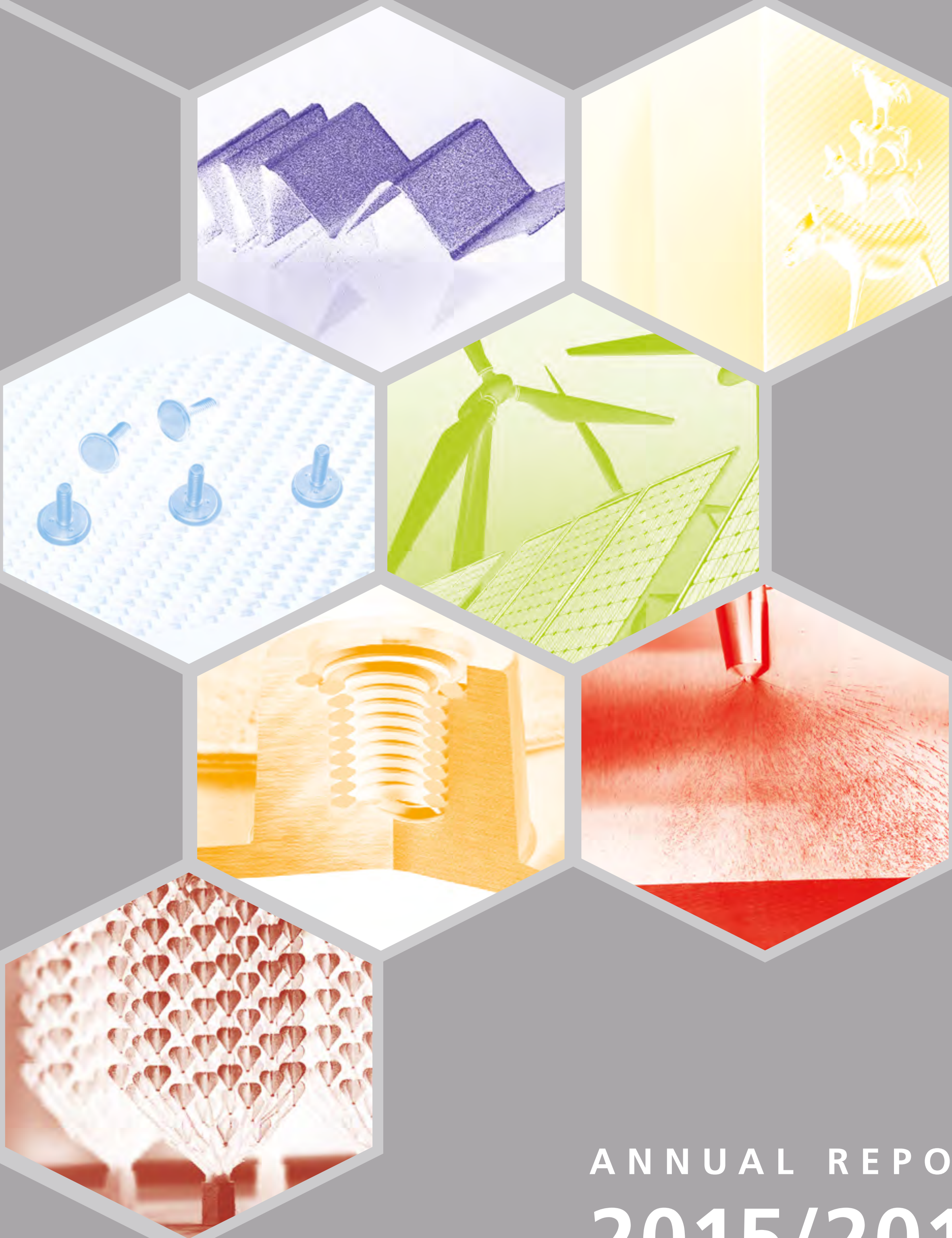
Fraunhofer

IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM



ANNUAL REPORT

2015/2016

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FOREWORD

Dear Reader,

2015 was a successful year for the Fraunhofer IFAM. As our institute has grown, so has our need for more space to advance in our specific R&D areas. The highlight of summer 2015 was the grand dedication of the building extension at our Bremen location. With 6,200 square meters of the most modern laboratories and offices, the new building has workspace for 60 scientists. To strengthen Bremen's scientific emphasis on materials sciences, the building was joint-financed, with equal contributions from the Land of Bremen and the federal budget. This third extension of the institute in Bremen facilitates our future expansion into new areas such as fiber-reinforced materials construction, energy, multi-functional coating systems and electromobility. Several strategic investment projects have been initiated to build up the instruments and equipment we have available for our expansion.

Our guiding principle for the building's design was its integration into the university campus and the adjacent technology park. The architecture of the extension is characterized by open research and work areas, providing plenty of space for discussion and exchange. A 30-meter glass bridge connects the newly constructed building to the main building. This bridge symbolizes not only the path to new horizons, but also the possibility of cooperation by bringing together researchers from different specialties. Research into complex processes and development of innovations that are relevant for society require close cooperation between the sciences, economics, and politics.

The Fraunhofer IFAM is proud to present the newly established joint professorship in the area of Production Technology at the University of Bremen. Prof. Fabio La Mantia conducts research in the field of energy and energy conversion systems and is now applying his scientific expertise in our Electrical Energy Storage department in Oldenburg. Just as important for the future of our research, the junior staff group NanoMatFutur was approved by the Federal Ministry of Education and Research for Dr. Katharina Koschek. For the next four years, this scientific team will be researching fiber-reinforced plastics that can be reversibly formed using external impulses. Cooperation with universities does a lot for our institute by strengthening our scientific focus areas and promoting more connections in the scientific community. This applies not only to our collaborations with the University of Bremen, but also with the Technical Universities of Dresden and Hamburg-Harburg. Every year, these university cooperations result in a great many papers and theses sponsored by the Fraunhofer IFAM.

With the launch of the Fraunhofer Project Center in Wolfsburg as part of the public-private partnership "Open Hybrid LabFactory (OHLF)" under the leadership of the IFAM, an extraordinary network was successfully initiated. At the new project center, the three Fraunhofer institutes WKI, IWU, and IFAM work together using their specific competencies and are closely connected to other research institutes and enterprises in the region. The objective of these researchers is to find system solutions for the serial production of cost-effective lightweight construction components that can save resources. For the Fraunhofer IFAM as the leading institution as well as for the entire Fraunhofer-Gesellschaft, this form of organization is unprecedented.

The projects in the aviation business segment are also addressing important materials science questions. The work done by the EU-funded SARISTU project is an example of our systems and solutions expertise "from material to use". Leading up to the final step of validation in the wind tunnel, the steps of the component development began with the specifications of the aerodynamic loads using finite element analysis. The intervening steps included the assessment of the resulting material requirements shown by this analysis, followed by material development, component production, and integration solution

1 *The directors of the institute Prof. Dr. Bernd Mayer and Prof. Dr.-Ing. habil. Matthias Busse (from left).*

1

as well as mechanical tests. Moreover, in cooperation with European airlines, substantial investment in the strategically important European aviation program "CleanSky 2" was made, focusing on the areas of automated production and functional coatings.

The medical engineering and life sciences business segment has been further enlarged and the institute's competencies have been systematically bundled. We have intensified the exchange of information with producers and everyday clinical users of medical products. Examples of this development are the new coating system DentaPlas, which helps avoid infection in dental implants; an innovative screw nail as a fixation element in cruciate ligament reconstruction; and biodegradable, porous fiber structures made of magnesium for the treatment of bone defects. The latter development will be used as a bone substitute in the jaw.

In the automotive business segment led by the IFAM, the second phase of the "Fraunhofer Electromobility System Research" program was successfully completed. For this program, one of the biggest Fraunhofer-Gesellschaft projects, a huge number of scientists from a diverse range of disciplines worked together on system solutions for six years. At the end of the current project period, many of its developments were already mature enough to be implemented in their respective industries.

The ambitious goals of the turn toward renewable energy in Germany have drawn attention to the energy and environmental business segment. In order to reach these long-term climate protection goals, we are developing additional energy supply concepts and the strategies needed to implement them. These focus mainly on energy systems for buildings, but are viable also for villages, cities, and regions.

In this annual report, we can only give you the essence of the countless projects we worked on in 2015, although many others have produced significant developments that deserve to be mentioned. Special thanks go to our passionate employees, who were intimately involved in these projects and made them successful. Their excellent research and performance in 2015 were distinguished by many different awards and reflected in myriad publications.

The institute's excellence and consistently impressive development rest on the ongoing trust of our industrial partners, our contacts in governmental ministries, and project sponsors. These three pillars are the basis of our positive results. We would like to take this opportunity to thank you for your unwavering support. We look forward to further successful cooperation, exciting projects, and fruitful collaboration. Together we can reach our goals. We hope you enjoy reading more about them in this annual report.

Matthias Busse Bernd Mayer

Matthias Busse | Bernd Mayer

CONTENTS

1 *New building Fraunhofer IFAM, Bremen (© ATP / Stefan Schilling).*

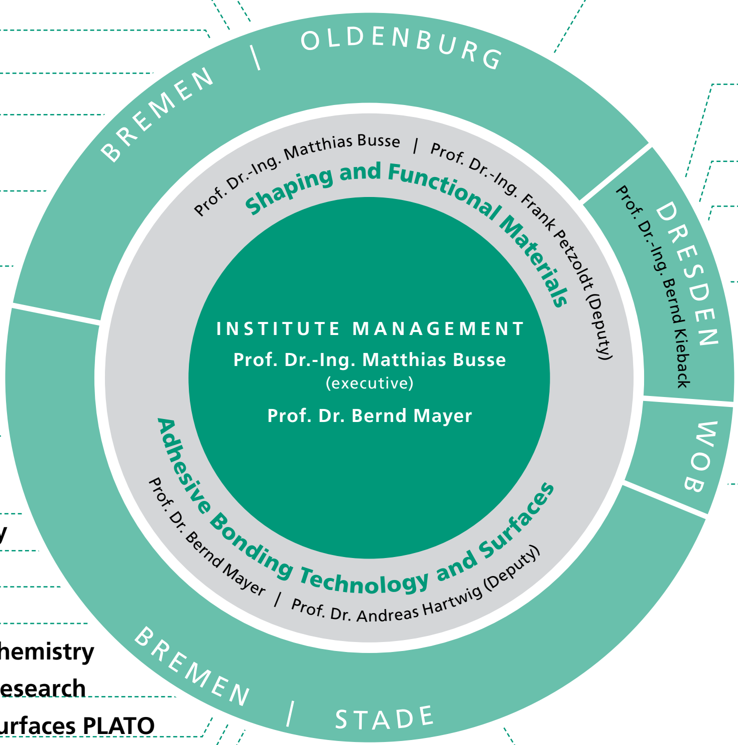
BRIEF PROFILE AND ORGANIGRAM

Founded in 1968 and integrated into the Fraunhofer-Gesellschaft in 1974, the Fraunhofer IFAM is one of the most important research institutions in Europe for adhesive bonding technology, surfaces, shaping, and functional materials. At our institute's five locations – Bremen, Dresden, Oldenburg, Stade, and Wolfsburg – we put our central principles into practice: scientific excellence, a focus on the application of technology, measurable utility for customers, and ensuring the highest quality.

Our 580 employees, working in 24 departments, combine their broad technological and scientific knowledge and expertise into seven core competencies: Powder Technology; Sintered, Composite, and Cellular Metallic Materials; Adhesive Bonding Technology; Surface Technology; Casting Technology; Electrical Components and Systems; and Fiber Reinforced Plastics. These core competencies - both individually and in combination with each other – are not only the basis of our strong position in the research market but also of future-forward developments that will be useful for society.

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

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 in accordance with DIN 6701
Workforce Training and Technology Transfer

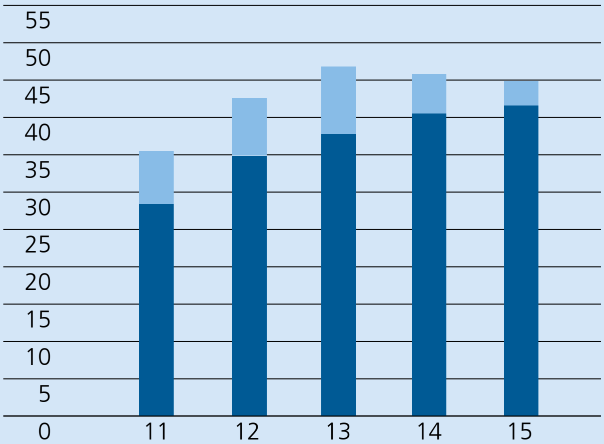


Electrical Energy Storage
Sintered and Composite Materials
Cellular Metallic Materials
Hydrogen Technology
Energy and Thermal Management

Fraunhofer Project Center Wolfsburg

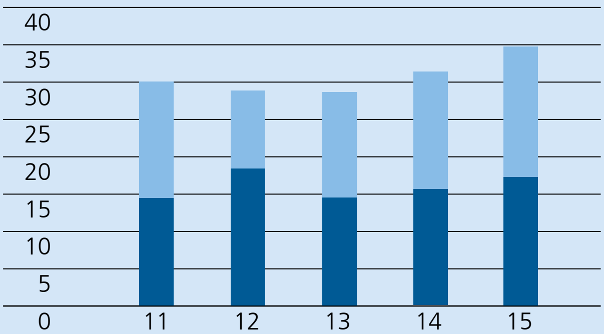
Automation and Production Technology

Operating and investment budget 2011–2015



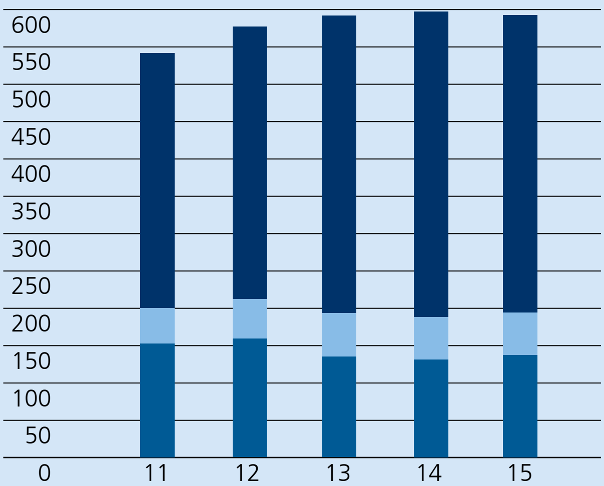
■	Operating budget	41.5 Mio €
■	Investment budget	3.2 Mio €

Project revenues 2011–2015



■	Industry	17.0 Mio €
■	Federal/state/EU/other	17.2 Mio €

Personnel development 2011–2015



Personnel structure 2015

On December 31, 2015 a total of 583 staff were employed by Fraunhofer IFAM in Bremen, Dresden, Oldenburg, Stade, and Wolfsburg.

Scientific-technical staff	393
Administration/IT/Service	55
Student assistants/Students	135
Total	583

■	Scientific-technical staff
■	Administration/IT/Service
■	Student assistants/Students

PROFILE OF FRAUNHOFER IFAM

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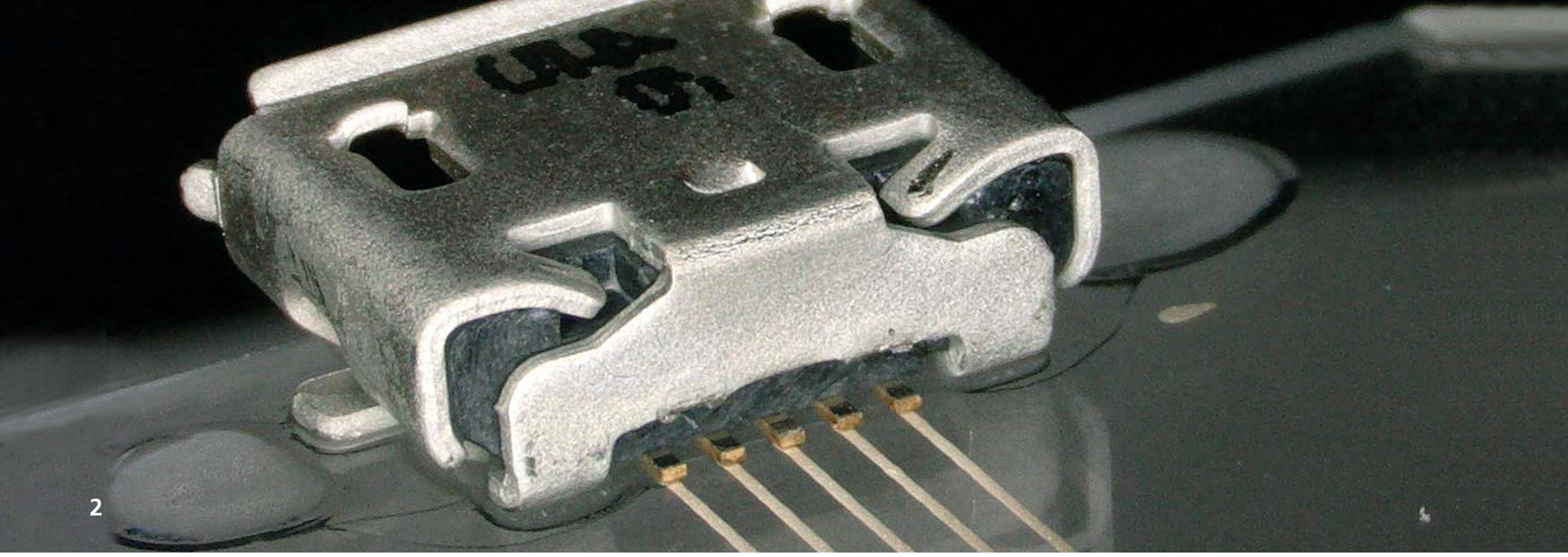

SHAPING AND FUNCTIONAL MATERIALS

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 are 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.

Transforming basic, application-oriented research into industrially viable solutions or component-specific developments requires us to continually expand our base of knowledge and methodological competency. 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.

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 fiber-composite materials.

In the area of "functional printing", we are working on formulas for functional inks and pastes and how to apply them to components. This allows components to be equipped with sensors in order to acquire information on operating and environmental 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 put 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 *3-Mill for paste homogenization.*

2 *Micro USB Port, contacted by means of a dispensing process.*

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.

In order to implement cellular metallic materials in modern products, we are developing customized solutions for different applications and continually expanding our knowledge of processes. Our R&D activities are constantly adapted to the needs of the market, thus identifying new technological challenges. 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' product developments.

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.

In the area of electrical energy storage, focus is moving from lithium-ion and metal-air batteries to solid-state batteries, which, instead of liquid electrolytes, use ion-conducting ceramics, polymers, or composites. These have decisive advantages with regard to safety and energy density. This is where IFAM's competency in materials and manufacturing technology for the necessary material and process development comes into its own.

Power-heat coupling and energy storage are considered when addressing topics such as renewable energy, energy efficient buildings, and grid-bound energy supply. A cross-departmental cornerstone of this concept is the analysis and assessment of the economics of complex energy systems, including the integration of electrical vehicles as mobile energy storage devices.

The range of technical education, training, and consultation we offer is continually being expanded and adapted to the individual needs of our customers.

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.

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. For another Fraunhofer Future Foundation project by the name of "IFEM", the Fraunhofer IFAM and the Fraunhofer IWU are collaborating on the large-scale industrial manufacture of coils, from casting to forming.

The Fraunhofer IFAM is also involved in the creation and expansion of a research and industry network for magnetocaloric systems.

Fraunhofer IFAM is also responding to the growing industrial interest in additive manufacturing technologies. The technical center located at the institute is to be expanded and more systems added to allow the qualification of additive manufacturing technologies, which can also be used in aviation and space travel.

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 *A silk-screen printing machine for component and flat-specimen printing on the robot-assisted assembly line.*

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 application-orientated R&D activities focus on adhesive bonding technology, surface technology, and fiber composites. The division's main goal is to work out system solutions with and for the industry.

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 *Wrinkle-free application of FlexPLAS® release film on a shaping tool.*

2 *Removal of FlexPLAS® release film from a fiber-composite component.*

technology, as well as adhesion and interface research are also key aspects of this core competence, which is complemented by our expertise in matrix resin development, fiber-matrix adhesion, and the sizing of joints.

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 Training 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. The Training Center for Fiber Composite Technology also 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 was first recognized in 2006 by the then-responsible agency, the Federal Railway Authority.

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 increasingly 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. The new German industrial standard DIN 2304, which sets out quality requirements for adhesive bonding processes, has given a new impetus to adhesive bonding technology. As a result, the implementation of this new standard in the industry has become an essential focus of the division's work.

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 (FRP) Manufacturer, Fiber Reinforced Plastic (FRP) Remanufacturer, and Fiber Reinforced Plastic (FRP) Specialist

3 *Optimization of the adhesive bonding application.*

PROFILE OF FRAUNHOFER IFAM

FIELDS OF ACTIVITY AND CONTACTS

INSTITUTE'S 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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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 and bond properties
- Development of custom-built inspection procedures
- Physico-chemical analysis of interface and material properties
- Wet chemical pre-treatment of surfaces
- Accredited corrosion testing laboratory
- Analysis of damage/failure

CERTIFICATION BODY IN ACCORDANCE WITH DIN 6701

Dipl.-Ing. (FH) Frank Stein
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→ www.ifam.fraunhofer.de/DIN6701

- Information relating to company certification in accordance with DIN 6701 ("Manufacture of adhesive bonds on rail vehicles and parts of rail vehicles") and with DIN 2304 („Quality requirements for adhesive bonding processes")
- 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

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- Automated assembly of large structures up to a 1:1 scale
- Sensor-controlled, mobile robots with high positioning accuracy
- 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

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

CHEMISTRY OF FIBER REINFORCED PLASTICS

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

ELECTRICAL DRIVE SYSTEMS

Dipl.-Ing. Felix Horch
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- 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

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- Battery-cell chemistry
- Paste development and electrode manufacture
- Cell assembly and design for
  - Lithium ionic batteries
  - Metall air batteries
  - solid state batteries
- In-situ analytics

ENERGY AND THERMAL MANAGEMENT

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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
- Mold temperature control
- Mathematical modeling of heat transport
- Simulation of melting and solidification processes
- Measurement of thermal material and transport parameters

ENERGY SYSTEM ANALYSIS

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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

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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 (aluminum, copper, iron, steel, salts)
- Investment casting
- Sand casting
- Development of core materials (salt cores, lost cores, compex geometries)
- Function integration/*CAST*^TRONICS®^
- Component identification/component labeling (individual identification as basis for industry 4.0)
- Composite casting/hybrid casting (hybrid options of metal and fiber materials)
- Topology optimization/light weight construction

ADHESIVES AND POLYMER CHEMISTRY

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→ www.ifam.fraunhofer.de/klebstoff

- 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
- Bonding electrically/optically conductive contacts
- Adhesive bonding in microsystem technology
- Adhesives in the construction industry

PAINT/LACQUER TECHNOLOGY

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- 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

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→ www.ifam.fraunhofer.de/analytics

- Analysis of damage/failure
- 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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→ www.ifam.fraunhofer.de/en/wolfsburg

- 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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frank.petzoldt@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/pt

- Powder injection molding
- Pressing and sintering
- Additive manufacturing
- Magnetic materials
- Composite materials
- Metal foams

TECHNICAL QUALIFICATION AND CONSULTANCY

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

SINTERED AND COMPOSITE MATERIALS

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→ www.ifam.fraunhofer.de/scm

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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

HYDROGEN TECHNOLOGY

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- Electrode materials and catalysts for water electrolysis
- 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
- Recycling of rare earth materials (magnets, production waste, etc.)
- Comprehensive analysis of H_2-solid reactions

WORKFORCE TRAINING AND TECHNOLOGY TRANSFER

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→ www.bremen-bonding.com
→ www.bremen-composites.com

- 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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markus.brede@ifam.fraunhofer.de
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- Testing of materials and components
- 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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→ www.ifam.fraunhofer.de/zmw

- Cellular metals from variant special materials
- Additive manufacturing via 3D screen printing
- Open-celled fiber structures, foams, and films
- 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
- Functional surface coatings with polymer-derived ceramics

PROFILE OF FRAUNHOFER IFAM


1

ADVISORY BOARD

Members

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Chair of the advisory board
Airbus Deutschland GmbH
Bremen

Regierungsdirektorin
Dr. Annerose Beck
Saxon State Ministry for
Science and the Arts
Dresden

Bernd Faller
RAMPF Production Systems
GmbH & Co. KG
Zimmern ob Rottweil

Michael Grau
Mankiewicz Gebr. & Co.
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Dr. Jürgen Groß
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Stuttgart

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Airbus Deutschland GmbH
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Gerd-Rüdiger Kück
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Science of the Free Hanseatic
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Bremen

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tesa SE
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Düsseldorf

Christoph Weiss
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Wilh. Herbst GmbH & Co. KG
Bremen

Guests

Andreas Kellermann
Daimler AG
Bremen

Prof. Dr.-Ing. Kurosch Rezwan
University of Bremen
Bremen

1 *New building Fraunhofer IFAM, Bremen (© Franziska Husung).*

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 67 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 2.1 billion euros. Of this sum, around 1.8 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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Electrical Energy Storage
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4
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Forschungszentrum CFK NORD
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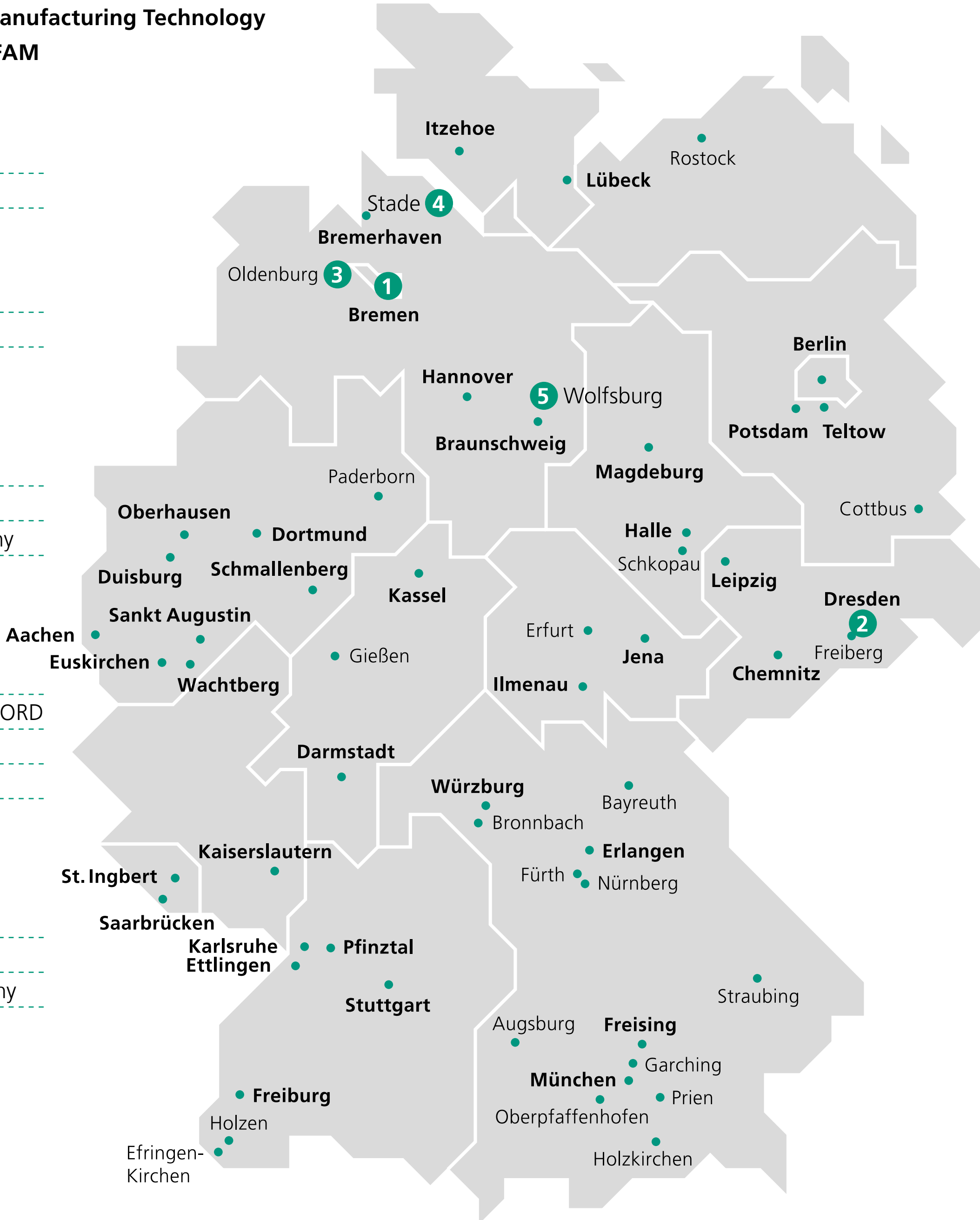
5
Fraunhofer Project Center Wolfsburg
Hermann-Münch-Strasse 1
38440 Wolfsburg, Germany



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 (©vege - Fotolia).*

FRAUNHOFER ALLIANCES

Fraunhofer Institutes or divisions of institutes with different 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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Dipl.-Ing. Manfred Peschka MBA
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FRAUNHOFER ADDITIVE MANUFACTURING ALLIANCE

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FRAUNHOFER CLEANING TECHNOLOGY ALLIANCE

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FRAUNHOFER SIMULATION ALLIANCE

Spokesperson for the Alliance | Contact at Fraunhofer IFAM

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FRAUNHOFER SPACE ALLIANCE

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FRAUNHOFER ACADEMY

Fraunhofer Academy is the umbrella organization for training courses that are offered by the Fraunhofer-Gesellschaft.

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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

The Training 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.

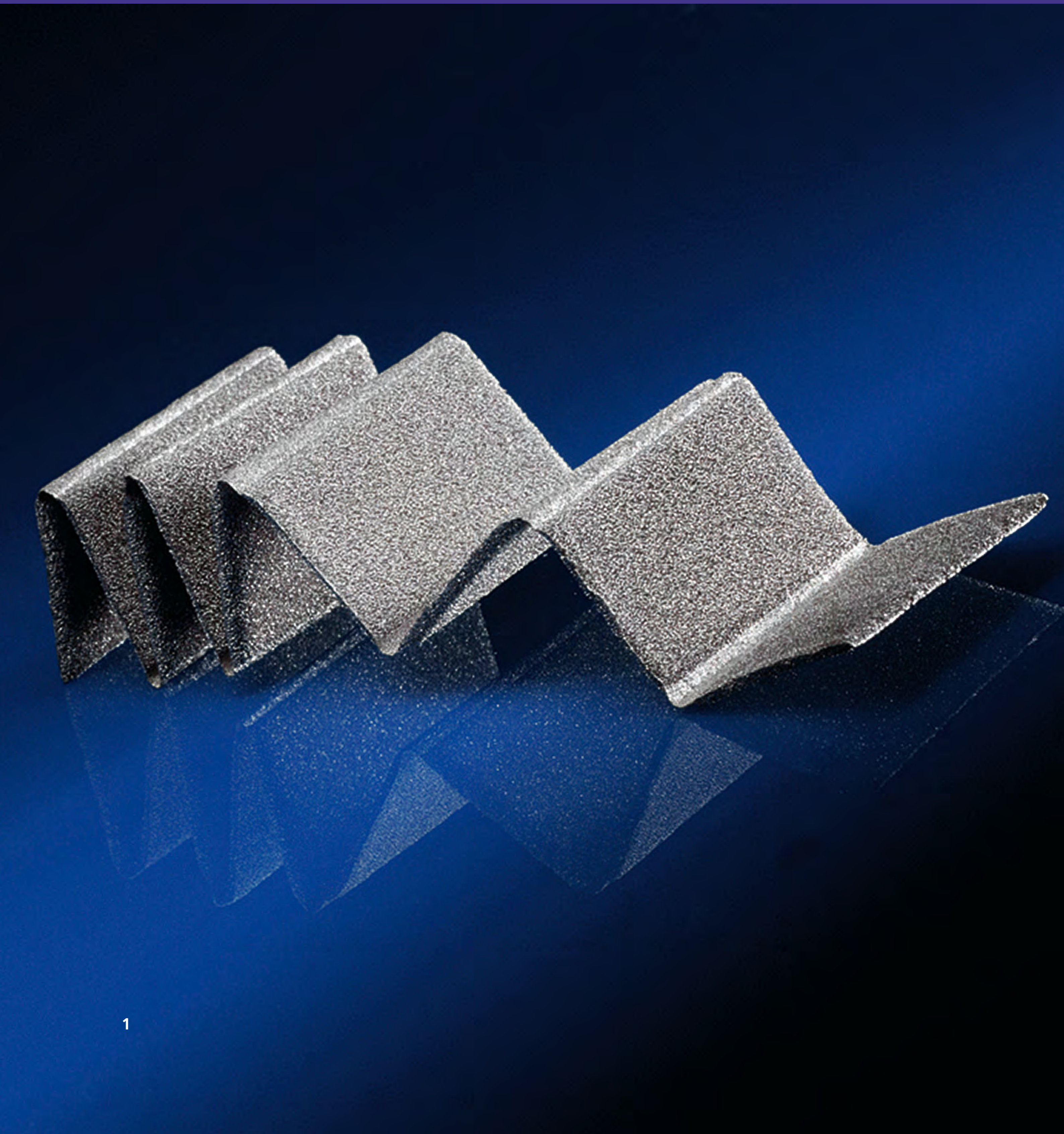
Recognition in accordance with DIN 6701

Since 2006, the Fraunhofer IFAM has operated a Certification Body for the Manufacture of Adhesive Bonds on Rail Vehicles and Parts of Rail Vehicles in accordance with DIN 6701.

→ **www.ifam.fraunhofer.de/en/qm**

1 *New building Fraunhofer IFAM, Bremen (© ATP / Stefan Schilling).*

SINTERED, COMPOSITE, AND CELLULAR METALLIC MATERIALS



1

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.

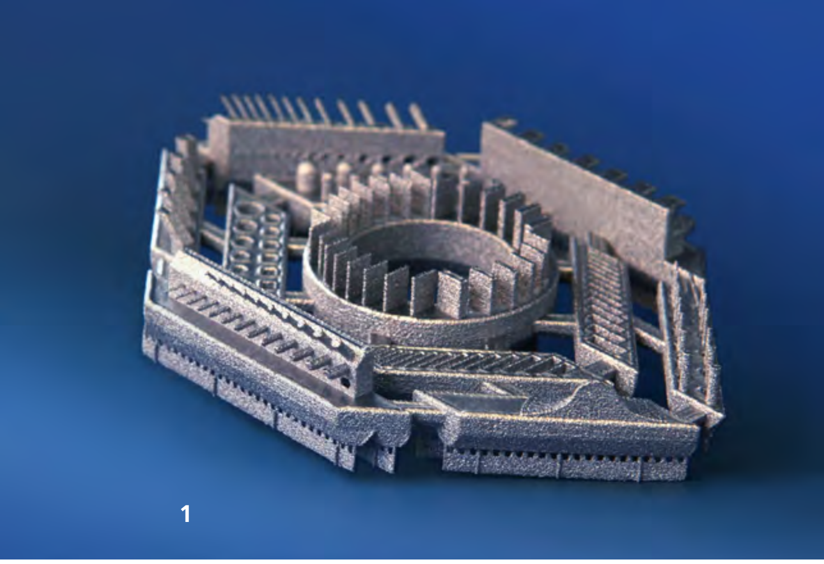
In the area of metallic and intermetallic sintered and composite materials for functional and structural applications, Fraunhofer IFAM possesses in-depth understanding of structure-property relationships and how to optimize these for specific applications. The complete powder-metallurgical technology 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 *Foam electrodes, folded design for supercapacitors.*



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COMPLEX, LIGHT, EFFICIENT – COMPONENTS MADE USING SELECTIVE ELECTRON BEAM MELTING

The Fraunhofer IFAM in Dresden has established Selective Electron Beam Melting (SEBM) as one of the highest performing additive manufacturing processes. Throughout many of its projects, have already found impressive industrial applications for this technology could be realized already.

With high power density, preheating of the powder bed, and a vacuum environment, SEBM is suitable for the processing of reactive high-temperature materials. As part of the TiAl Charger EU Project, for the first time the gamma TiAl alloy RNT 650 was successfully processed into complete, dense components. These turbocharger wheels, designed for use in automobiles, are characterized by a hollow internal cavity to reduce their weight. With downstream heat treatment, structures can be set to an optimal property profile.

The goal of the GenFLY aviation research program is to advance the technological level of additive processing for Ti-6Al-4V when used in aviation applications. Processes along the manufacturing chain are optimized, the adjustments are written down in specifications, and the attainable material properties are then determined. Through using the right heat and surface treatments, we could ensure that the static and dynamic strength of the SEBM parts exceeded the aviation industry's current requirements. The extensive application potential of additive techniques can be seen, for example, in the constructive improvement of a key component in a helicopter transmission (image 2). We were able to reduce the weight of a demonstration component by 40 percent by optimizing the topology.

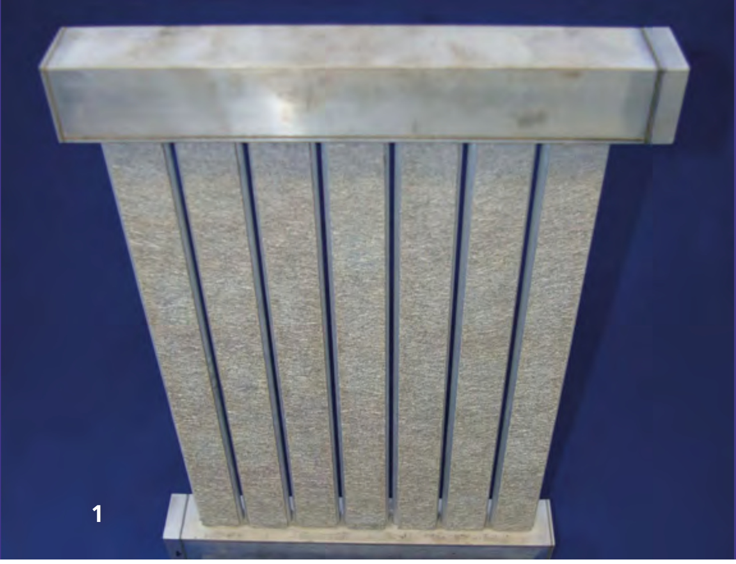
Opportunities, Market Potential, Perspectives

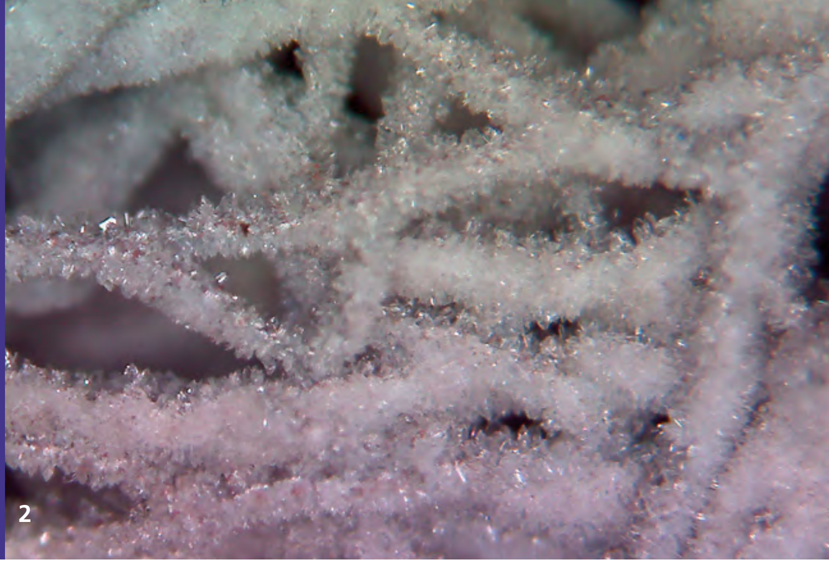
The strength of additive manufacturing can be found in its utilization of short process chains, and its great flexibility with regard to geometry and shape. Thus, components that are geometrically complex but have small batch sizes can be made economical. Furthermore, components with an optimal strength-weight ration are made possible due to the intrinsic freedom of design of powder bed processes especially. Additive manufacturing is also significantly more efficient in the use of material resources. The immediate advantages of the SEBM process lie in its high production rate and the ability to produce components that are already close to their final dimensions from materials that are normally difficult to process. Because the Fraunhofer IFAM benefits from many years of experience in powder technology and extensive competency in the relevant material classes, we can make valuable contributions in bringing Selective Electron Beam Melting into industrial production. For this purpose, we will be building an application center for Selective Electron Beam Melting in Dresden within the next few years.

→ **www.ifam.fraunhofer.de/ebm**

1 *Design demonstrator for SEBM made of Ti-6Al-4V.*

2 *Optimized component "MG bracket rear" (demonstrator).*





ALUMINUM FIBER STRUCTURES FOR HIGHLY EFFICIENT HEAT PUMPS

As part of the project "Development of a Gas Adsorption Heat Pump with a Crystallized Zeolite Heat Exchanger and a New Evaporator-Condenser Apparatus (ADOSO)", funded by BMWi, the Fraunhofer IFAM in Dresden is working with Stiebel Eltron GmbH & Co. KG, SorTech AG and the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg to develop a highly efficient adsorption heat pump for the provision of hot water and heat in residential buildings.

Efficient technology for the provision of hot water and heat in residential buildings is an essential cornerstone of a resource-efficient energy supply. Conventional heat pumps run on electricity, whereas these heat pumps use environmental heat sources such as geothermal sources, as well as solar or ambient air heat. In seeking to offer the next generation of natural gas technology, the successor to the gas condensing boilers currently available on the market, we have combined a gas-condensing boiler with a thermally driven heat pump module for use in gas heat pumps. The goal of the ADOSO project is to develop a zeolite-based heater using water. This will be significantly more compact and cost-efficient than current heaters on the market while producing comparable results, thanks to a novel adsorption heat exchanger, which will enable it to optimize the operation of the evaporator and condenser, whilst attaining an annual performance factor of higher than 1.3.

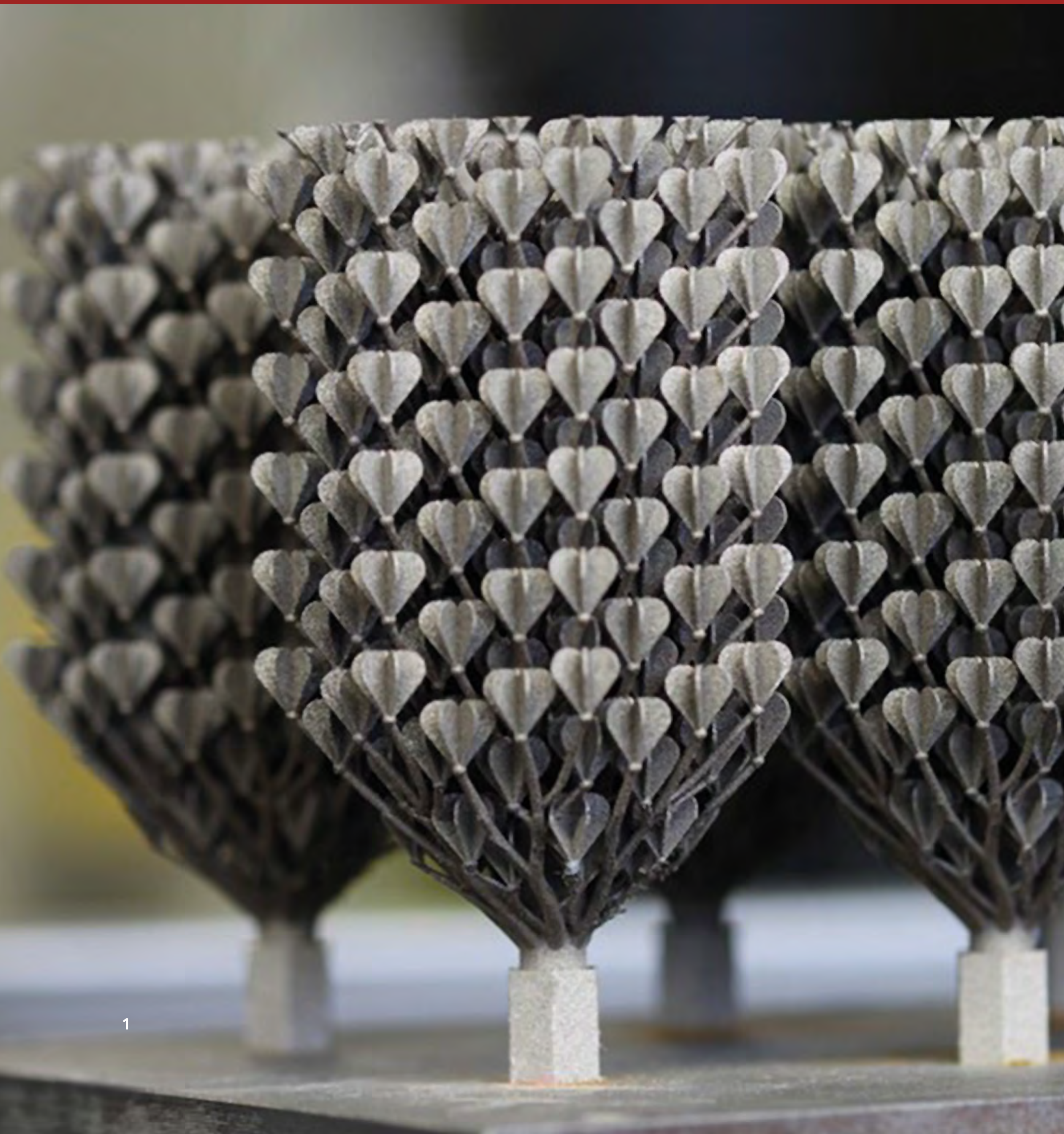
For the development of the adsorption heat exchanger, we have focused on porous but still thermally conductive materials that have a highly coatable surface. To this end, the Fraunhofer IFAM is working on structures made of sintered aluminum fibers. The short fibers made of AlSi1 aluminum-silicon alloy are firmly bonded together using liquid phase sintering. This creates open porous structures with a highly specialized surface on which the zeolite is crystallized. At 75 percent, the high proportion of surface pores allows steam to access the zeolite surface as well as the interior structure. The steam is captured on the zeolite and releases a large amount of heat, which is then transferred to the water pipes by the aluminum fiber structure. Desorption of the steam reverses this process, so that as the zeolite is heated, it releases the water molecules.

The large surface area of the metal fiber material in combination with the zeolite layer accelerates the dynamic of the adsorption and desorption in comparison to current technology. The first prototype, which has not been further optimized, has already doubled the performance density at 300 W/l. This brings the reality of compact, cost-efficient adsorption heat pumps within reach. This same principle can also be applied to refrigeration using waste heat, opening up another very interesting market. SorTech AG will soon begin field tests of the new generation of adsorber in their own line of refrigeration machines.

→ **www.ifam.fraunhofer.de/adoso**

1 *Heat exchanger with soldered aluminum fiber structures.*

2 *Aluminum fiber structure with crystallized zeolite (© SorTech AG).*



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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.

Successful powder technology solutions are based on a precise knowledge of the materials involved. The combination of powders alone can affect a component's characteristics, such as hardness, toughness, elastic modulus, wear, and thermal expansion, and can be adapted to the demands of the parts. Soft magnetic materials and 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.

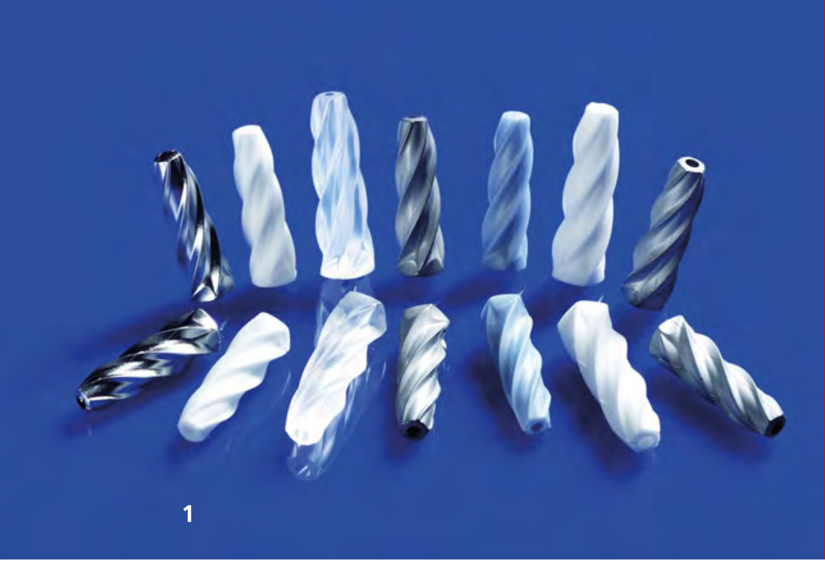
Fraunhofer IFAM also has many years of experience in additive manufacturing, where products are made from metal powders without molds directly from 3D CAD data, having virtually any desired shape. Currently, this method is not only being used for rapid product development but increasingly also for the 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 *Additively manufactured cooling system.*



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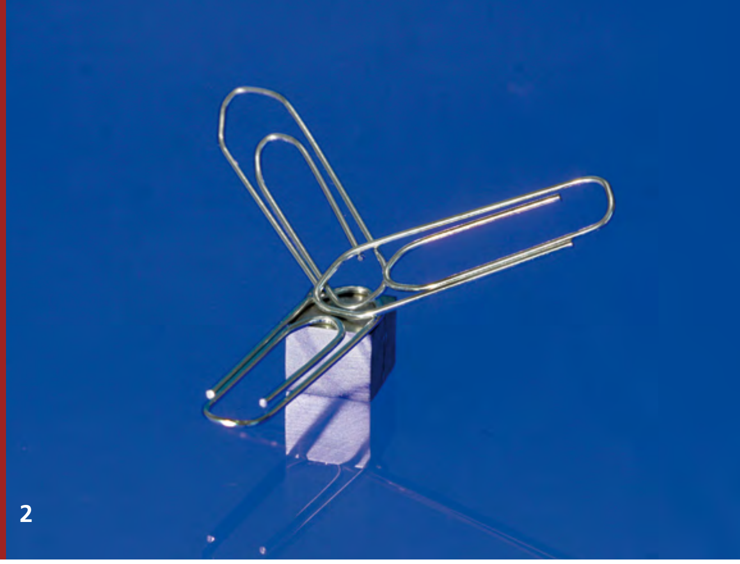

2

INNOVATIVE PRODUCTS MANUFACTURED WITH POWDER TECHNOLOGY

Powder technology at the Fraunhofer IFAM covers the whole process chain, from material development to shaping and characterization. In the following, we will present current topics relevant to each step of the process. You can find more information by clicking on the links.

"Screw nails" instead of screws

New materials for medical implants have been the focus of intense research at the Fraunhofer IFAM for many years. Materials that do not have to be removed from the body once implanted are of special interest. One promising class of materials is bioceramics.

The Fraunhofer IFAM has been working on this topic with its partners at the University of Bremen and the University Clinics of Gießen, Marburg, and Bonn, within the project "VIP (Validation of Innovation Potential) - Hydroxy Apatite Screw", which is being sponsored by the Federal Ministry of Education and Research (BMBF). An interference screw was adapted to the needs of ceramics and produced using calcium phosphate. Instead of being screwed into a pre-drilled hole in the bone like a classic interference screw, this screw nail (known as the "Schragel") is hammered into the hole like a nail. The threads of the screw nail cause it to rotate while being tapped into the hole. The screw nail turns fewer times than an interference screw, meaning the danger of injuring the transplant with the edges of the threads is reduced.

Considering the mechanical properties of the ceramic part, hammering the screw nail into a pre-drilled hole is still critical. That's why hydroxy apatite (HA) as the calcium phosphate with the highest strength was used in the development phase. In a second approach a certain amount of silicium dioxide was added to the HA, which induces the transformation of HA into completely degradable tricalcium phosphate (TCP) during the sintering phase of powder-based manufacturing process. Despite the significantly lower mechanical stability of TCP in comparison to that of HA, we were able to produce parts of comparable strength. This is a big step towards the implementation of these materials in medical engineering.

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

Alternative production techniques of sintered high-performance magnets

Our modern, everyday world would be impossible to imagine without hard magnets. They are used in everything from tiny vibration motors in our smartphones to enormous wind turbines. With increasing prevalence comes increasingly high standard requirements in the associated manufacturing technology. In the automotive sector and in consumer electronics fields there is a trend toward more and smaller motors and therefore magnets. Resource efficiency and post-process-

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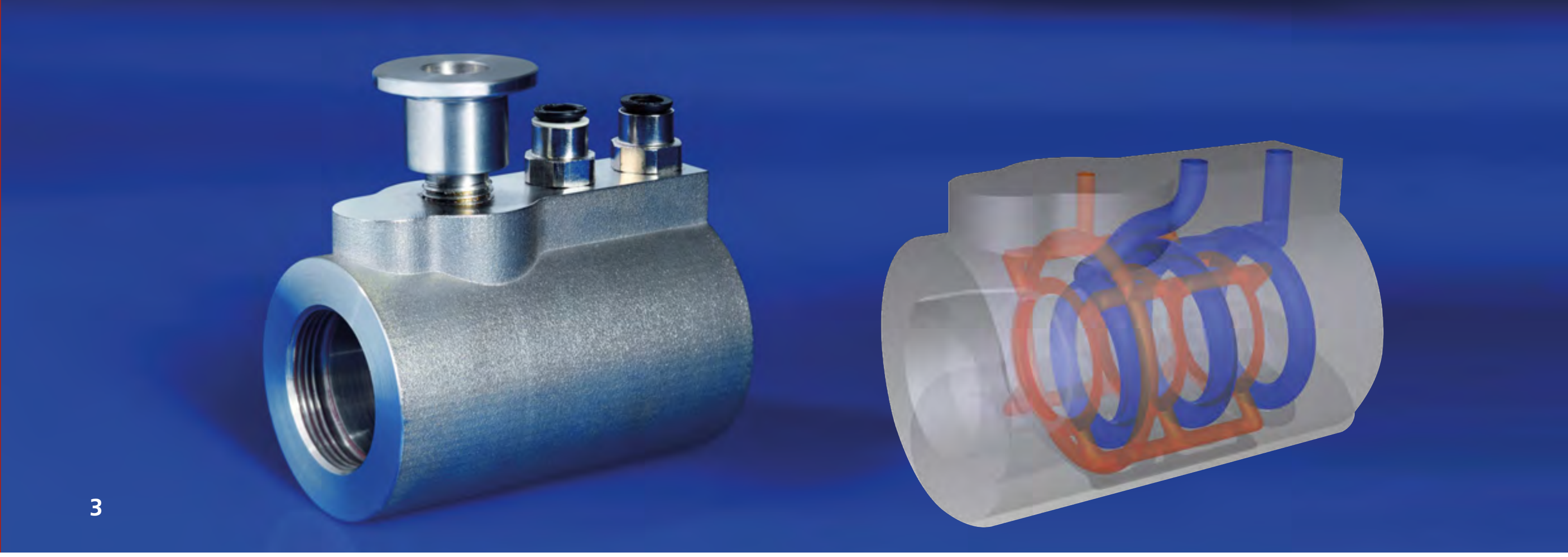


ing are becoming more and more important. Therefore, the Fraunhofer IFAM is investigating alternative production methods for hard magnets. As part of the Fraunhofer lighthouse project called "Critical Rare Earths" we are investigating the production of sintered neodymium magnets using the metal injection molding process (MIM). By mixing with an organic binder system, alloy powders are transferred into a thermoplastic mixture, the so-called feedstock. This feedstock can then be injected into a cavity to produce complex green parts. Following a multi-step binder-removal process, the components are then sintered conventionally. This enables us to produce isotropic as well as anisotropic neodymium magnets. The work includes the development of an individual binder system, shaping, and the development of the sintering process.

Another topic of this project is the reduction of the amount of heavy rare earths, such as dysprosium (Dy). This rare earth metal provides improved temperature stability for the neodymium magnets but is very expensive. There are different approaches to minimize the amount of dysprosium needed. The Fraunhofer IFAM is examining ways of introducing dysprosium in the MIM process and evenly distributing it in the final magnet, thus making the production of modern high-performance more magnets resource efficient.

→ **www.ifam.fraunhofer.de/magnete**
→ **www.seltene-erden.fraunhofer.de**

Additive Manufacturing – 3D Printing

By using additive manufacturing, components can be manufactured from metallic powders in nearly any complex form imaginable, directly from 3D CAD data. All of the current variations of the process work on the same principle of building up the pieces without using tools.

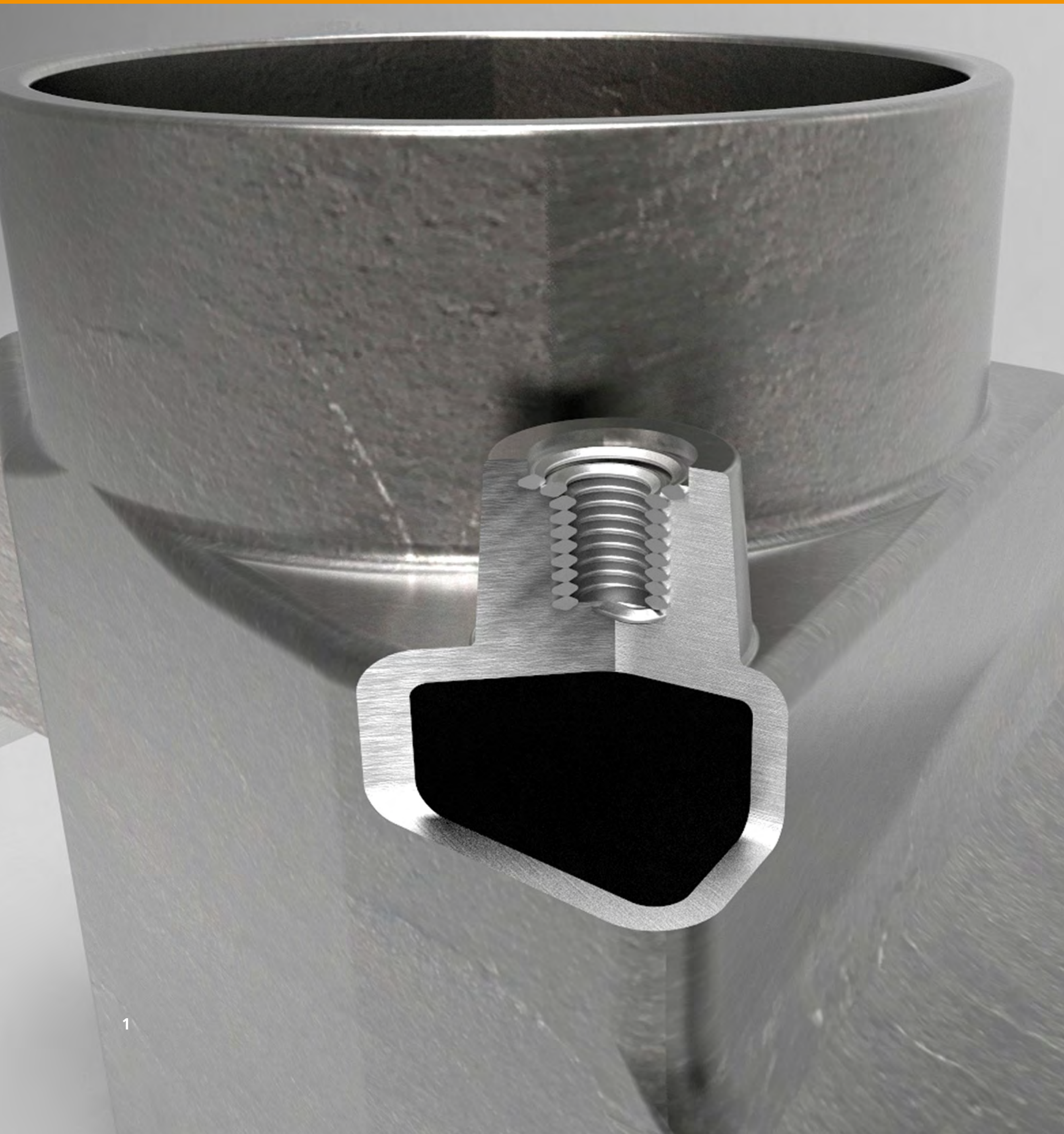
Selective laser beam melting is the most widespread method of additive metal powder processing today. During this process, the laser melts the material completely, which then immediately solidifies. 3D printing is also a process of building up layer by layer, applying binder point by point and thus bonding the metal powder, which creates "green parts" as in injection molding. One way of getting to the actual component is to debind the green part and infiltrate it with a low-melting material, like bronze. This creates a material mixture without shrinking the part. Another possibility is to debind the green part and sinter it in the original material, which causes a classical sintering shrinkage of the part.

In a subsequent heat treatment, the properties of the components from both processes can be further adapted to their final requirements, and using conventional post-processing, ready to be used parts can be produced.

The central principle of this kind of Fraunhofer IFAM projects is that the material and process development of both methods must be customer-oriented and suitable to the application. Process development encompasses the entire production chain, beginning with the creation of a 3D data model. The subsequent analysis of the raw metal powder and the additive manufacturing process itself are followed by a final inspection of the component's physical and geometrical aspects.

→ **www.ifam.fraunhofer.de/am**

1 *Biocompatible screw nails.*
2 *Anisotropic neodymium magnet, injection molded and sintered.*
3 *Additively (SLM) manufactured calibration tool with internal vacuum and cooling channels.*



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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.

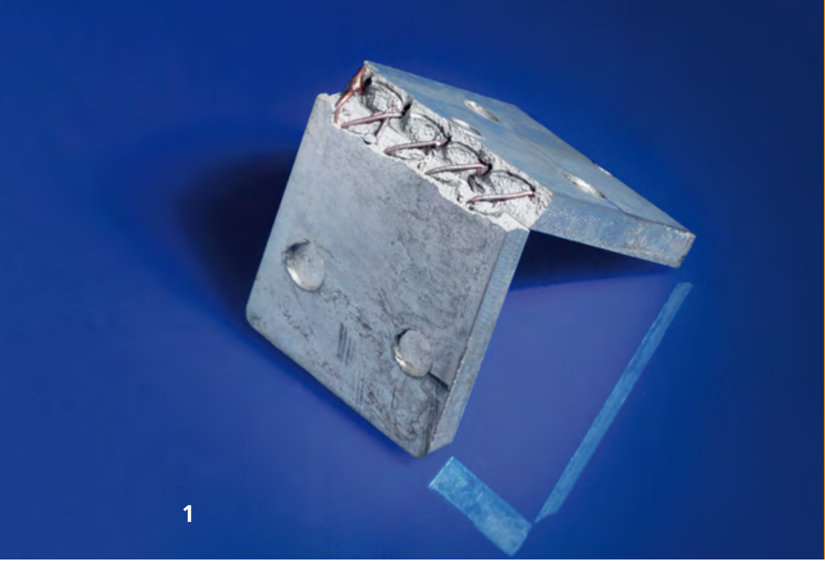
Lost foam technology is used for casting large and small parts of high complexity directly as near net shaped parts. The method allows complex components to be manufactured with any design of internal channels and undercuts – without demolding grooves or burrs. Low pressure casting is used to manufacture 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.

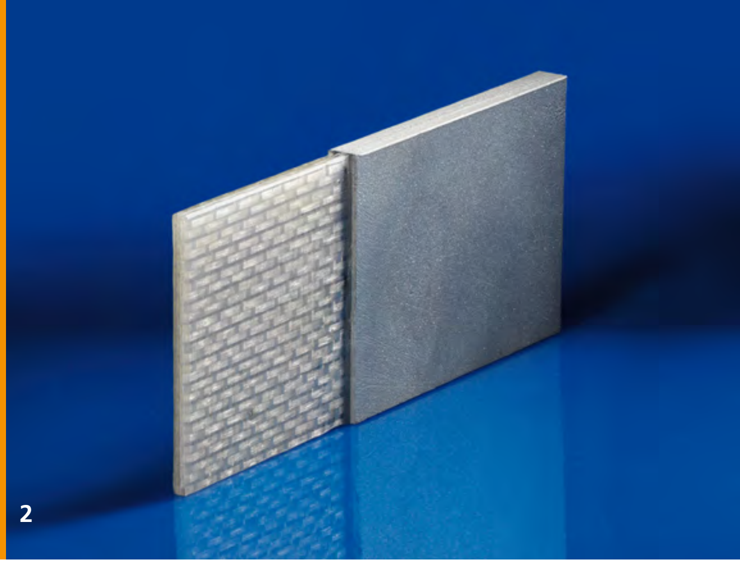
The casting materials used include aluminum, magnesium, zinc, copper, steel, and customer-specific alloys. In addition, special materials such as metal-matrix composites are developed and improved, opening up new applications for casting and cast components.

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*TRONICS®* technology allows advanced electronic, sensor, and actuator functionalities to be integrated into cast components.

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

1 *A cross-section of a pressure injection molded part with directly cast wire thread insert (© Böllhoff Verbindungstechnik GmbH).*



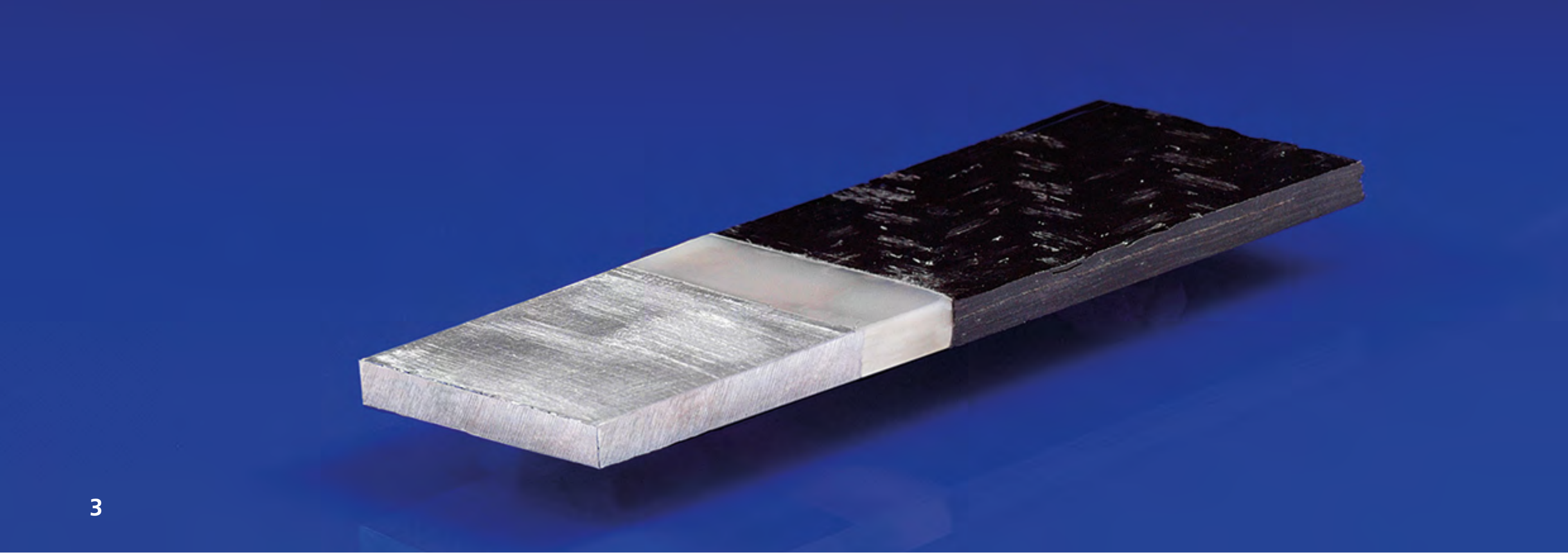


HYBRID CASTING – UNIFYING STRUCTURES IN THE CASTING PROCESS

To ensure economical, industrial-scale lightweight construction, it is essential to choose the right materials according to their properties and to integrate them into the appropriate structural areas. The result is the so-called "multi-material design" (MMD), which offers the greatest potential in lightweight construction. Today, putting the materials together requires costly binding processes that severely compromise economic efficiency. With casting technology, it is possible to directly combine different materials during the production process. The metal's starting condition as molten slag offers the ability to achieve flexibility of shape, strength, and substance-to-substance bonds, all with the widest possible range of materials. Functional elements can then be integrated into the components. The department of casting technology at the Fraunhofer IFAM has developed the direct introduction of wire thread inserts for screw connections in pressure casting. This new approach effectively shortens the process chain and saves time in the manufacturing process.

Rethinking structural components

Casting technology has certain advantages when combining different materials for structural components. The casting process can unify the structural components of various materials and property requirements, producing multi-material components in one single processing step. One example is steel sheet cast construction, which creates a hybrid part from the sheets and the casting components during the casting process. Pressure casting and low-pressure casting can be implemented in the production of compounds. Pressure casting makes it possible to produce high piece counts in a very short amount of time. Low-pressure casting allows a very high component quality, also in large-scale production. The material bonds of different metallic materials such as steel sheets are of special interest. The heat of the casting process can firmly bind the metallic structural elements to the cast components, avoiding the need for subsequent processes such as welding, bonding, and riveting. The material-bonded casting of metallic structures is currently the focus of several different studies in which a material bond is produced in the casting process, usually by coating or another surface treatment. Moreover, the properties of highly stressed structural casting components can be locally optimized using metallic stiffening elements. Here we focus on the local strengthening of lightweight metal casting components, adapted to the load path. In addition to the steel sheet casting combination, which increases the stiffness, wire mesh and carbon fiber can be used. Wire mesh serves to reinforce the casting components and provide a failsafe in a crash.



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Casting technology and fiber composites

Another focal point in casting technology research is the use of fibers in aluminum cast components. The fibers work as connecting elements to bind complex cast components to very stiff fiber-reinforced plastics (FRP). The Fraunhofer IFAM has several different projects dealing with the bonding of aluminum casting and carbon fiber-reinforced plastics (CFRP). The electrochemical corrosion of the base-metal aluminum and the CFRP is a huge challenge here. One technological solution is a so-called transitional structure, which electrochemically decouples the aluminum component from the CFRP. The load is carried by the transitional structures, which are constructed from alternating layers of fabric made of carbon fiber and fiberglass as well as fiberglass-loop connections. The fiberglass, or alternatively the ceramic fibers, are introduced directly into the casting process and partially into the aluminum casting components. They are later processed, in the production of fiber composites, into an integral aluminum-CFRP hybrid part. The advantage of this is the fiber-based design, which is different to that of conventional connection technology, reducing the weight and space required. Optimally, the load can be carried by the fibers to the metallic connecting element through direct casting of the temperature-resistant glass or ceramic fibers. This presents completely new construction principles and repair possibilities if fiber-reinforced plastic is used in otherwise metallic structures, such as automobile bodies. When a fiber-composite part is damaged, the metal connections of the whole structure can be dissolved and replaced by conventional joining processes.

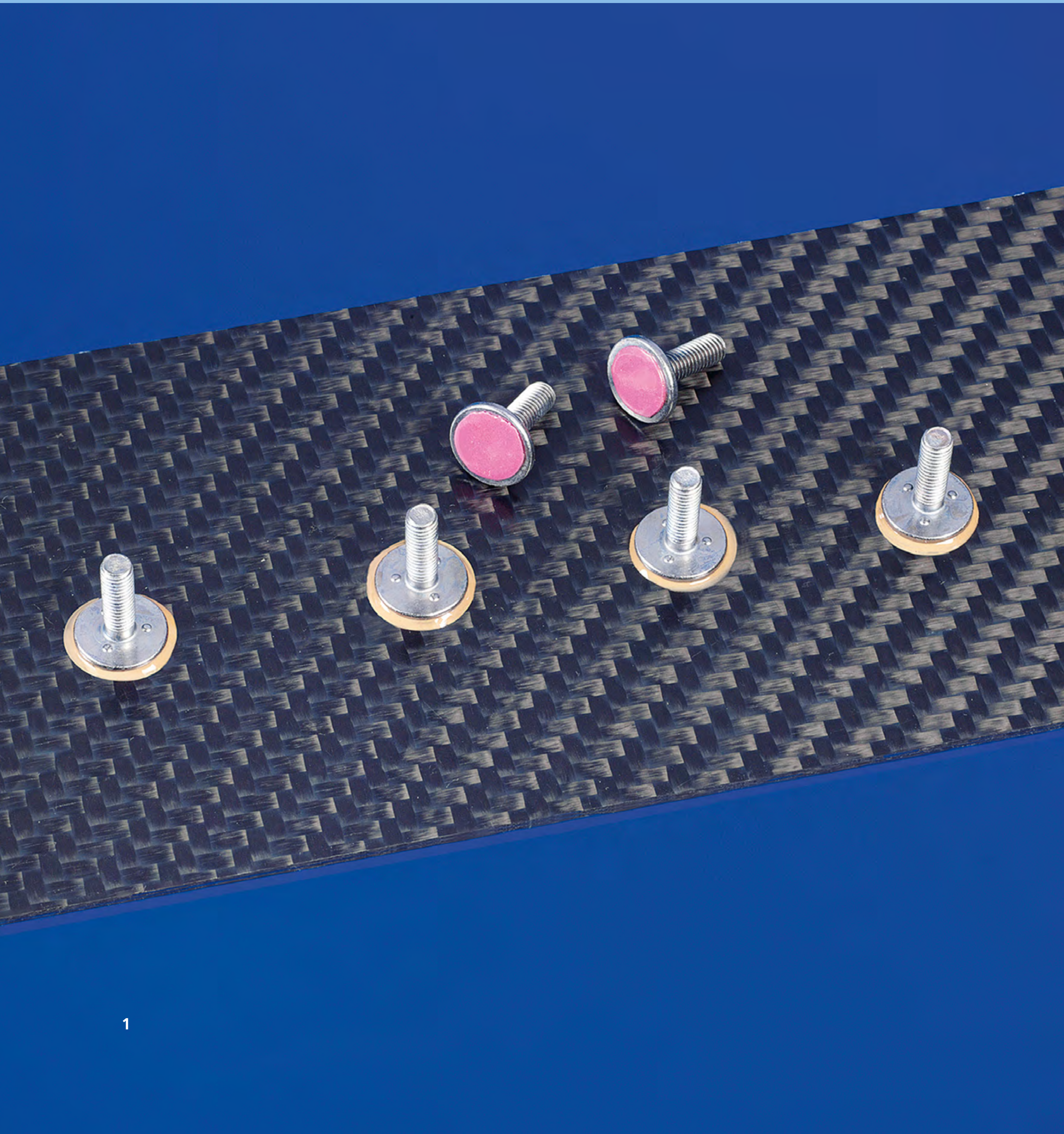
As part of the Fraunhofer Project Center in Wolfsburg in the Open Hybrid LabFactory, the industrial-scale production of hybrid components is being pursued with the motto "One step, one part". Its focus is on the the combination of fiber-reinforced plastics and metals for large-scale, economical production of lightweight hybrid components for the automobile industry.

The current project is working on the hybridization of aluminum casting and thermoplastic fiber composites. These components can be processed on a large scale with short cycle times, therefore allowing the economical production of hybrid structures alongside the industrial casting processes. The complete process chain, as performed with specially produced aluminum low-pressure presses and hybrid injection molding presses, is shown below. The combined injection molding process allows further functional elements to be injected, for example stiffening ribs made of thermoplastic, which are attached to the hybrid aluminum fiber-composite structure in order to produce highly integrated components.

1 *3D wire structure reinforced light metal die cast matrix.*

2 *Ceramic fiber-aluminum hybrid compound produced by aluminum high pressure die casting.*

3 *Aluminum-CFRP compound with injection-molded transitional structure with endless fibers.*



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 *Fastening elements with PASA® hotmelts for adhesive bonding on different materials (here: FRP).*

DIN 2304: ADHESIVE BONDING – FOR SAFETY'S SAKE!

Adhesives are reproducible-quality products. Most failures of industrial adhesives can be attributed to mistakes in application. In the future, with the German industrial standard DIN 2304 "Adhesive Bonding Technology – Quality Requirements on Bonding Processes", these mistakes can be avoided. This user standard is an attempt to control the entire adhesive bonding application process in an organized way. It is valid for all adhesives and material combinations as well as for all industries and bond types. DIN 2304 is a paradigm shift in adhesive use, because it puts more responsibility onto the user.

According to the ISO 9001, adhesive bonding is a "special process", which means that products cannot be tested 100% non destructively. All possibilities of defects must be excluded in a logical order. DIN 2304 cements the ISO 9001 and specifies the reliable state of the technology for proper implementation of adhesive processes. It determines the requirements of correct application of adhesive bonding as well as their general organizational, contractual, manufacture, and personnel principles. The standard defines three core elements:

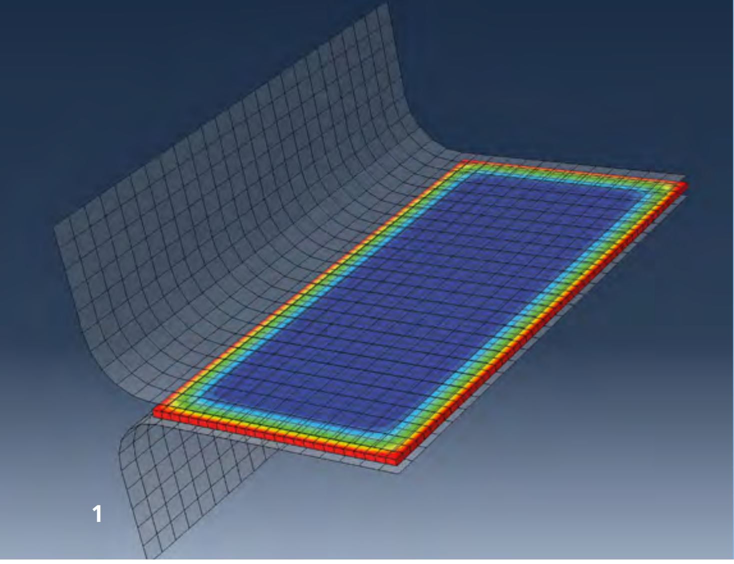
- Classification of bonds according to safety requirements
- Deployment of adhesive supervisory personnel (KAP)
- Verification management: stress > strength

The goals of the new DIN 2304 are to minimize application mistakes in adhesive bonding technology and reduce costs by avoiding rework and product recalls. The standard aims to promote all industries' trust in adhesive bonding technology.

The Fraunhofer IFAM actively supports users in implementing DIN 2304. We are able to offer and carry out research and development work in quality assurance along the entire process chain. Our developments in this field include new adhesives that use changing colors to show when the processing time has been surpassed; inline-capable systems for the detection of contamination of parts to be joined; and foolproof curing systems. The Fraunhofer IFAM also offers control and optimization of adhesive processes with regard to DIN 2304 and, in the future, all other steps up to and including standardized operation certification. Individual concrete concepts will have to be created and implemented, to reflect the technical aspects as well as the documents to be produced. This service is provided by experienced personnel qualified as DVS®/EWF adhesive engineers, who are knowledgeable in adhesive operation certification. Process support is customized, showing possible optimization potentials and concrete approaches to solutions. In addition to process controls, DVS®/EWF-certified personnel qualifications in accordance with DIN 2304 will be offered at the accredited Training Center for Adhesive Bonding Technology at the Fraunhofer IFAM.

1 *DIN 2304 - Observation of the entire adhesive bonding application process.*

2 *ISO 9001 - Technical and organizational quality assurance to guarantee product quality (© Fraunhofer IFAM, Fotolia).*



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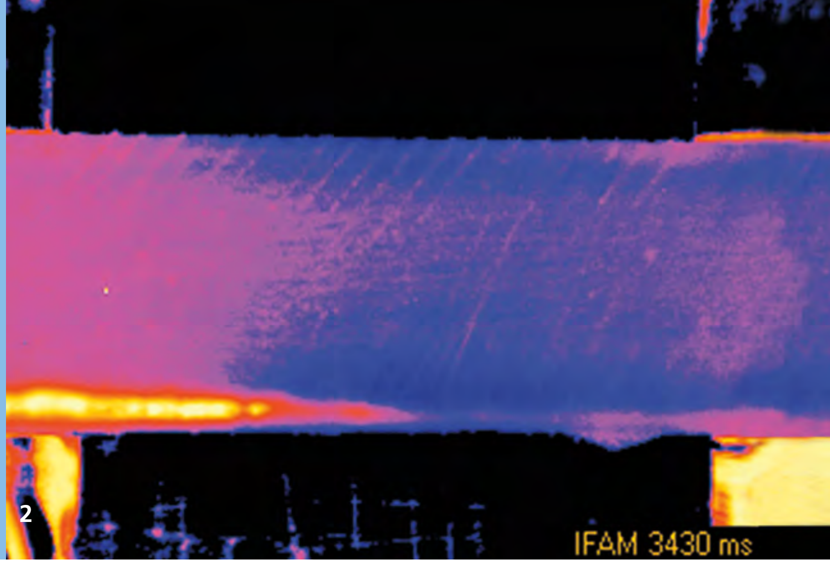

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UNDERSTANDING AND CALCULATING THE DURABILITY OF BONDED JOINTS

An essential requirement of adhesive bonds is endurance against aging caused by environmental factors over the lifetime of the product. This is the only way to guarantee the functional capability of bonded products. Moreover, calculated predictions of a component's properties are becoming a bigger question. This has led to the need for modeling the changes in the adhesive layer caused by aging. From the user's point of view, quantitative prediction of adhesive bond aging will be one of the most important tasks in the future development of adhesive bonding technology.

This is the challenge that has been taken up by the AiF-DFG research program "BestKleb: Understanding and Calculating the Durability of Adhesive Joints", which is divided into six research projects. The range of the projects stretches from basic questions like explaining chemical aging mechanisms to application-oriented work, such as the aging of wood-concrete compound systems used in construction. The Fraunhofer IFAM is working on many topics aimed at the efficient calculation of adhesive aging.

One tool used to simplify representations of adhesive bonds in finite element simulations is that of cohesive zone models. The automobile industry has come to depend on these over the last several years. In that industry, they are used in automobile crash simulations as a way to consider the behavior of adhesive bonds without incurring excessive costs. One of the most important model parameters is fracture toughness, which can be determined in the tapered double-cantilever beam test. This test now has already been performed on different adhesives exposed to various aging conditions, for example storage in hot-wet climate. A phenomenological model of reversible physical aging was developed for a polyurethane adhesive. This model can simulate the diffusion of water in the adhesive layer and then predict the subsequent changes in fracture toughness. A deeper understanding is necessary in order to make more complex aging processes calculable in practice. We performed basic investigations of fracture toughness in order to understand the underlying energy balance. For the first time, heat generation due to crack growth in the adhesive layer was measured using an infrared camera. With the help of experiments and simulations, the contribution of plastic adhesive deformation to the fracture toughness was quantified and the effect of the adhesive layer thickness was analyzed.

With the right tools, complex models can then be made available for wider use. A model developed by Saarland University to examine the influence of aging on the viscoelasticity of the adhesive layer was converted into a simplified cohesive zone model by the Fraunhofer IFAM. The IFAM also developed a method which significantly increases the precision of adhesive layer stiffness simulations. In order to minimize the costs of using these new models, we created a tool to automate model generation.

1 *Calculation of adhesive bonding layer aging as an effect of water infiltration.*

2 *Heat image of tear growth in the adhesive bonding layer.*

SURFACE TECHNOLOGY

1

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.

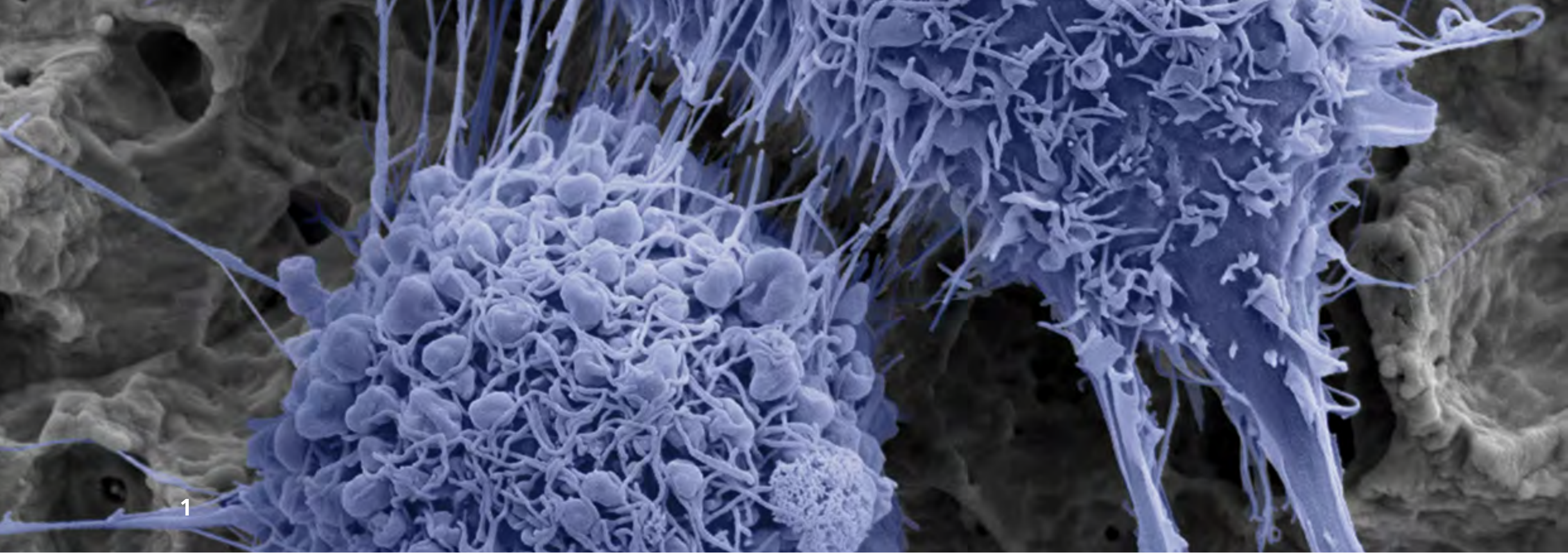
The expertise of Fraunhofer IFAM covers the whole process chain of surface technology from materials' development to the characterization and evaluation of surfaces, their functionalization and modification, and on to various application methods. The development of processes – such as dry and wet chemical 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 analyses 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 *Investigation of the wetting properties of surfaces using the aerosol wetting test.*



COATINGS FOR MEDICAL TECHNOLOGY

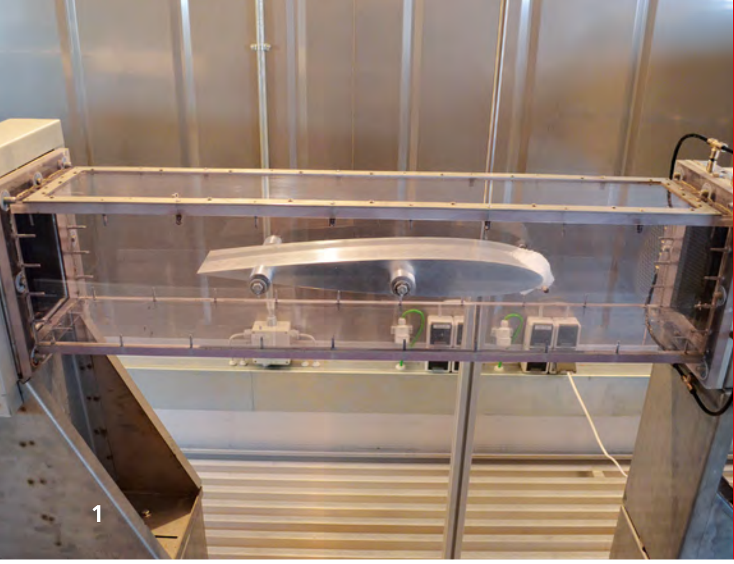
Coatings and surface functionalization are used in medical technology to give new material properties to well-known products or to alter their existing material properties. The range of possible applications is endless; it includes functionalizing silicon surfaces, optimizing the surface feel, and color-coding implants to avoid confusion as well as using bioactive coatings that optimize surface bone cell growth and antimicrobial functions.

The Fraunhofer IFAM has many years of experience in the area of antimicrobial, biocompatible, and non-cytotoxic coatings. These coatings are used to reduce the risk of infection following implantation of tooth replacements and to improve the long-term success of the implants. The DentaPlas coating was developed in cooperation with the medical industry. It inhibits the growth of bacteria on its surface, which means the implant can grow in better and become permanently anchored in the jaw. The researchers combined surface materials with different physical and chemical properties. The DentaPlas coating has a rough structure, which cells can easily grow on, and it is combined with a hydrophilic plasma polymer coat, which attracts water. While only 100 nanometers thick, the researchers integrated silver nanoparticles into the plasma polymer layer, where they continually release antimicrobial silver ions.

Another example of our work in our core competency of surface technology is that of atmospheric coating technology for implant color-coding. This was developed to help avoid the confusion of implants during surgery. The current developments focus on the integration of a data matrix or QR codes to create a unique device identification for the medical product. Using physical vapor deposition, polymer implants such as PEEK can be coated with titanium, ensuring the implant is biocompatible. The researchers were successful in increasing the titanium's adhesion to the PEEK with a special adhesion layer, preventing the possibility of detachment.

Another method of influencing the interaction between cells and the medical implant is that of controlling surface energy. For example, changing from a hydrophobic to a hydrophilic surface using plasma activation can significantly affect cell adhesion. The macroscopic surface structure is an important parameter for such adhesion. Laser structuring can give bone cells a growth boost, and these structured areas can be selectively applied to orthopedic implants, making them especially attractive for the bone cells.

1 *Two HeLa cells interacting on a functionalized surface.*



INNOVATIVE PAINT SYSTEMS

The Fraunhofer IFAM has many years of experience and competency in lacquer technology and has put them to use in a diverse range of projects. We would like to present two projects that were especially important in 2015. Further information can be found through the associated links.

Development of new ice protection systems for aircraft

The JediAce Project (Japanese-European De-Icing Aircraft Collaborative Exploration) is an international consortium with the goal of developing a multi-component de-icing system that meets the requirements of the next generation of aircraft. The project receives financial support from the European Commission and the Japanese Ministry of Economy, Trade and Industry (METI). Specialists from many different countries are working together on this project under the leadership of the Fraunhofer IFAM.

The aim of the project is to create an integrated ice protection system for airplane wings, covering three synergetic components: active de-icing technology, functional coatings to support de-icing, and sensors that observe both the ice formation process and de-icing in real time. The researchers from the Fraunhofer IFAM are focusing on developing anti-ice coatings and testing them whilst ice is forming on surfaces. A huge milestone was the construction of a wind tunnel that can reach freezing temperatures of -30 °C and wind speeds of up to 350 km/h. Tests at the Fraunhofer IFAM have already shown the efficiency of the parts developed during the project.

→ **www.jediace.net**

Repair systems and concepts for corrosion protection coatings for offshore wind turbines

Corrosion is a critical factor for offshore wind turbines. The most important protection mechanism for areas of the towers that are not always completely submerged is a corrosion protection coating. A sustainable repair system that can be implemented offshore requires consideration of the complex relationships between the operations, local conditions, and the observation and assessment processes of the available protection systems.

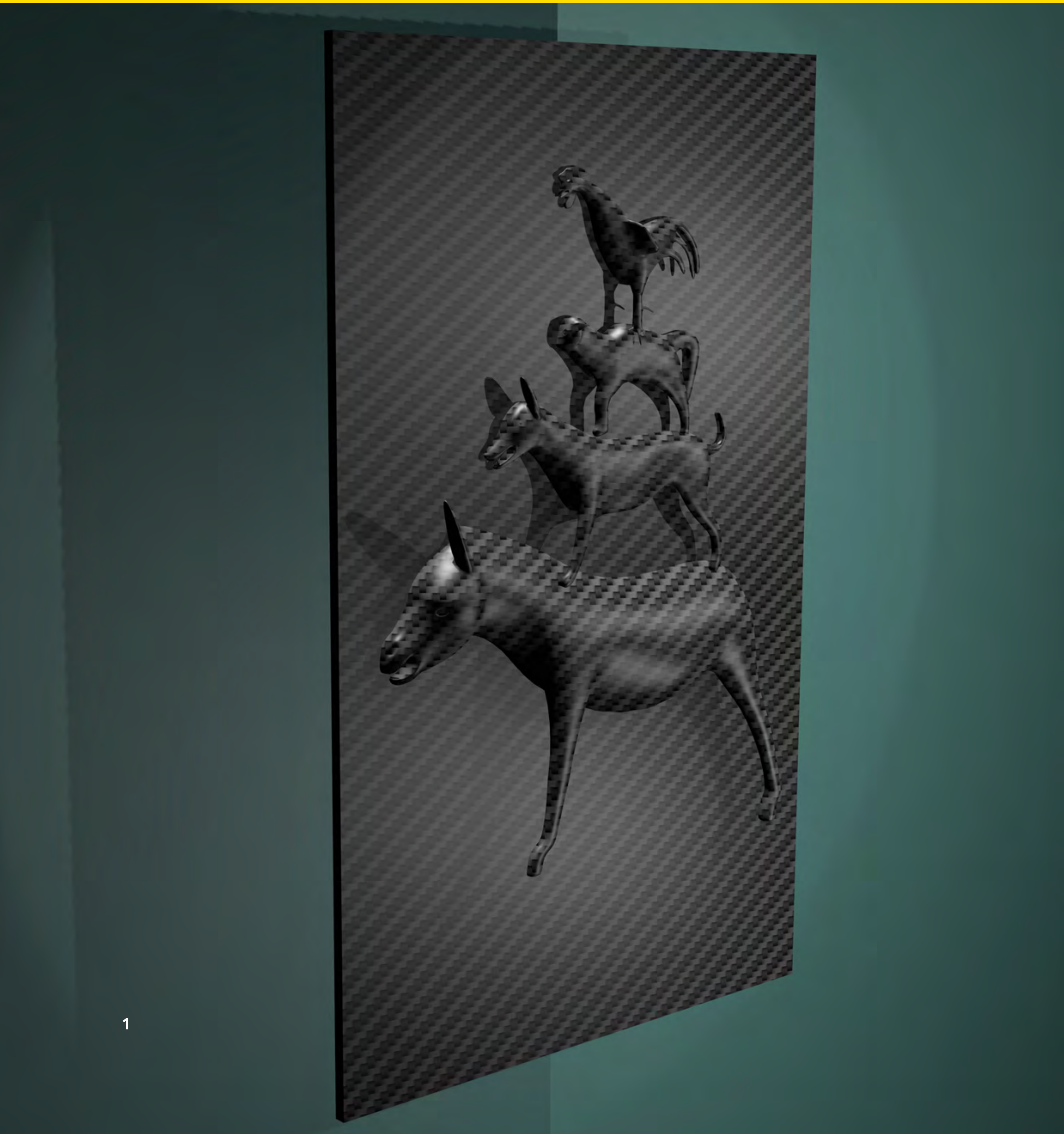
In the combined project "RepaKorr", sponsored by the German Ministry of Education and Research (BMBF), manufacturers of coating materials, contractors for coating systems, equipment manufacturers, system operators, steelworkers, and assessors were working together on the material, technical, conceptual, and organizational principles for an "on-site repair" concept. Important developments from this work concerned the repair of materials and on-site application methods as well as the development of a new method of inspection using drones.

→ **www.matressource.de/projekte/repakorr/**

1 *Investigations of wing profile icing in the icing wind tunnel.*

2 *Repairs of an offshore wind turbine.*
(© Muehlhan AG, Hamburg).

FIBER REINFORCED PLASTICS



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CORE COMPETENCE FIBER REINFORCED PLASTICS

Fiber reinforced plastics, especially fiberglass or carbon-fiber reinforced duromers, have become indispensable in making lightweight structures for aircraft and automobile construction possible. In the field of renewable energy, especially wind energy, they provide energy-efficient and thus more economical construction methods. Their advantage lies in the high rigidity of the direction of the fibers in combination with the shaping by the matrix.

The Fraunhofer IFAM's spectrum of competencies in the field of materials reinforced by glass, carbon, or natural fibers spans from resin development through the design and production of components and surface modifications, to automated assembly and processing.

Origin is with the selection and development of the appropriate resin systems, for parts with good mechanical characteristics as well as for special requirements like conductivity, lightning protection, and impact-resistance modifications. The resin system essentially determines the processing methods and times. New duromers are our current focus, since they can be processed thermoplastically with a high degree of automation, despite having a three-dimensional network structure. Semi-finished and finished components can be efficiently manufactured with raw materials from renewable sources.

Extraordinary material features can only be achieved by finding the optimal interaction between the fibers and the matrix resin. We can make this happen by using various surface technologies, such as plasma treatment of the fiber surfaces. When producing or further processing components, surface modifications like cleaning and activation, coating, and applying functional layers play a central role. Adhesive solutions and customized corrosion protection concepts help avoid contact corrosion in material compounds combining CFRP and metallic materials.

Fast, quality-assured processes are essential for serial production. The Fraunhofer IFAM offers automation solutions that can save a lot of assembly and processing time, even for very large, less dimensionally stable fiber-composite structures. This leads to the emphasis being placed on light, mobile, modular system components that can be adapted to a versatile production line without extra effort or cost. Quality assurance is another competency cornerstone that spans all industries. One of the goals in this area is the constant observation of the component's surface conditions using customized inspection methods to optimize specific manufacturing processes. This work is supported by our staff training: we run an extensive range of personnel qualifications that apply to many industries and products. Technology transfer takes place during training, allowing cross-pollination of scientific knowledge and methods which eventually find their way into industrial applications.

→ **www.ifam.fraunhofer.de/fvk**

1 *Formed from one FRP sheet: artistic design from FRP modeling.*

ASSEMBLY OF CFRP VERTICAL STABILIZERS AUTOMATED FOR THE FIRST TIME

The goal of the joint project "Flexmont", funded by the Lower Saxony Ministry of Economy, was to significantly reduce assembly times and costs for the vertical tail plane's CFRP box on the A320 family of passenger planes. This included the future-forward box design (VTP-NG – Vertical Tail Plane Next Generation), which assists the automation of the assembly process. What's special about the design solution is that the side panels made of CFRP sandwich are stiffened on the inside of the box, each with eight horizontally extending half-ribs with a double-T profile. On closing the box, geometrical tolerances accumulate inwardly at the distance of the half ribs, which converge at an acute angle. The resulting gap is closed with an individually 3D-printed wedge.

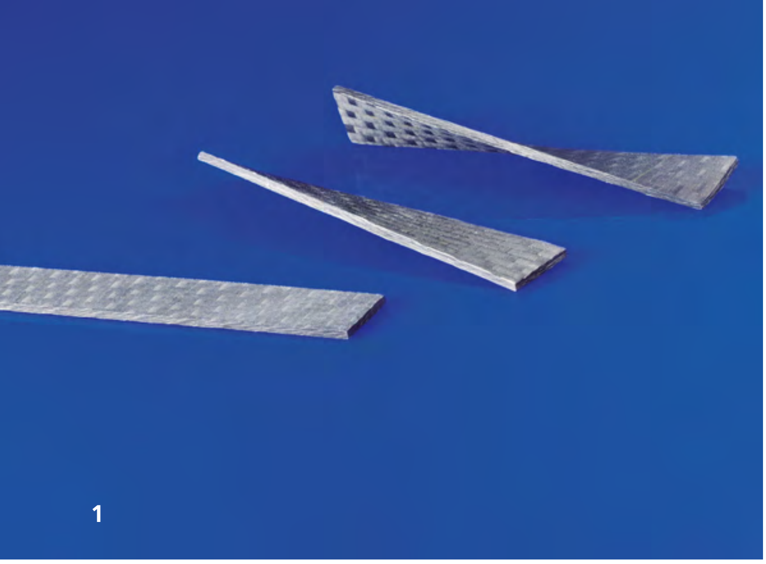
The Fraunhofer IFAM and its partners Airbus Germany, CTC GmbH, FFT Production Systems, Mahr Metering Systems, and Quiss Quality Inspection Systems faced many diverse technological challenges in automating the box assembly process, which had previously been conducted manually.

As a first step, the project team decided to automate the bonding of the half-ribs to the panel skin. There were many steps involved here: the synchronization of the components; cleaning and pretreatment of the surfaces to be joined; the application of adhesive to each and every gap individually depending on distance; applying pressure to the highly viscous adhesive for minimising gap widths; and finally, setting the ribs to cure. The goal of avoiding heavy steel construction meant that the necessary pressure for the adhesives of up to 4000 N over a wide area was much more than the robots could provide. The Fraunhofer IFAM and FFT solved this problem by using a two-part multifunction gripper on the robot that both arranged the ribs and uniformly applied pressure to the adhesive with vacuum suction. One special feature was a small fixation unit on the gripper that stayed on the rib during curing while the robot reached for the next rib with the outer combination gripper.

Other exceptional joining solutions allow the box to be closed with the front and rear spars in a box assembly station. After the robots have automatically synchronized the components, a press unit closes the adhesive seams between the rear spar and side panels. A lightweight construction robot, controlled by an industrial robot as an end effector, then inserts the wedge. The Fraunhofer IFAM completed the work by developing a handheld applicator which aerodynamically seals the relevant seams on outside areas, as well as automated processes for the reliable sealing of rivet heads and irregularly broad and deep hems. Finally, a robot-guided camera system with automatic image analysis inspected the bonds and seals regarding specified quality criteria.

1 *Rib assembly station in the Fraunhofer assembly hall of the CFK Nord (CFRP Research Center), robot with ribbed multifunctional gripper.*

2 *Box assembly station with a press unit at the CFK Nord (CFRP Research Center).*



STRONG AND FLEXIBLE – MALLEABLE LIGHTWEIGHT CONSTRUCTION MATERIALS

The beginning of the year 2015 was the starting signal for the new department "Chemistry of Fiber Composite Materials". For the project "Recyclable and Formable Duromers for the Production of Modular Fiber-Reinforced Plastics" (DuroCycleFVK), financed by the German Ministry of Education and Research (BMBF), a team of scientists was tasked with researching formable fiber-reinforced plastics.

Fiber-reinforced thermosets are excellent for many different applications in the field of lightweight construction. Despite widespread usage and new markets, the synthesis concepts and polymer matrices already in use have long remained unchanged. In comparison to other classes of polymers, thermosets possess amazing mechanical properties and chemical stability as a result of their three-dimensional networked molecular structure. The resulting compound is extraordinarily resistant and flexible, but no longer deformable. This currently limits its use in industrial-scale manufacturing and makes recycling of worn-out components almost impossible. This becomes problematic when looking at future-oriented topics such as resource efficiency and sustainability, which means that processes using FRPs are becoming more and more important. Recyclability and product life extension must now be considered when planning and manufacturing with these materials.

This is where the "DuroCycleFVK" project comes in. We are developing fiber-reinforced plastics that are reverse-formable by means of heat or other methods. This requires the development of three-dimensional networked composites that can be re-formed under certain conditions. The work has focused on researching new polymer systems that bring together the desired characteristics of thermosets and thermoplastics. This can be achieved by choosing the right combination of polymer backbone, degree of networking, and type of polymerization. New methods of reversible polymerization need to be researched which can be narrowly modulated and which are also suited for use in FRP.

Working from these deformable plastics, simple, flat FRPs can be transformed into complex components like car bumpers using industrial-scale shaping processes (e.g. deep-drawing). Plastics that can later be re-formed and separated into their original ingredients would revolutionize the repair and maintenance of damaged parts, including the recycling of worn out parts. Natural fibers, as an alternative to carbon fibers, will improve the ecological balance of deformable FRPs and, along with organic-based polymers, will influence the future of lightweight construction.

1 *Shapeable fibre reinforced plastics due to thermo-responsive polymer matrices.*

2 *Shapeable fibre reinforced plastics due to thermo-responsive polymer matrices (© Fotolia/Vladislav Kochelaevs).*

ELECTRICAL COMPONENTS AND SYSTEMS

CORE COMPETENCE ELECTRICAL COMPONENTS AND SYSTEMS

Electrical systems are ubiquitous in every industry, and in society. The provision and efficient use of electrical energy in technical systems requires a comprehensive understanding of these systems. Starting from our knowledge of electrical and electrochemical material properties, the Fraunhofer IFAM provides technical solutions for the best use of electricity.

Electrical energy must be stored safely at high density and performance, and mobile applications such as smartphones represent a real challenge. The material and technical process aspects are our focus at the Fraunhofer IFAM, where we work to discover future electrochemical energy storage solutions. In addition to lithium-ion and metal-air batteries, using more and more on solid-state batteries, which can use ion-conducting ceramics or polymers instead of liquid electrolytes. During the development of required materials and processes, the IFAM's competency in materials and manufacturing technology comes into its own. Using customer-specific materials, we are developing and optimizing the entire process chain for cell manufacturing.

Electric drive technology has concentrated on the development, prototyping, and testing of highly efficient electric motors. To that end, we are working on new approaches to increase the functional safety of drive systems and efficiency-optimized control of permanent-magnet synchronous motors. This brings to the forefront the increase of performance and torque density as well as the development of specialized manufacturing processes for electrical drives. Adhesive bonding and surface technology, complement this core competency along with aspects such as joining, contact, insulation, and protection of electrically conductive materials.

At the Fraunhofer IFAM, we can use our technical expertise in the field of automobiles to put our weight behind the conception of vehicles, the development of reliable steering, and the building and testing of automobiles with electrical and hybrid-drive trains. To assess and increase reliability while in operation, individual components are tested with hardware-in-the-loop simulations of operating behavior on a drive train test bench.

A cross-departmental cornerstone of this concept is the analysis and assessment of complex technical energy systems, ideally involving electric vehicles as mobile power storage devices. Coupling electrical systems and heat supplies on a local and regional level requires the use of heat and electrochemical storage devices and converters. In this area, the Fraunhofer IFAM offers studies that consider the economic and current regulatory market conditions for electric power and district heating.

Finally, we are modeling the implementation of mobile and residential power storage devices into buildings to optimize both energy-efficiency and autarky and simulating this in a physical test field with real components.

→ **www.ifam.fraunhofer.de/elkos**

1 *The Fraunhofer IFAM is dedicated to current questions of sustainable, affordable, and safe energy supplies. (© Fotolia).*

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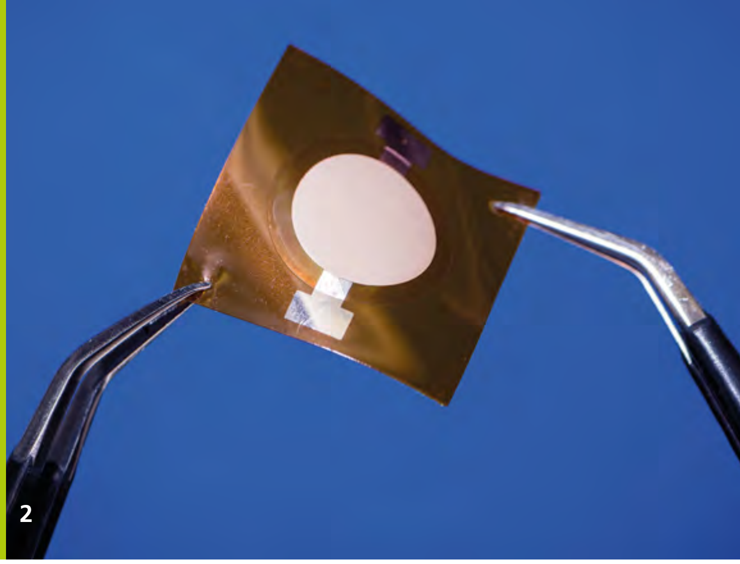

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SOLID-STATE BATTERIES – THE NEXT GENERATION OF ENERGY STORAGE

Rechargeable solid-state lithium-ion batteries are seen as the next generation of energy storage devices. Towards commercial lithium-ion batteries with liquid, gelatinous electrolytes they have many advantages with regard to safety, energy density, and long-term stability. In addition to new solid electrolytes with high lithium-ion conductivity, an important development of solid-state lithium-ion batteries are the associated processing technologies to manufacture the solid-state batteries. A deep scientific understanding of the processability of the chosen materials is essential in this field. With core competencies in powder and surface technologies, the Fraunhofer IFAM can accelerate the development of solid-state lithium-ion batteries with its cross-departmental approach.

High performance, inexpensive batteries are the key component of mobile and stationary electrically operated applications and are often the most challenging part of system development. Electrical energy storage devices used in automobiles must fulfill an especially wide spectrum of requirements that include parameters such as costs, energy and power density, durability, temperature range, and reliability.

Most of today's mobile devices use lithium-ion batteries because these have a significantly higher energy density. These batteries consist of a negative electrode, usually made from graphite, a positive electrode, and fluid, non-aqueous electrolytes. Typically, non-aqueous electrolytes are composed of lithium salt that has been dissolved in one or more organic solutions and is slightly flammable. If the widely used lithium salt (LiPF6) comes into contact with moisture in the air, the very poisonous substance hydrofluoric acid is created.

It would be advantageous to use solid-state electrolytes in this case. Solid-state electrolytes are solid ion conductors and come in very diverse structural forms. As an inorganic material, they are usually found as ceramics with crystalline or amorphous structure and, at the same time, can serve as a solid separator between the electrodes. Because they are not flammable, these so-called solid-state batteries feature an increased operating safety. This means that a secure, solid housing for the battery cells is no longer necessary, and so the total weight of the battery can be reduced. Moreover, without liquid electrolytes, more versatile designs are possible.

Due to their chemical stability with regard to reacting with elementary lithium and their high decomposition voltage, solid-state electrolytes allow the use of metallic lithium anodes and novel high-voltage electrode material with high long-term stability, which makes the batteries more energy dense. Along with a low level of self-discharge, these factors add to the decisive advantages of state batteries. One disadvantage is the

low movement of ions in the solid electrolytes. This presents a real challenge for the development of solid-state batteries. Another critical part of these systems are the charge transport resistances at the phase boundaries between the electrolyte and the electrodes. These processes are often strongly inhibited and cause a loss in cell voltage.

The manufacture of solid-state batteries requires new, different production methods. The work here at the Fraunhofer IFAM starts with production processes from the research areas of surface and powder technology, which are used to develop solid-state batteries with optimized phase boundaries. To significantly increase the energy content of solid-state batteries, alternative electrode architecture and cell designs will be necessary. The work group is examining solid-state composite electrodes, which consist of a composite of known electrode and electrolyte materials. Here we want to develop powder-based shaping processes to make more compact and more homogeneous composite electrodes. However, basic questions about oxide solid-state ion conductors must first be examined. Another approach investigates compensating for the electrolyte's poor ionic conductivity by minimizing the thickness of the electrolyte layer by means of physical gas-phase separation techniques. These methods can create very thin layers and very good phase boundaries, but they display low absolute energy content due to the small amount of material used. In cooperation with the junior staff group "Innovative Sensor and Functional Materials" at the University of Bremen, we are searching for possible solutions to optimize cell designs and the associated performance. The batteries built with thin-layer technology are mainly aimed at use in miniaturized, flexible applications, which are expected to see strong growth in the near future.

1 *Mixer for compounding composite electrodes.*

2 *Flexible thin-layer battery.*

3 *Vacuum chamber for thin-film separation within the glovebox.*

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

In the business segment medical technology and life sciences, the Fraunhofer IFAM is working on technical and biological materials that interact with humans and the environment. The complete process chain is covered, ranging from customized materials and material combinations to manufacturing technology and surface functionalization, and the complete characterization of the product. The Fraunhofer IFAM possesses specific knowledge in the field of biological assessment of medical products in accordance with DIN EN ISO 10993 and has established important tests for this standard in Bremen to accelerate the introduction of products to the market.

PEOPLE AND MOMENTS

FRAUNHOFER IFAM BUILDING EXTENSION DEDICATED

With a celebratory colloquium, the extension of the Fraunhofer IFAM building was dedicated on June 24, 2015. With 6,200 square meters of the most modern laboratories and offices, the new building has workspace for 60 scientists. With the goal of strengthening Bremen's scientific emphasis on materials sciences, the building was financed equally by the Land of Bremen and the German federal government. This third section of the institute allows us to further strengthen our current research areas and to expand into trailblazing new areas such as fiber-composite construction methods, energy, multi-functional coating systems, and electromobility.

More space for research and development – exactly what the IFAM scientists had wished for. In June, the first devices and machines were moved into and assembled in the building on Wiener Straße. In the "Additive Manufacturing" laboratory, all of the institute's 3D-printing systems were installed. In addition to selective laser melting, a binder-based printing process will find a home there, enabling the production of graded, 3D-printed metal components. Manufacturing aspects are also at the forefront of surface technology, including the continuous layering of plastic films in a plasma process.

In another room, research is conducted into material science solutions for the batteries of the future. The focus here is on the development of solid material batteries without liquid electrolytes. The expansion of the technical area for fiber-composite materials and lightweight construction is especially important. Its large areas allow systems to be realized in completely new dimensions and enable thinking in new concepts of materials and manufacturing, specifically in the aviation, automobile, and wind energy industries. The "Electrical Drives" department conducts research on the further development of electromobility, working on increasing efficiency, compact construction methods, and the necessary manufacturing technology. In the new technical center, prototype drive systems are being developed along with their integration into hybrid and electrical cars. A teaching laboratory offers practical training and also encourages technology transfer of the newest results in research.

The architecture and building technologies in this new building were planned by the "ATP architects engineers", with designs based on modern economic, ecological, and social criteria. The interior concept combines large lab spaces with clearly structured office areas and numerous communication areas. A welcoming, transparent entrance area, a foyer to connect elements of the building, and large windows into the research areas link the entire structure to the public. A glass bridge over Wiener Strasse connects the existing institute buildings seamlessly with the new research building and provides a useful shortcut.

1 *Senator Prof. Dr. Eva Quante-Brandt and institute directors Prof. Dr. Bernd Mayer and Prof. Dr.-Ing. Matthias Busse at the symbolic handover of the key to the Fraunhofer IFAM extension (from left to right).*


TIM TRANTENROTH WINS THE “KUNST AM BAU” BUILDING ART COMPETITION

On June 18, 2015, the jury voted on the artistic design competition for the Fraunhofer IFAM’s new building. The jury awarded first prize to Tim Trantenroth for his creative idea of a wall mural with topologically optimized structures. The mural, which combines acrylic, fluorescent and shiny “flip-flop” paints, has decorated the extension’s new foyer since September. With his use of perspective and a subtly changing play of colors, this Berlin artist defeated four other competitors.

Topology optimization is a computer-based calculation method which can determine the best component shape under mechanical stress. This method can save material resources and energy. Mr. Trantenroth’s creativity in embracing this scientific idea, which is intimately related to the Fraunhofer IFAM’s research fields, and his professional presentation, won over the jury of art experts. Dr. Eva Fischer-Hausdorf, Dr. Arie Hartog, Adorjan Lux, and Nadine Rinker, along with their fellow specialist jurors Prof. Matthias Busse, Prof. Bernd Mayer, Birgit Philipp, and Herbert Bayer as the construction representative, were excited by the mathematically precise structures and novel appearance of Mr. Trantenroth’s design.

Tim Trantenroth has also utilized other perspectives: the seemingly controlled chaos of his design symbolizes his reflections on research, the effect of a number of different perspectives, and the ability to perceive, which suggests the subjectivity of that research. This upside-down root-like mesh of topology optimization also represents the most complex research processes at the Fraunhofer IFAM. The perspective view requires us to continually train our visual perceptions: observation and recognition are also the basis of research, thus art and science interact.

About the artist: Tim Trantenroth, born in 1969, lives and works in Berlin. He has become known through his international individual and group exhibitions (e.g. Berlinische Galerie, Museum of Modern Art, Photography and Architecture). His works are represented in numerous collections.

Why a “Kunst am Bau” building art competition?

The official public building commissioner and his/her buildings have a special standing in the public eye. He/she has a responsibility to architectural culture and functions as a role model. The federal government is committed to this responsibility. The commissioner’s structures should reflect a high level of architectural culture and understanding and represent the nation, especially when they serve significant governmental functions and are exposed in prominent locations. The “Kunst am Bau” art competition is an element of architectural culture that helps shape the quality and expressiveness of buildings. “Kunst am Bau” is therefore an integral part of the construction project and the public building commissioner’s responsibility.

1 *Tim Trantenroth.*
2 *Jury, expert consultants, and guests.*

1

FRAUNHOFER PROJECT CENTER LAUNCHED IN WOLFSBURG

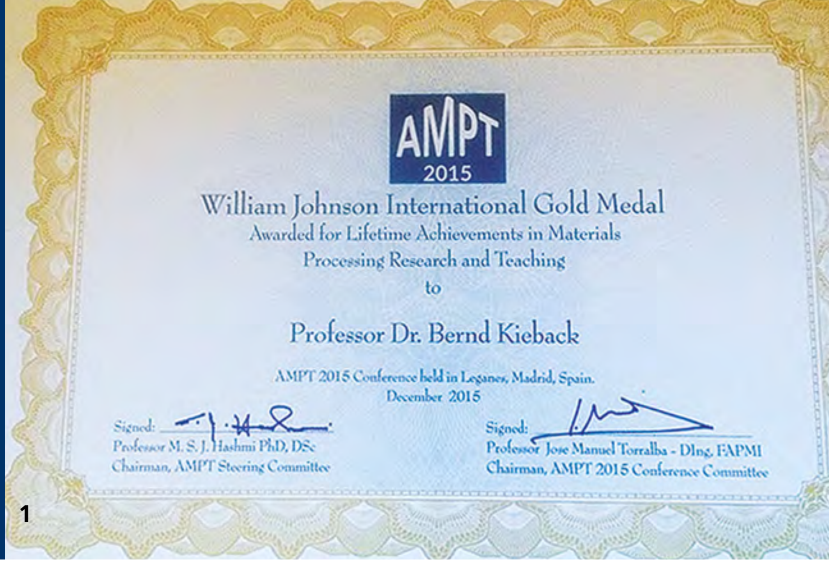
At the new Fraunhofer Project Center in Wolfsburg, three Fraunhofer institutes are working together. The center also boasts close ties to other research institutions and companies in the region. The researchers here are putting their heads together to find system solutions for the serial production of lightweight components for the automobile industry that save on resources and are cost effective. On April 22, 2015, the Minister-President of Lower Saxony Stephan Weil, former Volkswagen chairman Professor Martin Winterkorn, and Professor Reimund Neugebauer, President of the Fraunhofer-Gesellschaft, and many other partners signed a cooperation agreement between Volkswagen, the Fraunhofer-Gesellschaft, and the government of Lower Saxony in support of this research center.

"Lightweight structures, which have up until now been produced in small batches exclusively for sports cars and airplanes, will be available for all vehicles in the future. At the Wolfsburg Fraunhofer Project Center, we are developing concept solutions for sustainable materials and drive concepts. We have seized this opportunity to work together with our partners from the region to replicate a complete process chain for lightweight structures and to test it on a large scale, thus providing new impetus for industrial production", explained Professor Neugebauer. The launch team for this project, under the overall coordination of Professor Matthias Busse, consists of three Fraunhofer institutes: the IFAM in Bremen, the IWU in Chemnitz, and the WKI in Braunschweig. The Fraunhofer Project Center in Wolfsburg boasts an open structure and can be supported as needed by other Fraunhofer institutes and specialty fields. The project center is making an important contribution to the competitiveness of companies in Lower Saxony. Its discoveries can also be utilized for wind turbines, aircraft, and other means of transport.

The Fraunhofer Project Center expands existing network

With the establishment of the Open Hybrid LABfactory (OHLF) in Wolfsburg on May 27, 2013, a network of partners from industry and science have come together, making possible the development of a comprehensive value chain. With this goal in mind, the project partners combine different materials and develop new methods to produce fiber composites and to process and recycle renewable raw materials. Other topics include increasing efficiency, reducing emissions, and enabling industrial serial production capability. The researchers want to run pilot processes to demonstrate their work in material and process development. The Fraunhofer Project Center is now part of the OHLF and supports existing activities there.

1 *New building of the Open Hybrid LabFactory in Wolfsburg (© IC-L GmbH & Co.KG).*



PROFESSOR BERND KIEBACK RECEIVES WILLIAM JOHNSON INTERNATIONAL GOLD MEDAL

The Dresden materials scientist Prof. Dr.-Ing. Bernd Kieback has been awarded the William Johnson International Gold Medal at the Advances in Materials & Processing Technologies Conference AMPT in Madrid on Monday, December 14, 2015. Thus, his lifetime achievements in materials research and teaching have been recognized. Among others, he has led Dresden to become the leading site for powder metallurgy in Germany and Europe.

The William Johnson International Gold Medal is being awarded by the steering committee of AMPT to recognise and appreciate distinguished academic achievements in materials processing research and teaching. The award is named after Professor William Johnson, formerly of the University of Manchester Institute of Science and Technology and Cambridge University, whose pioneering work on materials processing and process modeling is internationally recognized.

During his career, the laureate 2015, Prof. Kieback, director of the Dresden branch of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM as well as professor for Powder Metallurgy, Sintered and Composite Materials at Technische Universität Dresden, has done research and teaching on different areas of powder metallurgy. In the beginning, he focused on sintered steel, later he mainly concentrated on hard metals.

In his functions, he creates a perfect symbiosis between powder-metallurgical research and its transfer into industrial applications.

With his presentation on occasion of the award ceremony at the opening ceremony of AMPT, Prof. Bernd Kieback addressed a cutting-edge topic under the title „Powder based Technologies for Additive Manufacturing: Oddity or Revolution?" - a topic in which powder metallurgy in research and application is currently very much involved.

In his presentation, he provocatively posed the question if additive manufacturing is leading the way into the next industrial revolution. With two technology examples, i.e. electron beam melting and 3D screen printing, he demonstrated solutions additive manufacturing is offering for topical industrial problems.

Not only does Prof. Kieback consider his accolade as a recognition of his achievements so far, but also as an appreciation of the accomplishments of all Dresden powder metallurgists. Furthermore, he regards the honor as an incentive to further actively participate in the powder metallurgical community and to advance powder metallurgy

1 *Certificate of Honor of the William Johnson International Gold Medal, awarded to Prof. Dr. Bernd Kieback on December 14, 2015 at the Advances in Materials & Processing Technologies AMPT Conference. .*

FRAUNHOFER IFAM DRESDEN IMPRESSES WITH HYDROGEN FUEL GAUGE

Researchers from Fraunhofer IFAM in Dresden were awarded the first prize in the Energy/Environment/Solar Industry Cluster at the award ceremony of the 11th IQ Innovation Prize of Central Germany, which took place at Naumburg Cathedral on July 1, 2015. Dr. Lars Röntzsch and Felix Heubner received the prize, along with €7,500, for their "innovative level sensor for hydrogen", which they developed in collaboration with their colleagues.

"This innovation significantly improves the condition monitoring and user-friendliness of metal-hydride based hydrogen storage. The new level sensor can also contribute to the market success of mobile and stationary fuel cell systems", said Jörn-Heinrich Tobaben, managing director of Metropolregion Mitteldeutschland Management GmbH, explaining the jury's decision.

The new level sensor for metal-hydride storage devices takes advantage of the fact that there is a change in the metal's volume when absorbing and releasing hydrogen. If the expansion of the metal is restricted during H_2 absorption, it creates a mechanical force that can be measured by the sensors. Thanks to the linear relationship between expansion and absorption, the measurement is highly dynamic, precise, and temperature-independent. The new system can be retrofitted as a bypass on all metal-hydride storage devices on the market today. The inexpensive sensor is designed for long-term operation of tens of thousands of cycles. The prototype should be ready for series production by the end of 2016.

With its IQ Innovation Award of Central Germany, the European Metropolregion Mitteldeutschland (Metropolitan Region of Central Germany) promotes new, marketable products, processes, and services to increase innovation and competitiveness in the regional economy.

1 *The winners: Fraunhofer IFAM with prize founders envia Mitteldeutsche Energie AG and Siemens AG; from left to right: Dr. Andreas Auerbach (envia Mitteldeutsche Energie AG), Felix Heubner (Fraunhofer IFAM Dresden), Dr. Lars Röntzsch (Fraunhofer IFAM Dresden), Kerstin Heinitz (Siemens AG)*
(© Guido Werner/GWP).

GDCH CONFERENCE PRIZE FOR SPECIALIST PRESENTATION ON THE TOPIC OF INTRINSIC SELF-HEALING

At the 79th annual conference of the lacquer chemistry specialist group of the Gesellschaft Deutscher Chemiker (GDCh) in Schwerin, Anastassija Wittmer was honored for her technical presentation. Dr. Michael Hilt, director of Coating Systems and Lacquer Technology at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and managing director of the Research Society for Pigments and Coatings, presented her with the first prize for the best presentation, which she had given on September 20th, 2015. Anastassija Wittmer presented the initial results of her doctoral thesis on "Intrinsic Self-healing Paints".

Coating materials are often exposed to extreme environmental conditions and must withstand high levels of stress during manufacturing processes. UV light, tree sap, mechanical abrasion, and internal tension increase the damage to the paint over time and lead to micro-fissures. This nearly invisible damage triggers greater material damage and ultimately leads to the failure of the component. Materials with self-repairing properties are able to mend this microscopic damage on their own or under the influence of an external stimulus. This can help prolong the life of the component and maintain the appearance of the material.

For many years, researchers in the field of lacquer technology have been working with extrinsic self-healing coatings based on capsule systems, and now, with her PhD dissertation, Ms Wittmer is expanding this area of expertise to include intrinsic self-healing mending polymers. Intrinsic self-healing is based on a specific polymer architecture, where the polymer has the ability to form a great number of reversible physical bonds. A self-healing reagent can be fixed covalently in a polymer network, or it can be added to the paint as an additional binder. In both cases, the molecules can build supramolecular networks through intermolecular and intramolecular physical interactions. This type of system is able to heal damage such as micro-fissures by reorganizing the molecules. Self-healing usually occurs at elevated temperatures and air moisture levels. It has been shown that the water from the moisture in the air plays a decisive role in the self-healing process.

1 *Dr. Michael Hilt, head of department of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and managing director of the Research Society for Pigments and Coatings, giving the conference prize to Anastassija Wittmer (© S. Schulte).*

ADDITIVE MANUFACTURING CHALLENGE 2015: STUDENT PROJECT WINS FIRST PLACE IN WORLDWIDE COMPETITION

"Cooling with Heat" is the slogan of a newly developed cooling process that functions without additional electricity. Five Production Technology master's students at the University of Bremen have carried out research at the Fraunhofer IFAM on how to create enough electricity from waste heat to run a cooling unit with heat pipes and a fan. Their use of energy harvesting with thermoelectric generators and the creative layout of the cooling fins won over the international jury at the Additive World Conference in Eindhoven (NL).

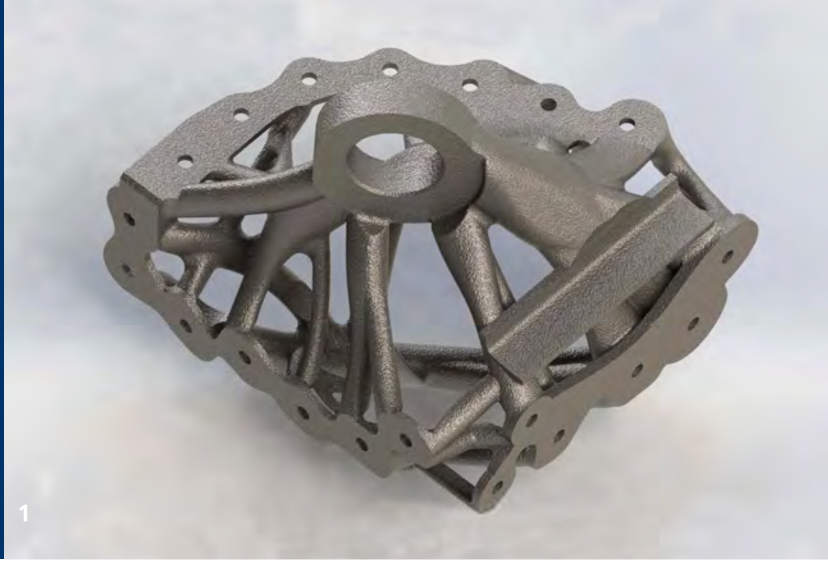
Cooling units are essential for equipment such as freezers, servers, and computers in order to dissipate heat from their processors, all of which release waste heat to the ambient air through cooling fins. Most of these cooling units use fans to generate air flow between the fins, so that the heat can be removed more quickly. The basic idea behind the new cooling units is to use some of the waste heat produced by the device to generate electricity, which in turn operates a fan. The young scientists also designed and constructed unique cooling fins with an especially high surface area inside a small space. Their idea was made into reality using additive manufacturing technology.

For a thermoelectric generator to continually produce electricity, a constant temperature gradient must be established and input into the generator. Simply put, one side of the generator must be hot, and the other cold. The maintenance of the temperature gradient was a particular challenge, because the waste heat from the processor must be quickly routed to the generator, and simultaneously the resulting heat energy must be dissipated as effectively as possible from the cold side. Heat pipes are ideally suited to these two tasks. For this project, they were individually constructed and optimized using additive manufacturing. The resulting heat pipes were designed with a maximum bend of 45 degrees and an internal capillary structure, allowing for quicker transport of the water to the warm parts. This complex structure can only be built using a 3D-printing process, such as selective laser melting (SLM).

To improve the cooling process as a whole, and specifically the heat transfer to the ambient environment, the students came up with an extraordinary innovation. Inspired by the branches of a tree, the cooling system uses limb, branch, and leaf structures, rather than a conventional rib structure. The purpose of the structure was to generate the highest possible surface-to-volume ratio, thus obtaining the most efficient possible heat transfer to the air. This complex and intricate structure was also manufactured using the SLM process.

The "Cooling with Heat" Team: Jonas Deitschun, Melanie Gralow, Lena Heemann, Sebastian Kalka, Daniel Knoop.

1 *Additively manufactured cooling system.*



LIGHTWEIGHT AND ECONOMICAL FOR AVIATION: FRAUNHOFER RESEARCH TAKES 3RD PLACE IN STUDENT DESIGN & ENGINEERING AWARD 2015

Michael Suess of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden received 3rd prize in the Student Design & Engineering Award 2015 on June 10, 2015, at RapidTech 2015 in Erfurt, Germany.

Mr. Suess was recognized for his master's thesis, which he completed at the TU Dresden in the design technology/CAD department, working together with the Fraunhofer IFAM Dresden. The aim of the thesis was to improve the design of a key element in a helicopter transmission by optimizing its topology. Not only was he able to reduce the weight of the component known as the "MG Bracket rear" by nearly 40 percent, but he also made it possible to combine the previously separate components into one. The initial components had previously been made of bolted castings or machinings. Due to the complex structure of the new components, as well as the simultaneous connection of two parts, the new assembly procedure involves the use of an additive process and is a significant advance over the previous state of the art. For manufacturing, Mr. Suess used the additive production process of electron-beam melting, which is distinguished by its combination of high production rates and long-term durability. This additive process therefore has great potential for development to meet the changing needs of the aviation industry.

This innovative production method also requires the use of far less of its main constituent material, which in this case is Ti-6A1-4V, than previous methods, and thus is a great improvement in resource efficiency.

As a result of this award for developing the demonstrator model, a number of promising opportunities have arisen for future R&D projects, including a planned product series.

The development took place as part of the "GenFly" project's aviation research program, supported by the German Federal Ministry for Economic Affairs and Energy.

1 *Optimized "MG Bracket rear" component (demonstrator).*

NAMES | DATES | EVENTS

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 the Fraunhofer IFAM. We have particularly close links with the University of Bremen and TU Dresden.

During the 2015 summer semester and 2015/2016 winter semester, researchers at Fraunhofer IFAM gave over 30 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 200 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 2015, 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 *Architectural art, topology optimized structure (Tim Trantenroth), Fraunhofer IFAM, Bremen.*

Patents

Patents document the ability of an organization to innovate. Fraunhofer IFAM was granted 21 patents in 2015, 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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