Fraunhofer
IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

FUNCTIONAL PRINTING

STRUCTURING ADVANTAGES – INTEGRATING FUNCTIONS

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WE UNDERSTAND MATERIALS

THE FRAUNHOFER GESELLSCHAFT

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 66 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of nearly 24,000, who work with an annual research budget totaling more than 2 billion euros. Of this sum, around 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. 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.

SHAPING AND FUNCTIONAL MATERIALS

The Shaping and Functional Materials division of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, with its facilities in Bremen, Dresden, Oldenburg, and Wolfsburg, develops innovative customized materials and adapts and improves existing manufacturing processes. The R&D activities range from materials and shaping processes to the development, functionalization and evaluation of components and systems. We develop individual solutions for customers in various industrial sectors including automotive industry, medical technology, aviation and aerospace, mechanical, electrical and environmental engineering, as well as the electronics industry.

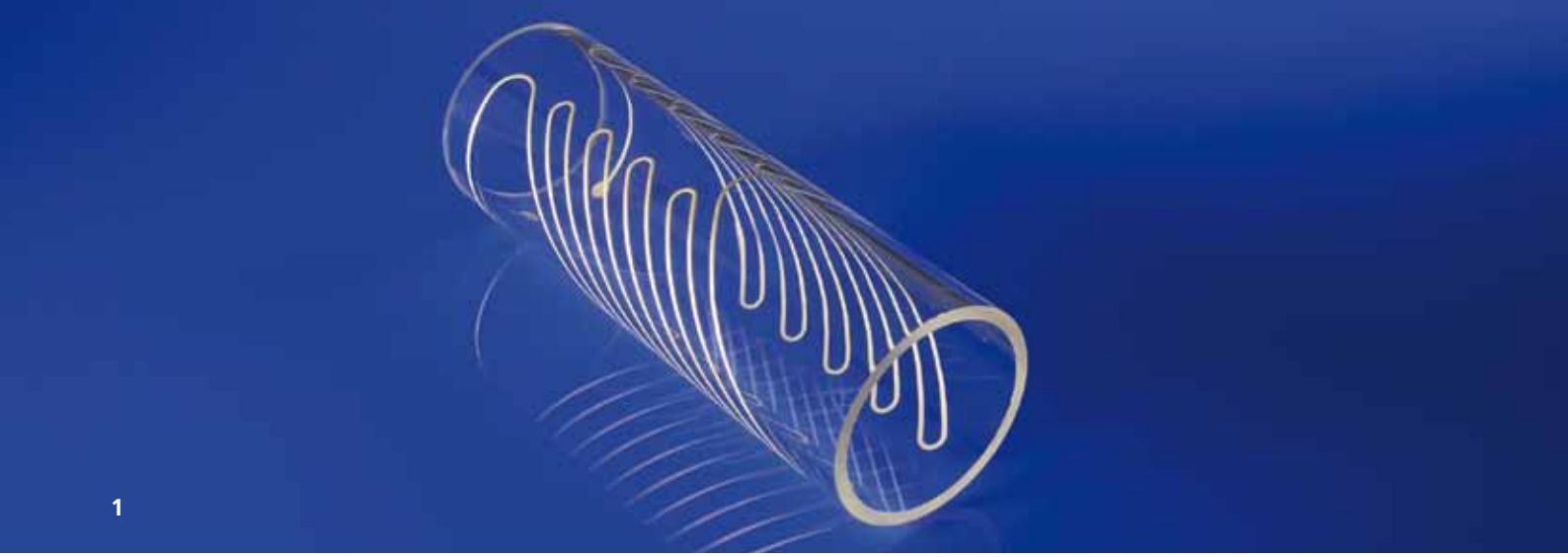
On the topic of electromobility, the division follows a holistic approach with three pillars. The focus of the work is on the areas of energy storage, electrical drive technology, and on the testing, evaluation, and optimization of the whole system. The Bremen/Oldenburg model region for electromobility is also developing the basis for new vehicle and traffic concepts.

Energy Systems Analysis additionally addresses questions of renewable energies, combined heat and power (CHP), energy-efficient buildings, as well as heat and power networks. A recently established technical training program transfers the latest R&D results and practical know-how on electromobility to industrial users.

In **Shaping** the focus is on developments for the economic and resource-friendly production of ever more complex precision parts and components. The latest powder technology and casting processes are employed to increase the functional density of components. The services offered include component design, simulation of shaping processes, implementation in production, and appropriate training of the company's personnel.

Functional Materials is all about developments to improve or extend the material properties and the processing of the materials. The functional materials can either be integrated directly into the component during the production process or can be applied to surfaces, giving the component additional or completely new properties such as electronic or sensory functions.

The specific properties of cellular materials, hybrid materials and fiber composites as well as biomaterials are also used to enable a wide variety of applications.



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FUNCTIONAL PRINTING

In industrial production there is a great demand for functional structures to optimize the properties of a wide variety of components. For selective functionalization, structures can be applied precisely on the required parts or components using printing technologies. Sensors or electronic components can thus be integrated into existing products.

1 *Cylinder functionalized using the dispensing process.*

Intelligent functionalization

The blades of wind turbines and components in automobiles and aircraft need to be lighter, but at the same time safer. One possibility of satisfying both demands at the same time is the sensor integration in components to monitor the loads. Smart phones, tablets or navigation systems are required to provide more and more functions on the go, but at the same time to consume as little energy as possible. Incorporating more functions and hence more power into products also means adapting solutions to the individual needs of the product. Ideally the extended functions for component monitoring or the integration of the electronics are adapted to the production process of the part in order to be able to implement the additional added value as efficiently as possible.

Tailored functional materials enable optimum integration of functional structures. For example, sensors can be directly integrated into composite materials – this allows a detection and identification of material defects. Energy self-sufficient remote monitoring is also possible: Using integrated sensor networks with thermogenerators, electronic modules are able to generate energy from their environment. The electrical energy can be used for measuring and wireless transmission of measured values.

The department of Functional Printing at Fraunhofer IFAM uses nano- and microstructured functional materials. Functional structures are integrated into parts or applied onto surfaces for the sensor application, the integration of electronic modules or for the energy generation. In addition to developing the concept, attention is also paid to the efficient, (semi-)automated integration into products. Our technologies such as 3D printing, inkjet and aerosol printing, screen and pad printing as well as sputter and compounding respectively extrusion techniques open up a broad array of potential applications.

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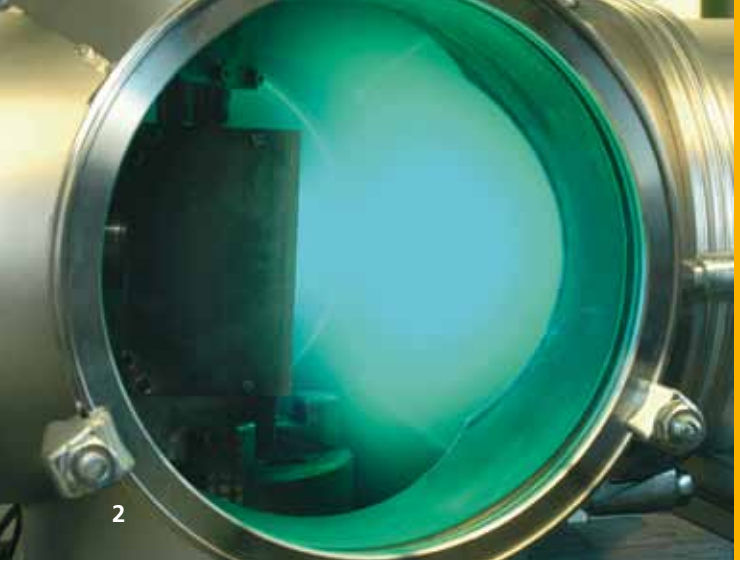

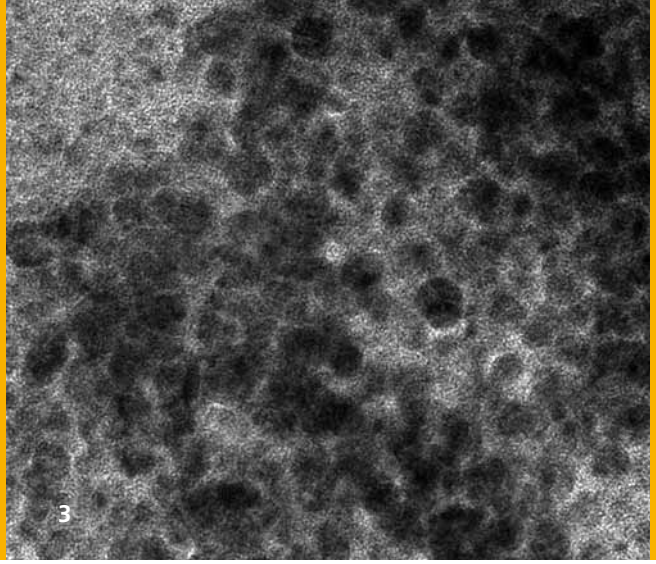

FUNCTIONAL MATERIALS AND COMPOSITES

Whether nanostructured materials or metal-polymer composites: The Functional Printing department at Fraunhofer IFAM develops tailored materials for practically any application.

Nano-/microscale materials

The material properties determine the applications. The variety of metals, ceramics and polymers can be applied by using particle-based materials in the latest additive printing processes. We formulate and use not only low-viscosity nano inks for aerosol or inkjet printing, but also high-viscosity pastes for dispensing and for pad and screen printing for the following applications:

- Printed electronics and printed heating structures
- Strain or temperature sensors of resistance alloys as well as gas, climate and biosensors
- Energy harvesters (e. g. thermoelectric generators) and energy accumulators

The same variety of materials can also be directly applied using physical deposition processes in a vacuum, such as magnetron sputtering or gas flow sputtering with process variants of co-sputtering or reactive sputtering. Tailored and highly porous thin films are used in:

- Selective coatings of filters or microreactors
- (Photo-)catalytic active coatings to remove pollutants and soiling – also on structured surfaces
- Functional films for solar cells and electrodes for fuel cells

1 *Twin-screw compounder for production of functional polymer-metal fiber composites.*

2 *Plasma in a special system for highly porous thin films.*

3 *TEM image of a nanoparticulate CuNiMn dispersion.*

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EFFICIENT PRODUCTION

Printing processes enable flexible production concepts. Challenging is the integration of the process into existing production lines. Fraunhofer IFAM qualifies these production processes through to pilot series maturity.

Cost-effective combination of printing processes

Modern printing processes with functional materials can be a "smart" alternative to conventional production processes or for the development of new products. In many areas its use permits a demand-oriented use of material, very great freedom of design and resource-efficient production. With our equipment ranging from laboratory desktop printer through to sophisticated industrial system, we evaluate the technical questions and economic challenges for the required applications. The used printing process depends on the demands on the printed films, the material properties and technical and economic decisions with respect to the products manufactured. Optimum solutions can be developed here by combining different printing processes and production methods.

Flexibility thanks to modular production concepts

From the production engineering point of view the integration of complex multi-layered functional structures into a component with an existing process chain is of the greatest importance. In the modular production line at Fraunhofer IFAM, screen printing, inkjet printing, aerosol jet and dispensing processes are combined into an example of a well-designed production unit to allow a very wide range of materials and processes to be combined to meet customers' requirements. The widely differing demands on the functionalization of two and three-dimensional surfaces can thus be satisfied in an automated near-series production process. The production line allows not only technology-relevant, but also and more importantly production-relevant R&D topics, such as reproducibility and profitability, to be evaluated under realistic industrial conditions.

The transfer of the processes developed at Fraunhofer IFAM is backed up by the development of application-oriented special systems. We develop and build turnkey systems on a laboratory and pilot scale tailored to special materials, intermediate and coatings.

1 *View of the production line for functionalization of surfaces and components using a combination of various printing processes.*

2 *Dispensing of functional structures.*

3 *Inkjet printing of thin-film structures.*

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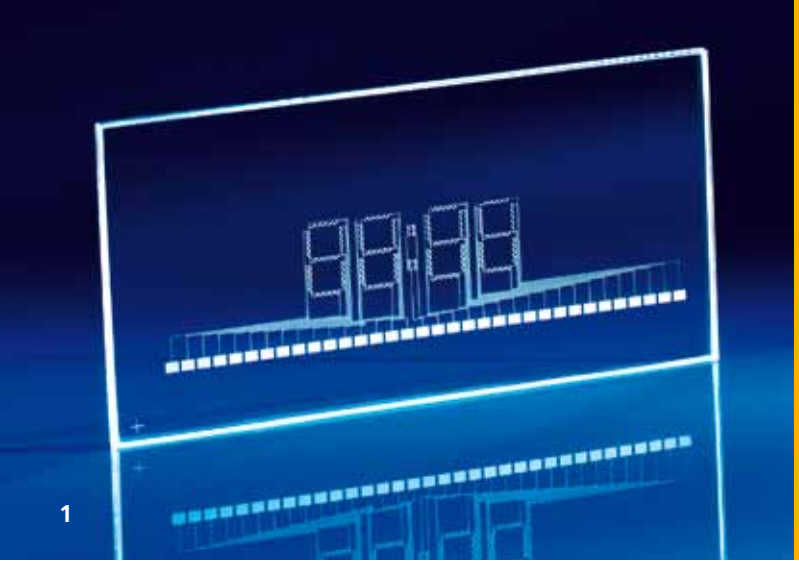

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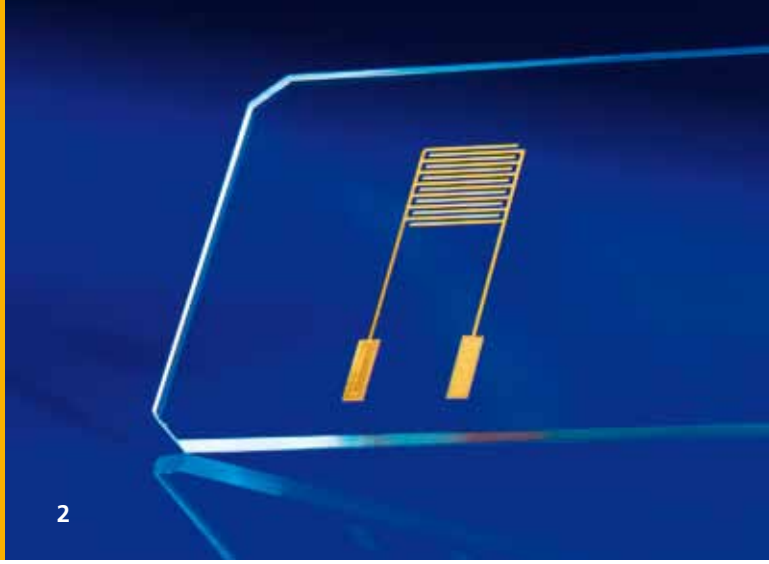

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PRINTED ELECTRONICS – FROM THE INK TO SERIES PRODUCTION

1 *Aerosol-printed 7-segment display on glass substrate.*

2 *Inkjet-printed gold inter-digital structure on glass substrate.*

New industrial developments have been made possible by "printed electronics". Further fields of application are developed for the industry by the use of different substrates and materials.

Know-how for printed circuits

We merge material functionality with substrate compatibility and printability. Depending on the requirements, we adapt the material to be printed to a specific printing process or for a specific substrate. Both rigid flat materials and flexible films or components can be used whose surfaces can be conditioned for the printing processes. The appropriate printable inks or pastes are formulated for the selected printing technology. The thermal activation often necessary for functionalization of the printed structure is performed in a furnace, using a laser, in the microwave oven or by UV curing. Temperature-sensitive materials can also be used in selective processes.

Sensor integration and mounting and connection technology

In addition to the actual printing of functional structures such as printed circuits, antennae, heating conductors or sensor films, the integration of printed structures to form functional "intelligent" components or modules plays an essential role. A sensor component, for example, requires not only the sensitive functional structure as such, but also a power supply, possibly a buffer memory and a data interface, in some cases also wireless. Here we use the possibilities of mounting and connection technology by combining conventional modules using modern printing processes or with generative production processes for parts.

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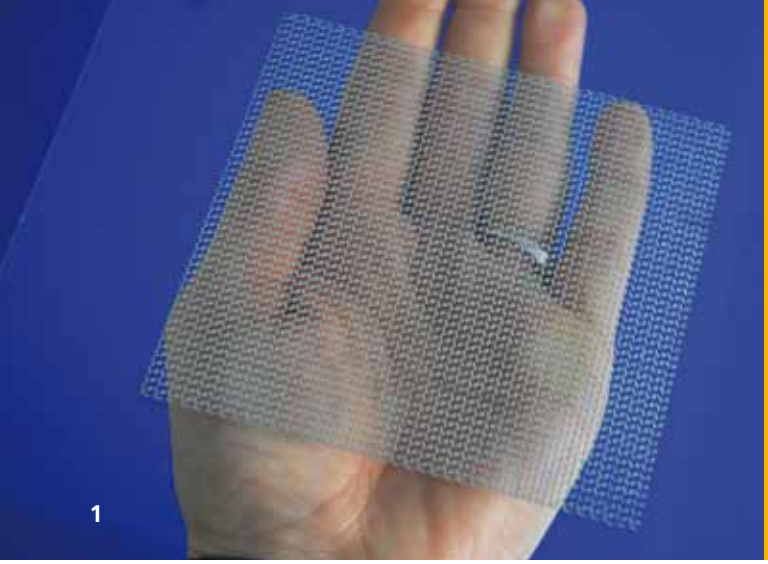

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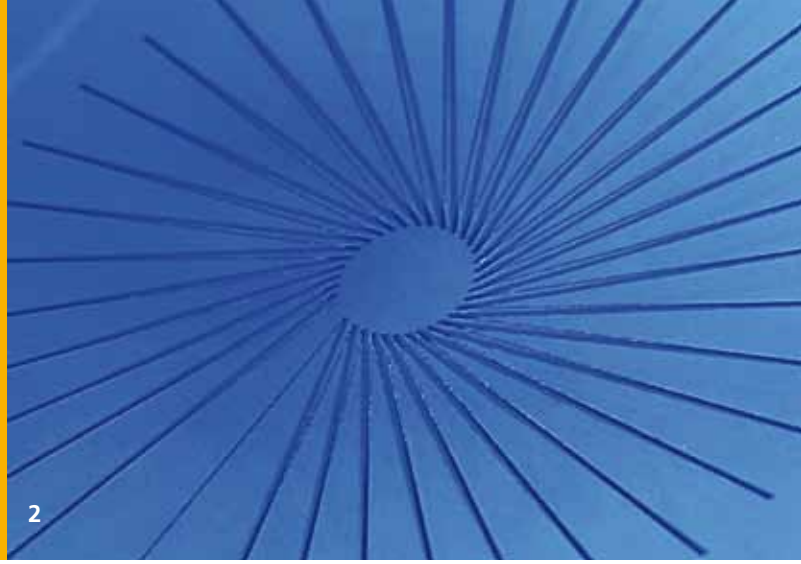

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ENERGY HARVESTING

The wish for enabling more functions using self-sufficient systems is becoming reality thanks to local "energy harvesting". Sufficient energy for the operation of certain modular groups can be generated from the wind, sun, mechanical vibrations and heat gradients.

Energy from the printer

Using printing processes thermogenerators or structures for solar cells can be applied directly to surfaces. This will be enabled on the one hand by a design adjusted to the product, and on the other hand by functional materials adapted to the printing process which can convert sunlight or temperature differences directly into electrical energy. Furthermore, functional structures made from piezoelectric composites can also generate energy from mechanical vibrations.

The solutions for the energy harvesting are thereby selected to provide sufficient energy for the process and simultaneously a highly integration should be practicable.

The generated energy can then be used either directly for the operation of electronic components, or can be stored in printed batteries or capacitors in order e. g. to be able to a wireless transmission of measured data such as temperature, humidity or wear at a given moment in time. This allows conclusions to be drawn as to the condition of the components even from a distance – e. g. whether maintenance work or repairs are necessary.

1 *Printed thermoelectric generator on glass substrate for electrical energy conversion from small temperature gradients.*

2 *Printed thermoelectric generator for electrical energy conversion on polymer surfaces.*

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OUR SERVICES

1 *Processing of functional materials to produce printable inks and pastes.*

2 *Production of thick-film structures by screen printing.*

Experimental R&D services

- Feasibility studies on printed electronics and sensors
- Feasibility studies for functional integration and integration of the processes into existing production lines
- Selection and adaptation of suitable printing processes for existing production lines
- Demonstrator/prototype and small series production
- Production of complex geometric parts from powder materials by 3D printing

Material development and quality assurance

- Development of (nano-)composites, e. g. for medical technology, electrical and power engineering
- Sampling and characterization of functional composites (electrically and thermally conductive polymers)
- Development and sampling of functional inks and pastes for printing processes
- Ink and paste characterization (viscosity, surface tension, etc.)
- Characterization of nanoscale powders and suspensions (particle size distribution, technological and chemical properties, rheology)
- Electrical and visual characterization of functional structures
- Sensor characterization, e. g. investigation of the reliability of printed structures
- Comprehensive materialography and film characterization by REM, TEM and XRD in the accredited laboratory

Consultation and know-how transfer

- Market studies on topics of "printed electronics"
- Advice on the selection and usage of printing methods and functional materials
- Scientific project support and advice
- Personnel training
- Technical/scientific comparison of additive production with conventional methods
- Design and construction of systems for the production of nanoscale functional materials
- Know-how and technology transfer

We are an interdisciplinary team of scientists and technicians where you will find contacts for the solution of a wide range of questions. We will be happy to develop concepts and ideas for the production and efficient functionalization of your products – on a confidential basis, of course.

LOCATIONS

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Prof. Dr.-Ing. habil. Matthias Busse
Prof. Dr. Bernd Mayer

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LOCATIONS AND DEPARTMENTS

BREMEN
- Adhesion and Interface Research
- Company audits in accordance with DIN 6701 | Adhesive Bonding Technology
- Business Development
- Electrical Drive Systems
- Energy System Analysis
- Functional Printing
- Casting Technology
- Adhesives and Polymer Chemistry
- Adhesive Bonding Technology
- Paint/Lacquer Technology
- Materialography and Analysis
- Plasma Technology and Surfaces
- Powder Technology
- Technical Qualification and Consultancy
- Workforce Training and Technology Transfer
- Materials Science and Mechanical Engineering

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

OLDENBURG
- Electrical Energy Storage Systems

STADE
- Automation and Production Technology

WOLFSBURG
- Lightweight Design and Electromobility

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