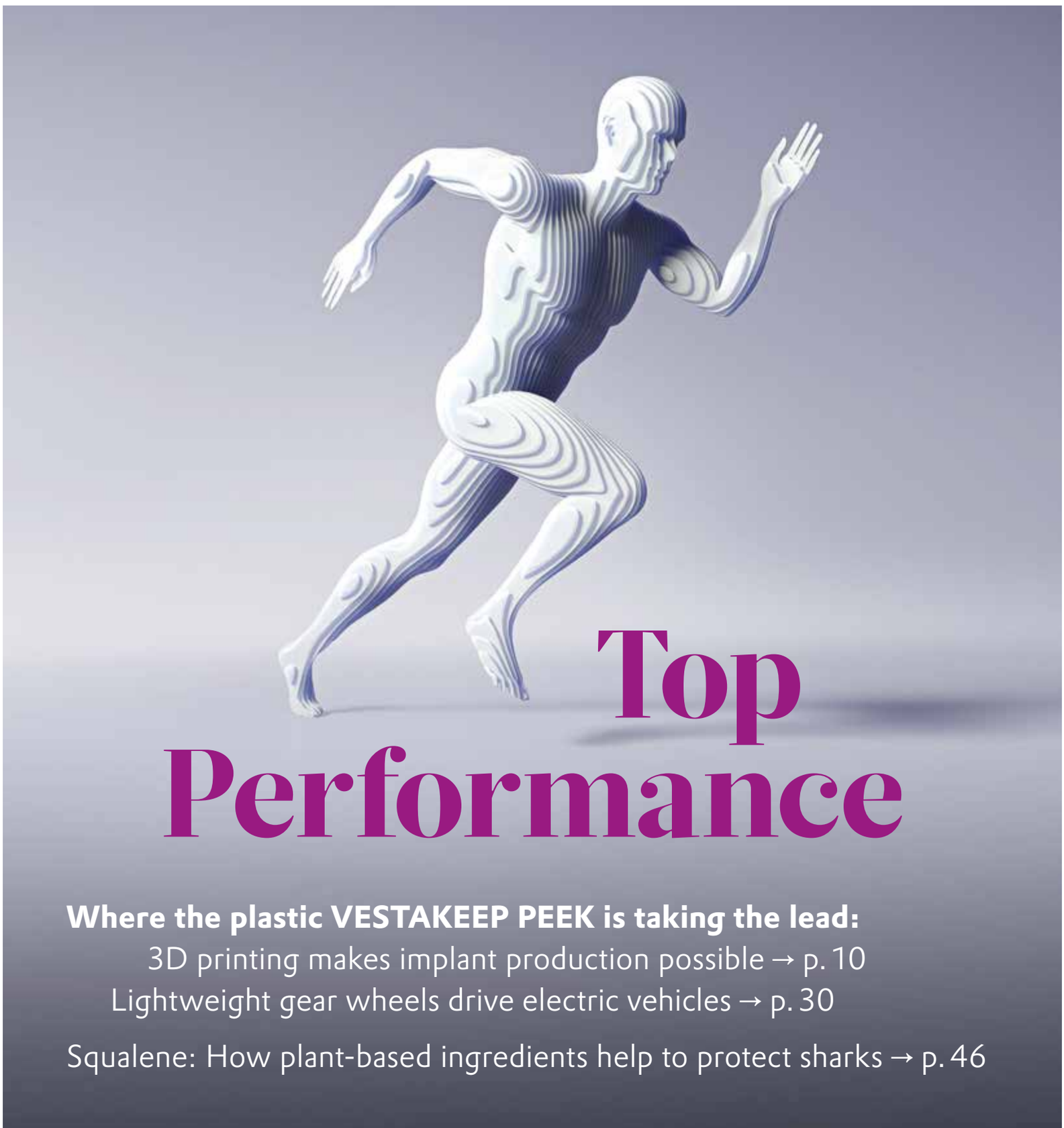
1/2024

EVONIK
Leading Beyond Chemistry

ELEMENTS

Research. Knowledge. The future.



Top Performance

Where the plastic VESTAKEEP PEEK is taking the lead:

Polyether ether ketone (PEEK)

A high-performance polymer

PEEK, an important material from the polymer group, was discovered in 1978. Its characteristics make it a high-tech raw material with a multitude of applications. PEEK is available as a powder or filament, and it can be molded, 3D printed or milled. It's a plastic that is extremely durable, recyclable, dimensionally stable, and light. PEEK is resistant to hydrolysis and impervious to weak acids and alkalis. The chemically stable molecular structure of this plastic makes it resistant to beta and gamma radiation. This is an important requirement in areas such as medical technology. Sectors such as aircraft manufacturing benefit from the low flammability and smoke emission of this material. The melting temperature of PEEK is 335 degrees Celsius. At temperatures between approximately -60 degrees and +300 degrees Celsius it has a high level of mechanical strength and rigidity.

Polymers Substances consisting of one or more identical molecular building blocks
Resistant to hydrolysis This is said of a material that remains stable when it comes into contact with water; it neither changes its structure nor decomposes
Rigidity A value in engineering mechanics that expresses a body's resistance to elastic deformation by a linear force or a torque

DEAR READERS,

Many people associate the word "plastic" with concepts such as "cheap," "mass-produced" or "short-lived." But the adjective "plastic" has a different set of associations. It can also mean malleable, with regard to shaping or modeling, or sculptural, in the sense of well-formed.

That's the real meaning of the word "plastic:" malleability that makes almost endless variety possible. In this issue we present two examples of how plastic helps to solve problems that would be hard to solve otherwise. Chemists and engineers have trained plastics to be high-performance polymers. These are not mass-produced goods—they're high-tech materials.

The first example is electric mobility. Many e-vehicles are too heavy and have ranges that are too short. A project group associated with the Technical University of Munich has now demonstrated that even highly stressed electric vehicle components such as gear wheels can be made of plastic. This not only reduces noise but also saves weight and thus increases the e-vehicle's range. The researchers are already working on the next components that can be replaced by plastic.

The second example leads into the human body. Physicians and institutions that deal with medical technology closely monitor whether a product delivers the result promised by the manufacturer. They also investigate whether the product is safe, because it affects human lives. A real-life Gyro Gearloose in the USA has overcome these obstacles, thanks to a high-performance polymer from Evonik. His innovative vertebral implants offer patients huge advantages. The implants' special feature is that they can be 3D printed.

Another topic in this issue also has to do with endless variety—in this case, the endless variety of Evonik's work. Sharks are hunted all over the world—because of their meat, but also because of valuable substances such as squalene in their liver. Evonik has developed a process for producing squalene, which is an important ingredient of certain drugs, from plants. That's a small contribution to the preservation of biodiversity in our oceans—entirely without plastic, for a change.

I wish you pleasant reading and new insights. If you have any questions, recommendations or criticisms, please write to me at elements@evonik.com

Jörg Wagner
Editor in Chief

All of the articles from the printed magazine, as well as additional current contents, are also available on the Internet at elements.evonik.com

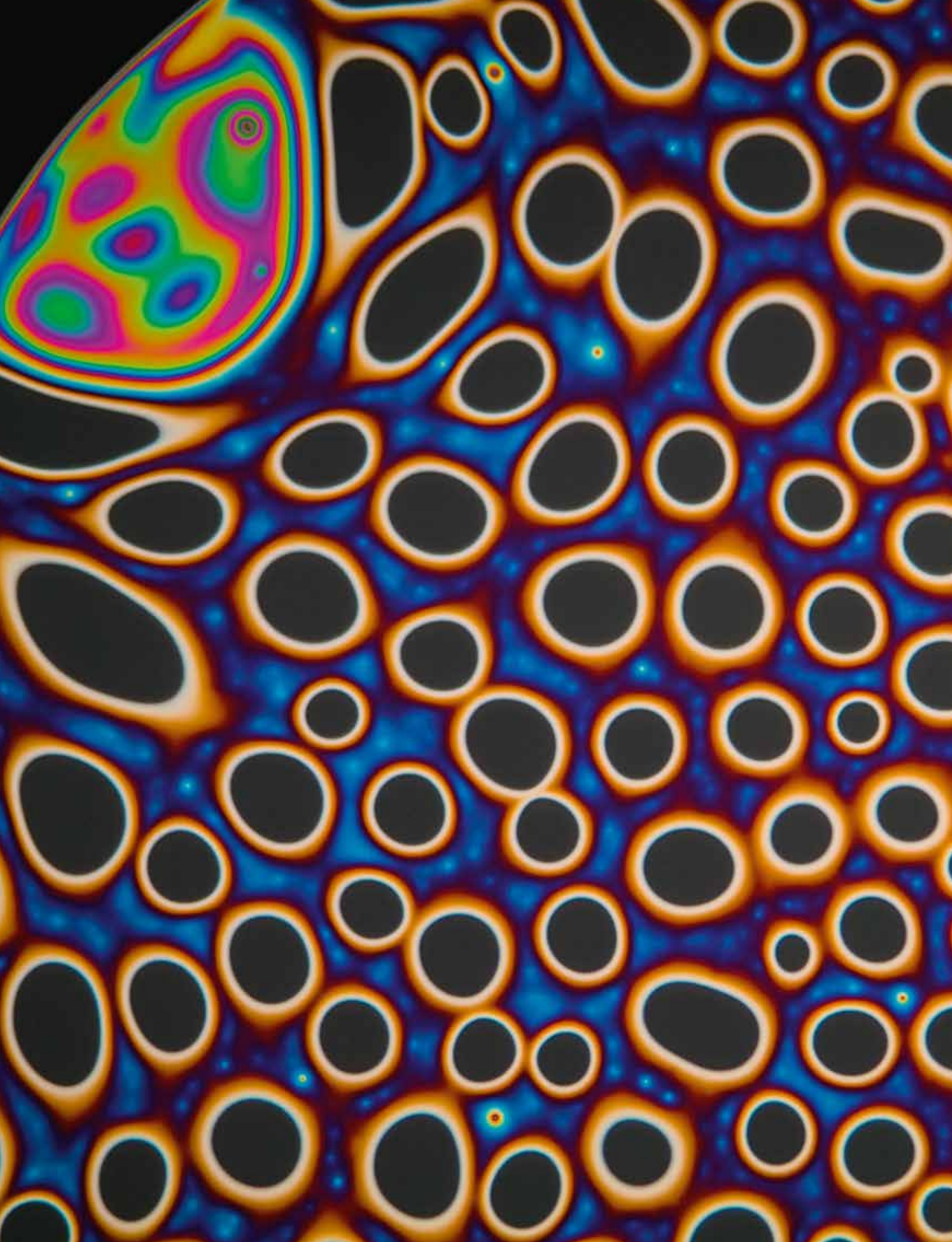
Printing instead of milling: At the medical technology company Curiteva in Alabama, 3D printers like this one are producing implants that make life easier for patients with diseases of the spinal column

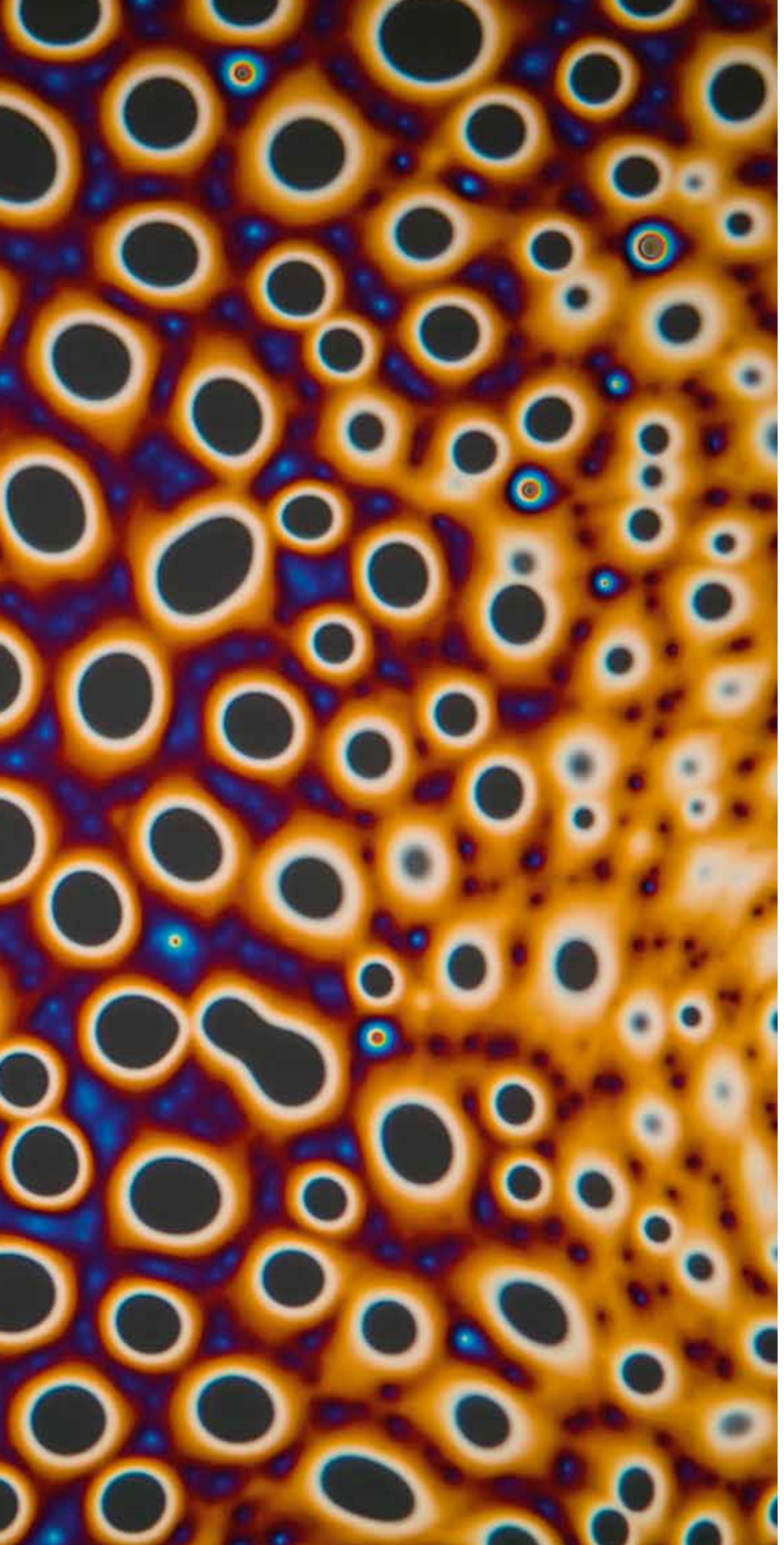
HIGH-PERFORMANCE POLYMERS

Rima Jaber aims to establish a product derived from amaranth plant oil as a sustainable substitute for squalene

BIODIVERSITY

The Twizy test car uses a transmission containing gear wheels made of plastic, thanks to the cooperation between Evonik, TU Munich, and the automotive supplier Werner Bauser





The United Nations has defined 17 Sustainable Development Goals (SDGs) to ensure the sustainable development of the world. Evonik is also making a variety of contributions to support this project. We present them here

Access to **CLEAN WATER AND SANITATION** is a human right that has not yet been realized for billions of people. Evonik is committed to the responsible use of water—for example through the development of **BIOSURFACTANTS**.

Surfactants enable detergents, shower gels, shampoos, and dishwashing liquids to have a cleaning effect. Evonik has developed biosurfactants that are especially environmentally friendly and gentle to the skin without sacrificing any of their cleaning performance. Known as rhamnolipids, these biosurfactants are produced in Slovenská Ľupča (Slovakia). In May a new plant will be inaugurated there that produces rhamnolipids on an industrial scale for the first time.

The Düsseldorf-based photographer Gerd Günther uses a microscope with 40x to 100x magnification to capture the interplay of colors on soap skins, which results from layers of different thickness

Plastic bags provide safety

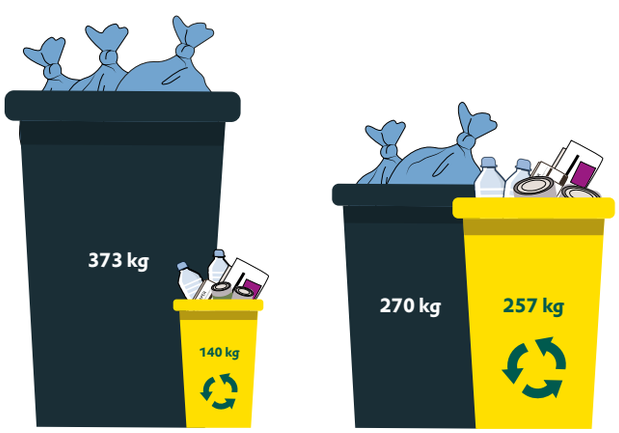
Discarded bags provide reagents for chemical reactions in industry and open up new avenues for the circular economy

Scientists in Japan have developed a new process that transforms ordinary plastic bags into a valuable raw material. Specifically, a team led by Koji Kubota, an associate professor at the Institute for Chemical Reaction Design and Discovery (ICReDD) at Hokkaido University, crushed plastic shreds made of polyethylene or polyvinyl acetate in a ball mill. In this apparatus, a steel ball repeatedly strikes the plastic particles. The mechanical force acting on the polymers was so great that radicals were formed—highly reactive molecules that can trigger a self-sustaining chain reaction. Kubota and his team used polyethylene as a chemical reagent for a radical reaction. The attempt was successful, as the researchers managed to remove several halogen atoms from a compound that is normally used as a flame retardant. Previously, industrial companies used potentially explosive compounds for this purpose, which made chemical processes of this type dangerous in some cases. The cost and safety advantages make the researchers confident that the process could be effective in an industrial environment. There is also a positive environmental aspect, because this unusual use of bags makes it possible to recycle plastic in new ways and make the circular economy more successful.

THAT'S BETTER

Less is more

Municipal waste landfilled and recycled per capita in the EU



Every EU citizen produces more than half a ton of waste per year. In 2000, just 27 percent of this waste was recycled; the rest was sent to landfills or incinerated. In 2021, 14 kilograms more municipal waste was generated per capita, but almost half of the waste was recycled. This is achieved, among other things, through material recovery, in which plastics are processed into granules and thus prepared for a new use, or through biological recycling, for example composting.

Source: Eurostat

20,000

LIGHT PULSES PER SECOND

are needed to detect fast electron movements. A Swedish-German research team recently used a laser to shoot attosecond light pulses (an attosecond is one billionth of a billionth of a second) onto a crystal surface, allowing electrons to be examined. The findings might help to produce more powerful energy storage systems.

PHOTOACIDS …

… are alkaline molecules that become acidic when exposed to light. Researchers at ETH Zurich used this effect to efficiently remove carbon dioxide (CO_2) from the atmosphere. To do this, they passed air in the dark through an alkaline liquid containing photoacid. The CO_2 from the ambient air reacted in the liquid to form salts of carbonic acid. Once they had accumulated, the liquid was exposed to light and thus became acidic. The salts reacted again to form CO_2, which bubbled out of the solution and could be easily separated. The process is reversible, but still needs to be optimized before it can be used in technology.

PEOPLE & VISIONS

"Our glue is water-based, reversible, and even sticks to difficult surfaces"

THE PERSON

Dr. Mark Geoghegan is Professor of Engineering Materials at Newcastle University in the UK. "Being a scientist was not the big motivation, I liked finding out how things work," says the physicist. With its "culture of curiosity," as he calls it, the University of Cambridge was the perfect place for him to do his Ph.D. project in polymer physics. This was followed by postdoctoral positions, including one in Bayreuth, where he came up with the idea of researching reversible adhesion, which is now his professional focus.

THE VISION

In 2022, Geoghegan held a finished product in his hands—15 years after the initial concept. "Our glue is water-based, reversible and sticks to difficult surfaces," he says. The trick is to use electrostatic adhesion: If a surface treated with the positively charged adhesive is connected to a negatively charged one, they stick to each other. Only when the pH value changes, for example when lemon juice is added, does the join dissolve. This helps with recycling, because the adhesive enables polypropylene labels, for example, to easily detach from PET bottles.

Sunshine on wood

With the help of kraft lignin, organic solar cells could be produced without petroleum-based materials in the future

Swedish researchers have developed a new composite material for particularly environmentally friendly solar cells. Conventional solar cells made of silicon are efficient, but their production is energy-intensive and complicated. Researchers at Linköping University and the Royal Institute of Technology in Stockholm have now developed an organic solar cell in which part of the electron transport layer consists of a renewable raw material.

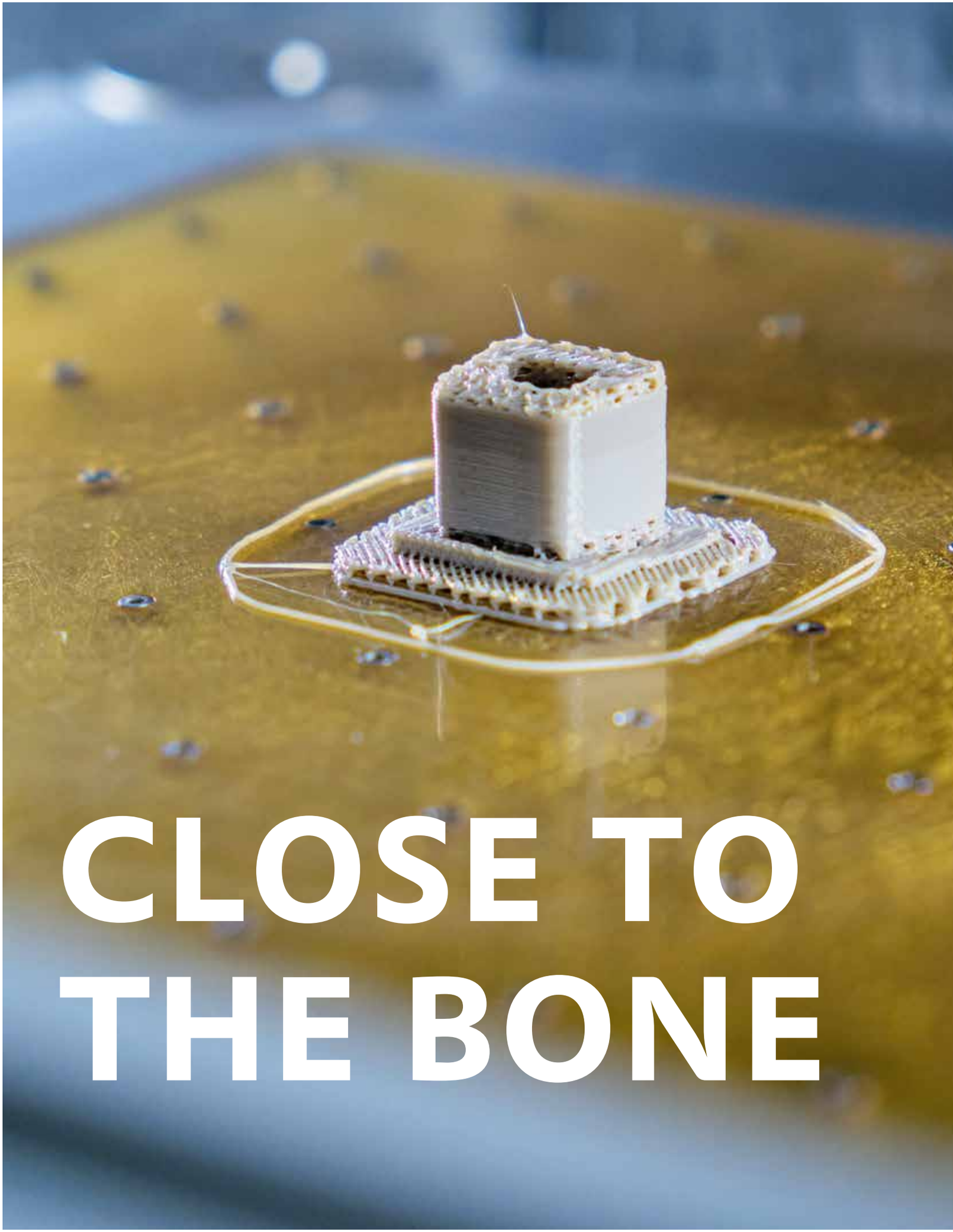
This material, which is called kraft lignin, is extracted directly from wood during paper production. The new composite material is environmentally friendly and makes the solar cells particularly stable. The reason for this is its ability to form hydrogen bonds, which act like a kind of glue at the molecular level. So far, only a small part of the solar cell is made of lignin, but in the long term it could be produced almost entirely from wood materials.

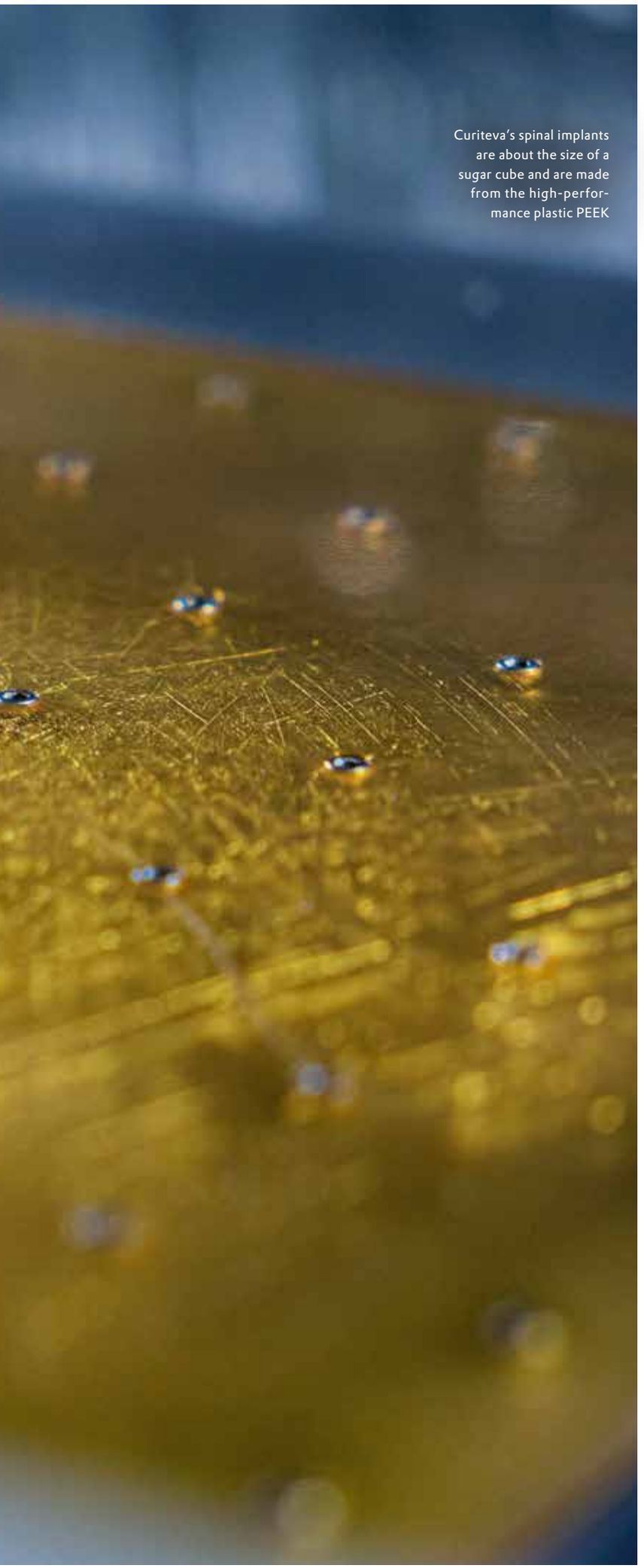
GOOD QUESTION

Ms. Devi, are headaches after red wine a question of chemistry?

Yes, most likely. Even small amounts of red wine can cause some people to get headaches. However, to date no single chemical constituent has been identified as the primary trigger. After testing about a dozen compounds contained in red wine, we became aware of a substance that could be responsible for the headaches: quercetin, which is found in grape skins and is known for its antioxidant properties. If the substance enters the bloodstream, the body converts it into quercetin glucuronide, which inhibits the breakdown of alcohol. The slowing down of the process causes acetaldehyde to accumulate in the body—a toxin that is often associated with negative effects such as headaches. Ongoing research, including clinical trials, is under way to prove this hypothesis.

Apramita Devi is a postdoctoral researcher in the Department of Viticulture and Enology at UC Davis, California.


CLOSE TO
THE BONE



Curiteva's spinal implants are about the size of a sugar cube and are made from the high-performance plastic PEEK

PEEK is an important material in the medical device industry. Together with an ambitious inventor and entrepreneur, Evonik has developed a variant of the thermoplastic that allows the manufacturing of 3D-printed implants that could improve the health of patients

TEXT **CAROLYN LAWELL**

Todd Reith has a list of admirable abilities: software engineer, manufacturing entrepreneur, implant developer, guitar maker. Materials scientist was not one of them when the then Founder and Inventor of FossiLabs in West Chester, Pennsylvania, set out to develop a process to 3D print polyether ether ketone (PEEK) spine implants in 2017.

PEEK is a thermoplastic. The material softens through heating before being processed and left to cool and harden into its desired shape. It's known for its excellent mechanical and chemical-resistant properties and, therefore, is used in demanding applications across numerous industries, from engine components in cars to fuel systems in aerospace to implants in medtech. →

While PEEK was developed more than 40 years ago, it continues to evolve as materials companies produce new formulas and manufacturers build new applications with the polymer. A real quantum leap has now been made by 3D printing the material. It provides patients with spinal disorders better surgical options and thus a better quality of life. This is the result of a fruitful collaboration between a visionary inventor, Reith, and Evonik, a company with an extensive knowledge of materials. Reith's previous experiences provided him the opportunity to work with different materials and engineer expandable spine cages. That effort led him to believe that 3D-printed PEEK could be a pioneering innovation in orthopedics. He founded FossiLabs, a one-man shop in his basement, and set to work building a 3D printer from scratch. But his limited expertise in the material quickly opened Pandora's box.

When a patient experiences instability in their spine, a surgeon might remove the intervertebral disc and replace it with an implant. The goal is for the implant to attach or fuse to the vertebra bones above and below the device to reduce motion and stabilize the spine. Thus, implant materials play a critical role in a patient's recovery process. While every patient responds differently to surgery, implant materials can help with a quicker fusion or decrease the tissue scarring around the implant, both of which are important for the short-term and long-term health of the spine.

The X-ray image was taken one month after spinal surgery. The patient has a Curiteva Inspire implant between the sixth and seventh vertebrae

PEEK gained adoption in the orthopedic spine market for multiple reasons. The material is radiolucent, allowing physicians to assess the amount of osseointegration, without the implant or artifacts blocking the view in the X-ray or CT image. Furthermore, PEEK nearly matches the modulus of the surrounding bone, making it an ideal material for manufacturers of implants.

However, it cannot attach or integrate the implant to the bone. Over time, companies have launched PEEK spine implants with surface modifications. They injection mold or machine the implant and then add a coating, usually metal, that promotes fixation of the device to the vertebrae. Others began to additively manufacture titanium implants. Additive manufacturing—or 3D printing—allows companies to build structures that let bone grow through and around the device instead of just attaching to its surface.

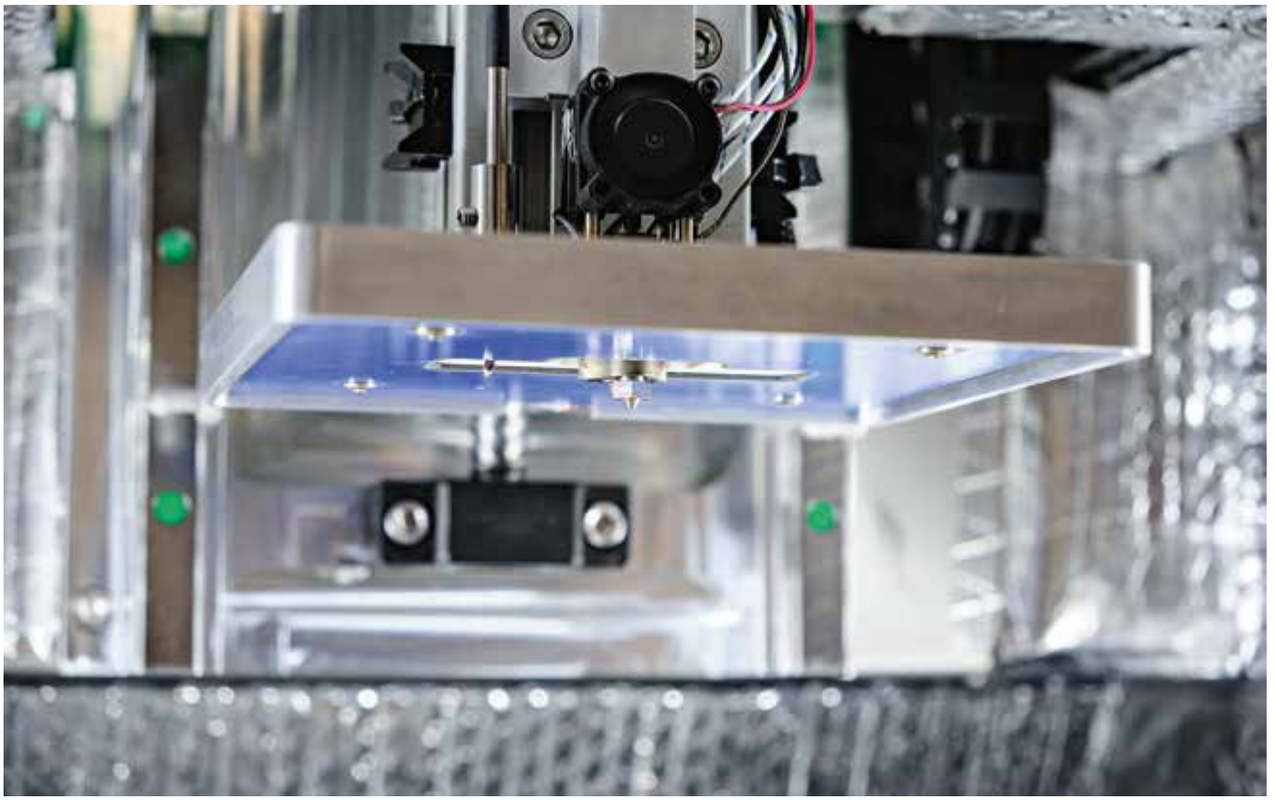
Reith believed that combining the best features of PEEK and 3D printing would create a superior technology. His aim was a fully porous spine implant that mimicked bone and integrated into it. "However, PEEK is nearly impossible to print," Reith says. "The first challenge was figuring out how to print the material consistently."

THE NEXT BIG THING

He knew that to achieve his goal, he would need the help of a materials company. Fortunately for him, Evonik's High Performance Polymers business line was in the development phase of its own implant-grade filament. Reith invited the materials company to see his work in his home lab, and a week later they put their support behind his efforts.

What has transpired over the last five-plus years is a collaboration of a David and a Goliath working together instead of sparing to pioneer innovation in the orthopedic market.

Evonik's flagship PEEK material, VESTAKEEP®, was launched in 2006 for use in various markets ranging from components in semiconductors to mechanical engineering for food and drinking water applications. Its implant-grade PEEK was first used in a spine device in 2013.



Curiteva implants are produced on Fused Strand Deposition (FSD) printers. Within the printer, a reflector ensures desired material properties by focusing thermal energy to the deposition layer

When Evonik saw the early adopters in this area 3D printing PEEK, the company's medical technology R&D team thought it could revolutionize the field, especially orthopedics—a $59 billion global market in 2023, according to market intelligence firm ORTHOWORLD Inc.

The company also has a rich history of developing materials that can be 3D printed. It, too, believed the marriage of 3D printing and PEEK could respond to surgeon needs and improve patient outcomes. Also, the application could have a wide range of potential, including patient-specific and standard implants for head, face, spine, and trauma applications. There's even an opportunity for point-of-care manufacturing, where a machine is put in a hospital, allowing surgical care teams to design and print anatomical models and implantable devices as needed. Further, surgeons and medical device companies were requesting implants with porous structures.

"We were visionary enough to say that this could be the next big thing in the market," says Marc Knebel, Global Segment Head of Medical Devices and Systems and Head of VESTAKEEP® Europe at Evonik.

Believing they could be the leader in this area, Evonik's global research team got to work to make VESTAKEEP® granules into a 3D-printable filament.

"The good thing is that we are using a material that has been in the implant market for more than ten years with approved applications all over the world," Knebel says. The technical challenge was to create a →

"PEEK is nearly impossible to print"

TODD REITH, INVENTOR AND VICE PRESIDENT EMERGING TECHNOLOGIES AT CURITEVA

filament that had very tight tolerances and fulfilled the requirements for medical implant applications.

Evonik developed a material specifically for fused filament fabrication (FFF), a type of 3D-printing technology that layers the material into a printed part. To achieve this vision, Evonik's scientists focused on the material's viscosity, the measure of a fluid's resistance to flow, and crystallization, the process by which a solid forms.

Each surgeon is supplied with an appropriate set of instruments and accessories to provide a successful surgery

An advantage of PEEK is that it's resistant to high temperatures. At the same time, this feature makes it harder to process: Most machines on the market 3D print standard polymers in a temperature range of 200 degrees Celsius, but PEEK needs to reach 400 degrees Celsius to liquefy, Knebel explains. PEEK is also semi-crystalline. Due to crystallization, the material can shrink as the melted structure changes into a hard structure. Evonik's experts also targeted a tight tolerance, which is especially critical for devices that are implanted in the human body.

The development of VESTAKEEP® i4 3DF was an iterative process that required a balance between the material's stability and printability. As it was in development, Evonik sent the filament to machine manufacturers worldwide and asked for feedback to further advance the product. This allowed Evonik to identify which manufacturers could produce quality 3D-printed parts. It turned out that Reith was one of them.

BONDED PARTNERSHIP

When Evonik visited his lab in late 2018, Reith had built a proprietary 3D printer. His early request was for Evonik to provide a filament that would satisfy US regulators and help with his understanding of the material chemistry as he perfected his process. They said yes.

Reith and the Evonik team in the United States were in constant communication as he sought to develop a 3D printing process that was highly precise and constantly repeatable. "Todd could make a change the next day if he wanted. We're slower than him due to our size," Knebel says. "But our management has given us the freedom to maneuver like a speedboat so that we are able to act and react in a way that startups are expecting."

The back and forth continued for three years. Reith would print parts, send them to Evonik and ask questions to troubleshoot obstacles, primarily with the crystallinity. Evonik's Director of Technology, Dr. Suneel Bandi, would review the parts and questions and respond with recommendations for temperature changes.

"I relied more on visual cues, where I was able to discover subtleties in the material properties," Reith says. When the color was golden honey coming out of the nozzle, he knew he was at the right temperature, viscosity, and flow rate. Then, when the filament would laydown on the build plate, he would watch the speed at which it went to an opaque semi-crystalline state. By controlling the temperature, Reith was ultimately able to control the amorphous state of the material. Evonik's feedback played a critical role in helping Reith perfect his process, and their collaboration con-

tinued when Reith sold FossiLabs to Curiteva, an established spine company based in Huntsville, Alabama.

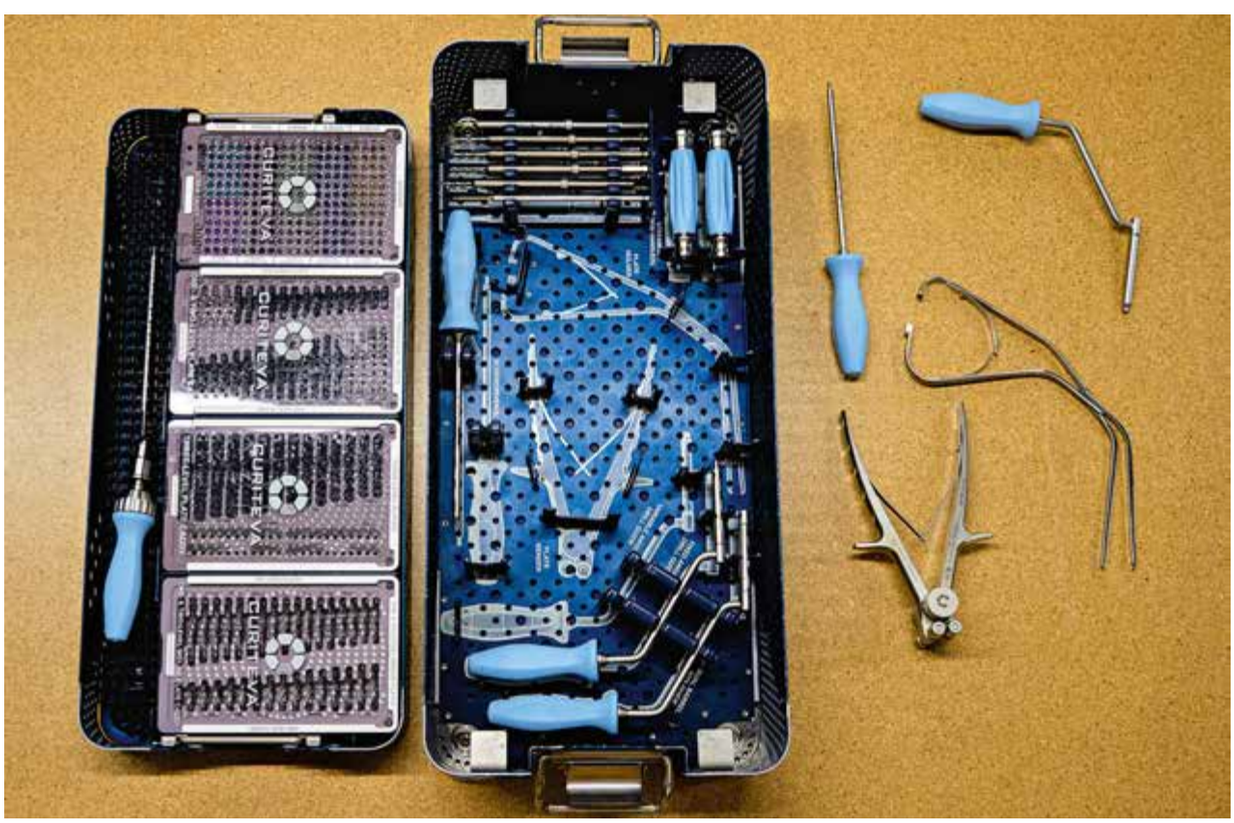
CRUCIAL TESTS OVER CHRISTMAS

Reith was named Inventor and Vice President of Emerging Technology of Curiteva when the company purchased his firm in 2020. Like Reith, Curiteva was interested in developing novel 3D-printed spine implants and immediately backed his work with the specialty chemicals company. "Evonik and I formed a tight partnership after the acquisition, because then we were on a path to a commercial product," Reith says. "The acquisition meant we had to turn it into a validated process."

Reith's proprietary Fused Strand Deposition (FSD) process prints an implant with diamond-shaped pores with a distribution between 100 and 600 microns (one micron is a thousandth of a millimeter). The design is notable. according to Dr. Erik Erbe, Chief Scientific Officer at Curiteva, because it leads to a stronger implant than can be achieved with compression molded PEEK. "At face value, people might say, 'Well, that's just PEEK that they printed differently.' That's not the case," Dr. Erbe says. The company's studies show that its implant's compressive strength is 70% to 80% higher than traditional PEEK implants. →

"We were given the freedom to maneuver like a speedboat"

MARC KNEBEL, GLOBAL SEGMENT HEAD OF MEDICAL DEVICES AT EVONIK



Curiteva's plate system is comprised of various surgical instruments as well as plates and screws to stabilize the implant into proper position

Curiteva's early studies showed that they had developed an implant that could be a potential game-changer for the spine market. Innovation, however, often comes with stringent regulatory hurdles. Evonik launched its VESTAKEEP® i4 3DF implant-grade filament in early 2022. This meant that Curiteva could submit its product for U.S. FDA clearance with a commercial material that met rigorous quality standards. Still, FDA sought affirmation that Curiteva's printing process didn't change the characteristics of Evonik's materials. FDA discussions have strict deadlines, and Curiteva needed to perform intensive chemical analysis in just a few days or risk losing their shot at market clearance.

A JOURNEY TO GERMANY

The timing heightened the high-stress moment—it was Christmas. Reith called his contacts at Evonik to phone in a big favor. They said yes again. "Normally at Christmastime, no one is in the office," Knebel says. "We asked people to stay because we knew it was time-critical." Reith traveled from the United States to Germany to hand deliver the 3D-printed implants to the Darmstadt facility. Dr. Jonas Scherble, Evonik's Director of Quality & Regulatory, oversaw the testing. "We have regulatory expertise and supporting data to provide our customers with a good foundation of knowledge," Knebel says. "It's all about trust at the end of the day. We want to generate trust with our customers and the authorities by proving that our material is suitable to 3D print implants."

The results of Evonik's material analysis satisfied the U.S. FDA's questions, and Curiteva received their clearance. The close collaboration between Curiteva and Evonik resulted in the first 3D-printed PEEK implant to reach the market in the USA—a trailblazing achievement for both companies.

"It was Herculean," Reith says. "It's one thing for startups to be quick and agile, but for a company like Evonik to get everyone aligned is impressive. What's awesome about this story is their willingness to take a risk on a small entrepreneurial company. What's even more remarkable is that this big company took a risk, and now they're in a leadership role. All of Evonik's competitors are playing catch-up now."

Surgeons performed the first surgery with Curiteva's Inspire system in April 2023. "I believe structure drives biology and the lattice PEEK architecture enabled by Curiteva's 3D printing process represents an exciting advancement in spine, orthopedics, and neurosurgical procedures which involve any type of biologic implant," says Dr. Alex Vaccaro. The president of the Philadelphia-based Rothman Orthopedic Institute is one of the first surgeons using the new implant.

"It's not just PEEK that we've printed differently"

ERIK ERBE, CHIEF SCIENTIFIC OFFICER AT CURITEVA

Curiteva currently produces implants with ten printers. Depending on the size, production takes between 15 minutes and several hours

Curiteva was founded in 2017 in Huntsville, Alabama, and specializes in the development of spinal implants

Curiteva sees market potential for various implant applications that can leverage 3D-printed PEEK, including foot and ankle, hand and wrist, and head and face. For example, a patient who endures skull trauma in a car accident could receive a 3D-printed PEEK implant that fits the exact size and shape of their fracture.

Evonik is the only supplier with a 3D-printable implant-grade PEEK material that has been used in an FDA-cleared device. The company is now working with manufacturers across the globe to bring products to market using its VESTAKEEP® i4 3DF materials. "Curiteva's application created a lot of interest in the market and opened doors for further discussions," Knebel says. "Not everybody has immediately jumped on using filament. However, it has started discussion and innovation at other companies. That's a good thing."

In October 2023, Evonik launched its carbon-fiber-reinforced PEEK filament for 3D-printed medical implants—the next advancement in its materials offerings. The carbon-fiber-reinforced PEEK is expected to be used for spinal cages, trauma plates, and patient-specific applications. The material's benefit comes from the strength of the high carbon-fiber content matched with the ductility of its PEEK components. It also includes the ability to define the alignment of the carbon fibers during the printing process.

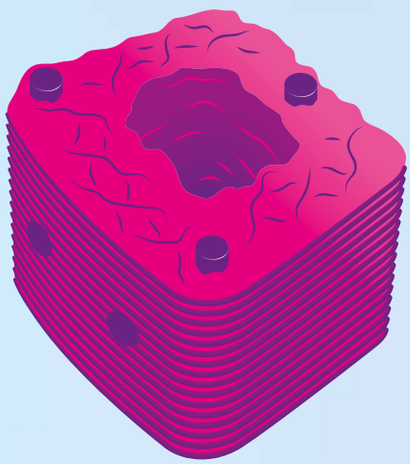
Evonik and Curiteva plan to work together to develop orthopedic implants using the new carbon-fiber PEEK filament. "Now we're sending Todd back to his lab to start again with the new material," Knebel says, laughing.

Carolyn LaWell is Chief Content Officer at ORTHOWORLD, a media firm that covers all aspects of the orthopedic market

From head to toe

For many medical applications, high-performance polymers or biosynthetic materials are indispensable. They can be formed into a wide range of shapes, are robust or biodegradable depending on their intended purpose, and are compatible with the human organism. Here's an overview of their possible uses in medical products.

INFOGRAPHIC **MAXIMILIAN NERTINGER**



VERTEBRAL IMPLANT

If an intervertebral disc has to be removed from a patient, the two adjacent vertebral bodies are braced by means of an implant. Recently it has become possible to use a 3D printer to produce implants made of VESTAKEEP® PEEK, whose porous structure accelerates fusion with the surrounding bones.

Material: polyether ether ketone (PEEK)

Durability: permanent

Processing: e.g. 3D printing, injection molding

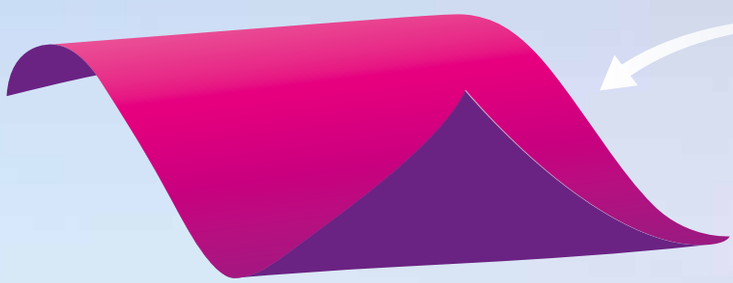
WOUND DRESSING

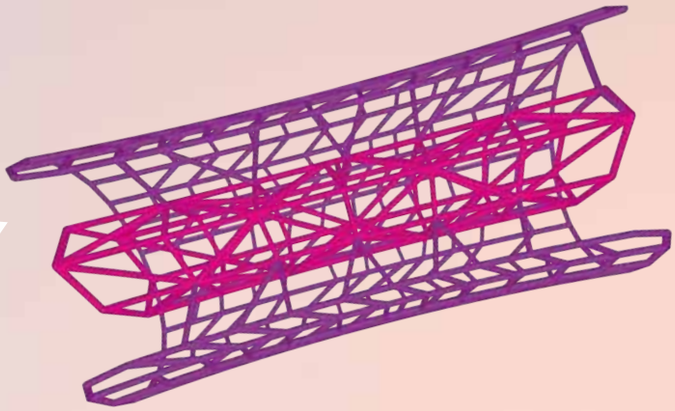
Biocellic®+ is used to treat burn and chronic wounds. The dressing consists of biosynthetic cellulose produced by means of fermentation. It cools injured skin areas and reduces pain. Biocellic®+ absorbs wound fluid and can be supplemented with active ingredients as needed.

Biosynthetic cellulose

Permanent

Fermentation

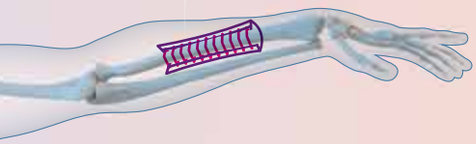




CAGE

Bioresorbable polymers such as RESOMER® are suitable for applications that include graft cages for fractures and the like. These cages hold bone or replacement material in the desired location during the healing process and enable the restoration of the bone.

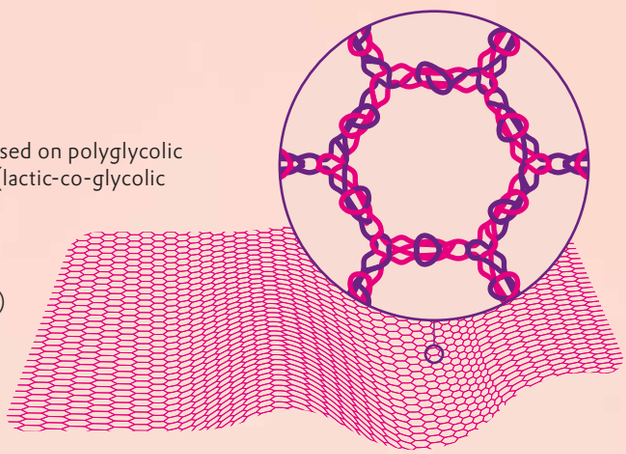
- **Polymer** (e.g. based on polycaprolactone/PCL)
- **Bioresorbable** (months or years)
- **3D printing**

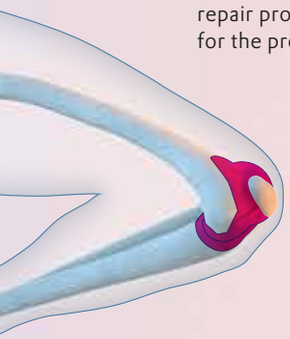


MEDICAL TEXTILES

A surgical mesh is an implant made of loosely woven fabric that is designed to provide structural support to organs or tissues, either as a temporary or permanent solution during surgical interventions, particularly in hernia repair procedures. Evonik provides polymers for the production of such meshes.

- **Polymers** (e.g. based on polyglycolic acid/PGA or poly(lactic-co-glycolic acid)/PGLA)
- **Permanent or bioresorbable** (weeks or months)
- **E.g. spinning, weaving**

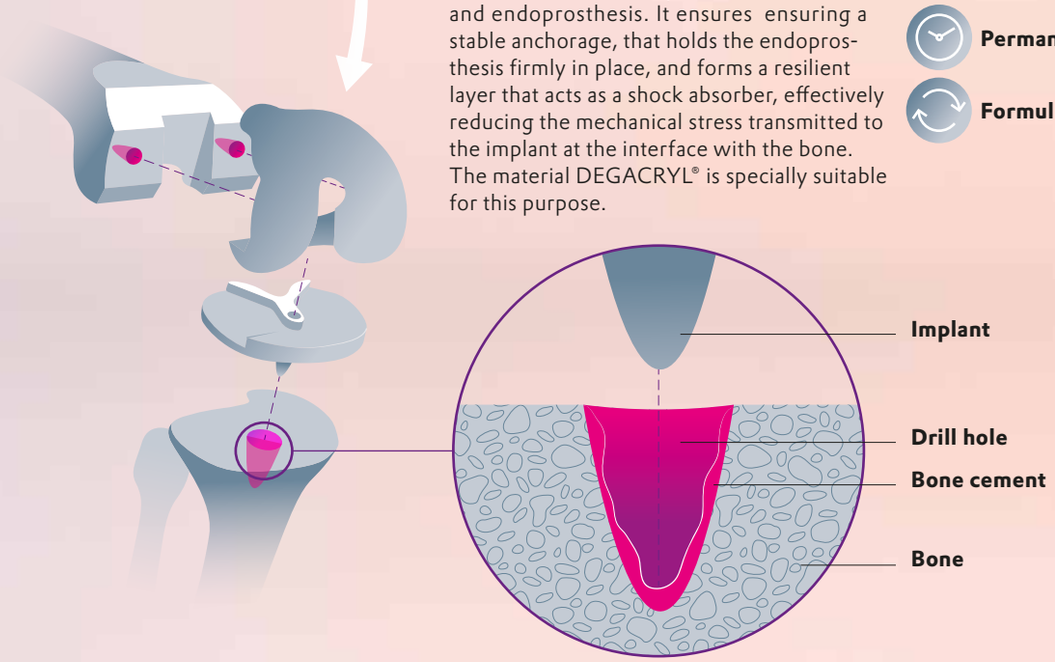




BONE CEMENT

Bone cement fills the space between bone and endoprosthesis. It ensures ensuring a stable anchorage, that holds the endoprosthesis firmly in place, and forms a resilient layer that acts as a shock absorber, effectively reducing the mechanical stress transmitted to the implant at the interface with the bone. The material DEGACRYL® is specially suitable for this purpose.

- **Polymethyl methacrylate** (PMMA)
- **Permanent**
- **Formulation**



“Plastics help to reduce CO_2 and conserve resources”

High-performance polymers easily withstand impacts and high temperatures, are lightweight, and can be formed into every possible shape. They play an important role in many products. Dr. Ralf Düssel, the Head of Sustainability at Evonik and the chairman of Plastics Europe Germany, talks about the advantages of this material—and how it can be recycled even more thoroughly in the future

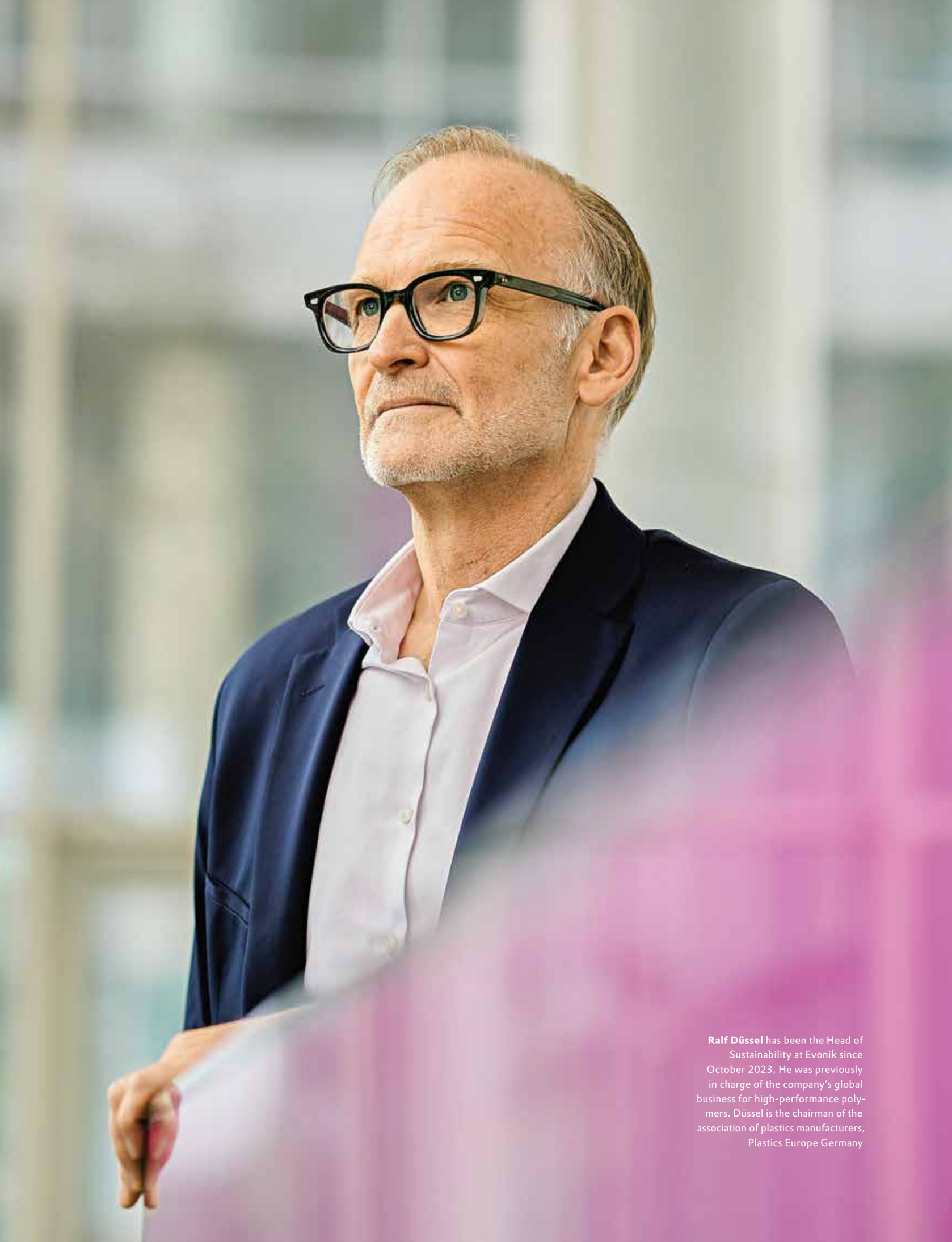
INTERVIEW **BERND KALTWASSER** & **CHRISTIAN BAULIG**

Mr. Düssel, today the word “plastic” makes many people think of microplastic particles in food or the Great Pacific Garbage Patch. But you regard plastic as an especially sustainable material. Why?
Most people don’t have a problem with plastics as such. However, they’re concerned about the careless way plastics are being dealt with, especially in the area of disposable products. We need plastics to solve the huge challenges that confront us today, ranging from the thermal insulation of buildings to modern concepts of mobility, digitalization, and the expanded use of renewable energy sources. No wind turbine spins without plastics. No train runs without plastics. No mobile phone functions without plastics. Plastics help us to make products smaller and more robust. In many cases, that reduces CO_2 and conserves resources. By comparison with glass, metal, and wood, plastic weighs less, is easier to process, and is more durable in many applications.

What role do high-performance polymers play in these areas?
They are used wherever standard plastics such as polyethylene and PET aren’t up to the job—for example, in the production of small and moving components or in products that are subjected to extraordinary environmental and climatic conditions or high levels of thermal and mechanical stress. These high-performance polymers are rarely found in packaging, but they are often used in machines, electric appliances, furniture, and high-quality design objects. Polyamide 12 is used in automobile production and the manufacture of consumer goods, among other things. 3D printing is creating brand-new areas of application for powder or filaments made of this high-performance polymer.

What properties make a plastic a “high-performance polymer”?
The more specific a material’s characteristics are, the more challenging is its production process and the smaller is the amount produced. Although several tens of millions of tons of the standard plastic polypropylene are produced every year, only a few tons of polyether ether ketone (PEEK) are produced. In the well-known pyramid of plastics, the standard plastics form the base and the high-performance polymers form the tip. Between them are the technical plastics such as polyethylene terephthalate, which is used for PET bottles.

Why are these top-rated materials so interesting for researchers?
Because they can be developed to perfectly fit specific applications. If customers have very specific requirements, high-performance polymers often offer the properties that are needed. For example, battery casings for electric vehicles have to be especially lightweight and heat-resistant. In addition, they have to optimally protect the battery from damage in case of a collision. Here’s another example: Since the 1970s, the proportion of plastics in airplanes has increased from four to approximately 50 percent. That’s another reason why today airplanes consume less kerosene and fly for longer periods of time. Developing materials that fulfill such demanding requirements is very exciting. →



Ralf Düssel has been the Head of Sustainability at Evonik since October 2023. He was previously in charge of the company's global business for high-performance polymers. Düssel is the chairman of the association of plastics manufacturers, Plastics Europe Germany

Ralf Düssel envisions diverse applications for plastic in the future—for example, for this 3D-printed component (left), which is used in robot grippers

What application has been the most impressive for you personally?
One important area of application for these materials is medicine. Just last year, an initial set of patients received vertebral implants that had been completely 3D-printed using PEEK. In Europe we now have the first clinics that print individual cranial implants themselves for people who have sustained serious head injuries in an accident. And just think of the children for whom 3D printers are creating customized prostheses that hardly weigh anything and enable the kids to regain more mobility. These solutions are hugely improving the patients' situation and directly supporting their recovery.

What role is played by the combination of high-performance polymers and 3D printing?
Customized applications are becoming increasingly important—and that's exactly where high-performance polymers are demonstrating their strength. They make it possible to produce small batches very flexibly. This means that replacement parts that are no longer available can be created individually in a 3D printer. This will help to repair high-quality products and machines more easily and inexpensively. In the future, the right to repair will affect more and more areas of industry, and high-performance polymers can play an important role there.

In the years ahead, will there be completely new materials that can be used to produce high-performance polymers?
This is certainly an exciting time for researchers working in this area. Again and again, we're seeing new challenges that can sometimes be solved with a monomaterial and at other times with a composite.

However, in recent years we haven't seen any completely new monomer that plays a role on an industrial scale. Why is that?
It's true that ideas for new monomers are constantly cropping up. Evonik too regularly tests new materials. But there are high hurdles that a completely new material has to overcome with regard to its scalability. When plastics processors are selecting materials, a crucial role is played by factors such as specific weight, prices, and availability, as well as the CO_2 footprint and recyclability. Many requirements can already be basically met by the high-performance polymers or composites that are available today. When a new monomer offers a crucial advantage only in a very specific application, the market is often too small for this new product to be commercially successful.

High-performance polymers are comparatively expensive. Is there a danger that they will be driven out of the market by advanced standard plastics?
It's true that better additives, as well as progress in the area of processing, have improved the performance of standard plastics. For example, if you touch a piece of artificial leather today, you can hardly tell it apart from genuine leather. However, if especially stringent requirements are set regarding durability and robust-

ness, there's no alternative to high-performance polymers. Thermal and electric insulation properties play a huge role in many applications. Applications in automobiles require crash resistance and radar transparency for the sensor system. In plant construction, low levels of material fatigue, as well as resistance to chemicals and X-rays, are crucial. And in the area of prosthetics, the important qualities are biocompatibility, biostability, and bone-like mechanical properties. All of these conditions are fulfilled only by high-performance polymers.

How can the sustainability of plastics be further improved?
It's important to look at the entire life cycle of a product. It already begins with the design. Products must be designed so that they need as little material as possible to manufacture and that at the end of their life cycle their various materials can be easily separated from one another.

However, even if the product has been used as economically as possible, the problem of disposal remains.
It's essential to systematically collect plastic waste and feed it back into the cycle. However, high-performance polymers are often produced in small quantities and processed in long-life products such as automobiles or large machines. So it's not easy to recycle the material and reuse it after the end of these products' life cycle. So far, it has seldom been worthwhile for mechanical recyclers to extract high-performance polymers and correctly sort them according to type. That's why this kind of plastic waste still lands in the incinerator much too often. We have to change that!

How could this plan work?
There are several possible starting points. Some plastic producers are working to develop recycling systems. For example, for every correctly sorted kilo of material that is delivered to them, they offer a discount on the next order. Chemical recycling is another option. This makes it possible to break down even mixed and soiled high-performance polymers into their chemical components and transform them into new raw materials. Digital product passes and tracing technologies can also help with the AI-controlled collection and sorting of high-performance polymers in automated sorting facilities to obtain pure materials for recycling.

Is it necessary to cut back on performance so that plastics can be recycled more easily?
If special solutions are required, today we can sometimes use composites or materials whose properties are improved by means of additives. For high-performance polymers of this kind we need special recycling processes that are already being worked on. High performance is not incompatible with recyclability. We must continue to do intense research in areas such as replacing composites with new and very high-performance monomaterial plastics.

Are recyclates or alternative raw materials suitable as a basis for high-performance polymers?
Yes. Plastics made from chemically recycled materials have the same quality and material properties as new materials made of fossil raw materials. And of course the carbon that is needed for producing high-performance polymers can also be derived from biomass and CO_2. Today 19.5 percent of all newly produced plastics in the EU already consist of circular raw materials, and this proportion will go on growing. Evonik also has a broad portfolio of high-performance polymers that are already based partly or wholly on biomass. In the process, we are relying on the mass balance system...

...in which the bio-based raw materials are not used directly but are ensured by means of a certification, so that the corresponding amount is fed into the system as a whole. Why is this path necessary?
Because this is how we can directly use even small amounts of bio-based or recycled raw materials. That's because the available amounts are often so small that it wouldn't be possible to operate a separate facility or production line with them.

What plastic product is still missing in your life?
I'm looking forward to air taxis, and I hope they appear as soon as possible. That would be a new mobility option, for example, thanks to high-performance polymers in the rotors.

TURNING WITH THE TIMES

Numerous elements in cars are already made of plastic. However, steel has been used for transmission components up to now. The Technical University of Munich now wants to create a new application—gear wheels made of high-performance polymer—and thus help to drive forward the transformation of urban mobility

TEXT **TOM RADEMACHER**

Researchers at the Technical University of Munich are testing the plastic gears in a Renault Twizy. Such microcars are ideal for lightweight materials

A midget drives in circles through the drizzle in Garching near Munich: In a research project, an electric Renault Twizy microcar circles around buildings at the Technical University of Munich (TUM). The car isn't road-ready yet. Its transmission is only a prototype. Scientists at TUM have installed plastic gears in the transmission on a trial basis, replacing the steel components that are otherwise employed. This is made possible by a special material from Evonik.

This research project funded by Germany's Federal Ministry for Economic Affairs and Climate Action (BMWK) aims to develop and evaluate a lightweight transmission that uses high-performance plastic gears. The transmission is intended for small urban electric vehicles. In addition to TUM and Evonik, the Werner Bauser company, a medium-size specialist in the precise manufacture of plastic gears, is also involved. The three of them want to turn the plastic into an alternative material for small electric vehicle transmissions. They want to prove as practically as possible that it can withstand the forces within the transmission over a long period and at the same time make driving more economical and quiet. The demonstration vehicle is a Twizy that has slightly less than 13 kilowatts of peak power and a top speed of 80 km/h.

"The performance class of these electric microcars makes them ideal for plastic-based transmissions. Both—microcars and plastic components in the drivetrain—can play a key role if we want livable cities with sustainable mobility in the future," explains Dr. Karsten Stahl, Professor of Machine Elements at TUM and Head of the Gear Research Center (FZG). (See "Midgets on the Move," p. 29, for more information on microcars.)

A BLIND SPOT OF SCIENCE

The FZG has been researching gears for more than 70 years. Many internationally valid guidelines and industry standards originated here. Almost 100 test benches run in parallel in the institute's rooms—often at night, when they don't disturb anybody. From individual gear wheels to complete turbofan gearboxes for aircraft turbines, pretty much everything is put to the test here. Research contracts also come from car manufacturers and suppliers who want to get the last bit of efficiency out of their gearboxes. "It's the epitome of mechanical engineering," says Stahl about this work and adds, "For decades, many scientists underestimated the trend towards plastic gears."

"For decades, many scientists have underestimated the trend towards plastic gears"

KARSTEN STAHL, PROFESSOR OF MACHINE ELEMENTS AT THE TECHNICAL UNIVERSITY OF MUNICH

Plastic gears have long been used everywhere and are usually more prevalent than gears made of other materials—even in cars: The fuel pump, oil pump, windshield wipers, power windows, seat adjustment, ventilation, and much more are set in motion by plastic parts. This isn't surprising, because gear wheels made of plastic are not only less expensive to manufacture, they also save weight and waste less energy because less mass is set in motion and the surfaces slide against one another very

To enable the transmission to accommodate a gear wheel made of Evonik's VESTAKEEP® plastic, the housing had to be widened accordingly

well. They also absorb vibrations, and that makes them particularly quiet. Only in the drivetrains of cars, where high torques, chemically aggressive lubricants, and high temperatures prevail, is steel still the material of choice. But even this bastion is crumbling.

TRANSMISSIONS AS A STUMBLING BLOCK

Mercedes-Benz has been using plastic gears in mass-balance transmissions in its series-production models since 2022. Such transmissions compensate for engine vibrations and ensure smoother running. Because the gears come into contact with hot engine oil, they always used to be made of steel. At Mercedes, they are now made of VESTAKEEP® 5000G, a heat-stable high-performance polymer from Evonik, which makes the entire assembly more efficient and also reduces vibration. The research project at the FZG is now taking this material one step further. "This is the first time we are using plastic directly in the drive system for power transmission," says Professor Stahl. "That's totally new."

Stahl quotes from a paper by the Wissenschaftliche Gesellschaft für Produktentwicklung (Scientific Society for Product Development), according to which constant technical evolution has made transmission technology around four to five percent more compact, more efficient, and quieter every year. It's a kind of Moore's →

MIDGETS ON THE MOVE

Four-wheeled one- and two-seaters with an engine output of up to 15 kilowatts, such as the Renault Twizy, belong to the EU vehicle category L7e. Known as microcars, these vehicles are designed for urban use. A McKinsey study from 2022 predicts that "mini-mobility" with vehicles in the niche between e-bikes and cars will be "the next big thing." The global market could grow to around US$100 billion by 2030. This isn't the first time that microcars have been predicted to make a major breakthrough. But the reality is still quite different. In Germany, a mere 1,487 microcars were registered last year, compared to a total of almost 2.9 million new registrations. This represents a share of just 0.05 percent. However, national climate targets and municipal initiatives for traffic-calmed cities could act as a turbocharger for the electric midgets. In 2023, a group of European manufacturers joined forces in the Microcar Coalition to proactively campaign for state funding and privileges in cities. In the meantime, brands such as Opel and Citroën as well as some startups and Chinese manufacturers have put microcars on the road. Although Renault discontinued production of the Twizy last year after a good ten years and around 33,000 units sold worldwide, it is entering the car-sharing business with the vehicle's successor, the Duo.

TUM doctoral candidates Nicolai Sprogies (left) and Stefan Reitschuster preset the torque on the transmission test bench in Garching

law for machine parts. Just as the processor density of microchips in semiconductor technology has regularly increased over the decades, the performance of transmissions is also continuously improving. "High-performance polymers enable us to continue this development," says Stahl.

The Twizy's transmission was deliberately chosen as a simple demonstration object: The two-stage transmission in the electric microcar cannot be shifted and consists of just four cogwheels. "The aim was to use plastic gears to create a transmission stage in a series-production vehicle but otherwise change as little as possible," explains Stahl. The two gear wheels of the first stage were replaced. Those in the second stage, where the torque is greater, are still made of steel. Another concession is that in order to distribute the force over a larger area, the plastic gears are around twice as wide as their metal counterparts. To achieve this, the housing was widened by two centimeters.

Following extensive computer simulations, the FZG built three prototypes of such modified transmissions. While one runs in the vehicle, two others are braced against each other on an especially developed test bench. "This allows us to run the transmissions against each other with a defined torque and examine them in isolation from external factors," explains Stefan Reitschuster, while he and his colleague Nicolai Sprogies use their muscles to preset the torque. Reitschuster and Sprogies are two of several TUM doctoral candidates working on the project.

The tests have been running for several months. Speed, torque, and oil temperature are varied externally according to standardized test cycles in order to simulate tens of thousands of kilometers of real everyday road use in a short space of time. A host of sensors monitor the whole thing. Twenty-eight probes document the temperature alone, and the measurement of vibrations and noise will be the subject of a separate doctoral thesis. One finding is that the new gears show no significant signs of fatigue after the first 10,000 kilometers of driving.

This surprises no one at Evonik in Darmstadt. "Our VESTAKEEP® 5000G is pretty much the best-performing polymer on the market at the moment," says Philipp Kilian, who heads the Tribology department in the High Performance Polymers business line at Evonik. The work at this department focuses on everything to do with wear, friction, and lubrication, he says. The specialty chemicals company not only supplied the material for the gear wheel, but also the material data for the simulation.

TOUGH STUFF

In addition to high-performance polymers, Evonik also produces high-performance lubricants. Evonik operates a test laboratory for both in Darmstadt. As in Munich, machine parts are maltreated behind soundproof doors in the service of research. In cooperation with the gear manufacturer Werner Bauser, Evonik has developed a test bench specifically for plastic gears. From the first "pits" in the side of a tooth to the catastrophic "tooth root breakage"—the total loss of a transmission—Evonik can use this test bench to generate realistic wear and analyze it under its own scanning electron microscopes, for example.

The brand name VESTAKEEP® is used to designate polyether ether ketone, or PEEK for short. For the past several years, this class of plastics has been replacing more and more steel components in various sectors. The material is extremely resistant to abrasion and many aggressive chemicals. In addition, the material can permanently withstand temperatures of around 250 degrees Celsius and even endure up to 300 degrees Celsius for short periods. "It is also inherently flame-retardant, highly pure,

and very dimensionally stable. That's why the semiconductor industry, for example, uses high-precision tools made of PEEK to process sensitive wafers," explains Sandra Kao, who is responsible for VESTAKEEP® marketing worldwide for Evonik from Taipei (Taiwan). "Some car manufacturers are also using PEEK to develop safe new batteries, busbars, and other components for the ever-increasing currents in next-generation electric cars."

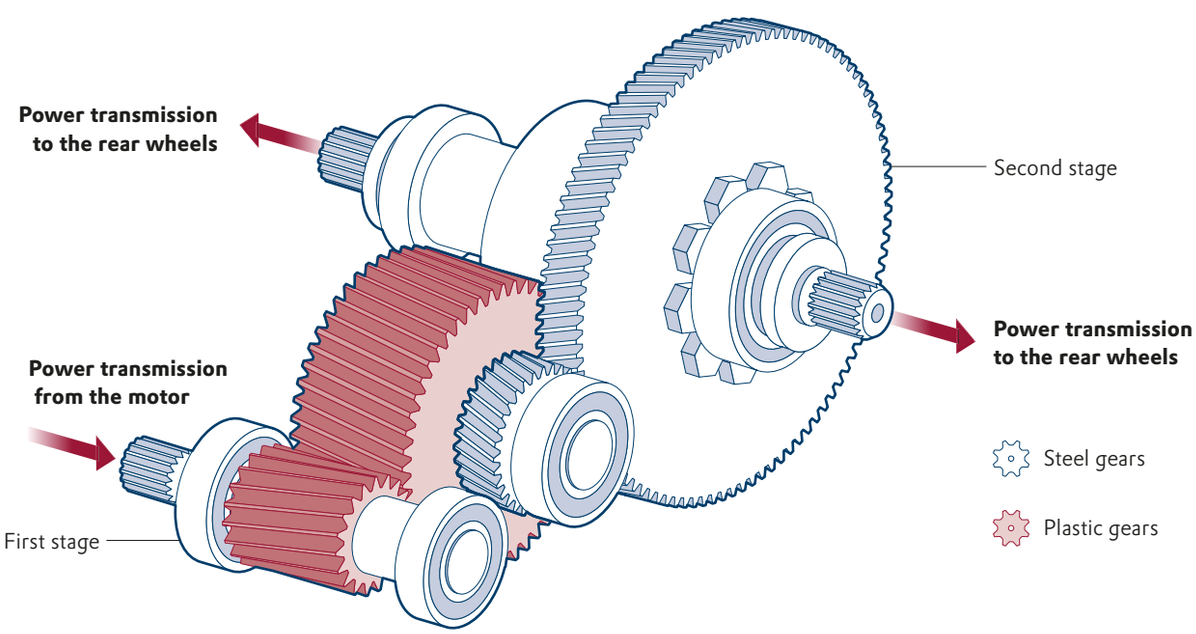
VESTAKEEP® 5000G, which Mercedes-Benz and the FZG use, is Evonik's top product when it comes to PEEK. The number 5000 refers to the highest molecular weight currently available, i.e. the particularly long molecular chain. The G stands for the delivery form as granules. For the tests at the FZG, Werner Bauser manufactured around a dozen gears from this product. The family-run company from Wehingen on the edge →

"We can mold plastic into very complex shapes, which is not possible with steel"

THOMAS SIMON, HEAD OF SALES AT THE GEAR WHEEL MANUFACTURER WERNER BAUSER

From the motor to the wheels

The Renault Twizy's two-stage transmission translates the high speed of the electric motor into sufficient torque to drive the two rear wheels. The largest gear wheel turns around ten times slower than the smallest, thus increasing the torque ten times. The first stage was recently made of the plastic VESTAKEEP® for the first time. In order to better distribute the forces on each tooth, the plastic gears are about twice as wide as the original steel ones.



“Making the most of its talents”

Professor Karl Kuhmann is the Head of Technology and Process Development for Plastics Processing of High Performance Polymers at Evonik and has been teaching plastics technology at the Friedrich-Alexander University in Erlangen-Nuremberg for over 20 years

Professor Kuhmann, you are once again offering your annual introductory course on multi-component plastic injection molding for students of mechanical engineering and materials science. What do you teach there?
The students are usually amazed at what can be done with plastics today using injection molding technology: How wide the range of applications is, for example, and that even completely finished complex multifunctional components can be produced fully automatically from different materials.

High-performance polymers are increasingly replacing steel, especially in automobile production. Do you still have to overcome prejudices against plastic?
The potential is still far from exhausted. But it’s not about promoting one material at the expense of the other. Plastic can do things that steel can’t—and vice versa. I see the greatest benefit when we use the advantages of both types of materials in a very targeted way and combine them correctly. For example, in hybrid components that make optimal use of the strengths of steel and, in key areas, the strengths of different plastics.

Why does plastic unfold its potential here in particular?
Lightweight construction and efficiency are especially in demand. And there are always exciting new possibilities coming up in polymer design itself, in new processing technologies, and in the plastic-compatible production of components. 3D printing, for example, brings additional design freedom. Moreover, injection molding allows us to combine various components with different material properties into one component. However, this has not come all of a sudden, but is instead the result of decades of intensive research and development in plastics technology. We can simply exploit more of plastic’s potential if we bring the various disciplines such as plastics technology, metal and gear engineering, and materials science closer together in order to make the most of the material’s talents.

of the Swabian Alb has been exclusively manufacturing plastic screws and gears since it was founded 60 years ago. They are used in drills and garage door drives, for example. Recently the trends towards height-adjustable desks and e-bikes have once again boosted demand, says Bauser Sales Director Thomas Simon.

INJECTION MOLDING AS THE CRUCIAL FACTOR

The people at Werner Bauser are particularly proud of their expertise in transmission design and their precision in injection molding. “Not everyone can produce large machine components with tolerances in the micrometer range,” says Simon. But that is precisely what is needed. Injection molding is what makes plastic gears inexpensive and economical to produce. Steel gears are milled individually, which is laborious and creates waste. Injection molding machines, on the other hand, spew finished gears onto the assembly line—up to 750,000 a day at Bauser. “We can also produce very complex shapes from a mix of very different materials, which is not possible with steel,” says Simon. 3D printing is likely to open up even more possibilities. Researchers at the FZG are already dreaming of plastic gears with integrated sensors and coolant channels, among other things.

However, the most important argument in favor of plastic is neither the lower costs nor the design freedom—not even the weight savings, says Stahl. “All gear experts are currently working on improving the acoustic behavior of transmissions,” he reveals.

In electrically powered cars, the transmission is the number one source of noise. When there is no rumbling combustion engine, other noises are all the more noticeable. The industry calls this phenomenon “noise, vibration, harshness,” or NVH for short. That’s because it’s not just about noise, but also about vibration and harshness. The latter term comes from psychoacoustics and describes frequency ranges that are consciously and unconsciously perceived as unpleasant. It is known that the viscoelastic behavior of plastic gears enables them to absorb more of these frequencies. As a result, the gears can significantly improve NVH values.

“Just replace steel with plastic? Unfortunately, it’s almost never that simple”

PHILIPP KILIAN, HEAD OF THE TRIBOLOGY DEPARTMENT AT EVONIK’S HIGH PERFORMANCE POLYMERS BUSINESS LINE

Nevertheless, Bauser, Evonik, and TUM are familiar with the old saying among mechanical engineers: “People who know plastic choose steel.” Advanced materials science has produced many plastics for highly efficient and intelligent applications (see interview on the left), but the use of plastics still has its own challenges, says Kilian. “Just replace steel with plastic? Unfortunately, it’s almost never that simple.” That’s because plastic is more complex than steel. Plastic reacts more dynamically, more flexibly, and is more temperature-dependent than steel. Added to this is the wider range of plastics, which react very differently depending on their molecular structure, manufacturing process, and additives. Accordingly, a lot of research still needs to be done.

The successor of the research project in Munich is ready for launch. In this new project, TUM, Evonik, and Bauser have brought other automotive suppliers and even a car manufacturer on board to develop a plastic transmission from scratch. The arrangement and shape of the teeth, the transmission ratio, the housing—everything has to be tailored precisely to the strengths of the material. “The steel gears have a 100-year head start in automobiles,” says Professor Stahl. “We are still at the beginning with this plastic, but that’s what makes it so exciting.” —

Tom Rademacher is a freelance journalist based in Cologne. He writes about scientific and industrial topics, among others

Innovation needs open hearts and open borders

Research and development thrive on international cooperation, because the major problems of our time call for global answers. Those who rely on national isolation and exclusion are endangering our future as a hub for innovation

by Harald Schwager

Harald Schwager is the Deputy Chairman of the Executive Board of Evonik

Act only according to that maxim whereby you can at the same time will that it should become a universal law." Immanuel Kant formulated the categorical imperative back in 1785. Almost 240 years later, his injunction has lost none of its urgency. Today as back then, the same principle applies: We must stand up for the values we hold in our hearts. In a democracy, all of us are called upon to be active—especially now, during a time when some people want to bring into question values that used to be regarded as securely established.

Science and research in particular have a responsibility. Our German history has taught us only too well about the cruel excesses that can result when researchers leave the democratic base and let themselves be harnessed before the cart of dictatorial regimes. Today every scientist can clearly see the immense benefits of open international communication and cooperation. That in itself keeps them from toying with the idea of national isolation.

Nonetheless, in many European countries right-wing populists are gaining more and more public approval. In six of the 27 EU countries, they are already participating in the national government. In Italy, Hungary, and Croatia they even provide the head of government. In most cases their political program is simple and by no means well-intentioned, but to many people it nonetheless seems attractive. People who think differently and look different are vilified, and the imminent collapse of the value system and the culture is invoked. Seemingly simple solutions are proposed to eliminate global problems. The populists seek salvation through strict nationalism and profound hostility against everything they presume to be foreign. They claim that the solution is either rigorous isolation or—something that is verbally more discreet but therefore even more insidious—the "remigration" of millions of people.

"Each one of us will soon be able to help decide whether Europe will continue to be a magnet for scientists from all over the world."

We must oppose this! The freedom to think and be able to say what you think—this freedom makes all the difference. That also applies to research. The categorical imperative is the guiding principle that prevents freedom from turning into arbitrariness. That's because a definition of freedom that is limited to the simple-minded attitude "People have every right to say that!" would pave the way for despotism.

Freedom thrives in a society based on responsibility. Freedom makes it possible to be actively involved and to do research on behalf of our country and our well-being. Innovation requires open borders and open hearts!

What happens when freedom and responsibility are lost in equal measure is demonstrated by the darkest capital of our history. The National Socialists' seizure of power in the 1930s was followed by the "cleansing" of the science system. Dissidents were systematically deprived of their freedom. This precipitated the biggest exodus of intellectuals in recent history. The regime forced the physicist Albert Einstein and the author Thomas Mann into exile, along with thousands of other leading thinkers. The annexation of Austria was followed by the expulsion of pioneers such as the mathematician and philosopher Kurt Gödel and the founder of psychoanalysis, Sigmund Freud. This caused a massive and long-term weakening of science in Germany. What remained was a forcibly standardized "German science" that was free of a sense of responsibility and lent itself to cruel and senseless research projects. Ideology replaced the striving to gain genuine knowledge and thus perverted the basic concept of science.

43 NATIONS DO RESEARCH IN ONE ORGANIZATION

Today science is very internationally oriented, and the discussion of responsibility and the limits of science is conducted at the global level. Here's one example: More than 1,000 scientists from 40 countries cooperated in the process of decoding the human genome. A look at Evonik affirms this internationality. People from 43 nations work together in our research organization to develop sustainable solutions that make life a little bit better, day by day.

Openness and a readiness to cooperate are fundamental principles that make it possible to do outstanding science. This is shown by the successes achieved by European integration. Europe, which accounts for almost 25 percent of worldwide knowledge production—even though it holds just under six percent of the world's population—is a strong engine of progress. The essential elements of this status are unobstructed communication with the leading thinkers of our time and an uninterrupted appeal for talented young people.

Each one of us will soon be able to help decide whether Europe will continue to be a magnet for scientists from all over the world. At the beginning of June about 350 million Europeans will be called on to elect the tenth European Parliament. It's in our hands. Let's use our vote, so that the global challenges that confront all of us are addressed.

DEMOCRACY NEEDS ACTIVE DEMOCRATS

However, by voting an individual naturally does not give up his or her own voice. You can't delegate the responsibility to defend your own values and social cohesion. Democracy needs active democrats. Where would the American civil rights movement be without Rosa Parks? In 1955, when this African-American woman was told to give up her seat to a white man, she refused. Her "no" became the banner of the civil rights movement in the USA. In her novels Herta Müller, the recipient of the Nobel Prize for literature, enables readers to experience what life was like under the Romanian dictator Ceaușescu. In her works she examines the role of the individual inside the system, and through her precise language she reminds us to think critically and take on responsibility.

These examples show that every individual can and must prove that he or she has a backbone. We must never accept discrimination and emotional brutalization, the downplaying of hate-filled rhetoric, and the categorization of people into valuable and less valuable individuals.

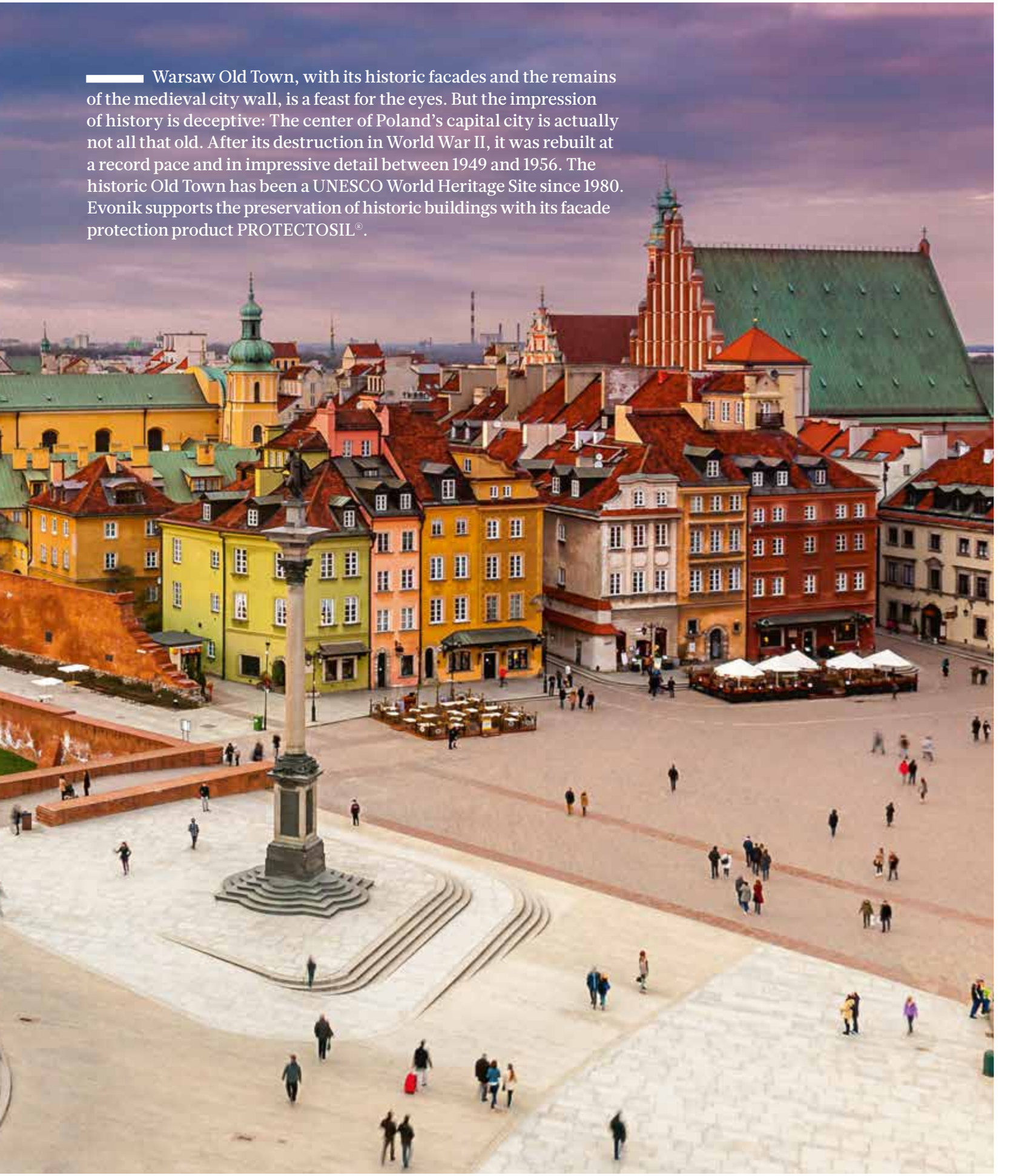
The American historian Peter Hayes, who researched the history of Evonik's predecessor company Degussa during the era of National Socialism, vividly summarized his findings: When freedom and human rights come under threat, we should not settle for the status quo by asking "What other choice do I have?" Instead, we should ask "What do I basically forbid myself to do?" This is how we become capable of action and can oppose populists and charlatans.

That's because true tolerance can't exist without taking a stand. This requires having one's own point of view. The readiness to say no. The philosopher Karl Popper put it this way: "We should [...] claim, in the name of tolerance, the right not to tolerate the intolerant. We should claim that any movement preaching intolerance places itself outside the law."

AN OLD FACADE, A MODERN HEART

Poland is rich in tradition, and the companies based here have become coveted partners in many sectors. From precision craftsmanship in furniture manufacturing to future-oriented concepts of green energy, Poland skillfully combines its historical heritage with pioneering solutions.

TEXT **PAULINE BRENKE**



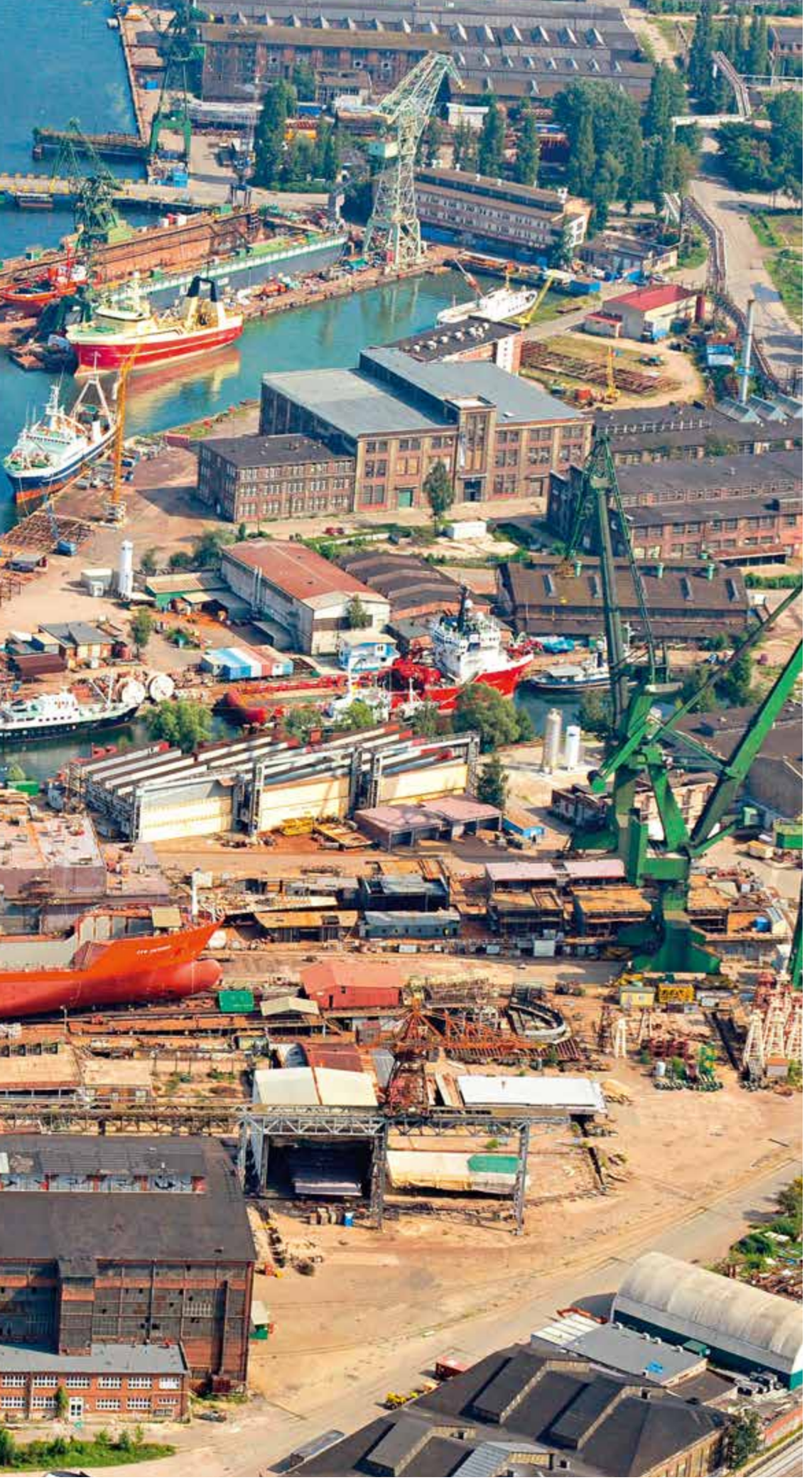
Warsaw Old Town, with its historic facades and the remains of the medieval city wall, is a feast for the eyes. But the impression of history is deceptive: The center of Poland's capital city is actually not all that old. After its destruction in World War II, it was rebuilt at a record pace and in impressive detail between 1949 and 1956. The historic Old Town has been a UNESCO World Heritage Site since 1980. Evonik supports the preservation of historic buildings with its facade protection product PROTECTOSIL®.

Along the Baltic Sea, West Pomerania beckons with waves, dunes, and pine forests. Poland's coastline is more than 500 kilometers long. It's a good place to spend a vacation, and it also offers attractive sites for the wind power sector. In the future, the wind turbine rotors will spin not only on land but also in the Baltic Sea. Plans call for the first offshore wind farms to already be feeding electricity into the grid in 2025. One of them is being built between Koszalin and the Danish island of Bornholm. Evonik provides the equipment for wind farms operating on the high seas. For example, cross-linkers make the rotor blades durable, while paint additives and polyurethane foam components protect the turbines from rain, salt, and hail.

Poland is one of the six EU member states with the largest forest areas. That's one reason why this country has a long tradition of woodworking. Over the years it has developed an important market for furniture, which most recently generated almost eight billion euros in sales. The largest segment is living-room furniture. Today Poland is one of the world's five biggest furniture exporters. About 90 percent of all its manufactured units are shipped abroad. Evonik ensures a high-quality look for tables, chairs, and cabinets. The silica ACEMATT® gives wooden furniture a matte finish and protects the surface.

Every year in April and May, Poland's fields of rapeseed bloom in brilliant yellow, creating magical patterns in the landscape that resemble an abstract painting. About two months later, the oil-bearing seeds are harvested. At a volume of more than 3.7 million tons, Poland was the EU's third-largest producer in 2022. Rapeseed is used to produce food-grade oil and protein-rich animal feed, among other things. Rapeseed oil, along with used cooking oil and animal fats, is the basis for the production of bio-diesel. NM30 alcoholates from Evonik are used as a catalyst in the production process.

The port of Gdańsk is one of Europe's 15 biggest harbors and the only one in the Baltic Sea with direct container links to China. The shipyard in Gdańsk (photo) has been considered the nucleus of Poland's pro-democracy movement ever since the Solidarność labor union was founded there in 1980. Ships are still built and repaired in its dry docks today. Ships' hulls and superstructures are protected with coatings containing DYNASYLAN® from Evonik. The water-based binders are especially environmentally friendly. They release hardly any volatile organic compounds, for example.



A BROAD SPECTRUM

Evonik has been active in Poland with a sales team since 1990 and has been present in a new office in Warsaw since 2020. Here a team of 14 people manages sales from four divisions with a total of twelve business lines, including Animal Nutrition, Interface & Performance, Healthcare, and High Performance Polymers. Poland is a central trade partner of Germany as well as an essential pillar for Evonik in eastern Europe.

Evonik locations
1 Warsaw

At

1

location Evonik has

14

employees.

A coveted catch: The spiny dogfish is fished because of its meat as well as the substances in its liver. Like many other shark species, it is on the red list of endangered species

A BETTER CATCH

Lush blooms: Amaranth is a pseudo-cereal. Evonik researchers have successfully developed a substitute product for squalenes that comes from amaranth seed oil

Squalene enhances the effect of pharmaceutical products and plays an important role in research into new therapies. Until now this raw material was primarily extracted from shark livers. Evonik is now presenting an alternative product made from amaranth oil

TEXT **CHRISTOPH BAUER**

Although sharks are one of the world's most important and useful animal groups, they've been given a bad name by a best-selling novel and a blockbuster movie. The 1974 thriller *Jaws* portrays the gristly fish species as a man-eating monster. Both the author Peter Benchley and the film director Steven Spielberg explicitly regretted this portrayal afterwards. Nevertheless, sharks' alleged monstrosity has made them sought-after trophies for sport fishermen. Many sharks also die as bycatch in fisheries. Their fins are considered a coveted delicacy in Asia. The pharmaceutical and cosmetics industry is also putting increased pressure on some shark species that are already highly endangered. Sharks are a source of squalene, a substance that also plays an important role in human metabolism. Squalene is used in cosmetic applications, as an ingredient in medicines, and in vaccines. Evonik can now offer the pharmaceutical industry a GMP plant-based alternative that delivers even more reliable results. GMP stands for Good Manufacturing Practice and is a guarantee of uncompromisingly high quality.

Squalene is traditionally extracted from the liver of sharks, whose Latin name *Squalus* also gives this substance its name. In cartilaginous fish, the large oily liver partially takes over the function of the swim bladder in bony fish. A shark liver makes up between 20 and 40 percent of a shark's body weight. Squalene currently plays an important role in inactivated vaccines, particularly flu vaccines. It can also be used in pharmaceutical creams and ointments to make them more effective. The sebum produced by human skin also contains a proportion of squalene. →

Rima Jaber is responsible at Evonik for lipids that are used in parenteral applications such as vaccines

The finished product is clear and colorless. The squalene has a purity that is close to 100 percent

Rima Jaber has a Ph.D. in pharmaceutical technology and is the global product manager at Evonik Health Care for lipids in parenteral drug delivery solutions—in other words, routes of administration in which the active ingredients do not pass through the gastrointestinal tract. Jaber is aware of the threat that the use of animal-based raw materials poses to the populations of this animal group, which is more than 450 million years old. "Animal-derived squalene contributes to the decimation of shark populations," she says.

AN IMPENDING CASCADE

In the past the spiny dogfish, *Squalus acanthias,* was one of the most common shark species in the world. Today it is already considered critically endangered in the northeast Atlantic. This is largely due to the fact that the boneless belly flap of the spiny dogfish is a coveted fish specialty. Some common names for the fish, such as "huss" (UK) or "Seeaal" (sea eel, Germany) conceal their true origin. In the German North Sea, the spiny dogfish is considered extremely rare and is threatened with extinction, according to the German Red List.

Ulrich Karlowski, a biologist who is a board member of the German Foundation for Marine Conservation, explains the important role that sharks play in marine ecosystems: "The more than 500 shark species known today act as important apex predators and mesopredators—that is, they function like a gigantic oceanic cleaning crew. Put simply, they are an essential part of the ocean's health police." The population of almost all the monitored deep-sea shark species has declined by an average of 70 percent over the past 50 years. Because there is a lack of data for many species, it is not even possible to assess the size of their current populations.

Ulrich Karlowski says that the extinction of sharks would be devastating for the world's oceans: "Sharks are one of the key species in the oceans. Their disappearance would trigger a cascade in which ecosystems such as tropical coral reefs, which cannot exist without

Dr. Andreas Jakob, who headed the entire project from his base in Hanau, talks to the laboratory assistant Lea Lietzenmayer

healthy shark populations, would perish." It would be difficult to predict the consequences of such a cascade for countless marine species that are wholly or partially dependent on coral reefs. The consequences would also be drastic for human populations. Hundreds of thousands of small-scale fishermen would lose their livelihoods due to the collapse of fish stocks, and millions of people in the Global South would lose a significant part of their food supply. "It is therefore in people's best interests to protect sharks, reduce the pressure of exploitation, and rebuild their populations," Karlowski concludes.

A PHARMACEUTICAL-GRADE SUBSTITUTE

The protection of cartilaginous fish is particularly important, as these species reproduce very slowly. Species living in the deep sea, such as the Greenland shark, have a life expectancy of about 400 years and do not reach sexual maturity until they are 150 years old. The heavily fished mako shark takes at least 20 years. In addition, sharks have very few offspring.

The extraction of squalene from shark livers is not the central problem leading to the decimation of shark populations. However, on average three sharks have to die to produce one kilo of squalene. In the future, plants could serve as an alternative source of this raw material. Until now, it has been a hurdle to extract it from plants in the quantity and purity required for pharmaceutical products. But Evonik has now succeeded in producing PhytoSquene®, a pharmaceutical-grade substitute product. The raw material for PhytoSquene® is the oil of amaranth, a pseudo-cereal from the *Amaranthaceae* family. This plant is cultivated in many parts of the world, is also suitable as food, and is very beautiful with a deep-purple, lush flowered stem. "We have a high security of supply of this raw material due to the large number of possible cultivation areas," explains Rima Jaber.

Prof. Katrin Böhning-Gaese, the director of the Senckenberg Biodiversity and Climate Research Centre in Frankfurt am Main, calls the project an example of the term "seeds of the good Anthropocene." She's referring to the possible positive transformation of the current geological age, during which human beings have become one of the most important factors influencing the biological, geological, and atmospheric processes on earth. "Transformation happens when lots of small things change," she says. "Such model projects are necessary, helpful and inspiring." (see the interview starting on page 50)
PhytoSquene® is one of Evonik's Next Generation →

“Wherever we can replace animal products with plant-based or biotechnologically produced products, we do so”

THOMAS RIERMEIER, HEAD OF THE HEALTH CARE BUSINESS LINE

Solutions—that is, products with outstanding sustainability benefits. The topic of sustainability has become increasingly important in the pharmaceutical industry in recent years. However, the production of the new plant-based raw material initially presented Evonik’s researchers with several challenges—for example, the need to guarantee extremely high purity. The solution was developed together with the process engineering team and consists of upstream clarification of the oil in combination with a chromatographic process. This enabled a purification process that is not only economical but also guarantees the production of squalene with a purity of 99 to 100 percent. Evonik now produces the concentrate in this outstanding pharmaceutical grade at its Dossenheim site, near Heidelberg.

“The residual oil produced during clarification is also a valuable natural raw material,” says Jaber. “I’m confident that we will also find a useful application for it.” PhytoSquene® is part of the portfolio of products of non-animal origin that Evonik has introduced in recent years. Another example is PhytoChol®, a plant-based cholesterol that can be used in the production of mRNA and gene therapeutics as well as in cell culture. The collagen Vecollan®, which is produced by fermentation and is suitable for medical applications, also contains no animal or human materials. Vecollage®, another plant-based collagen, is produced for the beauty and personal care sector.

Within two years, the team succeeded in bringing PhytoSquene®, the first pharmaceutical-grade plant-based substitute for squalene, onto the market

These products open up new possibilities for vegans and people who, for cultural or religious reasons, do not want to use medicines or care products containing animal ingredients. Today every pharmaceutical product must already state whether the active ingredients it contains come from animal or plant sources. "Wherever we can replace animal products with plant-based or biotechnologically produced products, we do so," explains Thomas Riermeier, the head of the Health Care business line. "In this way we contribute to the preservation of biodiversity and at the same time ensure the maximum consistency, quality, and purity of the product."

A RELIABLE BOOSTER

There is a huge demand for squalene in the pharmaceutical industry. Squalene enhances the effect of drugs and the immune response of vaccines. It serves as an adjuvant, enabling lower doses, thus limiting possible side effects. However, there can be quality issues with squalene from animal sources. Because sharks are usually at the top end of the food chain, toxins such as methylmercury accumulate in their livers. The Federal Environment Agency warns that this substance can damage the nervous system. The composition of the animal-origin squalene also varies from batch to batch, and that leads to fluctuations in the quality of the end product.

The amaranth oil used by Evonik, on the other hand, is of consistently high quality and free of mercury residues. "The product must also meet the same specifications as squalene of animal origin—for example, the requirements of the *European Pharmacopoeia*," says Jaber. This reference work records the quality standards for drugs and the substances used to manufacture them, for all 47 member states of the Council of Europe.

Intensive research is currently being conducted into the use of squalene in mRNA vaccines. Initial tests have shown that their addition increases shelf life. This would be a major advance, especially for countries where temperature-sensitive vaccines cannot be kept refrigerated throughout.

The processed amaranth oil, which has a light yellow color, comes from the process technology unit in Marl

Intensive research is also currently being carried out in the field of cancer research into the use of squalenes in mRNA therapies. "The initial results are very interesting," says Jaber. At Evonik's site in Vancouver, Canada, where research is being conducted on lipid nanoparticles (LNPs) for mRNA vaccines and therapies, scientists are now also working on the use of plant squalene with new formulations. "I am confident that we will also be able to replace squalene from animal sources with PhytoSquene® in future solutions," Jaber explains.

Christoph Bauer is a journalist who works at Evonik's Communications department

“The goals must be measurable”

Ecosystems are under threat all over the world. But Katrin Böhning-Gaese, the director of the Senckenberg Biodiversity and Climate Research Centre, believes that a turnaround is possible—under strict conditions

INTERVIEW **CHRISTOPH BAUER** & **BERND KALTWASSER**

Ms. Böhning-Gaese, you recently visited Mount Kilimanjaro. What's the current level of biodiversity on Africa's highest mountain and its melting glacier?
Glaciers are not of central importance for biodiversity and human beings. The important thing is the vegetation on the mountain. The landscape there is hot and dry. If no mountain were there, the region would have precipitation only a few times per year. Mount Kilimanjaro generates orographic rain. The trees and bushes, lichens and mosses "milk" the clouds, so to speak—and that's important for the capture of water. Today 1.4 million people live on the mountain or around it.

How can forests support so many people?
The special thing about Mount Kilimanjaro is the Chagga Home Gardens. Banana trees grow in these tree gardens, with coffee plants growing under them and vegetables flourishing even further down under the coffee plants. The banana leaves are spread out on the ground, thus preventing the soil from drying out or being washed away. They also return nutrients to the soil. Once in a while you'll see a cow in the Gardens. There are pigs and chickens. Meanwhile, huge rain forest trees have been left to grow. All of these factors are creating one of the most sustainable and biodiversity-rich systems we know of. People can have a healthy and sustainable diet on and around this mountain. This would be a model for many regions of Africa.

In many parts of the world there is only a very slight awareness of climate protection and the conservation of nature. Why is that?
People need to understand that climate change is connected with the loss of biodiversity. They have to know what must be done in order to protect the climate and biodiversity. Almost every measure for protecting the natural environment is also a climate protection measure, but not every climate protection measure serves to promote biodiversity. Just think of the cultivation of bioenergy plants, for instance.

There have been five mass extinctions of species in the history of the earth. Dominant species always perished. Now you're talking about the sixth mass extinction, and the dominant species is the human being. Can this process still be stopped?
Yes, we are working on the topic of biodiversity with the same kinds of models as in climate research—in other words, future scenarios in which we look at various different futures. As a society and in our political decision-making, we are deciding which scenario we want to pursue. If we continue to behave as we have so far, biodiversity will continue to decrease. But there is also a scenario with which we can avoid disaster.

We'd like to hear more about it.
In order to stabilize biodiversity by 2030 and even increase it by 2050, we need three packages of measures: first, huge protected areas that are well managed and a renaturation of ecosystems; second, sustainable and productive agriculture; and third, a change in consumption, meaning less food waste and a more plant-based kind of nutrition. If all of this is implemented, biodiversity will recover and can even increase.

In 2022 there was a breakthrough at the UN Biodiversity Conference COP15 in Montreal, Canada: The community of states adopted a framework agreement according to which 30 percent of the earth's surface is to be placed under protection by 2030. Can this plan succeed?
Basically it can. In Germany we're already near the mark. But we're very bad at implementing this protection effectively. For example, the Wadden Sea National Park has no parallel anywhere in the world. However, fishing with bottom trawl nets is legally practiced in its core zone. In some countries in the Global South, the challenges are smaller than they are in Germany because they have lower population densities. If Brazil would protect its extensive forests, it could easily reach the 30 percent goal.

In the past we've failed to reach many goals. Has the bar been set too high?
If the policymakers don't set ambitious goals, we've already lost the struggle. The next step is to make these goals measurable so that we can demand their attainment. We've already become better in this regard: The goals of the Montreal agreement are more frequently quantitative than was previously the case. There is also a bigger consensus among the public and the media that more has to be done. We can only implement legislative changes or a reallocation of subsidies if this public backing exists. →

In the area of agriculture, we're seeing that policymakers quickly revoke restrictions if people only protest loudly enough.

If you have 200 farmers with 200 tractors, that always looks like a lot of resistance. But I believe that the EU Nature Restoration Law, through which we are to reach the 30 percent goal, will be adopted—unlike the pesticide law, for example, which was too narrowly conceived and was not well thought out. But even though farmers protest against one measure or another, we have to keep in mind that organic farmers' associations, for example, strongly advocate renaturation. Agriculture is an important key: Three quarters of the world's arable land are used to grow animal feed. If our consumption of animal products were halved, a great deal of arable land would become available.

So, vacant fields for industry?

No, the goal for industry must be the circular economy: reduce, reuse, recycle. This means that biomass is not cultivated and then burned, and that waste materials are utilized very differently. The promotion of bioenergy has given us the wrong incentives: Wonderful meadows were dug up in order to plant corn for producing energy. We have to make very sure that this time we pursue a strategy that doesn't once again turn out to be counterproductive. If renewable raw materials are introduced into the chemical value chain, that's different from putting them into a gas tank and then blowing them into the air again after fractions of a second.

How does the economy benefit from more biodiversity?

A current report of the World Economic Forum states that in the next ten years five environmental risks will be among the biggest threats to the economy. Biodiversity and the collapse of the environmental systems have moved upward to third place. First place is occupied by extreme weather events, and in second place are critical changes in the earth system. If you look at it from the negative side, you can put it this way: There is no business on a dead planet. From a positive perspective, companies that invest in biodiversity today are creating market advantages for themselves, because the regulatory agencies will soon demand this anyhow.

Can industrial locations compete with one another fairly? No matter how advantageous green energy may be in the EU, it can't compete with fracking gas in the USA in terms of pricing.

This is where the policymakers need to act. For example, the European Union is now introducing mandatory reporting by companies. In the future, companies must document the size of their footprint in various environmental dimensions ranging from biodiversity and the protection of ecosystems to the circular economy.

Will that lead to the desired goal? At the moment, chemical production is primarily increasing in China.

Through the supply chain directive, we at least have an instrument that extends into other countries. If Chinese suppliers want to do business in Europe, they have to provide documentation about the conditions under which their products were manufactured. It may take a while for the importance of biodiversity to be recognized in Beijing as well. However, the Chinese population has experienced what happens when a business promotion policy completely ignores environmental issues. It leads to incredible levels of air pollution or dust storms that cause huge problems for cities. China has now enforced very ambitious plans in this regard.

What would you like the economy to do?

Companies are indeed part of the problem, but they're also part of the solution. The level of ambition is raised higher by means of more stringent reporting requirements. Ultimately, companies should have a positive influence on biodiversity. That would push the business model in the right direction. In the food industry, companies are already emphasizing animal welfare or a strongly plant-based product range—because consumers are demanding these measures.

How long will it take for us to be able to feel, or at least measure, a turnaround?

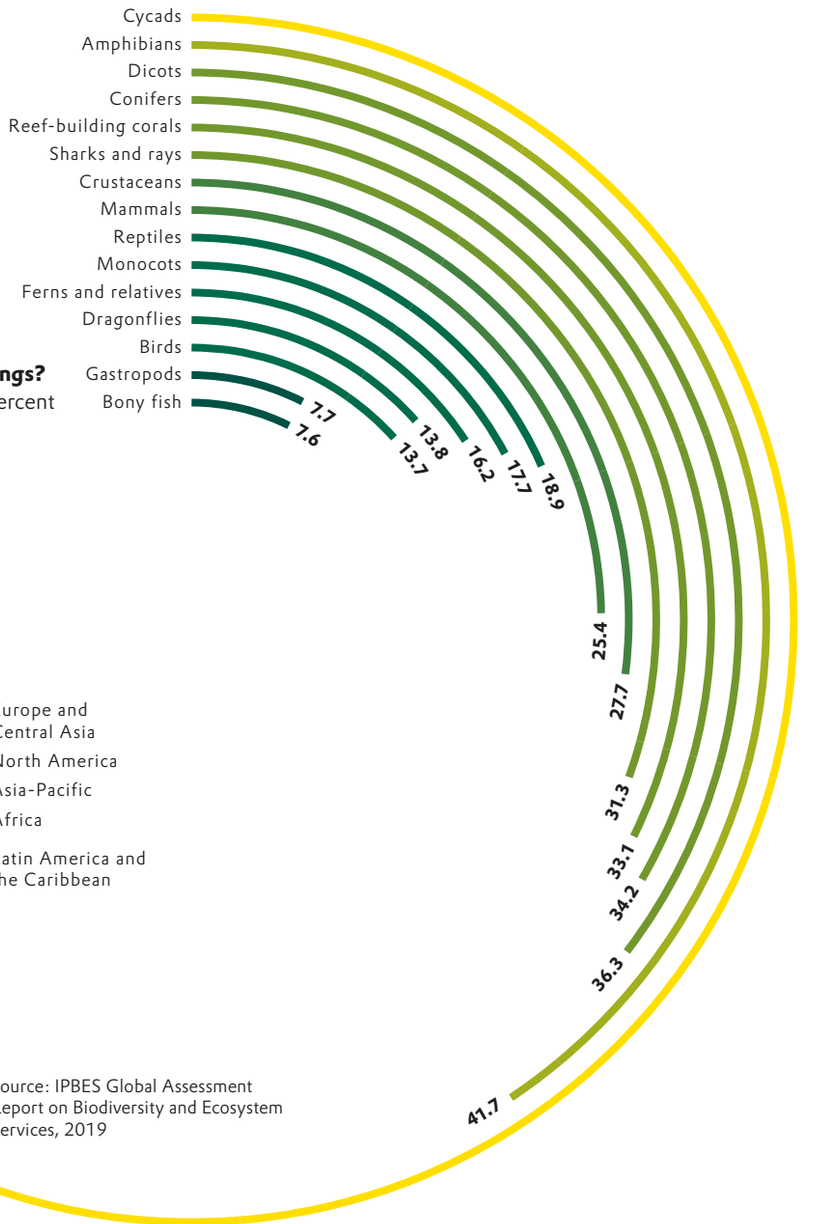
People who redesign their gardens to be more natural notice the difference in just a few years. The same applies to agriculture. For forests, it can take more time. In Tanzania they are now trying to establish a huge nature conservation area in a parched and partially oversalted savanna. The trees are growing slowly because the region is relatively dry—but people are already seeing the first herds of impalas and zebras. As you can see, change can happen quickly.

PRESERVING DIVERSITY

Almost one million species are threatened with extinction in the coming decades. Which groups are particularly at risk? And what is being done to prevent their extinction? A numerical overview.

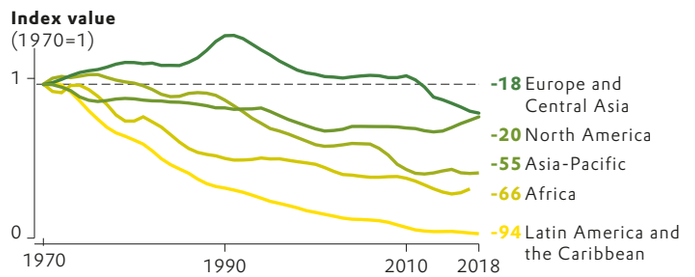
INFOGRAPHIC **MAXIMILIAN NERTINGER**

How endangered are the various groups of living beings?
Estimated proportion of threatened species in 2019, in percent



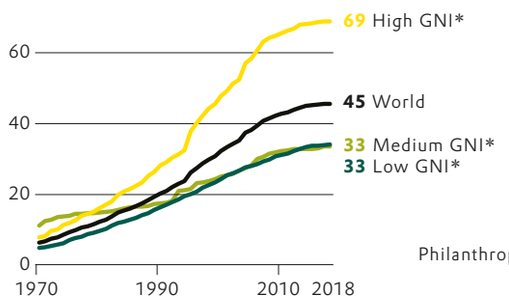
Source: IPBES Global Assessment Report on Biodiversity and Ecosystem Services, 2019

Where species are particularly at risk
Development of population sizes of vertebrate species* according to the Living Planet Index, in percent



*31,821 populations and 5,230 species
Source: WWF/ZSL Global Living Planet Index, 2022

It's easier for rich countries…
Share of protected areas in particularly biodiverse areas, in percent

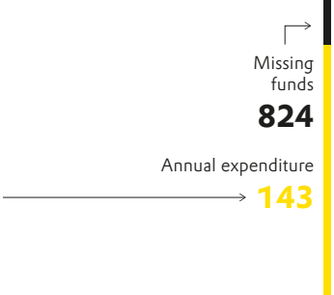


*Per-capita gross national income; high, medium or low as estimated by the World Bank.
Source: IPBES Global Assessment Report on Biodiversity and Ecosystem Services, 2019

Large sums flow into the protection of biodiversity…
Estimated expenditure (upper limits) for the conservation of biodiversity in 2019, in billions of US dollars

Source: A. Pinzón, N. Robins, M. McLuckie, G. Thoumi, 2020
Difference in total due to rounding

…but a big gap remains
Estimated annual expenditure and required funds (upper limits) in 2019, in billions of US dollars



Same appearance, different gene activity? Identical twins provide epigeneticists with valuable insights into the changes in our genetic material over the course of our lives

THE ODD COUPLE

Although identical twins are genetically identical, they develop in dissimilar ways. Epigenetics researchers investigate why this is so—and thus develop approaches for healing genetic diseases

TEXT **BJÖRN THEIS**

Identical twins have fascinated people throughout history. In many cultures they were long regarded as beings that were not quite human and presaged either a blessing or a curse. Thanks to the natural sciences, we know that there's nothing magical about them. Nonetheless, for a long time they presented geneticists with a riddle: If the rules of heredity are valid, how can it be that one identical twin develops a hereditary illness such as diabetes while the other one can eat muffins without a qualm, even though both of them have identical genetic information?

Famines provided the initial answers. A few years ago, epidemiological studies showed that the grandchildren of men who had experienced famine as children were much less likely to suffer from diabetes or heart disease than the grandchildren of men who had never starved. The findings indicated that the environmental impacts that have been experienced could have an influence on genetic information.

A LARVA OR A QUEEN

Another example of the huge effects that environmental impacts have on individual development comes from honeybees. All honeybee larvae have the genetic potential to develop into a queen bee, but only the larva that is fed with royal jelly grows up to be the queen. So there must be a mechanism that turns genes on or off, depending on the specific nutrition received. The branch of biology that searches for these mechanisms was named epigenetics—a combination of the word "genetics" and the Greek syllable "epi" ("besides" or "over"). This concept refers to research focusing on hereditary changes in genetic activity that do not change the sequence of bases in the genetic material.

The main focus of this young discipline is currently on two epigenetic mechanisms. One of them is methylation. In this process, a methyl group consisting of one carbon atom and three hydrogen atoms overlays sites along a strand of DNA. As a result, the genes cannot be read. The second switch is histone acetylation. When a strand of human DNA is completely unfolded, it is about two meters long. In order to fit inside our cells, it is packed in what is known as a histone complex. When information has to be read, the strand is not fully unfolded. Instead, the histone packages are opened only at the required site. Both of these mechanisms are reversible.

In the case of identical twins, research has shown that there are hardly any differences between their epigenetic markings while the twins are young. However, as the twins grow older they become more and more dissimilar epigenetically. In other words, life leaves traces in the molecular biology of our cell nuclei and influences which genes are switched on and which are switched off. If we want to understand the development of an organism, we therefore have to observe not only its genome but also its epigenome—that is, the totality of all its epigenetic structures.

THE END OF ALZHEIMER'S DISEASE?

Valuable knowledge is hidden in the epigenomes of human beings and animals. It can be assumed that, thanks to epigenetic applications, in the future it will be possible to identify many diseases at an early stage, accelerate healing processes, and simply switch off genetic diseases. That's why epigenetics could be a game changer for the field of medicine.

It's a good thing that Creavis, which has research teams in Germany and Singapore, is already active in the field of epigenetics. The goal of the teams is to make relevant epigenetic information readable quickly and affordably. The Foresight team will also be sounding out the future of epigenetics. Who knows? Maybe this is exactly the hiding place of the right switch that will finally banish the terror of Alzheimer's disease or diabetes.

Björn Theis heads the Foresight department at Evonik's innovation unit Creavis

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S
Sulfur

"Without sulfur there would be no life"

LOG **RANA SEYMEN**
PHOTOGRAPHY **LILY WANG PHOTO LLC**

Patricia Nadeau is a geologist working at the Hawaiian Volcano Observatory, which is located on Big Island within sight of the Mauna Loa volcano. Her special area of research is the analysis of volcanic gases.

The exhalations of a volcano are suffocating, acrid, and sulfurous. We can get a sense of what this smell is like during breakfast. When we crack a boiled egg open, an amino acid containing sulfur is released. Sulfur, which has an intense odor, is one of the basic elements that enabled life to develop on earth. Without sulfur we could not produce any amino acids, the building blocks of proteins. This element is also essential for the formation of vitamins such as biotin and thiamine.

I regard volcanoes as a spectacular manifestation of nature. Their explosive power is generated by the expansion of trapped gases as the magma rises. The gases primarily consist of water vapor, carbon dioxide, hydrogen chloride, and sulfur dioxide. As a volcanologist, I work together with the local observatory here on Hawaii to monitor the emission of sulfur dioxide. The presence of 0.0005 grams in one cubic meter of air is already toxic and can irritate the respiratory tract. Regular monitoring of the threshold values gives us insights into the volcano's activity. The aim of our work is to minimize the volcano's effects on the environment and human health.

My fascination with volcanoes brought me to Mauna Loa on the island of Hawaii. The people who live here say that the volcano is a living being that is shaping and changing the island. They attribute something magical to Mauna Loa. In spite of its dangers, it is regarded as a divine blessing and treated with reverence.

I realize that my work is not without risks. An eruption can occur at any time, and my team and I would then have to act quickly to save ourselves and others. But the work I do is a passion and a vocation that I don't want to miss in my life. I'm fascinated by the beauty and power of volcanoes, and I want to help ensure that the people of Hawaii can live here safely.

Masthead

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“Things are never as they are …

… they are always what we make of them,” according to the French author and playwright Jean Anouilh (1910–1987). Most of the heroes and heroines of his works such as “Antigone” bravely fight for their ideals and resolutely execute their plans.

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