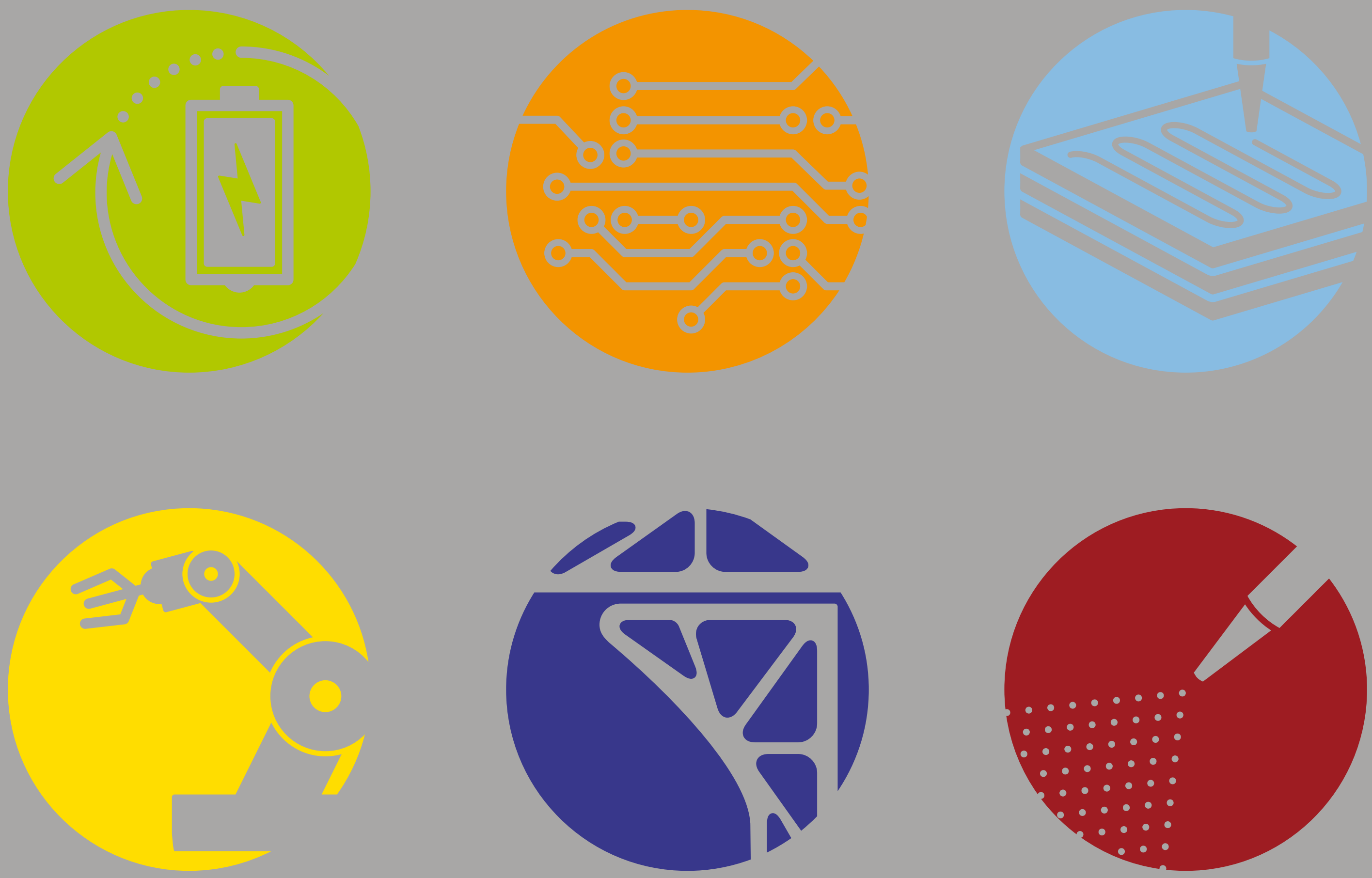
Fraunhofer
IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM



ANNUAL REPORT 2016/2017

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2016/2017

FOREWORD

Dear Reader,

In 2016, Fraunhofer IFAM again was able to continue its positive development. The last twelve months were characterized by a successful project business both in the industrial and public areas, as well as by a large number of successfully completed scientific works and numerous awards.

2016 was also strategically important. With our seven core competencies, the institute's branches can work together on a range of complex projects and are ready for future technological challenges. Be it progressive digitalization on the way to industry 4.0, innovative manufacturing technologies, new materials, or renewable raw materials, all these topics require a high level of attention and a substantial need for research and development.

Digitalization is one of the most important future topics of the economy. Industry is always striving for the automization, flexibilization and individualization of existing processes. The transportation industry, especially the automotive and aviation sectors, is not excluded and is undergoing radical changes.

In the context of industry 4.0, the aviation industry has begun an offensive to automate its production, moving away from individually designed, specialized machines to all-purpose robots. The "Automation and Production Technology" department in Stade is developing high-precision machining processes for large CFRP components using mobile robots working in parallel.

In this context, the Fraunhofer-Gesellschaft has also put strategic emphasis on so-called lighthouse projects. The goal is to turn original scientific ideas into marketable products as quickly as possible. Fraunhofer IFAM qualified for another project in 2016. In the lead project "Go Beyond 4.0 – digital manufacturing in mass production", digital manufacturing techniques are used to meet the challenges connected to the development of individualized components in production technology.

1 *Institute directors Prof. Dr.-Ing. habil. Matthias Busse (left) and Prof. Dr. Bernd Mayer. (© GfG Bremen/Thomas Kleiner)*

As well as advancing automation, all of the large automotive groups have also started to invest in alternative drive technology. The "Electric Drive Systems" department has focused on developing compact electric machines with increased torque and power density. Innovative manufacturing technologies offer new possibilities in this area. As part of a Fraunhofer Future Foundation project under the leadership of Fraunhofer IFAM, several technological approaches are being pursued in order to develop large-scale, production-oriented processes for the production of coils, which would put electric machines in higher efficiency classes and would provide room for a more flexible machine boom design.

The development of the battery also plays a central role, not only for its relevance to our electromobile future. An emphasis of the research work of the department of Electrical Energy Stores in Oldenburg lies in the development of polymer-based solid-state batteries, a technology characterized by high energy density and safety.

To achieve innovative objectives, investment in new manufacturing technologies is essential. Therefore the largest plant in Germany for the additive manufacturing of three-dimensional components using electron-beam melting (EBM) was launched by our Dresden team in 2016. EBM is great for manufacturing components with complex shapes out of materials such as titanium, titanium alloys, or super alloys, to be used in aviation as well as automotive and medical technology.

The Fraunhofer Project Center in Wolfsburg, which also deals with new machines and production chains, moved into a 1600 m^2 office and laboratory area with the opening of the

“Open Hybrid LabFactory” Lightweight Construction CAMPUS in September 2016. Three Fraunhofer Institutes, WKI, IWU, and IFAM, work together at the Project Center under the guidance of IFAM to develop the entire lightweight-structure process chain and test it on a large scale.

As with all technological advances, the effects on the environment and especially humans must always be considered. Sustainability in the context of the efficient use of natural resources plays an important role in this respect. Renewable raw materials are relevant for fiber-composite materials as well as for the development of adhesives and coatings. Biocomposites and organic raw materials such as lignin, starches, fats, and polylactic acids are ideal source materials. The development goal is an improved biocompatibility of the materials developed and a better balance of CO_2.

Fiber-composite materials have become firmly embedded in the entire process chain, as well as in continuing education at Fraunhofer IFAM. Following the introduction of our internationally recognized adhesive bonding technology courses, we have established a modern Training Center for Fiber Composite Technology. The course offerings have now been expanded with the development and implementation of the “Fiber Composite Engineer” qualification.

In the growing business area of medical technology, we constantly bear in mind our great responsibility to human well-being. The use of natural raw materials also contributes to our progress in this area. For example, we have developed a bio-ceramic implant screw nail made of calcium phosphate whose composition is essentially the same as bone. Another internal research project supported by the Fraunhofer-Gesellschaft is taking on the important topic of the prevention and healing of implant infections.

Sustainable technical solutions are always the result of expert competencies and an intense exchange of ideas. In the context of strategic partnerships, we cooperate with excellent research partners worldwide. Our cooperative projects with the University of Bremen and the Technical Universities of Dresden and Hamburg are very important to our teams at these sites. The “U Bremen Research Alliance”, a newly founded network consisting of a large number of regional research institutions and the Excellence University of Bremen, is a further step toward bringing coordinated research strategies to a new qualitative level.

To bring humans, environment, and technology into balance – a challenge our scientists face with great commitment. Their passion and expertise are crucial to our success, and we are especially thankful to our employees. Our progress is also supported by the long-standing confidence in us shown by our partners in industry, our contacts in government ministries, and project sponsors. We would like to take this opportunity to express our sincere thanks for your support and funding.

Let us continue to shape the future together. We hope you enjoy reading our annual report.

Sincerely,

Matthias Busse   Bernd Mayer

Matthias Busse   Bernd Mayer

CONTENTS

1 *Aerial photograph of Fraunhofer IFAM.*
(© Fraunhofer IFAM/Peter Sondermann)

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 69 institutes and research units. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 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 state 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**

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

1 Wiener Strasse 12
28359 Bremen, Germany

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2 **Branch Dresden**
Winterbergstrasse 28
01277 Dresden, Germany

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3 **Electrical Energy Storage**
Marie-Curie-Strasse 1–3
26129 Oldenburg, Germany

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4 **Automation and Production Technology**
Forschungszentrum CFK NORD
Ottenbecker Damm 12
21684 Stade, Germany

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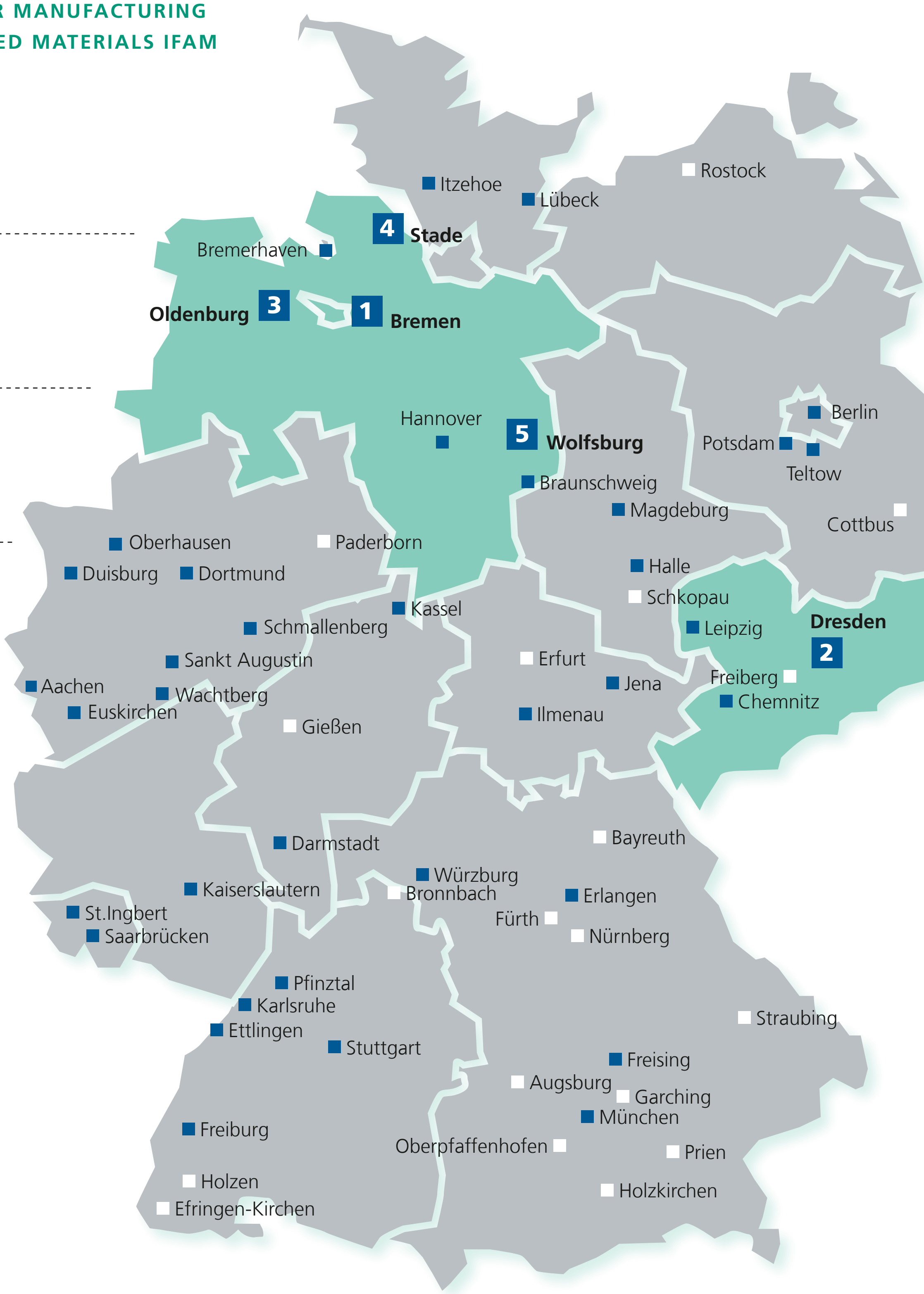
5 **Fraunhofer Project Center Wolfsburg**
Hermann-Münch-Strasse 1
38440 Wolfsburg, Germany



■ Institutes and facilities
□ Other locations

BRIEF PORTRAIT AND ORGANIGRAM

Founded in 1968 and integrated into the Fraunhofer-Gesellschaft in 1974, 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 over 600 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.

WOLFSBURG

- Fraunhofer Project Center Wolfsburg

DRESDEN

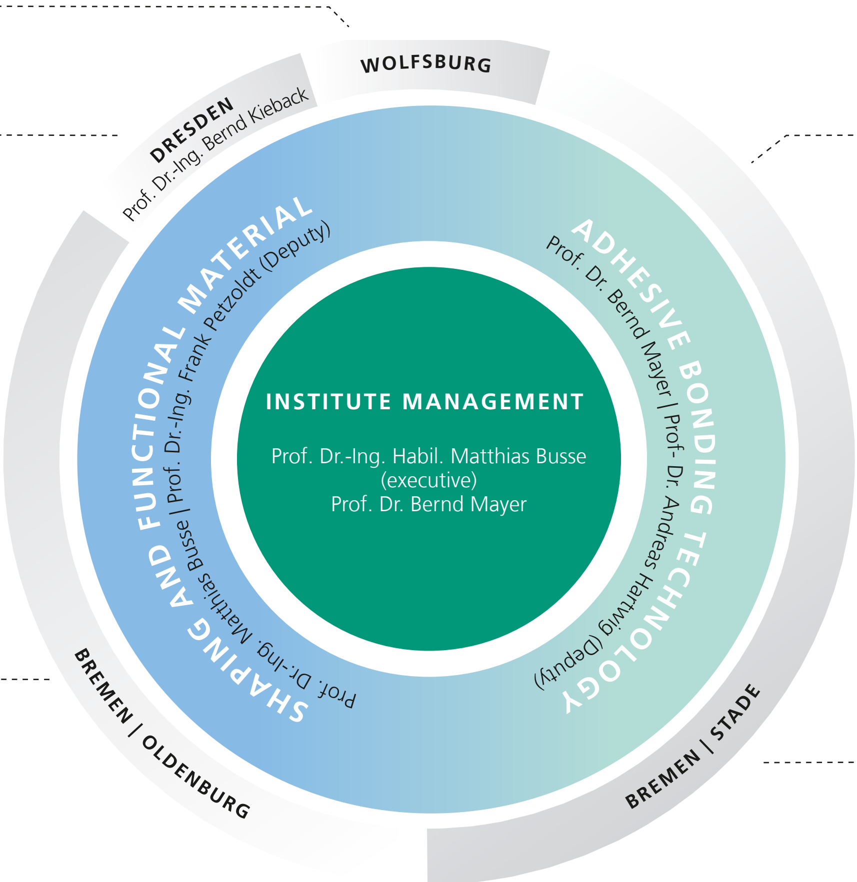
- Sintered and Composite Materials
- Cellular Metallic Materials
- Hydrogen Technology
- Energy and Thermal Management

BREMEN

- Powder Technology
- Casting Technology
- Functional Printing
- Energy System Analysis
- Electric Drive Systems
- Technical Qualifications and Consulting
- Materialography and Analytics

OLDENBURG

- Electrical Energy Storage



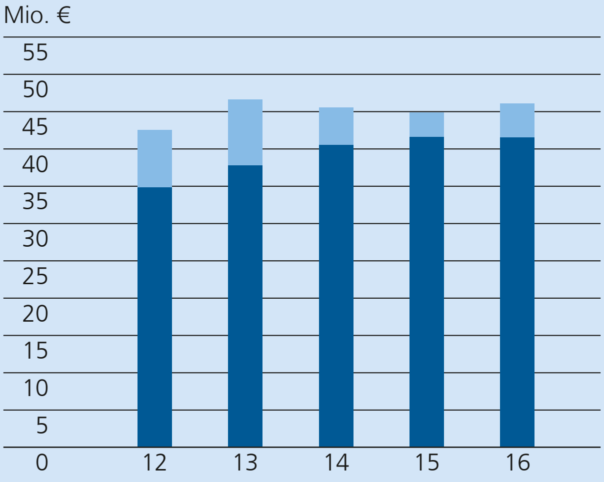
BREMEN

- Business Development
- Adhesive Bonding Technology
- Chemistry of Fiber Reinforced Plastics
- Paint/Lacquer Technology
- Material 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

STADE

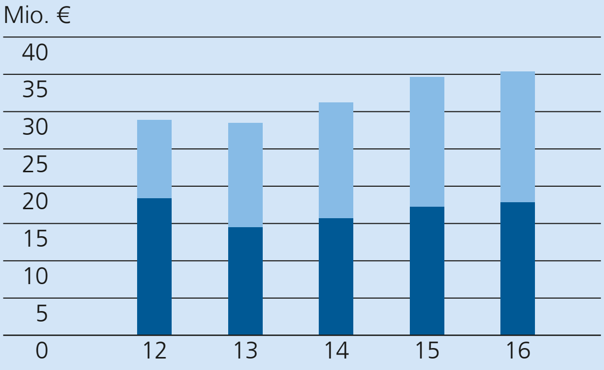
- Automation and Production Technology

Operating and investment budget 2012–2016



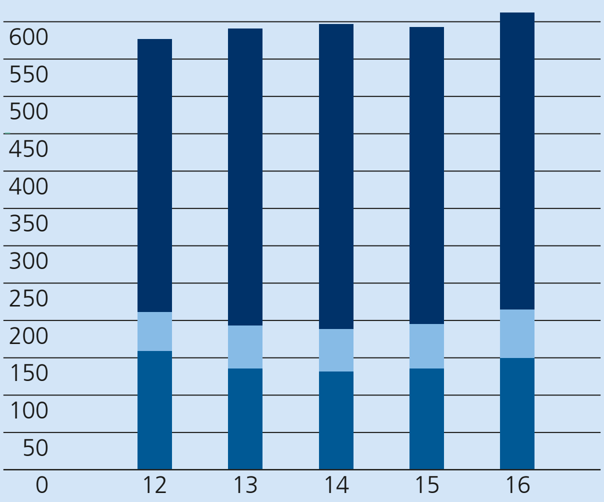
■	Operating budget	42.7 Mio €
■	Investment budget	4.2 Mio €

Project revenues 2012–2016



■	Industry	17.5 Mio €
■	Federal/state/EU/other	17.7 Mio €

Personnel development 2012–2016



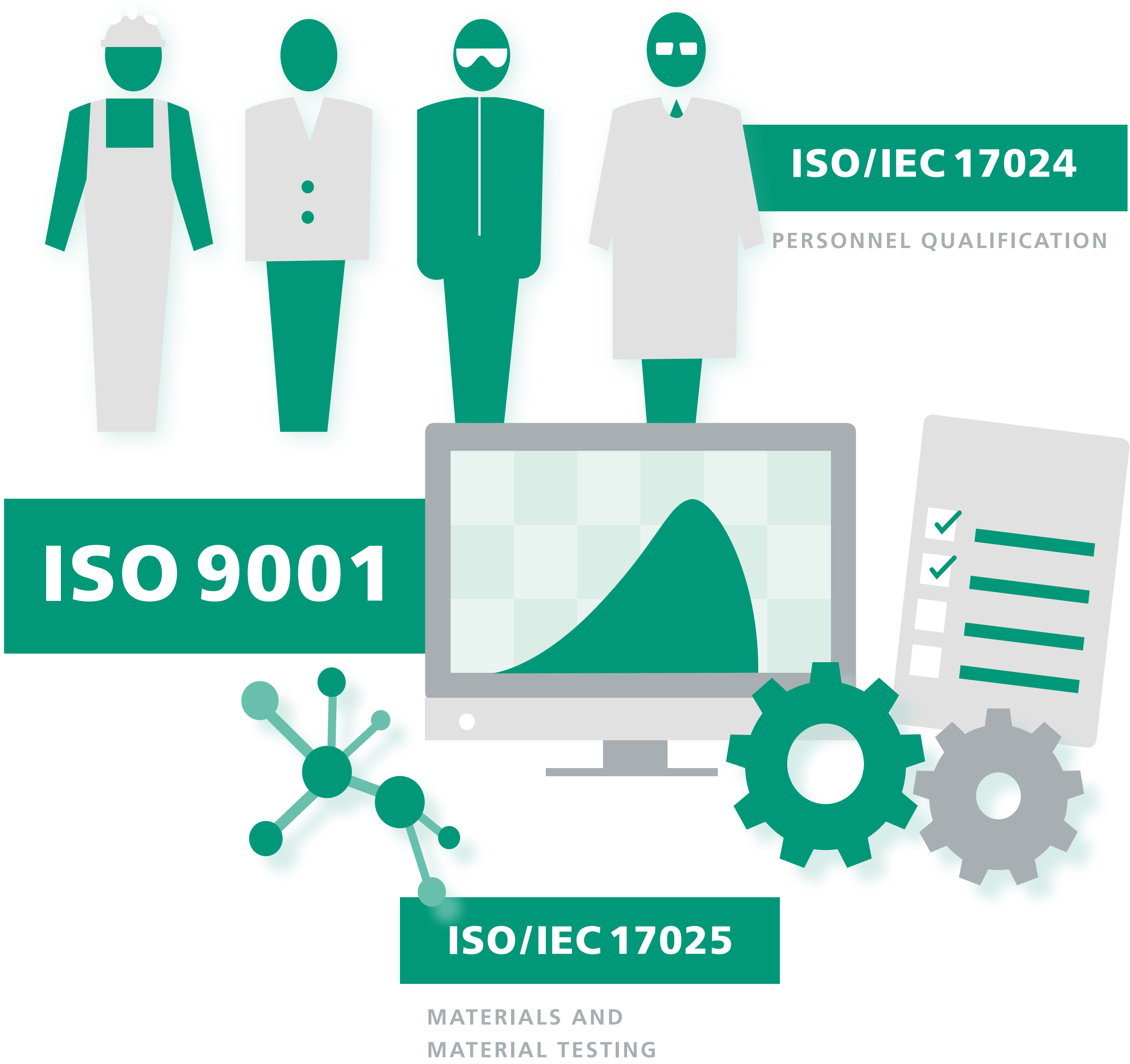
Personnel structure 2016

On December 31, 2015 a total of 609 staff were employed by Fraunhofer IFAM in Bremen, Dresden, Oldenburg, Stade, and Wolfsburg.

Scientific-technical staff	395
Administration/IT/Service	65
Student assistant/Students	149
Total	609

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

PROFILE OF FRAUNHOFER IFAM



QUALITY MANAGEMENT

Certification according to 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 analytics, powder measuring technology, and trace analysis
- Laboratories for material testing, paint/lacquer technology, corrosion testing, materialography and analysis

Accreditation according to DIN EN ISO/IEC 17025

The testing laboratories for material testing, paint/lacquer technology, corrosion testing, materialography and analytics in Bremen have also been DIN EN ISO/IEC 17025-accredited since 1996. Accreditation by the DAkkS (German Accreditation Body) is only valid for accreditations listed in the document appendix D-PL-11140-02-00.

At the Dresden branch of Fraunhofer IFAM, the testing laboratory is DIN EN ISO/IEC 17025-accredited for special testing of the characterization of inorganic powders and sintering materials as well as for material tests of metallic materials. Accreditation by the DAkkS is only valid for accreditations listed in the document appendix D-PL-11140-06-00.

Recognition according to DIN EN ISO/IEC 17024

The Adhesive Technology Center at the Education Center for Adhesive Bonding Technology is an internationally recognized training center for personnel qualification and has been approved by DIN EN ISO/IEC 17024 accreditied DVS-PersZert® (German Welding Society, authorized National Body for Personnel Certification) since 1998.

PROFILE OF FRAUNHOFER IFAM

1

THE ADVISORY BOARD

Members

Dr. Rainer Rauh
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.
Hamburg

Dr. Jürgen Groß
Robert Bosch GmbH
Stuttgart

Dr. Sebastian Huster
Lower Saxony State Ministry
for Science and Culture
Hannover

Prof. Dr. Jürgen Klenner
Airbus Deutschland GmbH
Bremen

Staatsrat
Gerd-Rüdiger Kück
Senator of Education and
Science of the Free Hanseatic
City of Bremen

Dr. Georg Oenbrink
Evonik Industries AG
Essen

Dr. Ralf-Jürgen Peters
TÜV Rheinland
Consulting GmbH
Köln

Dr. Stefan Röber
tesa SE
Hamburg

Dr. Rainer Schönfeld
Henkel AG & Co. KGaA
Düsseldorf

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

Guests

Andreas Kellermann
Daimler AG
Bremen

Prof. Dr. Andreas Breiter
Vice President of Research
and New Scientists
University of Bremen
Bremen
(since June 2016)

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

PROFILE OF FRAUNHOFER IFAM

BUSINESS SEGMENTS

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. 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, 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. 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.

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**
  Phone +49 421 2246-100
  matthias.busse@ifam.fraunhofer.de

DRESDEN BRANCH

- **Prof. Dr.-Ing. Bernd Kieback**
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ADHESIVE BONDING TECHNOLOGY AND SURFACES DIVISION

- **Prof. Dr. Bernd Mayer**
  Phone +49 421 2246-401
  bernd.mayer@ifam.fraunhofer.de

ADHESION AND INTERFACE RESEARCH

Dr. Stefan Dieckhoff
Phone +49 421 2246-469
stefan.dieckhoff@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/interface

- Surface and nanostructure analysis
- Corrosion protection and electrochemistry
- Computer-aided material simulation
- Quality assurance – monitoring surface and bond properties
- Development of customer-specific inspection procedures
- Physico-chemical analyses of interface and material properties
- Wet chemical pre-treatment of surfaces
- Accredited corrosion testing laboratory
- Failure analysis

CERTIFICATION BODY IN ACCORDANCE WITH DIN 6701

Dipl.-Ing. (FH) Frank Stein
Phone +49 421 6960 6793
stein@tbbcert.de
→ http://www.tbbcert.de

- 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 and DIN 2304
- Member of the work group on adhesive bonding in accordance with DIN 6701

AUTOMATION AND PRODUCTION TECHNOLOGY

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

- Automated assembly of large structures up to a 1:1 scale
- 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

Prof. Dr. Bernd Mayer
Phone +49 421 2246-401
bernd.mayer@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/netzwerker

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

CHEMISTRY OF FIBER REINFORCED PLASTICS

Dr. Katharina Koschek
Phone +49 421 2246-698
katharina.koschek@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/durocycle

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

ELECTRIC DRIVE SYSTEMS

Dipl.-Ing. Felix Horch
Phone +49 421 2246-171
felix.horch@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/ea

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

ELECTRICAL ENERGY STORAGE

Dr.-Ing. Julian Schwenzel
Phone +49 441 36116-262
julian.schwenzel@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/ees

- Battery cell chemistry
- Paste development and electrode manufacturing
- Cell assembly and design of
  - Lithium-ion batteries
  - Metal-air batteries
  - Solid-state batteries
- In-situ analytics

ENERGY AND THERMAL MANAGEMENT

Prof. Dr.-Ing. Jens Meinert
Phone +49 152 56608698
jens.meinert@ifam-dd.fraunhofer.de
→ www.ifam.fraunhofer.de/en/etm

- Efficient storage of heat and cold
- Development of high-performance latent heat storage
- Optimization of heat transport operations
- Cellular metals in compact heat exchangers
- Structuring of evaporator surfaces
- Thermal management – heat-generating components
- Mold temperature control
- Mathematical modeling of heat transport
- Simulation of melting and solidification processes
- Measurement of material and transport temperatures

ENERGY SYSTEM ANALYSIS

Dr. Bernd Eikmeier
Phone +49 421 2246-7023
bernd.eikmeier@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/elsys

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
- Electric vehicles in residential systems
- Integration of energy storage systems

FRAUNHOFER PROJECT CENTER WOLFSBURG

Dr.-Ing. Torben Seemann
Phone +49 421 2246-126
torben.seemann@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/wolfsburg

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

FUNCTIONAL PRINTING

Dr. Volker Zöllmer
Phone +49 421 2246-114
volker.zoellmer@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/printing

- 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

Dipl.-Ing. Franz-Josef Wöstmann MBA
Phone +49 421 2246-225
franz-josef.woestmann@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/casting

- Cold- and warm-chamber pressure casting (aluminum, magnesium, zinc)
- Lost foam casting
- Low pressure casting (aluminum, copper, iron, steel, salts)
- Investment casting
- Development of core materials (salt cores, lost cores, complex geometries)
- Functional integration / CAST^TRONICS®
- Component identification/component labeling (individual identification as the basis for industry 4.0)
- Composite casting/hybrid casting (hybrid options of metal and fiber materials)
- Topology optimization / lightweight construction

ADHESIVES AND POLYMER CHEMISTRY

Prof. Dr. Andreas Hartwig
Phone +49 421 2246-470
andreas.hartwig@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/adhesives

- 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

Dr. Holger Fricke
Phone +49 421 2246-637
holger.fricke@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/abt

- 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
- Coating of sheet materials (adhesives, lacquers, functional materials)
- Adhesive bonding of optical systems
- Adhesive bonding of electrically/optically conductive contacts
- Adhesive bonding in microsystem technology
- Adhesive bonding in construction industry

PAINT/LACQUER TECHNOLOGY

Dr. Volkmar Stenzel
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volkmar.stenzel@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/paint

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

MATERIALOGRAPHY AND ANALYTICS

Dr.-Ing. Andrea Berg
Phone +49 421 2246-146
andrea.berg@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/analytics

- Analyses 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

PLASMA TECHNOLOGY AND SURFACES PLATO

Dr. Ralph Wilken
Phone +49 421 2246-448
ralph.wilken@ifam.fraunhofer.de
→ www.ifam.fraunhofer.de/en/plato

- 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

SINTERED AND COMPOSITE MATERIALS

Dr.-Ing. Thomas Weißgärber
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→ www.ifam.fraunhofer.de/scm

- Powder-metallurgical technologies
- 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

POWDER TECHNOLOGY

Prof. Dr.-Ing. Frank Petzoldt
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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 QUALIFICATIONS AND CONSULTING

Dr.-Ing. Gerald Rausch
Phone +49 421 2246-242
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→ www.ifam.fraunhofer.de/tqb

- Technical training in electromobility
- R&D Insider – knowledge and technology transfer
- Knowledge update – management workshop

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

Prof. Dr. Andreas Groß
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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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→ www.ifam.fraunhofer.de/materialscience

- 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

Dr.-Ing. Olaf Andersen
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- Cellular metals from variant special materials
- Additive manufacturing via 3D screen printing
- Open-cell 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

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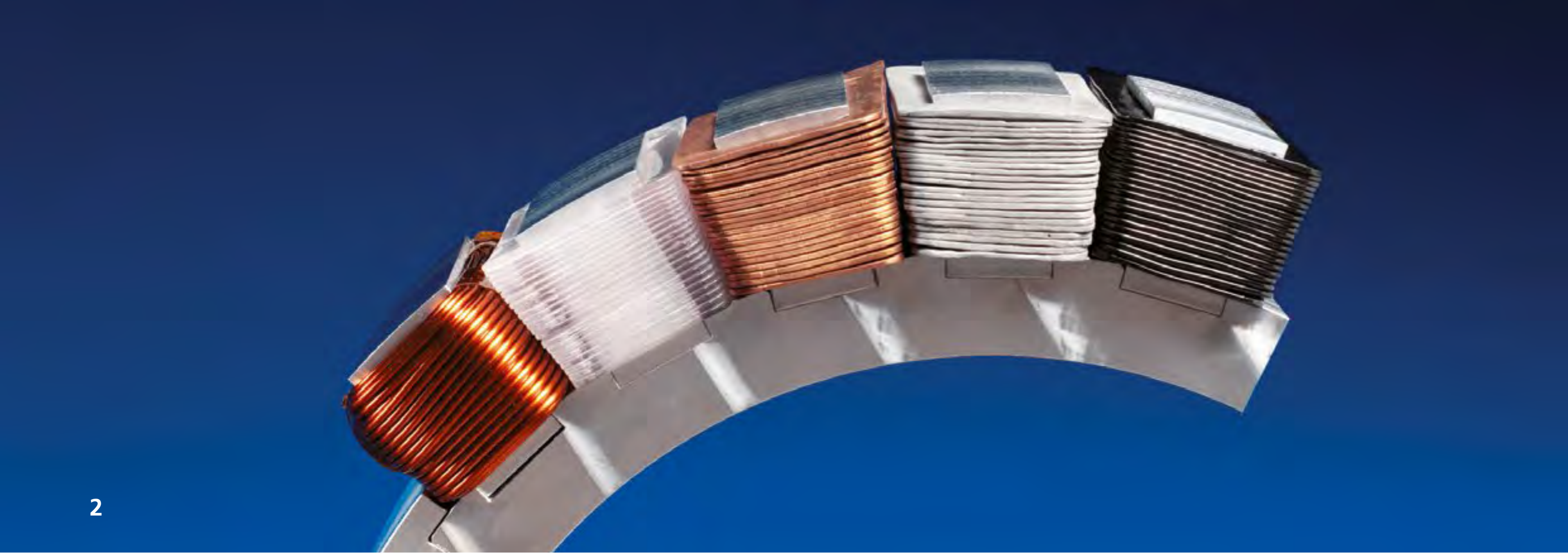

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SHAPING AND FUNCTIONAL MATERIALS

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 introducing sensor integration via printing techniques into automated industrial production processes.

State-of-the-art casting equipment, analytical facilities, and indepth 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. 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.

1 *Functionalized cylinder using the dispensing process*

2 *Demonstrator comparing a wound coil, a rapid prototyping model, and three die-cast coils.*

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.

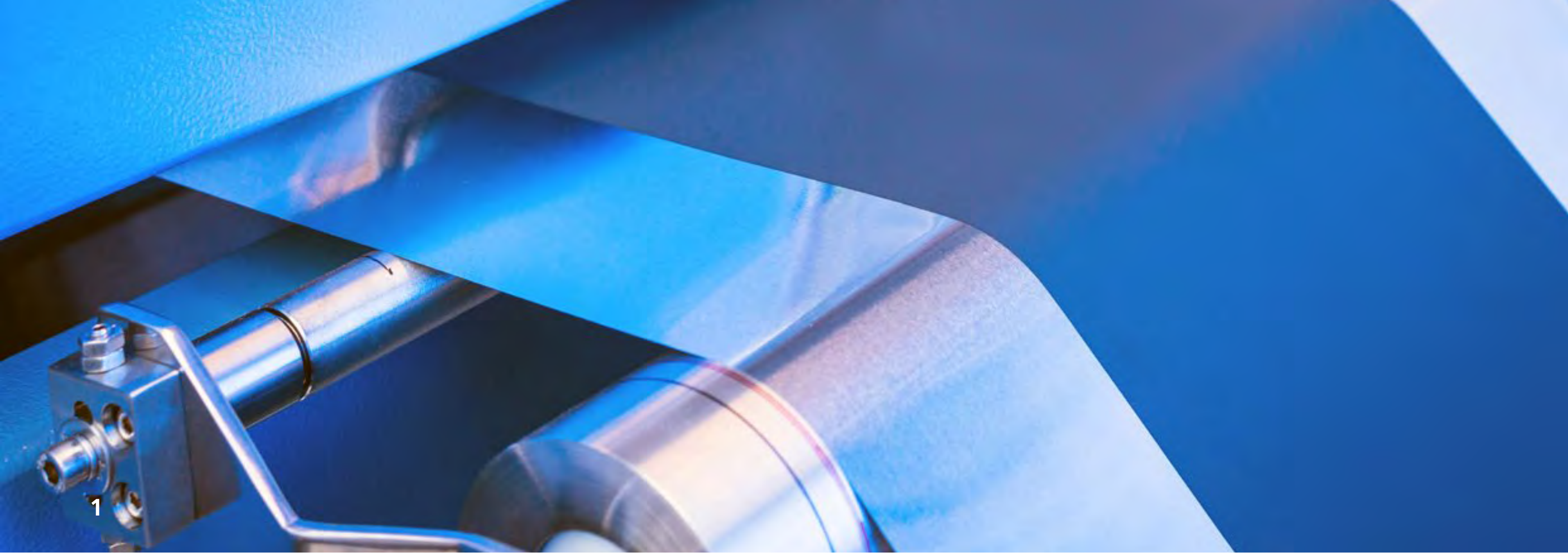
Our ever increasing expertise in special functional materials such as magnets, thermal management materials, thermoelectric and magnetocaloric materials, and nanocomposites is opening new opportunities for our customers' product developments.

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 in 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 earth elements" it is being demonstrated, by means of two case studies on permanent magnets in electric motors, how the primary demand for heavy rare earth elements can be halved or how to subsequently completely replace them altogether.

In a second key Fraunhofer project "Go Beyond 4.0", led by the Fraunhofer ENAS, Fraunhofer IFAM and four other institutes are working on ways to individualize mass-produced products by integrating printing technology and laser processing into the production process.

As part of the "Harvest" project of the Fraunhofer Future Foundation, 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", Fraunhofer IFAM and Fraunhofer IWU are collaborating on the large scale industrial manufacture of cast or formed coils.

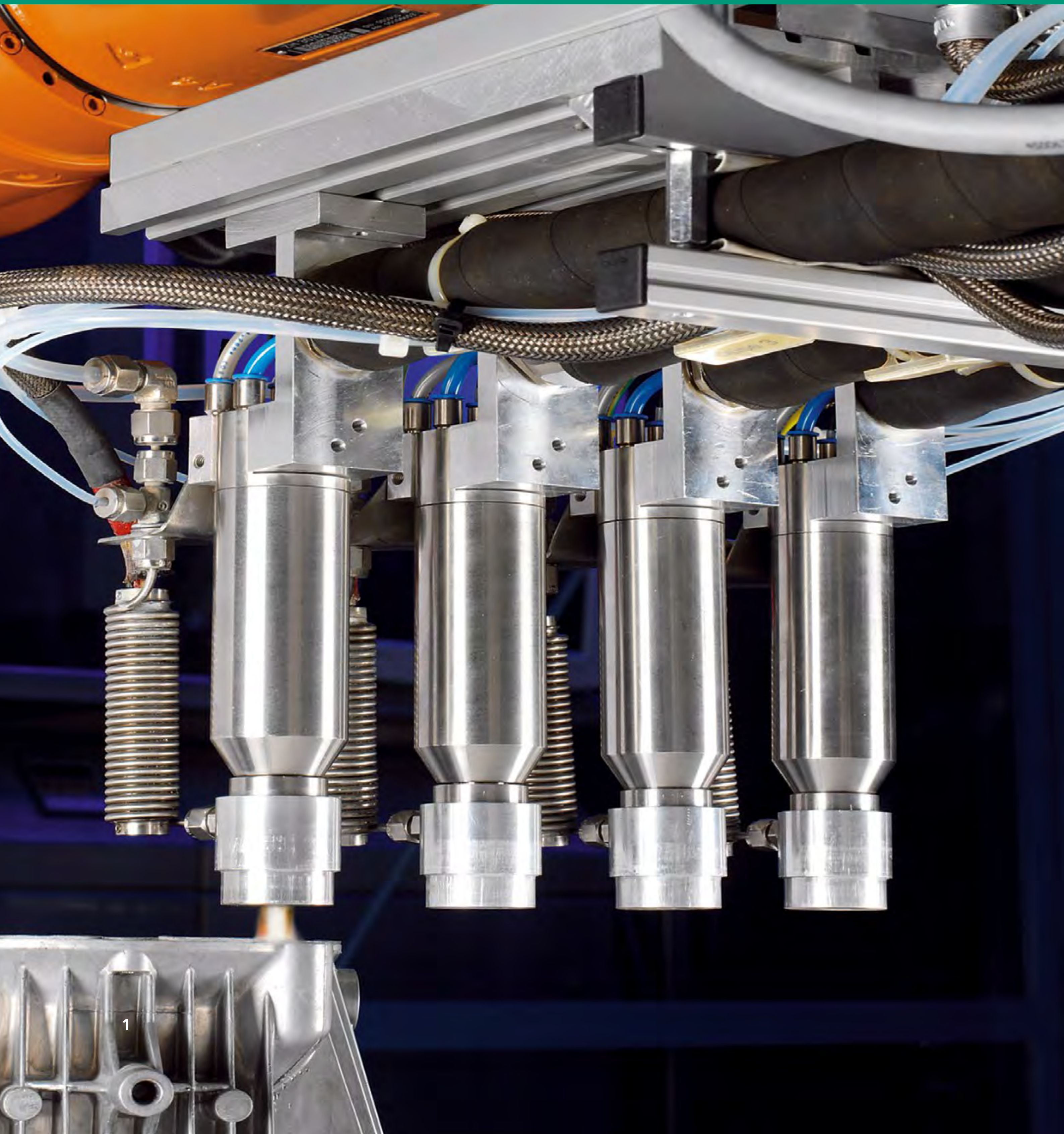
Fraunhofer IFAM is also involved in the creation and expansion of a research and industry network for magnetocaloric systems.

Fraunhofer IFAM is responding to the growing industrial interest in additive manufacturing technologies. The technical center located at the institute is to be expanded and more equipment added to allow the qualification of additive manufacturing technologies for aviation and space travel applications.

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
- Material 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

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

To be able to provide our customers with solutions and new developments in the field of materials and joining methods, it is necessary for us to constantly research new technical paths and put them into practice in the areas of adhesive bonding technology and surfaces. These activities range from fundamental research and production technologies right up to the market introduction of new products in collaboration with our 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.

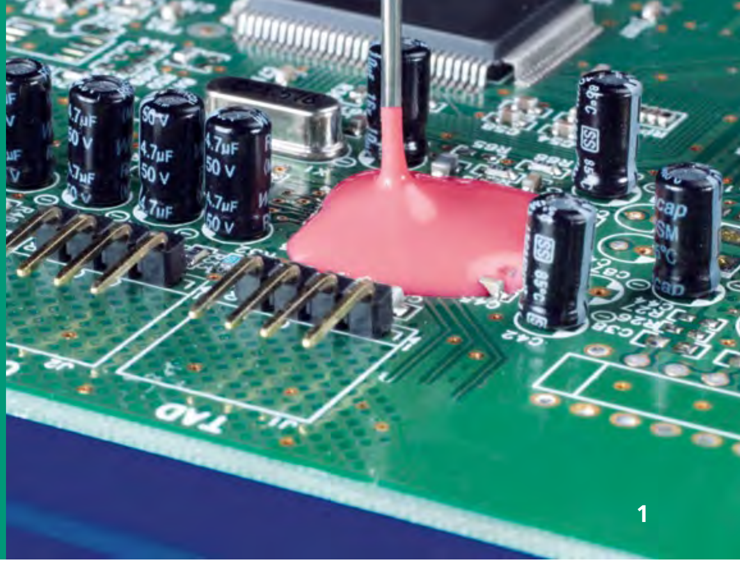
"Adhesive bonding technology", one of our core competencies, involves the development and characterization of adhesives and the design and simulation of bonded and hybrid joints, as well as the characterization, testing, and qualification of such joints. We also provide the following additional services: the planning and automation of industrial production as well as process reviews and certified training courses in adhesive bonding technology and fiber-composite technology.

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 coatings.

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 technology, as well as adhesion and interface

1 *Multi-jet tool for two-dimensional coating of components using atmospheric pressure plasma.*

2 *Steel blade with attached cutting segments for cutting granite.*



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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 than 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.

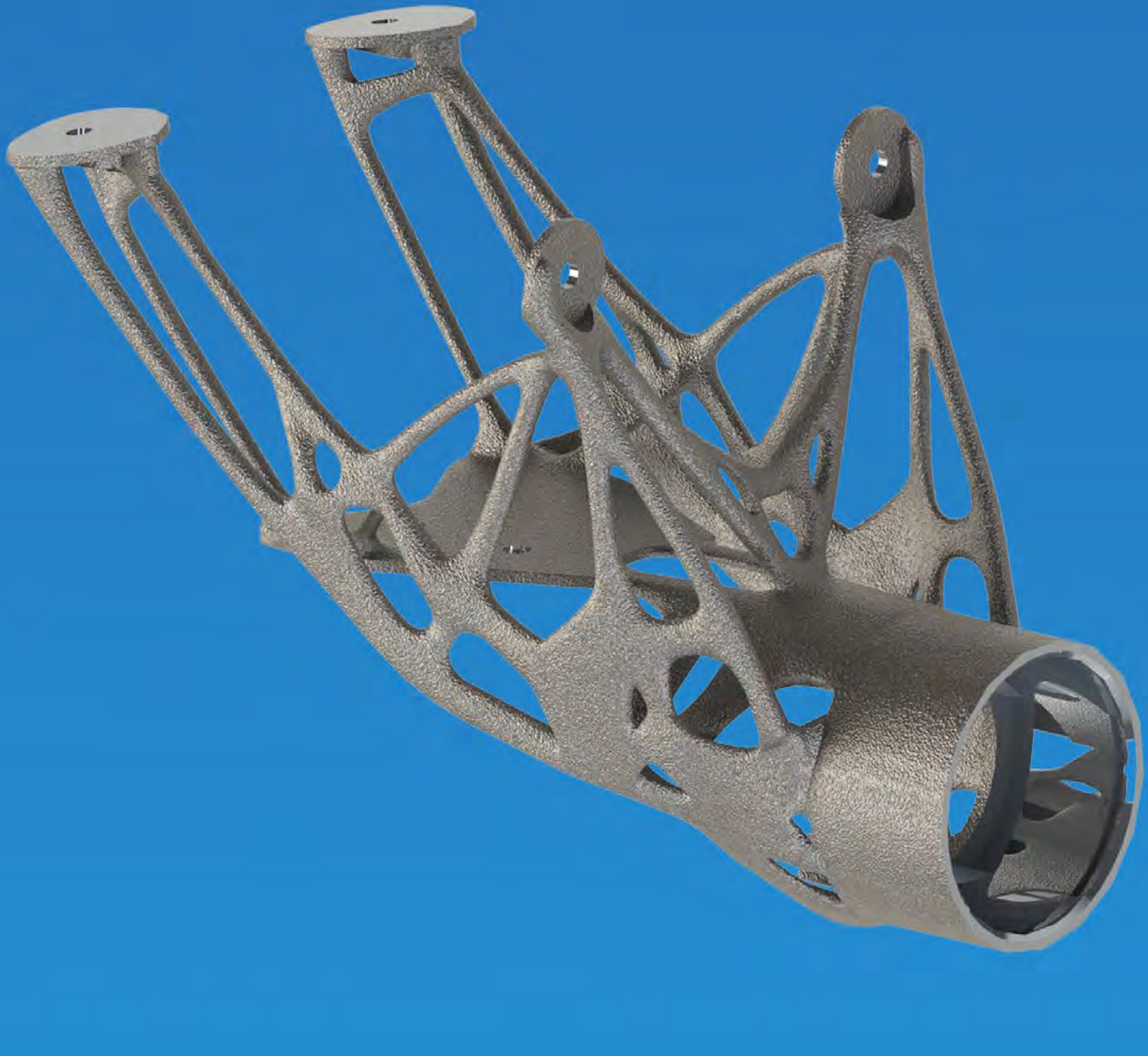
In all areas, Fraunhofer IFAM is making increasing use of computer-aided methodologies. For example, the numerical description of flow processes in dosing pumps and valves, multiscale simulation of the molecular dynamics at a molecular level, and macroscopic finite element methods for the numerical description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

Key areas of work

- Synthesis, formulation, and testing of new polymers for adhesives, matrix resins for fiber-composite materials, casting resins, and coatings
- Development of additives (nanofillers, initiators, etc.) for reactive polymers for use in adhesives and matrix resins
- 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 quantummechanical 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, and training modules for Fraunhofer Composite Engineer (formerly Fiber Composite Engineer)

1 *Casting an electrical component.*



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CORE COMPETENCE SINTERED, COMPOSITE, AND CELLULAR METALLIC MATERIALS

The development of materials with customized properties and combinations of properties, efficient manufacturing technologies, and 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. We are now expanding this with our use of methods such as the 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 the comprehensive knowledge of alloys and processes needed in order to manufacture light metal components, in particular those made of aluminum, for weight reduction in car manufacture. Regarding metallic composites, our focus is on materials development for the 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, nanostructured 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 the 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 *Structure-optimized steering column holder for a Formula Student vehicle produced using electron beam melting. (Joint project by Fraunhofer IFAM and the Technische Universität Dresden.)*

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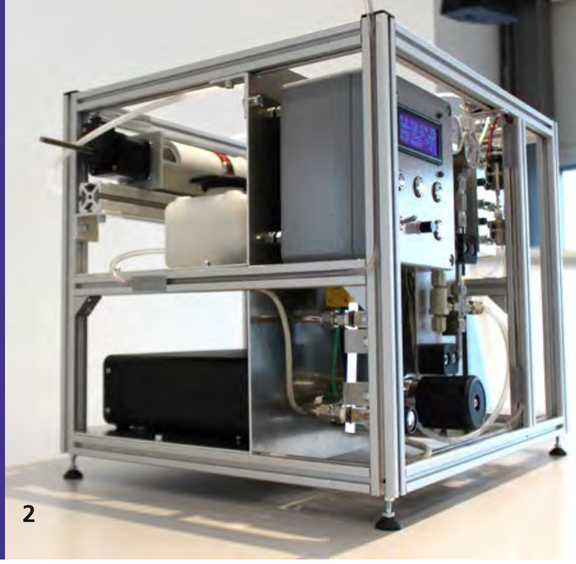

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POWERPASTE – HYDROGEN WITHOUT STORAGE PRESSURE

The most important advantages of hydrogen as a secondary energy carrier have long been known. However, hydrogen has not yet been widely established on the market, for example for fuel-cell applications in the mid-performance range, because until now the available hydrogen storage solutions could not be established in the market due to costs, problems with their technical implementation, or lack of hydrogen infrastructure. PowerPaste, a new development from Fraunhofer IFAM in Dresden, has the potential to fundamentally change this situation.

A well-known alternative to conventional hydrogen storage methods, such as high-pressure or cryostorage, is hydrogen production using so-called hydrolysis reactions. One challenge facing this technology is comparably low energy densities of the materials that have been previously used for hydrolysis. Above all, it is problematic that, when producing hydrogen by hydrolysis, the required amount of hydrogen needs to be assessed in advance, because the material continuously reacts with the hydrogen as soon as the components have been mixed. Also, in principle, only a relatively small predetermined performance range can be covered.

Fraunhofer IFAM in Dresden has developed a new technology that solves all three of these problems for the first time. The most important component of the technology is the PowerPaste, a high-energy pasty material mixture based on magnesium hydride (MgH_2), which releases hydrogen on contact with water according to the following chemical reaction:

$$\mathbf{MgH_2 + 2\,H_2O \rightarrow Mg(OH)_2 + 2\,H_2}$$

1 *PowerPaste based on magnesium hydride.*

2 *Demonstrator (technological maturity level 4) with 50W PEM fuel cells for PowerPaste hydrolysis. Dimensions are approx. 40 × 40 × 40 cm³.*

Releasing hydrogen in this way was not possible in the past, because magnesium hydride forms passivation layers when in contact with water that significantly reduce the reaction speed. However, after developing the technology further, Fraunhofer IFAM has succeeded in making magnesium hydride usable for technically relevant applications. Powdered magnesium hydride is first modified by adding inexpensive, non-toxic substances that effectively prevent the formation of the troublesome passivation layers. In the next step, esters are added to create a pasty material – the so-called PowerPaste. The PowerPaste reacts dynamically with water, causing a fully controlled hydrogen-producing reaction, which can power the fuel cell as needed, directly generating electrical power.

The feasibility of functional power generators based on this technology has already been demonstrated with a stationary 50W demonstrator at a technological maturity level of 4 as well as with a mobile 300W power generator at a technological maturity level of 5, which were both developed at Fraunhofer IFAM in less than a year. As a whole, the technology has huge economic potential, especially for power-hungry mobile and portable fuel-cell applications such as light electromobility (e.g. electric bikes for consumers and fleets), drones, and emergency power systems.

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EFFICIENT USE OF ENERGY USING THERMOELECTRIC MATERIALS

Increased energy efficiency, resource conservation, and the reduction of CO_2 emissions are some of the most important social and economic challenges of our time. When energy is produced, up to 50% of the primary energy is lost as waste heat, however. Thermoelectric generators (TEG) can contribute to more efficient and low-emission energy usage by recovering energy from this waste heat.

Current technology uses waste heat in heat exchangers, heat storage devices, burners for air heating, heat pumps, and cooling machines. To produce electricity from waste heat, the ORC (organic rankine cycle) process, steam turbines, and Stirling engines can be used. Electricity is generated indirectly via intermediate media in liquid or gaseous form.

TEGs on the other hand convert waste heat directly into electrical energy, working without moving parts. They are silent, maintenance-free, and scalable, adapting easily to the space available. In comparison to the technologies mentioned above, they have significant advantages and cover a broader spectrum of applications.

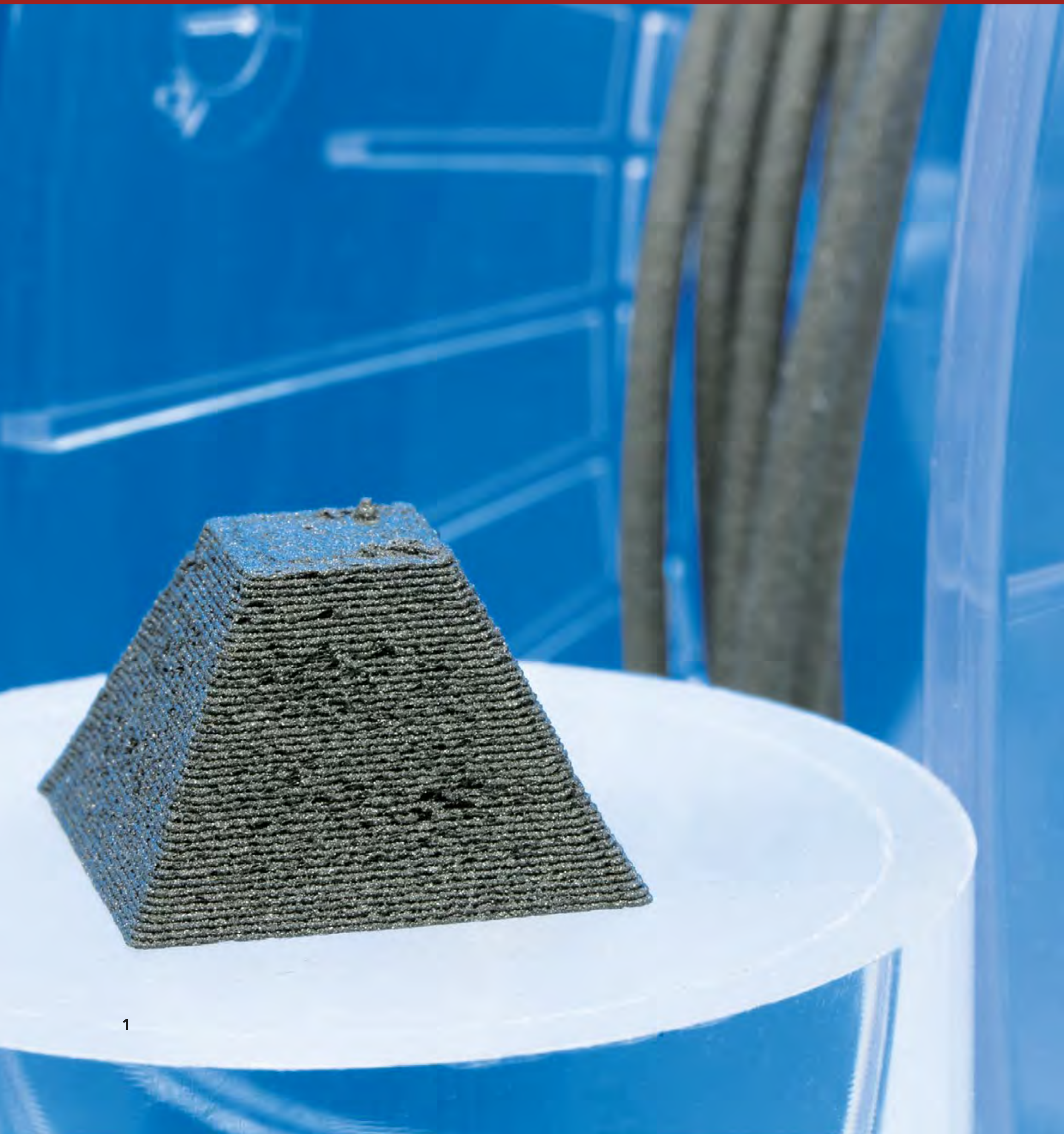
Since 2007, Fraunhofer IFAM has been developing *n*-$Mg_2Si_{0.4}Sn_{0.6}$ and *p*-$MnSi_{1.8}$ as thermoelectric (TE) materials; these are made from inexpensive, non-toxic elements easily found in nature and can be used in applications at up to 550°C. For TE modules made from these silicides, efficiency levels of up to 7% have been reported in the literature. This dramatically exceeds the operating temperature and the efficiency of commercially available modules made from Bi_2Te_3-based connections (250°C and ~ 3%). Fraunhofer IFAM has focused its research activities on scaling up material production (currently up to 1 kg starting powder per batch and 0.25 kg per sintered body) in the manufacture of TE components (TE legs) in various dimensions with regard to industrial-scale production. To cover the entire value chain, we are currently developing configuration and connection technology for module production from the components.

The TE silicide chip modules developed by Fraunhofer IFAM (chip thickness of only 0.5 mm) will be installed in diesel locomotives in a BMWi-funded project on energy recovery from waste heat.

To win over users with this technology and to establish TEGs on the market, the positive properties of the materials as well as high-volume, cost-effective industrial production of TE modules must be demonstrated. For this reason, a partially automated production chain for silicide-based modules is being built at Fraunhofer IFAM in Dresden, in order to significantly reduce the hitherto high unit costs.

Customers: DFG, BMBF, BMWi, SAB
Project partners: Max Planck Institute for Chemical Physics of Solids, FZJ, the University of Tübingen, the University of Hamburg, TU Chemnitz, Fraunhofer IWM, Fraunhofer IPM, Fraunhofer IKTS, TU Dresden; companies: Mahle, Tenneco, Curamik, O-Flexx, Bombardier

1 *Thermoelectric modules made from silicide material.*
2 *Silicide discs, 500 µm thick.*



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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 a thorough understanding of the whole process chain, from powder to feedstock systems and from injection molding through to the sintered product. Our range of services includes component development, the production of pilot series, know-how transfer, and the training of production personnel. Also covered are shaping processes for special products such as micro-MIM, two-component MIM, and extrusion.

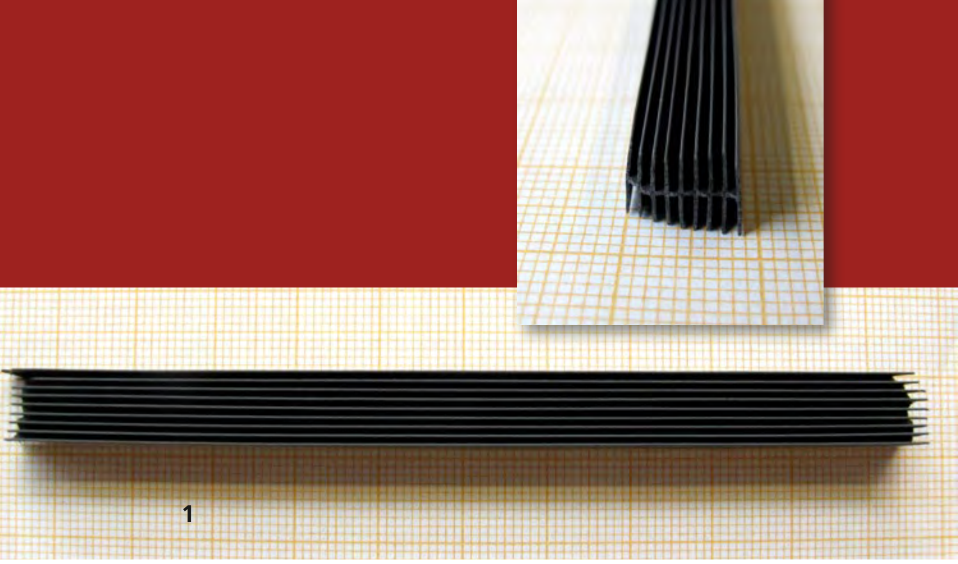
Fraunhofer IFAM also has many years of experience in additive manufacturing, where products are made from metal powders without molds directly from 3D CAD data, having virtually any desired shape. Currently, this method is not only being used for rapid product development but increasingly also for the production of high-quality, individualized products for end-users. Fraunhofer IFAM offers an in-depth know-how of the entire process chain of the three additive processes Selective Laser Melting (SLM), Electron Beam Melting (EBM) und 3D Binder Jetting.

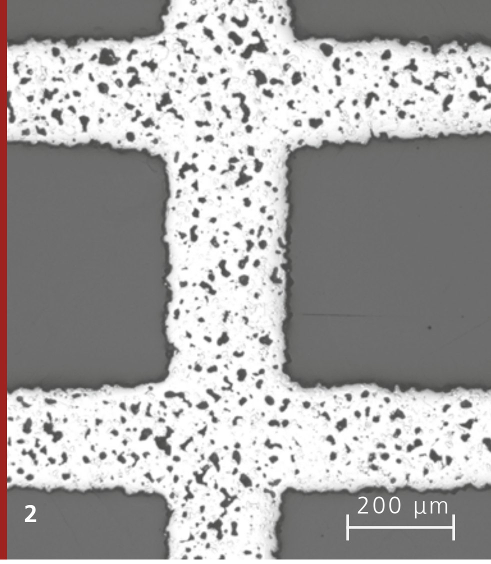
Functional printing is used to add functions to components. Various powder-based printing technologies are, therefore, also an important part of our expertise in powder technology. The methods are being transferred to an industrial scale using a specially designed automated production line.

Our 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 *Special conductive filaments for 3D printing.*





MAGNETIC REFRIGERATION – POWDER METALLURGICAL SHAPING FOR INNOVATIVE COOLING TECHNOLOGY

Magnetocaloric materials have the potential to provide an energy-efficient alternative to compressor cooling. Fraunhofer IFAM works in various projects to establish a powder metallurgical shaping technology for these materials and to allow building innovative magnetic cooling systems.

Magnetocaloric materials change their temperature when they are exposed to a varying magnetic field. Based on this effect, cooling devices can be built that are 30% more energy efficient than conventional compressor coolers and work without using harmful greenhouse gases as refrigerants. Apart from the material's magnetocaloric effect, the shaping into thin-walled heat exchanger structures is crucial for the overall efficiency, since the temperature change generated by the material has to be transferred to the system. For this application, plates or channel structures with a large surface area and a wall thickness of less than 500 µm are favorable. However, the alloys with a high magnetocaloric effect that have been developed in the last few years (LaFeSi and MnFeP-based compounds) are not only difficult to produce by casting but also hard to machine due to their brittleness.

At Fraunhofer IFAM, the industrial-scale processes metal injection molding and metal powder extrusion are used to create the required fine heat exchanger structures and to combine production and shaping of the materials into only a few process steps. Structures with wall thicknesses of less than 300 µm have already been produced in this way. By adjusting the sintering process, it is possible to vary both the porosity and the microstructure of the samples and thereby optimize the magnetocaloric and mechanical properties.

Additionally, additive manufacturing of magnetocaloric materials using laser beam melting (LBM) is studied in a project funded by the AiF (German Federation of Industrial Cooperative Research Associations). In this project, the IWT Bremen is producing starting powders that are customized for LBM and are then processed at Fraunhofer IFAM. The freedom of design offered by the LBM method allows the production of various heat exchanger geometries that can be evaluated in demonstrators and prototypes of magnetocaloric cooling systems.

1 *Green part after extrusion, thin-walled heat exchanger geometry.*
2 *Sintered structure made from magnetocaloric material ($La(FeSi)_{13}$ alloy).*

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HIGHLY EFFECTIVE EVAPORATOR STRUCTURES

In the context of the Fraunhofer foundation project "Highly Efficient Adsorption Compound Systems for Energy Technology (HARVEST)", Fraunhofer IFAM in Bremen, the Dresden branch and Fraunhofer ISE in Freiburg are working together to develop innovative components for heating/cooling machines that are needed for particularly energy-saving heating, cooling, and hot-water systems.

Water evaporator and condenser elements are essential for these heat pumps and chillers, which have very diverse boiling properties in this process due to the low pressure conditions. The operating principle of an evaporator is that it converts liquids to gases by adding heat. The necessary heating temperature and other performance parameters essentially determine the losses, the resulting efficiency of the overall process, and the space required for the individual elements and the system as a whole.

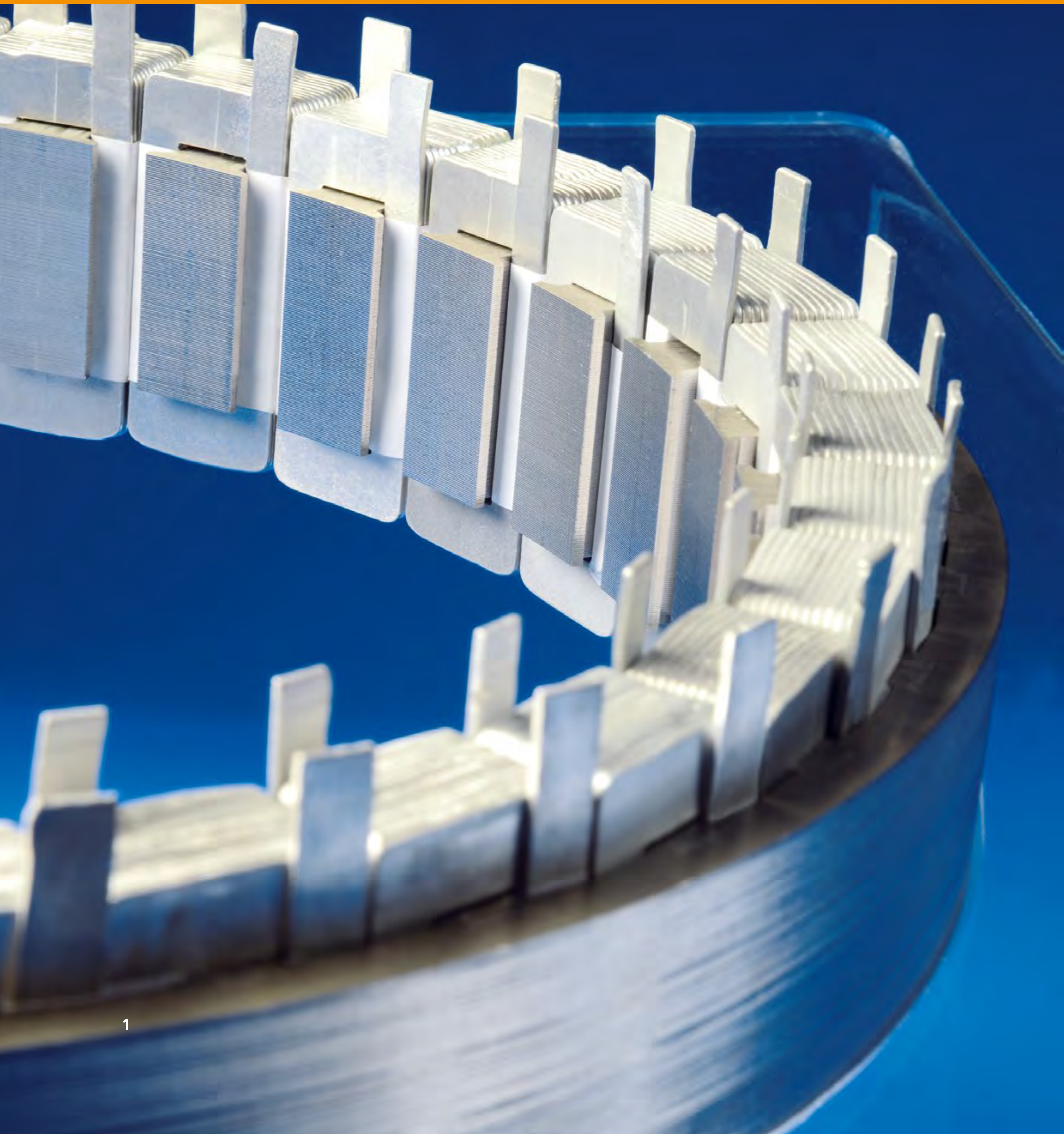
Evaporation and condensation processes are determined by many mechanisms and their parameters, such as the heat conduction and temperature distribution, the wetting or flooding conditions with the liquid coolant, the bubble nucleation, the bubble stalling behavior, the share of micro-zone areas with intensive evaporation, the flow behavior of the liquid gas mixture, and the flow of liquid along the heated surface of the evaporator element.

The evaporator/condenser element developed by Fraunhofer IFAM in Bremen consists of a porous aluminum sponge with high thermal conductivity and numerous porous particles embedded in its surface so that they partially protrude from the surface. The porous particles serve as a kind of boiling stone for evaporation, providing a place for bubble nucleation. In addition to their function as boiling stones, the embedded particles also influence local temperature distribution, local wetting behavior, and the mobility of the 3-phase interface along the surface of the evaporation element. Moreover, they also act as reservoirs for steam residue, the preferred nuclei for new bubbles. In addition to improving evaporation itself, the embedded particles can also serve as local fluid reservoirs and prevent fluid from dripping off.

Measurements in the boiling-curve testing station at Fraunhofer ISE revealed that, at a boiling pressure of 13 mbar and a sample flood of 11 mm, bubble nucleation already occurs at a superheat temperature of only 3 K in the newly developed evaporator structure. An excellent heat flux density of 36,000 W/m² was measured at a superheat temperature of 11 K. The basic principle of the direct integration of porous granules into the surface of a good conductive metal sponge is not limited to evaporators but can also be used for other structures and applications such as the integration of silica gel or zeolites in metal structures.

1 *Bubble nucleation at 11 K superheat temperature in the boiling-curve testing station at the Fraunhofer ISE. (© Fraunhofer ISE)*

2 *Evaporator structure made of porous aluminum sponge with embedded boiling stones.*



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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 research areas currently include lost (salt) cores, casting structural components, and the hybrid joining of fiber materials (carbon, fiber optic, wire mesh, etc.) and casting materials, as well as the direct integration of electronic components for sensors or component identification.

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 their 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 directly casting large and small parts of high complexity 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, with minimal post-treatment and highest functional integration.

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, copper and other refractory materials, as well as non-metallic melts. The casting materials we use 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 embedded into components during the actual casting process, is also gaining increasing importance. So-called CAST$^{\text{TRONICS®}}$ technology allows advanced electronics, sensors, and actuator functionalities to be integrated into cast components.

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

1 *Cast aluminum coils for an air-cooled wheel hub motor mounted on a stack of soft magnetic sheet metal.*

RFID AND INTEGRATED SENSORS MAKE COMPONENTS READY FOR INDUSTRY 4.0

Production cycles for die-cast components are becoming shorter and shorter, and the quality requirements are rising steadily. To meet these challenges head-on, we are monitoring our production processes even more strictly. In the age of digitalization, the fourth Industrial Revolution is now in full swing. Identification of individual components and their traceability has become more and more desirable. This includes a desire for the components to be able to provide "intelligent" information about their condition. This is done by using a radio frequency identification system (RFID) transponder. Integrated sensors can be used to monitor the condition of the component. Even cast parts with high annual production volumes can be identified individually rather than only by batch.

At Fraunhofer IFAM, we have succeeded in demonstrating the cost-effective, direct integration of RFIDs into die-cast components during an ongoing production process. This creates the conditions that can make die-cast products individually identifiable when they are produced – an important enabler for the implementation of industry 4.0 in aluminum foundries. To make components intelligent, IFAM is doing more research into sensor integration in the "Sensor Integration in Cast Aluminum – SINA" project.

Challenges with the digitalization of industry

The increase in efficiency brought about by industry 4.0 should allow economic production of "batch size 1". The use of radio frequency identification (RFID) has long been standard in these processes. This identification system serves to monitor the flow of materials and provide traceability. For cast components, such identification will have been conducted visually, if at all, and not necessarily for each component.

Fraunhofer IFAM has been doing research on functional integration for 10 years. This means that cast components will in future become "more intelligent" by integrating transponders and/or sensors into them. All of this began with the development of a "pedal" with in-built piezoelectric sensors. This allowed dynamic forces to be measured directly in the component for the first time. The resulting patented CAST$^{TRONICS®}$ technology was also used to make reflectors made of zinc that were uniquely identifiable with RFIDs during the prototype process.

This was followed by studies of suitable insulation materials and of different transponder sizes. The European "MUSIC" project (MUltilayers control & cognitive System to drive metal and plastic production line for Injected Components) then demonstrated this by means of an industrial production process. Tests were carried out with a sample geometry at the University of Applied Sciences Aalen/Casting Technology Aalen (GTA), to test the use of encapsulated RFIDs in aluminum die casting. A concept was then developed on how to automatically insert the encapsulated transponder into the die-casting tool.

This was then successfully implemented in the experimental foundry at Audi. The transponders were taken from a


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magazine above the die-casting system by a gripper attached to a release-agent-spraying robot and then placed in the mold after the release agent was applied. Immediately after the component was cast and cooled, the transponder was tested for readability and the individual unique code of the transponder was linked to the casting parameters of the cast. All data and parameters could now be traced to the unique component of "batch size 1". Deburring was carried out as the final step.

RFID integration implemented cost-effectively in series production process

The structure of the casting cells at Audi demonstrates that process integration can be done quickly with little effort and cost, changing the cycle time only slightly. Writing the process data to the transponder takes only a few seconds, while traditional identification systems like etching a data matrix code (DCM) and plain text take over half a minute. The procedure also proved to be very stable. All of the cast transponders were readable and could uniquely identify the component.

All the materials used are available on the market, including the RFID technology. The magazine that provided the capsules, the gripper on the release agent robot, and the selection units are all modular units and could be removed after the tests. Using the release agent spray robot to carry the gripper allows for cost-effective integration. The standardized interfaces of the RFID evaluation units make for simple integration into the ERP system or into the process control. Identification via radio frequency as opposed to optical, camera-based detection has a distinct advantage in that the information remains readable even when the surface of the component is contaminated with soot or dirt. The components can even be painted afterwards.

"Smart materials"

Along with identification, the "intelligence" of components is another focus of this research. This means that important, safety-relevant components can provide information about the thermal and mechanical stresses they are exposed to using integrated sensors.

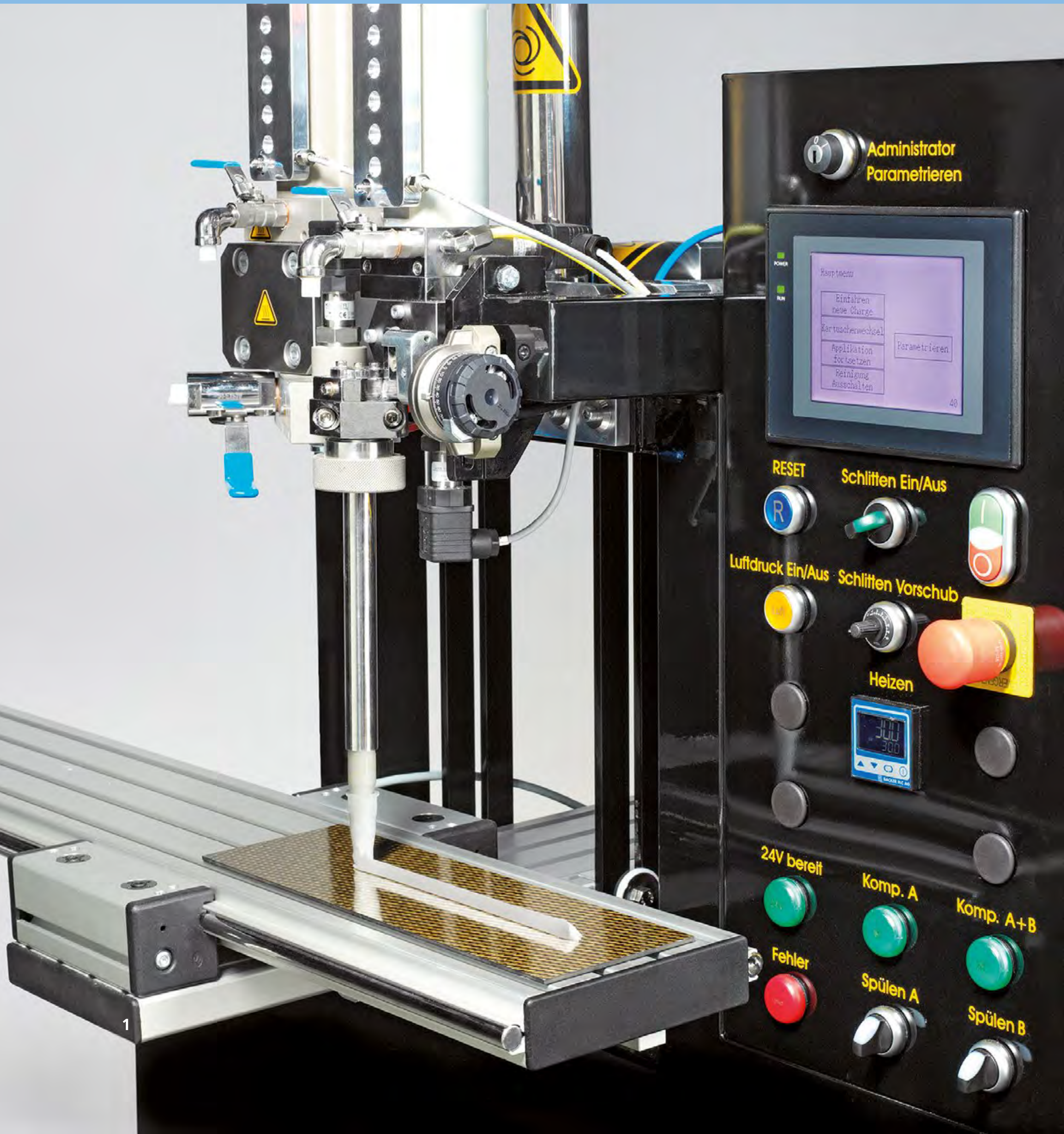
The adverse conditions that metal components are exposed to during production have, until now, prevented the integration of sensitive electronics into them. New combinations of materials, and the experience gathered over a decade of functional integration at Fraunhofer IFAM, are being studied as part of a new DFG research project in cooperation with Prof. Dr.-Ing. Walter Lang from the Institute of Microsensors, Actuators and Systems (IMSAS) at the University of Bremen, aiming to demonstrate feasibility. The goal is to produce die-cast components with piezoresistive sensors. This combination of sensor and casting technology is a novel approach to the research.

Preview

In the coming years, RFID integration and "smart materials" should be ready for serial production. Solutions have already been found for the central challenges facing RFID technology. The first UHF transponders that were cast were able to demonstrate the feasibility of an RFID frequency widely established in logistics.

With the "SINA" project, Fraunhofer IFAM is further expanding its competence in functional integration into the area of cast parts, and has shown it is well positioned to tackle the current issues in the industry.

1 *Cast transponder; DMC with plain text; integrated RFID transponder (top of image).*
2 *Removing the transponder from the magazine. (© Audi AG)*
3 *Inserting transponder into the die-cast mold. (© Audi AG)*


Administrator
Parametrieren
Hauptmenu
Einfahren neue Charge
Kartuschenwechsel
Applikation fortsetzen
Reinigung Ausschalten
Parametrieren
RESET
Schlitten Ein/Aus
Luftdruck Ein/Aus
Schlitten Vorschub
Heizen
24V bereit
Komp. A
Komp. A+B
Fehler
Spülen A
Spülen B

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CORE COMPETENCE ADHESIVE BONDING TECHNOLOGY

Over recent decades, adhesive bonding has been increasingly 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 has been working in this area for more than 50 years. Fraunhofer IFAM has become an internationally recognized independent research organization in the field of "adhesive bonding".

The core competence "adhesive bonding technology" at Fraunhofer IFAM involves the formulation and characterization of materials, the development and implementation of various application techniques, the design and validation of structures, as well as in-depth quality control. This also includes the detailed design of the bonding process in customer-specific industrial processes and industry-wide qualification of operational staff up and down the hierarchy.

Fraunhofer IFAM has solid experience regarding the modification of polymer systems, as well as the development of adhesives and sealants. Challenges such as fast curing, adhesion promotion, and protection against aging are an integral part of IFAM's portfolio, as are the development and use of biomimetic adhesives. The aging behavior and estimated service life of bonded joints are often key aspects. For characterizing adhesives and bonded joints, a wide spectrum of chemical, physical, and mechanical test methods is utilized.

For high-quality bonded joints or difficult surfaces, pre-treatment of the surface is often necessary before bonding. The substrates are cleaned, activated, or modified to enable adhesives to adhere to the substrates with good long-term stability. Process automation is important in many industries, as is the design of bonded joints and their dimensioning. The latter is based on experimental parameters for materials, joints, and components determined in a DIN EN ISO 17065-accredited test laboratory, taking into account the specific boundary conditions of the application.

Fraunhofer IFAM provides sought-after, comprehensive consultancy on industrial adhesive bonding. Investigations often start by choosing the right adhesives for the specific requirements of the customer's application. This can include an optional specific surface treatment of the parts and automation of the adhesive application, leading to the introduction of a quality-assured production process on-site at the company's premises. Optical measurement methods, in-line analysis, and a wide variety of destructive and non-destructive test methods can also be used.

A long-established comprehensive portfolio of training courses in adhesive bonding technology is also offered, with internationally recognized certificates. These courses are another key aspect of our quality assurance concept for adhesive bonding technology.

Fraunhofer IFAM also acts as a DIN 6701 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. Using the DIN 2304 "Adhesive Bonding Technology – Quality requirements in adhesive processes" as a basis, the standardized inspection of industrial bonding processes is an essential component of the core competence of adhesive bonding technology.

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

1 *Optimization of adhesive application.*

FAST CURING IN WOOD CONSTRUCTION: THE FIVE-MINUTE BOND

Bonded rods have proven to be highly performant connectors in timber engineering. However, the current practice of using cold-curing 2K adhesives exhibits disadvantages. Full curing takes hours or days, and requires minimum temperatures onsite that are not always reached.

A way out of this problem is inductive heating which allows full curing within five minutes. It offers a contact-free method of controlled heating. If components themselves cannot be heated by induction, like wood, fiberglass composites and glass, susceptors have to be inserted directly into the adhesive. Metallic meshes can be placed in the adhesive layer, or particles can be mixed into the adhesive. The series of experiments that were performed using Curie materials showed a theoretical solution to the problem of temperature control in inductive heating. Curie particles can only be heated inductively below a certain temperature (labelled Curie temperature, TC). Curie particles added to the adhesive simply "turn off" the induction heat above TC, a very effective and particularly robust means of controlling and regulating the induction process.

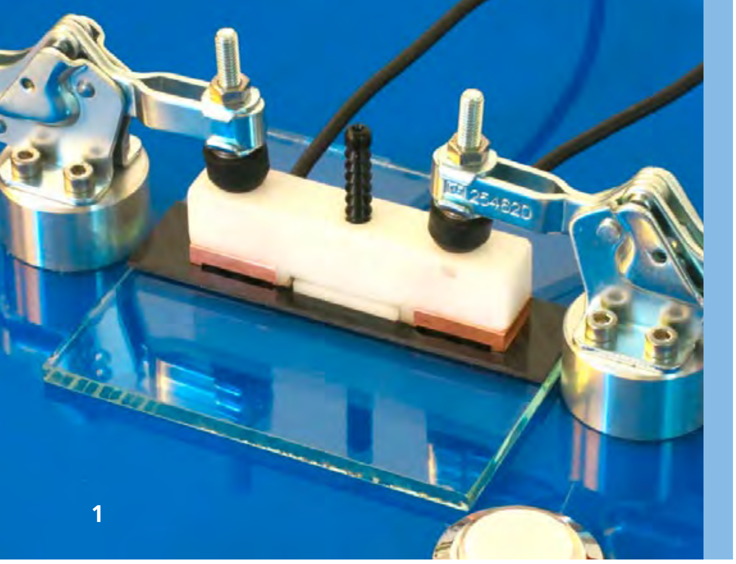
Three series of experiments on inductive heating were performed, demonstrating successes, problems and possible solutions:

- Threaded rods glued in beech wood
- Fiberglass rods bonded with PASA® in beech wood
- Bonded fiberglass rods in beech wood with Curie particles

The first and second series of experiments showed that, although curing could be completed in five minutes, the temperature could only be regulated by means of thermal elements embedded in the adhesive, which is a serious disadvantage for practical applications. The use of pre-applied adhesives (experiment 2) significantly simplified the production process by separating the application of the adhesive from their curing. The third series of experiments focused on eliminating the need for elaborate control of the induction input during the process. To this end, particles of Curie material were used instead of magnetite. The results proved that Curie particles alone were not sufficient to guarantee fast heating. This was only achieved when magnetite was added, which also improved the constant temperature distribution.

Before inductive heating can be considered state of the art, questions need to be answered on how the particles influence the strength and durability of the adhesive joints, and technical implementation must be tailored for the construction industry. The scientists at Fraunhofer IFAM are currently working hard to provide answers to these questions.

1 *Experimental setup for bonded threaded rods.*



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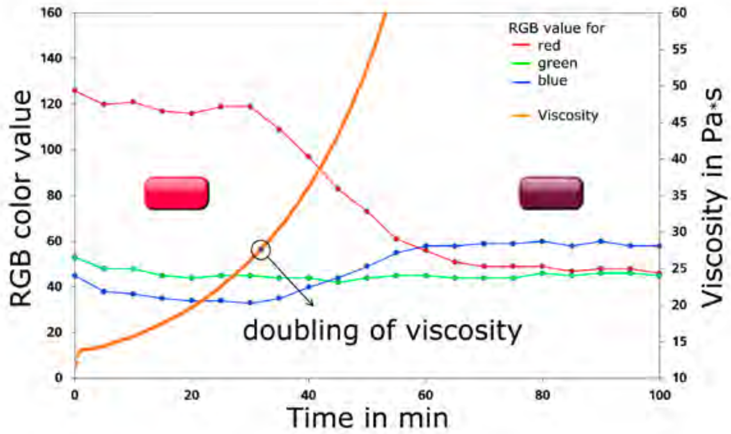

BONDING: FAST, CONTROLLED, RELIABLE

The demands on adhesive joints are constantly increasing in terms of their reliability, cost-effectiveness and safety. To increase the productivity of bonding processes, the fastest possible curing is demanded, while at the same time a lengthy processing time for the adhesives is desired, in order to control processes with ease and react flexibly. To overcome these intrinsic contradictions, fast curing processes are increasingly being used.

In most cases, fast curing is carried out by heating the adhesive quickly to a high temperature, whereby, according to Arrhenius, curing speed should approximately double for every 10°C temperature increase. True fast curing, also called "snap cure", should be completed within a time frame of between a few seconds and a few minutes. But in practice, there are some drawbacks that have to be overcome. The measurement and control of the temperature slope is one of the real challenges. Another is the question of which properties the adhesive should display after fast curing, because many adhesives are not suitable for this process.

At Fraunhofer IFAM, there are numerous methods available for thermal fast curing. A few of these include: induction (working frequency 50–800 kHz, power output 10 kW); infrared radiation; microwave calorimeter and free-beam microwave; contact heating with heated stamps; and hot air heating. But the question remains as to how to measure and control the temperature in the adhesive joint, as the measurement of the component surface temperature during fast curing is not sufficient.

Two methods have been developed to measure the temperature inside the adhesive joint and to use the data for process control. The E-FAST® method uses a metal strip coated on both sides with an adhesive (e.g. PASA®, pre-applicable structural adhesive) placed between the components. The strip of metal is heated with an electric current, curing the adhesive. Since the resistance of the metal depends on the temperature, it can be used to quickly measure the temperature in the adhesive joint aside the function as heating element. The temperature in the adhesive joint can alternatively be identified using the temperature dependency of the electromagnetic resonance of added particles. This procedure can be used for many different fast-curing methods.

A color reaction has also been developed to allow visual monitoring of the adhesive's curing status. Colorimetry allows quantification of color changes and thus also the curing status, although it is often necessary to measure the color at the edge of the adhesive joint.

The examples show that critical process parameters can also be measured and controlled during fast curing processes. Which method is appropriate and necessary according to DIN 2304 "Adhesive Bonding Technology – Quality requirements in adhesive processes" must be worked out and decided on a case-by-case basis.

1 *Prototype of an E-FAST® system: bonding a plastic stud to CFRP.*
2 *Monitoring the curing process of an epoxy adhesive using colorimetry. The beginning of the decrease of the red portion correlates to a doubling of the viscosity (end of pot life).*


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CORE COMPETENCE SURFACE TECHNOLOGY

New materials often drive innovation and end up as part of key technologies in everyday life. The industrial range of uses for many materials can be considerably expanded through the 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 wide 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 material development to the characterization and evaluation of surfaces, their functionalization and modification, and on to various application technologies. The development of processes – such as dry and wet chemical pre-treatment, coating processes and printing processes, as well as thin/thick film technologies – and also of 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 experimental and computer based 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 various functional attributes of surfaces have to meet the respective application requirements. 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 processes 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. In addition, accredited test facilities are operated, which are also used 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 *Robot-guided wetting test of a carbon-fiber component.*

MICROBIAL-INFLUENCED CORROSION AND ANTIFOULING COATING

Biological growth (biofouling) on surfaces in water-based systems causes economic losses worldwide. Environmental aspects and resource efficiency also play an important role in this context, for example the use of biocides as a protection mechanism, increased fuel consumption in the case of ships, and material and energy losses due to oversizing components. Fraunhofer IFAM is developing innovative, biocide-free coatings to prevent biofouling. Using testing methods and outdoor weathering test stations, a holistic view of formulation, application technology, and practical testing in the field can be gained.

Biological growth on surfaces in a water-based system starts within a few minutes. What begins with simple molecules adhering to a surface soon becomes a complex, highly diverse community of bacteria and algae. The biological variability and the organization in a biofilm create a complex chemical environment that becomes a big influence on the choice of material and its reliability. This first stage of fouling plays an especially decisive role in microbial-influenced corrosion (MIC). This type of damage occurs mainly in underwater steel construction and in pipes. Until now, only one chain of evidence could prove whether or not damage had been caused by MIC. But anyone who wants to reduce costs and minimize risks needs a timely method of detection. In a microbiological laboratory, Fraunhofer IFAM is exploring effective methods of detection and strategies to prevent MIC. The main focus is on functionalized surfaces and anti-microbial substances.

1 *Biochemical evidence of microbial activity in Fraunhofer IFAM laboratory.*

2 *Removal of test bodies on a frame at the field-testing station on the island of Sylt.*

However, microbial growth is not only relevant in the context of MIC. Biofilm on the hull of a ship with a roughness of 100 µm already causes a significant loss of efficiency. The propellers and the hull must therefore be protected against fouling. This loss of efficiency, which in practice is balanced out by higher fuel consumption, increases exponentially when macroscopic fouling organisms start colonizing the surfaces. Mussels, barnacles, and various other marine organisms can form layers that are several centimeters thick.

Fouling also complicates the inspection of underwater structures, clogs pipe systems, and alters load distribution with its considerable weight. Until it was completely banned by the IMO in 2008, tributyltin (TBT) was an effective ingredient in antifouling coatings. The elimination of TBT-containing antifouling coatings took away the industry's most effective remedy. Taking a holistic approach, the experts at Fraunhofer IFAM have developed novel antifouling strategies on commission from customers and for public projects. Modern laboratories as well as static and floating maritime field-testing stations allow new and further developments while considering the various stages and effects of fouling.

COST-EFFECTIVE LOCAL DEPOSITION OF TITANIUM-DIOXIDE LAYERS

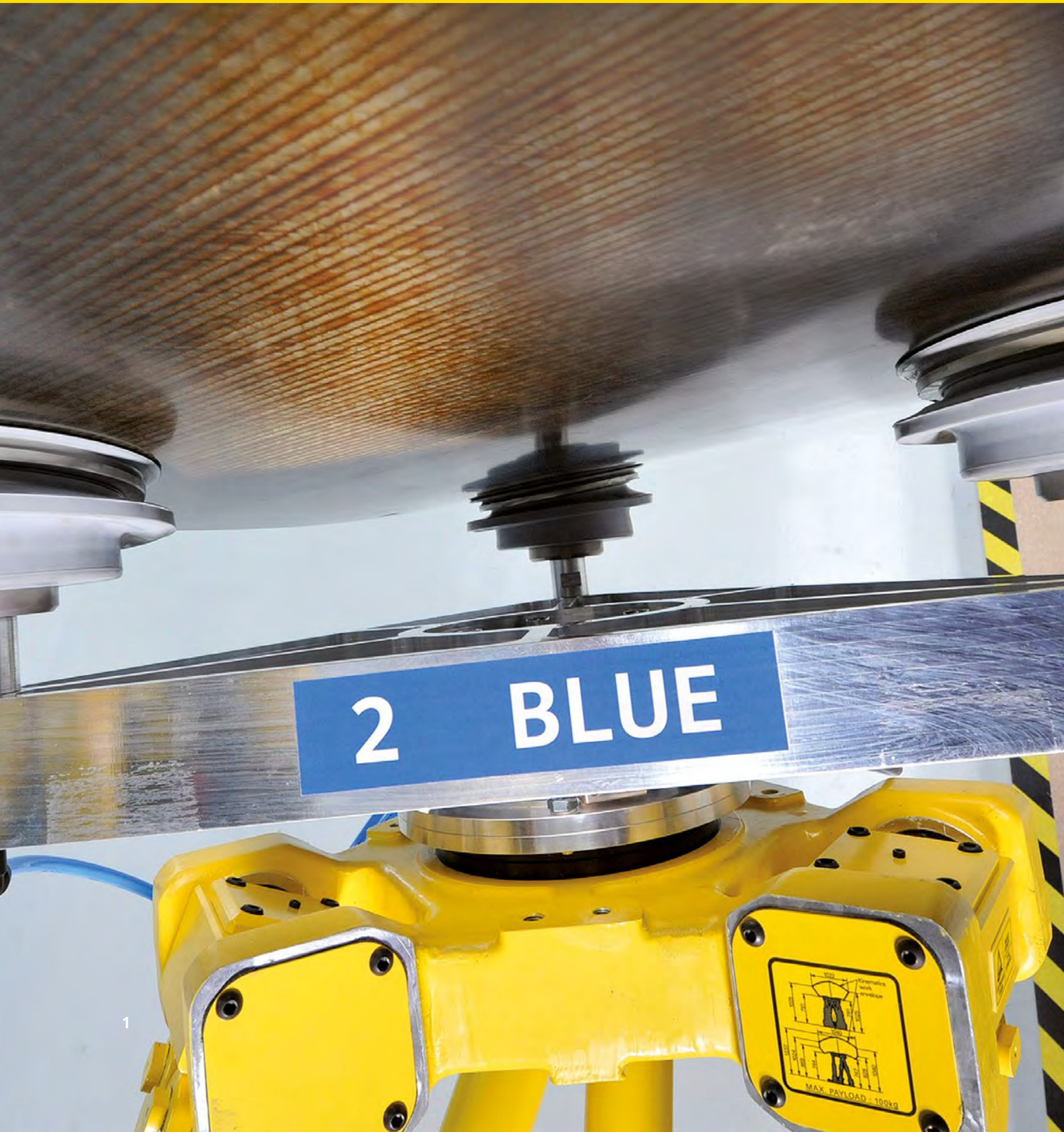
Thin coatings are used in many technical applications to equip surfaces with special functionalities. For that purpose, titanium dioxide (TiO_2) offers a wide range of possible applications because of its chemical and physical properties, in semiconductor technology, medical implants, and instruments. Deposition of TiO_2 is typically achieved by vacuum processes, which lead to high investment costs and restrictions due to materials that can be used. An alternative is given by a cost-effective deposition process carried out under atmospheric pressure, which has been developed at Fraunhofer IFAM.

Depending on the deposition conditions and the type of treatment, TiO_2 layers can be adjusted to have self-cleaning and photocatalytic properties, long-term stable high wettability and also decorative properties. The AP-CVD technology (Atmospheric Pressure Chemical Vapor Deposition), developed at Fraunhofer IFAM, is based on chemical layer deposition resulting from the reaction of a titanium organic precursor with moisture added in a defined way. Extra energy, for example by means of heating the substrate, is not needed in this case, making the process suitable also for temperature-sensitive materials. The combination with a pre-treatment process allows the application of the TiO_2 layers to a variety of metal and polymer materials. Because the process is carried out under atmospheric conditions, it is cost-effective, in-line compatible, flexible, and can be used for specific features of individual component surfaces.

The local color design of metallic components is one example of this technology, which allows a high degree of freedom for decorative applications. Patterns can be achieved with either masking or a targeted, layered removal of the TiO_2 using a laser. Due to the excellent biocompatibility of TiO_2, the layers are especially interesting for medical applications, to ensure faultless identification of implants and instruments. Current research efforts are the integration in data matrix or QR codes.

The TiO_2 layers are currently being developed further for their dielectric properties in a project founded by German Ministry of Education and Research in cooperation with industry partners and the University of Bremen. The purpose of this project is the reduction of fouling effects on filtration membranes using electric fields (dielectrophoresis) to improve water treatment. Dielectric encapsulation of the electrodes with an adapted TiO_2 layer deposited by AP-CVD is necessary for the formation of the electrical fields. This allows for a significant improvement of the long-term filtration capacity of the membranes.

1 *Decorative design on a surface with TiO_2 layers, produced using AP-CVD.*



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CORE COMPETENCE FIBER REINFORCED PLASTICS

Fiber reinforced materials, 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 advantages lie in the high rigidity of the direction of the fibers in combination with the shaping by the matrix.

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

This begins with the selection and development of 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 on 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. Fraunhofer IFAM offers automation solutions that can save a lot of assembly and processing time, even for very large fiber-composite structures that are not accurate in their sizes. This leads to the emphasis being placed on light, mobile, modular system components that can be adapted to a versatile production line without extra efforts and costs.

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/frp**

1 *CFK-AFMO development platform.*

MOBILE MILLING ROBOTS FOR VERSATILE PRODUCTION

Six-axis industrial robots are optimized to continuously carry out repetitive sequences of motion. However, versatile production lines with components of low shape tolerances require robots that can precisely adjust their movements to changing tasks and components. For large components in the construction of aircraft, enormous flexibility in production is possible when multiple robots are working on the part at the same time.

These requirements lay out the objectives of the "ProsihP II" project funded by Lower Saxony. Upon completion of the project in November 2016, the project partners showed in a live demonstration of contour milling on the shell of a CFRP vertical tale plane that a system consisting of an autonomous ground vehicle (AGV) and an industrial robot could perform applications that were not possible for the 6-axis robot due to its lack of absolute accuracy and its limited workspace.

A whole series of innovations enable these new applications. The automation team at Fraunhofer IFAM has designed and put into operation a mobile carrier vehicle for heavy-duty robots of up to three tons, in cooperation with the project partners. The cost-effective motion platform that was built from state of the art components, is stabilized by three pillars to ensure a statically definite stand. Three extendable wheels enable the entire structure to performe wide range of movements, including on-spot-rotation. Thanks to newly developed software, the system will be calibrated to the component.

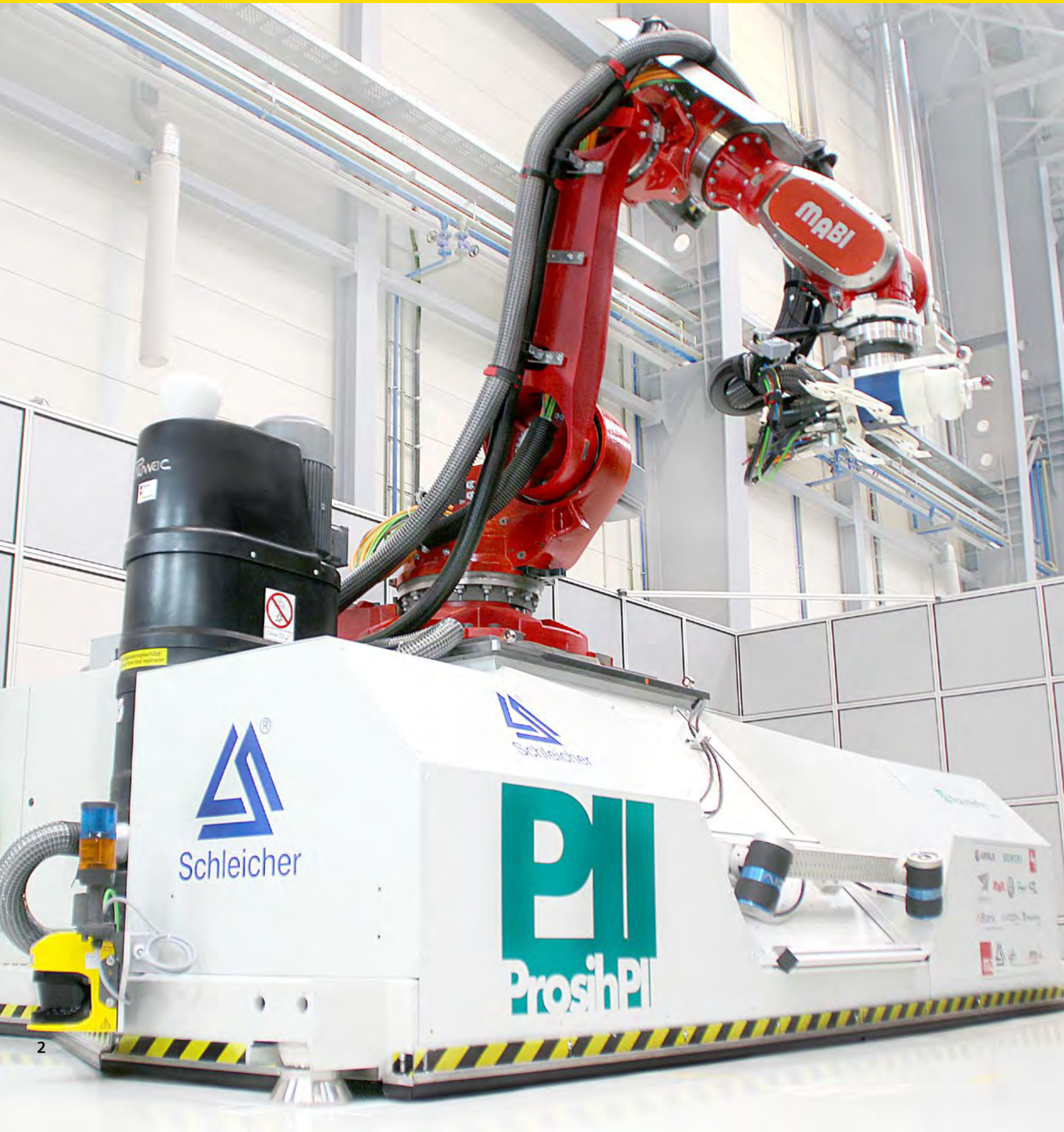
For this project, the requirements of absolute positioning and path accuracy of the complete system consisting of the robot and the AGV were so challenging that the robot's performance had to be increased significantly. To that end, the robot kinematics was equipped with a CNC-control (Siemens SINUMERIK 840D sl), compatible motors and secondary encoder measuring systems on each axis to correct any structural deviations of position. A highly developed stereo camera system identifies the current pose of the robot to enable real-time correction by comparing actual and reference data. This cooperation and development has produced one of the most accurate machining robots in the world. The Fraunhofer IFAM worked closely with PD Dr.-Ing. Jörg Wollnack, private lecturer at the Hamburg University of Technology, to achieve this progress in the field of robotics.

The system has been designed for components of up to 30 m in length, achieving local accuracy of 0.1 mm. It can be used for various primary aircraft structures such as wing covers or fuselage segments. With some slight modifications, it can also be used for rotor blades of wind turbines or large components in shipbuilding.

The following institutions were involved in the project:
Aicon 3D Systems GmbH, Airbus Operations GmbH, Artis GmbH, CTC GmbH Stade, Fraunhofer IFAM, IPMT of the Hamburg University of Technology, Ludwig Schleicher Plant Construction GmbH, Mabi AG, mz robolab GmbH, Siemens AG and Volkswagen AG.

1 *ProsihP-II system for the machining of an A320 vertical tale plane.*

2 *Mobile CNC robots for machining of large structures.*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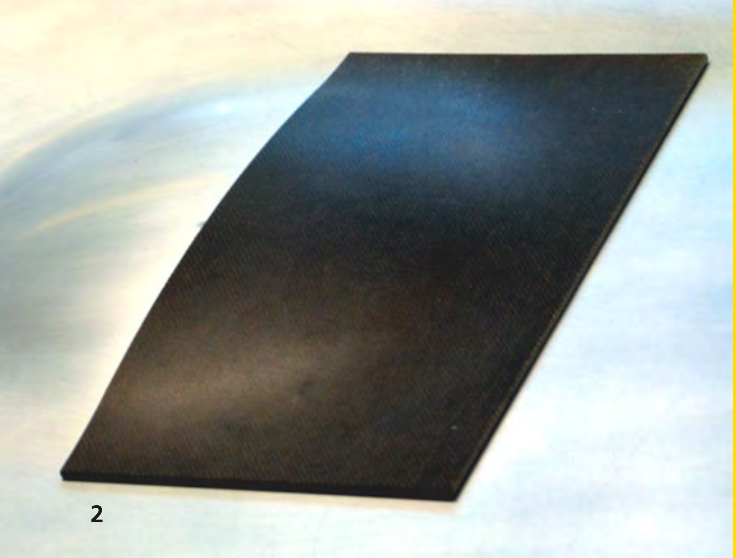
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NEW SEMI-FINISHED COMPONENTS FOR AUTOMATIC MANUFACTURE OF THERMOSET FRP

Fiber reinforced plastics (FRP) are produced with either reactive resins or thermoplastics as a matrix polymer. The reactive resins form thermosets with good mechanical properties but require more complex processes to produce FRPs than when using thermoplastics. The goal of this development was to combine both of these advantageous properties.

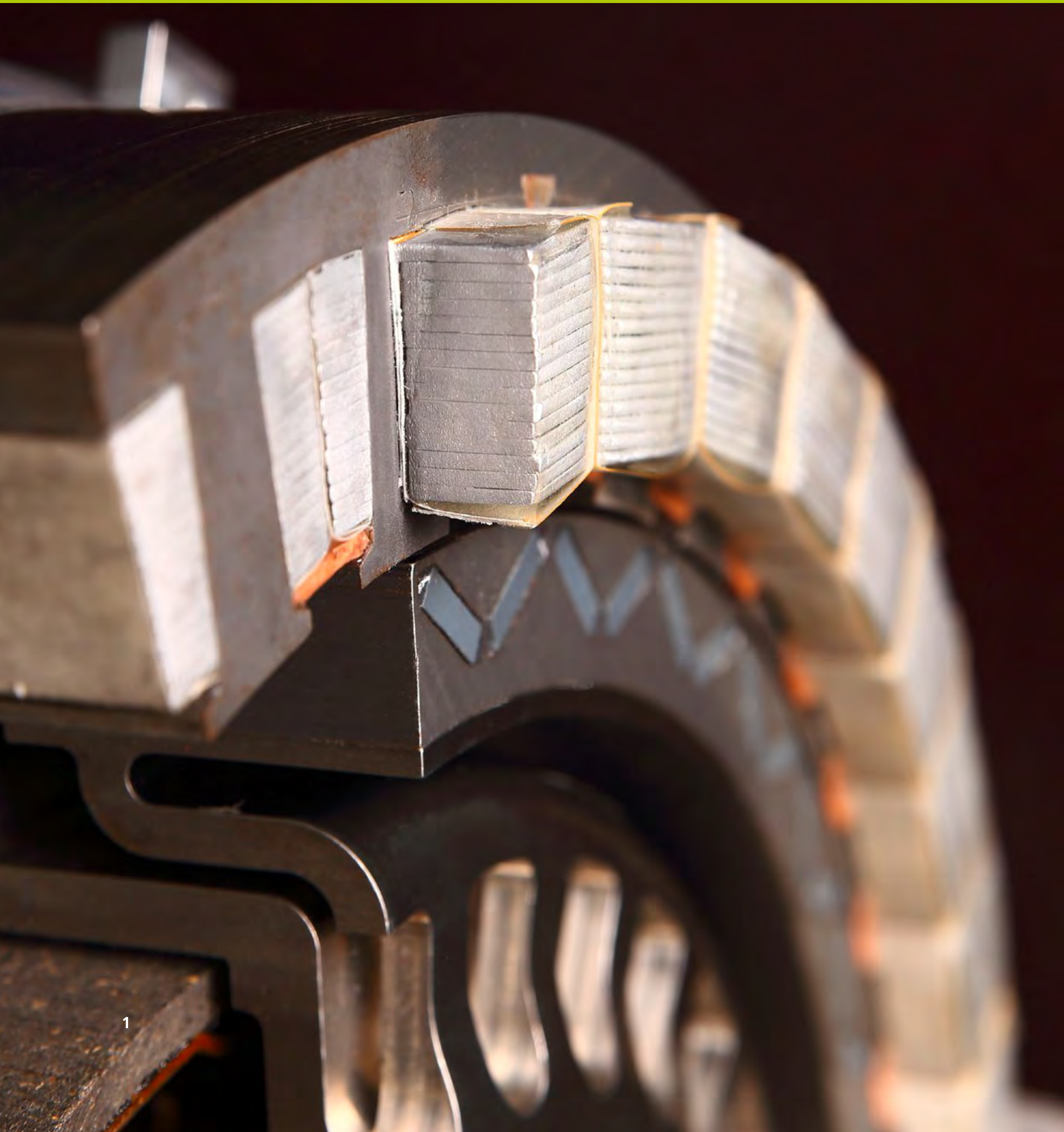
These new fiber-based semi-finished products, such as prepreg, are characterized by matrices that can be processed thermoplastically and crosslinked to thermosets. The properties of the resins can be formulated in such a way that they can be used in a wide range of applications. Solvents are not needed when manufacturing prepreg using water-based systems. High temperatures, as in the case of cost-intensive melting impregnation with conventional thermoplastics, can be avoided, making it possible to use heat-sensitive fibers such as polyethylene or cellulose. The innovative resins are dried at only moderate temperatures.

Manufacturing the semi-finished products does not require any new infrastructure. The fiber coating can be applied roll-to-roll by immersion, knife coating, or spray. After drying, the fibers are protected against slipping and thus facilitate insertion in the tool that is suitable for the load path. Below the softening temperature of approximately 60°C, the material is not sticky, rather it remains flexible and drapable. In contrast to conventional prepregs, it can be stored stably at ambient conditions for many months. At temperatures below 60°C, the shape is stable, and the semi-finished product is still workable between the softening temperature and the hardening temperature (above 120°C). Curing to make the product into a thermoset component is carried out either during or after forming, as a subsequent step. To do this, the dry layered structure can be formed in a heating press and cured. Another advantage is that the component can be removed from the press while still hot, but the shape is already stable.

During component manufacture, as with other procedures for FRP production, mold release agents must be used. For this step, the Flex[Plas®] release films that have been developed by Fraunhofer IFAM have proven particularly useful. These films are shaped with the fiber sheets and have permanent release layers with different release properties on both sides. The highly effective release layer leads to easy removal of the part from the mold, whereby the side of the film attached to the part does not release as quickly and the film remains attached to the component until further use. After removing the film, the component can be processed further without the usual surface treatment.

1 *Thermoplastic prepreg for the manufacture of thermoset components: not sticky, stable for storage, roll-to-roll processing.*
2 *Thermoset jute fiber component manufactured in the heating press, similar to sheet metal forming.*

ELECTRICAL COMPONENTS AND SYSTEMS



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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, Fraunhofer IFAM provides technical solutions for the best use of electricity.

Electrical energy must be stored safely at high density and performance, which represents a real challenge for mobile applications such as smartphones. The material and technical process aspects are our focus at Fraunhofer IFAM, where we work to discover future electrochemical energy storage solutions. In addition to lithium-ion and metal-air batteries, we are 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 the entire process chain for cell manufacturing.

Electric drive technology focuses on the development, prototyping, and testing of highly efficient electric motors. To that end, we are working on new approaches in order to increase the functional safety of drive systems and efficiency-optimized control, especially 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 electric drives. Adhesive bonding and surface technology complement this core competency along with aspects such as connection, contact, insulation and protection of electrically conductive materials.

At 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 (building/district) and regional level requires the use of heat and electrochemical storage devices and converters. In this area, 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, simulating this in a physical test field with real components.

→ **www.ifam.fraunhofer.de/ecs**

1 *Stator of the wheel hub motor mounted on the Fraunhofer electric concept car "Frecc0 2.0".*

POLYMER COMPOSITES FOR SOLID-STATE BATTERIES

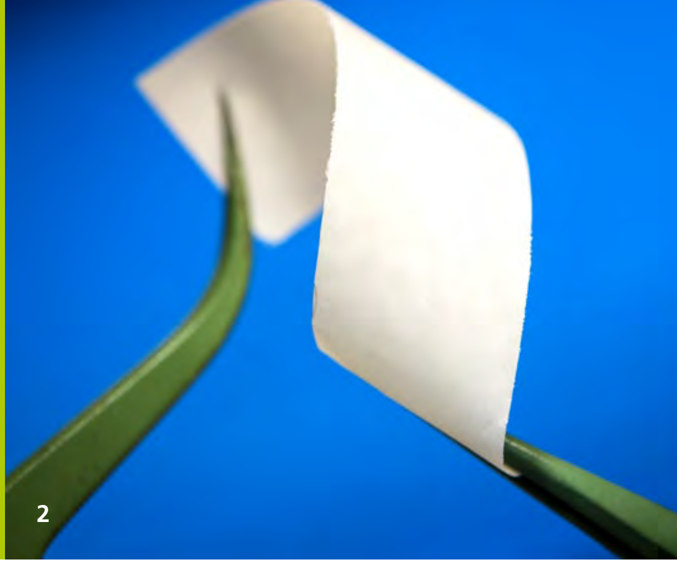
Rechargeable solid-state lithium batteries are seen as the next generation of high-performance energy storage devices. They have advantages over current lithium-ion batteries with aprotic, liquid, or gel electrolytes in the areas of miniaturization, electrochemical stability, energy density, and especially operational safety. One of the challenges in this area is to develop materials and methods for solid-state batteries that will lead to phase boundaries with low contact resistances and cycle stability. For electrode production, this means it is absolutely essential to use modified production technology and, depending on the cell design, also new technology in cell assembly. That is why manufacturing concepts for the serial production of solid batteries still have not been defined or prototypes developed. The production of these polymer composites is the starting point for the work done at Fraunhofer IFAM.

Electrochemical energy storage is vital for many applications. In addition to stationary applications like intermediate storage for renewable energies, this plays a decisive role in fields that depend on mobile applications. The growing functional density in the consumer sector and the demanding requirements for electric vehicles require powerful, reliable energy storage devices. Many forecasts predict that lithium-ion technology will dominate the years to come.

Solid-state lithium-ion batteries have great potential for development. This is due to the increase of energy density and the intrinsic safety inherent in substituting liquid electrolytes with a solid material (polymer/ceramic/glass). Moreover, system solutions could be significantly simplified by eliminating cooling systems and safety equipment (fire protection). This technology is therefore especially interesting for OEMs in the automotive industry. Currently, we still do not know which material concept will prevail, inorganic or polymer-based. There are two main tasks when dealing with solid-state electrolytes. First, the materials used generally have lower intrinsic lithium-ion conductivity than liquid electrolytes. Second, manufacturing a battery that consists of only solid materials is very challenging, both for a cell and for the system. A deep scientific understanding of the processability of the materials is necessary to create phase boundaries with low transition resistances and cycle stability.

While ceramics require high temperature processes, polymers can be processed directly or with the aid of solvents that can be removed in later steps. This flexibility is also reflected in the components themselves. Volume changes when charging and discharging the battery can easily be dealt with by the elastic properties of the polymers.

This is also the approach of Fraunhofer IFAM, as we use our competencies in powder technology, interface, and polymer chemistry to advance the development of polymer-based solid-state batteries. In addition to questions on material selection, scientists are pursuing the question of which process technology can produce this kind of battery



cell on an industrial scale. The shaping of polymer matrix composites has a special role in being able to repeatedly produce organic-inorganic composite electrodes after incorporating additives and fillers. One main focus is on the interaction between the solid ceramics and the polymer in the composite. The interfaces formed here are of vital importance for the functioning of the battery.

In cooperation with the Young Scientist Group for Sensors and Functional Materials at the University of Bremen, the possibility of embedding lithium-ion-conducting ceramics in a polymer matrix to produce flexible, free-standing electrolytes, combining the advantages of ceramic and polymer-based systems, is assesed. It is possible to adjust the strength and conductivity of the solid electrolytes by precisely mixing ceramic particles into the polymers.

To significantly increase the energy content of solid-state batteries, alternative electrode architecture and cell designs will be necessary. Here, powder-based shaping processes to make more compact and more homogeneous composite electrodes are developed. The challenge is to combine the individual components into a functional stack of cells. There is a wide variety of solvent-based and solvent-free methods available to do this, such as dispersion, kneading and compounding, extrusion, calendering, and lamination, which have played a central role for many years in the manufacture of polymer-metal and polymer-ceramic composites in the areas of lacquer and powder technology, adhesives, and shaping. The goal is to manufacture polymer-based composite electrodes and to characterize them physically and electrochemically in solid-state batteries.

1 *Conductive polymer in a blade mixer.*

2 *Free-standing, flexible composite electrolyte.*

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OPENING OF THE OPEN HYBRID LABFACTORY

The Open Hybrid LabFactory research campus works with research institutes and enterprises in Wolfsburg to develop key future technologies for automobile design. The new building of the research campus was inaugurated with a ceremony on September 22, 2016. Among other partners, three Fraunhofer Institutes work together on an interdisciplinary basis under the direction of Fraunhofer IFAM.

Lighter materials and new production techniques make it possible to manufacture cars in a more environmentally friendly way than in the past. At the research campus, the entire value chain for hybrid components is represented, from design and the production of reinforcement textiles to hybrid production processes and recycling. The goal is to lay the groundwork for the production of very light, and thus energy- and resource-efficient vehicle bodies and drive systems in large numbers. To do that, researchers are developing a so-called hybrid design. This approach uses materials with different properties such as metal, plastics and textile structures and assembles them into the lightest possible components, offering the same high level of safety and performance as conventional cars.

Up to €30 million of the research pursued at the Open Hybrid LabFactory is funded by the German Federal Research Campus Program. The research campus consortium, under the leadership of the Automotive Research Center Niedersachsen (NFF) at the Braunschweig University of Technology, and with the involvement of industry partners such as Volkswagen AG, is one of the nine funded campuses. A total of more than €90 million was provided by the German Federal Ministry of Education and Research, the Land of Lower Saxony, the city of Wolfsburg and industry partners, to fund equipment and first research projects. €60 million of that amount has been invested in the building, the plant technology, and the initial setup. In the next 15 years, research projects with funding of over €200 million will be run at the Open Hybrid LabFactory.

To make this possible, experts from universities, research institutions, and industry work together as peers under one roof in the research factory. Next to the NFF and Volkswagen Group, many different institutions and companies work in cooperation, including Volkswagen, BASF, DowAksa, Engel, IAV, Magna, Siempelkamp, ThyssenKrupp, Zwick Roell, Institutes of the Fraunhofer-Gesellschaft, the Clausthal University of Technology and the Leibniz University Hannover as well as a number of other companies. International technology leaders introduce their expertise to the research process and gain from the know-how of the participating academic institutions. Students, junior scientists, and scholars also benefit from the diverse perspectives and experience of our partners. This new center of expertise and research in economic lightweight design and innovative material and manufacturing technologies was set up in Wolfsburg, not far from the main plant of Volkswagen AG and very close to the MobileLifeCampus.

1 *Open Hybrid LabFactory research campus. (© OHLF e. V.)*

2 *Representatives from politics, the Fraunhofer-Gesellschaft and other institutions participating in the Open Hybrid LabFactory. (© OHLF e. V.)*

SUCCESSFUL START TO THE "1ST BREMEN FIBER COMPOSITE DAYS"

The "Adhesive Days Bremen" have been an institution since 2003 – not only for former participants of the adhesive bonding training courses at Fraunhofer IFAM. On September 29–30, 2016, the "1st Bremen Fiber Composite Days" were offered in the same spirit.

The history of this event is as follows: In 2007, the Training Center for Fiber Composite Technology (WZF) was founded at Fraunhofer IFAM as a training center both for fiber composite materials and for adhesive bonding technology, providing personnel certification courses across the industry and for all hierarchy levels.

In 2016, the time had come to give the former participants of the WZF the opportunity to learn about the latest developments in fiber-composite technology, meet old contacts, and make new ones. The "Bremen Fiber Composite Days" were started to complement the courses at the Training Center for Fiber Composite Technology and also to provide interesting, up-to-date information to those interested who had not yet taken part in the courses.

This concept arose along with the ambition to create a platform to present and discuss challenges and solutions in fiber composites "in practice". Following interesting presentations and discussions, the get-together in the evening gave the 65 participants ample opportunity to discuss the newest developments in fiber composites in small and large groups. The discussion took as its theme the Low German saying, "Een und een is mehr as twee" ("One and one is more than two"). The "2nd Bremen Fiber Composite Days" are scheduled for August 31 to September 1, 2017.

1 *Beate Brede, director of the Fiber Composite Training Center at the "Bremen Fiber Composite Days".*

PROF. DR. ANDREAS HARTWIG AWARDED FOR KNOWLEDGE TRANSFER

Prof. Dr. Andreas Hartwig was awarded the De Bruyne Medal for his outstanding transfer of scientific knowledge at the European Adhesion Conference EURADH 2016 in Glasgow.

This prestigious prize is presented by the Society for Adhesion and Adhesives to a particularly deserving researcher in adhesive bonding technology every three years. Norman Adrian de Bruyne FRS, born on November 8, 1904 in Punta Arenas, Chile, was a British scientist and pioneer of lightweight design, who had a special understanding of how to implement theoretical scientific knowledge in practical applications. He developed the first structural adhesives and later invented honeycomb core plates that are still used today in aircraft construction.

In light of this history, Matthew Cleaver, representing Hexcel Composites Ltd., presented Prof. Dr. Andreas Hartwig the De Bruyne Medal on September 21. In his function as deputy director of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM and as head of the Department Adhesives and Polymer Chemistry, the chemist Andreas Hartwig has dedicated himself to scientific questions on the topic of adhesives since 1992. He has acquired an international reputation for his important contributions to research in the field of adhesives chemistry and adhesive bonding technology as well as for transferring this knowledge to industrial practice.

He was commended in particular for his work on cationic curing epoxy resins and pre-applicable reactive adhesives – PASA® for short. In his lecture "Polyurethane adhesives: Influence of curing on dynamics and property changes with time", the prize winner focused on the industrial aspects of this technology, in accordance with the purpose of the foundation.

1 *Prof. Dr. Andreas Hartwig (left) receives the De Bruyne Medal from Matthew Cleaver, representative of Hexcel Composites Ltd.*

DR. GESA PATZELT RECEIVES AWARD FROM THE GDCH (SOCIETY OF GERMAN CHEMISTS)

With her presentation on "Omniphobic surfaces for the improvement of anti-ice and anti-contamination properties", Dr. Gesa Patzelt was able to convince the jury at the 80th annual meeting of the paint professional group in Paderborn on September 14, 2016. Out of 25 presentations, her contribution was given the award for the best scientific content and speech quality.

Dr. Gesa Patzelt has carried out research on anti-ice and anti-contamination properties of coatings in the department of paint/lacquer technology at Fraunhofer IFAM for many years. In the aviation industry and the production of wind energy plants especially, the continued performance of surfaces regarding energy efficiency is essential. However, efficiency is reduced by the formation of ice and contamination by insects. Various possibilities for the modification of surfaces are currently being studied, including the chemical composition of the coating, its roughness, and the surface structure. Scientists have conducting research on innovative surfaces since 2009. In the last few years, the focus has been shifted to omniphobic coatings.

Omniphobic surfaces are characterized by both hydrophobic and lipophobic properties, reducing the formation of ice on surfaces and allowing insects to be removed very easily. A variation on the production of the surfaces is the SLIPS approach (slippery liquid-infused porous surface), whereby porous surface structures are soaked with functional oils. The biological model for this approach is the carnivorous pitcher plant Nepenthes spp., whose wax crystals react to insects with an increased secretion of adhesion fluid, thus causing them to slip down into the plant. It could be shown that such a surface very effectively repels various forms of contamination, such as oils, clear ice, and blood, and in contrast to classic superhydrophobicity and the associated so-called lotus effect, light damage can self-regenerate with the flowing of the functional fluid.

For an improvement of this approach, a boehmite structure, grown on an aluminum alloy (AA 2024), acted as a reservoir for functional oils. Both synthetic oils, such as hydraulic oil, and fluoro-modified oils were used as functional oils. Before being filled with functional oils, the surface of the structure was modified using the sol gel process. After the chemical modification and use of fluoro-modified oils, a unique omniphobic surface was produced.

In other experiments, metal surfaces were given micro- and nanostructures using lasers; these were then accurately transferred to a coating using a special procedure. These surfaces could also be modified and filled. Furthermore, it could be demonstrated that the surface repelled both water and oils.

1 *Dr. Gesa Patzelt at the award ceremony with Dr. Michael Hilt from the GDCh (Society of German Chemists).*

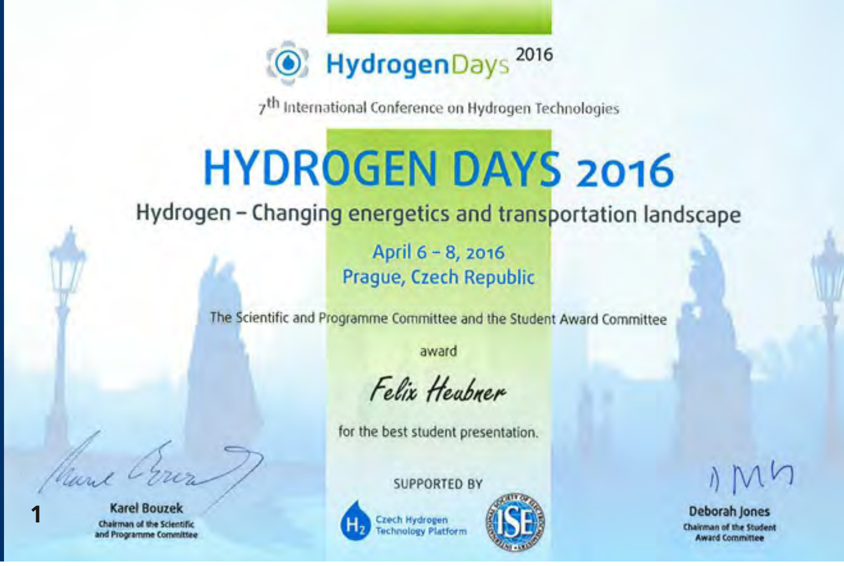
ANASTASSIJA WITTMER RECEIVES THE "BEST YOUNG SCIENTIST" AWARD

Anastassija Wittmer received the "Best Young Scientist" award for her presentation at the European Technical Coatings Congress 2016. Her lecture "Intrinsic self-healing coatings" impressed the jury at the internationally renowned congress in Birmingham on May 25. Out of 56 presentations, her contribution was rewarded for its scientific originality with outstanding results and for being the best presentation.

Since November 2014, Anastassija Wittmer has been a doctoral student in the Department of Paint/Lacquer Technology at Fraunhofer IFAM and has worked on the intrinsic self-healing of polymers for her doctoral dissertation. Her research is based on the fact that coating materials are often exposed to extreme environmental influences and process-related demands. UV light, tree sap, mechanical abrasion, and internal tension increase 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-healing properties are able to heal this microscopic damage on their own or under the influence of an external stimulus. This can lead to prolonging the component's life and maintaining the material's appearance. The paint and lacquer scientists at Fraunhofer IFAM have researched the extrinsic self-healing of coatings using capsule systems for many years, which has already led to the first commercial product, a self-healing window paint.

Intrinsic self-healing occurs within a specific polymer network, where the polymer has the ability to form a large number of reversible physical bonds. A self-healing reagent can be fixed covalently onto 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-cracks by reorganizing the molecules. Self-healing usually occurs at elevated temperatures and high humidity levels. It has been shown that water from moisture in the air plays a decisive role in the self-healing process.

1 *Anastassija Wittmer at the award ceremony at the European Technical Coatings Congress.*



INNOVATIVE METAL-HYDRIDE COMPOSITE MATERIALS – AWARD FOR "BEST STUDENT PRESENTATION"

At the 7th International Conference on Hydrogen Technologies in Prague on April 6–8, 2016, Felix Heubner from Fraunhofer IFAM in Dresden received the "Award for the Best Student Presentation".

In his presentation entitled "Anisotropic stress generation of metal hydride composites", the young scientist performed a fundamental and systematic evaluation of selected metal hydride composite materials (MHC) and the resulting boundary conditions for hydrogen storage systems. Hydride-forming metal alloys are used for industrial H_2 storage, for example for marine applications, stationary energy systems, and portable fuel cell-powered electronics. The composite materials presented here, which are composed of the H_2-absorbing storage material as well as a shape-stabilizing and highly conductive second phase, are completely new and clearly superior to conventional pure metal hydrides, for example in terms of their volumetric storage capacity, storage dynamics, and process safety.

In his presentation, Felix Heubner presented the image of the real-life behavior of MHC in a storage tank in consideration of the volume expansion associated with hydrogenation. The expansion of the metal can be directed into the pores of the composite material, generating measurable force. This relationship was used to illustrate the fill level and the state of health of a metal hydride-based storage system (DE patent 10 2015 100 584 B3).

Support for this project, which was conducted by the Technische Universität Dresden and Fraunhofer IFAM, was provided by the Friedrich and Elisabeth Boysen Foundation, the German Research Foundation DFG and the German Federal Ministry of Education and Research.

1 *Award for the Best Student Presentation for Felix Heubner.*

ELECTRON BEAM MELTING – AWARD FOR BEST FUNCTIONAL PART

At the Arcam User Group Meeting, a meeting of the worldwide experts in the field of electron beam melting (EBM), Dr. Burghardt Klöden of Fraunhofer IFAM in Dresden was awarded the prize for "Best Functional Part".

Users of the Arcam plant technology as well as other guests from the field of additive manufacturing came together in Falkenberg, Sweden from September 20–22, 2016. The participants were invited to bring their own components and to apply for one of the prizes in the three categories of "Best Innovative Part", "Best Functional Part", and "Best Creative Part". All the components were set out during the event and, in addition to being viewed, could be handled as well. Finally, all the participants were called on to vote on the prizewinners.

The team from Fraunhofer IFAM Dresden received the prize for "Best Functional Part" for the main gear bracket, a helicopter component, which was optimized by the GenFly project and produced using EBM. The prize not only awards the achievement of a single component, but also strengthens the reputation of the prizewinners within the worldwide community of EBM professionals and beyond.

1 *Prize for the "Best Functional Part" for Dr. Burghardt Klöden.*

INFIANA AND FRAUNHOFER IFAM RECEIVE THE AIMCAL AWARD

At the management meeting of the American "Association of International Metallizers, Coaters and Laminators" (AIMCAL) in Carlsbad, California, Infiana and the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM jointly received one of the coveted AIMCAL Awards – a special recognition for the global provider of specialty films and for the developments brought by Fraunhofer IFAM. The partners were honored with the "2016 Technology of the Year Award" for their Flex$^{PLAS®}$ release film.

Flex$^{PLAS®}$, a plasma-coated release film, which was developed further and distributed in cooperation, plays an important role in the production of large, complex fiber-reinforced plastic components for lightweight applications. Users can save up to 60% of the manufacturing process time. Lightweight components, which are needed for aircraft, wind energy plants, and automobiles, can be removed from their molds without the use of liquid release agents and solvents. This innovative approach was the deciding factor in the expert AIMCAL jury's decision.

The AIMCAL industry association is an international network with around 260 members. These are mostly companies from the film and paper industries. The three-day management meeting happens once a year, and members can enjoy technical presentations, workshops, and expert panels in addition to the awards presentation. Keith Fedewa, Vice President of Sales at Infiana USA, who represented the Infiana Group and Fraunhofer IFAM and accepted the prize, explained, "This award and the networking at the management meeting are the perfect opportunity for us to show our partners, suppliers, and customers how we continuously innovate and work to develop our products."

1 *Flex$^{PLAS®}$ release film after deep drawing in a double curved form.*

COOPERATIVE AND SCIENTIFIC

Collaboration with universities and technical colleges

Close collaboration and networking with universities and technical colleges are important for Fraunhofer IFAM. We have particularly close links with the University of Bremen and TU Dresden. During the 2015 summer semester and 2015/2016 winter semester, researchers at Fraunhofer IFAM gave over 30 teaching courses at, amongst others, the University of Bremen, TU Dresden, University of Applied Sciences Bremen, and University of Applied Sciences Bremerhaven.

You can find an overview of the lectures and seminars given by employees at the various institutions at:

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

Scientific networks

Over 200 publications from last year documented the R&D work of Fraunhofer IFAM, confirming its strong position within the academic community. This achievement is further emphasized by the awards and prizes bestowed on the employees of the institute. In 2016, Fraunhofer IFAM scientists participated in a large number of conferences, congresses, trade fairs, and seminars. In addition to active participation in these events, held in Germany and other European nations as well as in Asia and North and South America, the IFAM also regularly hosts its own events. The detailed list of scientific publications can be found on the Internet at:

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

Patents

Patents document the ability of an organization to innovate. Fraunhofer IFAM was granted 18 patents in 2016, maintaining the high level of recent years, and also registered and published 17 patents in that year. You can find an overview at:

→ **www.ifam.fraunhofer.de/patente**

FRAUNHOFER GROUP FOR MATERIALS, AND COMPONENTS – MATERIALS

For 20 years now, the Fraunhofer Group for Materials and Components – MATERIALS has pooled the expertise of the Fraunhofer Institutes that work in the field of materials science. With more than 2500 scientists and a total budget of approximately €500 million in contract research, it is the largest group within the Fraunhofer-Gesellschaft.

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 a quasi-industrial scale, characterization of properties, and evaluation of applications. The same applies to 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, covering the spectrum from molecules to components and up to complex systems and process simulation. The Fraunhofer Group MATERIALS covers metals, inorganics/non-metals, polymers, renewable raw materials, and semiconductors. In the last few years, hybrid and composite materials have gained in importance.

With the Materials Data Space© (MDS) initiative, founded in 2015, the group has presented a road map for materials compatible with industry 4.0. The group sees an essential prerequisite for the sustainable success of industry 4.0 in the digitalization of materials along the entire value-creation chain.

Key objectives of the group include

- Support for accelerated innovations in the markets of our customers and partners
- Increased success for industry 4.0 with suitable material concepts (digital twins, Materials Data Space©)
- Increased density of innovation and improvement of usage properties of micro-electronic components and micro-system technology
- Better use of raw materials and improved quality of the products derived from them; recycling concepts
- Increased safety and comfort as well as reduced consumption of resources in the areas of transportation technology, machine and plant engineering, construction and housing
- More efficient systems for energy production, conversion, storage, and distribution
- Improving biocompatibility and the functionality of materials used in medicine and biotechnology and the development of improved material systems for medical diagnosis, prevention, and treatment
- Improved protection of people, buildings, and infrastructure using high-performance materials in unique protection concepts.

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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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