ESSENTIAL

FREUDENBERG SEALING TECHNOLOGIES

ART OF ENGINEERING

MATERIAL WORLD

From an Idea to a Material

BLUE LIGHT

Interview with Shuji Nakamura, Nobel laureate in physics.

LEATHER AND POLYMERS

How materials have helped Freudenberg renew itself over its history.

INNOVATION TEAMWORK

Dr. Ruth Bieringer: Why material development requires sharing knowledge.

the magazine 2_22

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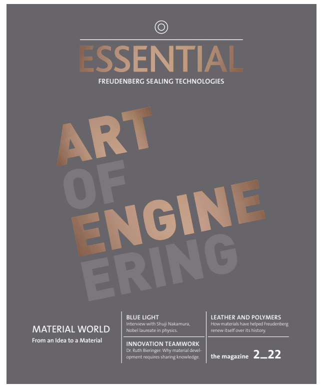
IN FIFTY WORDS



Progress has always been associated with new materials. The invention of bronze, ceramics and paper. Of elastomers and polymers. Materials are combined and changed. Others are created. Innovation is the key ingredient in every composite. A spark of genius. An idea. Ingenuity starts in our thoughts. It creates new worlds.

Material World

By Claus Möhlenkamp, Chief Executive Officer,
Freudenberg Sealing Technologies

How do you control a gas that, before crystallizing, has an extremely hard time deciding what form to take? The material in question is silicon carbide. When this hard, shiny, metallic material is sufficiently heated, it doesn't melt — it is transformed into a gas that crystallizes when it comes into contact with a surface. Today the silicon carbide crystals that emerge from it are in high demand for use in semiconductor chips for photovoltaics and electric mobility. A debt is owed to a group of scientists in the 1980s who worked out a way to control the process and, out of 177 possibilities, produce exactly the desired structures.

Inventive minds produced steel, ceramics and glass. The great leaps of civilization have often involved new materials.

The history of materials development and research is full of similar examples. It highlights the creativity and determination used to develop material breakthroughs again and again, both in centuries past and today. Researchers alter raw materials, transform their aggregate states, combine them and create composites that have entirely different characteristics than those of their ingredients. The history of humanity began with the use of raw materials. But it didn't stop there. We would not have reached today's level of civilization with stone, iron and wood. Inventive minds produced steel, ceramics and glass. The greatest leaps in civilization were frequently driven by leaps in early materials science: Without the cellulose mixture known as paper, the revolution wrought by the printing of books would have unlikely occurred. Without the mixture of sulfur, charcoal and saltpeter, commonly known as "black powder," the history of the world would have taken a different course.

Materials progress has always been achieved through trial and error. Not just in today's era of complex composites, but even dating back to about 4,000 B.C. when copper mining began. This soft metal was only of limited use for tools. But early societies quickly recognized that copper from different deposits could vary in its hardness because it sometimes contained other elements such as arsenic or lead. While lead made copper more malleable, even a small amount of arsenic made the metal significantly harder. It took some time to progress from this insight to the production of the first global alloy – bronze – made from a combination of copper and tin. Bronze made completely new tools and weapons possible.

Many composite materials were inadvertently produced by early chemists during experiments that produced unexpected results. The world of atoms was not yet understood. The discovery of polymer chemistry would change this, but its initial acceptance in scientific circles was slow and fraught with doubts. During the 1920s, for example, when Hermann Staudinger proposed that large, long-chained molecules existed, his renowned colleagues accused him of "lubrication chemistry." Staudinger's tests were not pure from a chemical standpoint and were, therefore, worthless, Paul Niggli insisted. Macromolecules? "There's no such thing," Niggli shouted in the middle of one of Staudinger's lectures. He was wrong, of course. The age of polymers had begun.

These highlights make one thing clear: A material's most important ingredient is not found in the mixture itself. It is found in the human capacity to innovate. It is found when the idea to combine or alter ingredients grows into in-depth research that delivers important new materials. And it is found when these new materials are used to develop products capable of solving current and even future global challenges. We are devoting this issue of ESSENTIAL to this wealth of human ingenuity and the resulting, multifaceted world of materials science. We will explore how materials have changed and shaped our world. The issue, aptly named "Material World," offers an in-depth exploration of many materials science topics – and how materials continue to shape and influence our world. We can modestly say we are pleased that our Freudenberg experts have played, and continue to play, a significant role in the understanding and advancement of materials science. Our materials, products and developments encompass elastomers and even move beyond them. We too are convinced that power of innovation and a dash of ingenuity are a very important part of this development. And we are proud of our employees, who personify this very art of engineering. ◎

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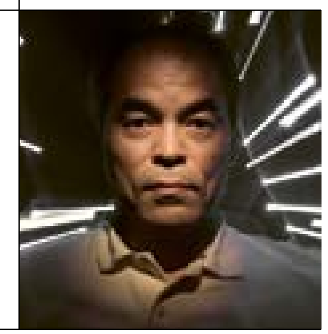
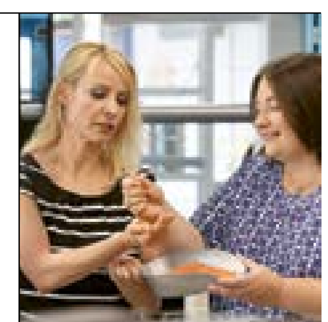
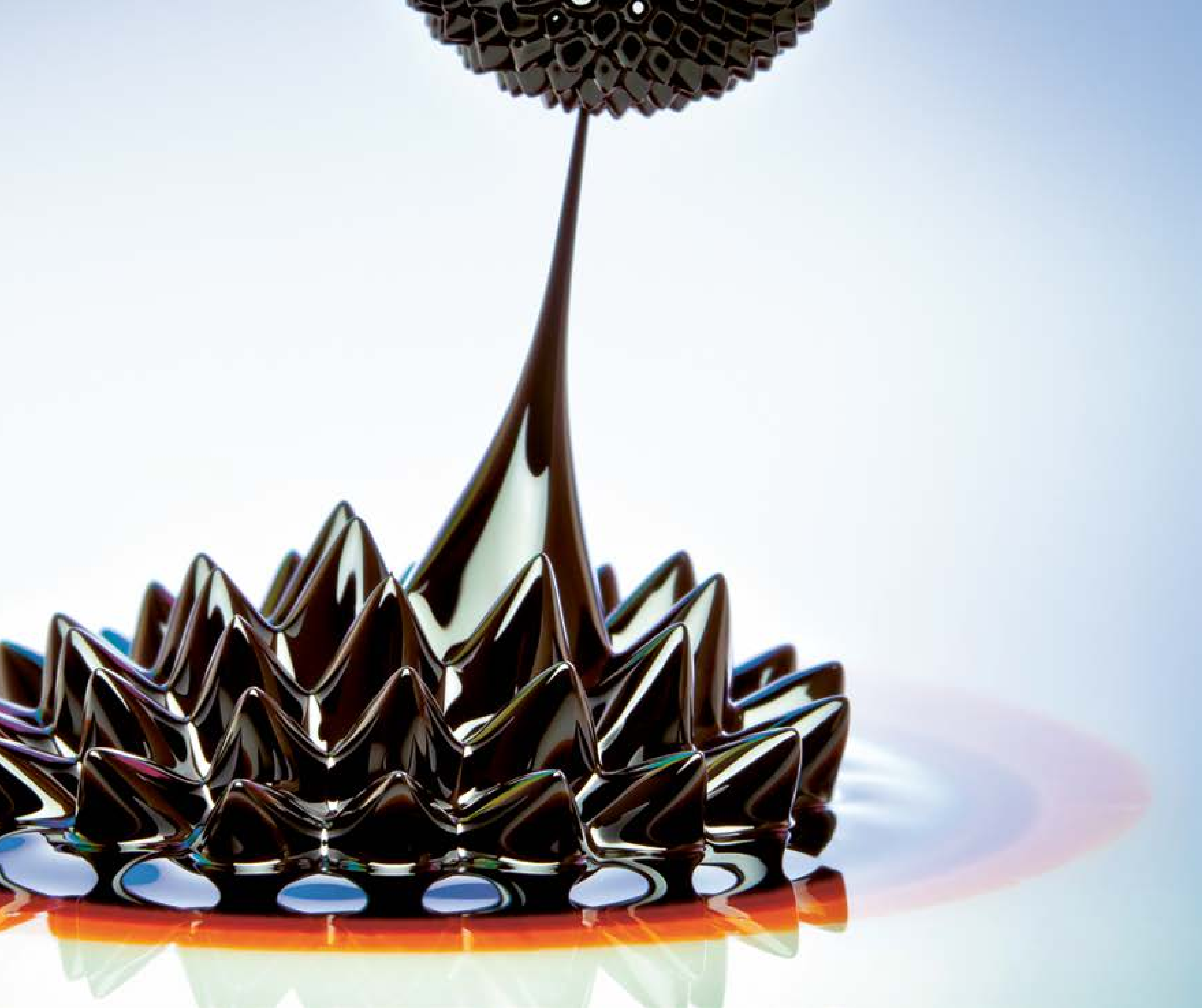
Content





Quality Guaranteed

The right materials are fundamental to the production of many products. They impart special qualities. In some cases, for example, they help make products more resistant to high temperatures. Many materials lend themselves to use in particular products, and the rare earth neodymium (shown here) is a good example. With the right mixture of iron and boron, it is used to make the world's most powerful magnets. Some of them maintain their full attractive force even at temperatures of 230°C (446°F). So, materials are an important factor of production – all the more since the end products make our daily lives easier. That's why material expertise is enormously important to manufacturers.



Sourcing Materials

The materials used in products have to be extracted from the right natural resources. For example, there are ore-bearing rocks that contain molybdenum disulfide, a source of molybdenum. The element is used in the production of stainless steel or as a mixture for alloys since it has a high melting point and is impervious to attacks from reducing acids. These qualities have been known for about 125 years. Molybdenum has been used to strengthen steel for a long time. As an ingredient in alloys, it has also made metals more resistant to heat and corrosion right down to the present. It also has uses in lubricants. As an ingredient in some high-performance materials, molybdenum has made many technical processes possible for the first time, even from an economic standpoint.

Testing Ground

The molybdenum used in the aerospace industry has clearly demonstrated its advantages as a dry lubricant on the exteriors of spacecraft. Outer space is often a testing ground for the development of new materials. Astronauts at the International Space Station (ISS) continually do research on different elements or investigate mixing proportions. Based on how the materials behave under weightless conditions, researchers can draw insights regarding their uses back on Earth. Or their work opens up new opportunities, perhaps by making certain mixtures more stable. One recent space mission dealt with antimicrobial surfaces. They would be an important addition to life on the ISS – and in hospitals. ◎

“Trust Your Own Creativity!”

For three decades, blue light-emitting diodes seemed an impossibility. Then, a Japanese engineer made a breakthrough in 1993 by turning to a material that everyone else had written off. An interview with Shuji Nakamura, a Nobel Prize winner in physics, on the limits of research, fires in the lab, and the light that is changing the world.

Shuji Nakamura

Born in 1954, he worked for Nichia (then a small company but today one of the world’s largest manufacturers of LEDs) after completing his studies in electrical engineering. He developed the first bright gallium nitride light-emitting diode and was awarded his doctorate from the University of Tokushima in 1994. His other research successes include an indium-gallium nitride LED and a blue laser. In 2001, he sued Nichia, arguing that the company had inadequately remunerated him for his research successes with the equivalent of an approximately 150-euro bonus. The two parties ultimately agreed on 6 million euros, so far the largest bonus ever in Japan. Today, Nakamura is an American citizen. In 2014, along with Isamu Akasaki and Hiroshi Amano, he received the Nobel Prize in physics for his LED research.

DR. NAKAMURA, YOUR CAREER ACTUALLY BEGAN SOMEWHAT UNUSUALLY.

You mean because I started out at a chemical company in 1979, even though I was an electrical engineer right out of college?

YES. NICHIA PRODUCED PHOSPHORUS. THERE WAS NO DIRECT CONNECTION TO ELECTRONICS.

The company was looking for new markets. One idea was to use phosphorus to produce gallium phosphide, a semiconductor material for red light diodes. That was my assignment. In any case, I had already worked with compound semiconductors during my studies.

STILL, YOU WEREN'T ACTUALLY A MATERIAL DEVELOPER.

I had to teach myself how to grow crystals from gallium and phosphorus. That required heating the materials to more than 1,000°C (1,832°F). Now just imagine: My office had about 10 square meters (about 108 square feet) of space – and phosphorus is explosive. If you heat it too much and it reacts with oxygen, you get an explosion and flames rising to the ceiling. Burning phosphorus flies in all directions. That occurred about once a month.

THAT ACTUALLY HAPPENED?

Yes, at about 5 o'clock in the afternoon, when my coworkers were on the way to the parking lot, the temperature would reach 1,100°C (2,012°F). When the material exploded and I doused the fire with water, there was an impressive amount of smoke. In the beginning, employees would come in and ask me whether everything was all right. I was never actually hurt.

WITH ALL DUE RESPECT, THAT SOUNDS BIZARRE FROM TODAY'S PERSPECTIVE.

Well, the company was out in the country. This would not have been possible in the middle of Tokyo. One problem was that I needed quartz test tubes for the process. The ones that we had were open-ended, so I had to fuse them myself. The more I mastered all the processes, the fewer explosions there were.

In just three years, Shuji Nakamura succeeded in mass-producing gallium phosphide. But since the company was small, the market's response was tentative. So its sales team came up with an idea: If you already know the technology for semiconductor materials, why not go ahead and produce red light diodes? Nakamura provided the necessary steps. And he made a decision: He wanted to do more. He wanted to invent blue LEDs.

YOUR BREAKTHROUGH LEADING TO BLUE LEDS BEGAN WITH A BOLD DECISION: YOU SELECTED GALLIUM NITRIDE AS THE SEMICONDUCTOR MATERIAL.

The reason was quite simple. I wanted to finally earn my doctorate. In Japan, you have to publish your research results to get it. I thought to myself, hundreds of papers have already been written on zinc selenide. Everyone believed it was the semiconductor material that would deliver the breakthrough. There was hardly anything on gallium nitride. I was able to experiment and do new research on it.

It is hard to escape the personal magnetism of Shuji Nakamura. He is reserved and modest in a refined way, yet approachable and likable at the same time. What he almost dismisses as a coincidence fell in line with a series of advances in material development that he had tackled with determination and creativity – quickly putting himself years ahead of research departments and universities.

If you want to make crystal layers for a light-emitting diode, you need an MOCVD, a very expensive machine that I was not familiar with. Our plan was for me to spend a year at the University of Florida and become acquainted with the technology there. Instead, I had to spend 10 months assembling a machine that had just been delivered.

SO THAT WASN'T THE PLAN ...

No, but it gave me a very fundamental understanding of the technology. When I started to experiment with gallium nitride, I was able to adapt the machine, rebuilding and re-welding individual parts. Researchers don't normally do that. They need technicians for this. And technicians have little understanding of materials research.

Research always involves setbacks. If you want to make progress, you have to experiment."

> It makes sense for companies to think in terms of products. Scientists can give free rein to their desire to contribute to humanity's progress."

IT SEEMS AS THOUGH EACH APPARENT SETBACK ACTUALLY MOVED YOU FORWARD IN THE END.

Research always involves setbacks. If you want to make progress, you have to experiment. I have read a lot on the subject, but you have to stop reading at some point and be creative. You have to ignore everything that seems certain.

LIKE THE FACT THAT ALL THE EXPERTS REJECTED GALLIUM NITRIDE AS A SEMICONDUCTOR MATERIAL?

Well, sometimes the research papers are wrong, too. You can't develop your own ideas if you are always replicating. I always say: Trust your own creativity. The truth lies in your experiments.

YOU WERE A LONE WOLF. YOU WERE PRACTICALLY THE ENTIRE DEVELOPMENT DEPARTMENT – WAS IT AN ADVANTAGE TO BE SO INDEPENDENT?

Yes. Curiously, other material developers later told me that I was lucky. These were people who worked in departments with a dozen other researchers. But nine out of 10 would say, "Let's do research on zinc selenide," and the sole creative voice is outvoted. I could decide on my own. I was the only one in the company who had immersed himself in the subject. Sometimes it is individuals who have to come up with the crazy ideas.

What Nakamura has presented so positively was a complicating factor for a while: On a number of occasions, the management wanted to terminate his research. For a long time, he had a small budget and inadequate equipment, which he improved on his own. He was passed over for raises and did some of his work in defiance of top management.

ARE LUCK AND COINCIDENCE ALWAYS FACTORS IN INVENTIONS?

They at least play a role. People have been doing research on LEDs since the 1970s. There was progress. There were even experiments with gallium nitride. But for a really bright light-emitting diode, you have to improve the electrical conductivity of the semiconductor. You need negatively and positively charged material. For a long time, people thought that positive gallium nitride was an impossibility. The material had other weaknesses as well, but in the end it turned out that some of the weaknesses weren't important. On the other hand, the potential light yield was huge. The next hurdle was producing indium-gallium nitride with sufficient quality to generate blue light. And everyone considered that to be impossible.

TODAY YOU NO LONGER WORK FOR A COMPANY – YOU HAVE BEEN EMPLOYED AT A UNIVERSITY SINCE 1999. WHAT DIFFERENCE DOES THAT MAKE FOR DEVELOPMENT WORK?

In a company, you rarely have to worry about financing. But it is generally a challenge at universities. We also have high turnover here. Students stay for five years on average. The advantage is that we can be crazier and more creative. At a company, a product has to ultimately emerge.

DOES IT LIMIT A RESEARCHER'S WORK TO BE TIED TO A PRODUCT OR DOES IT ALSO PROVIDE FOCUS?

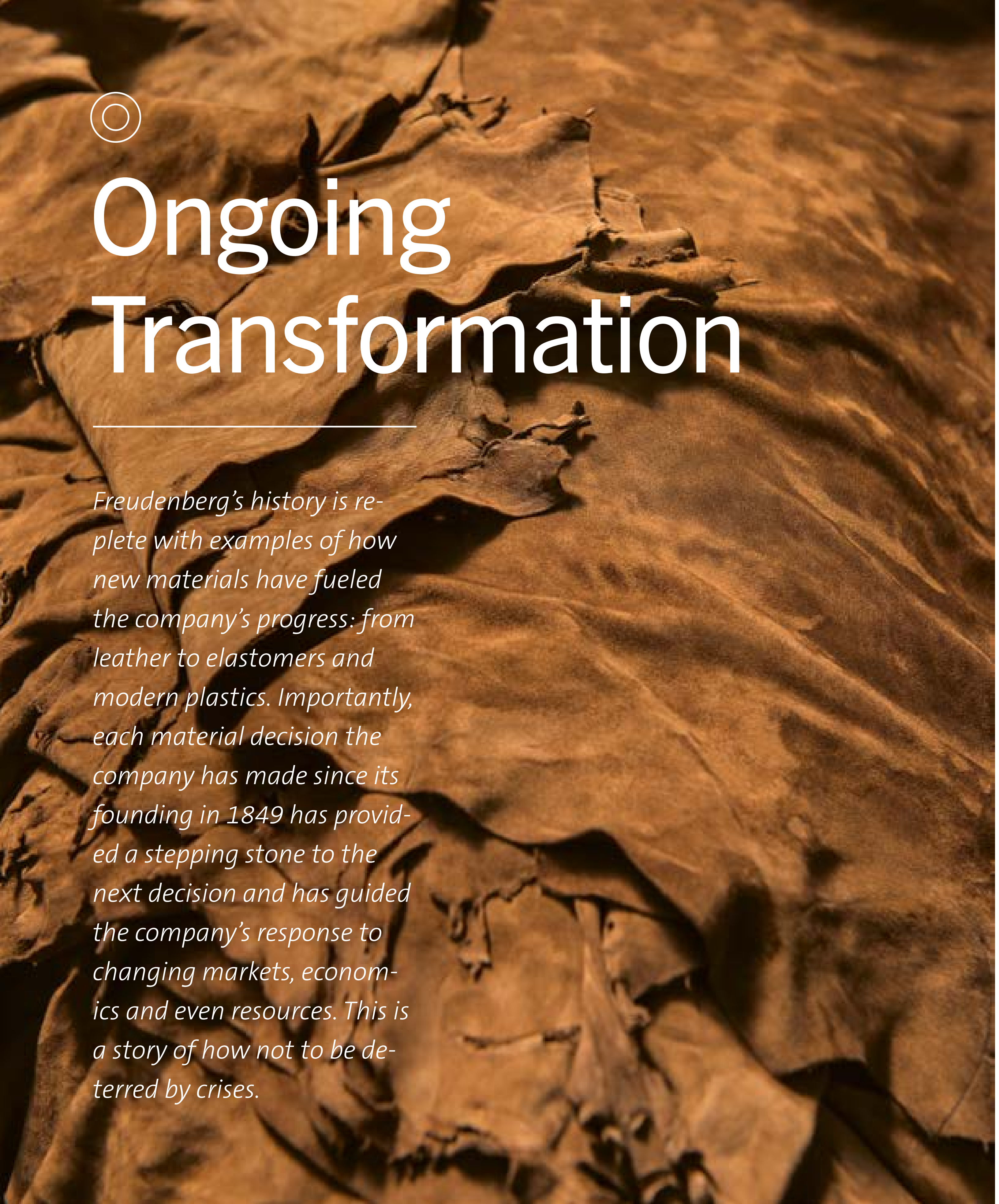
Both. It makes sense for companies to think in terms of products. Scientists can give free rein to their desire to contribute to humanity's progress. Otherwise, there is the risk that their work could remain theoretical. In the end, it is products that move humanity forward.

WHAT AREAS ARE YOU INTERESTED IN RIGHT NOW?

Lasers continue to be a multi-layered field. Laser diodes can advance quantum computing and nuclear fusion. Both are exciting areas for the future. In all, there are a great many advances to which laser diodes and light-emitting diodes are contributing. Think about how important LEDs are to sustainability: We are saving huge amounts of energy because they produce more light and less heat.

WHAT WOULD BE YOUR ADVICE TO FUTURE MATERIAL DEVELOPERS?

The fact that they have to run risks at some point. Once you have mastered the fundamentals, it all comes down to creative execution. ◎



Ongoing Transformation

Freudenberg's history is replete with examples of how new materials have fueled the company's progress: from leather to elastomers and modern plastics. Importantly, each material decision the company has made since its founding in 1849 has provided a stepping stone to the next decision and has guided the company's response to changing markets, economics and even resources. This is a story of how not to be deterred by crises.

The material requires UV light: Patent leather dries in the sun on a meadow at a Freudenberg site.

Freudenberg & Co. KG, Corporate Archive

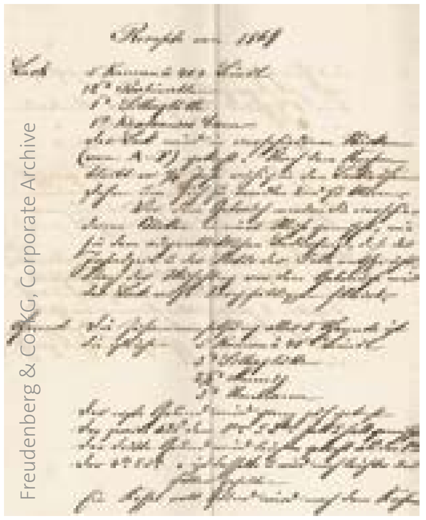
Patent leather marked the starting point. In the mid-19th century, the trend spread across Europe. "Everything that was supposed to look beautiful was made with patent leather," said Dr. Michael Horchler, Head of Corporate Archives at Freudenberg: "Shoes, bridles, even sofas." And fire department helmets. The patent leather varnish made them more flammable, "but they looked good." Producing patent leather required expert knowledge of varnish and a deep understanding of leather. One German tannery was well positioned to capitalize on the trend. Its owner, Carl Johann Freudenberg, had always emphasized quality and ideas. In combination, which meant material expertise. "He had a high standard of excellence," Horchler said. For the first time, the tannery began to develop in new directions.

Engine for Growth, Economic Shock

Leather production was complicated at the time: It took about 75 steps just to process a raw hide into finished leather. Freudenberg relied on skilled craftsmen to perform these steps; the company still lacked machinery at that point in time. "If you

Of Sheep and Bees

Varnish was the focus of what may have been the first employee innovation in Freudenberg history: Once it was lacquered, leather was placed in a field so it could dry in the sun, but when the varnish hardened, it suddenly had unwanted yellow stripes. This was a conundrum until an employee offered an idea: Buy a herd of sheep. The problem was that bees had gathered pollen from the clover growing in the meadow and then had crawled over the leather, leaving yellow pollen behind. When the sheep devoured the clover, the bees began looking for greener pastures.



A careful record: A recipe from 1869 describes the resins needed for patent leather.

A successful idea down to the present: A cross-section of a Simmerring® with a worm spring.

wanted a good product, every step in the production process had to be optimized." This carried over to the company philosophy, the archivist and company historian pointed out. "Material expertise must always be open to innovative ideas."

Patent leather became the first great engine of the company's development. By the mid-1870s, thanks to this line of business, the company had risen to become one of Germany's largest leather producers. When chrome plating was introduced in 1900, Freudenberg expanded to become the largest leather maker in Europe and one of the largest in the world – and held that position until the end of the 1920s. Then came the shock. With the arrival of the global depression, the leather market collapsed. New markets were desperately sought to secure the company and avoid the dismissal of several hundred employees.

"Changing to Be Successful"

Salvation came in the form of seals. At the time, seals were made of impregnated felt or leather. Their production required knowledge of materials as well as lubricants such as oils. Once again, materials expertise was in demand, and Freudenberg could provide it. "Leather is a highly resistant material," Horchler said. "But without a coating, it doesn't stay leakproof for long." In the case of leather seals, the company's expertise with patent leather carried the day. One development led to another. The company was already selling its first leather seals by 1929. One admonition from Carl Johann was ever-present, Horchler said: "It takes the capacity to change to be successful in the long run." So, the company continued to experiment. In 1932, it combined leather with metal, and the Simmerring® was born. Walther Simmer built a spring into a metal housing to adjust the amount of pressure required for different sealing applications. Its spring simultaneously held the seal against the rotating

Cow hides await processing: Until the 1950s, leather was the predominant material at Freudenberg.

shaft and secured the seal lip within the metal housing. For the first time, radial shafts could be sealed really well. "That was Freudenberg's great breakthrough in the seals business."

Rubber Becomes a Competitive Advantage

Although leather remained an important material in Freudenberg's seal production well into the 1950s, leather wasn't the only material being courted by the company. Early efforts with elastomers were initiated in the 1930s, since leather was in short supply starting in 1934. The National Socialist Party took control of the country in 1933, and it wanted the domestic economy to be as self-sufficient as possible. Natural raw materials were suddenly scarce, forcing Freudenberg to search for acceptable leather substitutes. As a result, the company's chemists and scientists became some of the first industrial experts to work with synthetic nitrile rubber. The composite material was a mixture of nitrile, sulfur and carbon black that became dimensionally stable when vulcanized. "That is why seals are often black," Horchler explained. Despite – or perhaps because of – a scarcity of materials, Freudenberg found a solution that also expanded its materials expertise. A steady flow of elastomer compounds followed.

"We were the absolute pioneer with the first rubber seals," Horchler said. The German auto industry became the company's most important sales market.

Dr. Michael Horchler

Dr. Michael Horchler has worked in the Freudenberg Group's Corporate Archives for more than 20 years. He took over management of the collection in 2008. A historian, business manager and media researcher by training, Horchler joined Freudenberg during his doctoral studies. He is passionate about his profession. "Unlike many historians who specialize in defined timeframes, we work on a living thing. Our history continues to be written. We deal with the company's past, present and future," he said.

75

production steps
are involved in leather
processing.

But Simmerrings®, bellows and O-rings from Freudenberg were also used in machine-building. The new material was a big hit: "Rubber can be shaped more precisely and easily than leather," Horchler said. This made it possible to adapt seal lips to unique application requirements. Freudenberg's elastomer seals quickly set themselves apart from the leather seals of its competitors.

Within a century, Freudenberg's use of materials had moved from leather to synthetic elastomers. And that ensured its survival. "Only one or two of the major tanneries of the 1920s still exist today," Horchler said. Critical to the company's longevity and success, Horchler noted, was its determination to stay very close to its original business.

Innovations Keep Coming

The years of the German economic miracle showed just how rewarding the investment in elastomer research was. More and more people were able to afford cars, and the German machine-building industry was exporting products abroad. "Those were the real boom years for seals," Horchler said. Freudenberg's product line grew and continues to grow to this day. The company currently has about 200,000 elastomer compounds available in its materials portfolio, thanks to a continual focus on innovation. "There were a great many failed attempts during the early years of elastomer research," Horchler acknowledges. "But even if they didn't always work out at first, something good often emerged in the end."

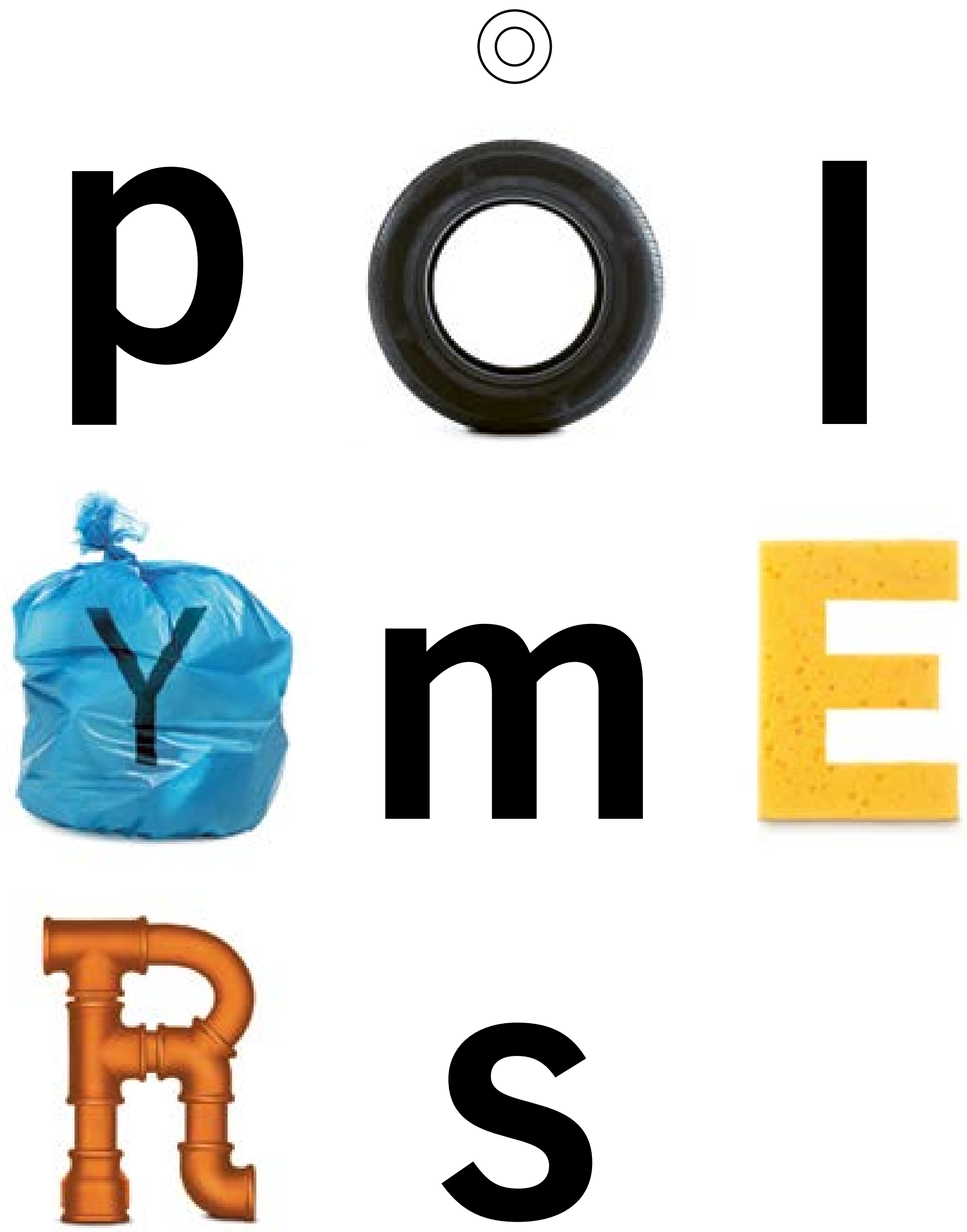
That's the impressive aspect of material innovation. Again and again, important solutions seem to emerge by accident. For example, because Freudenberg had expertise in the interplay of elastomers and metals, it was able to build components that reduce vibration and noise. A new line of business, vibration control technology, arose. "Today's auto industry would be inconceivable without vibration control technology," Horchler said. Nonwovens became a Freudenberg product line in much the same way. Originally a carrier material for latex synthetic leather, they have now become a key component in cars, clothing and shoes, and in medical and technical applications such as wound dressings, batteries and wiring systems, they are also used in Vileda cleaning products. But there is more to the story: "Nonwovens burned through development funds for a decade." Yet the research continued. This is not just characteristic of Freudenberg – it is explained by the company's history.

"The company was always on the lookout to see what new raw materials were available in the market," Horchler said. When in doubt, the company looked at each crisis as an opportunity to develop further – just as the first leather seals emerged from the emergency created by the global depression. "Today the production of seals has its own corporate division – Freudenberg Sealing Technologies." In 2002, after the leather business had proved unprofitable for years and output had fallen to low levels, Freudenberg bid farewell to this founding material. But not before a modern, innovative, knowledge-based company was secured. ◎

BY THE NUMBERS

1.7 Trillion

Applications for 5G wireless technology. Vaccines to protect against illnesses. Materials for electric mobility. Building materials that absorb CO_2 in a time of climate change. In addition to plenty of time and know-how, innovations like these require one thing above all else before they can reach the market: money. According to UNESCO, the total global expenditures on research and development prior to the coronavirus pandemic amounted to 1.7 trillion USD. A full 80 percent of the funds were spread among just 10 countries. In the United States, a substantial 581 billion USD flowed into research and development. The figure was about 500 billion USD in China. Japan, Germany and South Korea clearly lagged behind the leaders. Companies around the world are providing even more funds than governments do. Amazon alone invested nearly 29 billion USD in 2019, putting it ahead of Samsung, Huawei, Microsoft and Volkswagen. This shows that the information technology and electronic sectors are significant drivers of innovation today. When the expenditures are expressed as a share of total revenue, the pharmaceutical industry is at the top of the list. A survey by the European Commission found that the sector invested more than 12 percent of its revenue in research and development. ◎



They are in the packaging for our foods and in the paneling of our vehicles. In our daily life, we mainly interact with them as plastics. But polymers are so much more.

We are surrounded by polymers. They are in everything from plastic food and drinking bottles to the PVC flooring we walk on. They crop up in a wide range of forms, colors and consistencies. For example, they are soft and pliable in household sponges, yet hard and stable in window components. They can be natural or synthetic, depending on their molecular makeup. They can withstand the heavy loads placed on them in aerospace applications, and they can be as fine as a strand of hair or thread of silk. This is precisely why the fascination with polymers exists: They are all-around, extremely versatile players.

The name of the material reflects this. The syllables “poly” and “meros” are derived from ancient Greek and can be translated as “many” and “part.” The many parts are so-called monomers: molecules that react with one another and branch into long, chain-like macromolecules. The different macromolecular structures found in polymers have allowed scientists to bind polymers by families. For example, the molecular chains of materials grouped into the thermoset polymer family form a dense network that becomes hard and stable. In the elastomer family of polymers, which includes rubber, the molecular chains are less densely meshed, giving them their typical elastic properties. Thermoplastics polymers have molecular chains that resemble loose threads. Thermoplastics are solid at low temperatures but melt when heated and can be reshaped as needed. Thermosets and elastomers, on the other hand, are heat-resistant and do not melt. When further processed with additives, thermosets and elastomers develop new performance characteristics that can result in the creation of complex plastics, plastic fibers and even dyes or adhesives. In some cases, polymers even become additives themselves. In the cosmetics industry, for example, the hyaluronan polymer family includes hyaluronic acid, an eagerly sought after and proven defense against skin wrinkles.

Petroleum-based polymers are certainly less stable than other raw materials such as wood, iron or other metals. But they are lighter. In vehicle components, they cut down on overall weight and help reduce fuel consumption. Especially with the development of electric and hybrid powertrains, lightweight plastics are making it possible to meet ever more stringent environmental and safety requirements for the first time. The use of polymers in production also requires comparatively low energy inputs. But in an era of climate change, another issue has become important: Synthetic polymers like plastics and other elastomers can only be separated and recycled to a limited degree. The solution could involve using biological materials from renewable resources, such as plastics made of corn, or textiles made of spider silk. But biologically based materials often increase manufacturing costs, and thus, prices for consumers. And there is another environmental consideration as well: The longevity of synthetic polymers such as plastics has a positive effect on their ecological handprint. So, it is important to consider whether it is more sustainable to turn to synthetic materials that hold up well or to bio-based alternatives that may not last as long.

Polymers

Polymers also occur in nature and even in people, in the form of enzymes, hair or silk, for example. Even our genetic material, deoxyribonucleic acid, is a polymer. The first man-made fibers and plastics were made of natural fibers. Some have been in use for a very long time: rubber is a natural polymer still used in tire production, among other applications.

“Innovation Always Takes Teamwork”

What does industry-governmental collaboration have to do with sustainability? Dr. Ruth Bieringer, Vice President Technology & Innovation at Freudenberg Sealing Technologies, is convinced that joint cooperation, expertise and research are key to new, more sustainable developments in the materials field. And if you want to be successful, you have to keep the future in mind.

DR. BIERINGER, WHAT FASCINATES YOU ABOUT MATERIALS?
The creativity and the inventiveness. You are creating something new. We are coming up with a recipe, and that takes a knowledge of raw materials, processes and the later applications. In our company, for example, we have more than 3,000 active materials alone in our portfolio. Ultimately, it is a multifaceted challenge from every standpoint to design a clever product, to keep designs and processes cost-effective, and meet all the customer requirements. The product stands and falls on the material. If the wrong one is chosen, you just get gruel coming out the back.

ARE THE REQUIREMENTS CHANGING RIGHT NOW?
Yes, our mission and our portfolio of materials are expanding – because our product portfolio has also grown. The changes are offering opportunities even beyond our classic sealing business. In this case, I am referring to the transformation of mobility and the energy supply. Thermoplastics will replace metal in many fields, and sustainability is steadily increasing in importance. There is also a paradigm shift in the developmental timeframes: Manufacturers can no longer afford to declare a “design freeze” and a “materials freeze” too early, meaning the point after which nothing about the project may be changed.

WHY IS THAT?
Because the political conditions are changing faster and faster, to cite one example. Manufacturers have to respond on ever-shorter notice to emissions legislation or recycling quotas. Business processes and innovation cycles are accelerating. That leaves less and less time for development.

ARE MATERIALS DEVELOPED TO SOLVE SPECIFIC PROBLEMS OR IS A NEW MATERIAL CREATED BEFORE PEOPLE EVEN ASK WHAT IT MIGHT BE GOOD FOR?
Both. There is push and pull. Customers may say a seal swells too much so they want something new. That usually leads to incremental progress: You know exactly what you have to do. Which levers to pull. But this seldom leads to an innovative breakthrough. That’s why we are always looking ahead: What new materials are there? What issues do we see coming? What is the focus of current research? What will the market need in five years? Innovation mostly occurs when people give themselves permission to think creatively and crazily.

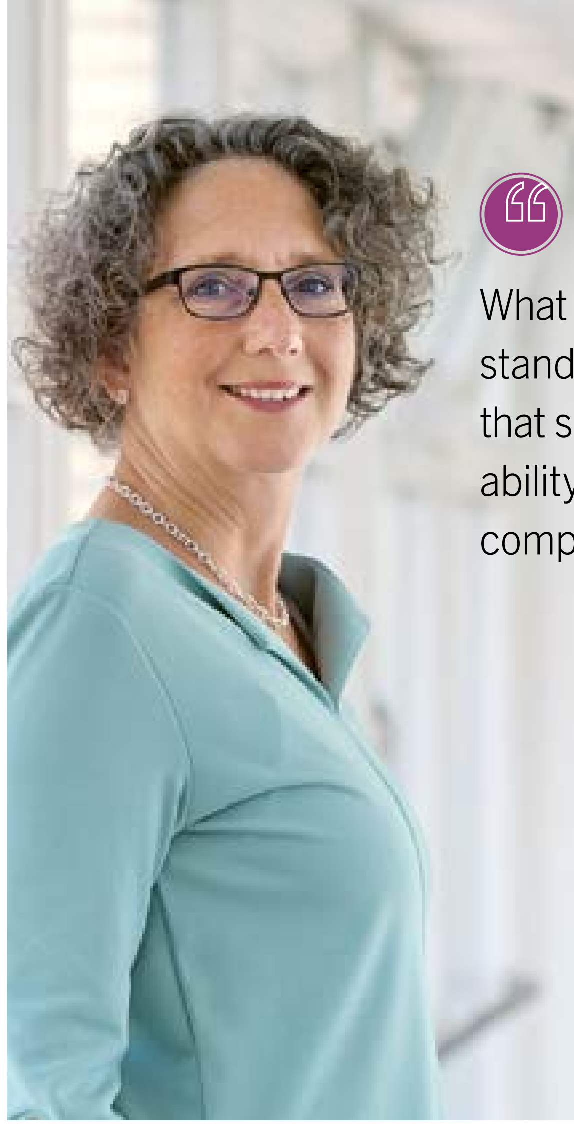
> Innovation mostly occurs when people give themselves permission to think creatively and crazily.”

WHAT ARE YOU THINKING ABOUT RIGHT NOW?
We know that we are strong in elastomers, so we are considering what we can still do creatively with them. For example, a seal that not only communicates its level of wear but also predicts that it will need to be replaced in two weeks. Or components that don’t merely seal but are electrically conductive as well. Or can shield against heat or electromagnetic radiation.

YOU HAVE JUST ADDRESSED THE REGULATORY LANDSCAPE – TO WHAT EXTENT DOES THIS CHANGE THE WORK OF DEVELOPERS?
It is changing a great deal. For one thing, the scientific knowledge relating to materials is continuing to advance. As a society, we once classified some substances as harmless, but those old certainties are now in question. Chemicals are being restricted or completely prohibited. And this is happening in shorter and shorter timeframes. At present, the European chemical framework REACH is being reworked. Authorities are moving toward the regulation of whole material groups, instead of restricting substances individually. In the future, the issue will be less the risk that a material poses – and more a consideration of its essential uses. This is a general paradigm shift in chemical legislation.

Dr. Ruth Bieringer

Dr. Ruth Bieringer studied chemistry at the Johannes Gutenberg University of Mainz and deepened her knowledge of polymers during advanced studies at the University of Massachusetts Amherst. She then earned her doctorate in polymer chemistry at the University of Bayreuth. After holding various leadership positions within the Freudenberg Group, she has overseen the Freudenberg Sealing Technologies’ Technology & Innovation – Materials Technology activities since 2020.



> What we now need urgently is greater standardization so that the figures that say something about the sustainability of our products are actually comparable."

SO YOU HAVE TO LOOK FOR ALTERNATIVES ALL THE MORE INTENSIVELY?

Yes, PFAS is the classic example: per- and polyfluorinated alkyl substances. This group includes nearly 5,000 different compounds and is used in numerous industrial processes and products. We know that some of these materials are toxic. But now we are facing the possibility that the entire group could be regulated because these materials are persistent, meaning they don't degrade in the environment. A widely used material such as PTFE would fall into that category. That concerns us.

HOW COMPLICATED IS IT TO FIND A REPLACEMENT IN SUCH CASES?

It can be very complicated because one-to-one substitutes are very rare. People are not using certain materials because they are cool but rather because they have a very special characteristics profile. Fluorine chemistry is unique. Humanity can naturally do without specially coated frying pans or waterproof athletic shoes, but fluorine chemistry goes far beyond that. Entire industrial processes would have to be completely changed.

WHAT ROLE IS THE ISSUE OF SUSTAINABILITY PLAYING?

A crucial role. Up until now, many elastomers have been petroleum-based, even down to the present. In broad terms, there are three sustainable alternatives: biomaterials, recycled materials and carbon extracted directly from carbon dioxide. New approaches on biomaterials have recently emerged, and developments in material recycling are taking off. As a producer, we are depending on players ahead of us in the value creation chain to do their homework. But there are some things we can do ourselves, such as avoiding waste and making our processes more sustainable. Here we have powerful levers to reduce our global footprint. And it is in our own interest to optimize costs and performance. We benefit from this ourselves. In the future, sustainability will be an important differentiator in the market. Just like many of our customers, we have set very ambitious goals. We are on an exciting journey.

FOR A LONG TIME, SUSTAINABILITY SEEMED LIKE LIP SERVICE.

It isn't any longer. The automakers are far along in this and are requiring data, statistics and supporting evidence from us. What we need urgently is greater standardization so that the figures that say something about the sustainability of our products are actually comparable. If our competitors calculate or extract data differently, it's all pointless.

WHO WOULD BE RESPONSIBLE FOR SETTING THESE STANDARDS?

We see this as the responsibility of the associations and the standardization bodies. For example, the German Association of the Automotive Industry (VDA), or the DIN standards organization in Germany or ASTM in the United States. Alternatively, politicians could step in and take action. We need uniformity. Take the issue of lifecycle analysis. There are already metrics and calculations in that field, but they are so crude that you can't really compare one analysis with another.

IS THAT A REASON WHY YOU ARE SO PERSONALLY ACTIVE IN INDUSTRY ASSOCIATIONS AND PUBLIC-PRIVATE COLLABORATION?

Yes. I am active on the elastomer and thermoplastic elastomer (TPE) working committees at the VDA. The work heavily focuses on materials. Many standardized material tests already exist, but they are often insufficiently defined for our purposes. Officially, the VDA can only make recommendations, but so many people follow them that they often become the standard. So it is all the more important to be active on these bodies and take part in planning.

TO A LOT OF PEOPLE, WORKING ON COMMITTEES AND IN ASSOCIATIONS DOESN'T SOUND VERY SEXY …

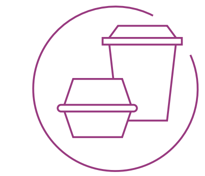
It definitely isn't. A great deal of knowledge is shared in a scientific association like the German Rubber Association or the German Chemical Society, just like many other groups worldwide where colleagues are active internationally. All of these associations are committed to the dissemination of knowledge and are important networks. They promote joint research on fundamental topics and identify trends at an early stage.

DOES IT MAKE SENSE FOR MANUFACTURERS TO SHARE THEIR KNOWLEDGE?

It certainly does if the cooperation relates to a VDA recommendation dealing with standards, for example. Perhaps we can make sure a rule is a good fit for our testing labs or applications for our materials. And we do benefit from others' knowledge – it is give-and-take. We embrace technological leadership. We are the ones who want to come up with innovative new products. Our reputation depends on our participation in scientific communities. We want to be a valued contact on new research topics. Networking with external experts is important for this; we need the view from outside.

INNOVATION NEEDS INFORMATION-SHARING?

If you look back to the last two years, the coronavirus taught us something: We are not very innovative when we're at home. Innovation requires an exchange of views, those fortuitous conversations in the coffee room, where people jump from one subject to the next, and then suddenly, someone comes up with a new idea. Innovation always takes teamwork. The first reliable studies show that we are less innovative when we work alone. And since we won't be going back to the "old normal" – indeed, we cannot – we need channels where we can meet and exchange views. I am very confident about our prospects. Throughout our history, materials development has always been very important, even though the work is protracted and complex. Our customers know us by the names of our materials. You can copy a design. That's much less true for a material. ◎



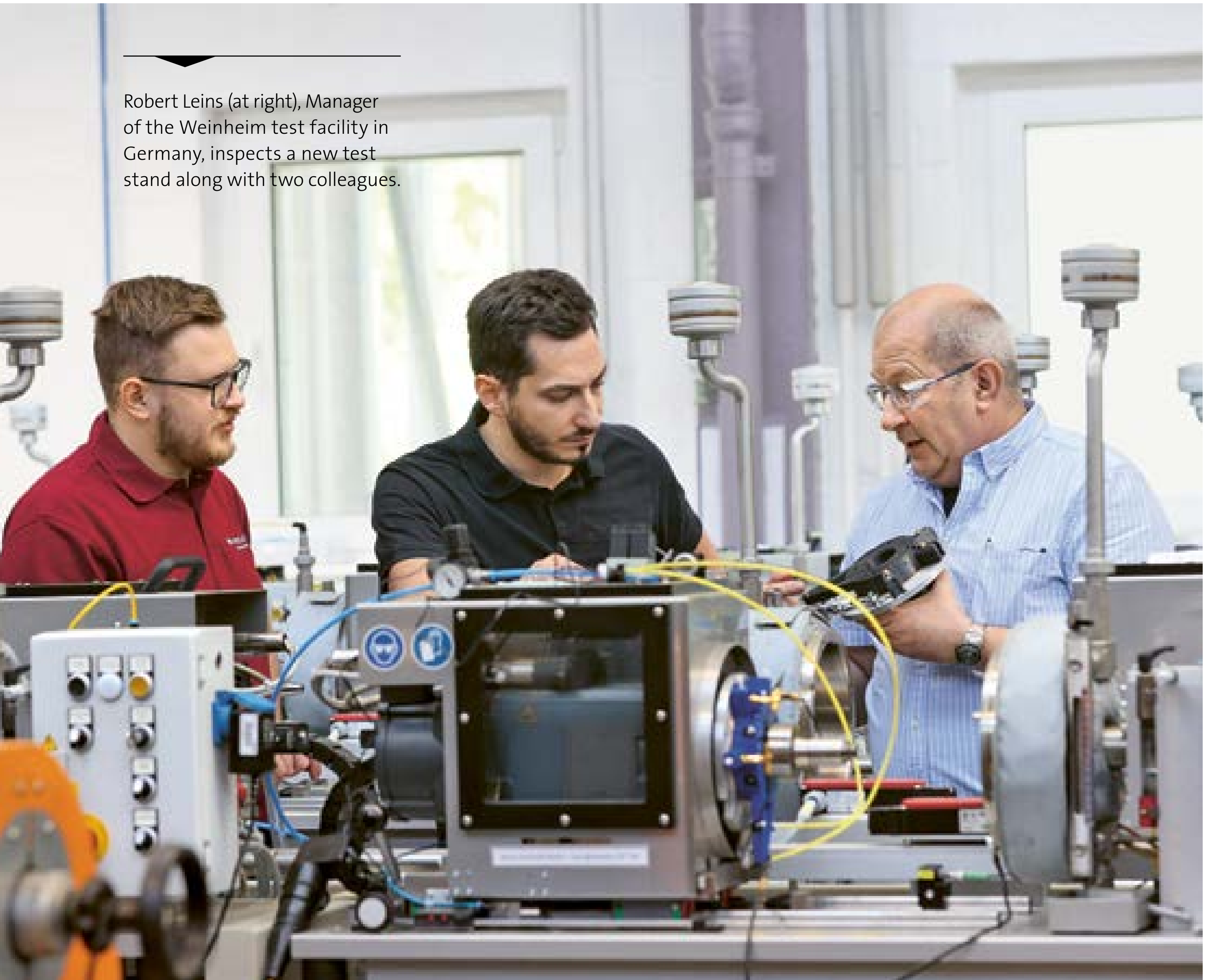
5,000

materials are included in the material category known as PFAS, per- and polyfluorinated chemicals. They are now a component of many everyday products, including packaging.

A Time-Lapse Stress Test

Before new seals and materials reach the market, they have to prove themselves in demanding tests. Freudenberg Sealing Technologies has turned to its own high-quality test stands to put them through their paces.

Robert Leins (at right), Manager of the Weinheim test facility in Germany, inspects a new test stand along with two colleagues.



The calamity began when the electric vehicle started to vibrate while being driven. Loud noises from the motor added to the impression that something had gone wrong. But what was causing the sudden problems that a French vehicle manufacturer noted in 2015? "Electric erosion was to blame," said Stefan Morgenstern, an advanced development specialist at Freudenberg Sealing Technologies. "After a few years, it had damaged the bearing to such an extent that the vibrations and noises were inevitable." Due to the buildup of voltage when the electric powertrain was running, countless tiny sparks struck back and forth against the component's ball bearings and the running surface. At some point, surfaces struck in this way become grooved and are no longer smooth. A motor breakdown was on the horizon.

The French automaker sought advice from Freudenberg Sealing Technologies in Weinheim, Germany. That same year, the sealing company came up with a solution. Its experts applied an electrically conductive nonwoven to the radial shaft seal. The product called eCON guided the harmful electric current past the bearings. To demonstrate the performance of the integrated solution, Morgenstern and his team felt the need to come up with a suitable test stand and find the right testing process in the bargain. This took pioneering work in light of the problems with electric motors at the time. Ultimately, the team added new equipment to an existing test stand and established a valid testing process. eCON's effectiveness was clearly proven and has been confirmed in practice with great success since then.

Simulations of Arctic and Desert Driving

In any case, eCON showed how important it is to have the right expertise to set test specifications and effectively use the company's high-quality test stands in new and innovative ways. At its headquarters in Weinheim, Freudenberg Sealing Technologies had a test bay with a wide range of test stands. "Using these stands, we try to approximate reality as closely as possible," said Robert Leins, Test Facility Manager. "To test our Simmerrings®, we can simulate driving in the Arctic, the desert and through water."

With Freudenberg Sealing Technologies' simulations mimicking a wide variety of conditions in motors, wheel bearings and other applications, it is possible to demonstrate the effectiveness and the efficiency of its innovations. Leins and his staff also perform tests for manufacturers of equipment, vehicles and fluids who set their own specifications for the tests. This

This video features the test facility and its operation in Weinheim, Germany.

Test stands are always built according to precise specifications, but they can always be modified.

Tests on behalf of manufacturers of machines, vehicles and oils also take place on the stands.

reduces the need for tests in real vehicles. "In the end, it is more practical to test in test stands than to wait until a wheel bearing has racked up 300,000 kilometers (186,000 miles)," Leins said. "At our test stands, we work with high rotational speeds, pressures and temperatures, just as they occur in real life. When materials are tested in this way and solutions withstand the stress tests, it can be assumed that they will achieve a specified lifespan in practice," he said. The tests are significantly shortening the time it takes to attain reliable results. And if adjustments become necessary, they can be made more quickly.

Avoiding Growing Pains in the First Place

All the test stands are programmable, and the measurement data generated (rotational speed, torque, media temperature and internal pressure) is automatically recorded and documented. "In the auto industry, test stands largely help to ensure that new models are not out on the road while they are still suffering growing pains," Leins said. "People used to be more lenient on this. But now everything is tested and put through the paces as much as possible. If we are now referring to special test stands, we can produce rotational speeds up to 36,000 revolutions per minute," he proudly continued. "We can check seals from just a few millimeters in diameter up to one meter. We can alternately rotate left and right. We can expose sealing systems to dust, mud, spraying water and even oil. And when necessary, we can also simulate axle play — from -40°C to +150°C (-40°F to 300°F)."

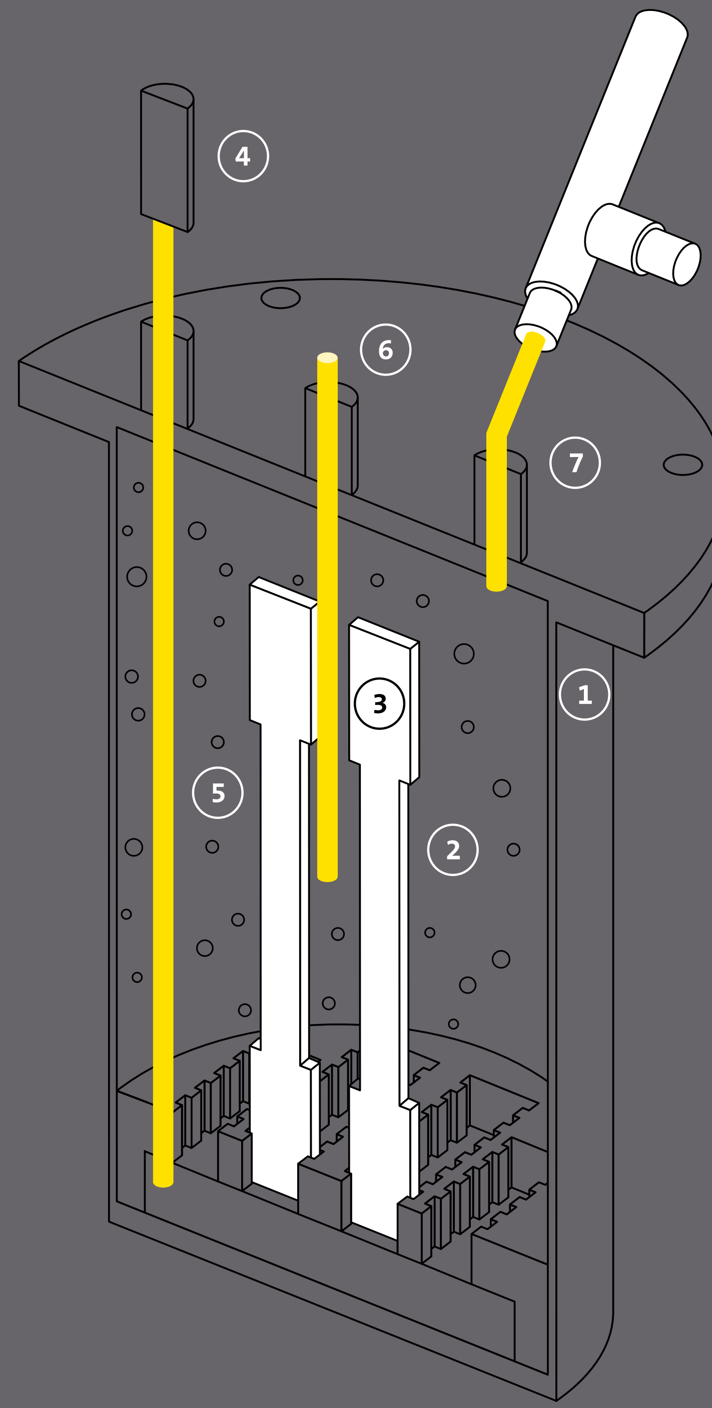
Freudenberg Sealing Technologies is working closely with a special machine manufacturer on the construction of its test stands. It produces the devices based on precise specifications. The test stands are modified when new requirements become necessary. In some cases, Freudenberg Sealing Technologies undertakes the changes on its own. "We hardly have a test stand today that is in its original condition. We consider the ability to add software and hardware to our computer-supported equipment to be essential," Leins said. "Our test stands position us superbly as a company. Independent measurement labs rely on comparable test stands. In some cases, we are even pioneers."

Advanced Test Stand for Electrolyzer Materials

One example is the latest test stand in which Freudenberg Sealing Technologies invested a six-figure sum at its Plymouth, Michigan/USA, site during the summer of 2022. It rigorously tests sealing materials that are used in electrolyzers, which enable hydrogen production on a large scale. "With this test stand, we can simulate in a few weeks how our materials will behave over years of continuous use," said Dr. Alexander Hähnel, a materials specialist at Freudenberg Sealing Technologies.

This advanced test stand can successfully simulate the operating conditions found in different electrolyzers, allowing testing experts to accurately assess how materials are behaving in such aggressive environments. As if in a time-lapse sequence, it measures and visually tracks how materials react to high temperatures in combination with caustic potash or sulfuric acid. During these tests, the stand also simulates how well the materials withstand oxygen being forced into them at very high pressures. The results make additional targeted developments possible. The test stand's documentation also offers the makers of electrolyzers an advantage: They can validate the reliability of the seals they build into their products.

With test stands like those in Plymouth and Weinheim, Freudenberg Sealing Technologies is differentiating itself among a large group of materials manufacturers. And if a customer ever has a problem, its experts are ready to track down a solution. ◎



As if in a time-lapse: A new Freudenberg test stand simulates how aggressively the challenging environment in electrolyzers attacks seal materials. In this process, a two liter pressure chamber (1) is filled to 80 percent with caustic potash or sulfuric acid (2) and then heated. Material samples are located inside (3). Pure oxygen (4) is fed into the chamber at a pressure of 35 bar; its gas bubbles (5) flow around the sample. Two sensors monitor the temperature (6) and the speed (7) of the gas bubbles.

How to create a material

It takes several steps to produce a material from its ingredients. The process is a bit like baking a cake, a visit to the Freudenberg Sealing Technologies mixing plant in Bristol, USA, shows.

Mixing Plant in Bristol, Tennesee/USA

Freudenberg Sealing Technologies' Bristol mixing plant is the second largest producer of rubber compound globally among the 10 facilities that make up the company's Global Rubber Mixing Lead Center. It is the top producing site in the Americas, contributing more than 40 percent of the region's total production volume. The site primarily serves the company's local New Hampshire seal making facilities, but also supports all other sites in the region. Bristol has around 45 employees, just over 33,000 square feet of production space and manages more than 172 active compounds.

1 Storing and Tracing
Freudenberg Sealing Technologies uses various raw materials as ingredients to make its rubber compounds. All ingredients arrive at the Bristol mixing plant where they are stored. The enterprise resource planning system supports labeling and traceability throughout the entire production.

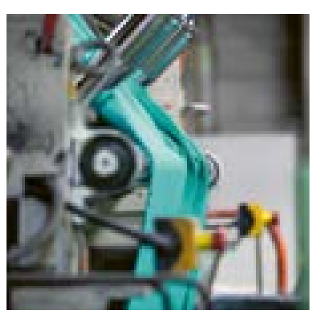
2 Weighing Ingredients
The recipe for a particular compound is designed to meet the requirements of the end-product. Depending on the end-product requirements, Bristol uses a variety of ingredients and ingredient amounts to produce compounds that address temperature range, pressure resistance and other environmental factors. The recipe's ingredients are precisely weighed to the (milli)gram and prepared for the next step.

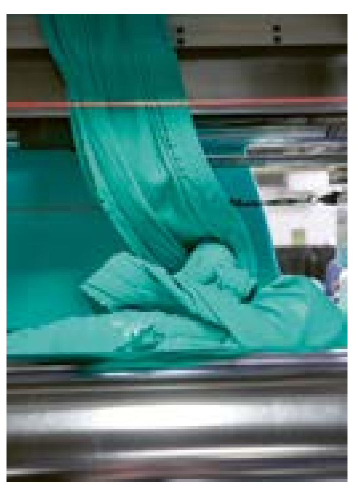
3 Mixing and Kneading
The weighed ingredients are then combined in a large kneading machine. Here it is important to follow a specific series of actions and time sequences. The temperature inside the machine is about 100°C (212°F), which helps to blend the ingredients into a homogeneous mass called a batch.

4

Milling

The batch is conveyed to a roll mill machine. It is then blended further and cooled by constantly folding and rolling it on the mill. This process helps to improve the homogeneity of the compound. At this point in the process, the batch is now fully transformed into a finished compound.





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Testing and Quality Control

Each batch has to pass a stringent quality inspection. In part, this involves taking a sample and testing it for density and hardness with a die (below). A tensometer also pulls the compound in opposite directions to determine the strength and elasticity (above).

6

Finishing, Extrusion, Pre-forming

In parallel with quality control, the rolled compound is cut off the mill and laid out to cool while it awaits quality release. The Bristol plant produces compounds that are only supplied to the company's seal-making operations. Depending on the order, the compound is formed into strips or 'rope,' using an extrusion machine. A different type of extrusion machine equipped with a knife produces pre-formes pieces of compound.

7

... Packaging and Shipment

The finished compounds are then packaged and transported to Freudenberg Sealing Technologies' seal production operations for use in manufacturing seals.

It’s All in the Mix

In mixing plants, the right raw materials and ingredients are blended together to create new materials with the desired characteristics. At Freudenberg Sealing Technologies, this has resulted in more than a thousand elastomer compounds.

At our mixing plant in Shelbyville, Indiana/USA, we produce a wide range of rubber compounds that end up in numerous applications. For example, they find their way into dynamic seals, which are in demand in the vehicle sector and specialized industries. The compounds are also used in engine and transmission seals as well as pipe and piston seals, not to mention special devices in the oil and gas segment. Our products mainly supply Freudenberg companies. We offer them as elastomer compounds in many different forms: in strips, slabs, pucks and pads. Thanks to our central warehouse, we are capable of supplying our customers quickly. Our very experienced team especially stands out in the market, along with our outstanding record for quality. At our facility, men and women work together as chemists, material experts, rubber producers, engineers and operation leaders. They embody our product and process knowledge.

We use the latest technology in Shelbyville. We produce more than 100 rubber compounds on our mixing lines. The total output is 170 tons per month. Autonomous mobile robots (AMR) transport material to the mixer, rolling mills, strainers, extruders and batch-off systems that are used in post-processing. By optimizing production processes, we can do without post-treatment in a number of cases, allowing us to reduce costs. Special tools also help us improve our efficiency and reduce process variation. Furthermore, during our SAP launch, we simplified and harmonized our data models. We are also using some of our own solutions as we move ahead with digitalization.

We have recently begun focusing on the industrialization of silicone production. We are in the process of benchmarking the optimal mixing process for silicone. A special thank you goes out to Tillsonburg, Canada, and Weinheim, Germany, for their help. This is giving us the chance to expand into the electric mobility space, since silicone compounds play a major role in battery management.

KEVIN TEMPLETON
has worked for Freudenberg-NOK Sealing Technologies since 2012. As Director of Application Center Components, he is responsible for the safe execution of daily operations at Shelbyville, Indiana/USA, mixing facility.

We produce a tremendous variety of elastomer compounds at our Weinheim, Germany, mixing plant. They are the basic material for all sealing products. That makes our plant one of Freudenberg Sealing Technologies' core operations. We mainly mix rubber with cross-linking materials, fillers and one or more special ingredients to give the products the desired characteristics. We have long been known in the market for our uniformly high quality. Our development of special compounds has given us a unique selling point. Our material developers regularly create tailored solutions for our customers. At our mixing plant, we have the expertise to industrialize specific developments, that is, to move them into production. We are experts – and we are the market leader – in the field of elastomer production and are well-equipped to handle the most demanding products on our own.

We had previously adopted the classic structure of a mixing line, consisting of a kneader, a rolling mill and a batch-off system. Among other changes, the trend is now greater automation, the integration of other process steps in-line with the help of extruder technology. We are also striving to automate more of the processes that are still manual. That's why we are turning to digitalization at all of our locations. We are networking machines and taking advantage of the opportunities for remote support. We also want to move toward apps and process controls that will facilitate our global transparency.

At Weinheim, a great many employees from a range of countries are integrated into our production processes. Our mixing plant requires more than one skill set. A whole range of qualifications is needed since the facility and the chemical processes taking place inside them are complex. In 2021, we produced about 9,000 tons of elastomer compounds in Weinheim. Our compounds end up in each of Freudenberg Sealing Technologies' elastomer parts. We also supply other Freudenberg companies along with select external customers.

> We are also striving to automate more of the processes that are still manual. That's why we are turning to digitalization in all of our locations."

DR. BORIS JAKOBI
is Senior Vice President of the Components Division and, among other duties, responsible for all mixing, PTFE and stamping plants at Freudenberg Sealing Technologies. He holds a doctorate in mechanical engineering and has been with the company for 20 years.

A Combination of Diverse Elements

The development of innovative materials for extreme operating conditions is a collective activity. Working as a team, Dr. Tina Andrä and Kira Truxius are helping to propel a new class of materials to a breakthrough. Along the way, they are making the case for diverse teams and an inclusive culture.

Organic chemists study the structure, properties, and reactions of molecules that contain carbon. They also design and make new organic substances that have unique properties and applications. These compounds, in turn, have been used to develop many commercial products, such as pharmaceutical drugs and plastics.

Organic chemistry is the branch of chemistry that deals with carbon compounds, and there are countless compounds to be explored. Each new organic compound dazzles with unique properties that only result from a particular molecular structure. It is no different with teams: Where people are allowed to develop and can contribute their viewpoints and

(1,832°F)

1,000°C

or more: That's the temperature that the Quantix® ULTRA material withstands. It even remains rigid and robust under these conditions.

Dr. Tina Andrä

Since April, chemist Tina Andrä has worked as Foresight Manager at Freudenberg Technology Innovation, focusing on materials and topics for the future such as hydrogen. She previously worked for more than five years at Freudenberg as a project manager in the material technologies field. She began her professional career as a lab manager at BASF Polyurethanes GmbH.

strengths, they produce more innovations in a shorter time. That is the reality, and the collaboration between chemist, Tina Andrä, and plastics engineer, Kira Truxius, shows that the development of innovative materials depends on it.

Working together, they have pressed ahead with the development of a new class of plastics that had not previously existed. Even at temperatures of more than 1,000°C (1,832°F), the material known as "Quantix® ULTRA" does not melt (see box page 50). When the two experts are both at work in the technical center, where new materials are mixed and processed into granulate, people don't realize that they actually work for two different companies within the Freudenberg Group. Andrä coordinates research into future materials for Freudenberg Technology Innovation, while Truxius looks for new thermoplastic applications for Freudenberg Sealing Technologies.

Despite the differences, the life journeys of the two women have parallels. Andrä's love for chemistry began in childhood when she browsed through the library of her grandfather, a chemistry teacher. The structure of complex molecules was merely a source of fascination in the beginning. Her understanding grew, however, when she began taking science classes in school. After graduating from high school, she continued her education in chemistry at the Chemnitz University of Technology. In Truxius' case, it was initially her grandfather, a metallurgical engineer, who sparked her interest in technology. He and his granddaughter repaired vintage devices from a flea market. She was excited by the way tools are used. When she was still in

Joint effort: The chemist and the plastics engineer each contributed their special expertise to the development of the high-performance plastic Quantix® ULTRA.

primary school, she bought a pinball machine for 150 Deutschmarks. As it no longer worked, her interest in doing repairs was aroused. To this day, one of her hobbies is restoring and repairing pinball machines. The fact that Truxius ultimately chose to study plastics technology at the Darmstadt University of Applied Sciences has its roots in an earlier detour: She started college with the goal of becoming a dental technician, a career that would have involved using many malleable materials. She enjoys working with them – especially thermoplastics – and wants to build up her knowledge about them.

Uniting Theory and Practice
Early on, both women decided to tie their studies to practical applications. Andrä worked on her graduate thesis in a BASF applications-oriented research project. For her part, Truxius joined Celanese (the former Hoechst company) as a work-study student and wrote her bachelor's and master's theses there. Even back then, she found materials development to be especially exciting, seeing the field as the intersection of chemistry and mechanical engineering. While Truxius joined Freudenberg right after she completed her studies, Andrä first earned her doctorate and then joined BASF Polyurethanes in Lemförde. For personal reasons, she was soon looking for a position in southern Germany and started at Freudenberg one year after Truxius.

In 2019, the Freudenberg Group relaunched a strategic program and called on six of its subsidiaries to combine forces and look for new materials for use in extreme operating conditions. Andrä took over

Kira Truxius

Since 2015, graduate engineer Kira Truxius has worked for Freudenberg Sealing Technologies as a materials expert in the thermoplastics field. She previously completed her master's degree in plastics technology at the Darmstadt University of Applied Sciences. She also does volunteer work with the moveMINT (STEM) program at the University of Mannheim.

> That allowed us to gather everyone's experience and knowledge and make rapid progress."
>
> Kira Truxius, materials expert specializing in thermoplastics

overall coordination, a task that suited her sober, analytical nature. One area of exploration involved electric powertrain plastics that are resistant to high temperatures. Truxius led and coordinated the program at Freudenberg Sealing Technologies' end. "We were all equal, whether in the technical center, in the lab or in a testing facility, including the experienced employees operating equipment day in and day out," Truxius recalled. "That allowed us to gather everyone's experience and knowledge and make rapid progress."

Appreciation Makes the Difference

And yet it was not just measurable knowledge that contributed to success. The two experts got along well right from the start and appreciated each other's work. Here is what Truxius says about Andrä: "She greatly appreciates all the team members but never loses sight of the big picture. She knows what to do." For her part, Andrä values her coworker's technical knowledge as well as her enthusiasm and persistence. "Kira makes sure that nothing goes astray." Andrä and Truxius look with pride at the new material group, "Quantix® ULTRA." It would never have come about without a large team and mutual support, they say.

Andrä and Truxius are dealing with a reality at Freudenberg: As women, they are still in the minority in technical-scientific positions in 2022. "It's not just about gender diversity," said Truxius, who almost exclusively encountered male classmates and professors while in college. "We have to become even more diverse." Individuals can make a difference. For example, Truxius champions diversity and inclusion at Freudenberg and offers insights into the worlds of the LGBTQIA+ community, rainbow families and STEM women. The signing of the Charter of Diversity, in which Truxius participated, obligates Freudenberg to recognize diversity inside and outside the organization, value its potential, and harness it for the company's benefit. Diversity gives you an edge – and not just in organic chemistry. Truxius is also involved in the STEM program at the University of Mannheim on Freudenberg's behalf, smoothing the path for women in STEM fields as they start their professional lives. In the future, she would like to build children's interest in STEM careers. ◎

A New Class

With "Quantix® ULTRA," Freudenberg Sealing Technologies is introducing a new class of plastic materials that neither melt nor catch fire at very high temperatures. Semi-crystalline thermoplastics first show a slight reduction in rigidity when they are heated. If a particular temperature is exceeded – which experts call the glass transition temperature – the plastic gradually softens and is significantly less rigid. If the temperature continues to rise, the material eventually reaches its melting point. But "Quantix® ULTRA" exhibits a significantly higher glass transition temperature where rigidity declines. Instead of becoming softer as the temperature rises and ultimately melting, the material becomes as elastic as an elastomer. In one lab test, a sample of the material less than 1 millimeter thick survived for 10 minutes in a flame reaching 1,200°C (2,192°F).

NOW I'M TELLING YOU

Polytetra-fluoroethylene

While I have features that benefit a great many people, they are not familiar with my name. But that's OK. I just keep doing my job, making sure that food doesn't stick to frying pans. And I make it possible for joggers, cyclists and hikers to wear functional apparel that is wind- and waterproof and breathes. My name is PTFE, and I am a high-performance material. Those who deal with me regularly praise my versatility. I am flattered by that. In any case, the examples cited above already suggest my positive attributes.

I was discovered by pure accident. In 1938, the American chemist, Dr. Roy J. Plunkett, was looking for a refrigerator coolant and was experimenting with tetrafluoroethylene. Instead of a coolant, he discovered a waxy solid material: Me. What are some of my characteristics? I am electrically insulating, corrosion-resistant, nonflammable and tremendously heat-resistant. I also offer low surface adhesion. If I am heated, I don't melt away. I soften like rubber. I cannot be harmed by organic and mineral acids, bases, oils or alcohols.

It didn't take long to figure out what I might be good for. I can now be found in the seals and bearings used in machine and vehicle manufacturing and in the supports and slide bearings used to move structures in the construction sector. In the electrical engineering field, I am used as insulation, and I am quite useful in the production of valves, pumps and many other devices used by the chemical industry. I am even on another planet: With my help, components on the Spirit and Opportunity Mars Rovers will operate longer. ◎

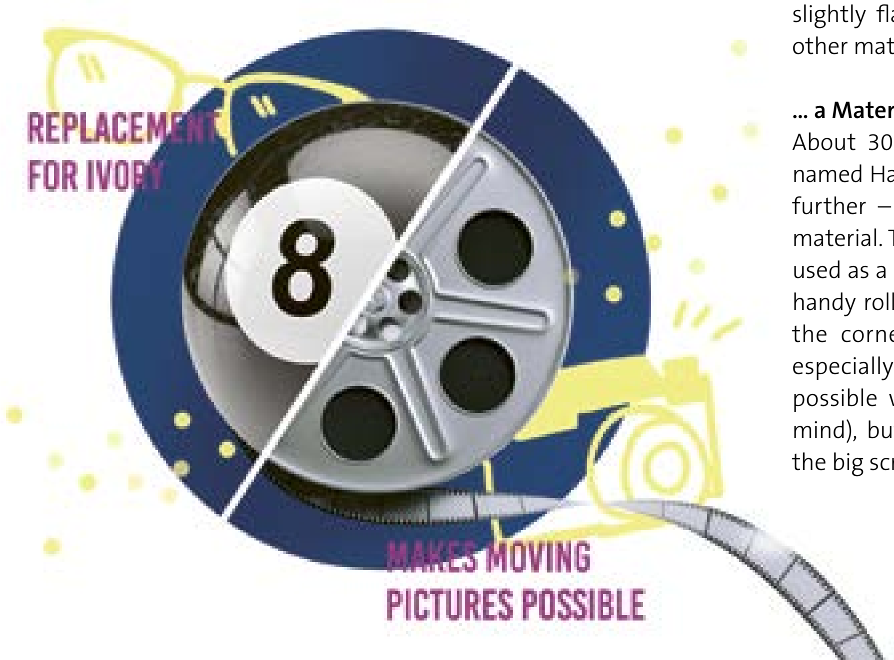
Another Look at Innovation

Suppose a new material is discovered. Do people immediately recognize its potential? That sometimes takes a bit longer …

Celluloid

A New Material …
In the 1860s, chemist John Hyatt was looking for a new material to make billiard balls out of. They had mostly been produced from ivory at the time, which made them an expensive luxury good. In his search, he ran into a mixture of nitrocellulose and camphor that had been discovered several years earlier. He refined its production process and made the material suitable for mass production. The new plastic turned out to be extremely multifaceted and suitable for everything from frames for glasses to combs and toys. Unfortunately, the material was slightly flammable, leading to its replacement by other materials beginning in 1950.

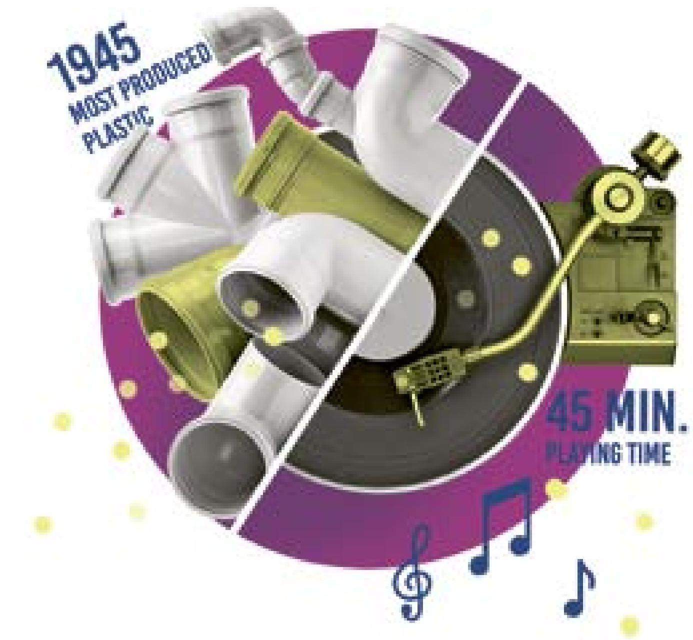
… a Material for Something New
About 30 years after Hyatt's work, an American named Hannibal Goodwin developed the substance further – into a flexible, elastic and transparent material. This celluloid film replaced the glass plates used as a carrier material in photography. Suddenly handy rolls of film could be produced and became the cornerstone for modern photography, and especially for movies. Moving pictures were impossible with glass plates (slide shows come to mind), but rolls of film brought dreams to life on the big screen.



Carbon

A New Material …
An entire material group was discovered in the 1870s in the wake of another groundbreaking innovation: the light bulb. In his search for the perfect filament, Thomas Edison experimented with various materials. He was looking for a fiber that was supple, robust and electrically conductive. He finally found a Japanese bamboo whose fibers offered exactly those characteristics when they were carbonized by heating (carbonization). It made the lightbulb competitive. In the process, he also invented the first carbon fibers.

… a Material for Something New
To be sure, other raw materials are used in carbonization today, although the production methods continue to be based on Edison's. With extreme heat, all the contents except for carbon are expelled from the original material. The result is fibers that offer greater tensile strength and a lighter weight than steel. Carbon is used wherever a light yet durable material is needed – in cars, prosthetics and aircraft, for example. Carbon fibers account for about half of the Airbus A350. Even as Edison's light bulbs are gradually being replaced by LEDs, the long march of his incidental discovery – carbon – has continued unabated.



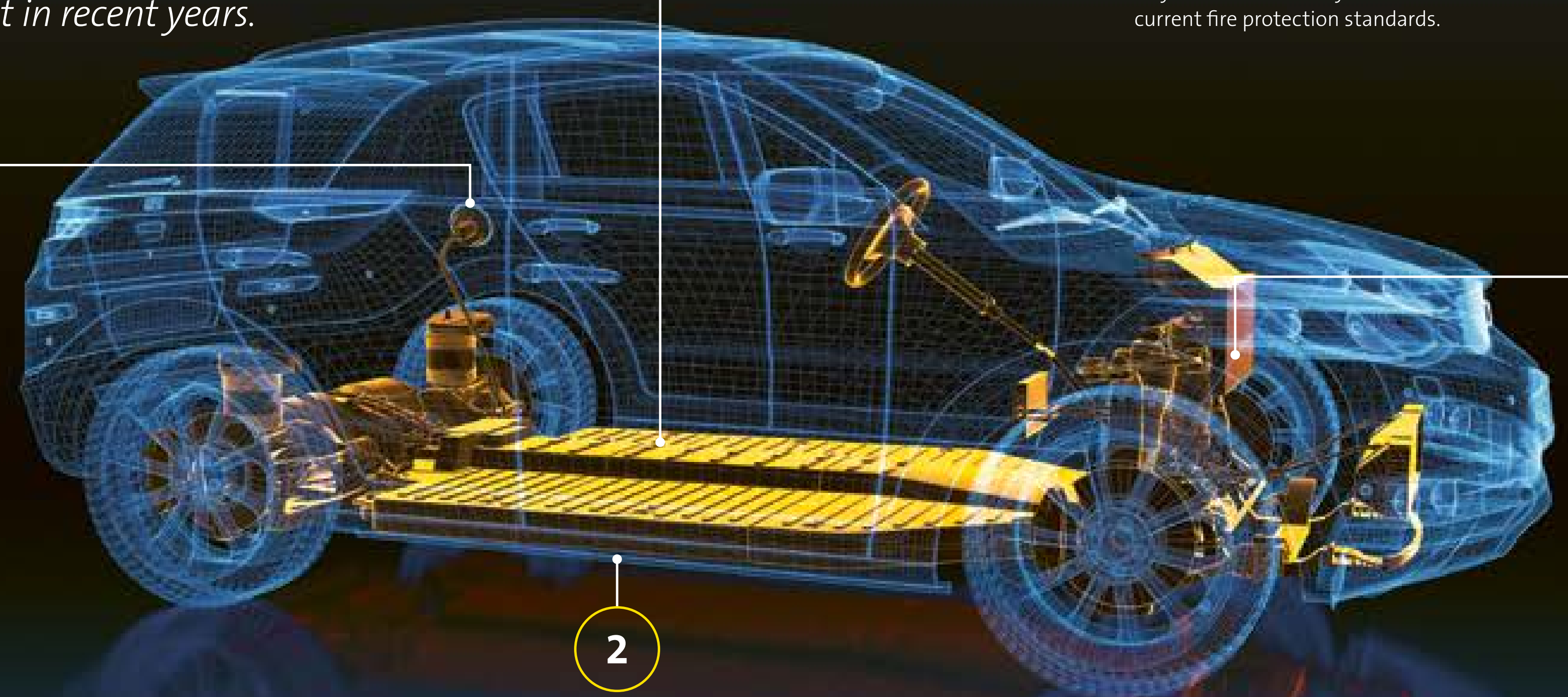
Polyvinylchloride

A New Material …
In 1838, Henri Victor Regnault was not exactly conscious of what he was doing when he exposed a newly discovered material known as vinyl chloride to sunlight and it turned into a white powder: polyvinylchloride, or PVC for short. At first, no one had a use for it. It was only the raw material shortages after World War I that brought the new material success. At that point, PVC could be industrially manufactured. Film sheets, tubes and other building materials were made from the new material. In 1945, it was the most-produced plastic in the world.

… a Material for Something New
The new material had what may have been its most revolutionary impact in another field: music. Until the 1940s, phonograph records made of shellac were widely used. But they were not suited for shipment – they were too heavy and too fragile. The search for alternatives led to a wholly different material … PVC. Records made of the new plastic were lighter and nearly unbreakable. This not only improved the sound quality of the recording – it extended playing time considerably, from 9 to 45 minutes. The development led to the first long-playing records as well as the unstated rule that an album should play for 45 minutes – a notion that survived well into the age of CDs.

E-Factory

Greater range, faster charging: Electric cars are becoming practical for everyday use. Components made of innovative materials are a key factor. Freudenberg Sealing Technologies has accelerated their development in recent years.



1 Heat-Conductive Charging Sockets

Drivers waiting at a charging station appreciate fast charging that forces massive numbers of electrons into a battery over a short period of time. For safety reasons, the charging current is monitored by a temperature sensor right at the plug. For the system to function flawlessly, the plug should transmit heat but not electric current. Freudenberg Sealing Technologies has developed a silicone-based material to ensure this. The sensor and the contact pins for the plug are over-molded with the material. The supporting connector plate is made of a conventional thermoplastic produced in the same mold. The result is a single, mountable component.

2 Electromagnetically Shielded Battery Case Lid

More kilowatt hours per kilogram: A reduction in weight boosts the range of an electric car without the need for a larger or more costly battery. One contribution to the lightweight design could be a battery-case lid made of plastic instead of metal. But to keep a vehicle's electronics from being disrupted, the plastic has to shield against electromagnetic waves. A coating technology developed by Freudenberg Sealing Technologies makes this possible. It involves coating a plastic component with a water-based material containing an electrically conductive filler.

3 Electrically Conductive Seals for Electric Powertrains

Power semiconductors deliver electric current to the electric motor and switching occurs up to 20,000 times per second. This leads to tiny voltage fluctuations, and their frequency can be transmitted to the rotor shaft. This can result in two undesirable side effects: On the one hand, the shaft acts as an antenna and emits disruptive electromechanical radiation. On the other, the resulting electric current can discharge and cause electric corrosion, especially in the shaft bearings. Freudenberg Sealing Technologies turns off both effects with its new generation of electrically conductive seals.

4 Fireproof Cell Packing

Electric cars are no more likely to catch fire than vehicles with internal combustion engines, according to the German Insurance Association. Still, there is a risk of a "thermal runaway" when lithium-ion batteries overheat. In that situation, one battery cell after another catches fire. Freudenberg Sealing Technologies has developed a kind of fire door using a material that originated in the aviation industry. The protective shield consists of an extruded profile applied from above on each of three battery cells. Flammability tests show that the technology clearly meets current fire protection standards.

Not Just Safe but Pure

Clean surfaces are essential when it comes to the production of pharmaceuticals. Impurities often show up at the microscopic level and cannot always be recognized immediately. Here is how the industry ensures safety with standards and the right materials.

When infants around the world were born with abnormalities in the 1960s, doctors and scientists looked feverishly for the cause. It took several years for them to identify the connection between the abnormalities and the sedative Contergan. The new drug had not been adequately tested for side-effects before it was introduced. As a result, scientists demanded clearer and stricter rules. In 1968, the World Health Organization (WHO) finally called on manufacturers to follow guidelines for "good manufacturing practice," or GMP for short.

The guidelines did not merely involve side effects. They called for companies to ensure that the product remained pure at each step in the production process. Contamination had to be prevented. These GMP guidelines are the standard today. The WHO examines and reworks them regularly, and they serve as a foundation for medical drug laws in individual countries. The regulatory framework covers the entire lifecycle of the medicine, from quality management during production, to transport and storage, all the way to its consumption by the patient. That's because there is the risk of pharmaceutical contamination at each step.

Contamination Can Happen at Any Time

All of this was new at the time. There had never been the continued monitoring of medicines beyond their actual production before. But it became increasingly clear that contamination can happen at any time, and the tiniest particles can enter the product at any point in the chain.

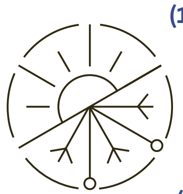
One of the most obvious solutions available today is to thoroughly clean surfaces and machines. This is where the material used in the machines becomes crucial. If machine surfaces are cleaned with aggressive chemicals, they have to withstand the exposure. It is even better to design surfaces so they are easier to clean. For decades, a rule has been applied to the pharmaceutical industry: Ingredients are not the only thing that are all-important – it is just as

Stainless Steel 1.4301

This material is the earliest example of non-rusting steel that is still commercially available today. It can be used from 600°C (1,112°F) down to almost absolute zero. This steel is resistant to food acids, weak organic and inorganic acids, water and atmospheric humidity. It is used where surfaces have to be hygienically clean, as in the food-service and pharmaceutical industries.

Stainless steel with the material number 1.4301 has uniform characteristics between

600°C (1,112°F)



(-459°F)

and **-273°C**

crucial to use the right materials. And that applies to the materials in all the machines and on all the surfaces that play a role in the process.

Stainless Steel, Grass and Plastics

Materials such as stainless steel and glass quickly caught on in the pharmaceutical industry. They were both resistant and robust. In concrete terms, that often meant stainless steel type 1.4301. This material has been used in the pharmaceutical industry since the 1920s. It offers still other advantages: It doesn't rust and can withstand a wide range of temperatures – from -273°C (-459°F) to +600°C (1,112°F). These qualities make stainless steel an ideal material for surfaces and pharmaceutical equipment and machine components.

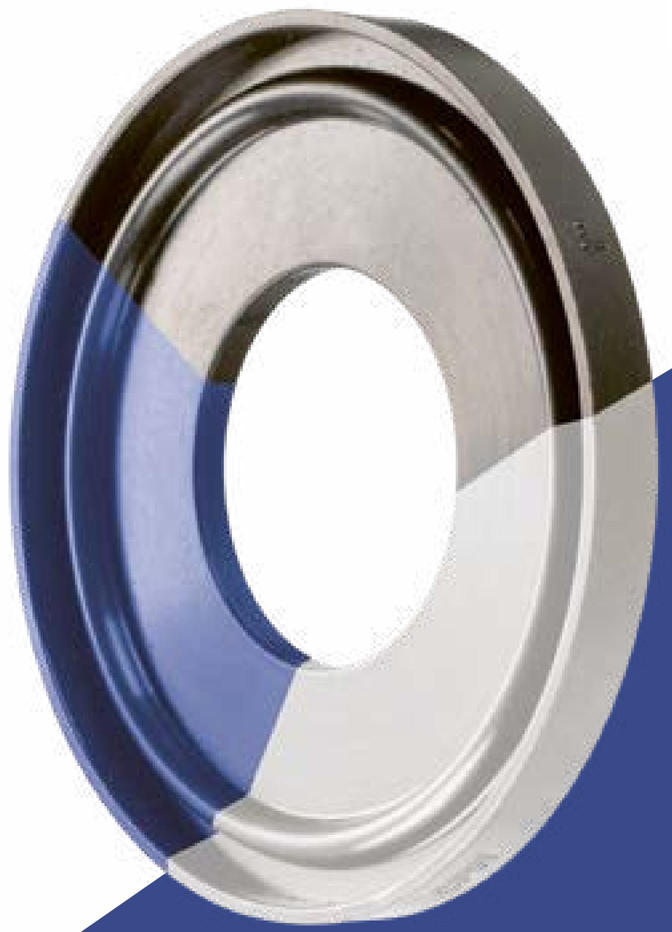
But not everything could – or can – be made from stainless steel. Even before the era of widespread plastic use, medical devices had individual components made of these materials, especially buttons and switches. Today plastics have prevailed on a broad front. So it is all the more important to pay attention to details like chemical resistance (see page 59). Some pharmaceutical developers are increasingly turning to antibacterial materials containing a percentage of silver ions. This special additive destroys the cell walls of microorganisms, killing them. This doesn't eliminate the need to clean surfaces regularly, however, but it does minimize the risk of contamination between cleaning intervals.

The key aspect of the GMP guidelines is that they especially hold the pharmaceutical manufacturers responsible. Before a medicine is introduced, they have to define a multi-step release process and continue to monitor the product after the launch. As a result, nearly every pharmaceutical company today has its own quality assurance department. The employees who work there constantly audit the purity of the medication and the cleanliness of the manufacturing and packaging operations. The formula is stringent guidelines, complemented by the right materials, to produce a reliable quality standard. For a medication to heal the patient, it is not just important to consider its effectiveness or its side effects. The environment where it is manufactured is important as well. ◎

"Less in, Less out"

Materials that are specially developed to meet the requirements of the food industry have turned out to be outstanding options for the pharmaceutical industry. By contrast, seemingly plausible ideas sometimes make little sense. An expert in the field, Mike Minow highlights the materials that are making headway in the medical field.

The clothing worn in many medical professions is white, in part because the color makes it easier to see contaminants. But Mike Minow, Global Key Account Manager for Freudenberg Process Seals, is surprised when he offers a white material to pharmaceutical manufacturers. It turns out that very few want it. "In black EPDM, we replaced the carbon black with silicates to create the white coloring," Minow said. In reality, though, the color proved to be an obstacle. When the pharmaceutical industry uses black plastic, "medicine producers can see any detachment of particles in the product more easily," he explained. And if necessary, they can discard an entire batch. For pharmaceutical companies, it is more economical to throw out contaminated batches than to have dirt particles in their products.



(392°F)
200°C

Fluoroprene® XP is highly temperature-resistant and can be used at temperatures up to 200°C (392°F).

Expensive End-Product

Thus, there are similarities and differences between the pharmaceutical and the food industries. Hygiene is a central concern for both. Even the smallest impurities are a problem. "The investments in the development of a pharmaceutical product are considerable," Minow said. "That makes the end-products many times more expensive than those for the food industry." Freudenberg Sealing Technologies has extensive experience with specialized products for the food and beverage sector. One thing has been clear for some time: Many of them can be successfully carried over to the pharmaceutical equipment and are an extremely good fit. And, for the most part, pharmaceutical companies are willing to invest in innovations because of their products' price structures.

"When a batch of an already expensive end-product has to be destroyed, we are quickly talking about a half-million euro loss," Minow said. That's why the use of the right material is especially important. Seals in hygienically pure equipment have to withstand high temperatures and resist aggressive cleaning agents.

An Entirely New Material

One of these materials is Fluoroprene® XP. The blue material has a special status in the Freudenberg Sealing Technologies portfolio. "We designed it specifically for the food sector and then found that it also works for the pharmaceutical industry," Minow said. "This is a material that had not been available on the market in its current form." The development process originally focused on solving an issue in the food industry: Companies were looking for a material that totally blocked the transfer of flavors from one food product to another during production. "We were sure that there would be a basic need for this."

Then the need grew greater than expected and came from other sectors like the pharmaceutical industry. Fluoroprene® XP is even more resistant to extreme temperatures than ethylene

Insight into the pharmaceutical industry: Mike Minow, Global Key Account Manager at Freudenberg Process Seals.

propylene diene monomer rubber, or EPDM. Fluoroprene® XP can be used at temperatures up to 200°C (392°F). A material that offered resistance to all other substances and that withstood high temperatures was completely unique. "That makes it overdesigned for some applications," Minow admitted, but just right for many uses in the pharmaceutical industry.

As Little as Possible Inside

"The EPDM 291 version clearly has the highest sales at our company," Minow said. The material is ideal for use in hygienically pure facilities. It is chemically resistant and especially sterile. Since sterility is so crucial to the industry, some manufacturers and pharmaceutical producers are experimenting with antibacterial plastics – even Minow and his team have thought about this. But this rather enticing idea has a catch: "You would be adding something to a tried-and-tested material," he said. "And it is never clear what the effects will be." In short, the pharmaceutical industry is sensitive to these issues and wants to avoid unnecessary risks. Instead, it can turn to a material proven to be ideal for the job.

It makes much more sense to design equipment from the outset without dead space where dirt can accumulate. "It is better to rely on hygienic design than on extra chemicals to correct for something that was not well-designed in the first place," Minow pointed out. The goal would be to restrict inputs into the equipment as much as possible. That means "the less in, the less out" when it comes to materials.

Problem Solver and Intermediary

In the area of facility design, Freudenberg Sealing Technologies can be an intermediary between machine-builders and pharmaceutical manufacturers. "The two sides don't always speak the same language," Minow noted. An engineer's bright idea could cause an unforeseen problem on the pharmaceutical side. "But we can often solve these problems," he explained, "because we look at things from the standpoint of the material – in both directions." This helps both sides. The machine-builder designs a better product, and the pharmaceutical company can produce its medicines more reliably.

"We have long experience with materials," Minow added. High-quality products do have their price though. But in return, they can be traced back to the manufacturer. "That is especially important to smaller companies." They are ready to spend money on that. The reason: Errors in production processes quickly become a question of survival for smaller suppliers. "The industry needs high-purity materials, traceability and guidance." Freudenberg Sealing Technologies will continue to develop ideas, even if they may not be well-received in the market at first – like the white plastic. "Which, incidentally, is by no means a failure," Minow concluded. It was precisely the right solution for some pharmaceutical producers' special processes. ◎

September 2022

Storm-proof on the High Seas

Wind turbines out in the ocean even have to withstand hurricanes. Sealing solutions from Freudenberg Sealing Technologies help them do that. In the North and Baltic Seas, offshore installations are often anchored into the sea floor with monopiles. The tower of the installation is then largely supported by a connecting piece (or flange). The dozens of bolts used to attach the flange are inaccessible after the tower's assembly. Freudenberg seals protect the screw connections from corrosion in more than 800 offshore wind turbines.

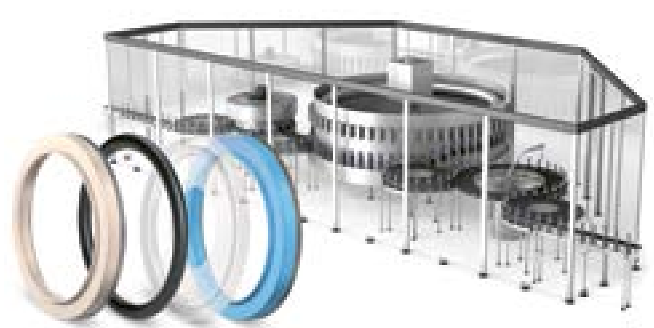
Freudenberg also manufactures the all-important ring seal at the upper end of the tower. A double version keeps minor damage from impairing its function during transport and assembly at the turbine location. The ring seal is primarily manufactured as a customer-specific product, although it can also be ordered as a standard product. In addition, ring seals with air chambers close the gap between the tower and the connecting piece. If the gap is filled with cement, a ring seal keeps the hardening cement in position. And in the monopiles, a special Freudenberg seal protects attached maintenance platforms from the penetration of biological gases.

Today, the life expectancy for components used in sea-based wind turbines is nearly 35 years. Test stands cannot validate lifespans of this duration, so Freudenberg extrapolates the results of intensive six-week endurance tests with an adapted Arrhenius algorithm. It involves coupling chemical and physical effects with the structural-mechanical behavior of the material. ⊚

April 2022

For Global Use

Freudenberg Sealing Technologies is expanding its materials portfolio by adding technical plastics for the global food and beverage industry. The portfolio includes two high-performance PTFE materials, Y002 und Y005. Both materials meet all global food-specific certifications and reliably resist strong temperature fluctuations and aggressive media. They stand out for their very high purity, their suitability for use in a wide range of temperatures, and high resistance to nearly all media.



They are just two examples from the broad portfolio of Freudenberg materials that conform to the requirements of the process industry. ⊚

June 2022

Green Sealing Expertise

The market for green hydrogen produced with electrolysis has grown significantly as a result of ambitious industrial emission goals. Freudenberg Sealing Technologies is using its expertise in fuel cell seals to develop advanced seals for electrolyzers. With the integration of the sealing material in the electrolyzer stacking plates, the company is offering reliable, easy-to-assemble plate modules to maximize seal performance in aggressive electrolyzer environments.

H

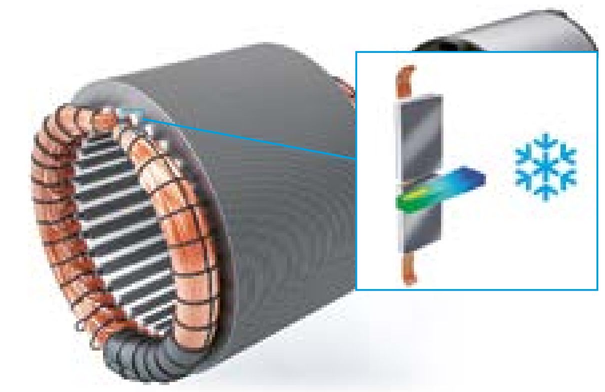
1 Gigawatt

of output from green hydrogen
is currently available worldwide.

For its seals, Freudenberg has turned to a range of its own rubber-based materials such as EPDM and FKM. Thanks to first-class material testing and analysis labs, its experts can develop and test recipes for materials that are tailored to the individual requirements of customers' applications. Sealing materials and binders can also be adapted for the best possible performance in various electrolyzer systems. Lean production makes it possible to change production processes quickly and adapt them to the needs of new markets and products. ⊚

April 2022

E-motors with the Right Temperature



Freudenberg Sealing Technologies has developed important TCEI (thermally conductive, electrically insulating) materials for e-mobility. They have outstanding mechanical characteristics and are resistant to high and low temperatures. Compared to other thermoplastic materials, they show reliable heat conductivity and improved electrical insulating characteristics. The company's Quantix® 90-5, a thermoplastic that incorporates a suitable filler, offers a high degree of heat conductivity – 0.6 W/mK through-plane and 4 W/mK in-plane. The material also offers strong electrical insulating properties (volume resistance of 2 x 1014 Ω·cm).

These are important advantages for manufacturers of electric vehicles since they can maximize the performance of their electric motors through improved heat management. Undesirable heat accumulation and excessive temperatures in electric motors are avoided. Meanwhile, lower interior temperatures contribute to the motor's greater power density and facilitate the use of a simplified cooling system that promotes a longer lifespan. ⊚

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Out of the Oven

Some materials get their final touches during post-curing at high temperatures in ovens. That takes energy – and it may not even be necessary. Materials expert Joe Walker explains how it could be innovative to do without the process.

Sometimes innovation is an accident. In 2001, Joe Walker, Global Technology Director, Materials and Laboratories at Freudenberg Sealing Technologies, and his team were supposed to develop a static seal that used a plastic insert for a customer. The competition had turned to a material that had to be post-cured – but the process deformed it. “It was a very undesirable trait,” Walker said. So, he and his team experimented. They developed the first-ever product of its kind that did without post-curing in a furnace. They ended up with a solution that performed all important functions, had a long operating life and was sustainable in the bargain.

> The world is demanding that we change the way we do things. So we have to talk to our customers and discuss alternatives that are more friendly to the environment and simultaneously reduce production costs.”

Post-Curing for Clean Materials

Some background information: One of the typical post processing steps for some rubber materials is to heat them in a furnace. When heated, the materials change in terms of some of their properties. Here the term “post-curing” is somewhat imprecise, said Walker, who oversees materials and laboratories for Freudenberg Sealing Technologies in the US: “When it comes to post-curing, we mostly think about changes in the crosslinking, which in turn directly affects the material’s mechanical and physical properties." These effects are not the only reason for a trip into the furnace: For example, rubber has to be post-cured just to get rid of undesirable by-products of the curing process. They result when individual ingredients mix and react chemically with one another. But if they stay in the material, they can change its attributes – or even cause damage. Other materials used in the food or pharmaceutical industries have to reach a certain level of purity. Productivity can also be improved at such high temperatures. This is true for polymers that are molded under heat and pressure and then are finished off in a furnace. "The machine cycles for the materials can be kept short," he said. That means the molds are freed up more quickly since large batches are post-curing in furnaces.

Turning off the Oven and Saving Energy

So there are some good reasons for post-curing. But Walker and his team have been selectively developing materials that dispense with the process. "They are typically FKM and EPDM materials," he explains. Both are based on rubber and are used to produce seals in a wide range of segments – FKM in the automotive, aerospace and commercial vehicle industries, for example, and EPDM in the food and pharmaceutical sectors, among others. There are financial reasons to eliminate post-curing in some cases: They relate to the massive energy consumption that the process involves. "In our oil seals manufacturing process, one cycle in the oven consumes about 41 kWh of electric current," Walker said. There might be three of these cycles per day, and there are 250 days of use a year. If you translate the electricity consumption into the CO_2 that is generated, you get emission levels in the millions – amounts that would not be incurred if ovens are not used. "We will never be in a position to completely do without ovens," Walker said. "As I said, some polymers have to be post-heated to eliminate harmful by-products and to create special cross links." But there would be a big payoff for ramping down or even shuttering furnaces when they are not strictly necessary. CO_2 emissions could be significantly reduced. The costs for energy, as well as staffing, would be lower as well. After all, employees have to maintain the ovens and load and unload them. Cycle times would be shorter.

Francis Joseph Walker

Joe Walker has worked with elastomers and plastics for more than 43 years. At Freudenberg Sealing Technologies, he monitors developments in advanced materials in the US. He has been honored many times for his achievements in the rubber industry. For example, members of Rubber Technologists Network named him the US Rubber Technologist of the Year in 2016.

First the Material, then the Specifications

But why have ovens been standard procedure so far? "Specifications are one of the problems," Walker said. They are the precisely determined characteristics that customers and Freudenberg Sealing Technologies agree on for the development of a material. The development mostly takes place in reverse order: first, the mixing and testing take place in the lab. As soon as the material is shown to "work" properly, the characteristics are documented as specifications retrospectively: What is its strength? What is its resistance to pressure? What is its mechanical profile? This is important to guarantee uniform quality. "But sometimes we have to post-cure materials to meet certain specifications, even though the performance of the material does not depend on it," Walker said. This is because specifications may have been determined in advance.

Innovation Requires Dialogue

So, it is all the more important to consider in advance whether post-curing is required or not – and plan the specifications accordingly. This was possible for some materials, Walker's team learned. For example, Freudenberg Sealing Technologies already has wide-ranging varieties of materials in use worldwide that are not post-cured. The situation is more difficult for materials that are already established with customers. To introduce new materials, employees at both the customer and manufacturer have to evaluate and test them and then adapt their processes. That takes time and resources. But companies are already facing serious challenges, including the fact that raw materials are in short supply, supply chains have been interrupted, and many processes are changing in response. But it is still worth entering into a dialogue: "The world is demanding that we change the way we do things. So we have to talk to our customers and discuss alternatives that are more environmentally friendly and simultaneously reduce production costs." ◎

Lifelong

With its advanced simulation methods, Freudenberg Sealing Technologies has succeeded in forecasting the decades-long lifespans of seals. What has already become the standard in wind power is making headway in other sectors as well.

The world's largest offshore wind power facility will rise 280 meters (nearly 920 feet) above the surface of the ocean when it is put into operation near Østerild, Denmark, next year. With an output of 14 megawatts, it is expected to generate 80 gigawatts of electric power annually – about as much energy as 25,000 electric cars consume in a year, assuming each is traveling 15,000 kilometers (about 9,320 miles) annually. Offshore wind power is striving to break record after record.

Their CO_2 balance sheet is only slightly clouded by the huge quantities of concrete and steel that are consumed in their construction. The Fraunhofer Institute for Building Physics calculates that an offshore wind turbine releases a maximum of 11.8 grams of greenhouse gases once you add the emissions produced during its construction into its operations. The calculation makes something else clear: The longer a wind power facility lasts, the more climate-friendly its balance sheet will be.

It was not that long ago when experts in wind power expected a minimum lifespan of 25 years. Now operators expect up to 35 years. What is good from the standpoint of sustainability is posing new challenges to Freudenberg Sealing Technologies engineers. After all, they have to design the seals that are used between the mast and the supportive steel pillars – which experts call "monopiles" – for a lifespan of three decades as well. Since the seals protect screw connections from corrosive sea water, their flawless functioning until the turbine's final day of operation is a necessity.

180,000

or more full load hours:
That's what a modern offshore wind turbine has to endure.

It is impossible to achieve these long lifespans solely with tests on a test stand. That is why Freudenberg first investigates certain material characteristics in six-week stress tests. An advanced version of the Arrhenius algorithm then comes into play. Over the past few years, Freudenberg materials experts have systematically continued developing a well-known algorithm named after the chemist and Nobel Prize winner Svante August Arrhenius. The process makes it possible to extrapolate lifespans. Freudenberg experts significantly improved the longevity model by coupling chemical and physical effects with the mechanical and structural behavior of the material.

A Proven Tool

"The systematic development of simulation tools is a key part of modern material development, since our customers expect declarations from us that go beyond the usual 1,000-hour endurance tests in laboratories," said Dr. Boris Traber, who is in charge of advanced material development at Freudenberg Sealing Technologies. "There are now very good models available to calculate the long-term aging behavior of elastomers used in static seals, and they have already come into use in many of our customers' processes. We worked with Freudenberg Technology Innovation to establish a new method to determine the impact of damage from oxygen – so-called thermo-oxidative aging – and to integrate the values into the models. This has made database values for more and more materials available, and experts can use them."

But Traber says this success is not enough. There are many other factors that influence the lifespan of a seal. And static seals are not the only varieties that have a great deal to withstand. "Many static seals are overlaid with dynamic oscillations, a frame seal in an engine block of a gas turbine that operates at very high temperatures, for example," Traber said. The manufacturers of these turbines would like to see operating times of up to 99,000 hours. In these applications, it is not enough to look at the sealing materials. It is primarily the interplay between the seal and the medium being sealed that has the crucial impact on aging. In gas turbines, there are two media involved: motor oil and water as a coolant. "Even if that is the pinnacle of lifespan forecasting today, our standard has to be the ability to forecast challenges of this kind in the future," Traber said.

Long-term durability is even becoming more important to the auto industry. Manufacturers and suppliers are increasingly asking for long operating lives under extreme conditions – for seals used in electric drives or in the exhaust systems for hydrogen motors, for example. The same rule applies here: The longer the life, the more sustainable the product. ◎

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If you no longer want to receive ESSENTIAL, simply send an email including your address to: **essential@fst.com**

We look forward to a dialogue with you!
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BCM Award 2022 – Silver
Trailer, Category Moving Image Fiction

BCM Award 2022 – Gold
Trailer, Category Audience Award

BCM Award 2019 – Silver
Category Magazine B2B Commerce / Transportation / Logistics

ICMA 2021 – Best of Decade
Category Customer Media B2C

PR Daily Award 2019 – Winner
Category Print Publication

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FOX AWARDS 2022 – Gold
Category Industry, Technology, Production

FOX AWARDS 2022 – Silver
Trailer, Category Industry, Technology, Production

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Category Industry, Technology, Production

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FOX VISUALS 2022 – Gold
Category Industry, Technology, Production

FOX VISUALS 2022 – Silver
Trailer, Category Industry, Technology, Production

FOX VISUALS 2021 – Silver
Category Industry, Technology, Production

FOX VISUALS 2020 – Silver
Category Transport, Logistics

FOX VISUALS 2019 – Gold
Category Industry, Technology, Production

Videographer 2019 – Gold
Trailer Thirst, Category Video Production | Video | 43. Other

Videographer 2019 – Gold
Trailer Digitalization, Category Video Production | Video | 43. Other

Galaxy 2019 – Gold
Category Corporate Magazines

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