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Fraunhofer Competence Field
Additive Manufacturing

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Editorial

For the 3rd time, the Fraunhofer Competence Field Additive Manufacturing presents the formnext special edition of NEWS 2.22 with highlights of all exhibitors at the Fraunhofer joint booth.

Let me pick out three examples: The cover picture shows the Dresden Frauenkirche, which was additively manufactured from copper via LMM (Lithography-based Metal Manufacturing) by Fraunhofer IFAM Dresden. This example demonstrates the ability of LMM technology to create extremely fine 3D micro-structures. Fraunhofer IKTS shows high-performance thermal cyclers for harsh conditions. High heating rates can now be combined with high cooling rates – a previously unattainable combination of properties. And finally, Fraunhofer IST presents surface functionalization for precisely fitting 3D printed bone implants. The new method makes it possible to apply a cell-growth-promoting coating also to the interior of implants.

My colleagues and I look forward to a lively exchange with you directly at formnext!

We wish you a successful visit to the trade fair and would be happy to welcome you at our booth D51 in hall 11.0. Last but not least, do not miss out to register for the Fraunhofer Direct Digital Manufacturing Conference (DDMC) on March 15 and 16, 2023 in Berlin, Germany!

Dr. Bernhard Mueller
Spokesperson Fraunhofer Competence Field Additive Manufacturing

Editorial

Our Exhibitors

Office, Fraunhofer IWU, Dresden

Fraunhofer Competence Field Additive Manufacturing

The Fraunhofer Competence Field Additive Manufacturing integrates 19 Fraunhofer Institutes across Germany and represents the entire process chain of additive manufacturing. This includes the development, application and implementation of additive manufacturing methods and processes. Many years of experience from national and international industrial contracts and research projects form the basis to develop customer-specific concepts and master complex tasks.

Fraunhofer IGD, Darmstadt

Fraunhofer Institute for Computer Graphics Research IGD

Fraunhofer IGD is the internationally leading organization for applied research in Visual Computing. Numerous basic technologies are necessary to bring images, audio, video, and interactive 3D worlds to the viewer in high visual quality. Our visual displays create the opportunity of presenting complex and interdependent content through sensor data and simulations. Data and experience can be analyzed with the help of visual displays. Our goal is to keep more and more complex computer systems and increasing amounts of data manageable for humans, society and economy.

Fraunhofer IST, Braunschweig

Fraunhofer Institute for Surface Engineering and Thin Films IST

Fraunhofer IST stands for excellence in surface technology providing expertise in the associated product and production systems. Through modification, structuring and coating of the surface the most diverse functions and functionalities – and therefore future-oriented products and systems – are realized. In collaboration with customers from industry and research, we develop tailor-made and sustainable solutions: from prototypes, through economical production scenarios, and on to scaling-up to an industrial dimensions – also taking into account closed material and substance cycles. Our key strength: We design the optimum process chains for your task on the basis of a broad spectrum of processes and coating materials.

Fraunhofer Institute for Material and Beam Technology IWS

Fraunhofer IWS stands for innovations in laser and surface technology. The Dresden scientists offer one-stop solutions ranging from the development of new processes to implementation into production up to application-oriented support. The fields of systems technology and process simulation complement the core competencies.

Fraunhofer IWS, Dresden

Fraunhofer Institute for Casting, Composite and Processing Technology IGCV

Fraunhofer IGCV stands for application-oriented research with focus on efficient engineering, networked production and smart multi-material solutions. Our unique selling proposition lies in interdisciplinary solutions for casting, composite and processing technology. A special highlight is our AMLab, where we conduct research together with the iwb at Technical University Munich on various processes, e.g. laser-based powder bed fusion of metals (PBF-LB/M) or arc-based additive manufacturing.

Fraunhofer IGCV, Augsburg

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Fraunhofer IKTS is your research partner for high-performance materials, especially ceramics. The institute offers complete AM solutions ranging from powder and suspension/feedstock development, the design and development of (functionally graded) components, the manufacturing technology selection as well as thermal processing of 3D printed parts. As a plus, IKTS offers the characterization and assessment of the manufactured components and systems.

Fraunhofer IKTS, Dresden

Fraunhofer Institute for Machine Tools and Forming Technology IWU

The Fraunhofer IWU stands for innovations in the research and development of production engineering. We open up the potential for competitive manufacturing in automotive and mechanical engineering, aerospace technology, medical engineering, electrical engineering, and precision and microengineering. We focus on scientific developments and contract research regarding components, processes, methods,

Fraunhofer IWU, Chemnitz, Dresden, Zittau and the associated complex machine systems and their interaction with humans – the entire factory. Thereby, the institute banks on highly flexible, scalable cognitive production systems using nature as an example.

Fraunhofer IFAM, Dresden and Bremen

Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

Fraunhofer IFAM offers the whole range of metal powder-based AM processes to provide thorough access to the various possibilities of additive manufacturing technologies. The comprehensively equipped additive manufacturing application center at Fraunhofer IFAM in Bremen comprises the complete process chain for LBM[1] and MBJ[2]. At Fraunhofer IFAM in Dresden, the Innovation Center Additive Manufacturing ICAM® brings together SEBM[3], 3D Screen Printing, FFF[4], Gel Casting, MoldJet® and LMM[5] under one roof.

Fraunhofer ILT, Aachen

Fraunhofer Institute for Laser Technology ILT

Activities of Fraunhofer ILT cover a wide range of areas such as the development of new laser beam sources and components, precise laser based metrology, testing technology and industrial laser processes. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modelling and simulation as well as in the entire system technology. We offer feasibility studies, process qualification and laser integration in customer specific manufacturing lines.

Office, Fraunhofer IFF, Magdeburg

Fraunhofer Group for Production

The Fraunhofer Group for Production unites 12 institutes and research units offering innovative system solutions in the wide field of production technology and logistics. The range of services covers the entire value creation process. In the field of additive manufacturing, our institutes can provide solutions in upstream and downstream processes of the value creation chain. The consolidated expertise covers digitalization and networking of tools and AM machines, hybrid manufacturing chains, product engineering, quality assurance and rework, training and AM material flow.

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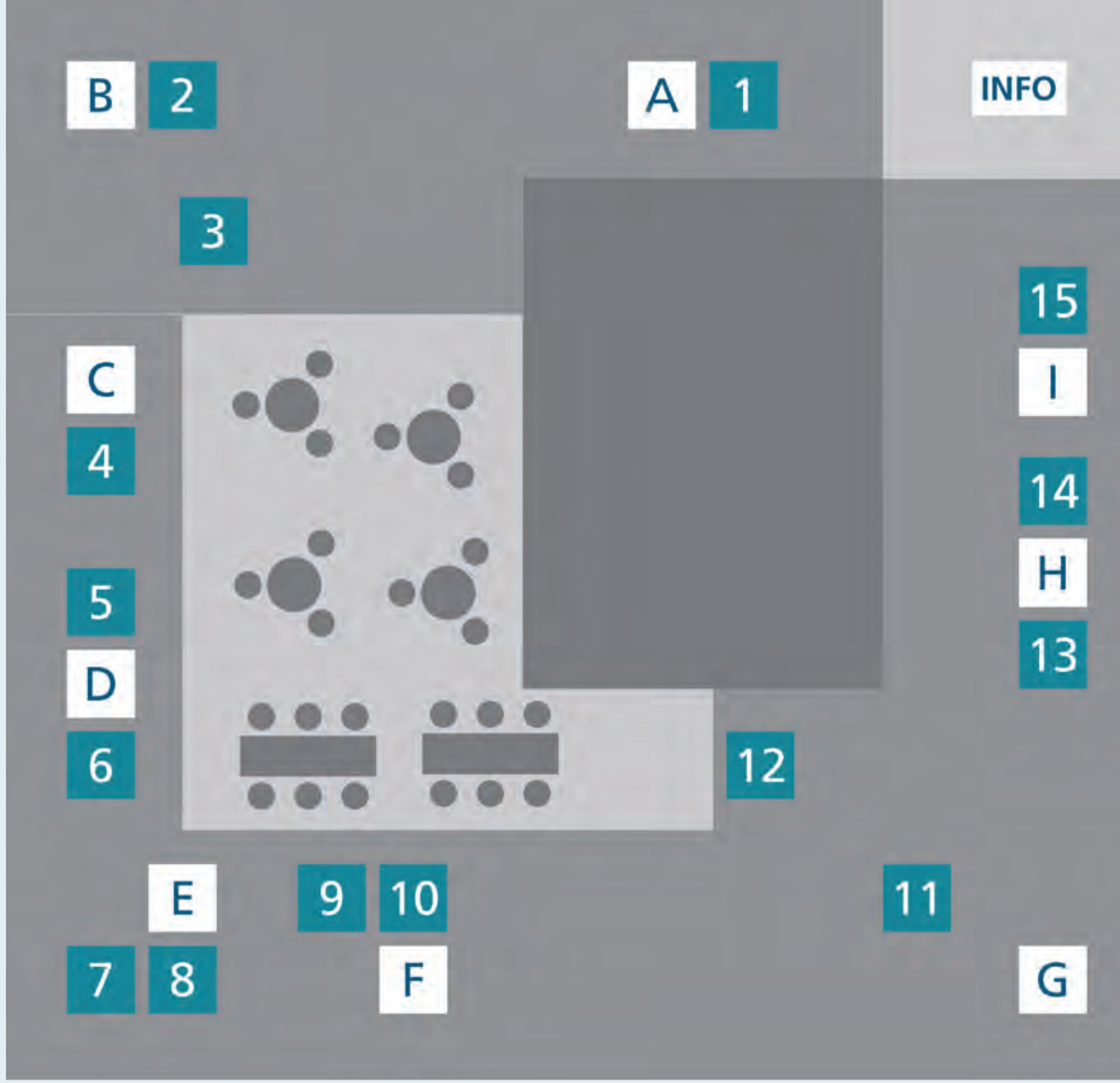
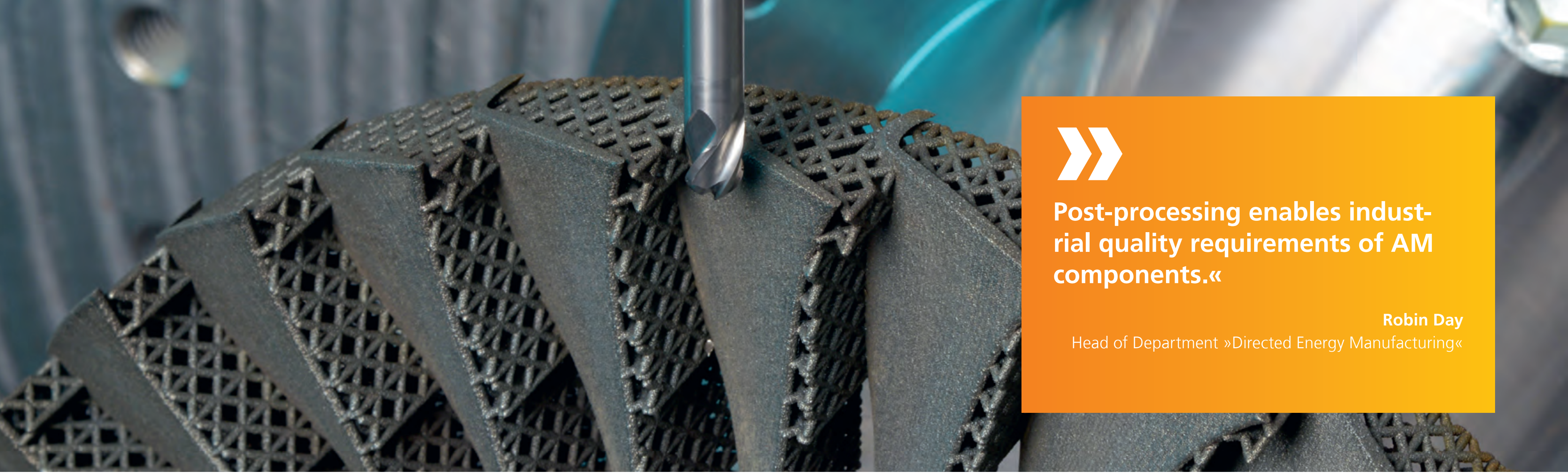
1 LBM: Laser Beam Melting
2 MBJ: Metal Binder Jetting
3 SEBM: Selcetive Electron Beam Melting
4 FFF: Fused Filamemt Fabrication
5 LMM: Lithography-based Metal Manufacturing

Inhalt





> **Post-processing enables industrial quality requirements of AM components.«**
>
> **Robin Day**
> Head of Department »Directed Energy Manufacturing«

The picture shows the subtractive reworking of a BLISK (Blade Integrated Disks) manufactured in the L-PBF process

Beyond the ready-to-print doctrine

About the advantages of combining additive and subtractive manufacturing steps

Additive manufacturing is playing an increasingly important role in modern production technology. With its energy efficiency and flexibility, it is the key to resilient and ecological production. In order to increase the value of additive manufactured components, the entire manufacturing methods should be taken into account. The advantages offered here must be incorporated into modern manufacturing and process chains.

Friend or foe of subtractive manufacturing processes?
The manufacture of the 3D printer, the preparation and removal of the build plates, the post-processing and many other upstream and downstream manufacturing steps are necessary to successfully print components. Experience has shown that collaboration in these different steps always results in more than one process.
The H2 combustion chamber combines is one example for the best of these worlds. While additive manufacturing cannot achieve the tight tolerances in the functional range, integral printing of the rings reduces manufacturing costs by a factor of 10. The modern challenge will be to expand our additive horizons to a larger scale and to take advantage of subtractive manufacturing to combine the best of subtractive and additive manufacturing. Thus, results can be achieved that go far beyond the capabilities of any single process.
The ability to access a full-scale production chain takes additive manufacturing to the next level. Material removal, surface quality, dimensional accuracy, manufacturing tolerances and many other production goals are easier to achieve when the production chain can include subtractive and additive manufacturing steps. Since the beginning of the rapid rise of 3D printing, ready-to-use parts from the printer has been a never-ending doctrine, like all doctrines it has just emerged and had no real beginning.
But let's conclude by returning to our friend or foe question. That additive manufacturing has a high cost factor is undisputed, these costs do not increase further by omitting machining steps. But what if the value of the finished part increases exponentially because additive and subtractive processes were considered and combined at the design stage?

Fraunhofer Group for Production

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Removal of the powder with the aid of a suction device developed at the Fraunhofer ILT

In-situ integration of sensors with AM to increase the quality of production chains

The integration of RFID chips and other sensors in additively manufactured components enables digital component tracking, which simplifies logistics and makes piracy more difficult. In addition, integrated sensors can be used to measure environmental parameters such as temperature or pressure, for example in medical technology and the automotive industry. By using additive manufacturing processes, the industry can reduce work steps, but also irreversibly integrate an RFID chip into the component. In order to make in-situ integration possible, however, the laser sintering process must be modified.

Additive manufacturing using selective laser sintering (SLS) enables the production of functional components with almost unlimited geometric complexity thanks to the layer-by-layer manufacturing process. At Fraunhofer ILT, design guidelines for integrating RFID chips with reliable readout probability in plastic components made of polyamide 12 have been developed. The chips can be integrated by a geometric solution after the build process in an additional work step or in situ during the additive manufacturing of the component. For the geometric solution, barbs are used to integrate a shuttle-receiver approach, which is flush and irreversible. The in-situ integration requires a process interruption during which the powder is extracted from a cavity inserted into the part, and the RFID chip is inserted into the cavity. The build process is then continued. Fraunhofer ILT developed a reliable process for powder removal and investigated the influence of process interruption on component quality.

With the method developed at the Fraunhofer ILT, RFID chips and other sensors can be irreversibly integrated into plastic components in situ. In future projects, the process of in situ integration must be automated in order to significantly increase reproducibility and productivity.

Fraunhofer Institute for Laser Technology ILT

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> **We unleash the full potential of EHLA for repair applications.«**
>
> **Viktor Glushych M. Sc.**
> Coatings LMD and Heat Treatment

Automated process chain for the repair of metal components by EHLA and turning

Circular economy through hybrid process chain

Components subject to high levels of wear and corrosion often fail due to local surface damage. The replacement of failed components is resource intensive and recycling of metal components involves energy intensive smelting processes. Furthermore, the growing demand for increasingly scarce raw materials leads to economic dependence on importing countries and causes a significant environmental footprint due to the CO_2 emissions generated in the manufacturing process.

At Fraunhofer ILT, an automated hybrid process chain for the sustainable repair of metal components is being developed. By combining the processes of turning and Extreme High-Speed Laser Material Deposition (EHLA), additive manufacturing as well as pre- and post-processing of metal components is possible in a single setup.

The EHLA process is already established within the industry in the field of surfac coatings. The use of EHLA is particularly interesting for repair applications that require:

- Wide range of possible material combinations,
- Low dilution and heat affected zone enabling repair of quenched and tempered steels,
- Layer thickness between 20 µm and 500 µm,
- Metallurgical bond,
- Powder material efficiency > 9 %.

The centerpiece of the process chain is a sequence of subtractive and additive manufacturing process steps. Local material removal in the shape of a defined g oove geometry is first performed at the damage area of the defective component. Then, EHLA is applied to rebuild the volume in the pre-processed area. Subsequent subtractive machining is used to restore the original contour of the repaired component. Automation of the process chain is achieved by using a selection of sensors in combination with user-friendly software to provide intuitive operation of the repair process. Optical sensors allow characterization of the component surface before, during and after repair. Spatially resolved image data and height profiles a e used for automated defect detection as well as for adaptive path planning for subtractive and additive process steps. The data is processed to establish the application-related circular economy and to enable predictive maintenance.

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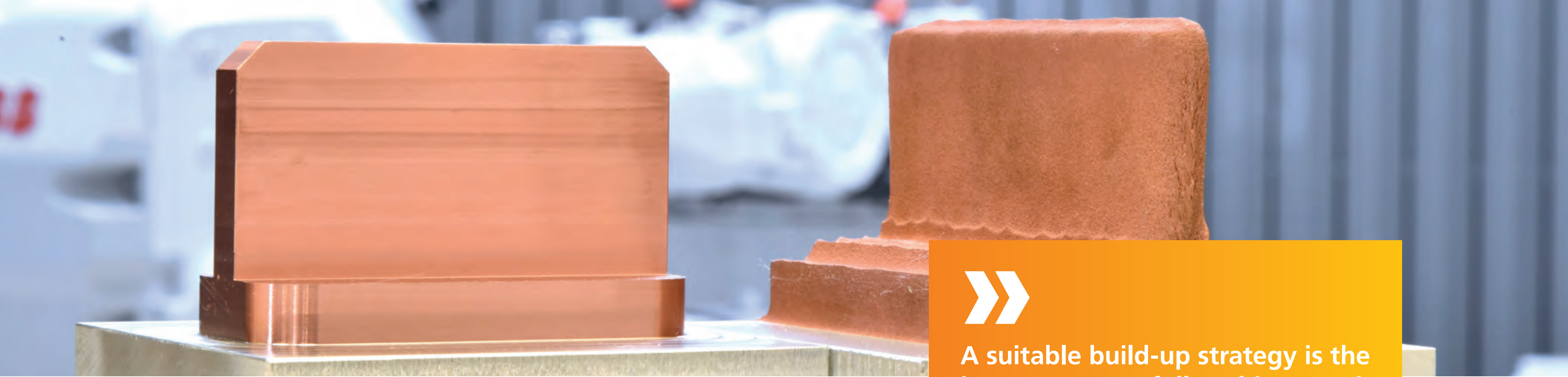

> »A suitable build-up strategy is the key to a successfully cold sprayed AM part«
>
> **Dr.-Ing. Georg Schlick**
> Head of Department AM Metals and Multi-Materials

Cold Spray Additive Manufacturing – a novel approach for multi-material parts

A brief overview of a promising technology

Cold spray was developed in the 1980s, initially as a metal coating process. In recent years it has also been discovered and used as an additive manufacturing technology. Ensuing, the process is briefly explained and the current challenges are highlighted.

In this process, powder particles are accelerated to supersonic speed by means of a carrier gas stream and a Laval nozzle. When impacting on a substrate, the particles deform plastically and form dense layers with the subsequent impacting particles. Apart from a decrease in the plastic deformability of the material and an associated increase in hardness, the properties of the feedstock material are thus maintained. With regard to the plant technology, it is important to distinguish between high-pressure and low-pressure cold spray systems. The latter enables less expensive equipment as well as lower operational costs (e.g., due to the use of air as carrier gas), but the range of materials that can be processed is somewhat limited. High-pressure cold spray, on the other hand, enables the processing of high-strength materials such as Inconel alloys and is considered below and abbreviated as CS.

The CS process can be classified as a DED processes. Compared to Wire Arc Additive Manufacturing (WAAM) or Laser Metal Deposition (LMD), CS offers higher or similar deposition rates but has the disadvantage of a lower resolution. Another advantage is the possibility of manufacturing multi-material parts avoiding problematic interfaces between different materials. Single cold sprayed tracks show a Gaussian-like cross-section. This shape also continues in the subsequently built-up layers. In order to overcome this existing hurdle to additive manufacturing, adapted build-up strategies are necessary. One approach provides tilted spraying of the outer tracks, thus compensating the Gaussian shape. Depositions at right angles to the substrate are therefore possible. Likewise, progress has already been made in combining basic geometries into more complex structures (e.g., the part on top of the page).

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PBF-EB for Medical Technology

As a special example for the suitability of Selective Electron Beam Melting (PBF-EB) for medical technology, Fraunhofer IFAM in Dresden presents the successful close to the KMU-innovativ joint project "Opti-HueftE". Within the project, titanium hip stems were additively manufactured by PBF-EB. This allows the components to be tailor-made instead of using a few standardized geometries. The PBF-EB process parameters and subsequent heat treatments were optimized for high mechanical performance. Additively manufactured near-net shape parts were mechanically finished and spray coated.

Together with their partners Aristotech, HIP PM Volker und DOT GmbH medical implant solutions, Fraunhofer IFAM managed to reduce the manual reworking compared to forging. Three hip stems have passed the standardized fatigue test according to ISO7206-4. The research could be conducted thanks to the support by the Federal Ministry of Education and Research.

For more insights into the project and into the possibilities of PBF-EB, please contact Dr. Burghardt Klöden and Dr. Alexander Kirchner.

PBF-EB is also part of ICAM®, the Innovation Center Additive Manufacturing at Fraunhofer IFAM in Dresden, which brings together the wide variety of additive manufacturing processes available at the institute site.

Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

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Small, yet powerful with Lithography-based Metal Manufacturing (LMM)

As one of the first users in applied research and development worldwide, Fraunhofer IFAM in Dresden runs a system for Lithography-based Metal Manufacturing (LMM). This innovative approach in Additive Manufacturing is ideal for filigree structures with high surface quality.

The institute's progress in material and application development is significant. The Dresden Frauenkirche is just an example to demonstrate which metal 3D microstructures can be possible with this innovative sinter-based stereolithography process.
Fraunhofer IFAM applies LMM to open up new areas of application that were previously not feasi-ble with other additive technologies. These range from aesthetic applications such as jewelry to microfluidics and electronic components.

The LMM system of Incus GmbH is part of ICAM®, the Innovation Center Additive Manufacturing at Fraunhofer IFAM in Dresden. Here, the institute has joined its forces in additive manufacturing with all technologies in one spot: Fused Filament Fabrication, Gelcasting, 3D screen printing, MoldJet® and Selective Electron Beam Melting. Because: If AM - then IFAM!

Contact Dr. Thomas Studnitzky or Jakob Scheibler to learn more about LMM at Fraunhofer IFAM.

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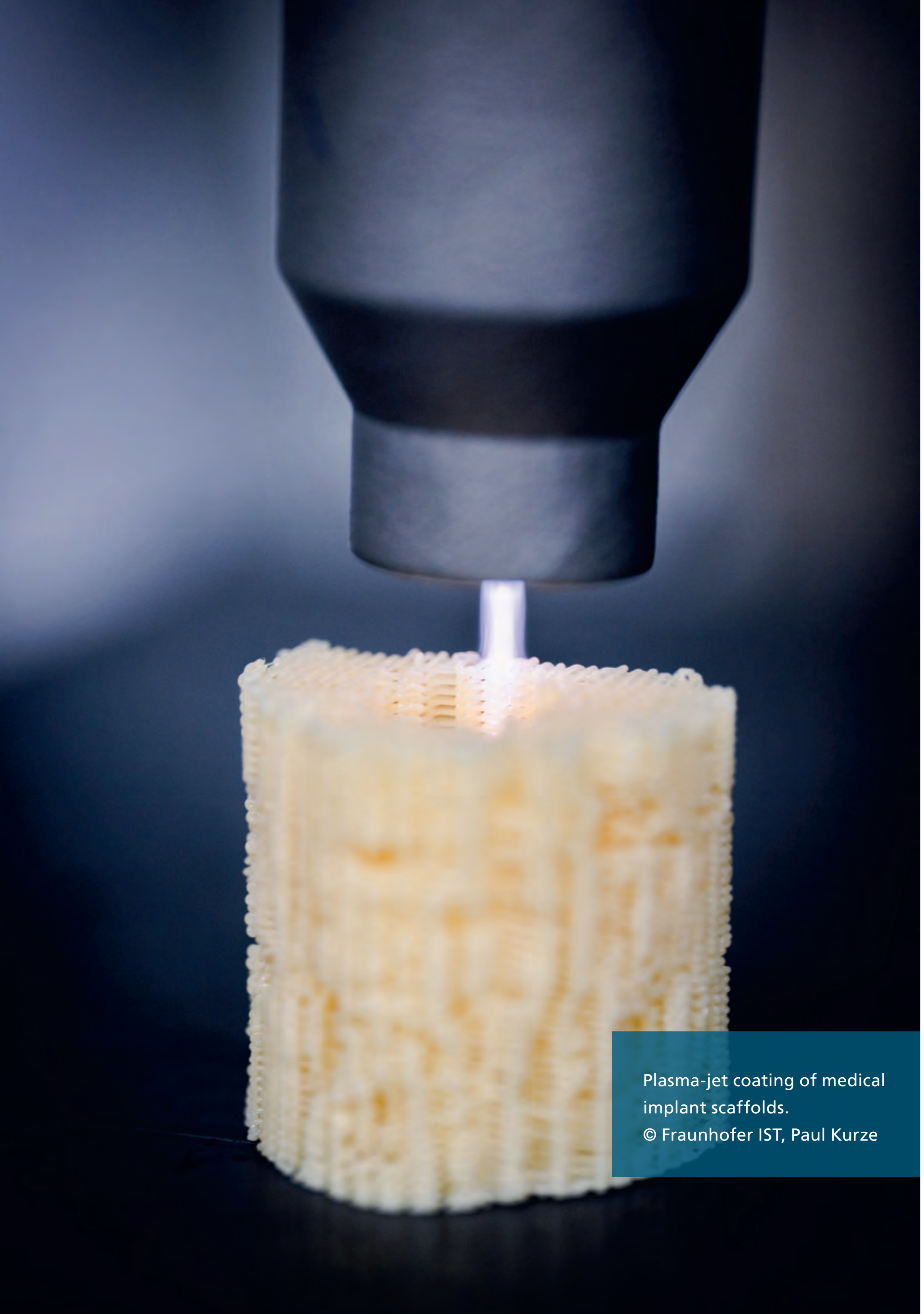

Plasma-jet coating of medical implant scaffolds.
© Fraunhofer IST, Paul Kurze

Surface functionalization: Precisely fitting bone implants from the printer

Cancerous tumors, infections or bad fractures can make it necessary to surgically remove bones and insert implants in their place. 3D-printed porous polymer framework structures, so-called scaffolds, present an interesting new approach for the treatment of missing bone fragments. The secret of this new method lies in the printing process, where the individual layers are treated with a cold plasma in order to improve the adhesion of bone-forming cells.

Whereas conventional surface treatments have a limited penetration into the interior of bone implants, the new method developed at the Fraunhofer IST makes it possible to apply a cell-growth-promoting coating also to the interior of the implants. A plasma jet blows molecules with reactive groups directly onto the printed layers. The groups bond with the surface and ensure that bone cells find a convenient substrat to which they readily adhere. A unique feature of the technique is that the 3D printing and coating processes go hand in hand and are combined in one device. Because no chemical pretreatment with solvents is required for the coating, it is not only cost-effective, but environmentally friendly also. The scaffold itself is built is made from a special copolymer that is modeled on the natural bone. The 3D printing technique permits very individual, precisely fitting design and stability. The goal is for the bone cells to grow into the synthetic structure as quickly as possible and finall replacing the implant which is broken down gradually by the body's own enzymes.

The mechanical stability of the implant can be controlled not only via the density of the printed scaffold structure, but also via special fillers that a e added to the copolymer: the higher the filler concentration, the g eater the stability. This development makes it possible to individually vary the stability inside the implant. Like natural bones, implants can now have areas with different strengths. Moreover, active drug additives such as antibiotics can be incorporated in the filler to educe the risk of infection.

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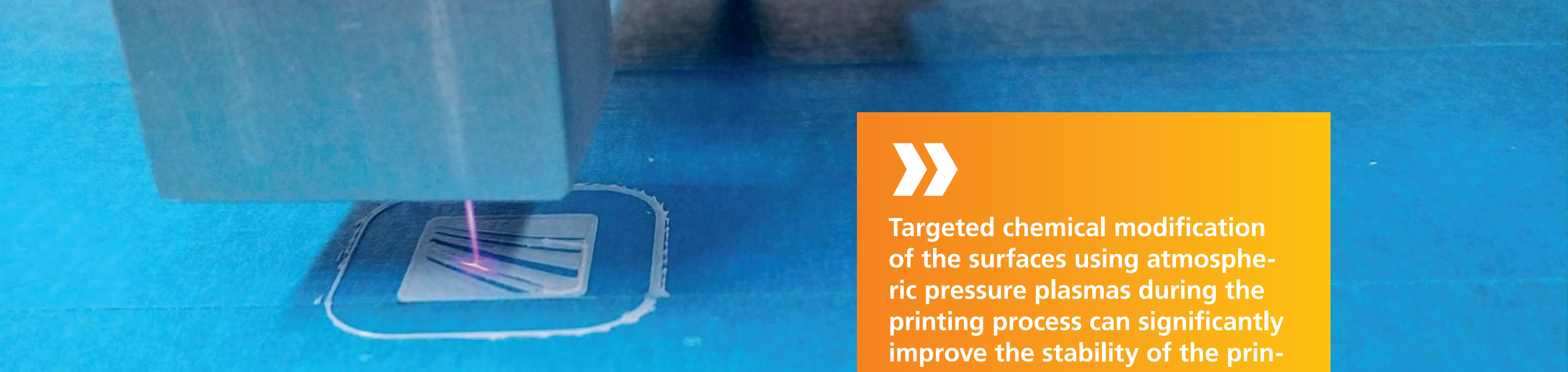

Punctiform atmospheric-pressure plasma source integrated into FDM 3D printer.

Atmospheric pressure plasma sources for additive manufacturing

Adhesion plays an essential role in additive-manufacturing processes such as fused deposition modeling (FDM), a manufacturing process in which a workpiece is built up layer by layer from a fusable plastic. It influences the stability of the printed components, the print quality and the adhesive forces between different surfaces. Through the integration of atmospheric-pressure plasma technology into additive manufacturing, it is possible to influence the interfacial chemistry and, consequently, the adhesion on the treated surfaces. As a result, subsequent processes, such as painting or bonding, can be optimized and different materials, e.g. composites and metals, can be better combined with one another. Applications range from the automotive industry, through the aerospace sector, and on to medical technology. Especially in the field of medical implants the technology opens up new possibilities through a targeted chemical modification of the surfaces with functional groups.

At the Fraunhofer IST, two approaches are being pursued for the application of atmospheric-pressure plasma sources in additive manufacturing in order to develop customer-specific process-engineering solutions.

»Targeted chemical modification of the surfaces using atmospheric pressure plasmas during the printing process can significantly improve the stability of the printed components.«

Dr. Thomas Neubert
Interfacial Chemistry and Adaptive Adhesion

The first approach uses a miniaturized conventional plasma nozzle. A punctiform nozzle of this kind allows the structured sequential treatment of printed polymer layers in high resolution. In the second approach, an annular plasma sources is being investigated, which is mounted around the extrusion nozzle and thereby allow direct treatment of the surfaces in parallel with the printing process.

Through the developed patented prototypes, it is possible to extend extrusion-based 3D printing processes by a parallel or sequential plasma treatment. With the aid of plasma treatment, various functions can be achieved at the interface. The possibilities range from etching and cleaning, through chemical modifications and functional coatings, and on to crosslinking of surfaces or polymers. As a result, the application areas of additive-manufacturing processes can be significantly expanded – including for sustainable materials – enabling existing products to be improved and new products to be developed.

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Mounting on the process head

Process reliability can be significantly increased by using the newly developed sensor ”POWDERscreen”.

»POWDERscreen« detects powder particles

Increased process reproducibility through permanent monitoring of the powder mass flow rate

Controllable alloying within the process possible

For a stable and therefore reproducible process, in addition to process shielding with ”COAXshield” and the qualification of the powder cone by the »LIsec«, it is also necessary to know all input variables exactly and to control them, if necessary. Especially the continuous measurement of the fed powder quantity has been a great challenge so far. The ”POWDERscreen” sensor, which is currently being developed at Fraunhofer IWS as part of an EU research project, detects exactly when and how much of the different particles are fed into the melt pool. The fed powder mass can be calculated exactly on this basis. As a result, it is possible to detect fluctuations in the particle mass flow and report them to a downstream controller. Not only does this significantly increase the process reliability, but it also enables several different powders to be mixed in a targeted manner during the welding process. A discrete-time measurement of the powder mass flow also significantly increases the process digitization level and provides data for creating a digital twin of the created component.

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»LLsec« lights the powder flow

A measuring system for automated characterisation of the powder nozzle during laser powder build-up welding

Plant integrated measurement

The LLsec powder nozzle measurement system measures powder flows after leaving the nozzle.

Increased process reproducibility through tool measurement

While tool calibration is state of the art in conventionally used ablative processes such as milling, in laser powder buildup welding it is still a great challenge. The Fraunhofer Institute for Material and Beam Technology IWS developed the measuring device "LLsec" to solve this challenge and to move the limits to technical feasibility. The abbreviation stands for "Light Section" and already reveals the principle: A measuring laser scans the powder flow after leaving the nozzle. A right-angled camera records light sections through the powder and forwards them to an analysis software. The three-dimensional distribution of the powder flow can be calculated with high precision. This allows significantly simplified quality control and provides information on the wear degree of the powder nozzle.

For example, it can be used to repair damaged or worn turbine blades on aircraft in higher quality and more reliably than before. In this respect, the measuring device can contribute to greater safety and lower maintenance costs in aviation. The Dresden institute is already working on the industrial implementation of the technology with several well-known international companies and research institutes.

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SEAM-HEX 3D printer with a build volume of 1100 mm x 800 mm x 600 mm

SEAM - High-Speed 3D printing process for the production of large-size polymer components

In recent years 3D Printing has developed rapidly and opens up entirely new product and manufacturing approaches. However, many 3D printing processes are too expensive and too slow for industry. Therefore R&D activities focus on producing large quantities in a short time at competitive costs.

The Fraunhofer Institute for Machine Tools and Forming Technology (IWU) has developed the Screw Extrusion Additive Manufacturing 3D process (SEAM). For this purpose, an innovative machine tool (hexapod) and a patented plasticizing unit were combined. By using the SEAM process the cost-effectively and resource-efficiently production of large-size, load-bearing polymer components is possible.

Elastomers and ceramic feedstock systems can be processed into complex structures as well. The process speed of the SEAM 3D printing process is 8 times faster and 200 times lower in cost than conventional manufacturing processes. SEAM opens up completely new fields of application for 3D printing, e.g. in aircraft or railway industries. With the spin-off of the company 1A Technologies and the close cooperation with Metrom, a flagship for the Saxony region was created, which generates jobs through growing sales opportunities on national and international markets. On 12th October 2022, this innovation was awarded with the 2nd prize of EARTO Innovation Award for Impact Delivered.

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Additive manufacturing technologies for next-generation powertrains

The oil-free operation of the gearbox is achieved by an innovative coating of the gear teeth, which enables virtually maintenance-free operation. In addition, higher damping of sound transmission from the gear mesh to the bearings is achieved by an optimal gear body geometry, which is realized by a combination of printable carbon-containing polymers (flange) and steel (ring gear). The innovative approach is to integrate design features into gear components. In combination with gear grinding and ta-C surface coatings, maximum dry-running efficiency is achieved. The increase in gear efficiency is achieved through optimization approaches in the design to minimize heat losses while striving for the best possible strength and lowest noise emission.

The pictured pinion shaft with integrated cooling channels was manufactured using the LPBF process. The drive shaft shown has a metal gear rim, which is connected internally to a CFRP (carbon fiber reinforced plastic) wheel body. After manufacturing, the gears were hardened and ground to achieve the required quality. The gears were then coated and exhibited high surface quality with a measured coating thickness of 2.5 µm. Measurements of the efficiency and acoustics were then carried out in the gear test rig. It was found that an increase in efficiency can be achieved, particularly in the low-load range, which can be attributed to the use of low-loss gearing. The targeted stiffening of the transmission housing can thus be used to shift acoustically critical speed ranges (e.g. constant operating speeds in rail vehicles) outside the operating speeds.

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*left: MMJ printed multi–material ignitor enables reliable, controlled reuse. |
right: MMJ printed luminescent glasses for security and design applications*

CerAM MMJ – Multi–Material Additive Manufacturing of High-Performance Materials

It is important to innovative manufacturers that their products have the functions that offer added value to their customers as the product users.

Product properties providing these functions result from two essential factors – the geometric design and the materials used. The more complex a product application area is or becomes, the more multifunctional respective products must be. As a result, the complexity of product geometry is increasing, and the materials used in the manufacturing process are becoming more demanding in their processing.
Multifunctional products designed to meet the demands of an increasingly complex world require manufacturing processes that allow a high degree of freedom in geometric shaping as well as the selective and targeted use of the optimum materials for the respective application.
Multi Material Jetting (CerAM MMJ), a 3D printing process technology with high productivity developed at Fraunhofer IKTS, has the great advantage of independence of the manufacturing process from the material used due to processing all classes of materials, such as metal, plastic, or ceramics. The material is deposited in the form of tiny drops only where the material is needed. This process is sustainable just like the reusable material as well as the binder systems, which are not harmful to the environment. Fitted with multiple print heads, CerAM MMJ is ideally suited to produce multifunctional products due to the possibility to change the material with every drop. Especially in the case of multifunctional components, a wide variety of material classes can be freely selected and combined if co-processability is given.
A Fraunhofer IKTS spin-off will commercialize the CerAM MMJ technology with support from the EXIST research transfer program of the German Federal Ministry for Economic Affairs and Climate Action. From 2023 onwards, the startup will supply easy entry operation industrial 3D printers with a high degree of process control and modular mountable tools, and a large quickly expandable material portfolio. As a plus, manufactures can bring their own powder to get their own exclusive material for printing on a CerAM MMJ 3D printer. Furthermore, a personal service will be provided, which includes the escort of CerAM MMJ 3D printer users along the AM value chain based on many years of expertise and special multi material know-how.

»The Fraunhofer IKTS spin-off enables manufactures to print functionally graded components in one step«

Dipl.-Ing. Steven Weingarten
Fraunhofer IKTS

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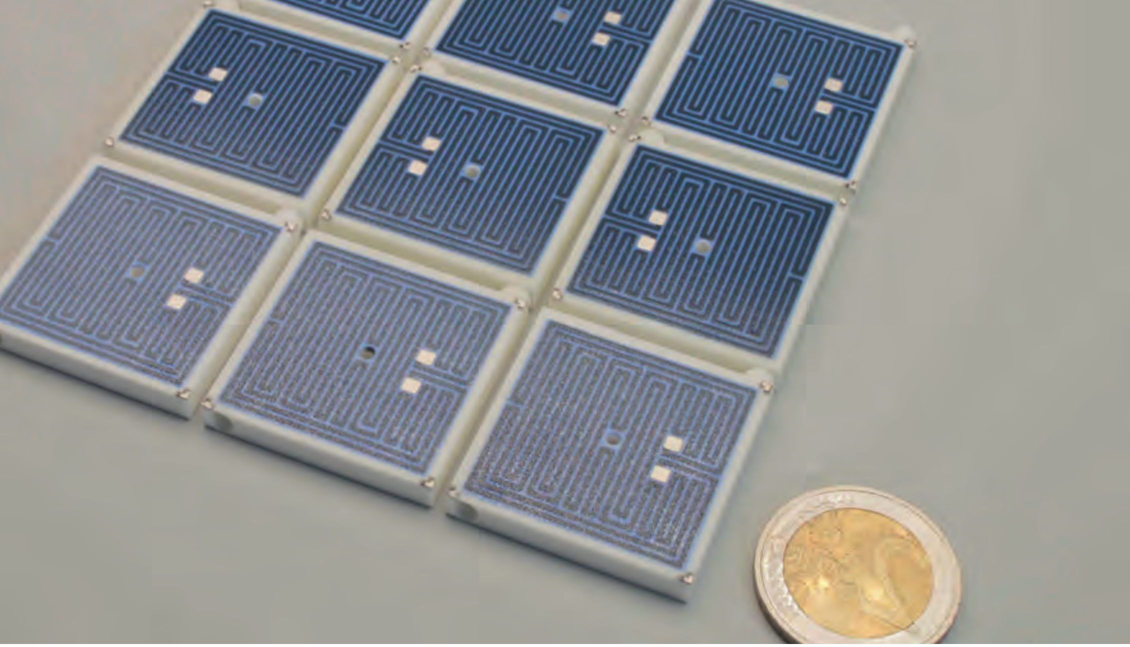

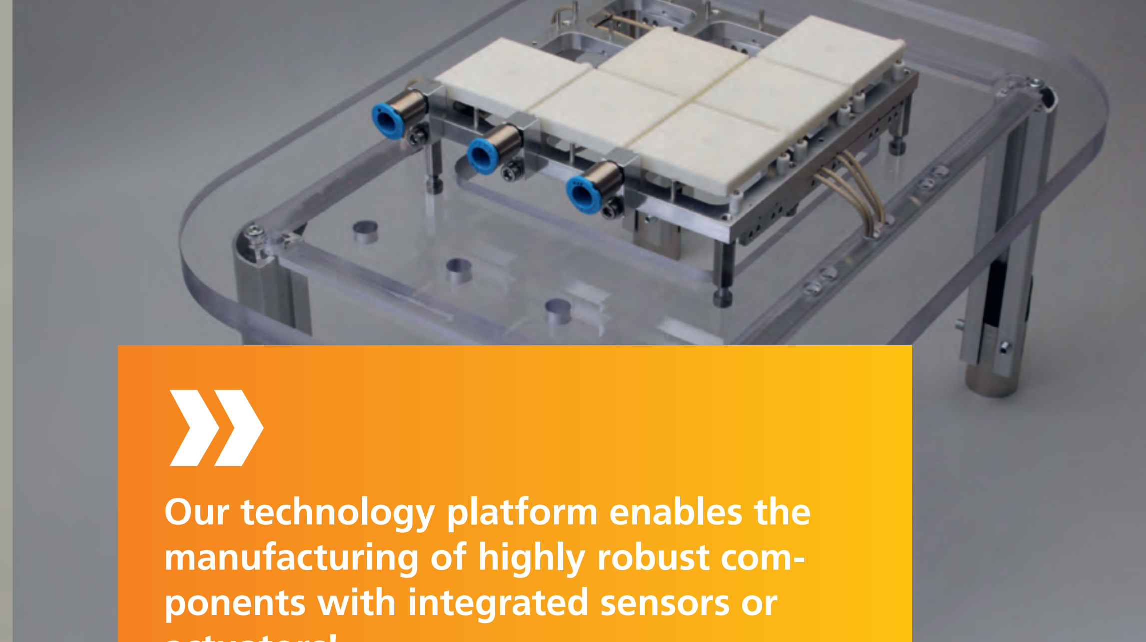

Highv-performance thermal cyclers for harsh conditions

Ceramic materials are used where others fail.

»Our technology platform enables the manufacturing of highly robust components with integrated sensors or actuators!«

Dr. Lars Rebenklau,
Team Manager, System Integration and AVT

By hybridizing materials and manufacturing technologies, previously unattainable combinations of properties can be realized. For example, high heating rates can now be combined with high cooling rates in thermal cyclers.

By combining them with functional materials, the outstanding mechanical, chemical and thermal properties of ceramic materials can be extended even further to create components with, for example, applied electrically conductive structures, passive electrical components, sensors or actuators. For sintered ceramic substrates with a simple geometry (plates, cylinders, tubes), the material systems of thick-fi m technology known in electronics technology offer reliable processes for this, which have been established for many years.

Further functional integration becomes possible by increasing the geometric complexity of the ceramic substrates. Additive manufacturing is a »game changer« especially for ceramic materials, which are difficult to machine due to their high hardness. Previously unknown component geometries can now be realized directly and functions such as cooling channel or mixer structures can be integrated.

As part of the »DynaCool« project (BMWK, VDI/VDE-IT, FKZ: 16KN054345), the functionality of a segmented heater for soldering processes, which was developed in a previous project (»DynaTherm«, BMWi, VDI/VDE-IT, FKZ: 16KN054336), was expanded together with the company budatec so that the individual pixel segments can not only be heated quickly, but rapid cooling rates are now also possible. The segmentation enables a targeted inhomogeneous heat input into PCBs and the solder used, which is needed because the assembly of new metal core PCBs is not homogeneous. As a result of the optimization of the process control, less energy is also required to heat the solder joint. At the same time, the ceramic substrate is effectively cooled by integrated cooling channels, so that a lower energy requirement during heating can be combined with a shorter process time during cooling.

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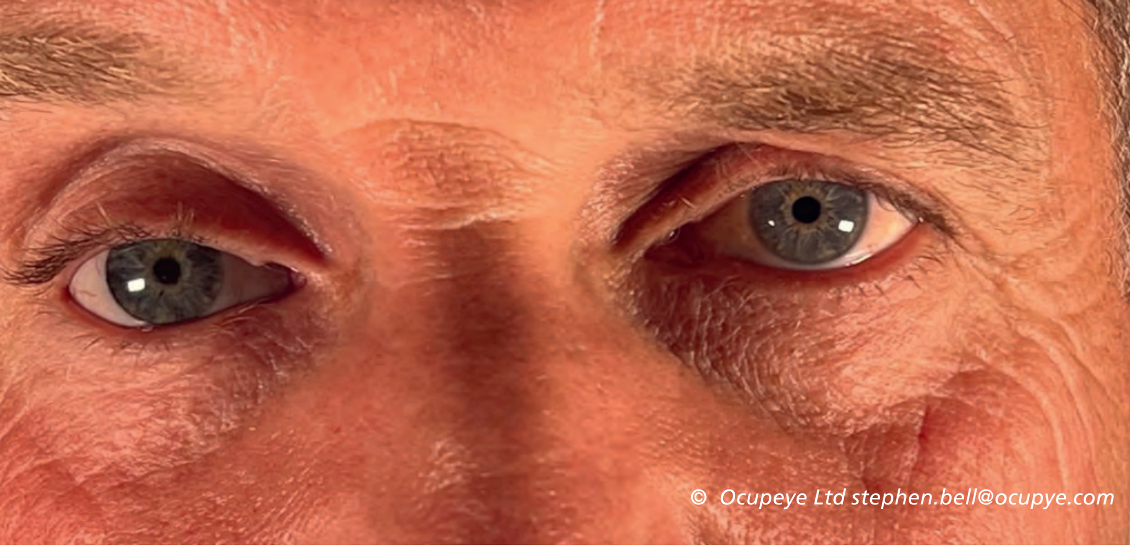

The patient's right eye (left in the picture) is a 3D-printed prosthetic eye created by a fully-automatic digital end-to-end workflow.

Featured Exhibits of Fraunhofer ADDITIV

3D-Printed Eye Prosthesis

Our member institute **Fraunhofer IGD** in Darmstadt presents the first 3D printed eye prosthesis (cosmetic eye replacement) in which, according tov professional ocularists, the iris and pupil look more realistic than in traditionally manufactured prostheses. The 3D model of the eye prosthesis was computed by the data-driven design software »Cuttlefish:Eye« from clinical patient data and produced on a Stratasys J750 3D printer using the »Cuttlefish« 3D printer driver. Special attention was paid to the accurate reproduction of color and translucency.

Ready-to-use technical ceramics

The **Fraunhofer Center HTL of the Fraunhofer ISC** uses VPP to fabricate ready-to-use technical ceramics for various demanding applications. In using topology optimization and the simulation of the thermal processes for debinding and sintering and the (high-temperature) mechanical performance, it is possible to design and process the parts in the most efficient and load-oriented way.

»All-HC are recyclable single component composites for 3D printing«

Dr. Raimund Jaeger,
Head of Polymer Tribology, Biomedical Materials

3D Printed Components for Circularity

A gear made from a single component composite is presented by **Fraunhofer IWM**. In contrast to conventional composites (e.g. glass fiber-reinforced composite), the matrix and reinforcement of this all-hydrocarbon composites ("All-HC") consist of the same material. Therefore, matrix and fiber do not have to be separated during recycling, and all-HC are recyclable several times without loss of mechanical performance. The mechanical reinforcement is based on an orientation of the polymer chains during processing: the mechanical characteristics improve by a factor 4-6 compared with conventional poly(ethylene) The orientation can also be achieved in the nozzle of a 3D printer.

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Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.

The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future.

The Fraunhofer-Gesellschaft's interdisciplinary research teams turn original ideas into innovations together with contracting industry and public sector partners, coordinate and complete essential key research policy projects and strengthen the German and European economy with ethical value creation. International collaborative partnerships with outstanding research partners and businesses all over the world provide for direct dialogue with the most prominent scientific communities and most dominant economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research.

The impact of applied research goes far beyond its direct benefits to clients: Fraunhofer institutes enhance businesses' performance, improve social acceptance of advanced technology and educate and train the urgently needed next generation of research scientists and engineers.

Highly motivated employees up on cutting-edge research constitute the most important success factor for us as a research organization. At the Formnext 2022, they will showcase the technologies that will truly shape the future of 3D manufacturing.

Fraunhofer. WeKnowAM.