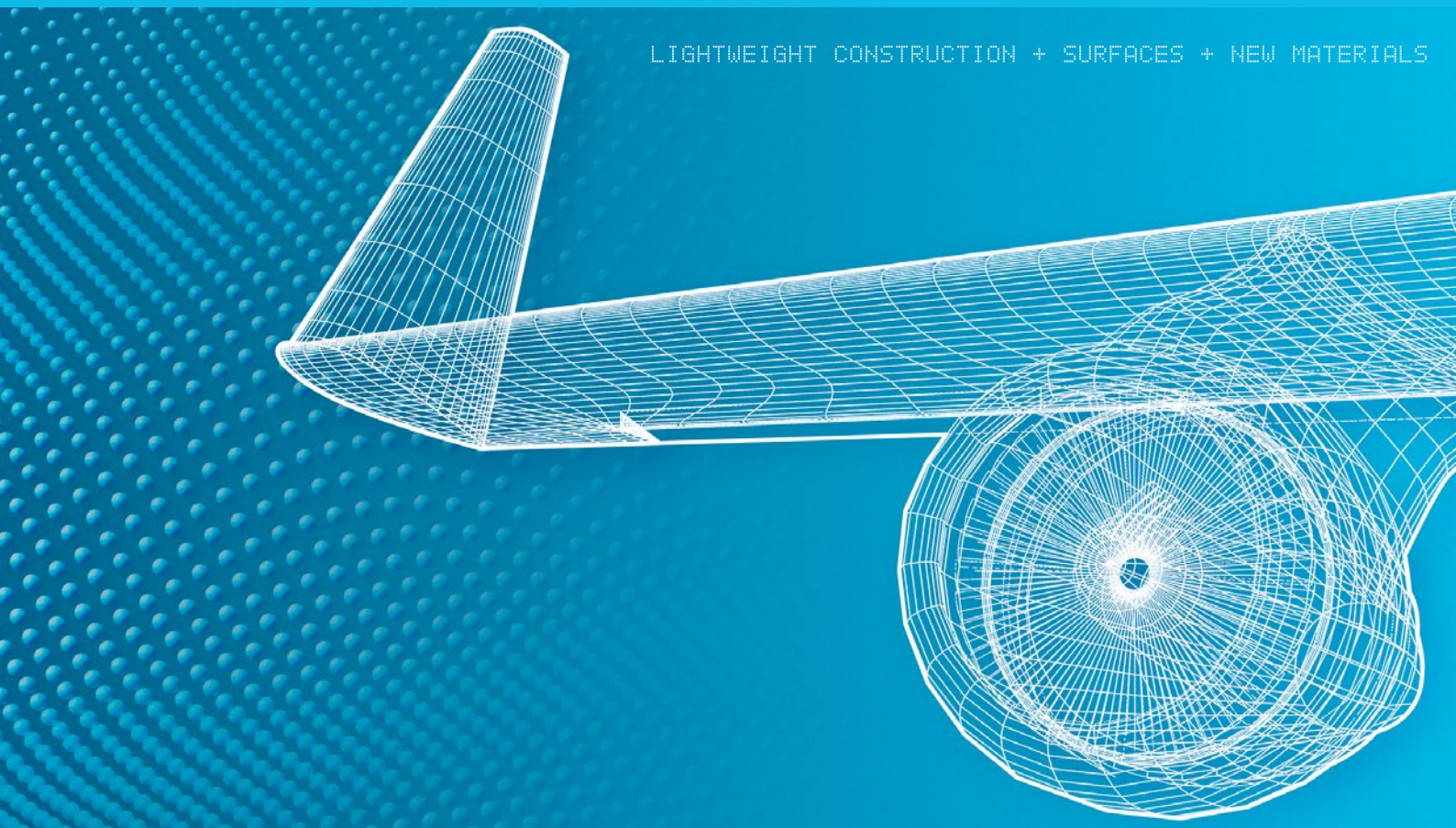
Fraunhofer
IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

BUSINESS SEGMENT AVIATION



COMPOSITE MATERIALS + POLYMERS + INDUSTRY 4.0

JOINING + ADHESIVE BONDING + AUTOMATION + DIGITALIZATION + FUNCTIONALIZATION

CONTENT

TECHNOLOGY FOR PEOPLE AND FOR THE ENVIRONMENT

THE FRAUNHOFER-GESELLSCHAFT

The Fraunhofer-Gesellschaft promotes and carries out applied scientific research and development work. Founded in 1949, the work of the Fraunhofer-Gesellschaft is geared to the requirements of industry and society. Our contract partners and customers are companies in the manufacturing and service sectors as well as public organizations. The Fraunhofer-Gesellschaft currently operates 72 institutes in Germany and employs more than 26,600 people, most of whom are scientists and engineers.

The various institutes within the Fraunhofer-Gesellschaft collaborate as groups or come together to form flexible alliances, depending on specific technical demands. In order to develop specific and customized solutions, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM is involved in the Fraunhofer Group "Materials and Components – MATERIALS", as well as in ten other alliances and the Fraunhofer Academy.

FRAUNHOFER IFAM

Fraunhofer IFAM is one of the leading independent research organizations in Europe in the fields of "Adhesive Bonding Technology and Surfaces" and "Shaping and Functional Materials". The focus of all our R&D activities is to provide customers with effective, application-oriented solutions. Most of the products, processes, and technologies we develop are designed for sectors where sustainability is particularly important, namely for the automotive sector, energy technologies, aviation industry, maritime technologies, as well as medical technology and life sciences.

Fraunhofer IFAM has a highly qualified workforce of around 680 people, organized into project teams and competencies covering specific topics. These topics include materials, shaping, joining technologies, surface functionalization and the development of complete components and complex systems. This means that Fraunhofer IFAM covers value chains from the development of materials and product design right up to the integration into industrial production – including pilot trials and customized workforce training in new technologies.

BUSINESS SEGMENT AVIATION

The aviation sector is not exempt from the challenges presented by ever shorter innovation cycles and the increasing performance and manufacturing demands related to efficiency and environmental sustainability. Indeed, companies working in this area not only have to develop new materials and material combinations but also introduce efficient manufacturing and process chains combined with the trend-setting topic of digitalization.

Fraunhofer IFAM undertakes research to find solutions to these challenges. Its scientists, including materials experts, mechanical and electrical engineers, chemists and process and plant component specialists, combine their expertise to develop the necessary system solutions. From customized materials, manufacturing technology and surface functionalization through to the characterization and qualification of components and processes, Fraunhofer IFAM, in cooperation with its clients, is able to find and provide the optimal solution.

SCIENCE AND SOLUTION ORIENTATED

We think analytically and we create solutions
The emphasis of our service is the development of practical solutions for practical demands. For specific tasks a team of experts will be put together according to your needs.

We work together in partnership
We listen, indicate concrete steps that can be taken, and take responsibility for achieving the goals that have been agreed upon. We are a neutral, independent institute and naturally keep your wishes and goals confidential.

We contribute and impart our knowledge
Expertise, many years of experience, and cutting-edge equipment form the basis for successfully dealing with your questions and problems. We continuously undertake ongoing research to better understand materials and processes and form strategic partnerships to handle complex tasks. For knowledge and technology transfer we offer case-to-case possibilities.

We stand for technological progress
We are on top of technological developments and know how to incorporate these into useful products. From prototype to small serial production, we fabricate and produce everything ourselves and accompany you over the long-term during any further development of your products.

We stand for future with quality
All relevant departments at the institute are certified according to DIN EN 9001 or DIN EN ISO/IEC 17024 or are accredited according to DIN EN ISO/IEC 17025.

1 *Printed functionalization on glass fibre fabrics.*

WE ARE HERE FOR YOU

The scope of our R&D services ranges from feasibility studies to marketable concepts or products. If requested, we also provide technology and know-how transfer as well as workforce qualification.

Market analyses and innovation identification
- Observation of technological trends
- Feasibility studies and cost effectiveness analysis

Optimization of existing processes
- Demonstrating and implementing potentials
- Establishment of new technologies

Developing products
- Manufacturing processes
- Prototyping and production of small series

Product improvement
- Performance improvement
- Cost efficiency improvement

Characterization and testing
- Modern testing facilities
- Result evaluation and certification

License provision
- Utilization of prior research results
- Licensing and their effective use

Qualification for the future
- Transfer of technology
- Professional training

COMPETENCIES IN AVIATION

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Fraunhofer IFAM works very closely with developers, suppliers and manufacturers of aircraft and aircraft components in the business area of aviation. With our core competencies of surface technology, metallic and polymer materials, adhesive bonding technology, shaping and functionalization, electromobility as well as automation and digitalization, our broad expertise and comprehensively equipped laboratories are available for customer-specific developments and system solutions.

Surface treatment and corrosion protection of aircraft components as well as different functional properties of the outer skin, such as drag, ice adhesion, contamination, erosion and abrasion are the main focal points for research in the field of surface technology. Wet and dry chemical surface pretreatment processes and coating solutions are already available for the surface modification of metal, plastic and ceramic materials as well as a variety of methods for surface and material characterization. In particular, this applies also to methods for in-line process control.

The core competency adhesive bonding involves the development and characterization of adhesives, component pretreatment, stress-related constructive design and simulation of adhesive and hybrid bonds as well as the characterization, testing and qualification of the bonds. The planning and automation of industrial manufacturing and process reviews, as well as certified training courses in the context of bonding technology and fiber composite technology, complement our competency profile.

The main focus in the field of powder technology is on important manufacturing processes such as metal injection molding and additive manufacturing, which are increasingly utilized in the aviation industry for the manufacture of geometrically complex components made of various metallic alloys. For targeted functionalization, sensory structures can be accurately applied to, or integrated into, the required component locations with a printing process.

MATERIALS

1

Aircraft construction is affected by a continuous pressure to innovate. Fuel savings to reduce CO_2 emissions, higher payloads and a longer range shall make the aircraft more profitable. New materials shall help to achieve these goals and continuously push the boundaries into the direction of more robust and cost-efficient materials.

In the search for cost-effective manufacturing concepts, research into new matrix resins for FRP (fiber reinforced plastic) components, or the utilization of smart adhesives, are just two examples of the kinds of development that can make an important contribution. Fraunhofer IFAM is also developing fiber composite materials with new characteristics – such as fast curing, improved stress relaxation, self-healing or recyclability – as well as using thermoplastic manufacturing processes for thermosetting polymers.

Taking into consideration the regulatory requirements for environmental and health protection in aircraft construction, Fraunhofer IFAM is also developing more effective, low maintenance and environmentally friendly non-chromate materials and processes for the corrosion protection of long-term, durable aircraft structures.

Peel$^{PLAS®}$ release film has been developed by Fraunhofer IFAM as an alternative to conventionally used liquid release-agents in the demoulding process of CFRP parts. The film remains on the part for protection against contaminants during transport or storage ensuring that, after its easy removal, no cleaning is needed before the utilization of subsequent coating or bonding processes.

The innovative solutions provided by Fraunhofer IFAM in the field of assembly are also geared towards the demand in industry for user-friendly processing and cost reduction. A good example here is the utilization of a pre-applied and fast-curing adhesive (PASA®) in automobile production; an adhesive which has subsequently been successfully transferred to aircraft manufacturing.

1 *Thermoplastically processible duromers.*

2 *The Peel$^{PLAS®}$ release film can easily be removed from the cured, contamination-free component.*

MATERIALS

Metals
- Titanium and titanium alloys
- Nickel-based superalloys
- Aluminum
- Magnesium
- Steel

Polymers
- New matrix resins
- Plasma polymers
- Adhesives

Composites
- Fiber reinforced composites
- Polymer composites
- Recycling of composites

2

1

COMPONENTS AND MANUFACTURING PROCESSES

MANUFACTURING PROCESSES

Hybrid construction

- Components for adaptive wings
- Metal composite hybrid bonds
- Morphing
- Corrosion protection concepts
- Casting bonds
- Adhesive bonds
- Rivet bonds
- Gap filling
- Design and simulation
- Testing and qualification

Additive manufacturing

- Selective laser melting (SLM)
- Electron beam melting (EBM)
- Metal binder jetting (MBJ)

2

Composite construction utilizing various materials has great potential for the development of the lightweight structures required in aircraft construction. We provide customized concepts to ensure safe, continuous operation with low maintenance requirements.

The use of fiber reinforced composites for lightweight construction makes it imperative to provide effective protection concepts which inhibit contact corrosion between FRP composites and metallic materials. Both technical adhesive and casting solutions and corrosion protection concepts support the manufacture of such composite materials. At the same time, concepts for repairing primary CFRP structures must be developed.

New component concepts are required for the development of adaptive wing components. In order to ensure the gap-free morphing of these, Fraunhofer IFAM has developed alternative, low-temperature elastomers. Components which have been produced by utilizing this new procedure have been tested according to technical aircraft requirements for aging, service life and constant mechanical flexibility. They have also been successfully tested in one of the largest wind tunnels in the world.

Fraunhofer IFAM is also active in the development of new manufacturing processes. In order to ensure laminar flow around wings, tailplanes and rudder units, it is necessary to observe very demanding surface requirements for joining processes during manufacturing. As part of this procedure, so-called "gap filling" involves the selection of appropriate materials, customized application methods, necessary nozzle developments as well as process qualification.

Additive manufacturing processes like selective laser melting and electron beam melting or metal binder jetting are analyzed regarding their use in aircraft production and specifically developed for this purpose.

AUTOMATION FOR THE PRODUCTION OF TOMORROW

One of the major challenges facing the serial production of aircrafts is the need to increase efficiency in the sense of an "intelligent factory" – which means adaptability, resource efficiency and the digital flow of information throughout the entire process chain. In addition, any response to this challenge must also include fast, quality-assured processes, mobile, easily reconfigurable production means, and safe human-machine interaction. In addition, tolerance management is of particular importance for large structural components of aircrafts due to their low shape accuracy. Manufacturing systems and processes must recognize deviations and react compensational.

All used technologies support digital data management in terms of industry 4.0 and fit into the concept of a digital factory in which electronic data exchange takes place both horizontally along the internal process chain and vertically with external upstream and downstream processes.

The purpose of continuous digitalization is to provide or capture the right information at the right place at the right time. In conjunction with mobile robots and component fixtures which adapt to individual components, it increases flexibility in production by giving production systems fast mutability. By these methods the static division of production into stations or lines to which certain processes are assigned is overcome. Furthermore the use of a digital twin provides fast optimization cycles.

PRODUCTION SOLUTIONS

- Industry 4.0
- Smart Factory
- Agile production
- Automated tolerance management
- Non-tactile geometry measurement
- Large structure processing
- Adaptive machining and assembly
- Autonomous navigating robots
- Robot calibration
- Human-machine interaction
- Quality-assured processes
- Mobile robots
- Digital Twin
- Machine Learning
- Artificial Intelligence (AI)

1 *Holding element manufactured using hybrid casting technology for aircraft construction.*

2 *Turbine blade produced using additive (SLM – selective laser melting) manufacturing.*

3 *Aircraft structure assembly system for correcting the shape and position of large components.*

4 *Mobile robotic system MBFast18 with multi-axis processing unit, robot, AGV and mobile laser tracker machining a vertical tail plane shell.*

1

FUNCTIONAL SURFACES

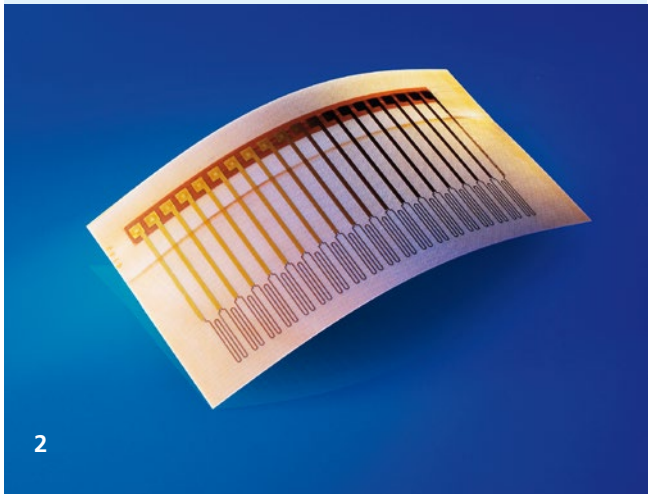
TECHNOLOGIES

Surface finishing technology
- Atmospheric pressure plasma
- Laser treatment
- VUV excimer technology
- CO_2 snow blasting
- Vacuum suction cleaning
- Wet-chemical pretreatment

Coating technology
- Coating application
- Powder coating
- Sol-Gel systems

Bonding in manufacturing
- Adhesive formulation / synthesis
- Catalysts and inhibitors
- Hybrid bonding processes

Simulation
- Finite element method
- Computational fluid dynamics
- Molecular modelling



2

The optimization of surface and interface properties of components is central to the development of surface treatment processes for coating, printing and adhesive bonding applications. It is an important part of the research being carried out at Fraunhofer IFAM.

The icing of surfaces on the outside of aircrafts is a pervasive problem that can significantly affect function and safety. At Fraunhofer IFAM, passive and active coating concepts are being developed which are more effective in preventing icing. These include heatable coatings and ice-repelling surfaces that are being tested for their suitability in the wind tunnel of our institute that realistically simulates icing conditions.

Another example of surface functionalization is the printing of sensors and electronic components onto the surfaces of metallic or FRP components. The integration of additional functionality into these – for example, sensors for detecting thermal and mechanical stresses or cracks (SHM – structural health monitoring) – is considered one way of being able to stretch future maintenance intervals. Sensors, heaters, wiring, contacts and antennas can all be printed directly onto components. The main advantages lie in the minimal effect on mechanical properties, individual design and manufacture of sensor structures, ideal positioning of the sensors on (or in) the component, and integration into the manufacturing process.

"Direct printing" is a new technology that makes it possible to print large and complex designs directly onto large components. Its functionality is comparable to an inkjet printer. This process enables the application of photorealistic images, color gradients and logos with sharp edges in just one step, significantly reducing throughput time and weight.

In addition to surface functionalization, reliable surface treatment is an important process in aircraft construction prior to the joining or coating of metal and fiber reinforced

plastics components. To achieve homogeneous wettability of material surfaces and durable adhesion, customized wet-chemical and dry-chemical surface treatment processes are being developed. In the case of dry-chemical plasma processing, the surface to be treated is effectively cleaned of organic contaminants as part of a continuous process that is simultaneously activating. In case of more severe contamination, the plasma procedure is combined with abrasive technologies such as vacuum suction or CO_2 snow blasting.

In addition to the options for dry-chemical pretreatment, chromium (VI)-free, wet-chemical procedures are being developed for the pretreatment of metals prior to bonding and coating. Apart from steel, light metals such as aluminum and titanium come to the fore. In short, the entire process is being taken into consideration; particular emphasis being placed on pickling, passivation and anodizing.

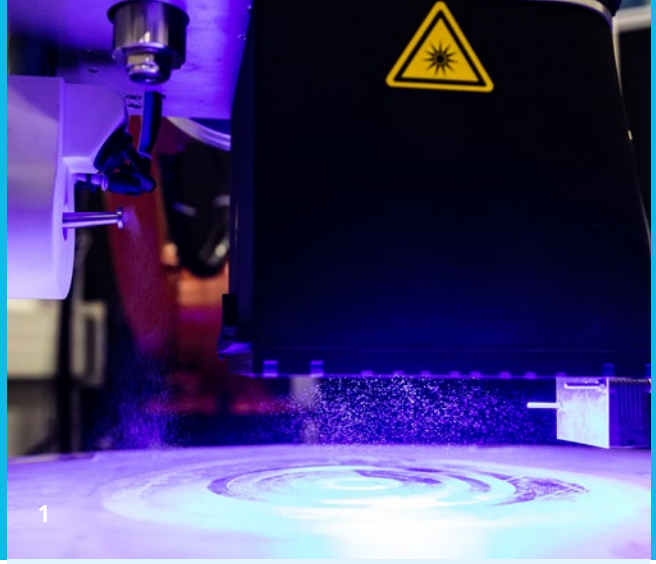
TECHNOLOGIES

Surface modification
- Pretreatment
- Cleaning
- Activation

Coatings
- Anti-icing
- Anti-erosion
- Friction reduction
- Drag reduction

Sensor technology
- Printed electrics
- Printed strain and temperature sensors
- Energy harvesting
- RFID

1 *Investigating icing of wing profiles in the icing wind tunnel.*
2 *Sensor integration in composite material by printing on fleece materials (cooperation with INVENT GmbH).*
3 *Direct printing in aircraft construction: Innovative painting concepts for the fuselage shell of an A320.*
4 *Quality-assured cleaning of FRP component surfaces with CO_2 snow.*



ANALYTICS AND QUALITY CONTROL

RANGE OF SERVICES

Imaging procedures
- Electron microscopy
- Computer and X-ray tomography

Chemical composition and structure
- Spectroscopy and spectrometry
- X-ray diffraction
- Chromatography
- Element and trace element analysis

Electrochemical characterization
- Impedance spectroscopy, noise analysis potentiometry

Surface analysis
- Spectroscopy and spectrometry
- Reflectometry
- Colorimetry
- Contact angle measurement

Physical analysis
- Rheology, tribology, magnetic measuring

Powder measurement technology
- Particle and powder analytics

Thermal analysis
- Gravimetry, calorimetry, dilatometry, dynamic analysis

Materials and components testing
- Mechanical and non-destructive testing
- Salt spray testing

The analysis and understanding of surface properties, interfaces and layers, and the targeted application of this knowledge in the development of materials, processes and quality assurance concepts, is one of the main focuses at Fraunhofer IFAM. A wide variety of sophisticated analytical procedures, including computer-aided simulation techniques as well as testing and examination procedures are available for this purpose.

In the field of aircraft construction, the process-integrated quality assurance of surface characteristics is of particular interest as it enables optimization of manufacturing safety and product quality and reduction in costly and unnecessary rectification work. This is particularly the case in the activation and pretreatment of material surfaces essential to high-quality, flawless coatings and finishes, for corrosion protection and also for adhesive bonds which must remain stable over the long-term. Here continuous monitoring is one goal of the inline procedure being developed at Fraunhofer IFAM. Digitalization is also used to optimize existing and new processes. For example, machine learning (AI) is used in combination with industrial image evaluation. The user is also specifically supported, e.g. by using data glasses, mobile robotics or drones.

Another example is chromate-free anodizing utilized in aircraft construction which, in contrast to conventional procedures, is visually less discernable. Similarly, a non-contact and non-destructive process based on reflectometry, which enables 100% monitoring of treated components, has also been developed and successfully tested in a manufacturing environment. In contrast to existing contact based processes, it is possible to determine the thickness of the oxide layer so that variations in the anodizing quality can be detected with extreme accuracy. Businesses targeting the professional use of adhesives and fiber reinforced plastics (FRP) on an industrial level have to ensure appropriate training of their staff. Training courses at Fraunhofer IFAM implement a technology transfer in which important state-of-the-art scientific findings and methods find their way into the – secure – industrial application. Fraunhofer IFAM also supports the implementation of standards – in particular DIN 2304.

1 *Robot-guided wetting test of a CFRP shaft.*

LOCATIONS AND DEPARTMENTS

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LOCATIONS AND DEPARTMENTS

BREMEN
- Adhesion and Interface Research
- Adhesives and Polymer Chemistry
- Adhesive Bonding Technology
- Business Development
- Casting Technology and Lightweight Construction
- Electromobility
- Paint/Lacquer Technology
- Plasma Technology and Surfaces
- Polymeric Materials and Mechanical Engineering
- Powder Technology
- Quality Assurance and Cyber-Physical Systems
- Smart Systems
- Workforce Training and Technology Transfer

BRAUNSCHWEIG
- Fraunhofer Project Center for Energy Storage and Systems

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

OLDENBURG
- Electrical Energy Storage Systems

STADE
- Automation and Production Technology

WOLFSBURG
- Fraunhofer Project Center for Lightweight Construction and Electromobility

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