Regulation for the accreditation and approval of training for employment promotion (AZAV).

Accreditation in accordance with AZAV

The Plastics Competence Center of Fraunhofer IFAM has been accredited in accordance with the German Regulation for employment promotion (AZAV) and meets the quality requirements of DIN EN ISO/IEC 17024.

Recognition in accordance with DIN 6701-2

The Certification Body for the Manufacture of Adhesive Bonds on Rail Vehicles and Parts of Rail Vehicles in accordance with DIN 6701-2 has been recognized by the Federal railway Authority (EBA) since 2006.

→ **www.ifam.fraunhofer.de/en/qm**

1 *Fraunhofer IFAM, Stade.*

INTERNATIONAL COLLABORATION

Electromobility: Training for technical personnel in China

Electromobility is a global issue. There are new opportunities especially for China to reduce smog in its large cities and so play a pioneering role in electromobility. The Peking government has clearly formulated its goals: By 2016 some 30 percent of official vehicles will be either purely electric vehicles or hybrids. Also, by 2020, some five million zero-emission vehicles will be on the roads. The Chinese Government is planning to spend about ten billion euros over the coming years to realize these ambitious goals. Currently the purchase of an electric vehicle in China is subsidized by up to 17,000 euros. The purchaser also immediately gets a registration plate. For conventional cars this can cost up to 10,000 euros and takes several months.

Whenever new technologies are introduced, there is not only a need for intense R&D work but also a need for effective training and further training of technical personnel. In order to firmly establish electromobility for the long term future, the “Technical Qualification and Consultancy“ department at Fraunhofer IFAM offers customer-specific training seminars and courses on electromobility at different theoretical and practical levels. Some of the courses are being held internationally, including in China.

In 2014, working in collaboration with the Beijing Academy of Science and Technology (BJAST), more than 40 participants attended four training courses on electromobility. The two-day courses gave an overall view of electromobility, providing many practical examples and demonstrating equipment (e.g. charge card/tag, cutaway model of batteries, personal protection equipment). The course participants were informed about current and future battery technologies and their advantages and disadvantages for use in electric vehicles. Furthermore, the courses gave an insight into electric drive systems and the components of electric motors. The second day of the course focused on the charging infrastructure, vehicle concepts, and safety for high voltage vehicles.

Due to the enthusiastic response of the participants it is planned to continue collaboration with BJAST and offer these two-day courses in electromobility as an ongoing service from 2015.

Visible scientific collaboration with Brazilian partners

Fraunhofer IFAM researchers have collaborated with Brazilian partners for more than a decade. Besides the focus on university research, there is now ever greater emphasis on collaborative projects in the area of applied research and industrial applications. The working networks that have been built up form the basis for further business relationships.

Indeed, this was the foundation for another fruitful year of collaboration in 2014 with our Brazilian partners. As part of a student exchange program funded by the Brazilian Government and the resources of researchers at Fraunhofer IFAM, an average of 20 Brazilian students study and work each year at the institute. There is currently a significant increase in the number of senior students, such as Ph.D. students, at the institute and Fraunhofer IFAM is also working ever more closely with highly qualified post-doctoral researchers from Brazil.

1 *Participants taking the electrical vehicle safety course in China.*
2 *Brazilian Bachelor and Ph.D. students at Fraunhofer IFAM.*

Fraunhofer IFAM scientists are supervising the Brazilian students in a wide range of technical areas. The success of this collaboration is reflected in the number of joint publications in journals and representations at conferences.

The core competencies of Fraunhofer IFAM were presented at the XIII Brazilian MRS Meeting in September 2014 as part of the symposium "Functional hybrid interfaces: from characterization to applications". This event was organized by Dr. Welchy Leite Cavalcanti in collaboration with the President of the Brazilian Society for Adhesives and Adhesion, Prof. Silvio de Barros. Dr. Leite Cavalcanti edited a special edition of the Applied Adhesion Science journal at the symposium documenting the scientific publications and results of the Brazilian researchers and Fraunhofer IFAM.

JediAce: A successful example of international collaboration

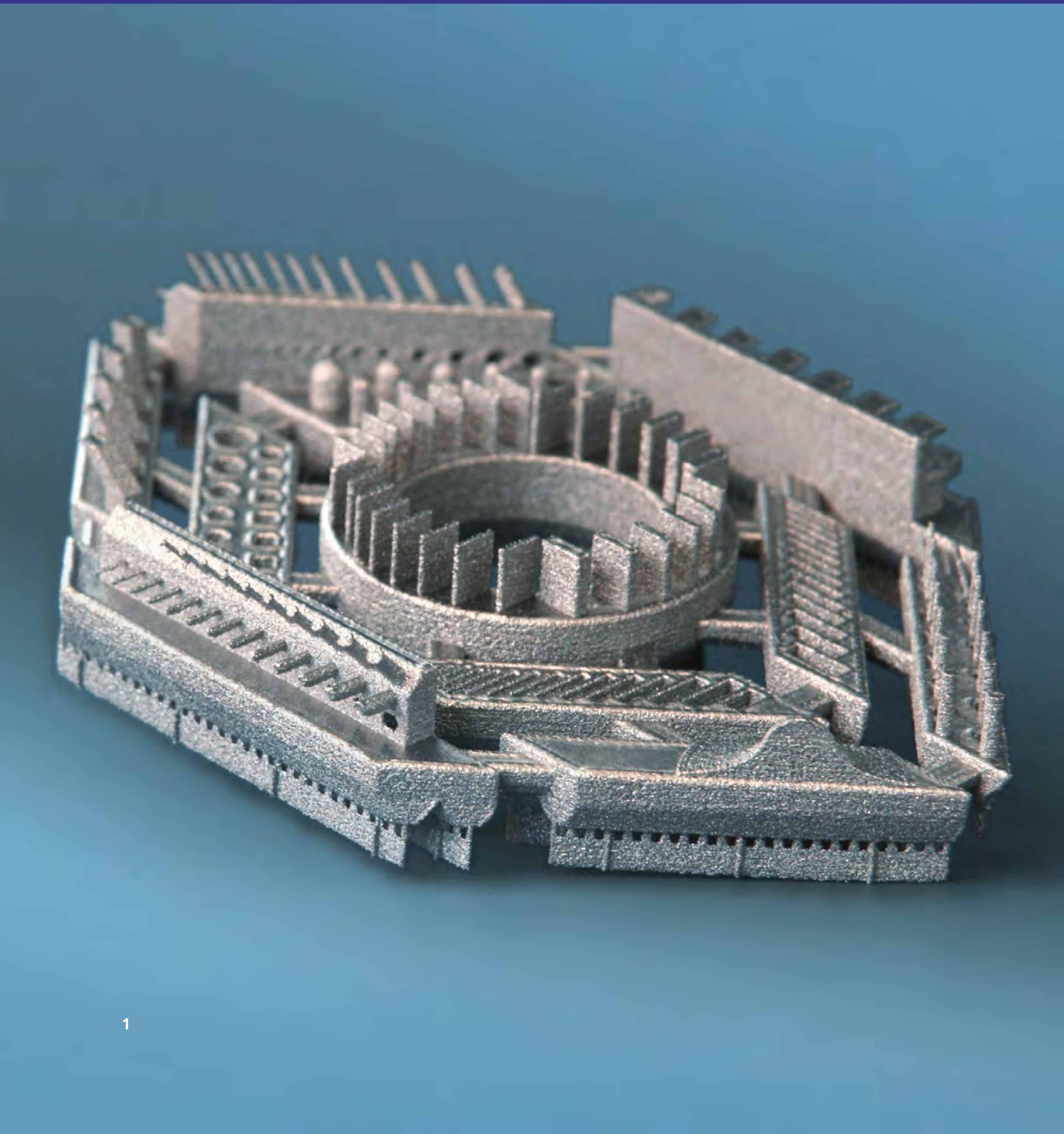
The JediAce project (Japanese-European De-Icing Aircraft Collaborative Exploration) is being carried out by an international consortium and aims to develop a multicomponent ice protection system which meets the requirements of the next generation of aircraft. The project began in November 2012 and is being funded by the European Commission and the Japanese Ministry of Economy, Trade and Industry (METI). The project partners come from four different countries and include: Fuji Heavy Industries Aerospace Company (Japan), Japan Aerospace Exploration Agency and Kanagawa Institute of Technology (Japan), Dassault Aviation (France), Universitat Rovira i Virgili – Center for University Studies in Aviation (Spain), and Fraunhofer IFAM (Germany), which is coordinating the whole project.

The objective of the project is to develop an integrated ice protection system for aircraft wings which comprises three synergistic components: Active de-icing technology, functional coatings (which assist the de-icing function), and sensor technology, which not only monitors the icing but also the de-icing in real-time. Fraunhofer IFAM researchers will be involved in the development of anti-icing coatings and testing the icing properties of the surfaces. Another key milestone was the construction of a wind tunnel which will enable the newly developed de-icing systems to be tested under icing conditions. Realistic icing tests at temperatures down to -30 °C and at wind speeds up to 350 km/h can be undertaken using this facility.

The JediAce project is a good example of how all partners can benefit from international collaboration. The intense exchange of knowledge between experts in different disciplines from different continents is making a major contribution to the success of the project.

3 *Participants at the fifth JediAce project meeting in Tokyo in November 2014.*

SINTERED, COMPOSITE, AND CELLULAR METALLIC MATERIALS



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CORE COMPETENCE SINTERED, COMPOSITE, AND CELLULAR METALLIC MATERIALS

The development of materials with customized properties and combinations of properties and efficient manufacturing technologies as well as additive manufacturing processes are key activities of Fraunhofer IFAM. The utilization and tailored development of sintering and shaping processes create numerous opportunities for the manufacture and optimization of innovative metallic materials as well as component geometry with unusual property profiles, in particular by combining properties in novel composite materials or by creating highly porous or cellular structures.

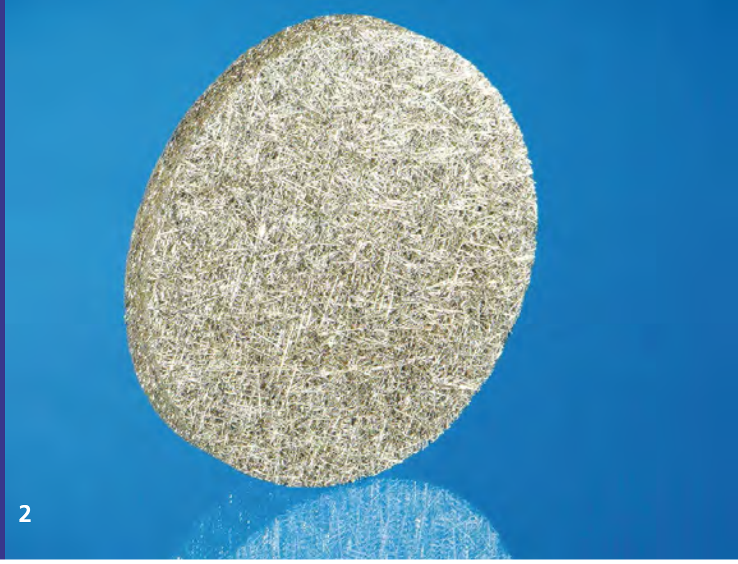
In the area of metallic and intermetallic sintered and composite materials for functional and structural applications, Fraunhofer IFAM possesses in-depth understanding of structure-property relationships and how to optimize these for specific applications. The complete powder-metallurgical technology chain from powder preparation and characterization through to various shaping and thermal treatment methods is covered. This is now being further expanded by methods such as rapid solidification of metallic melts (melt spinning and extraction) and special sintering processes (e.g. Spark Plasma Sintering) as well as innovative oven analysis.

Fraunhofer IFAM has comprehensive knowledge of alloys and processes for manufacturing light metal components, in particular made of aluminum, for weight reduction in car manufacture. Regarding metallic composites, the focus is on materials development for thermal management of electronics, friction materials and sliding materials for high tribological loads, and special materials for mechanical and corrosive stresses at high temperature (> 800 °C). The manufacture and testing of functional materials for energy storage and conversion is of growing importance. Key areas here are new and, in particular, nano-structured materials for hydrogen generation and storage, for heat storage, for efficient thermoelectric generators, and for supercapacitors.

Cellular metallic materials are another key development area. Prudent selection of materials and a wide range of customizable cell and pore structures allow a wide spectrum of application-specific properties and material savings to be realized. For example, highly porous metallic materials such as fiber-metallurgical materials, hollow sphere structures, open-cell metallic foams, 3D screen-printed structures, 3D wire structures, and porous metal papers can be used for applications such as noise absorption, heat insulation, energy absorption, mechanical damping, and material and energy transport, as well as for achieving catalytic effects.

→ **www.ifam.fraunhofer.de/metallicmaterials**

1 *Design prototype made of Ti-6Al-4V via electron beam melting (CAD template: University of Duisburg-Essen, Department of Production Technology).*



METALLIC MATERIALS FOR IMPLANTS – HIGHLY POROUS AND DEGRADABLE

An ongoing medical problem is how best to treat major bone damage. Such damage does not heal spontaneously and requires implants. The best bone replacement is, and always has been, the patient's own bone. However, only limited amounts of this are available and its removal also involves risks. The use of a synthetic bone replacement is also accompanied by various risks. The ideal solution is a degradable material, namely implants which disappear after successful bone healing.

Magnesium comes very close to being the ideal material. It degrades in biological surroundings, has excellent biocompatibility, and bonds very readily to bone.

Fraunhofer IFAM in Dresden has developed a magnesium implant material whose structure also gives it other favorable properties. The metallic fiber structures form a highly porous lattice which assists bone growth and also the growth of blood vessels. Such structures are, however, of particular interest due to their reduced stiffness, very closely resembling the biomechanical properties of bone. This stimulates bone growth.

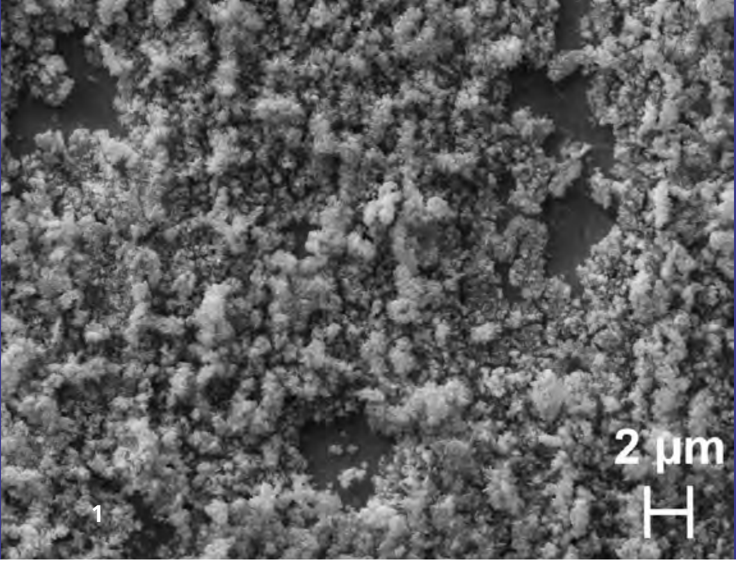
The starting point for the development work was the production of short magnesium fibers via extraction from the melt. These fibers are then homogeneously deposited and sintered. The particular challenge for manufacturing magnesium fiber structures is the sintering, which the material with extremely high oxygen affinity resists due to the stable surface oxides. The heat treatment is hence undertaken in a partial melt phase. Precise knowledge of the melt phase composition is decisive for the sintering result. The best sintering regime was determined using computer simulation methods. The resulting implants possess favorable mechanical properties and also excellent corrosion properties. Multiple depositions of Y_2O_3 at the grain boundaries allowed for a degradation behavior with reduced corrosion rate to meet the physiological requirements. In the animal model, slow corrosion was measured after 12 weeks but after 24 weeks the majority of the metal implant had disappeared.

As a winner of the Medical Technology Innovation Competition, the research was funded by the BMBF (Federal Ministry of Education and Research). The favorable properties of the implant material have in the meantime also convinced industry, with Botiss Dental GmbH now licensing the patent. The company plans to use this material in oral surgery and is currently evaluating the setting up of a suitable production chain.

→ **www.ifam.fraunhofer.de/implants**

1 *SEM micrograph of magnesium fibers.*

2 *Metallic fibers (prototype).*



HIGH-EFFICIENCY ELECTRODE MATERIALS FOR GAS-GENERATING REACTIONS

For political, security, and energy strategy reasons it is vital to guarantee the availability of raw materials. Hydrogen is one of the irreplaceable base chemicals of the chemical industry and, being an energy source, is one of the central pillars of the shift to renewable energy. The CO_2-neutral production of hydrogen can only be achieved industrially via the electrochemical splitting of water in an electrolyzer that is powered by renewable energy sources.

Improving electrolysis technology for "green" hydrogen

The further development of electrolysis technology has high strategic importance for Germany in order to generate "green" hydrogen for commercial use. At present, the conventional way to generate hydrogen is via gas reforming. This is economically favorable due to the availability of natural gas but is accompanied by very high CO_2 emissions. Fraunhofer IFAM in Dresden is undertaking development work to improve electrolysis technology for commercial hydrogen manufacture. The main costs (investment costs and operational costs) of electrodes and stacks are the focus. The aim of the development work is to considerably reduce the plant and hydrogen production costs using electrodes that have long-term efficiency.

Fraunhofer IFAM in Dresden is evaluating novel gas-generating electrode materials using electrochemical methods – combined with structural analysis. Degradation mechanisms of the electrodes are being elucidated, allowing conclusions to be drawn for improved electrode composition and manufacture. Favorable-cost nanocrystalline electrodes (Fe and Ni alloys) have been developed, whose high catalytic activity can be maintained by activation in the electrolyzer. In addition, the electrode materials are being tested under real conditions in single-cell test stands to gain information about gas bubble transport in the cells. This then allows adaptation of the electrode and cell geometry. The end result is the development of customized electrodes with advantageous gas bubble transport. Our in-depth knowledge of electrochemistry, metallic materials, and production technologies make Fraunhofer IFAM an expert partner for manufacturers of electrolyzers.

→ **www.ifam.fraunhofer.de/electrodes**

1 *SEM micrograph of an electrode surface.*

2 *Single cell electrolyzer at Fraunhofer IFAM in Dresden for testing electrode materials.*

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CORE COMPETENCE POWDER TECHNOLOGY

Powder technology has long been successfully used by industry. Like no other production process, powder technology allows the customization of material properties and the shaping of precision geometry simultaneously. Powder technology is a core competence of Fraunhofer IFAM. Our expertise here extends from the powder to the product on all matters concerning the materials, shaping and tolerances, process reliability, as well as special requirements.

The starting point for powder technology solutions is the specific material used. The mixing of powders allows materials to be manufactured with the required property profiles. For example, properties such as hardness, toughness, E-modulus, wear properties, and heat expansion can be adapted to requirements. New soft magnetic materials as well as hard magnets are playing an increasingly important role.

We have in-depth expertise in various forming and production processes, and in particular in shaping and sintering – the two most important processing steps in powder technology.

Metal injection molding (MIM) is an example of an established and important shaping process. The experts at Fraunhofer IFAM have thorough understanding of the whole process chain, from powder to feedstock systems and injection molding through to the sintered product. Our range of services includes component development, the production of pilot series, know-how transfer, and training of production personnel. Also covered are shaping processes for special products such as micro-MIM, two-component MIM, and extrusion.

Fraunhofer IFAM also has comprehensive expertise in additive manufacturing, where products are made from metal powders without molds directly from 3D CAD data, having virtually any desired shape. Currently, this method is not only being used for rapid product development but increasingly also for the production of high-quality, individualized products for end-users.

Functional Printing is used to add functions to components. Various powder-based printing technologies therefore are also an important part of our expertise in powder technology. The methods are being transferred to an industrial scale using a specially designed automated production line.

The Powder technology competence is complemented by a variety of enabling technologies. These include the simulation of shaping processes and topology optimization as well as analytical technologies with a focus on powder characterization and rheology.

→ **www.ifam.fraunhofer.de/powdertechnology**

1 *Turbine blades produced by additive manufacturing.*

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POWDER-METALLURGICAL PROCESS FOR MANUFACTURING COINS WITH BRILLIANT SURFACES

Many people love collecting things – including valuable objects. Coins made of metals such as silver, gold, platinum, and palladium are widely collected. Besides the metal value of a coin, other properties such as the surface quality are of particular importance. Increasing metal prices and highly complex motifs in deep relief have created a need for a precision manufacturing process for coins which is superior to the established production process. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, in a project funded by the Federal Ministry of Economic Affairs and Energy, has developed a power-metallurgical process that is now being used by Reischauer GmbH.

The stamping of coins is a mechanical process whereby the coin blanks – also known as rounds – are shaped in a fraction of a second between two punches in a die. The coin blanks themselves are punched out of rolled sheets of the relevant metal. The hot rolling of the cast ingots into sheets can, however, change the metal in such a way that the quality of the starting material no longer suffices for high-quality collector coins. For example, there can be adverse effects on the metal microstructure. This so-called texturizing orients the material grains in the direction of the rolling. Also, the strain-hardening makes the material harder, making it difficult to mint and necessitating an additional soft annealing process. These phenomena together lead to rougher surfaces on the stamped coins. On top of this there are economic disadvantages: The production results in a lot of residual metal which has to be melted again after the manufacturing process. Also, the thickness of the rolled sheets varies, leading to weight variations in the coin blanks. Coins may never be lighter than their nominal weight, only heavier. The high cost of precious metals means that the latter is not beneficial for manufacturers.

Pressing and sintering:
Sparkling coins from fine powders

The powder-metallurgical manufacture of coins is in itself not new. In Russia, platinum ruble coins were manufactured from powders a long time ago. The process involved multiple annealing and forging steps. As melting technology did not exist at that time, the platinum coins had to be made from powder. Nowadays there are economic and technical reasons which are again making the powder-metallurgical manufacture of coin blanks of interest. A production process developed at Fraunhofer IFAM offers coin manufacturers a viable alternative for high-quality coin production.

In a special manufacturing step the powder is first of all generated by atomizing melts using a high pressure water jet. The atomization parameters are chosen so that the yield of the serviceable powder fraction is maximized. If the resulting powder is too coarse, it is sieved and returned to the manufacturing process. The coin metal is then weighed out accurately as a very fine powder and pressed under high

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pressure into a simple round mold. Subsequently, the compacted powder is heated in a furnace under a protective gas at temperatures below its melting point and thus sintered. The material takes on the required density and is simultaneously soft annealed again. Furthermore, due to the sintering in the solid state, the finer microstructure of the powder is largely retained as is the disordered arrangement of the grains. The material is texture-free and has no preferred orientation. Together, these effects mean that more complex motifs can be manufactured at lower required pressure. The surfaces of highly texture-sensitive alloys – for example silver – can be realized in much higher quality. The lower required minting force also means that the dies have a longer service life. The rounds have weight constancy due to the accurate weighing out of the powder and this saves extra processing steps to correct the weight. When the sintering process is carried out optimally, the surfaces of the rounds are of such good quality that further treatments, the likes of which are required for rolled rounds, are not necessary.

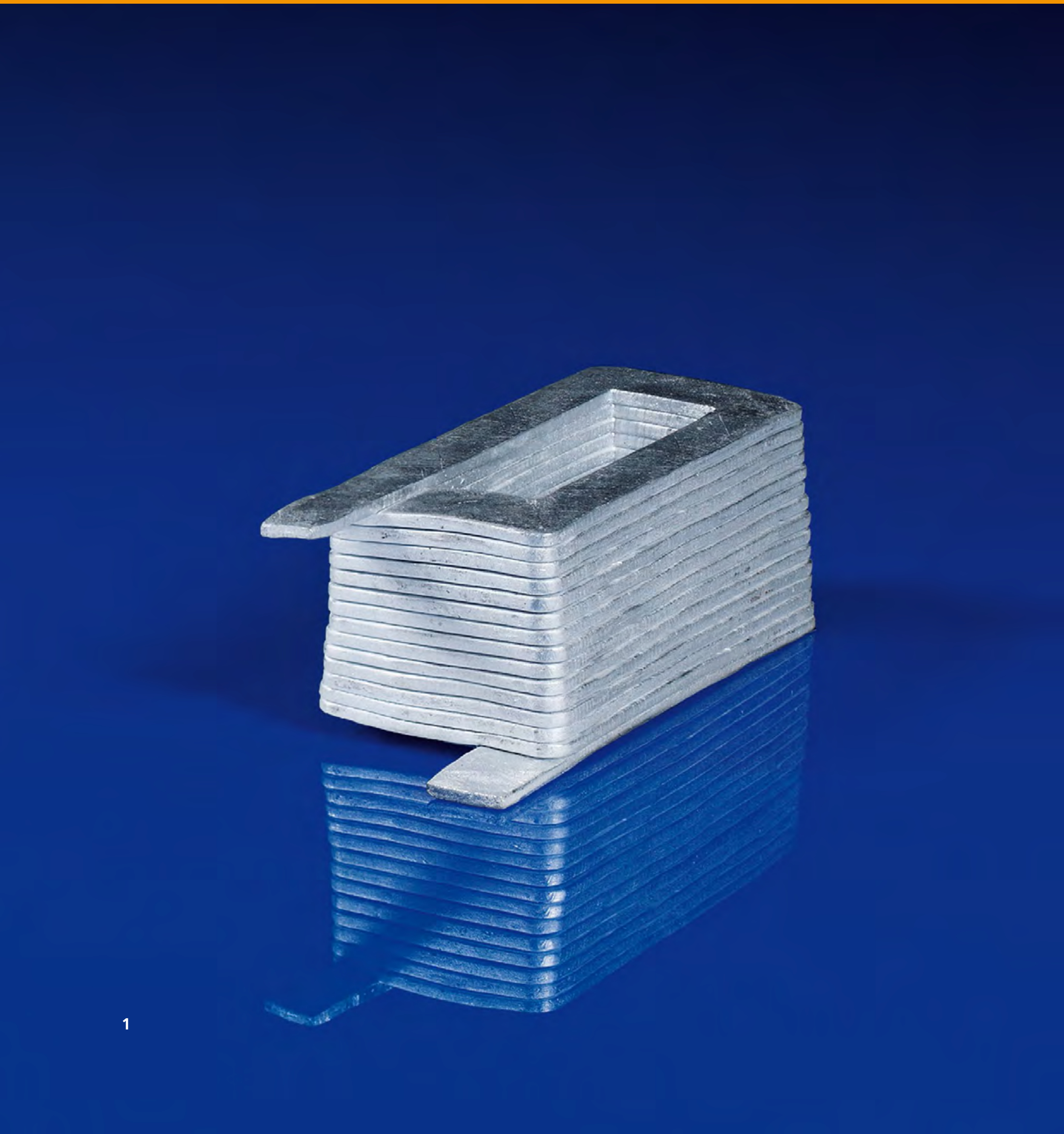
This process has been developed at Fraunhofer IFAM up to the first scale-up stage for fine silver and gold, for alloys of silver and gold, as well as for copper and copper-nickel alloy. Based on the project results, Reischauer GmbH has transferred the whole process chain from the powder manufacture and pressing through to the sintering to industrial scale at its premises ready for series production. The process is not only suitable for manufacturing of coins, it can also be used for other formed metal semi-finished products.

Project funding

The project was carried out for Reischauer GmbH in Idar-Oberstein under the Central Innovation Program for SMEs (ZIM). This was funded by the Federal Ministry of Economic Affairs and Energy.
Funding reference: KA 315 8301SU3
Project term: 1.9.2013 to 28.2.2015

1 *Coin made of PM silver (copy of a historical coin).*
2 *Test mint from a fine silver blank made via a powder-metallurgical process (King Andrew III of Hungary).*
3 *Test stamping from Ag 925, sterling silver (Martin Luther).*
4 *Production line with powder atomization plant, press, and sintering furnace at Reischauer GmbH, Idar-Oberstein.*

CASTING TECHNOLOGY



CORE COMPETENCE CASTING TECHNOLOGY

Fraunhofer IFAM supports industrial customers in the area of casting technology, from the initial idea to the final product. A variety of casting processes and materials are available for specific tasks.

Fraunhofer IFAM has wide know-how of casting technology and has an extensive range of facilities for high pressure die casting, investment casting, lost foam casting, low pressure casting, and gravity die casting. Computer simulation of casting processes and extensive analytical facilities are also available at Fraunhofer IFAM.

Die casting is the most productive casting process and has enormous potential for enhancing value creation. Key current research areas include lost (salt) cores, casting structural components, and the hybrid joining of fiber materials and FRPs with casting materials, in particular CFRP and aluminum.

Investment casting is useful for complex and delicate structures with fine surfaces. Fraunhofer IFAM possesses a number of casting plants for this work. An example of current work is the development and manufacture of cast coils for electric motors. Here, a wax model with the desired geometry is prepared or manufactured via injection molding, embedded in molding material, and then heated. The resulting hollow space is then filled with melt in the investment casting plant.

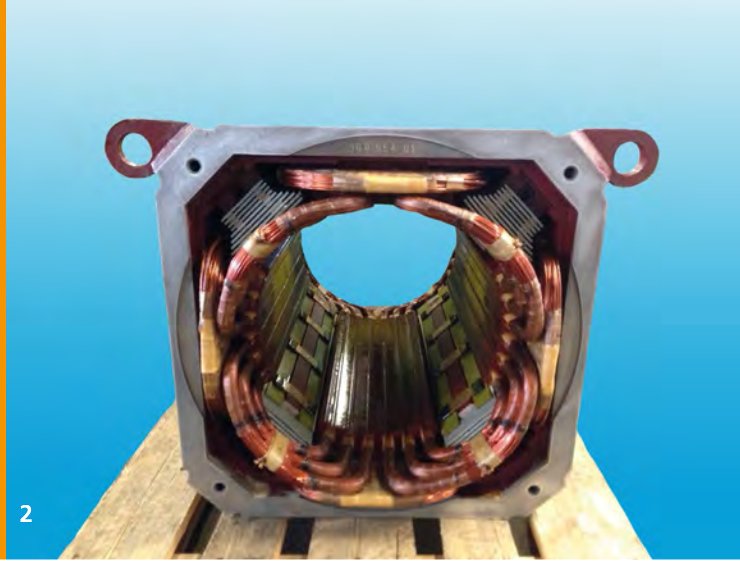
Lost foam technology is used for casting large and small parts of high complexity directly as near net shaped parts. The method allows complex components to be manufactured with any design of internal channels and undercuts – without demolding grooves or burrs. Low pressure casting is used to manufacture high-quality cast components, with a choice between permanent molds and lost molds. When the melting furnace is pressurized, the melt passes via a feed tube into the mold. This enables steady, uniform mold filling with high reproducibility and small amounts of return material. The versatile low pressure casting plant has an interchangeable crucible system which allows the casting of aluminum, steel, grey-iron, and copper as well as non-metallic melts, for example for manufacturing salt cores.

The casting materials used include aluminum, magnesium, zinc, copper, steel, and customer-specific alloys. In addition, special materials such as metal-matrix composites are developed and improved, opening up new applications for casting and cast components.

The in-process integration of functions, whereby electronic components such as sensors and RFID transponders are being embedded into components during the actual casting process, is also gaining increasing importance at Fraunhofer IFAM. So-called CAST$^{\mathit{TRONICS}®}$ technology allows advanced electronic, sensor, and actuator functionalities to be integrated into cast components.

→ **www.ifam.fraunhofer.de/castingtechnology**

1 *Cast coil made of aluminum.*



COILS MADE OF ALUMINUM INSTEAD OF COPPER – LOW PRICED, LIGHT, AND EFFICIENT

In collaboration with Lloyd Dynamowerke GmbH & Co. KG (LDW) in Bremen, Germany, Fraunhofer IFAM has manufactured for the first time aluminum coils for a large electric motor using the lost foam process and installed these in industrial machinery. The result is a technically improved alternative to traditional wound copper coils. The fill factor and cooling performance are enhanced using the design freedom of casting technology. The use of aluminum coils also means a huge reduction in the raw material costs as well as reduced weight and lower overall losses of electric motors.

Lost foam casting has been used by Fraunhofer IFAM to manufacture the complex shape of coils as cast components, with key advantages over all the winding techniques. The main challenge for the casting process was the small thickness (4 mm) relative to the long flow distance (700 mm) of the castings geometry. For the pouring, the polymer foam pattern is first coated and afterwards covered with binder-free molding sand (quartz sand). Decomposition of the pattern by the hot melt results in production of the cast component. In order to surround the pattern all over with molding sand, the conductor geometry is stretched and is fitted with a gating system. The bending radii that must be maintained for conventional winding technology do not apply here. The design freedom of casting technology allows slot fill factors of up to 90 percent to be realized. Wound coils, in contrast, normally only have slot fill factors of up to 50 percent.

Lloyd Dynamowerke GmbH & Co. KG installed four of these lost foam cast coils in a 330 kW direct current motor for a crane and evaluated this on a test stand. Despite the lower specific electrical conductivity of aluminum, the electrical resistance of a cast coil is similar to that of a wound copper coil due to the increased slot fill factor. Besides maximizing the conductor area, the geometric design of the cast commutator pole coils improved the heat dissipation from the commutator poles. As such, the temperature rise of the commutator poles during continuous operation could be decreased from 75 to about 45 kelvin. Due to the lower temperature there was simultaneously a slight reduction in the total losses in the motor.

For the example of the direct current motor of LDW, the raw material costs for the aluminum coils compared to conventional copper coils were reduced from 52 euros to 6 euros per coil. The weight of the motor was also reduced by about 50 kilograms.

1 *Cast aluminum coil for Lloyd Dynamowerke GmbH & Co. KG.*
2 *Direct current motor (330 kW) for a crane with four cast commutator pole coils made of aluminum.*

HIGH-TECH FROM SALT – CAST SALT CORES OF COMPLEX GEOMETRY

Lost cores made of salt – a key technology for manufacturing cast components with complex internal geometry, voids, and undercuts. Their manufacture has hitherto largely been limited to very simple geometries with the salt cores made via a pressing process or via gravity die casting or pressure die casting. Using lost foam casting, it is now possible to manufacture complex salt core geometries whilst simultaneously reducing plant corrosion. The low pressure casting process is also being investigated for the economical manufacture of hollow cast salt cores.

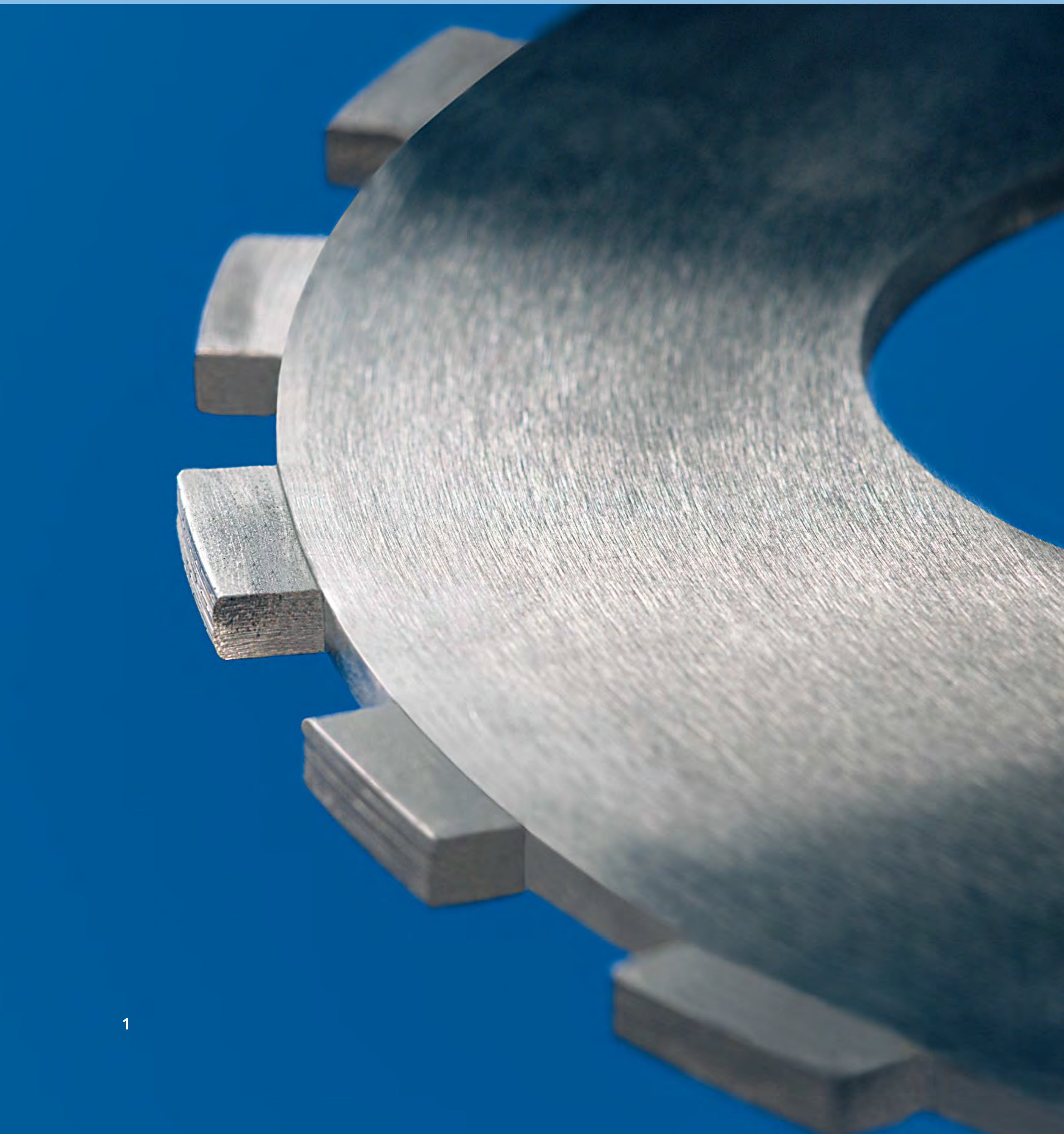
When cast components of highly complex geometry are required, for example with integrated channels for water cooling, lost foam casting offers maximum freedom. Fraunhofer IFAM scientists have now succeeded in also using this process for manufacturing salt cores. Complex-shaped salt cores with voids, undercuts, or a porous support structure, having at the same time a stable, closed, outer skin, can now be manufactured. Small, detailed structures and also large, heavy structures up to 50 kilograms in weight can be manufactured. The method is particularly economical for prototypes and small numbers of work pieces.

A special feature when using the lost foam method to manufacture salt cores is the ability to realize supporting, sponge-like, and porous internal structures whilst at the same time having a closed, solid outer skin. The advantages are the easy removal of the lost core and low weight, plus lower salt usage. The surface structure of the salt cores can be freely varied. As such, the flow properties of media in channels (oil ducts, water jackets, etc.) can be customized. The lost foam process does not require metal permanent molds or steel casting chambers which are exposed to highly corrosive salt melts during the manufacture of salt cores using die casting. There is less wear and hence less plant maintenance is required.

A further innovative approach for manufacturing salt cores is also being pursued at Fraunhofer IFAM. This involves low pressure casting as an alternative to pressure casting. The advantages are the reproducibility and high quality of castings due to the laminar and controllable mold filling with the salt melt. The isolated and encapsulated melting furnace reduces plant corrosion. Low pressure casting also allows, via return of the melt, the manufacture of hollow cast salt cores with a solid outer skin.

1 *Lost foam salt cores with optional porous support structure.*

2 *Lost foam salt core and resulting pressure cast component with void including surface structuring after removal of the salt core.*



CORE COMPETENCE ADHESIVE BONDING TECHNOLOGY

Adhesive bonding refers to a manufacturing method, belonging to the group of joint processes, that involves the joining of substrates using an adhesive to form a material-fit joint. Over recent decades, adhesive bonding has become ever more widely used by a host of industries. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM realized the potential of adhesive bonding technology at an early stage and developed this as a core competence. Fraunhofer IFAM is internationally recognized in this field and is the largest independent research organization in Europe working in this area.

The core competence Adhesive Bonding Technology at Fraunhofer IFAM involves development and characterization of materials, development and usage of various application techniques, design and validation of structures, as well as in-depth quality assurance.

The institute has a wealth of experience regarding the modification of polymer systems as well as the development of adhesives and sealants. Challenges such as adhesion promotion and protection against aging form part of the portfolio as do the development and use of biomimetic adhesives. For characterizing adhesives and bonded joints, a wide spectrum of chemical, physical, and mechanical test methods is utilized. The aging behavior and service life of bonded joints are often key aspects.

The integration of adhesive bonding technology into industrial production requires an application method adapted to the specific utilization. To achieve high-quality bonded joints, it is often necessary to pre-treat the substrate surfaces. The substrates are cleaned and activated or modified to enable the adhesives to adhere to the substrates with good long-term stability. Process automation, including tolerance-specific production methods, is important in many industries. Also important are the design of bonded joints and the dimensioning of bonded structures. This is based on experimental parameters for materials, joints, and components determined in an accredited test laboratory, taking into account the specific boundary conditions of the application.

The institute provides consultancy on all matters relating to adhesive bonding technology. Optical methods, in-line analyses, and a wide variety of destructive and non-destructive test methods are used for quality assurance purposes. An established and comprehensive portfolio of training courses in adhesive bonding technology is also offered. The certificates of the courses, which are given worldwide, are accredited and recognized in all of Europe. These courses are a further key aspect of the quality assurance concept for adhesive bonding technology.

Fraunhofer IFAM also acts as a Certification Body of the Federal Railway Authority for auditing and approving companies that carry out or subcontract adhesive bonding work, sell bonded products, or offer services regarding the designing and dimensioning of bonded components for rail vehicle construction.

→ **www.ifam.fraunhofer.de/adhesivebonding**

1 *Cutting disc with bonded on teeth.*

PASA® TECHNOLOGY – NOT ONLY FOR THE AUTOMOBILE INDUSTRY

According to ISO 9001, adhesive bonding is a process "which cannot be adequately verified by monitoring or measurements". This makes the processing of adhesives highly challenging for users because the quality of, in particular, safety-related bonded joints can only be assured by strictly complying with all the specified process-related parameters and conditions. The latter include the storage of adhesives, the mixing of reactive adhesive systems prior to the actual application of the adhesive, and the curing.

Many users would benefit from a simplified overall process which did not involve mixing and application of liquid or paste-like adhesives in the production. This can be achieved by having the adhesive pre-applied as a solid, non-tacky layer on the substrates to be joined.

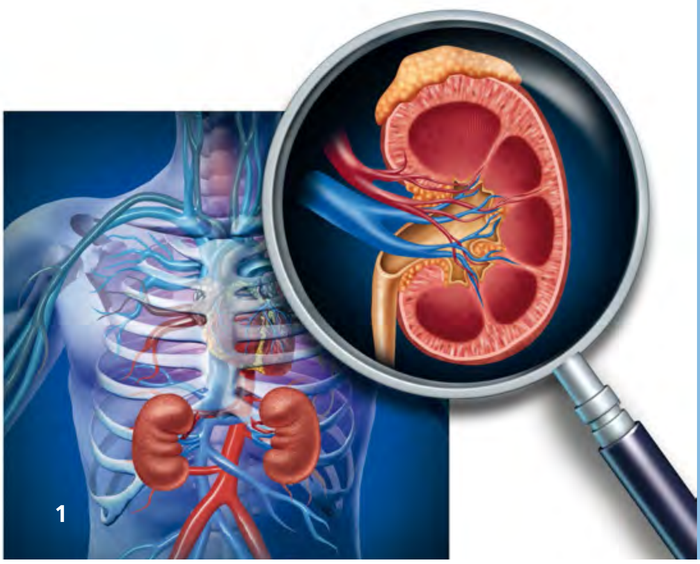
In collaboration with Tucker GmbH, Fraunhofer IFAM has commercialized a pre-applicable reactive epoxy resin adhesive system and called this technology PASA® (*P*re-*A*pplicable *S*tructural *A*dhesives).

Tucker GmbH is a major supplier to the car manufacturing industry. This company manufactures, amongst other things, threaded bolts, hundreds of which are used on vehicle bodywork. The ever increasing use of different materials for vehicle bodywork, including the use of fiber reinforced plastics, means that the securing of these bolts is often no longer possible via welding. Adhesive bonding is an alternative way, but involves considerable costs for original equipment manufacturers (OEMs) in order to realize the aforementioned demanding process. Tucker GmbH therefore approached Fraunhofer IFAM in Bremen to develop a novel adhesive which could be pre-applied to bolt heads, which is not tacky, and which could be subsequently melted and crosslinked/cured in less than ten seconds by the action of heat.

These requirements initially seemed impossible to meet, bearing in mind that the chemistry involved has limitations which cannot be altered. However, many experiments later after intense development work, we successfully developed a system that is of great benefit for both the commissioning party and OEMs alike. In 2014, this work was awarded the Joseph von Fraunhofer Prize (see Page 71).

A high number of enquiries from different industries has in the meantime demonstrated that separating the adhesive application from the adhesive curing also has processing advantages for other industries. Examples include the joining of assemblies in the electronics industry, securing of fasteners in the construction industry, and bonding onto glass.

1 *Fasteners with PASA® hotmelts for bonding onto different materials (steel, CFRP, glass, and GFRP).*



mediNiK: ADHESIVE FOR REMOVING KIDNEY STONE FRAGMENTS

In Germany ca. 750,000 people per year are treated for stones in the urinary tract. Some 400,000 of these patients undergo endoscopic intervention. The number of such cases is almost double the incidence of stroke or heart attack. The consequence is almost six million lost days of work, representing an economic loss of billions of euros.

A main issue is that the smaller stone fragments arising from endoscopic laser therapy (ureteroscopy) and extracorporeal shock wave lithotripsy (ESWL) have up until now not been able to be effectively removed. The risk of recurrence – growth of new kidney stones – is hence very high. Experts estimate a recurrence rate of more than 50 percent within just a few years of the first treatment.

The GO-Bio project "mediNiK" is addressing this issue by developing a medical adhesive for removing kidney stone fragments. A biocompatible medical adhesive for removing kidney stone residues has been successfully developed at Fraunhofer IFAM for endoscopy treatments. In close collaboration with Priv.-Doz. Dr. Martin Schönthaler and Priv.-Doz. Dr. Dr. Arkadiusz Miernik of the Urology Clinic of the University Medical Center Freiburg, the researchers aim to have the new product ready for market introduction within four to five years. This will enhance the chances of patients remaining free of stones after treatment. The mediNiK project meets the respective requirements for the development of medical products and the first phase of the project will conclude with tests in accordance with DIN EN ISO 10993 and a preclinical animal study.

The advantage of the mediNiK technology is that the adhesive application can be readily integrated into existing ureteroscopy procedures without new instruments or new procedural steps. After removing the large kidney stones, the remaining fragments are bonded to the mediNiK adhesive which is introduced via the urinary tract. The adhesive-stone conglomerate becomes so large that it can readily be removed using standard instruments. The adhesion is selective: The adhesive does not bond to either medical instruments or kidney tissue, but only to stone fragments. The polymerized and elastic adhesive gel is visible to x-rays so the urologist can see any adhesive residues. First experiments to assess the biocompatibility have shown that the adhesive components individually and in the cured state meet the requirements of DIN EN ISO 10993-5. The ex-vivo kidney model also showed that the requirements were met.

1 *Anatomy of the human kidneys. (© Fotolia/freshidea)*

2 *Macro-image of kidney stones after shock wave therapy. (© Fotolia/airborne77)*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CORE COMPETENCE SURFACE TECHNOLOGY

New materials often drive innovation and end up in key technologies of everyday life. The industrial range of uses of many materials can be considerably expanded by customized modification of their surfaces. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has long-standing and in-depth expertise in surface technology, acquired in projects with partners from a range of industries and involving many innovative products and processes.

In general, materials are designed to meet predefined property requirements, such as strength, elasticity, and heat resistance, or to meet the requirements of a production process. If components have to suit certain additional needs, this is often only possible using special surface technologies. Intelligent surface technologies such as pre-treatments and coatings are able to improve the properties of materials and components or provide them with additional functions.

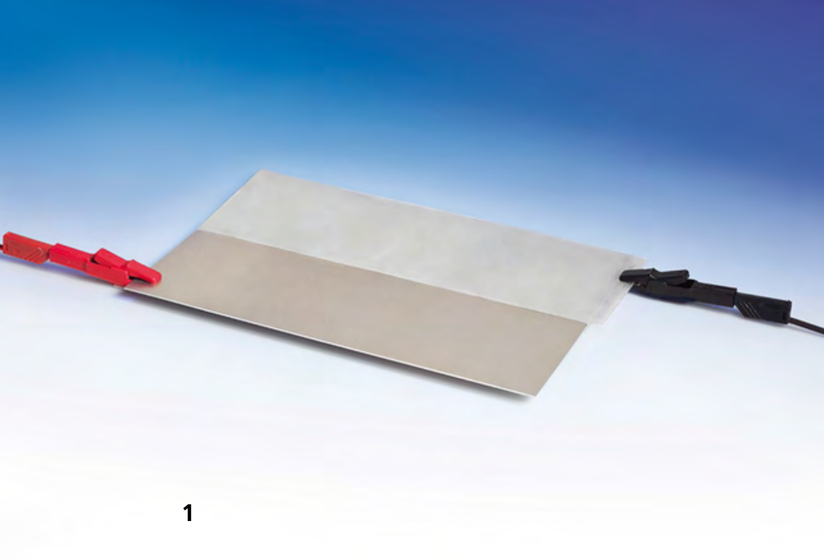
The expertise of Fraunhofer IFAM covers the whole process chain of surface technology from materials' development to the characterization and evaluation of surfaces, their functionalization and modification, and on to various application methods. The development of processes – such as dry and wet chemical pre-treatment, coating processes, printing processes, as well as thin/thick film technologies – and also quality assurance are key areas of the work. The characterization and evaluation of surfaces using chemical, electrochemical, and structural analysis is an important aspect of the institute's work, as is the application of various simulation methods.

The experts at Fraunhofer IFAM have comprehensive knowledge of customized surface modification and functionalization. This includes the cleaning as well as the activation of surfaces and the suitable pre-treatment prior to coating or bonding. The functional attributes of surfaces are very varied and depend on the respective application. Surfaces can be customized with low-drag, anti-icing, dirt-repellent, anti-fouling, antibacterial, and biocompatible properties. Specific tribological or optical requirements as well as sensor functions can also be provided. In addition, a very wide spectrum of application methods can be used, ranging from the laboratory scale to pilot plants as far as upscaling for (large) series production.

Quality assurance is an important aspect of surface technology. In-line quality assurance concepts and test methods, which allow constant process monitoring, are developed at Fraunhofer IFAM. The institute possesses accredited test facilities, which are also utilized for failure analysis. Finally, special training courses are given and there is a regular transfer of surface technologies to industrial practice.

→ **www.ifam.fraunhofer.de/surfaces**

1 *Removal of Flex$^{PLAS®}$ film from a fiber reinforced plastic component coated with a gel-coat in the mold.*



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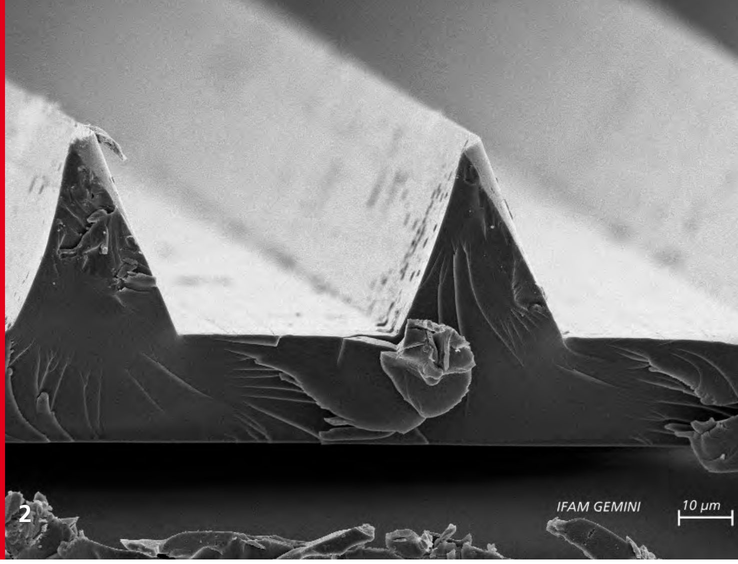

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CHARACTERIZATION OF SURFACES AND MATERIALS

Fraunhofer IFAM has built up in-depth expertise in surface technology, acquired in projects with partners from a range of industries and involving innovative products and processes. A number of current R&D areas are discussed here to give you an idea of the scope of the work in the area of surface technology. For further information see the relevant links.

Functional adhesive tapes for local pre-treatment of aluminum

Anodization is often used to treat aluminum components prior to adhesive bonding or lacquering and is usually carried out in immersion baths. A functional adhesive tape for local anodization has been developed at Fraunhofer IFAM for applications where bath treatment is impossible (repairs, reworking, treatment of large components).

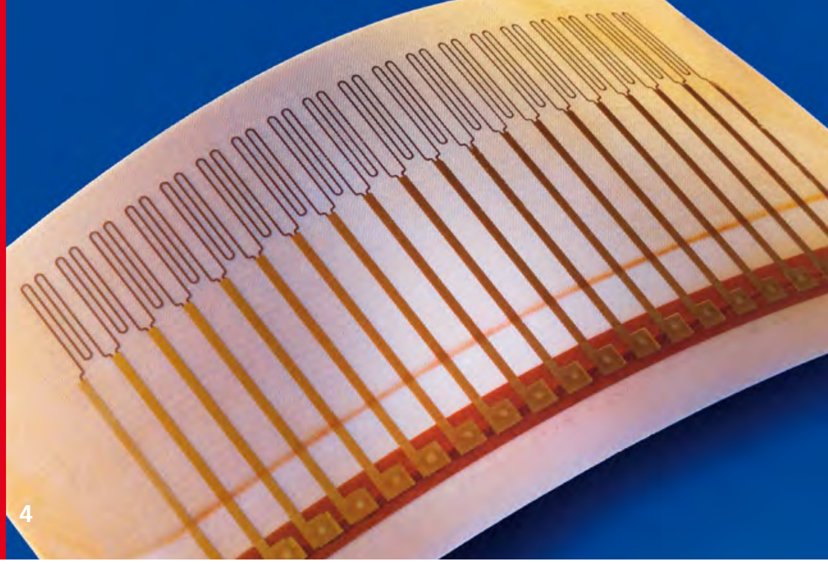
The anodizing tape is bonded to the surface to be treated and a DC voltage source is connected to the component and to the cathode integrated into the adhesive tape. After anodization the adhesive tape can be removed free of residues from the surface. The procedure is simple and effective, reducing the use of chemicals.

→ **www.ifam.fraunhofer.de/adhesivetapes**

Quality assurance of riblet surfaces

Innovative surface concepts help, for example, to reduce the drag of aircraft and consequently lower fuel consumption and CO_2 emissions significantly. In order to be able to assure the effectiveness of the surface microstructures (so-called riblets; Figure 2), any abnormal structural geometry must be detected at an early stage. Such deviations can arise, for instance, due to incorrect coating application or the effects of erosion during usage. Fraunhofer IFAM hence developed an optical system for measuring the quality of riblet coatings. This NDT technique detects even minute structural abnormalities in extremely short inspection times. Therefore, the test system can successfully be deployed for maintenance work as well as production processes.

→ **www.ifam.fraunhofer.de/en/riblet**



Anti-icing technologies

The icing of surfaces is very costly and impairs the functioning and safety of a wide range of machinery and equipment, including means of transportation such as aircraft and rail vehicles and also cooling and ventilation systems or wind turbines.

Fraunhofer IFAM develops tailored solutions to meet the relevant technical requirements. This includes heatable coatings, surfaces with poor water wetting and poor ice adhesion as well as coatings that depress the freezing point. The effectiveness of these anti-icing technologies is tested at Fraunhofer IFAM under near-real conditions. An icing laboratory with integrated wind tunnel is available for this work: Characteristic icing tests can be simulated and further research regarding ice adhesion is possible to be processed.

→ **www.ifam.fraunhofer.de/antiice**

(Combating) Corrosion of historic organ pipes

The distinctive sound of historic lead organ pipes are a feature of the famous Schnitger organs found in the northwest of Germany. Over the last 10 to 15 years, corrosion damage has become an ever greater threat to this cultural and historic treasure. A pilot project is being carried out by Fraunhofer IFAM, in conjunction with the Institute for Materials Testing (MPA) and under the leadership of the University of the Arts Bremen, to investigate the cause of the corrosion and develop protective measures. The damage is being analyzed in detail using microscopic and surface-analytical techniques in order to develop protection systems for preserving these and other organs.

→ **www.ifam.fraunhofer.de/organpipes**

Integration of printed sensors into composite materials

The integration of sensors into fiber reinforced plastics is often desirable for quality control or during usage. The Functional Printing department is developing printing processes for functional structures, such as temperature and strain sensors including lines and contacts, on and in fiber reinforced plastics. This involves printing metal-filled pastes onto tissue which can be used as an impregnatable textile layer in the FRP manufacturing process. The advantages of this approach are the minimum effect on the mechanical properties of the FRP and the customized design and production of the sensor structures which are ideally positioned on or in the component. There are applications for this technology in the aviation and aerospace industries, in car manufacturing, and for wind turbines. The work on integrating printed sensors into FRPs involved a joint project funded by the Federal Ministry of Education and Research (BMBF).

→ **www.ifam.fraunhofer.de/printedsensors**

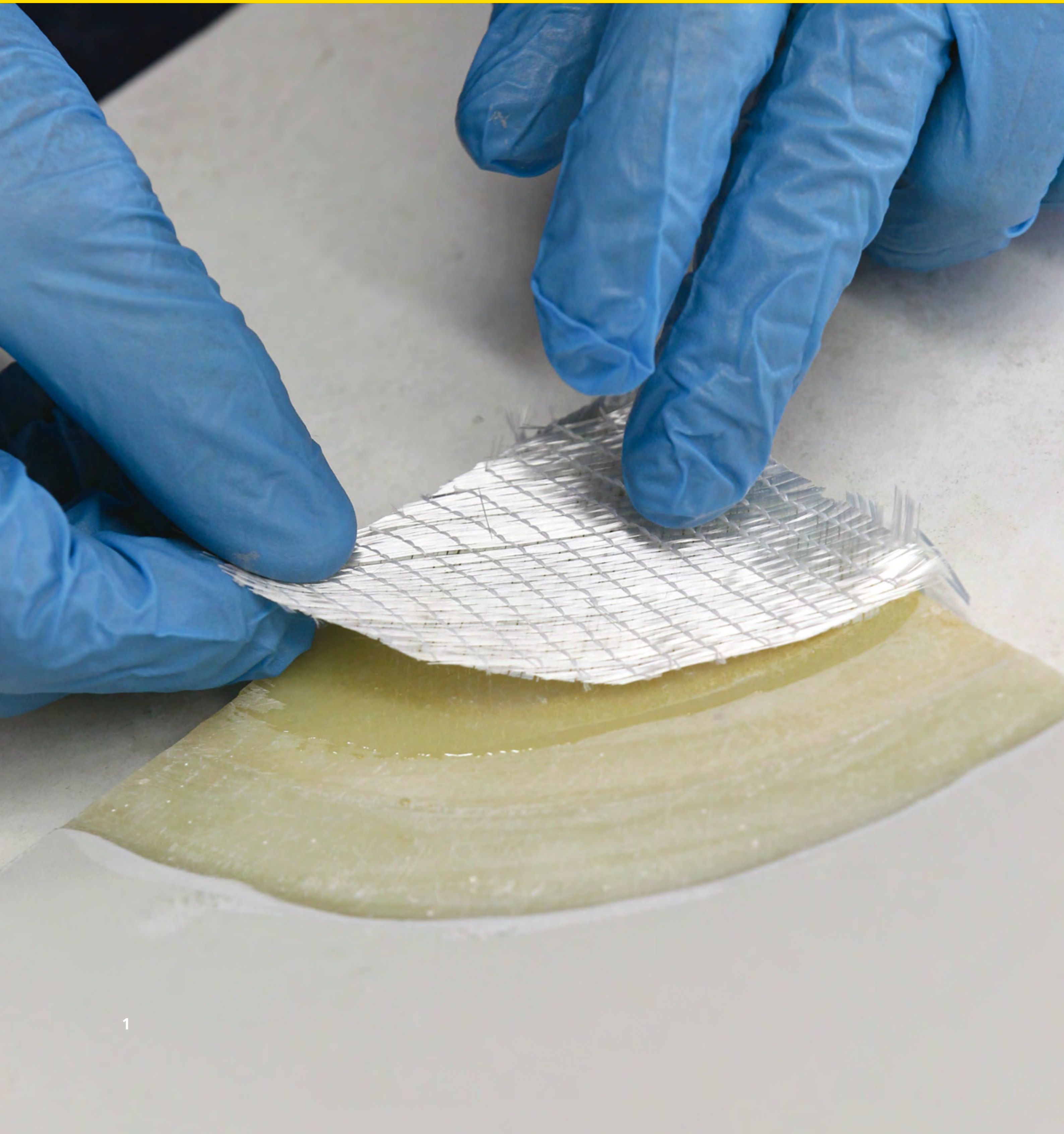
1 *Functional adhesive tape for the local anodization of aluminum.*

2 *Microstructured coating for reducing drag (riblet coating or sharkskin coating).*

3 *Historic organ in the Evangelical Church of St. Marien and Pankratius: Mariendrebber.*

4 *Sensors and lines printed on glass tissue, integrated by Invent GmbH into GFRP.*

FIBER REINFORCED PLASTICS



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CORE COMPETENCE FIBER REINFORCED PLASTICS

Fiber reinforced plastics, and in particular thermosets reinforced with glass or carbon fibers (GFRP and CFRP), have become indispensable materials for, e.g., the manufacture of aircraft and cars. In the area of renewable energy, and especially wind energy, FRPs allow energy-efficient construction methods and improve the profitability of wind turbines. The advantages of FRPs are their high stiffness in the direction of the fibers and ability of the matrix to be shaped.

The expertise of Fraunhofer IFAM in the area of glass fiber, carbon fiber, and also natural fiber reinforced plastics ranges from resin development, component design and manufacture, as well as surface modification through to technologies for automated machining and assembly.

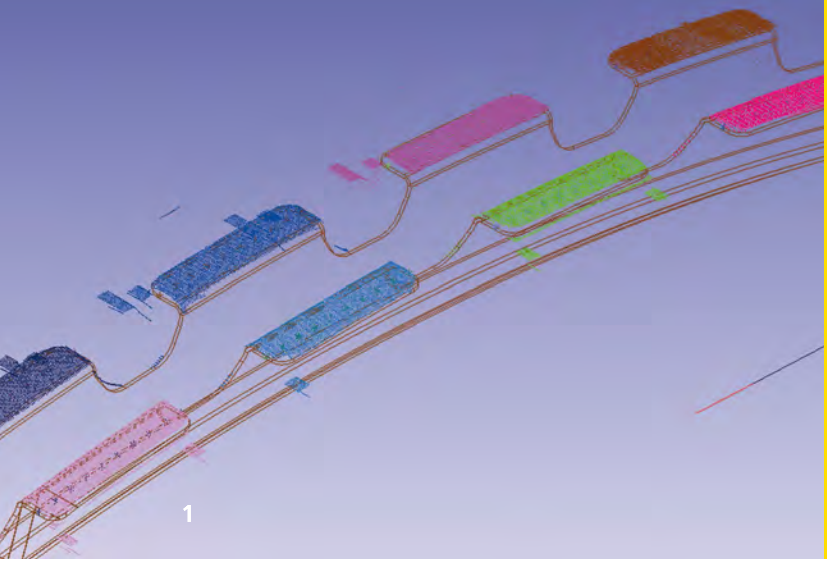
The starting point is the selection or development of suitable resin systems in order to meet the special requirements of the process such as low curing shrinkage and rapid curing. In addition, challenges such as electrical conductivity, lightening protection, and modification for impact resistance are addressed. Only with optimum adaptation of the interfaces between the fibers and matrix resin can the material properties be optimally utilized. This is achieved not least by employing a wide variety of surface techniques, for example plasma technology, on fiber surfaces. Surface modification also plays a central role in the manufacture and processing of components. Important methods in this regard are cleaning and activation, coatings, and the application of functional layers.

One of the main challenges for mass industrial production is the realization of rapid, quality assured processes via, for example, automation. A key issue is the low accuracy of shape for, in particular, large heat-cured FRP components. To address this, Fraunhofer IFAM has developed a range of automation solutions which allow precision assembly and processing at considerable time-saving, even for very large FRP structures having low dimensional accuracy. Under the motto "Precision via measurement technology and sensor systems instead of via heavy steel structures", the emphasis is put on light, mobile, and modular system components which can be adapted to different production situations without significant time or cost considerations.

Quality assurance is an absolute must in all phases – namely during the manufacture, assembly, and repair of fiber reinforced plastics. This is facilitated by Fraunhofer IFAM's comprehensive range of training courses. The workforce training courses offered also allow important technology transfer to take place, whereby scientific findings and methods are passed to industry.

→ **www.ifam.fraunhofer.de/frp**

1 *Repairing the layer structure of a glass fiber composite – a skill learned in the training courses offered by Fraunhofer IFAM.*



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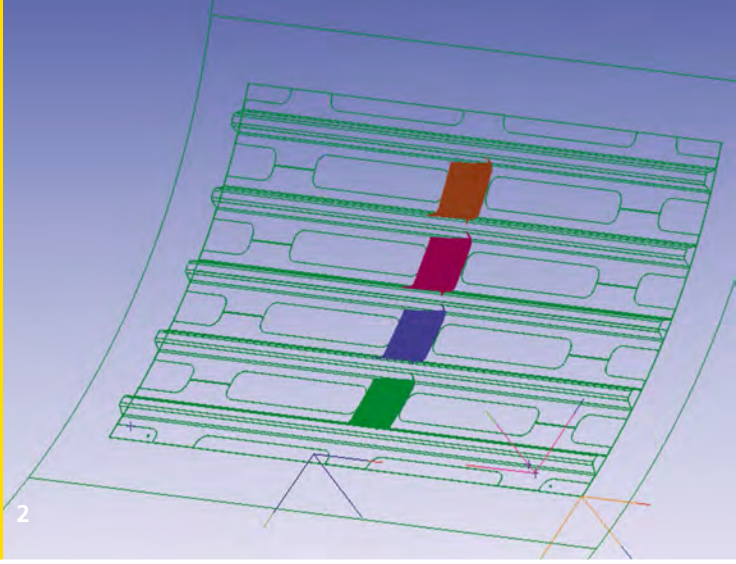


2

AUTOMATED ASSEMBLY OF CFRP FUSELAGES FOR AIRCRAFT MANUFACTURE

The Automation and Production Technology department of Fraunhofer IFAM in Stade has been involved in the project "Verification of innovative design and manufacturing concepts for fuselage sections" (VIA) funded by the Federal Aviation Research Program. Their sub-project "Automated robot-based assembly technologies for future generations of aircraft" (F-AroMon) was completed at the end of 2014. The ambitious objectives of the project were realized in full and indeed partly exceeded. The work covered the development of various automated assembly processes for aircraft fuselages made of carbon fiber reinforced plastic (CFRP) as well as the design, construction, and testing of a 1:1 scale assembly plant.

The project consortium included Fraunhofer IFAM, who carried out most of the work for the sub-project F-AroMon, and also Airbus Deutschland GmbH, Broetje Automation GmbH, and Premium Aerotec GmbH.

The objective of the project was to automate the bonding of selected CFRP frames and brackets to CFRP fuselages. The brackets were automatically joined to the CFRP fuselage of the A350 XWB and the Technology Readiness Level 6 (TRL 6) was demonstrated, which according to the TRL guidelines represents "prototype demonstration in a relevant environment".

The technological requirements on processes for the automated joining of CFRP frames to CFRP fuselage structures are aimed not just at improving processing reliability and reducing production times but also specifically at tolerance management. CFRP materials are very different to metallic materials in this regard. On demolding large CFRP components which have been cured in autoclaves, there are often differences in shape and size, to a lesser or greater degree, which must be taken into account in assembly processes. When bonding integral frames, this is observed as the non-uniform gap between the frame end and fuselage skin. In order to secure the frame in its desired final position, this gap must be filled with a 2-component epoxy resin adhesive. The amount of adhesive which must be applied depends on the gap and thus on the frame dimensions.

Experts at Fraunhofer IFAM have succeeded in replacing the hitherto manual frame assembly and gap filling, which was based on the iterative principle of trial and error, by a fully automated procedure involving surface treatment, joining, and inspection. A robot uses a laser scanner to measure the geometry of the bonding surfaces of the frame and also the relevant joining areas on the CFRP fuselage. Using this geometrical data, a software program accurately determines the gap size, without test joining being required (Figure 1).

The further process involves converting the data into information for adhesive application on the frame customized to the gap geometry. The adhesive is applied by a robot equipped with a 2-C dosing and mixing unit that was developed by Fraunhofer IFAM in collaboration with Mahr Metering Systems GmbH.

The exact automatic positioning of the curved frame on the curved fuselage skin, with optimization for all gap sizes, was a huge challenge. The Fraunhofer IFAM team solved this problem working with robotic expert Dr.-Ing. habil. Jörg Wollnack of the Technical University Hamburg-Harburg.

At the start of the project, it was already evident that the contact forces which even a large robot can provide would not suffice to squeeze the adhesive between the frame and fuselage skin to form the desired thin layer. The scientists and engineers in Stade thus designed and manufactured special frame grippers. These grippers not only mechanically pick up and position the frames but also provide automated pressing via vacuum suction pads and pressure cylinders.

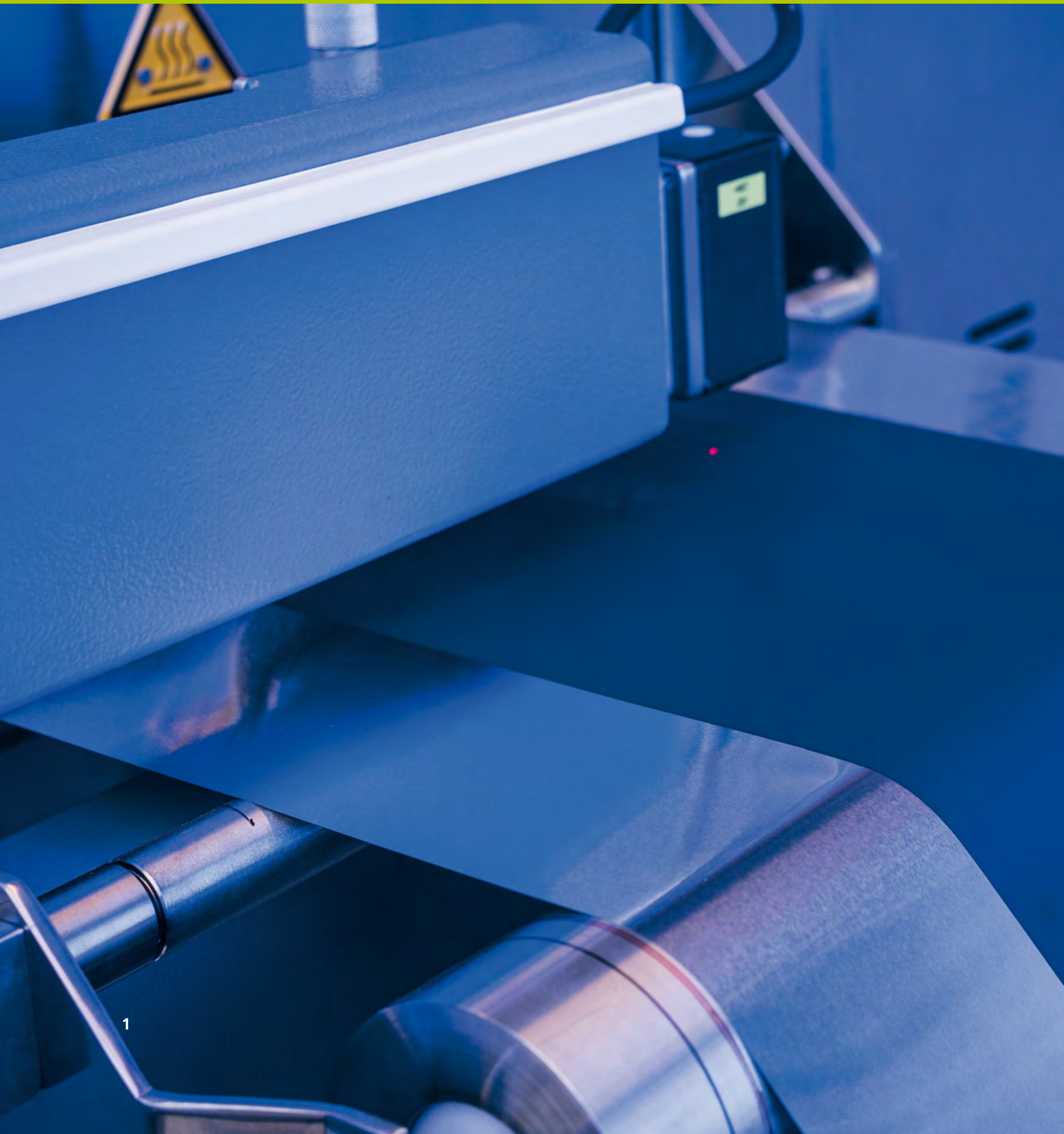
The processes were validated on the plant for assembling CFRP fuselages on a 1:1 scale that was developed as part of the project. The flexible part fixture with integrated holding robots developed by Fraunhofer IFAM in collaboration with Dr.-Ing. habil. Jörg Wollnack enables fuselage sections to be shifted, tilted, or rotated as a whole as well as adjusted locally in their shape for assembly with other components. Simultaneously the vacuum grippers measure the forces and moments for optimization of the assembly procedure (Figure 2).

Using the concept of mobile, sensor-driven robots and adaptive component pick-up for versatile automation, the team in the Automation and Production Technology department of Fraunhofer IFAM at Research Center CFRP NORTH (CFK NORD) have developed pioneering assembly systems and also shown themselves to be an ideal partner for the development of further intelligent automation concepts under the "Industrie 4.0" initiative for sectors such as the aircraft manufacturing industry, car and commercial vehicle industry, rail vehicle manufacturing industry, and the energy industry, each involving specific requirements and materials.

The acquisition and construction of the described assembly plant for project VIA, sub-project F-AroMon, was made possible with funding from the State of Lower Saxony. The three year project ran from 1.1.2012 to 31.12.2014.

1+2 *Schematic representation of the scanned frame/fuselage surfaces.*

3 *F-AroMon assembly unit with CFRP fuselage.*



1

CORE COMPETENCE ELECTRICAL COMPONENTS AND SYSTEMS

Electrically powered systems are vital in many industries and for society in general. The production and efficient usage of electrical energy in complex technical systems requires in-depth systems knowledge. Fraunhofer IFAM develops technical solutions for the efficient usage of electrical energy based on the electrical and electrochemical properties of materials.

The safe storage of electrical energy with high energy density and power is always challenging and is important particularly for mobile applications. Fraunhofer IFAM focuses on material and process related aspects to develop novel electrochemical storage systems, for example Li-ion and metal-oxygen batteries. The complete process chain starting from powder material to finished battery cells is covered when developing customer-specific materials. The processes are optimized, e.g., by using in-situ analysis techniques.

The electrical drive technology focuses on the development, prototype assembly, and testing of electric motors with high energy efficiency. Strategies for improving the functional reliability of drive systems are developed as well as efficient control systems, in particular for permanent magnetic field synchronous motors. The emphasis is on increasing the density of both power and torque and on developing special production technologies for electrical drive systems. Adhesive bonding technology, surface technology, and coatings extend our expertise needed for joining, contacting, insulating, and protecting the electrically conducting materials.

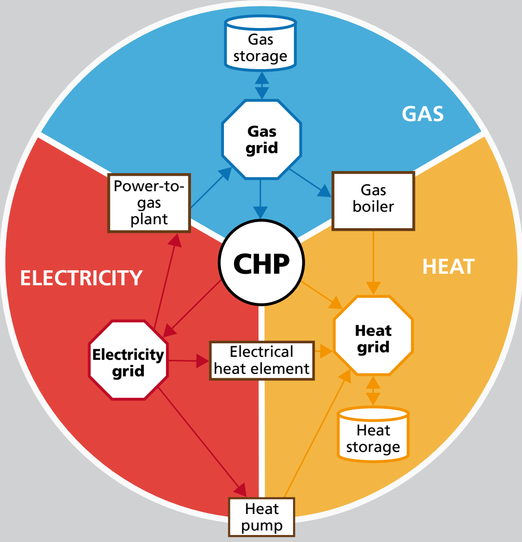
The expertise in the area of vehicle technology covers the design, efficient control, assembly, and testing of electric and hybrid drive systems for vehicles. In order to evaluate and improve operating reliability, individual components such as the electric drive shaft are being qualified by "hardware in the loop" simulation of operating performance in an engine test-bed environment. An example of the multidisciplinary approach of Fraunhofer IFAM is the casted coil. This innovative product developed at Fraunhofer IFAM brings together the expertises in casting technology, electric drive technology, and special insulating coatings.

An overarching aspect is the analysis and evaluation of complex energy systems – ideally with electric vehicles integrated as mobile storages for electric energy. Combining electrical systems with short- and long-distance heat supply at a local (home/district) and regional level, respectively, requires the use of both thermal/electrochemical storage and energy conversion systems. Fraunhofer IFAM performs studies in this area, which also take into account the commercial and recent regulatory boundary conditions for the electricity and heating market.

Finally, the integration of mobile and stationary systems for energy storage and conversion in residential environments is considered to optimize the energy efficiency and/or the energy autarky. All these activities are based on an in-depth understanding of electrical systems.

→ **www.ifam.fraunhofer.de/ecs**

1 *Roll-to-roll coating plant – layer thickness measurement of the finished electrode.*



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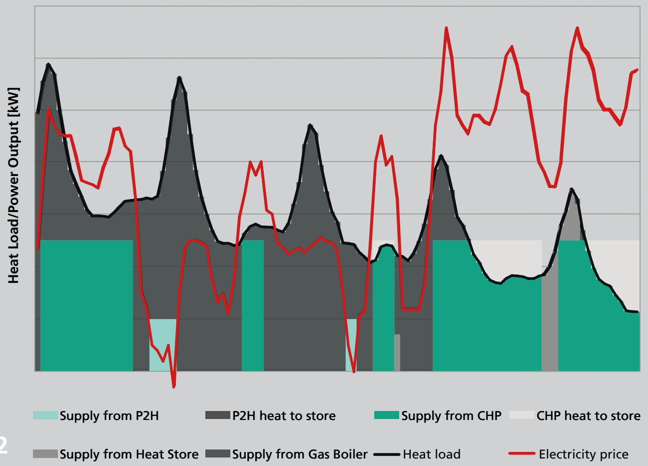


2

ELECTRICITY PROVISION: EFFICIENT INTEGRATION OF RENEWABLE ENERGIES

Electricity provision in Germany requires increased flexibility in order to be able to integrate electricity generated from fluctuating renewable energy supplies. Heat and gas grids can compensate some of the fluctuations and help stabilize a future energy supply system that comprises a high proportion of generation from renewables. The Multi-Grid-Storage project (MuGriSto) is being funded by the Federal Ministry of Economic Affairs and Energy and within the framework of this project Fraunhofer IFAM is investigating the option of heat and gas grids storing electricity when there is oversupply and providing electricity when there is undersupply.

An electric boiler, a heat pump (Power to Heat, P2H), or an electrolyzer (Power to Gas, P2G) can transfer the excess renewable electricity to a heat or gas grid. If a power plant (combined heat and power plant, CHP) is connected to the same grid, there is then the option of supplying electricity. A conversion chain comprising an electrolyzer, optionally in combination with a methanization plant, gas grid, and CHP plant can be considered to be a storage chain. The same applies, even if only for energy balancing purposes, for a chain comprising an electric boiler, heat grid, and CHP plant. In this case the heat itself is not returned but rather the gas that was saved because the heat was generated from electricity and not from gas.

The storage chains have the same function as classic electricity storage systems. The first step of the MuGriSto project was therefore to compare the efficiency and costs. The heat chains today are in some cases relatively efficient and favorable in cost.

The MuGriFlex model, which was developed as part of the project work, also calculates the interactions of the energy converters within the storage chains. MuGriFlex optimizes the electricity procurement from electric boilers and electrolyzers on an hourly basis as well as the electricity production from CHP plants (Figure 2). Excess heat and gas are stored, the residual heat demand is supplied from the storage system or a gas boiler. The hourly electricity prices and heat demand are both input values of the model. Plant parameters (plant capacity, efficiency, and fuel costs) and the energy-related framework (e.g. use of system charges, taxes, etc.) are external system variables and can be freely set. The model allows the detailed analysis of energy conversion chains with respect to commercial and technical parameters as a function of variable plant parameters and the energy-related framework. For example, current framework conditions disadvantageous for the utilization of the flexibility of heat and gas grids were identified and proposals for possible improvements were verified. These findings will be useful for the future design of the German electricity supply system with a high proportion of electricity generation from fluctuating renewables.

1 *Energy converters between the grids.*

2 *Usage planning for the MuGriFlex model.*

WHEEL HUB DRIVES WITH INCREASED FAULT TOLERANCE PASS EXTENSIVE ROAD TESTS

Electrical drives in wheels not only have design advantages and virtual freedom from wear but have promise for improving the safety and driving dynamics of electric vehicles. Having an independent drive in each wheel is however a huge technical challenge for implementation, especially in terms of safety requirements.

The advantages of wheel hub drives are obvious: The direct coupling of the drive to the wheels means they can take on functions such as electronic stability control and the anti-locking system and they allow improved cornering. On the other hand, incorrect wheel torque can present a safety risk.

In a joint project funded by the Federal Ministry of Economics and Technology (BMWi), which is coordinated by DLR, researchers from Fraunhofer IFAM and the Institute of Drive Systems and Power Electronics of Leibniz University of Hanover successfully developed advanced wheel hub drives which even guaranteed safe driving on malfunctioning of the converter. The implementation of innovative fault detection means that there is effective localization of faults. Faults with the angle sensor or current sensors are readily identified by comparing the measured and model-based values. In the event of sensor failure, the model data are used. The treatment of complications is based on a fault-tolerant design of the drive system. Consequently, any shortcomings that occur can be isolated and the braking torque compensated.

The effectiveness of the concepts was tested at the ATP test circuit in Papenburg. A prototype vehicle developed by the Fraunhofer-Gesellschaft was used for the road tests. This had two wheel hub drives on the rear axle. The permanent field motors each provided power of ca. 76 kW at a peak torque of 900 Nm per wheel.

The tests showed that safety is considerably improved, in particular for speeds in the limit region. Impermissibly high breaking torque was avoided in all driving situations. The vehicle remained controllable on fast cornering and on wet road surfaces. First estimates of the economic viability of the concepts also show that the safety measures can be integrated at no additional cost, meaning that transfer to other industrial applications is also possible.

Project title: Improvement of the functional safety of permanent field synchronous motors in traction drives – FuSy
Funding reference: 01MY12007
Project term: 1.11.2012 to 31.10.2014

→ **www.ifam.fraunhofer.de/video/fusy**

1 *Wet handling course on the ATP test circuit: Advanced wheel hub drives successfully pass extensive road tests.*

INDUSTRY-SPECIFIC SOLUTIONS

The R&D work of Fraunhofer IFAM aims to bring innovation to as many industrial sectors as possible. The focus is on the drivers of innovation in the respective industries. The most important industries are defined as individual business segments.

Aviation

The aircraft industry is facing many challenges today, including further reductions in fuel consumption, noise levels, and toxic emissions. The Fraunhofer IFAM is working together with some of the leading European players in this sector to find cutting edge solutions. These include new materials and lightweight structures. Continuing cost pressures are not only forcing these companies to find innovative ways of further automating their manufacturing processes, but also the operators need to develop new and effective solutions for MRO.

Automotive

The Automotive business segment at Fraunhofer IFAM is aimed at car manufacturers and their suppliers. Challenges of the automotive sector are high cost pressure, the need for clear product differentiation, and in particular constant improvement of the eco-friendliness of their products. Strategies for meeting these criteria are lightweight structures and hybrid structures using new materials. In recent years, considerable emphasis has also been put on electric and hybrid drive trains. So-called electromobility is one of the key issues in the industry.

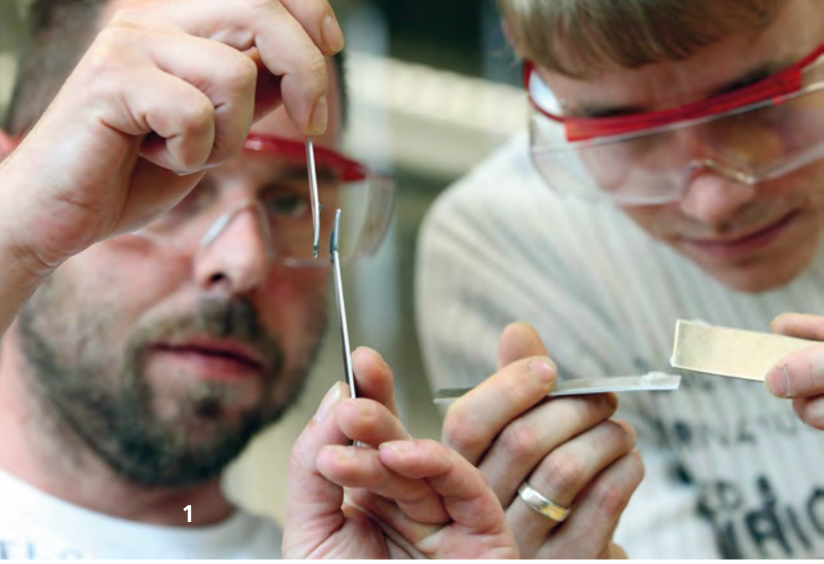
Energy and Environment

The Energy and Environment business segment focuses on companies involved in energy conversion (e.g., via combined heat and power (CHP) plants and electrolysis), energy distribution, and energy storage, thus contributing to a sustainable and reliable energy supply. The targeted increase in efficiency when utilizing electrical and thermal energy for buildings, transport, and industrial production is a constant challenge for many industries. The expertise of Fraunhofer IFAM in materials and components for storage of hydrogen and electrical/thermal energy, as well as in shaping processes and coating technology (paint, plasma) allows a wide range of solutions to be developed for companies in the energy, environment, and maritime sectors and for the construction and transport industries.

Medical Technology and Life Sciences

The medical technology area targets manufacturers of implants, instruments, and medical adhesives as well as coating companies. The focus in the life sciences area is on biological surface functionalization and biosensors. Depending on the specific application, materials must meet a large number of requirements for use in medical technology. The cleaning properties, durability, and mechanical properties must in many cases meet strict requirements.

PEOPLE AND MOMENTS



TEACHING ADHESIVE BONDING: 20 YEARS OF THE CENTER FOR ADHESIVE BONDING TECHNOLOGY

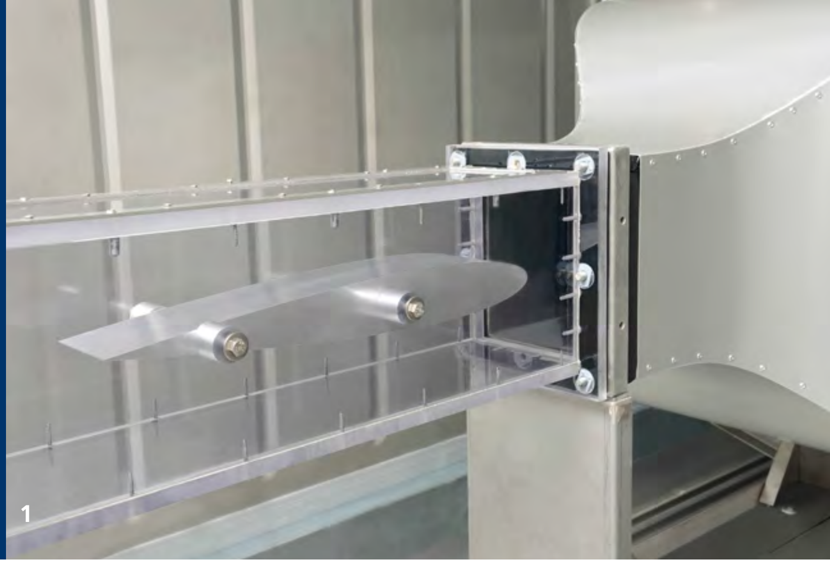
The development of new technical products is no longer possible without adhesives. Over recent years the demands on products and components have become ever greater. Indeed, they have to be smaller, lighter, faster, more environmentally compatible, favorably priced, and have an ever greater number of features. This can only be achieved by combining different materials: Wood, glass, ceramics, plastics, metals, and metal alloys. And often the only way of effectively joining these materials is by adhesive bonding. This most innovative of joining techniques is, however, of no use if nobody can correctly design a bonded product or if nobody in industry can effectively manufacture bonded joints. This is why training courses are so important.

Over the past 20 years, some 6000 people have taken training courses at the Center for Adhesive Bonding Technology of Fraunhofer IFAM. These courses are held at Fraunhofer IFAM in Bremen and at other venues in Germany and abroad. The range of training courses spans three target groups. The European Adhesive Bonder course is aimed at technical personnel who actually carry out adhesive bonding work following work instructions. The European Adhesive Specialist course is directed at employees with a supervisory/management role who prepare instructions for adhesive bonding work and instruct and monitor employees. Lastly, the European Adhesive Engineer course is for technical decision-makers. The latter course gives an overview of the many uses and interdisciplinary nature of adhesive bonding and enables appraisal of where and how adhesive bonding can best be employed. All the training courses are accredited by the Deutscher Verband für Schweißen und verwandte Verfahren e. V. (DVS) and the European Federation for Welding, Joining and Cutting (EWF).

Adhesive bonding is particularly important for rail vehicle manufacture, an industry which makes wide use of adhesives. Since December 2006, Fraunhofer IFAM has been a Certification Body of the Federal Railway Authority. There are only two such bodies in Germany. As such, the institute certifies and audits user-companies for the Manufacture of Adhesive Bonds on Rail Vehicles and Parts of Rail Vehicles in accordance with DIN 6701-2. A key prerequisite for this is that the company employees have the relevant qualifications in adhesive bonding technology.

To date, Fraunhofer experts have given courses in the USA, China, South Africa, South Korea, and Eastern Europe. The Center for Adhesive Bonding Technology has become the world leader in workforce training in adhesive bonding technology. Despite several extensions to the facilities in Bremen, giving courses abroad, and holding regular in-house seminars at companies, Fraunhofer IFAM can no longer manage the demand for the training courses alone. The solution: Contracted partners in Hamburg, Landshut, and Ulm as well as in the Netherlands, Poland, the USA, and China also carry out the courses according to the quality standards of Fraunhofer IFAM.

1 *Bonding in Bremen: Training course participants at the Center for Adhesive Bonding Technology.*



NEW ICING WIND TUNNEL ALLOWS TESTS UNDER NEAR-REAL CONDITIONS

In September 2014 the Paint/Lacquer Technology department at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM reached another milestone for testing anti-icing coatings and novel de-icing technologies: Following intense planning and construction, a large icing laboratory with integrated icing wind tunnel was officially opened in Bremen.

Preventing ice forming on surfaces is a major technical challenge. Ice formation can, for example, have serious consequences for aircraft, ships, rail vehicles, cars, cooling and ventilation systems, and wind turbines. The icing of surfaces is very costly and it impairs the functioning and safety of a wide range of machinery and equipment.

The new icing laboratory with integrated wind tunnel will be used by Fraunhofer IFAM researchers to simulate near-real icing conditions and so allow them to study the efficiency and effectiveness of new anti-icing and de-icing technologies. The test unit will allow fundamental studies on ice adhesion and icing processes to be undertaken under specific, technically relevant climatic conditions. Temperatures down to -30 °C can be simulated, along with wind speeds up to 350 km/h. An Fraunhofer IFAM-developed system for water mist introduction into the wind tunnel allows the generation of supercooled water droplets, so allowing simulation of representative scenarios for the surfaces of aircraft and wind turbines. This allows studies to be performed on the effectiveness and energy requirements of new materials using model structures.

Intensive R&D is underway to develop ever more effective technologies for preventing the formation and adhesive of ice on surfaces. One such strategy being worked on at Fraunhofer IFAM concerns the use of functional coatings. These include hydrophobic coatings containing surfactants or having nanostructured surfaces. The use of sprayable, heatable coatings is another area of ongoing research in Bremen. Highly promising for some technical applications are also coatings containing chemical or biochemical freezing point depressors to suppress or prevent ice formation on surfaces. When selecting or developing an anti-icing concept, knowledge of the relevant icing scenarios and the technical requirements on the coating material are very important.

The new test facility gives Fraunhofer IFAM scientists the opportunity to thoroughly test and optimize anti-icing technologies. This work is undertaken in collaborative project work with partners from industry and R&D organizations.

1 *Test zone with integrated wing section.*

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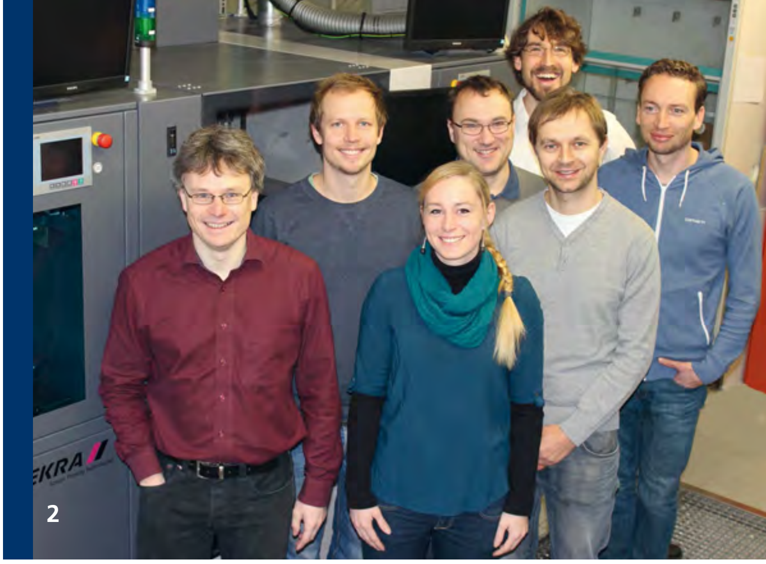

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COMMISSIONING OF THE WORLD'S MOST ADVANCED PLANT FOR 3D METAL PRINTING

October 2014 saw the commissioning of a completely new near-production-scale plant for 3D metal printing at Fraunhofer IFAM.

Three-dimensional screenprinting is an innovative advanced development of classic industrial screenprinting. A metal powder based paste is pressed through a mesh (screen) layer by layer. The resulting 3D structures are then solidified into the final products by heat treatment.

This technique has a wide range of industrial applications in Germany, for example for medical technology, new electrical drive concepts for cars, in chemical engineering and process engineering, in the development of cooling units for energy technology, and for magnetic materials.

The innovative plant was developed in collaboration with EKRA Automatisierungssysteme GmbH, a member of the ASYS GROUP, and gives Fraunhofer IFAM Dresden a facility for the latest 3D metal printing process and simultaneously supports the institute's work over recent years in additive manufacturing.

The plant is customized for 3D screenprinting and sets new standards for process technology. For users it means new products for subsequent commercialization. Concepts for quality assurance and process monitoring have hence been incorporated as standard in the classic screenprinting production lines at EKRA/ASYS for the automotive and photovoltaic industries.

The new plant with its two independently controlled printing tables (each 300 x 300 mm^2) is very versatile. A range of parameters can be set and combined with highly precise screen positioning.

As the tables themselves can be operated in parallel with different print settings, development work is considerably faster and productivity is doubled. Other features such as a control-climate process chamber, the ability to use both water and solvent based systems, and optional IR or UV curing guarantee that the 3D screenprinting plant will meet the R&D needs of Fraunhofer IFAM Dresden. This revolutionary plant will also open up new applications. In addition to component and process development, the emphasis will be on further productivity increase and quality assurance in order to support users with industrial implementation and also offer customers the starting point for their own screenprinting line. The installation of the new 3D screenprinting plant is a further milestone for the area of additive manufacturing at Fraunhofer IFAM in Dresden.

1 *New near-production-scale plant for 3D metal printing at Fraunhofer IFAM Dresden.*

2 *The 3D metal printing work group at Fraunhofer IFAM in Dresden.*

1

MINISTER-PRESIDENT OF THE STATE OF LOWER SAXONY VISITS CFRP NORTH

In July, Minister-President Stephan Weil visited Research Center CFRP NORTH (Forschungszentrum CFK NORD), which was funded by the State of Lower Saxony. Dr. Dirk Niermann, head of the Automation and Production Technology department at Fraunhofer IFAM, informed his guest about ongoing and future development work, such as the interaction between people and robots in the processing of carbon fiber reinforced plastics (CFRPs).

The State of Lower Saxony provides the majority of funding for a variety of projects. The work has been very successful. Groundbreaking technologies have become available, in particular for Lower Saxon companies such as Airbus, Premium Aerotec, and their suppliers. This has secured jobs and maintained company competitiveness. The technologies are already being readied for series production. The Fraunhofer approach is to develop innovative products and technologies for use in as many industries as possible, meaning that the results from the work in Stade can be transferred to other sectors. The Fraunhofer IFAM team is working here on solutions for the automation of joining and machining technologies for lightweight structures. The first aim is more efficient automated processing, and in particular effective collaboration between humans and robots.

Three major projects have been completed on assembly, machining, and component handling, with groundbreaking results being achieved. For example, using relatively cheap standard sensor-driven industrial robots for up to 13 meter long CFRP components, an accuracy has been reached which hitherto was only known for much more expensive and steel-reinforced special machinery. In collaboration with the TU Hamburg-Harburg, Fraunhofer IFAM has succeeded in using these robots sufficiently precisely by using sensors and software which act like a “correcting lens”. As such the robots can respond and individually adapt to the relevant production process. Up until now each CFRP component in the production has needed a customized, stiff steel holder which must be precisely manufactured and therefore is more expensive. Using the new versatile component handling system with integrated holding robots, fuselage sections of differing diameter can now be custom-shaped for assembly with other components. A further example of versatile production is a plant which mills and drills large CFRP components with high precision using three industrial robots from different manufacturers.

The robots obviate the need for unpleasant and unhealthy work by humans, such as lifting heavy loads, non-ergonomic body positions, and dust and noise. Robots and people complement one another perfectly even when there are very high requirements on precision and speed.

1 *From left to right, Prof. Dr. Bernd Mayer (Institute Director of Fraunhofer IFAM), Silvia Nieber (Mayor of Stade), Stephan Weil (Minister-President of Lower Saxony), Petra Tiemann (Member of the Lower Saxony State Parliament), and Dr. Dirk Niermann (Head of Department, Fraunhofer IFAM) in front of the plant for the automated assembly of aircraft fuselages.*

"JUNIOR ENGINEER ACADEMY" IN COLLABORATION WITH MERCEDES-BENZ WORKS

On July 10, 2014 the presentation of the third "Junior Engineer Academy" of Osterholz-Scharmbeck Gymnasium took place at Fraunhofer IFAM on the subject of "Crash tests with bonded vehicle bodywork". This project was for the first time funded by Mercedes-Benz Works Bremen. Eleven pupils in the 9th grade busied themselves with the topic of adhesive bonding over a period of two school years and got a glimpse of the work of engineers.

In collaboration with scientists, engineers, technicians and trainees at Fraunhofer IFAM and Mercedes-Benz Works in Bremen, the pupils got involved with the subject of adhesive bonding technology and in a final project they evaluated the stability of bonded joints on self-built model cars in a crash test.

Prof. Dr. Andreas Hartwig (Deputy Institute Director of Fraunhofer IFAM), Dr. Lars Höper and Torben Rimasch (both from Mercedes-Benz Works Bremen), Sandra Heidemann (Deutsche Telekom Stiftung), and teachers and parents of the young engineers were present at the final presentation. The young researchers carried out all the work themselves, from the first tests at school, researching the theoretical principles, undertaking the practical tests on model cars, building a crash course at Mercedes-Benz Works, and carrying out and evaluating the bonding tests at Fraunhofer IFAM.

After analyzing the crash tests, which were recorded by a high-speed camera, the pupils concluded that various adhesives should readily be used for the manufacture of high-strength model cars. The enthusiasm of the young engineers for their project was most apparent in their final presentation. This interest in engineering work and technical subjects has to be awakened at an early age and maintained if the shortage of career scientists and engineers in Germany is to be alleviated.

The "Junior Engineer Academy" of Osterholz-Scharmbeck Gymnasium found two willing funding partners in Fraunhofer IFAM and Mercedes-Benz Works Bremen and this will be continued in 2015 with a new JEA.

The JEA project at Osterholz-Scharmbeck Gymnasium was initiated in 2005 by the Deutsche Telekom Stiftung and was funded up to 2012. Since then Mercedes-Benz Works Bremen has supported the school to enable this program to be continued. During the two-year program, the pupils do not only learn technical matters. They also have exposure to workshops on presentation techniques and project management and they experience the world beyond school. This is excellent for personal development – as evidenced by the statements of the pupils themselves.

1 *Pupils of the 9th grade at Osterholz-Scharmbeck Gymnasium successfully completed the "Junior Engineer Academy" in collaboration with Fraunhofer IFAM and Mercedes-Benz Works Bremen.*

1

JOSEPH VON FRAUNHOFER PRIZE FOR PRE-APPLICABLE ADHESIVES

Prof. Dr. Andreas Hartwig, Dr. Matthias Popp, and Dipl.-Ing (FH) Andreas Lühring of Fraunhofer IFAM have successfully separated the adhesive application step from the actual substrate joining process. Pre-Applicable Structural Adhesives (PASA®) represent an effective and favorable-cost joining method and open up totally new applications for industry. For their innovative development work the three researcher were presented with the Joseph von Fraunhofer Prize 2014 at the Annual Meeting of the Fraunhofer-Gesellschaft on May 21.

In order to find a way of eliminating the need to apply liquid adhesive to fasteners prior to joining, the automotive supplier STANLEY Engineered Fastening – Tucker GmbH in Gießen turned to researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen. They came up with the idea of initially applying adhesive to one of the substrates, which after drying forms a non-tacky layer. The actual joining of the substrates and the adhesive curing subsequently take place in a later production step.

This principle was already used for non-structural adhesives. Indeed, even very early postage stamps were coated with an adhesive. Only after moistening could they then be stuck onto envelopes. Fraunhofer IFAM researchers have now successfully advanced this technique to allow high-strength adhesive joints to be manufactured for industrial applications. This was not an easy task because the adhesives have to fulfill different and sometimes contradictory requirements. Once the adhesive has been applied and has dried it must not be tacky and it must be able to withstand long storage times without the onset of curing. The adhesive also has to be very reactive and cure quickly once the substrates are joined. The solution: To combine a resin and hardener that melt at different temperatures, plus micro-dispersion to finely distribute the hardener.

The resulting reactive hotmelt adhesive can be used, for example, for the manufacture of fastening bolts. First the material is heated and then applied to the fastener. On cooling it solidifies again. The adhesive-coated fasteners can then be transported and stored. To cure the actual adhesive, it must be heated to more than 150 °C. Only then is the actual hardener melted and the adhesive curing initiated. In this way, the two substrates can be firmly joined to each other within seconds.

There is one disadvantage to reactive adhesives like these – they can be stored for a long time, but not indefinitely. That is why the researchers have incorporated a visual means of monitoring the state of the adhesive – on losing its functionality, it changes color.

These pre-applicable structural adhesives (PASA®) are also suitable for a host of other applications, including for wafer processing and local reinforcement of sheet components. In the meantime a "construction kit" of such systems has become available, covering different raw materials and different curing/hardening principles. Fraunhofer IFAM experts have altered the compositions of the adhesives so that they allow the best possible productivity and have optimal features for a wide variety of applications.

1 *Bonding without the need for adhesive application – a revolution in industrial joining technology. From left to right, Dr. Matthias Popp, Prof. Dr. Andreas Hartwig, and Andreas Lühring. (© Dirk Mahler)*

SURFAIR AWARD FOR INNOVATION FOR ANODIZATION TAPES

On June 6, 2014 at the 20th International Conference on Surface Treatment in the Aeronautics and Aerospace Industries – SURFAIR in Biarritz, France, the project work on "Anodization tapes for the local anodization of aluminum surfaces" was recognized with the SURFAIR Award for Innovation. Shane Arthur, Senior Manager & Enterprise Leader at Boeing, presented the award to Dr. Malte Burchardt, representing the development team at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen.

Anodization is often used to treat aluminum components prior to adhesive bonding or coating. The treatment is usually carried out in immersion baths. Anodization in immersion baths is not possible for repairs during usage or for reworking in the production. This is either due to potential damage to areas that do not have to be treated or due to the size of the component. In many cases it is also not desirable to treat the whole component.

A multidisciplinary team at Fraunhofer IFAM has developed a novel concept which brings together all the materials required for anodization in a functional adhesive tape. The development team comprised Antonina Krieger, Dr. Malte Kleemeier, and Katharina Teczyk (all from Adhesives and Polymer Chemistry) as well as Lissy Berndt, Dr. Malte Burchardt, and Dr. Stefan Dieckhoff (all from Adhesion and Interface Research).

The anodizing tape is bonded to the surface to be treated and a DC voltage source is connected to the component and to the cathode integrated into the adhesive tape. A comparable treatment time and voltage in an immersion bath gives porous oxide layers of up to 1 µm thickness. After anodization the adhesive tape can be removed free of residues from the surface.

The anodization tape allows local, Cr(VI)-free treatment prior to coating and bonding. The corrosion resistance and adhesion strength are drastically improved. Practical tests gave comparable results to those achieved in immersion baths. The procedure is simple and effective and the use of chemicals is reduced. The anodization tape also allows surface pre-treatment in some cases which has hitherto not been possible. Applications include local touch-up work in the production process, repairs, and pre-treatment of selected parts of large components in instances where bath treatment is uneconomical.

1 *Shane Arthur, Senior Manager & Enterprise Leader at Boeing, presents Dr. Malte Burchardt with the SURFAIR Award for Innovation. (© M. Pascal Guittet, Infopro Digital)*

2 *SURFAIR Award for Innovation.*

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ACADEMIC R&D AWARD FOR PRINTED THERMOELECTRIC DEVICES

The research team involved in the project "Printed thermoelectric devices for energy harvesting" was presented with the Academic R&D Award at Printed Electronics 2014 in Berlin. Dr. Volker Zöllmer received the award on April 1, 2014 on behalf of the Functional Printing department of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM. As part of the award ceremony he presented the main results of the work, outlining the extent to which energy can be supplied to sensors from temperature differences and giving examples of potential applications for printed thermoelectric devices.

The Fraunhofer scientists in the Functional Printing department are collaborating with the Chair of Prof. Dr.-Ing. habil. Matthias Busse at the University of Bremen in the area of energy harvesting. Wireless sensor networks can help here to monitor safety-related components. In order for the sensors to work in an optimal way they must be applied directly to the surface of the components or even integrated into them. Power is normally supplied via cable or battery. The limited storage capacity and service life of batteries as well as their recycling are key issues for users. Experience has proven that the design of an application is significantly defined by a replaceable battery and this limits the design freedom.

For sensor networks to be supplied with energy from energy harvesting, they must require very little electricity. If the sensors in smart networks are only active when sending and receiving data, only milliwatt quantities of power are required. This quantity of power can be provided, for example, by printed thermoelectric devices which convert ambient heat into electricity. The Fraunhofer IFAM researchers are using new additive production methods to manufacture customized generators.

Additive manufacturing processes allow sensors, sensor networks, and elements for the energy harvesting such as thermoelectric devices to be produced: The direct deposition of structures made of functional inks and pastes using ink-jet, aerosol-jet, screenprinting, and dispensing methods is not only able to functionalize various surfaces with electrical circuits and sensor elements, it is also possible to generate structures which harvest energy. The purposeful combination of metallic and thermoelectric materials, applied successively, allows structures to be manufactured which can be used as thermoelectric generators. The big advantage: The printed thermoelectric devices can be precisely adapted to the technical surfaces. This makes the sensors less liable to develop faults because the energy provision can be adapted to the relevant requirements.

1 *Dr. Volker Zöllmer and his department received the Academic R&D Award for their printed thermoelectric devices.*

NAMES | DATES | EVENTS

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The R&D activities of Fraunhofer IFAM focus on materials and manufacturing technologies. There is a strong emphasis on practical applications with much of the work involving collaborative projects with partners from a wide range of industries. Scientific excellence in core competencies provide the basis for this.

Collaboration with universities and technical colleges

Close collaboration and networking with universities and technical colleges are important for Fraunhofer IFAM. We have particularly close links with the University of Bremen and TU Dresden.

During the 2014 summer semester and 2014/2015 winter semester, researchers at Fraunhofer IFAM gave over 40 teaching courses amongst others at the University of Bremen, TU Dresden, University of Applied Sciences Bremen and University of Applied Sciences Bremerhaven.

Scientific publications and presentations

Over 300 publications during the year documented the R&D work of Fraunhofer IFAM, confirming its strong position within the academic community. This is further emphasized by awards and prizes bestowed on the employees of the institute.

In 2014, Fraunhofer IFAM scientists participated in many conferences, trade fairs, and seminars. The main part of the active contribution (in the form of talks or posters) were given through the year within Germany. The ever greater international networking of the institute is indicated by the fact that most presentations were given at events in foreign countries. The institute also regularly organized its own events.

1 *Fraunhofer IFAM, Bremen.*

Patents

Patents document the ability of an organization to innovate. Fraunhofer IFAM was granted 12 patents in 2014, surpassing the high number of previous years.

Detailed information about:
- conferences, seminars, and workshops
- scientific publications (Ph.D. theses, publications, presentations, and posters)
- patents and
- awards and prizes

can be found on the Internet at:

→ **www.ifam.fraunhofer.de/nde**

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