It’s clear that object 3D-0426 was a failure. The result was a fuzzy grayish-white structure with ragged edges. It’s hard to tell what it was originally meant to be. However, its neighbor, 3D-0308, is a splendid specimen. It’s a clean and smooth sphere that seems to be itching to be used on the billiard table. Bags bearing cryptic lettering and filled with small, delicate sculptures, blocks, and spheres take up an entire shelf of the Evonik lab in the Marl Chemical Park.

Next to it are the cabinet-size 3D printers that made all of these parts from powdered material in cartridges. The objects are the result of test runs in which the appropriate printing parameters are sounded out, new formulations are tried out, and the properties of a batch of material are checked. This is accomplished by repeatedly printing the same standardized objects, which are then subject to standardized stress tests. Without such laborious quality checks, no company would be willing to have its products made by means of additive manufacturing, which is the technical term for 3D printing. This nondescript lab is, to a great extent, helping to shape the future of additive manufacturing. “We ask companies what they are working on and what materials they will need five years from now,” says Sylvia Monsheimer, who is responsible for the New 3D Printing Technologies Market Segment at Evonik. “By providing the right materials, we enable new printing technologies to be launched on the market.”

ONE TECHNOLOGY—MANY POSSIBILITIES

Monsheimer travels a lot in her capacity as an ambassador for 3D printing. She has an outstanding network that encompasses technicians and engineers as well as the board members of well-known companies. She wants to make people more aware of how additive manufacturing might completely transform business models. For example, what would happen if a company could easily and quickly try out new manufacturing ideas on its own? If it no longer had to take the limits of a mold into account when designing components? Or if it could rapidly produce small batches that would be too expensive to make by other means? Monsheimer tells us about a visit she made to a textile factory that would like to switch its machines to new fabrics and patterns more quickly. “That’s possible if you use printed parts,” she says.

Although Monsheimer has been working on 3D printing for more than 20 years, she has never seen as much creativity and enthusiasm as in the past three years, she says. “For a long time, a few dominant —
At the Evonik lab in Marl, Sylvia Manzheuer is examining how the printing of a sample is going along.

The Group’s latest investments and partnerships in Israel, China, the USA, and Austria all serve to make additive manufacturing ready for mass production. 3D printing is steadily spreading throughout industry. One example is the automotive sector, where startups such as the US company Local Motors have made a name for themselves. The startup’s autonomous shuttlebus “Olli” consists of 80 percent printed parts. These parts are produced by printers the size of garages. However, they basically work like the printers you can get for a couple of hundred euros at electronics stores. The printer heats a plastic filament from a roll and deposits it layer by layer. This technique is referred to as Fused Deposition Modelling (FDM). It’s a robust method that doesn’t produce any dust during the printing process. Moreover, professional devices produce such a precise result that they can print medical implants or copies of organs that surgeons can use to plan complicated operations.

Evonik’s Venture Capital unit recently invested in one of the technology leaders in this field. The company in question is the Chinese startup Meditechnology, which is working on the PEEK material from Evonik. This material is approved for medical use and Meditechnology uses it to create a variety of products ranging from cranial implants to artificial intervertebral discs (see the overview on page 14). Such partnerships provide the material developers at Evonik with insights into the idea pipelines of sector pioneers. In its discussions with these companies about new manufacturing techniques, Evonik finds out what properties future printing materials will need. The printer’s manufacturer, HP, which is well known in offices and homes, has transferred its expertise with inkjet printers to additive manufacturing. The component’s cross-section is printed onto a layer of polymer powder in black ink, and the heat lamps are then switched on. The black markings heat up faster than the other areas, so the material fuses together there. Then the next layer of powder is laid down. The cycle of inkjet printing followed by heating is repeated again and again until a black and gray component is removed from the powder bed and blown clean under an extractor hood.

This technology is called Multi Jet Fusion (MJF). BMW, for example, is already using it in production. In 2010 BMW began to use plastic and metal-based processes, initially for small batches. According to the automaker, it has since then used additive manufacturing to produce more than one million components, including waveguide brackets for the Rolls-Royce Dawn and window guiderails for the i8 Roadster. The Group also uses 3D printing to produce customized decorative inserts for the dashboard and the body of the Mini.

3D printing is still being primarily used to create trim or small parts that are invisible to car buyers. This is not surprising, since every new application first has to prove its worth in less critical areas. 3D printing primarily has to compete against the well-established injection molding technique, which has been enhanced over a period of many years. The advantages of 3D printing are that it enables freedom in design and opens up completely new opportunities for materials and processes. Today the company primarily targets professional users. VW, for example, uses Ultimaker printers to develop and produce tools and assembly aids at its factory in Portugal. As a result, the development costs have decreased by 95 percent, while the time savings even amount to 95 percent.

Fused Deposition Modelling (FDM)
The material in this process is a plastic filament that is supplied by a roll head and jetted onto the building platform. A print head liquefies the material in a nozzle that is similar to a hot glue gun. As a result, the components are created by layering out of plastic liquid. A second print head adds support material, which is deposited into cavities and on overhangs, for example, because the component has to be reinforced in these areas during the printing process. This support material is removed after the component is finished.

Jetting (J)
Similar to the Powder Bed Fusion process, Binder jetting uses a powder that is deposited layer by layer. However, the powder is not fused instead is bound together with a binder that is applied by a print head. Binder jetting is suitable for producing models for metal casting, for example, because they can be easily removed from the finished models by burning out.
A Futuristic Quartet

New technologies require new partnership models. Evonik is cooperating with other companies worldwide in order to investigate promising future applications for 3D printing. Here are four examples.

CUBICURE

A Tough Material

Just one year after Cubicure was founded, the company held its first talks with Cranio, the innovation unit of Evonik, in 2016. Although the young company, which is a spinoff of TU Wien—formally Vienna University of Technology—has extensive experience with promising 3D printing methods, its field still presents it with numerous challenges. Stereolithography (SLA) creates components out of a liquid resin that reacts with light. The process is extremely precise, “but conventional resins are brittle and most of the finished parts have a lot of warping,” says CEO Robert Gmeiner. The problem is that SLA techniques use low-viscosity materials. “It would be better to use high-viscosity resins and pastes,” says Marc Knebel, who manages the medical business at Evonik’s High Performance Polymers Business Line. “A customized product is created for each and every patient.” In 2019 Evonik became the lead investor in one of the sector’s most promising startups: the Chinese 3D printing specialist Meditool. The company, which is based in Shanghai, prints cranial, facial, and mandibular implants out of PEKK, a high-performance polymer that Evonik sells under the brand name VESTAKEEP®. Evonik was the first manufacturer to launch this product on the market as a medical-grade material. Meditool’s long-term goal is to grow in an even more ambitious segment: implants for spinal disc surgery. One of the first products it has developed for this purpose are cages—artificial intervertebral discs with which body tissue grows together. Evonik and Meditool now want to jointly determine how the research and practical clinical work in this area are developing. “Meditool offers a unique combination of technical competence and clinical expertise,” says Knebel. “We can help this company expand its global footprint.”

MEDITool

Artificial Bones

Artificial cranial implants, joints, and bone sections: “Nothing else are the possibilities of 3D printing coming into their own as much as in medical technology,” says Marc Knebel, who manages the medical business at Evonik’s High Performance Polymers Business Line. “A customized product is created for each and every patient.” In 2019 Evonik became the lead investor in one of the sector’s most promising startups: the Chinese 3D printing specialist Meditool. The company, which is based in Shanghai, prints cranial, facial, and mandibular implants out of PEKK. This is a high-performance polymer that Evonik sells under the brand name VESTAKEEP®. Evonik was the first manufacturer to launch this product on the market as a medical-grade material. Meditool’s long-term goal is to grow in an even more ambitious segment: implants for spinal disc surgery. One of the first products it has developed for this purpose are cages—artificial intervertebral discs with which body tissue grows together. Evonik and Meditool now want to jointly determine how the research and practical clinical work in this area are developing. “Meditool offers a unique combination of technical competence and clinical expertise,” says Knebel. “We can help this company expand its global footprint.”

EVOLVE

Hot off the Press

It all began with a used digital printer that had been bought discreetly in an auction on eBay and then rebuilt in a garage. The US startup Evolve emerged from a development project of the 3D printing company Stratasys. Today Evolve’s investors include Lego, and Stanley Black & Decker. The company’s technology is based on laser printing. An image is created on a roller by means of an electric charge. Toner sticks to the charged areas, and the image is then transferred onto a high-speed electrostatic belt and transported to a layer bonding mechanism. “We first deposit the image layer by layer,” explains the Vice President of Evolve, Rich Allen. “After that, we compress the structure while applying heat in order to produce a stable part.” The main advantages of this process, which is now in the commercialization phase, are as follows: It’s quick, because both the laser printing and the layer bonding process can handle a wide variety of materials. It can also print multi-materials within the same layer because it has five individual printing units. “In addition, because the particles are very tiny the image’s resolution is extremely high compared to traditional manufacturing techniques,” says Allen. Evonik has been working on materials for this process together with Evolve since 2019. “We became partners very quickly,” Allen says. “Both Evonik and our company are aware of this technology’s enormous potential for mass production.”

CASTOR

By Other Means

Caster supports manufacturers that are introducing 3D printing. This Israeli startup has developed a system that analyzes engineering designs using their underlying CAD files and simultaneously evaluates thousands of components. It works out what kind of geometry characteristics each component needs to have, what kinds of processes and materials could be used to print them, and whether 3D printing would pay off. Caster is initially focusing on complex components that are manufactured in small batches. Its customers include several Fortune 500 companies. “We help companies harvest very low-hanging fruit,” says the company’s co-founder and CEO, Omer Blaier. “We also help them to adapt their engineering designs to the 3D printing process.” For example, the Caster system suggests which of the components that are located close together can be printed in 3D as a continuous workspace. It also recommends services that support customers as they convert their production processes to 3D printing. Caster does not create any fundamentally new designs. “That’s still the job of the engineers. We only help them along the way,” Blaier says. He regards Evonik’s entry as a new investor in Caster as a win-win situation: “Evonik’s expertise as we improve our software.”

Jetting along: Evolve’s technology enables combinations of various materials to be printed quickly
COVER STORY: 3D PRINTING BACKGROUND

In Marl, Evonik creates hundreds of test objects each week in order to improve materials and processes for researchers and engineers to develop lightweight components and create totally new functions. “We are completely redesigning the parts for 3D printing so that they will have the properties we want,” says Monsheimer.

This process is simplified by a new partner of Evonik: the Israeli startup Castor (see the overview on page 15). The company’s software conducts a comprehensive technical and economic analysis in order to determine when additive manufacturing is economical compared to conventional production methods.

A component that is reinvented for 3D printing often has little in common with the original part. Whereas an injection-molded part has to be heavy and massive so that it can withstand great stresses, an equivalent 3D-printed part can have a seemingly filigree design consisting of arches, struts, and honeycomb structures. It can withstand stresses just as well as the injection-molded part but weighs only a fraction as much. As a result, even as simple a part as the window guide-rails of a rooftop gives us a preview of how entire automobiles will be built in the future.

LIGHTWEIGHT PARTS FOR FLYING OBJECTS

These weight reductions make additive manufacturing a very interesting technique for aircraft construction. Every gram counts in this sector, and there is a rising demand for more fuel-efficient machines that are less damaging to the climate. The innovations of additive manufacturing are initially inconspicuous here as well. The US Air Force, for example, uses 3D printing to produce replacement parts for its veteran jet planes. The fact that 3D printing made a toilet seat much lighter but still robust thanks to the use of a honeycomb structure was considered newsworthy within the sector. The components that are being developed by the aircraft manufacturers Boeing and Airbus are more critical to an airplane’s operation. Metal powders are now being used to make the first wing and engine components, and the 3D printing of plastic parts is becoming increasingly common for cabin furnishings. In this case, it would often also be too expensive to create injection-molded parts—for example, when an airline modernizes its fleet. Such tasks require the expertise of specialists like the Belgian company Materialise, which, among other things, uses high-performance polymers to print components for Airbus.

According to Monsheimer, greater production volumes will, more than anything else, require additive manufacturing to become faster. “The process will become especially interesting for the automotive industry when we begin to produce tens of thousands or hundreds of thousands of units,” she says. The new partnership between Evonik and the US startup Evolve (see the overview on page 15) might be the key to unlocking this potential. The startup’s technique, which is known as STEF, basically works like a laser printer and thus achieves much higher speeds.

“Conventional powder-based processes always use a laser or print head that traces the print shape on the powder bed,” explains Innovation Manager Wolfgang Diekmann, who heads the 3D printing lab in Marl. “STEF, on the other hand, uses digital printing technology. The material is very quickly picked up by a drum, which then deposits it. Because the powder is very fine, the resulting component has a higher resolution than would otherwise be the case.”

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Econavik is contributing its decades-long experience with materials to the partnership, creating a win-win situation in the process, says Monsheimer. “We can develop new materials when we have a machine that we can test them with. Our partners, in turn, can develop a new machine when they have access to good materials,” she adds. As a result, the technical center in Marl is a veritable exhibition of the international 3D printing sector. In addition to machines from HP and 3D Systems, the center has devices from the German market leaders EOS and Vossjet, the Swiss company Sintratec, and the Chinese manufacturer TPM. The devices are extensively used, as is demonstrated by an opthalmic printer that Monsheimer is inspecting. “We want to know not only which materials we can develop for existing technologies but also how the existing technologies might be made better,” she says.

ADDITIVES FOR NEW PROPERTIES

This approach has enabled Evonik to move to more or less incidentally develop several 3D printing technologies of its own, which it licenses to other companies. “We have experimented with variants of High Speed Sintering (HSS),” says Monsheimer. In this technique, the powder is not directly melted by a laser, but instead an absorber is applied at the desired points. A heat source is then passed across the layer, similar to the approach used in Multi Jet Fusion.

Owning in-depth knowledge of such processes helps Evonik develop new powders for a variety of printing techniques, says Diekmann. “Depending on the requirements, it takes us between six months and two to three years—sometimes even more—to create a new material.” Polyamide 12 (PA 12), which is used in innumerable applications, often serves as the basis to which the developers at Evonik give new properties with the help of additives. “Flame retardants, for example, make it suitable for use in the electronics industry or in components for aerospace applications,” says →

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Diekmann. “And when a material has to be especially robust, we add glass particles, for example.”

The lab in Marl also creates completely new combinations of materials. Last year, for example, Evonik presented the high-performance powder PA 613, which combines the advantages of long-chain and short-chain polyamides. This powder is thermally stable, strong, and nonetheless flexible. Moreover, it absorbs little water. In 2018 the thermoplastic elastomer PEBA (polyether block amide), which was introduced in the 1980s, served as the basis for a powder that enables objects to be printed that have an almost rubber-like consistency.

“No other company in the world has as many different powder manufacturing methods as Evonik,” says Grosse-Puppendahl. What’s more, many of the applications that are still not possible should be achievable with a new production technology that the company purchased in 2019. This process was developed by the US startup Structured Polymers and enables a lot more materials to be pulverized than Evonik could achieve before. The best example of this is a new copolyester powder, which was also the first material to be produced with this innovative technology.

**POWDE RS AREN’T THE ONLY PRINTING MATERIALS**

The experts are also investigating other starting materials besides powders. Startups such as the Austrian company Cubicure (see the overview on page 14) and Creavis, the strategic innovation unit at Evonik, are working not only on powder-based processes but also on printing techniques in which the workpiece is drawn from a liquid photopolymer. Light sources such as lasers harden this light-sensitive material at the desired points. The precision is unparalleled, says Cubicure CEO Robert Gmeiner. “The resolution is only defined via the optical mask, which can be set with extreme precision,” he adds. Moreover, only ten percent of the starting material cannot be used for further printing after production. “Powder-based methods are a long way from achieving that.”

Other SLA-printing manufacturers are also working on the development of new materials in cooperation with the specialists at Evonik. Last year Evonik opened a new research hub in Singapore, where formulation specialists are developing next-generation photopolymers. “There’s still a lot of uncharted territory in the field of polymers,” says Monsheimer. But that is precisely why this work is so intriguing for Monsheimer and Diekmann. “Ever since I started to work here, I always wanted to get away from the principle of ‘One company, one process.’ I’m delighted that this is now happening,” she says.