Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung-27

Grenzenlose Fertigungsfreiheit

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Ob als Zwischensohlen von Turnschuhen, Triebwerkskomponenten von Flugzeugen oder Knochenimplantate: Die additive Fertigung ist bereits Teil unseres Alltags. Sie bietet sich immer dann an, wenn besonders komplexe, filigrane Geometrien gefragt sind und herkömmliche Verfahren an ihre Grenzen stoßen. „Alles, was vorstellbar ist, ist additiv herstellbar“, fasst Prof. Katrin Wudy zusammen. Gemeinsam mit ihrem Team erforscht sie die vielfältigen Möglichkeiten für die additive Fertigung von Serienbauteilen aus Kunststoff und Metall. Sie analysieren, wie sich Prozesse verbessern und neue Werkstoffe verarbeiten lassen. Ihr Fokus liegt auf dem sogenannten pulverbettbasierten Schmelzen (Powder Bed Fusion). Hier wird der eingesetzte Werkstoff als Pulver verarbeitet, das aus vielen Partikeln besteht, die einen Durchmesser von gerade einmal 50 Mikrometern aufweisen – was dem Durchmesser eines menschlichen Haares entspricht. Damit wollen Katrin Wudy und ihr Team die Prozesse für die Serienfertigung voranbringen und neue Materialien erschließen. □

Picture credit: Stefan Woidig; Graphics: ediundsepp

Unlimited Freedom in Manufacturing

Link
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If you come across a particularly complex filigree part, chances are it was made by way of additive manufacturing, also known as 3D printing. Additive manufacturing technologies are becoming firmly established in industry and enabling a much, much wider range of components to be produced. But there's still a great deal of research to be done. Prof. Katrin Wudy and her team want to drive the processes for series production forward and tap into new materials.

Prof. Katrin Wudy

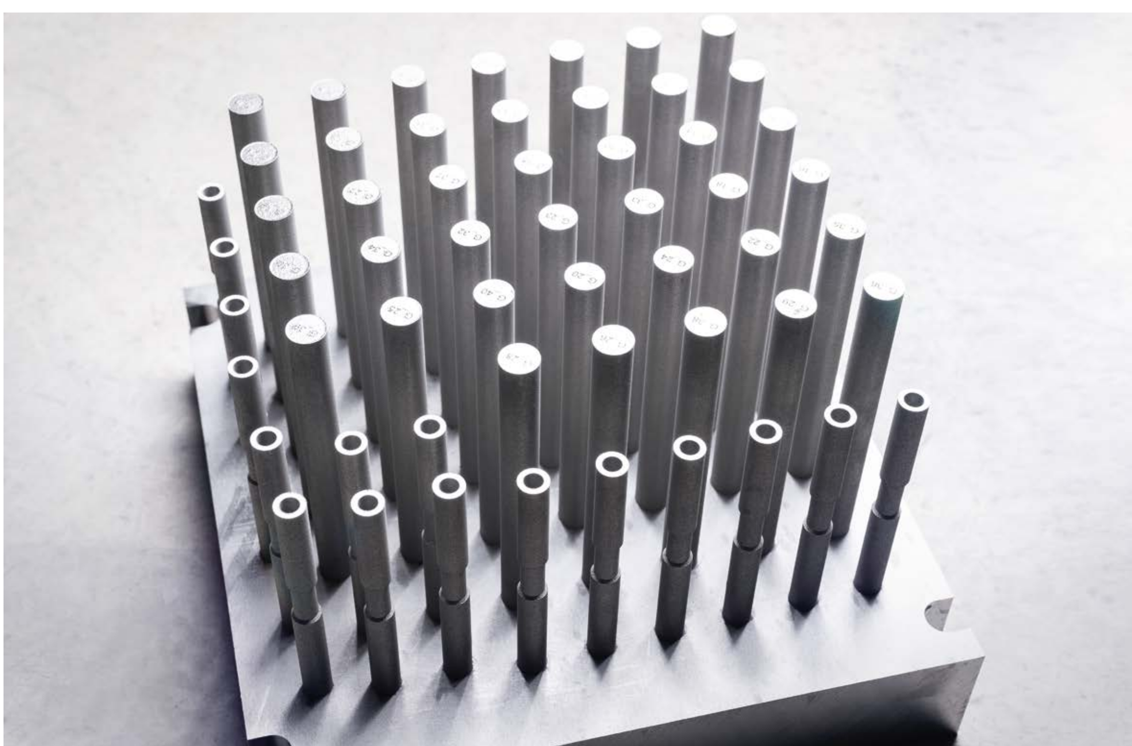
obtained her PhD in powder- and beam-based additive manufacturing from Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in 2017. From 2015 to 2019, Katrin Wudy was Managing Director of Collaborative Research Centre 814 “Additive Manufacturing” at FAU. She was appointed Professor for Laser-Based Additive Manufacturing at TUM in 2019. The industrial and practical relevance of her research is very important for Katrin Wudy. That’s why she and her team bridge the gap between fundamental research and application-driven projects with industrial partners.

"Additive manufacturing has become part of our everyday lives," Katrin Wudy says, pointing to her shoes. The trainers she's wearing have white midsoles with a lattice structure that ensures the shoes can cushion impacts effectively. "Very comfy," says Wudy, smiling. And that's not all. Most importantly, they're also 3D printed.

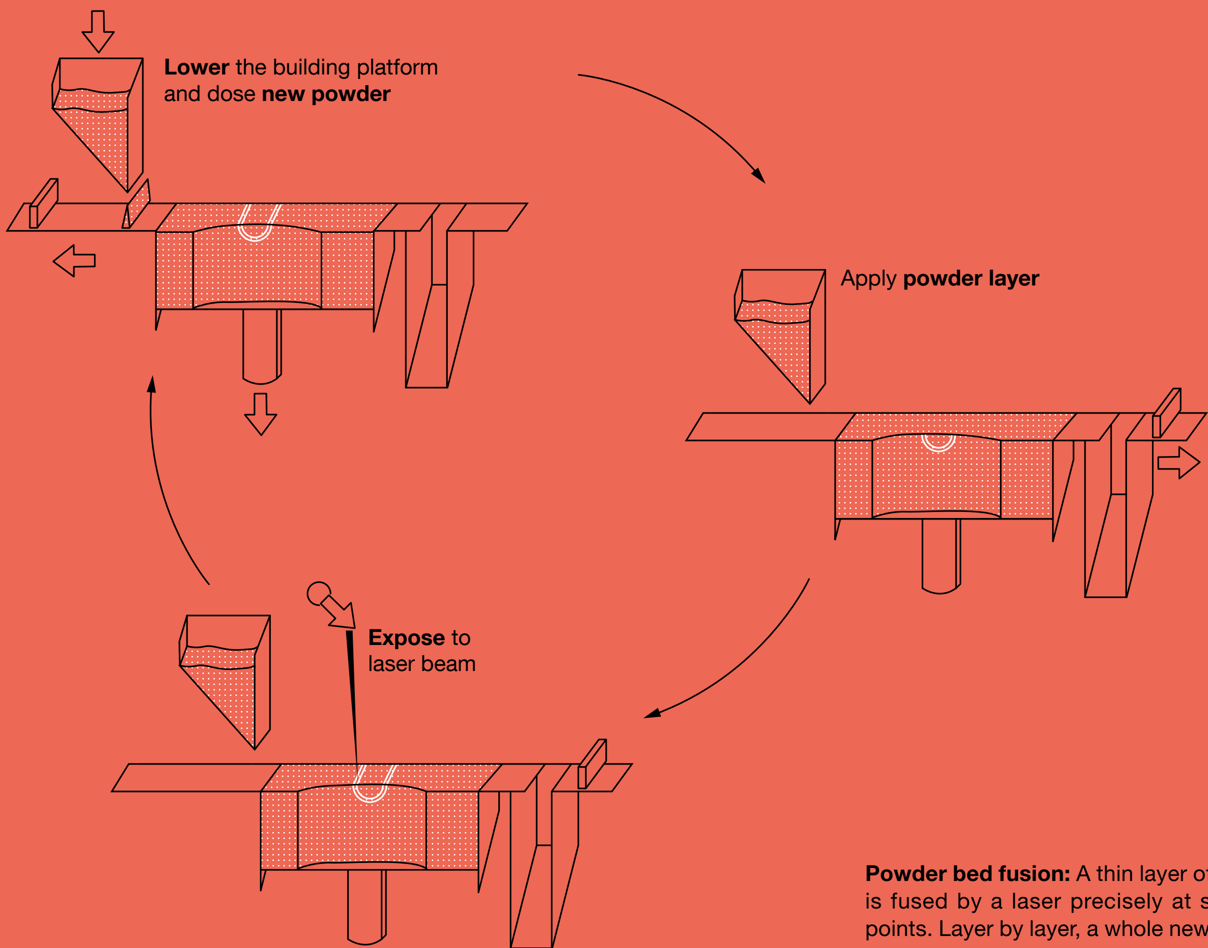
Whether it's in the form of these midsoles, fuel nozzles, mascara brushes or bone implants, we find the results of additive manufacturing almost everywhere. They often have complex, intricate geometries that conventional techniques struggle to cope with. Just why is this the case?

Additive manufacturing offers virtually unlimited design freedom, because the components are built up layer by layer based on a digital data model – with no need for any tools or molds whatsoever. It also allows materials to be used that would otherwise push traditional manufacturing methods to their limits. "If you can imagine something, you can use additive manufacturing to make it," says Wudy, putting it in a nutshell. "That's what I find fascinating about my area of research," she adds. ▷

Powder bed fusion of metals: Printed parts with support structures on a build platform.



Picture credit: Stefan Woidig



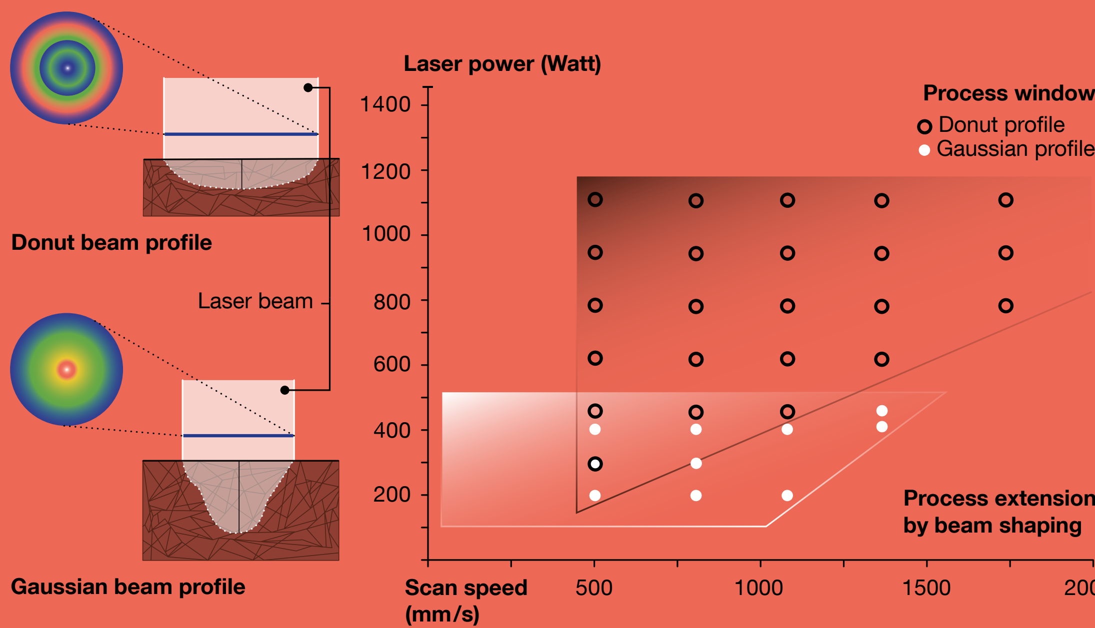
Powder bed fusion: A thin layer of powder is fused by a laser precisely at specified points. Layer by layer, a whole new component emerges.

Dual focus as global USP: Wudy's group researches additive manufacturing for both plastics and metals. Shown here: powder bed fusion of plastics (1) and metals (2) together with analyzing methods (3: plastics; 4: metals).

Mass-producing components

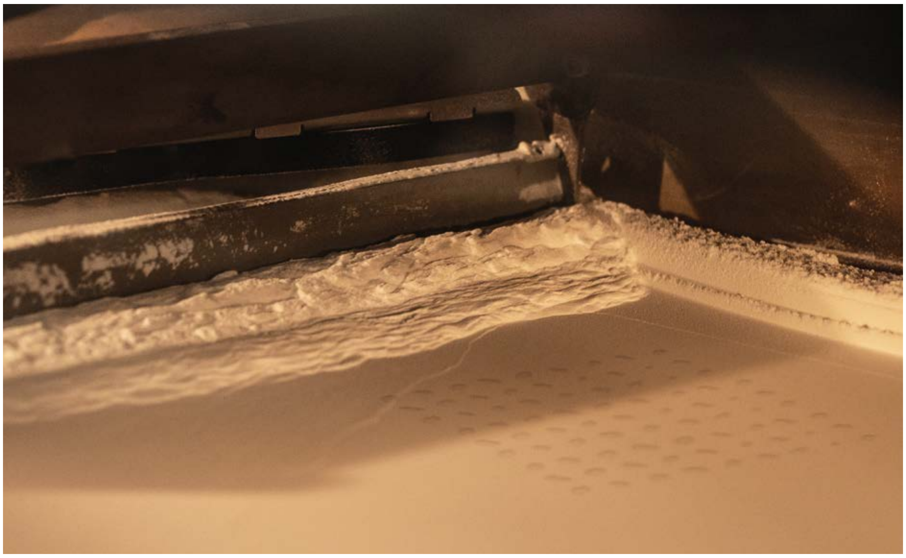
When they think of additive manufacturing, most people see a desktop 3D printer manufacturing different figures. There are several processes, however, that industry can draw on to make technically highly sophisticated products out of different materials. And this is precisely what Wudy and her team are interested in: they are analyzing laser- and powder-based additive techniques for mass products and studying how processes can be improved and new materials processed. Their focus is on "powder bed fusion", which uses as its material a powder consisting of spherical particles each just 50 micrometers in diameter – as thin as a human hair.

How does it work? First, a thin layer of powder is applied to a building platform of a production system, before a laser beam fuses this powder bed precisely at the points specified by the digital data model. The building platform is then moved down a layer, another thin layer of powder is added, and it too is fused on. In this way, a whole new component is created, one layer at a time. ▷

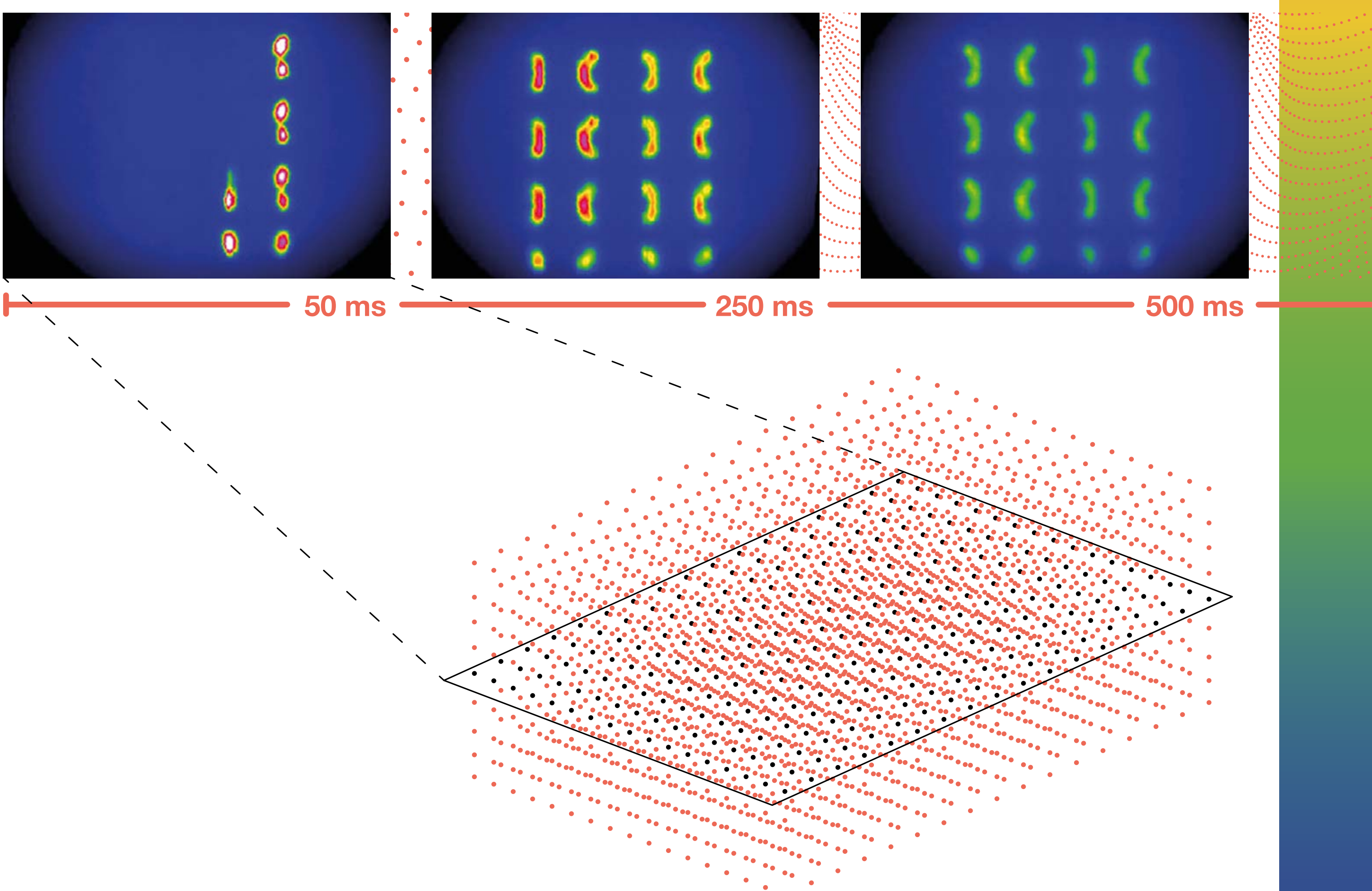


Speeding up metal additive manufacturing by varying the shape of the laser beam: A donut beam profile yields a large process window and thus allows for a faster laser process.

Picture credit: Stefan Woidig; Graphics: ediundsepp (source: Katrin Wudy)



Thermographic observation of the melting process as the laser beam moves across the powder bed.



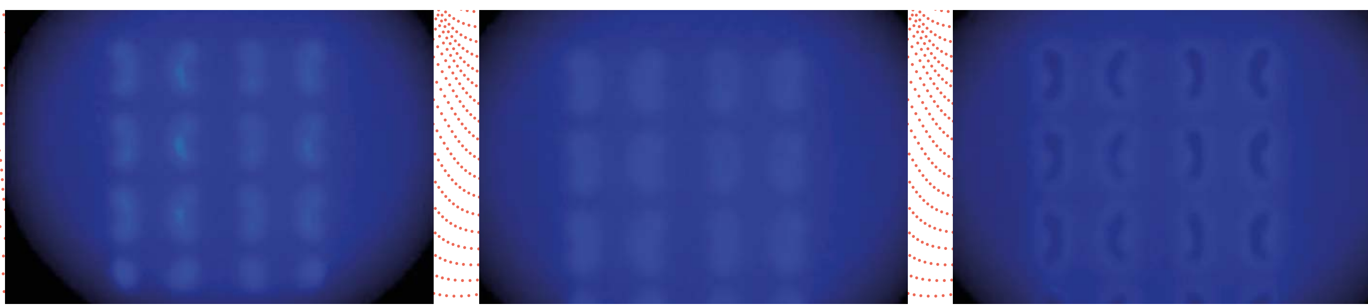
Implementing a new monitoring system for powder bed fusion of plastics to observe the thermal development of the melting process.

A focus on metal and plastic

The laboratory that Wudy shares with the Institute for Machine Tools and Industrial Management at TUM is home to five such machines plus a number of test benches. Here, she and her team are researching the additive manufacturing of plastics and metals in particular. This dual focus is a global USP for Wudy's professorship. "The industries are at different stages of research and manufacturing, so knowledge transfer is possible," she emphasizes. For instance, monitoring systems have already become well established in the metals sector but not for plastic powder bed fusion, where there hasn't been monitoring of the fusing process to date. This means that you don't know whether a component has been successfully manufactured – or not – until you take it out of the building process.

"If you can imagine something, you can use additive manufacturing to make it."

Katrin Wudy



1000 ms — 1500 ms — 2500 ms

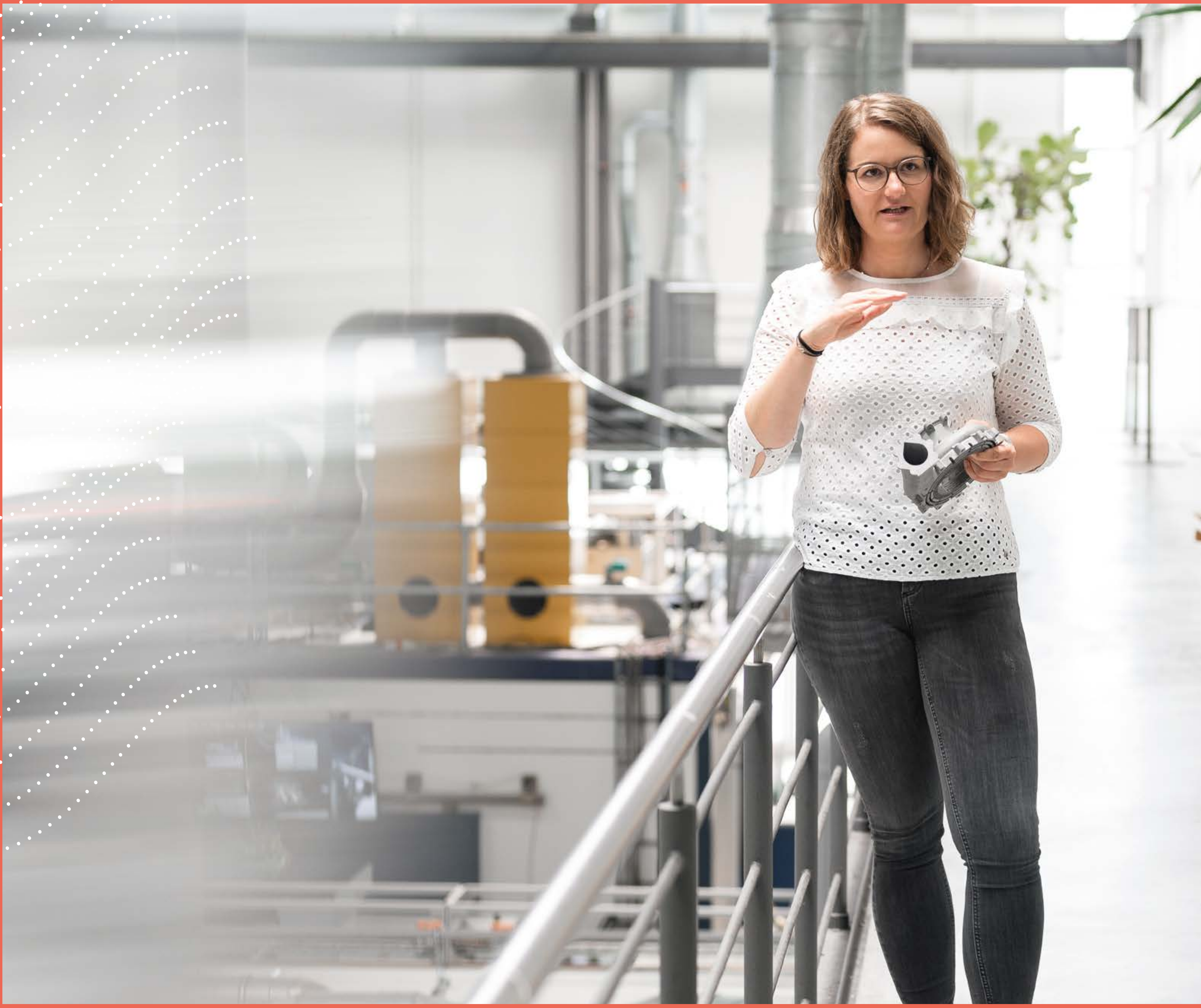
A great many process studies are needed, in other words. Wudy and her team are therefore keeping a close eye on various process parameters during manufacturing or processing so that they can evaluate the materials before the process has even finished. They are aiming high: in the future, hopefully, it will take a matter of days rather than months to develop stable additive processes for new materials. The questions that Wudy is seeking to answer are: What process parameters do I need to take into account for a stable additive process? How do I create a correlation with component properties? The critical factors include how the temperature changes over time and space during fusing and solidification. In order to monitor the temperature of the material during laser exposure, Wudy creates thermography images, which she analyzes in terms of how the fusing process develops over time.

When it comes to metals, Wudy and her team want to modify the melting process itself. The laser beam moves over the powder bed at speeds of up to a meter per second with a spot size of around 60 µm. This means that a very large amount of energy is delivered to a tiny area in an ultra-short space of time. Spatter and powder particles are flung out of the melt pool, which can introduce defects into the component. "We're now working on adjusting the energy input, such as by using different beam profiles, which is making the melt pool bigger and less volatile," Wudy explains. Today's state-of-the-art laser beam sources have an intensity profile that takes the shape of a Gaussian profile in their cross-section (see p. 47). In her tests, Wudy changed the energy input to a ring and donut profile and discovered that this enables her both to fuse larger areas and to speed up the process. A further benefit is that, since these ring and donut profiles allow the temperature gradient to be reduced during laser exposure, new materials can be processed. These include materials susceptible to cracking, such as hot-work tool steels. ■ *Gitta Rohling*

Picture credit: Stefan Woidig; TUM

"We want to develop novel additive manufacturing process strategies in order to realize the first-time-right production and to create products for the future."

Katrin Wudy



What position is additive manufacturing in today?

Some questions for Prof. Katrin Wudy


Picture credit: Stefan Woidig

Additive manufacturing is now part and parcel of everyday production in many industries. Where do some of the current challenges lie?
As well as optimizing the processes, we're also working on automating them. This is because many of the steps that come after the actual manufacturing process haven't been automated yet, such as releasing the components from the powder and then sorting them, or reusing the powder. We want to develop automated processes for this and get them stable.
Another challenge that we're working on solving is the fact that the range of materials that we could theoretically use in additive manufacturing has always been limited so far. Why's that? Because the micro-scale powder used in powder bed fusion has to exhibit decidedly specific properties, which makes sophisticated demands.

What's going to be studied in the future?
One issue that's going to be taking up more of our time is artificial intelligence (AI), which is becoming increasingly important in additive manufacturing, just like in many other industries. It'll definitely help us answer many of our research questions in the future. Right now, however, it's a question of analyzing and evaluating our datasets – and then gaining a better understanding of our processes and optimizing them. There's an awful lot of data to analyze on the components, which are often made up of thousands of layers. The advances made in AI for image recognition and analysis are proving particularly helpful for our monitoring, so we'll be working closely with our colleagues in Informatics going forward.
Overall, there's a lot of research needed in the field of additive manufacturing. After all, it's still quite a new research area. Although early additive manufacturing techniques were developed as far back as 1985, the first industrial applications only came about within the past ten years. There's still a great deal of progress we can make in research. The community that's researching and working here is young, dynamic, innovative – and keen to transform the world of manufacturing.
■

Gitta Rohling