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Dear Reader

Dr. Volker Zöllmer

The industrial demand for innovative, individualized components for energy-efficient production, the mobility revolution, aerospace and photonics is growing steadily. New manufacturing strategies are required that lead to increasing product diversity with high functional densities at the same time.

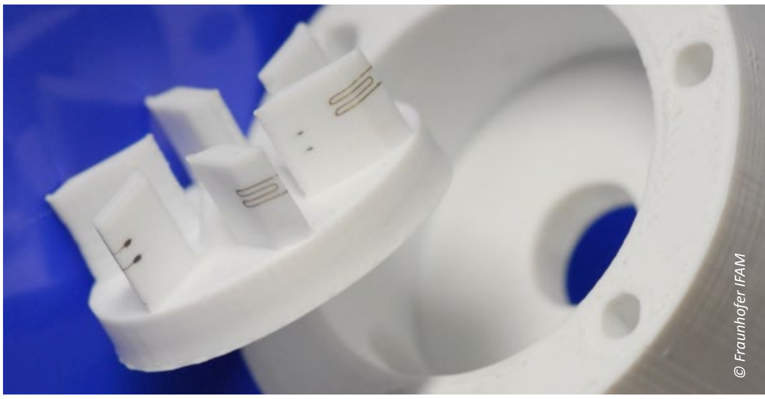
A promising approach is the generative manufacturing of components (3D printing), which is becoming increasingly popular as a manufacturing process for individualized component geometries down to batch size 1. In addition, the printed electronics technology platform enables additive functionalization of components and surfaces. A product-specific combination of 3D-printed components with printed functionalities not only opens up the possibility of functionalizing components and surfaces. Printed "3D electronics" also allows the development of completely new, innovative products, for example for the Internet of Things (IoT).

By integrating sensors on and in component parts, for example, it is possible to obtain component data that could not yet be collected with conventional sensors. Printed 3D electronics thus provide valuable data for new product developments via Big Data and AI algorithms.

The "component intelligence" arises from local, material-efficient integration of functional materials. Nanoscale functional materials can fulfill this requirement in an ideal way: both organic and inorganic nanomaterials can be applied to surfaces as so-called "functional nano-inks". Using digital printing processes functional structures of very different geometries can be formed.

Fraunhofer IFAM is working intensively on the production of such nanomaterials and the industrial reproducibility of their syntheses as well as on the reliability of the digital printing processes.

Dr. Volker Zöllmer
Head of the "Smart Systems" department at Fraunhofer IFAM



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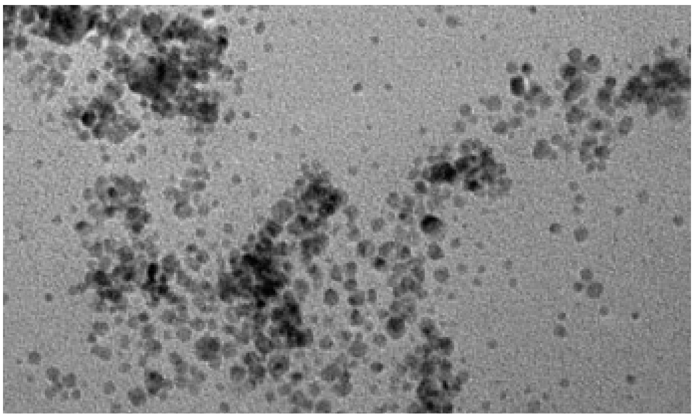
Aerosol jet printed functional sensor elements on 3D printed component.



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TEM image of nanometer-sized copper-nickel-manganese particles for functional nano-inks.

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Functional integration using 3D printing and nano-technology at Fraunhofer IFAM

The Fraunhofer Institute for Manufacturing Technology and Applied Materials Research IFAM is engaged in many research and development activities at the interface of materials and process development.

IFAM's competence portfolio includes the electrochemical analysis of battery materials.

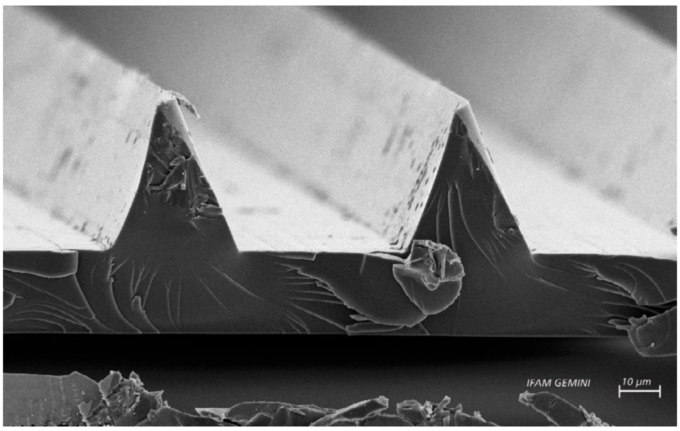
Nanotechnology represents a cross-sectional technology of the various activities of Fraunhofer IFAM and provides decisive impulses for new approaches to functional integration. Research and development at IFAM covers a wide range of technologies for systematic product development: from molecular modeling of nanostructures to chemical and physical methods for the production of thin films, particles, nanocomposites, and adhesives to printed structures with nanoscale dispersions, so-called nano-inks. The basis for this research is provided not least by the extensive analytics of Fraunhofer IFAM, which include application-specific tests and numerous methods of instrumental analysis.

For industrial applications, it is often desirable to precisely control mechanical properties, for example of polymers, or rheological properties of semi-finished products. For this purpose, nanoparticles can be functionalized by surface modification using plasma technologies, so that they significantly influence the subsequent processing technique. Modified particles are used, among other things, for the formulation of coatings, but also for matrix resins, for potting compounds or fiber-reinforced composites. Researchers at Fraunhofer IFAM have also succeeded in integrating particles that exhibit a temperature-dependent interaction with electromagnetic waves into adhesives. They exploited this to control the temperature in bonded joints and thus achieve rapid curing in just a few seconds. In another case, the properties of dental composites could be adjusted by modified nanoparticles so that they could be machined like a natural tooth.

There are many requirements for future battery generations and the respective technologies to meet the growing demand for energy storage. Nanoscale active materials and additives are being intensively investigated for these applications. At Fraunhofer IFAM, nanoscale functional materials can be applied using digital or mask-based printing processes in order to provide surfaces and components with specific functions and to individualize them. Thin nano-composite functional layers complete the development and application spectrum of nanotechnology at Fraunhofer IFAM.

Top: Currently, more than 700 employees at IFAM combine their broad technological and scientific know-how in seven core competencies: metallic materials, polymer materials, surface technology, bonding, shaping and functionalization, electromobility, automation, and digitalization.

Right: microstructured resist achieves the necessary mechanical stability through nanoparticles to obtain surface properties favorable to fluid flow.



Innovative metallic 3D printing at Kiel UAS

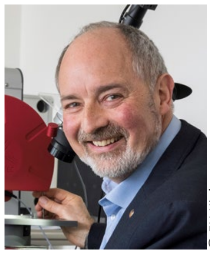
An interdisciplinary team from Kiel University of Applied Sciences obtains a €2.3 million federal grant to install a state-of-the-art integrated manufacturing cell for cutting-edge, innovative metallic 3D printing.

As of the second quarter of this year, Kiel UAS is equipped with a manufacturing cell that not only allows metallic 3D printing, but also additive and subtractive machining of the components in any sequence using an integrated 5-axis milling machining center. The necessary, and often time -consuming, post-processing of the components can thus be automated. “With its capabilities, the facility is unique in northern Germany”, enthuses Professor Schloesser, head of the Institute for Materials and Surfaces at Kiel UAS.

The state-of-the-art laser system offers a variety of advantages for research and development: 3D printing can take place under a complete inert gas atmosphere, making it possible to process highly reactive powders. Furthermore, the system has four integrated powder conveyors, which allow materials to be produced with spatially different compositions. This means that the material properties can be set exactly as required at any point on a workpiece.

This capability is also used for the research and development focus on graded materials. These are materials in which the chemical composition changes continuously across the cross section. This is of particular interest for material composites subject to high thermomechanical stresses: suitable material gradients reduce thermal stresses and thus the probability of failure at transition points. Properties such as modulus of elasticity and thermal conductivity can be locally optimized and thermal misfit reduced via a continuously variable composition of the material. This is of interest for applications in renewable energies and electromobility, among others, where materials have to achieve high surface-related functionality. With the new additive manufacturing system at Kiel UAS, it is possible to tailor graded materials from up to four different metallic powders. In addition, the production of metal-ceramic composites is part of the new research focus.





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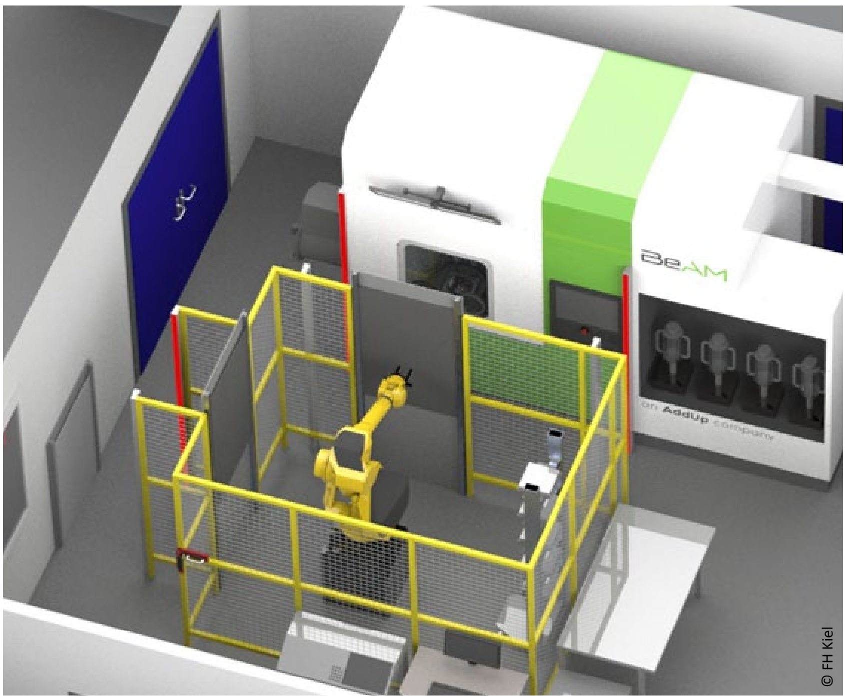
The interdisciplinary team of Kiel UAS from the departments of mechanical and electrical engineering acquired a federal grant of 2.3 million euros for an “Integrated manufacturing cell for innovative 3D laser powder metal deposition melting (project InFer3D)”: Prof. Schloesser, Prof. Mattes, Prof. Eisele and Prof. Weychardt. The team was supported by partners from industry and research, as well as NINa SH.

The cutting-edge capabilities of the manufacturing cell in the field of 3D printing open up entirely new research, development and transfer opportunities for applied materials development at Kiel UAS. Says Professor Schloesser: “In addition to the system as such, users have access to broad development and application expertise from our interdisciplinary team at Kiel UAS. In particular, we offer SMEs entirely new opportunities for materials and process development.” Accordingly, there are already numerous regional and national inquiries from interested companies.



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The BeAM Modulo 400 system enables cutting-edge 3D printing from up to four different metal powders and offers unique capabilities in the northern German region.

Additive manufacturing from Lütjenburg: 3D printing for dentistry

Merz Dental is a global partner of dentists and dental technicians for prosthetic dental restorations and consumables in dental practices and laboratories. Innovative products are created, among others, through the combination of 3D printing and nanotechnology.

Additively manufactured drilling template in a DLP printer

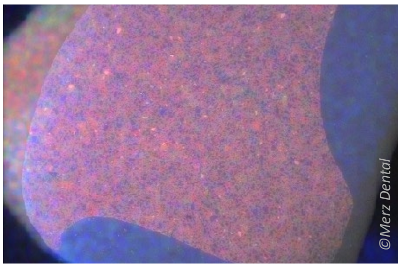
Nanotechnology is already widely applied in classic dental products, for example to increase the abrasion resistance of artificial teeth and dental filling materials, to improve the impact strength of plastics or to adjust rheological properties. In contrast, the use of nanomaterials in the field of additive manufacturing, which is quite new to dental technology, is still in the early stages of development.

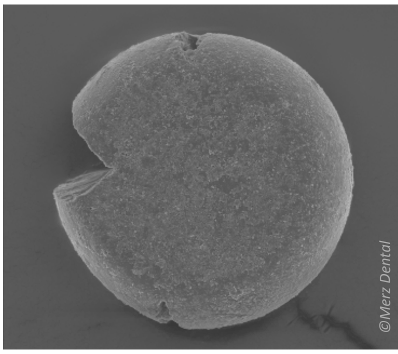
However, 3D printing technology already plays a key role in digital processes in dentistry. Merz Dental develops and produces various acrylate-based materials for the additive manufacturing of dental products such as models, grinding and bite splints. The so-called 3D liquids are adaptable for any open 3D printing system with a wavelength in the range of 385 nm and can therefore be used almost universally. Other medical materials for the additive manufacturing of dental products like impression trays and steam-sterilizable drilling templates are in the final stages of development. Highly abrasion-resistant yet transparent constructions are made possible by a currently developed nano-SiO_2-modified material with adapted optical properties.

Merz Dental develops and produces in Lütjenburg

To achieve opaque results, on the other hand, inorganic fillers are usually used, which can, however, settle. To solve this problem, Merz Dental is developing a printable acrylate mixture that does not require fillers. During curing, the resulting polymer chains separate into domains. The nano and micro domains formed in this way scatter light and provide an opaque resin with a matte surface, for example for printing dental models.

In order to contribute to shaping the future of the dental market, Merz Dental has established the *Digital Solutions* division in collaboration with universities and research companies and members of various networks, such as NINa SH. The fact that the division is now the second most important for the company demonstrates the potential of additive manufacturing and nanotechnology for dentistry and innovative dental products.





Top: artificial tooth made of nano- and micro-reinforced composite.
Bottom: PMMA bead with coating of nano-SiO2.

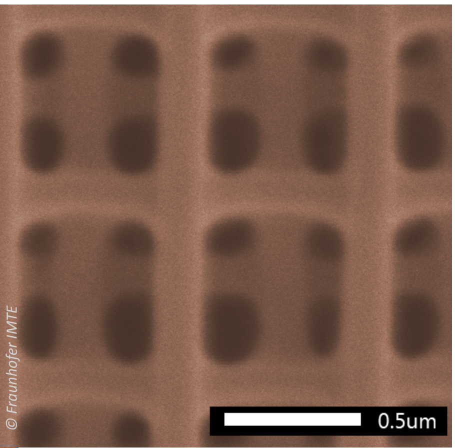
3D printing in medicine and technology: from nano to "heavy metal" at Fraunhofer IMTE in Lübeck

The new Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Lübeck places personalized medicine in the focus of application-oriented research. Together with the partners of the BioMedTec Science Campus, research from biology, medicine and technology is coordinatedly brought into application.

"Personalized medical technology is the textbook example of the application of additive manufacturing," says Dr. Thomas Friedrich, who heads additive manufacturing technology at Fraunhofer IMTE. The research group has a professional equipment pool of different printing technologies that cover a wide range of applications in technology and medicine.

In the field of 3D printing with polymers, newer techniques are available in addition to widely used methods such as the filament-based FDM process, PolyJet processes or conventional stereolithography. "The still rather unconventional processes are currently lesser used due to their complexity, but they offer unique possibilities," explains Friedrich. These specialized processes available to IMTE include, for example, multi-material multi-jet printing, in which objects can be created from several different materials and physical properties in a single printing process. This allows multicolored components or parts with areas of different mechanical, electrical or optical properties to be realized. This means that even complex prototypes can be produced within a very short time, combining an impressive level of detail with high reproduction accuracy.

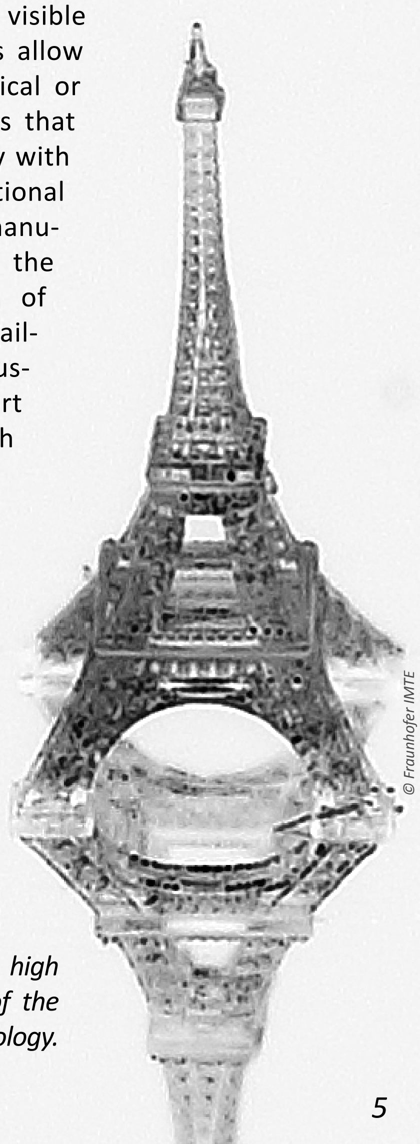
Selective laser sintering (SLS) at IMTE also enables the production of particularly robust functional components that combine the design freedom of 3D printing with the material properties of injection molding. Says Friedrich, "Thanks to SLS, we can quickly deliver reliable results even for very small series or individual pieces."



Nanostructure printed with 2-photon polymerization stereolithography (2PP-SLA).

Closely related to SLS is the selective laser melting, or SLM, process, which can be used to generate metal components of high quality and almost any shape. At Fraunhofer IMTE, SLM also enables components to be professionally manufactured from titanium and many other alloys. At the other end of the length scale, the additive generation of nano- and microstructures from photopolymers offers completely new possibilities for micromachines and lab-on-a-chip applications. In a 2-photon process, nanoscale structures can be produced that are significantly smaller than the wavelength of visible light. The resulting objects allow optical as well as mechanical or microbiological applications that could be implemented only with great effort using conventional lithography. "Additive manufacturing is embedded in the entire service portfolio of Fraunhofer IMTE and is available to research and industry for services and as part of joint projects," Friedrich sums up.

The Fraunhofer IMTE is organizing the *Additive Manufacturing Meets Medicine* conference (www.ammm.science) with partners on campus, where the institute will demonstrate its new capabilities.

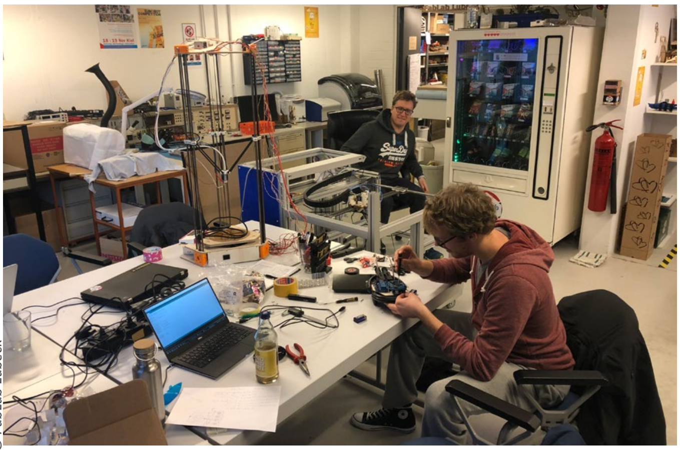


A micro model just 2 mm high demonstrates the precision of the 2PP-SLA printing technology.

3D printing hands-on at the Lübeck Technical Center

The Lübeck Technical Center (TZL) has been supporting founders and companies in the development and expansion of their business models since 1986. In addition to the rental business, cooperations have been expanded and new technologies promoted in a variety of projects over the years. Thus, the FabLab Lübeck was established in 2014 and the TZL Academy in 2018.

In the "open high-tech workshop" of the FabLab Lübeck, which is managed by the society of the same name, numerous 3D printers from different manufacturers and manufacturing processes are available for public use. The FabLab has been established in its new premises on the Lübeck campus since mid-2020. The association's more than 70 members combine expertise in all aspects of 3D printing and support the users with their knowledge. In addition to the FabLab, there are many other 3D printing stakeholders in the region who have linked up to form a network. The goal is to integrate 3D printing even more intensively with other key topics. For example, in individualized 3D-printed implants, which are specifically provided with nanoscale layers to simultaneously optimize fit and healing.



© FabLab Lübeck

FabLab Lübeck provides public access to 3D printers.

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The TZL Academy provides training in the use of 3D printers in various workshops.

In 2018, the Lübeck Technical Center founded the TZL Academy, primarily to strengthen the local economy, bring knowledge about the latest technologies and developments to companies in the region and enable them to apply it practically.

Based on the experience gained from previous projects and the expertise at FabLab Lübeck, workshops that teach how to get started with additive printing processes are offered for SMEs, trainees and students. Participants can undergo training as a 3D printing user in as little as a three-day workshop and transfer their newly acquired skills to their company or apprenticeship. For an initial introduction to 3D printing, a one-day crash course is offered specifically for this purpose. In addition to the technology and operation of the 3D printers, the workshops also cover the use of design software. This enables participants to plan and develop their own products.

Highlights from the community

25 million € for collaborative research centers at CAU Kiel

The DFG funds at Kiel University the new Collaborative Research Center (CRC) 1461 "Neuroelectronics: Biologically inspired Information Processing" with around 11.5 million euros. In addition, the CRC 1261 "Biomagnetic Sensing", which has been in existence since 2016, will receive approximately 13.5 million euros for another four years. The interdisciplinary large-scale research projects are both based at the Kiel Nano, Surface and Interface Science (KiNSIS) research center at Kiel University. "Both major projects offer exciting future potential at the interfaces of technology, biology and medicine," says Professor Simone Fulda, President of Kiel University.

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