ESSENTIAL

FREUDENBERG SEALING TECHNOLOGIES

PLASTICS

Breakthrough and Burden

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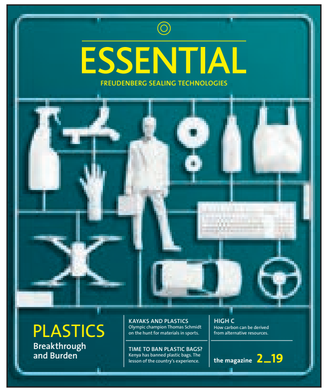
IN FIFTY WORDS



Plastics have a bad image, but that's no surprise. After all, this indestructible material causes a great deal of our waste problems. On the other hand, many novel, sustainable solutions would not be possible without high-performance plastics. Plastics are waste materials and a burden, as well as a tool for the future and a multi-faceted benefactor. ESSENTIAL gets to the bottom of the issue of plastics – as a breakthrough and as a burden.

Breakthrough and Burden

An Essay by Claus Möhlenkamp, Chief Executive Officer,
Freudenberg Sealing Technologies

Who Invented It?

Who exactly invented plastic is tough to answer. Was it Leo Hendrick Baekeland in 1907? He was granted a patent for Bakelit, the first fully synthetic, industrially produced plastic. Or was it Goodyear, who developed vulcanized rubber from sulfur and natural rubber in 1839? Or maybe we are in the wrong century, and our answer is the Augsburg Benedictine priest Wolfgang Seidel, who invented "artificial horn" in 1531. When he let low-fat cheese stand in the sun, it became as hard as bone. Or even the Neanderthals. They heated birch bark and extracted pitch from it. At the same time, it can be argued that German chemist Hermann Staudinger invented plastic in 1922. He was the first to explain that polymers are made of long chains of molecules. Goodyear's rubber and Stastny's Styrofoam are often described as accidental discoveries, however.

> Plastics are inexpensive to produce, incredibly multifaceted and extremely long-lasting. It is this last feature that is becoming a problem.

Inexpensive, Multifaceted, Long-lasting

Of course, the debate may be pointless. It might not ultimately matter who exactly invented plastic and when it was invented. But the question is relevant since it leads directly to another: What exactly is plastic? For one thing, it is our constant, omnipresent companion. About 9 billion tons of the material have been produced since 1950. That corresponds to the weight of 800,000 Eiffel Towers or a billion elephants. Plastic also has an image problem. The strengths of this modern, all-purpose material have now become disadvantages. Plastic is inexpensive to produce, incredibly multifaceted and extremely long-lasting. It is this last feature that is becoming a problem. No known microorganism has the ability to completely break down plastics. When they are no longer in use, plastic objects go into a landfill, float on the ocean or come back to us as micro-plastic in our bodies. Whether this could affect us and what it could do to us has not been adequately researched.

The Miracle Material

In ancient Greek, plastikos was the term for anything that could be shaped and changed. In art, plastic has survived as a term to describe three-dimensional objects. Even today, we use the word plasticity when we describe how formable a material is. Most early plastic objects were actually made with a forming process. For example, they were heated and shaped, and then they maintained their new form. Today there are plastics that are highly valued because they are tremendously rigid, just as there are viscous or elastic plastics that never become firm. The rigid varieties no longer have much of a semantic connection with the word's original Greek meaning.

The common denominator: All plastics consist of polymers, long chains or highly networked structures, and that is precisely what makes them so multifaceted. Synthetic polymers can create extremely stable connections, hold supporting parts of an aircraft together – or, on the other hand, dissolve quite easily. For example, plastic adhesives are used on self-detaching price tags. There is no better material than plastic for many modern applications. It is a lifesaver in sterile medical devices as well as safety applications in cars. And the more material in a vehicle is replaced by plastics, the lower its weight and fuel consumption. From the standpoint of sustainability, high-performance plastics not only make a great deal of sense – they are often the best possible solution.

The problem area is not plastic that reliably performs its functions over decades. Nor is it high-quality dolls, toy blocks and other playthings that are passed onto the next generation of children. It is our seductively convenient relationship with single-use plastic.

Freeing the World from Its Burden

It will take a new consciousness with regard to plastic bags, tubes, straws and outer packaging to keep the world from drowning in plastic waste. Once these items are used, they are immediately discarded. It is still an open question whether science will ever find or grow something that will completely decompose plastic. The carbon needed for the plastic is not likely to be replaceable since it has a unique way of combining into complex molecules. But what would happen if the carbon needed for plastic didn't come from crude oil but rather from renewable raw materials? There is research underway in this area, but it has run into a problem: Oil is cheap, and low-cost production is one of plastic's crucial advantages. On the other hand, fossil petroleum may not remain the most affordable option for plastic production forever.

Today plastics are both a breakthrough and a burden. It would be negligent to downplay one aspect or the other. The task of humanity will be twofold: to reduce plastic waste any way it can while doing more research on this miracle material. Who knows what could still be developed with innovative ideas – or with an accidental discovery like Styrofoam and hardened low-fat cheese? We at Freudenberg Sealing Technologies are committed to full sustainability in manufacturing and innovative research on the high-performance plastics of tomorrow. ◎

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Going with the Flow

Rivers are not just lifelines. They are also used to dispose of waste in many places and send large quantities of plastic into the ocean. Just two rivers, the Yangtze and the Indus, carry more than 21 million tons of plastic into the world's seas – per year. Oceanic currents then drive the plastic away from the coasts. Researchers have identified five areas in the Indian, Atlantic and Pacific oceans where plastic is accumulating in gigantic vortexes of trash. The largest of them, the Great Pacific Garbage Patch, covers an area four times the size of Germany. Experts suspect it contains 1.8 trillion plastic particles. The bulk of them fall into the microplastic category, meaning that they are less than one-fifth of an inch long. ◎

Plastics Center

Plastic's march toward its global rise began around 1950. At the time, worldwide annual production amounted to about 2 million tons. Since then, it has steadily grown, to nearly 360 million tons last year. China's contribution is nearly one-third of the annual production, making it the world's largest plastics producer. "Made in China" plastic is not just turned into lucky cats – it is mainly used in components for computers and smart phones, in shoes and clothing, and in toys. In each of these categories, this lightweight yet robust and malleable material can exploit its strengths to perfection. Incidentally, plastic is mostly used as a packaging material around the world. It also plays an important role in the construction sector. ◎

Super Storage

The argan tree only thrives in a small area of southwest Morocco, where its precious oil is extracted from the almonds within its fruit. Goats stand on the tree and eat its fruit and leaves with relish. Yet, due to forest clearing and reductions in groundwater, the number of argan trees is in decline. To halt this trend, a Moroccan research institute has experimented with super absorbers made of polymers that store water in quantities that are multiples of their weight. If they are applied to the soil, they give off previously absorbed water as soon as the earth dries out. It's a useful way to support the highly demanding cultivation of the trees. Super absorbers also make effective use of their characteristics in diapers and the encasement of underwater cables. There they are a good way to bind up moisture. ◎

Searching for the Holy Grail

Olympic champion, kayaker, boat designer, racing venue designer: Thomas Schmidt has already played a number of roles. He has always been involved with plastic – and has benefited from its virtues.

THOMAS SCHMIDT, YOU WON'T EVER FORGET SEPTEMBER 20, 2000, WILL YOU?
No, how could I? I was an Olympic champion in the kayak slalom in Sydney. It seemed inconceivable that I had won the most important event in the field. In the first and second heats, I was more than three seconds faster than my competitors – and that's in a sport where things are always tight. We have to battle through gates in whitewater without touching them, even against the current. Contact results in penalty seconds. But on that day, everything came together for me. It was an absolute dream.

BUT YOUR SUCCESS WAS STILL A SURPRISE IN THE END.
Definitely. A year earlier, I had dislocated my shoulder. That's a very serious injury for a kayaker. An operation was unavoidable. At times during rehab, deep down inside, I thought things looked bleak. I had to learn how to steer straight all over again. While the national team was training in Australia and New Zealand, I had to stay at home. But in the end, that was an advantage.

WHY?
I changed my technique, worked hard mentally and fine-tuned my boat extensively. When my teammates came back, I had become faster than they were and secured my starting position.

HOW DID YOU CHANGE THE BOAT?
I took over the boat of a heavier teammate. That's not unusual, but I had to adjust it to my body weight and my needs. Otherwise, due to its height, I would have kept getting hit somewhere

Thomas Schmidt

Born in 1976, Thomas Schmidt entered his first slalom competition at the age of 9. In 2000, he won a gold medal at the Olympic Games in Sydney, Australia, and then the overall World Cup a year later. After coming in fifth place in the Olympic Games in Athens, he ended his athletic career in 2004. A mechanical engineer with a master's degree in engineering studies, he has worked at KUKA since 2016. The company has focused on intelligent automation solutions. A key account manager, he is in charge of the sales of friction-welding machines and related automation systems.

The Rules

Green and white: A downstream gate must be navigated during the descent and is marked with two green- and white-striped rods. Each gate also carries a sign with a number. It must be legible in the direction of travel. The number is crossed off on the reverse side.

Red and white: An upstream gate must be navigated against the flow. It consists of two red- and white-striped rods.

while padding. I would have only been able to bring the stern underwater with difficulty. But that's crucial for control and speed. I had to make it flatter.

HOW DOES THAT WORK?

A kayak consists of two parts, an upper deck and a lower hull. I removed the boat's upper deck and ground off 0.75 to 1.2 inches and then glued it back on the lower hull. I changed the sitting position and reallocated the extra weight. That turned a good boat into an even better boat.

IS IT NORMAL FOR TOP KAYAKERS TO WORK ON THEIR OWN BOATS?

Absolutely, even though manufacturers have put about 20 to 30 models in circulation, it is important for athletes to determine the right dimensions for themselves. Not least of all, this is due to our individual paddling styles. In the end, it is the entire package – athlete, boat and paddle – that determines success. But there is always some tinkering. Everyone is looking for the Holy Grail.

FOR THAT REASON ALONE, TODAY'S RACING BOATS MUST DIFFER ENORMOUSLY FROM THE ORIGINAL KAYAKS.

Definitely. Especially in terms of the materials. Our kayaks are inspired by the boats of the Eskimos. They were made of wood and bone and covered with animal skins. In the first competitions, the athletes used folding boats consisting of a waterproofed linen tent material stretched over a collapsible frame. Plastic boats caught on about 50 years ago. The material today is carbon-fiber-reinforced plastic. The only parts of a kayak not made of plastic are the foot supports. They are aluminum.

HOW SHOULD WE ENVISION THE ARTIFICIAL SKIN OF A KAYAK?

The carbon-fiber fabric is processed with epoxide resin – an artificial resin – in multiple layers into a one-tenth-inch-thick laminate. You should look at the boat's wall as a sandwich. Two separate layers of carbon-fiber fabric are followed by a layer of polyurethane foam and then another two layers of fabric and resin. It ultimately resembles the wall of a travel trailer.

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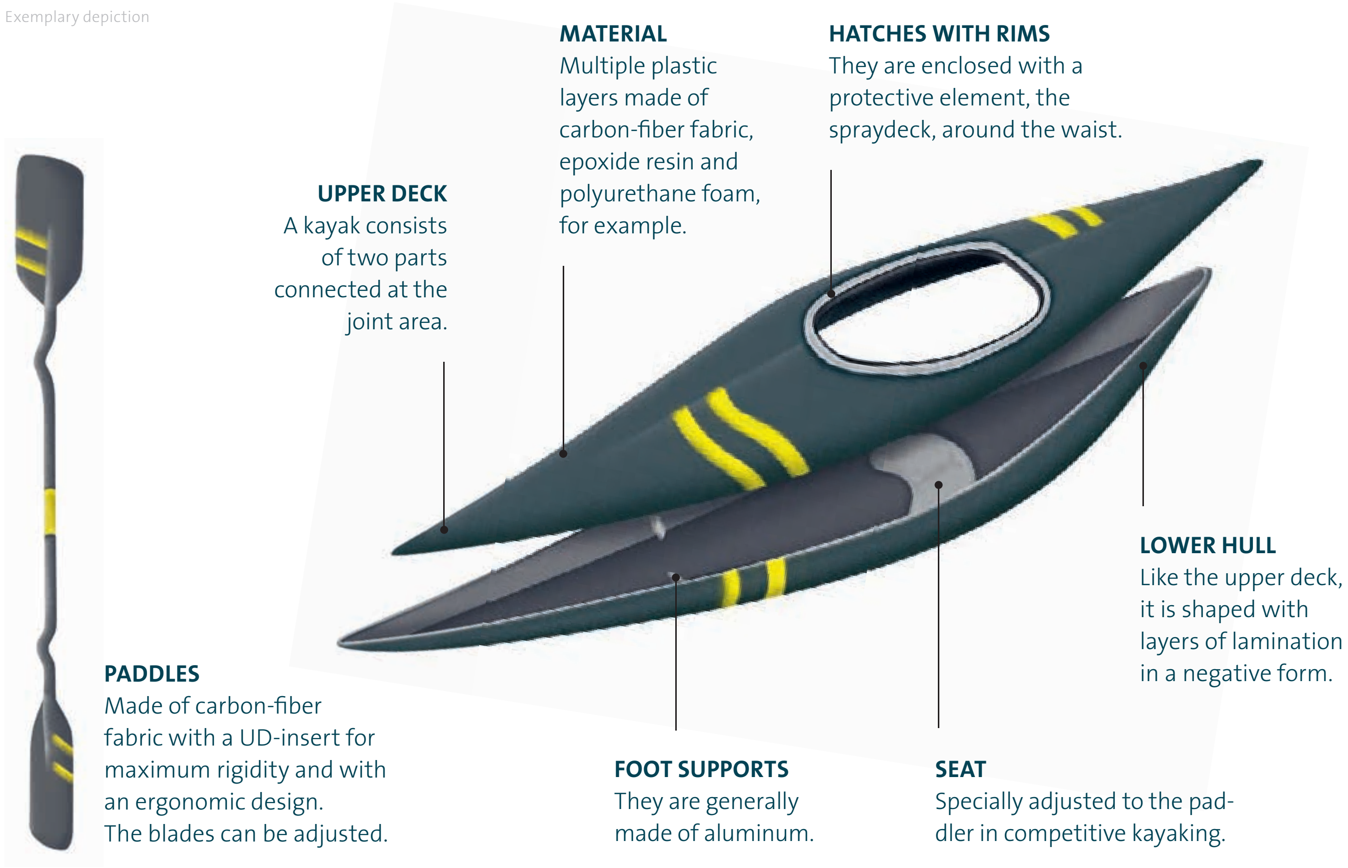
Exemplary depiction



MATERIAL
Multiple plastic layers made of carbon-fiber fabric, epoxide resin and polyurethane foam, for example.

HATCHES WITH RIMS
They are enclosed with a protective element, the spraydeck, around the waist.

UPPER DECK
A kayak consists of two parts connected at the joint area.

LOWER HULL
Like the upper deck, it is shaped with layers of lamination in a negative form.

PADDLES
Made of carbon-fiber fabric with a UD-insert for maximum rigidity and with an ergonomic design. The blades can be adjusted.

FOOT SUPPORTS
They are generally made of aluminum.

SEAT
Specially adjusted to the paddler in competitive kayaking.

WHY IS PLASTIC SO WELL-SUITED FOR YOUR SPORT?

Plastic gives a boat designer great freedom. It facilitates shaping and styling. Boats made of plastic can also be manufactured quickly, and the material is ultra-lightweight yet strong and tough. The robustness is important because there are obstacles made of concrete on my home course in Augsburg. A boat has to be able to withstand them. In turn, a boat's light weight makes it easier to control.

WHAT IS THE EFFECT IN WATER?

The turning process is significantly better. Paddling techniques have continued to develop with the new boats. Maneuvers that were impossible ten years ago are being executed today. It takes fewer paddle strokes to get through a gate against the current. Overall, the boats have become faster.

SO YOU COULD SAY THAT THE KAYAK AND CANOE SLALOMS WOULD NOT BE WHERE THEY ARE TODAY WITHOUT PLASTIC?

This form of the canoe and kayak slalom would be inconceivable. Speaking figuratively, we would still be up in the trees.

IN THE RUN-UP TO THE 2004 OLYMPIC GAMES, YOU WERE EVEN ABLE TO BUILD YOUR OWN BOATS.

That's true. After my studies, starting in 2002, I was able to direct a research project tailored to my needs at my university and get financial support for it. One important goal was to optimize the production process for the boats.

WHAT WERE THE INDIVIDUAL STEPS IN CONSTRUCTING YOUR BOATS?

You always need a negative form in which you can laminate. That's the only way the exterior skin of the boat can be made really smooth. To manufacture a negative form, you need a positive block. It is nothing more than the shape of the kayak. We played with it on the computer and then machined it from molded plastic with a milling machine. We obtained the desired negative mold by applying glass-fiber laminate onto the positive block.

came out of the same mold. They were also of very high quality. The material was even lighter than earlier options – and stronger.

WHY WERE YOU SO FASCINATED WITH PLASTIC?

It was the options for lightweight design that are associated with the material. There are diverse possibilities for the production process, and they open up entirely new opportunities for design. This interaction makes plastic very appealing. An incredible range of things become possible.

AT THE 2012 OLYMPIC GAMES IN LONDON AND THE 2016 GAMES IN RIO, YOU SWITCHED SIDES AND WERE IN CHARGE OF COURSE DESIGN. WHAT DOES THAT INVOLVE?

My job was to set the gates on the channels, determining the course. Here it was essential to take the characteristics of the particular channel, including its currents and waves, into account. The mission was to challenge the best kayakers while not overpowering the weaker ones. That's a fine line. I know from my own experience that you can only rarely get it right for the kayakers. I also had to take referees and TV broadcasters into consideration. Television wants spectacular images, and the referees want easily visible gates. That's not easy when the waves are so high.

THE COMPETITIONS HAVE LONG TAKEN PLACE ON ARTIFICIAL COURSES. PLASTICS ARE ALSO PLAYING A MAJOR ROLE IN THE CONSTRUCTION OF NEW CHANNELS.

That's right. Huge plastic walls produce the characteristic currents and vortexes. What seem to be boulders on TV are actually just fixtures on the walls. By manipulating the walls, the characteristics of the course can be easily changed. They are connected like Lego blocks or are pushed along on a rail system. The changes are made only once or twice a year, but they certainly make things entertaining and exciting for the athlete.

YOU ARE NOW AN EMPLOYEE OF THE INTERNATIONAL TECHNOLOGY COMPANY KUKA. WHAT ROLE DOES PLASTIC PLAY AT KUKA AND HOW IS THE COMPANY PROMOTING SUSTAINABILITY?

There is no way around the use of plastics in KUKA products. But in its sustainability report, the company highlights its efforts to procure recycled materials and to use recyclable plastics in manufacturing whenever possible.

THANK YOU FOR THIS INSIGHTFUL INTERVIEW. ◎

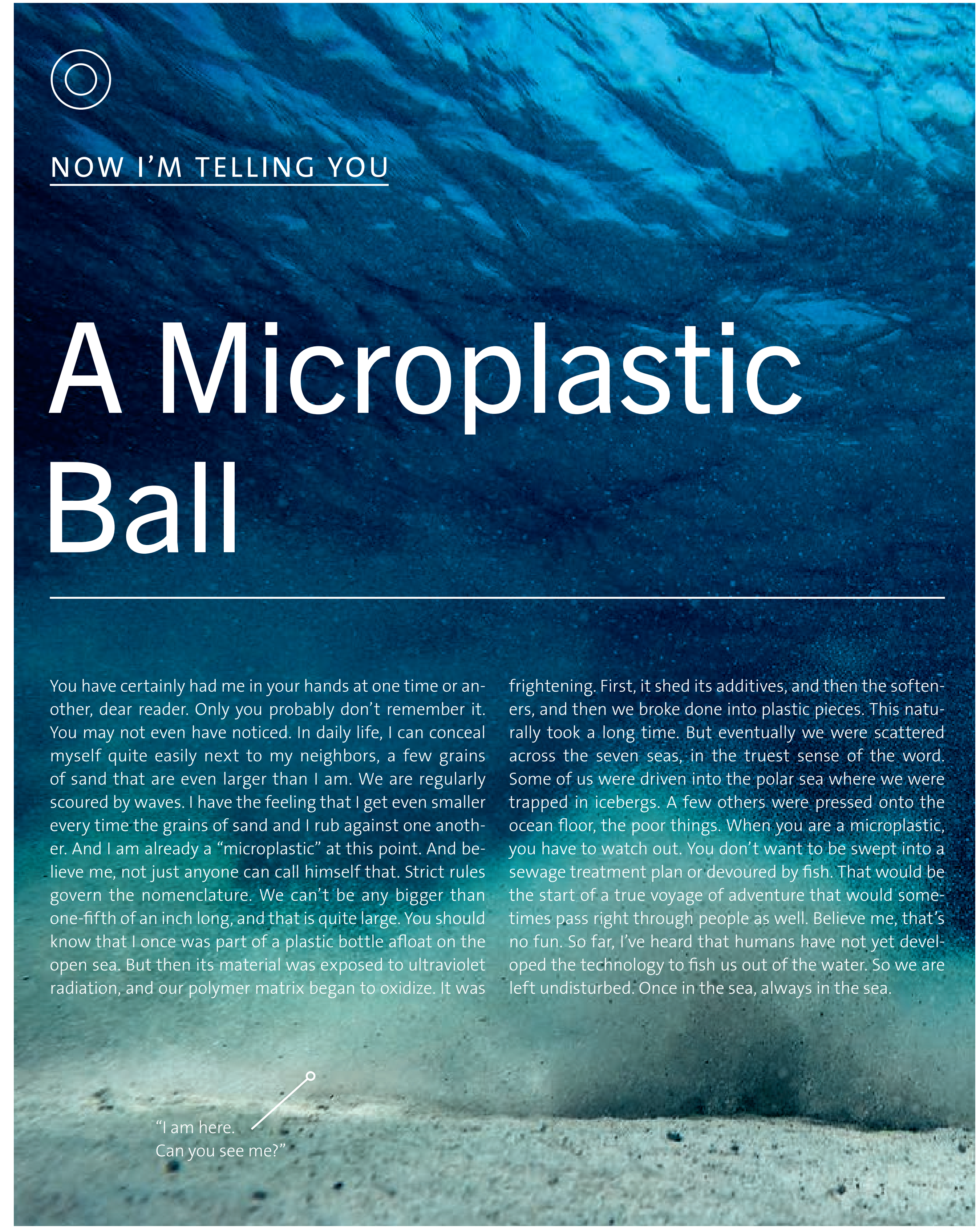
SO THE NEGATIVE MOLD ALLOWS YOU TO MANUFACTURE THE BOAT'S HULL?

Precisely. The sandwich material I mentioned earlier. I used carbon fibers preimpregnated in epoxide resin and a special polyurethane foam that I could place into the negative form without folding it. After we had joined the two halves of the kayak's form, the boat had to cure perfectly. The curing took place under great pressure in a special oven, an autoclave.

SO YOU MADE SURE THAT THE SHAPE OF THE BOAT DID NOT CHANGE IN THE PROCESS?

We placed a vacuum bag in the boat, which pressed against the wall and maintained the shape. Then we pulled the bag back out through the hatch. Using this technique, we manufactured two identical boats that were perfectly adapted to me. It was as though they

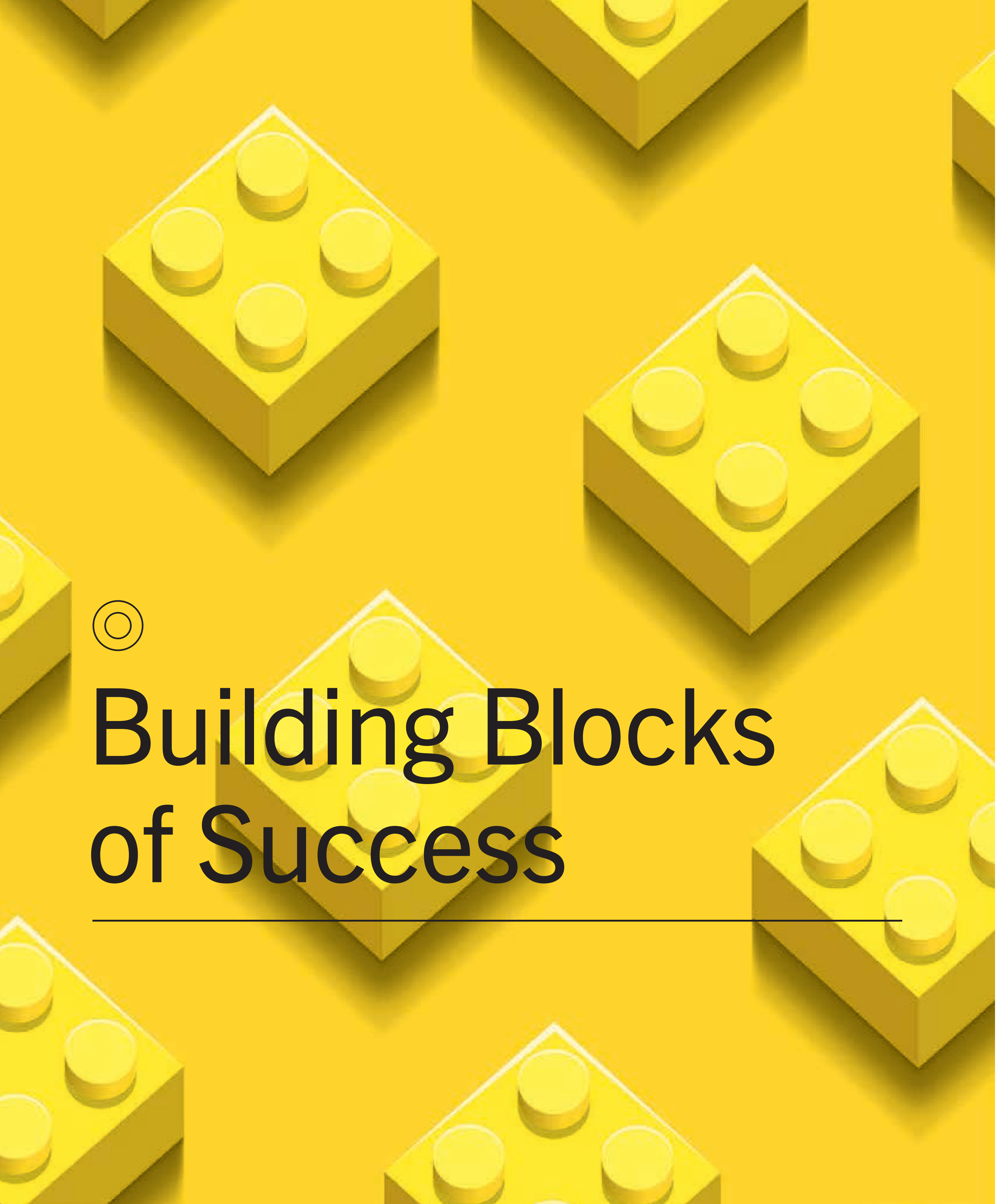
Read part two of the interview here:
https://bit.ly/2mSfFXN



NOW I'M TELLING YOU

A Microplastic Ball

You have certainly had me in your hands at one time or another, dear reader. Only you probably don't remember it. You may not even have noticed. In daily life, I can conceal myself quite easily next to my neighbors, a few grains of sand that are even larger than I am. We are regularly scoured by waves. I have the feeling that I get even smaller every time the grains of sand and I rub against one another. And I am already a "microplastic" at this point. And believe me, not just anyone can call himself that. Strict rules govern the nomenclature. We can't be any bigger than one-fifth of an inch long, and that is quite large. You should know that I once was part of a plastic bottle afloat on the open sea. But then its material was exposed to ultraviolet radiation, and our polymer matrix began to oxidize. It was frightening. First, it shed its additives, and then the softeners, and then we broke done into plastic pieces. This naturally took a long time. But eventually we were scattered across the seven seas, in the truest sense of the word. Some of us were driven into the polar sea where we were trapped in icebergs. A few others were pressed onto the ocean floor, the poor things. When you are a microplastic, you have to watch out. You don't want to be swept into a sewage treatment plan or devoured by fish. That would be the start of a true voyage of adventure that would sometimes pass right through people as well. Believe me, that's no fun. So far, I've heard that humans have not yet developed the technology to fish us out of the water. So we are left undisturbed. Once in the sea, always in the sea.



Building Blocks of Success

Lego bases its global fame on plastic. Few of its products are ever thrown away. They are more likely to be passed down to another child. Success didn't seem to be in the cards in the early days – back when Lego's founder was still betting on wood as the material for the blocks. A history of the company's path to plastic – and the difficult search for alternatives.

The Danish cabinet maker Ole Kirk Kristiansen stood on the brink of ruin in the early 1930s. He had just dismissed his last employee. Since the start of the global depression in 1929, customers were no longer ordering windows, drawers or kitchen cabinets. He tried to stay above water with wooden toys. He needed bank loans for that, and his siblings would only serve as guarantors reluctantly. They thought toys hardly qualified as a reasonable product line with good prospects for the future.

Nearly a century later, the toy-making operation founded by Kristiansen generates nearly $4 billion US in revenue and has about 14,000 employees. The Lego Group has been the world's largest toymaker since 2017. It turned out that toys were a very reasonable product line even in times of war and economic crisis. People were more likely to buy them than kitchen cabinets. But the story of Lego is not just a lesson in the business opportunities for toys. It's also the story of the continuing development of materials.

1934

Carpenter Ole Kirk Kristiansen decides to bet everything on the toy business. It was a daring step for his company at the time, but it would pay off handsomely.

1949

For the first time, Lego makes plastic blocks that can be joined to one another. But Kristiansen's sons all worry that plastics manufacturing could turn out to be a disastrous line of business.

1960

After a fire in the carpentry shop, Lego ceases its production of wood products. Until that point, it is still making trains out of wood, among other products.

1963

In its manufacturing operations, the company switches from cellulose acetate to ABS – the type of plastic used down to the present.

“Wood Is Stronger”

“You can make sweet and pretty things out of plastic – but wood is the stronger material,” said Godtfred Kirk Christiansen, the son of the company’s founder, in 1949. The Lego toy company had already begun experimenting with plastic, although its main products were wooden automobiles, airplanes and yo-yos. But high-quality beechwood was in short supply in Denmark after World War II. Three years earlier, Ole Kirk Kristiansen witnessed a demonstration of an injection-molding machine. But neither the right molds nor the right materials were available at the time. The situation called for initiative. Kristiansen experimented with cellulose acetate, one of the oldest thermoplastic plastics. Here cotton fibers (cellulose) are heated with acetic anhydride to 284 °F, and a water-insoluble powder was the result. It was used to form the first building blocks designed to be affixed to one another. The Lego blocks made from this material would prevail into the 1960s.

At least until an even better material was discovered: It was acrylonitrile butadiene styrene copolymer, or ABS for short. This very hard plastic is the preferred material for automotive parts, motorcycle helmets and, quite generally, any consumer good that has to be highly impact-resistant. It is scratch-proof, bite-resistant, and something else not insignificant to Lego: It is more colorfast than its predecessor. The material also costs less and can be easily processed using injection molding. In years past, Lego has gained so much experience with this production method that it came up with its own hot runner system in 1970. The ABS granulate is heated to 450 °F and then pressed into molds.

Describing the process as extremely precise would be an understatement: A deviation of just 1000th of a millimeter is allowed so components will fit perfectly when affixed to one another.

More Difficult than the Moon Landing?

A few years ago, Lego set the goal of exclusively using sustainable raw materials in its manufacturing operations and packaging by 2030. The Wall Street Journal reported in June that the company has now tested more than 200 different compounds in this effort – without success. Lego’s own standards are the obstacle. Materials turned out to be too soft if they were based on corn and could not duplicate colors if they were based on wheat. Other materials resulted in blocks that were either too hard or too fragile. ABS plastic still seems to be the one perfect material for Lego blocks. The company’s sustainability chief Tim Guy compared the challenge to the first moon landing. Back then, a large share of the technology had to be invented in the first place. At least Lego’s components for trees, bushes and leaves now consist of a polyethylene based on sugarcane. According to the company, they represent “1 to 2 percent” of the plastic produced.

The paradox: Lego has escaped one debate over plastic. Since complete Lego collections tend to be passed on, given away or resold, environmental pollution is kept within limits. Today the company is being measured against its own pronouncements. On the other hand, if the history of Lego shows one thing, it’s that people should be careful about crowning a material as the pinnacle of all the options too early. If Lego were still betting on wood as a “strong” material, the company would certainly never have become a global leader in the toy market. Nor would it be worth billions. ◎

Compatible Down to the Present

Lego’s success is in part due to the fact that the design of the original knobbed building block has basically remained the same. Cellulose acetate building blocks from the 1960s have been compatible with modern blocks down to the present. But environmental advocates warn against using the old blocks: A study by the University of Plymouth found that they contain amounts of cadmium that exceed all current EU limits.

A Better Fit than First Thought

The name Lego is composed of the words “Leg” and “godt,” which means “play well!” in Danish. The name emerged from a competition among employees working at the toy factory decades ago. The winner was awarded a bottle of wine. The notion that the name can also mean “I collect” or even “I assemble” in Latin – thus describing the basic principle of Lego blocks – only emerged much later.

1973

Lego develops its first hot runner for plastic production. The machines previously in use did not meet the company’s standards.

1974

The first Lego figure appears this year. At the time, it is just a round head attached to square blocks. Movable legs arrive four years later.

1989

Lego launches its “Pirates” series. For the first time, the figures have their own facial expressions. It is also the start of an increasingly diversified Lego world.

2003

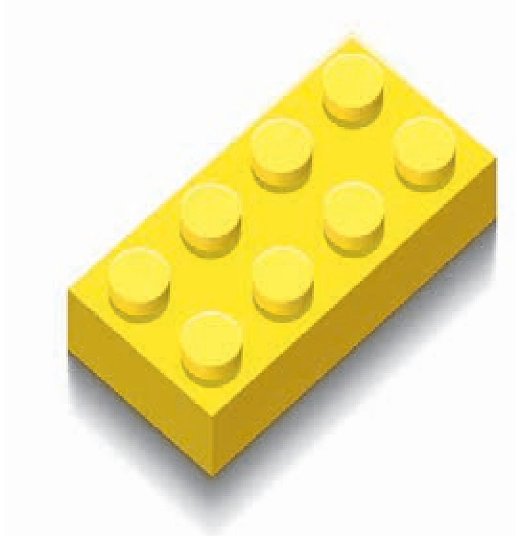
The company experiences its greatest crisis and reports a deficit of 1 billion Danish kroner. The company makes radical changes and focuses more on its core business.

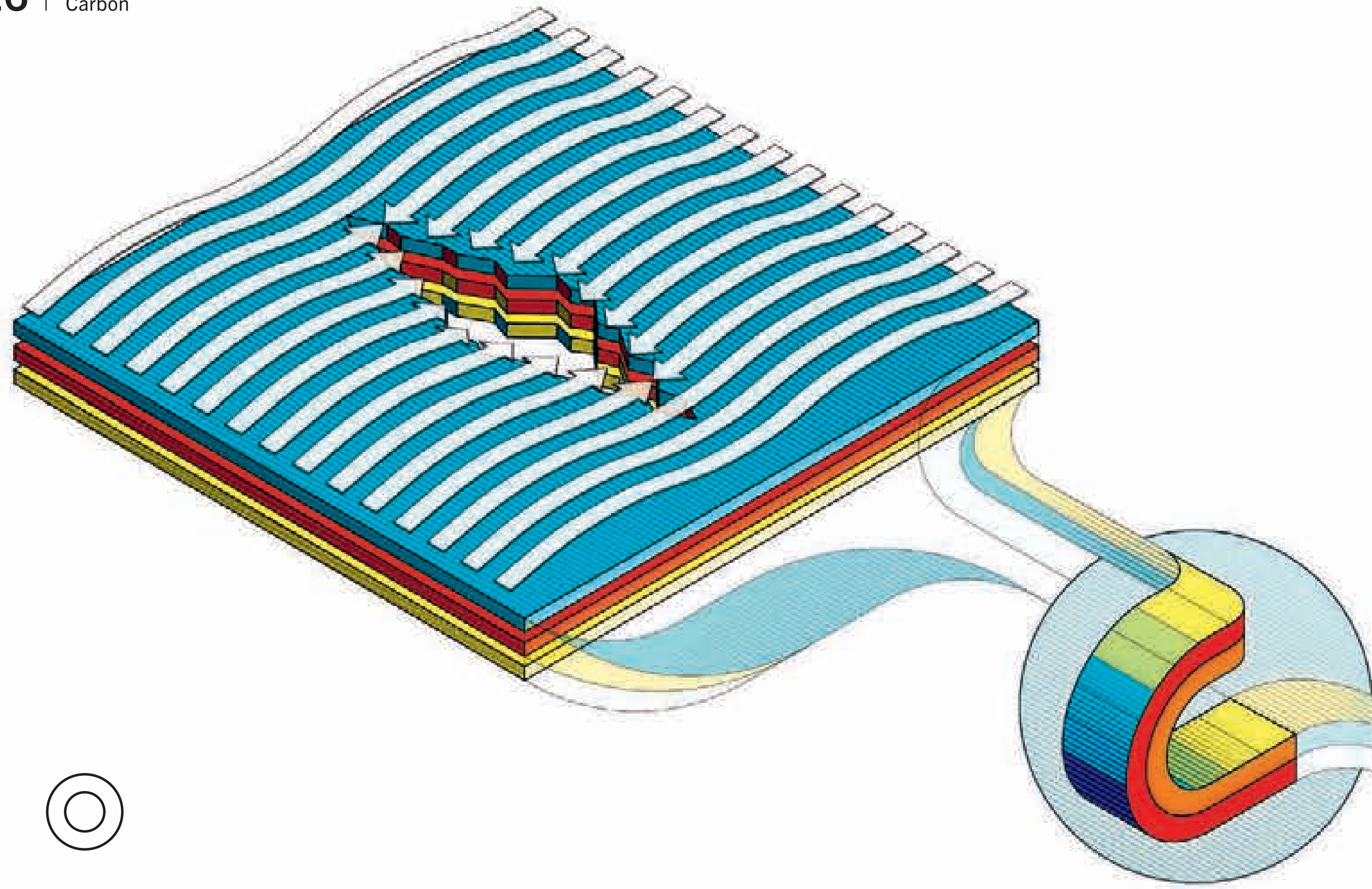
2016

With profit of 1.2 billion euros, the company records its most successful fiscal year ever. It is currently the world’s largest toy manufacturer with revenues of 4.8 billion euros worldwide, ahead of Hasbro and Mattel (each with about 4 billion euros).

2017

Incidentally, Lego is the world’s largest manufacturer of tires. In 2017, for example, the company produced more than 700 million small plastic tires. That’s more than Bridgestone, Michelin and Goodyear (each with about 200 million tires) combined.





High C

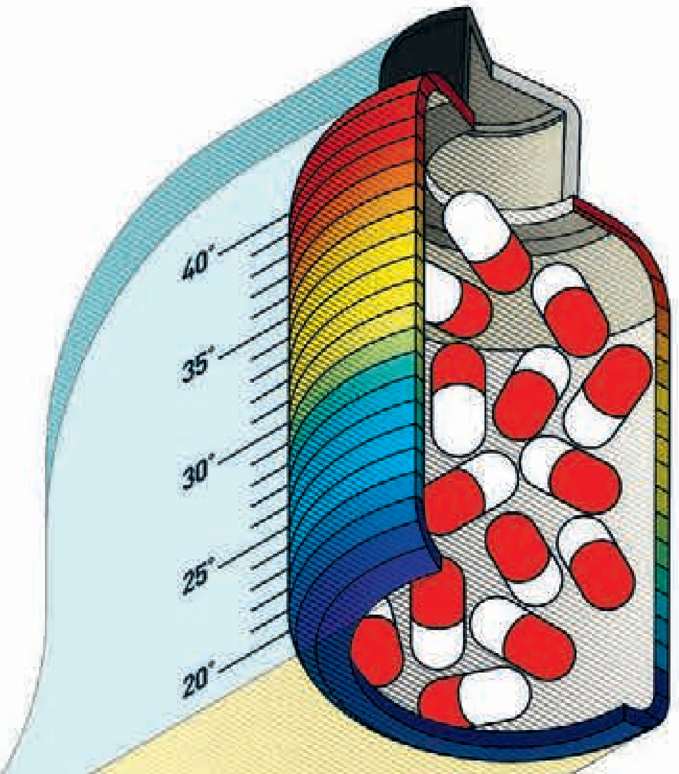
In chemistry, “C” stands for carbon, the most important base ingredient for plastic manufacturing. The source of the element doesn’t have to be a fossil material. Researchers have been working on alternatives inspired by nature for years.

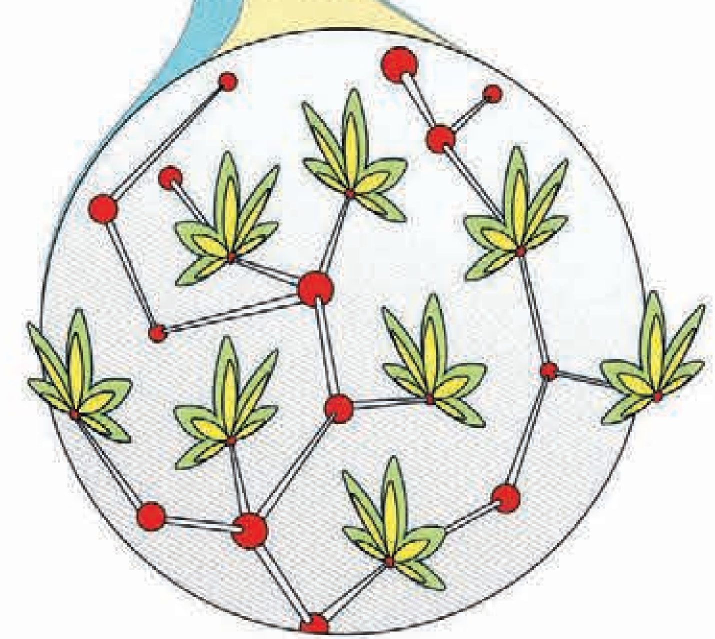
Self-healing Paint

It sounds like science fiction: A paint that repairs a scratch on its own. But the idea isn’t fiction at all. At Paderborn University, Dr. Oliver Strube is working with partners on the “Self-healing Surfaces” project. “For this project, we’ve chosen automotive clearcoat, one of the paint systems with the highest quality standards,” Strube explains. “The polymer networks of traditional clearcoat are irreversibly damaged if there is a scratch or other mechanical stress,” he adds. With the new clearcoat, the connections in the polymer network are designed to merely loosen reversibly if they are struck by a mechanical force. When the impact subsides, the connections close again, and the clearcoat surface remains undamaged. This innovative effect is made possible by the use of special biomolecules. “The fascinating aspect of natural materials is that biology in many areas is far more advanced than we are,” Strube said. “Plants can form structures and execute synthetic processes that cannot be reproduced by artificial means.” Researchers have developed an early composite using biomolecules that is now undergoing wide-ranging tests as a clearcoat additive. ◎

Thermochromic Plastic

Consider a plastic package that takes on another color as its temperature changes. That would not only make sense for drink packaging to display proper cooling or to alert the consumer to hot content. It could also be used to visually signal the proper temperature for storing pharmaceuticals. With his partners, Dr. Volker Eberhardt is working on a project called “Thermochromic Plastics Made of Natural Materials,” to determine how this type of packaging can be developed with biopolymers and natural, non-toxic and color-imparting additives. “The plastics industry has been rethinking its use of materials and is moving away from petroleum-based products and toward the use of renewable raw materials,” Eberhardt notes. “This rethinking also applies to functional elements such as chromogenic effects.” Many conventional additives used to produce color effects until now have not been authorized for contact with food. That’s why temperature indicators are merely glued to containers as labels. “With natural materials, the thermochromic effect could be used not just on the label but directly on part of the packaging,” Eberhardt said. The researchers are now working on an appropriate bio-plastic matrix and a selection of readily available colorants. ◎





Plant-based Car Body Parts

In 1941, the magazine Popular Mechanics published a report on a design engineer who used hemp to build a car. The “hemp car” had a steel frame, but was otherwise composed of 70 percent sisal, hemp and wheat straw. It weighed barely 1,500 pounds. But this innovative use of material ran into the “Marihuana Tax Act.” The law made hemp very costly in the U.S., and its industrial cultivation became unprofitable. The idea could have gotten traction: The design engineer was none other than Henry Ford. It was only many decades later that natural materials would enjoy a renaissance in the auto industry. In the mid-1990s, Mercedes-Benz replaced the plastic in the E- Class’s door paneling with fiber mats made of flax and sisal. BMW not only pioneered a new vision on the i3 in 2013 with its electric drive but with an instrument panel and door paneling based on natural fibers as well. Since 2017, the Braunschweig-based Fraunhofer Institute for Wood Research has been working with its partners on the “BioHybridCar,” in which natural fibers are combined with carbon and glass fibers. The researchers want to use bio-composite materials to make car body parts that are 60 percent lighter than their steel counterparts. ◎

Tender Leaves amid Mountains of Trash

Plastic trash from around the world ends up in Vietnam. At the same time, a new generation of innovative city-dwellers is discovering its ecological conscience. Are rice-flour straws and leaf-based packaging suitable solutions for the rest of the world? A visit to Southeast Asia.

Store Manager Tran Minh Duc has greatly reduced his use of plastic packaging.

Fresh herbs are wrapped in leaf packaging at the Bac Tom store.

E It seems as though it would be like eating uncooked pasta. The straws have quite a nice bite. After spending hours in cold water, they do become a bit curved at their lower end. But they are still far from "al dente." And really, who nurses a drink that long? Media reports have described the latest development from a Vietnamese firm as an "edible straw." But given their semi-raw state, they aren't something to nibble on as though they were snack sticks, the manufacturer says.

But the straws are certainly compostable, making them an environmentally friendly alternative to plastic. Vietnam's new eco-straws are made from rice flour, dyed with natural ingredients such as beets, sesame and spinach. HungHau Foods experimented at length to come up with a recipe for straws that were neither too brittle nor too limp, according to Vo Minh Khang, the company's Managing Director. HungHau Foods used its spaghetti factory in Sa Dec in the Mekong Delta to make the straws. It now has a capacity of about a million rice flour straws a day, some of which are sold abroad.

But it is not just compostable straws that are calling attention to the dawn of Vietnam's environmental consciousness. Almost coincidentally, the Hanoi food dealer Bac Tom came up with the idea of no longer selling lettuce and herbs in plastic bags – the foods are now wrapped in plant leaves. "We normally provided plastic packaging with our logo on it to farmers who delivered vegetables to us," said Bac Tom Manager Tran Minh Duc. "Once, when we didn't provide enough packaging, a farmer sent us vegetables wrapped in la dong leaves." A return to the country's roots, so to speak. In Vietnam, sticky rice cakes have been wrapped in this plant-based packaging, which resembles banana leaves, from time immemorial. The cakes are a traditional New Year's delicacy. "That went down very well with many of our customers. Some of them even shot selfies with the leaf wrapping," Duc said. He says offering at least some of his wares in leaf-based packaging is his small contribution to a rewarding trend that is slowly catching on in Vietnam. "We are seeing more and more people using their plastic bags multiple times or bringing sacks made of a different material with them," he said.

> That went down very well with many of our customers. Some of them even shot selfies with the leaf wrapping."
>
> Tran Minh Duc, Bac Tom Manager

The Land of Plastic Bags

Rice straws and leaf packaging cannot save the ocean from plastic trash, however. In light of the huge amounts of garbage piling up in all of Southeast Asia or wafting through the oceans, these efforts are a drop in the bucket at most. But they may be a stimulus for something far greater: "Initiatives of this kind can help awaken an awareness of the problem," says Nguyen Viet Dung, who heads the Vietnamese operations of the Ocean Trash Campaign of the environmental group Pacific Environment. He already sees people rethinking the issue. Still, it can't be denied that plastic pollution is a huge problem in rural areas. "Plastic bags are inexpensive, practical and ubiquitous in all the markets."

Vietnam's own trash problem is hard to overlook. Its entire 1,800-mile coastline looks like one long landfill, from the world-famous UNESCO heritage site Halong Bay, through the beaches of the central coast, to the tourist island of Phu Quoc in the far south, and everywhere in between. In Dalat, a vacation spot in the central highlands, heavy rains unleashed "an avalanche of trash" – part of a huge landfill on a ridge slid away and smothered the vegetable gardens below with a 4-yard-high layer of stench.

An estimated 8 million tons of plastic trash end up in the world's oceans each year, more than half of which come from China and four Southeast Asian nations, according to a study published by the environmental group Ocean Conservancy. They are all countries with a large share of their populations living near

They are made of rice flour and dyed with natural ingredients at a factory owned by HungHau Foods, a Vietnamese food company. There is now demand for the straws abroad as well as domestically.

Shrink-wrapped rambutan fruit. Plastic and Styrofoam packaging can still often be found in Vietnam's supermarkets.

the coast. They have also experienced enormous economic growth recently. Their waste disposal systems simply cannot keep up with their soaring consumption of the single-use plastic associated with rising prosperity. Vietnam ended up in fourth place among the five top ocean litterers, coming in ahead of Thailand and trailing only China, Indonesia and the Philippines.

Is Vietnam Becoming the World's Dump?

In view of this vast amount of plastic trash, it may seem paradoxical that Vietnam's powerful plastics industry is dependent on imports of old plastic from abroad. The aforementioned flood of plastic bags, for example, consists of recycled plastic – and 80 percent of this raw material is imported, with large amounts coming from Japan, the United States and Germany.

The country has too little of the waste management and recycling infrastructure needed to manufacture plastic from its mountains of trash on its own. That's why the country has to rely on imported plastic. In addition, its own old plastic is often of low quality. Only about 20 percent is retrieved by trash gatherers and sold to small, informal recycling shops, which turn it into plastic pellets as a raw material. The bulk ends up in landfills or in the ocean, or it is incinerated.

Imports of all plastic have increased enormously since China, once the world's biggest importer of waste, blocked further imports of old plastic in January 2018. Over a period of two decades, China had imported about 45 percent of the world's plastic trash – now this trash from the West has had to be rerouted to new customers, largely in Southeast Asia. It's no wonder that these countries are nearly choking on overwhelming quantities of plastic. Last year, Vietnam tightened up its inspections and requirements for importing old plastic, which caused thousands of shipping containers full of the material to be jammed up in the ports. The Vietnamese plastics industry, one of the fastest-growing sectors over the last decade, feared losses in the millions if Vietnam were to ban plastic imports at a single stroke.

An estimated

8 million

tons of plastic trash end up in the world's oceans each year.

Banning Plastic in Halong Bay

Local NGOs are trying to battle Vietnam's own trash tsunami with programs such as beach cleanups and informational campaigns. The authorities are taking action as well. For example, in Halong Bay, officials planned to ban plastic at all tourism-related organizations starting in September. "But the country needs sustainable solutions to make long-term changes and to reduce the supply as well as the demand for single-use plastic," Dung said. But the country still has no official plan, he said. People want to learn from the experience of other countries like Taiwan and South Korea and from their notions of manufacturer liability, he adds. "That all takes time. An important focus will be to sensitize people's awareness and urge them to avoid plastic or use it less, reuse it multiple times and ultimately recycle it."

Meanwhile, work is continuing on a small scale. The Bac Tom shop is still not completely plastic-free, and its customers are still not very receptive to alternative packaging, especially for meat, according to Duc, the shop manager. But he still wants to expand the concept to as many products as possible. And he is not the only one in Hanoi to join the eco-movement. Leaf wrappers have reached the shelves of large supermarket chains. The straw makers at HungHau Foods are already planning to produce environmentally friendly spoons and forks – and their rice flour straws are in the process of conquering the world's soft drinks and shakes. They are being exported to the United States, the United Kingdom, Portugal, Hong Kong and Malaysia, among other countries. They were presented at the anuga food fair in Cologne in October 2019. ◎

Side street in Hanoi: Vietnam needs to find ways to stem the flood of plastic bags that is overwhelming the country.

Time to Ban Plastic Bags?

127

countries have banned or increased the price of plastic bags.

Using, manufacturing or importing this contraband is prohibited, but it's not counterfeit currency or drugs – it's plastic bags. No country penalizes their use as harshly as Kenya does. But the measures are causing other problems.

Just two years ago, plastic bags could be found throughout Kenya. After they were thoughtlessly thrown away, they fluttered over roads. They were blown into trees and got trapped in fences. They plugged up wastewater channels, and elephants in national parks as well as cattle and sheep swallowed them. Slaughterhouses documented the presence of plastic in the stomachs of about one-half the animals they processed. In Kenya's supermarkets alone, about 100 million plastic bags crossed countertops every year. A bag is only used for an average of twelve minutes before being discarded. But it takes about 1,000 years for the plastic to completely decay.

The situation changed in August 2017. Plastic bags have largely disappeared from everyday use. Since then, a strict, complete ban has been in place. Anyone who disregards the measure risks fines as high as $40,000 and up to four years in jail. There are no exceptions, even for tourists. They are warned against carrying plastic bags in their luggage and are informed about thorough checks at airports.

Tough Adjustment in Everyday Life

As soon as the ban took effect, Kenya's government took drastic measures, launching raids, arresting plastic bag dealers and closing markets whose vendors failed to observe the new law. The prohibition at first led to severe economic difficulties. Plastic manufacturers thought the six-month transitional period was too short. According to industry statistics, a manufacturing segment collapsed for about 170 factories, leading to the loss of nearly 60,000 jobs. Retailers and street vendors complained about lower revenue. They were only able to pack their goods in compostable sacks or reusable tote bags, which were much more expensive than the cheaply produced polyethylene versions. It was mainly the poorer Kenyans who could not afford the price increase. There was a socioeconomic downside to the rapid and rigorously imposed ban on plastic. There was another factor: Plastic keeps perishable foods such as meat, fish, fruit and vegetables fresh longer. There is still no affordable substitute of equal value. Critics of the ban worry that germs could accumulate more easily and that food could spoil more quickly without using plastic – and it would be thrown away more frequently. But it is indisputable that Kenya's governmental pressure has boosted the awareness of measures to protect the environment and forced the plastics industry to move ahead with recycling while sustainable alternatives to single-use plastics are developed. Numerous startups are capitalizing on these trends.

From Single-use Item to Contraband

A total of 91 countries worldwide have already completely or partially banned plastic bags. With 31 countries on the list, Africa is a pioneer in the struggle against single-use plastic. For example, plastic bags are prohibited in Rwanda – a ban that has been in force since 2008. Ten years later, the UN report "Single-use Plastics. A Roadmap for Sustainability" (UNEP 2018) described this pioneer as one of the cleanest countries on the planet. But even in Rwanda, the measure has a flipside: The country has not been able to stem the smuggling of plastic bags and a flourishing black market in the items. The government wants to use tax incentives to encourage industry to invest in plastic recycling and the production of environmentally friendly tote bags. The people of Rwanda have gotten used to the absence of plastic bags in their lives. They use fabric sacks and paper bags. But there is still some controversy over the ecological footprint of these items. Aside from consuming considerably more water and energy than plastic does, their production processes use chemicals. And since paper bags are not particularly robust, they are often discarded in short order. The bags certainly aren't the kind of trash that lasts a millennium, but they are waste nonetheless.

Where Bans Run into Trouble

The UN Report's conclusion: "Plastic bag bans, if properly planned and enforced, can effectively counter one of the causes of plastic overuse." In fact, there are a number of factors that can work against a plastic ban. They include a lack of popular acceptance, the absence of affordable, practical alternatives, too few incentives for industry and lax enforcement. Rwanda, still a pioneer, is meanwhile ahead in the game. It is expected to prohibit even more plastic packaging, including single-use cutlery, straws and plastic bottles. ◎

“Sticking to the Facts”

In the emotional debate over microplastics and the littering of the oceans with trash, Dr. Ernst Osen makes the case for a sober accounting. As the Head of Global Material Technology at Freudenberg Sealing Technologies, he is pressing ahead with the development and use of eco-friendlier materials.

Dr. Ernst Osen

Dr. Ernst Osen, who earned his doctorate in chemistry, began his career in Freudenberg’s research activities about three decades ago. One of his first important projects was to explore the opportunities for recycling elastomers in the preparation for Europe’s first end-of-life vehicle directive. Today Osen is in charge of Global Material Technology at Freudenberg Sealing Technologies. In his free time, he does volunteer work in local politics and enjoys being outdoors.

RESEARCHERS HAVE EVEN FOUND MICROPLASTICS ON ICE FLOES ADRIFT IN THE ARCTIC. ARE YOU SURPRISED AT THE POOR IMAGE THAT PLASTICS HAVE?

It goes without saying that plastic should not enter the environment or the food chain. But we need to stick to the facts in the debate over plastic. A recent study by the Fraunhofer Institute for Environmental, Safety and Energy Technology found that nearly 90 percent of microplastics are produced at the use stage. If you include elastomers in the calculation, the greatest source in Germany is tire wear. On average, a car produces the equivalent of 2.2 to 3.3 pounds of microplastics over the course of a year. It is created by the friction between the pavement and the tires, although this is certainly desirable for safety-related reasons.

ABOUT HALF OF ALL MICROPLASTIC COMES FROM ELASTOMERS – THE CLASS OF MATERIALS THAT IS PROCESSED AT FREUDENBERG SEALING TECHNOLOGIES.

That's right. That's why we see the issue as our responsibility. Nevertheless, it is highly unlikely for residue from the abrasion of our products – above all seals – to reach the environment. First of all, we design our seals to produce so little friction that hardly any residue is produced even over relatively long periods of use – and if it is, it remains in the oil circuit of the vehicle or machine.

Microplastic

Particles are defined as microplastic if they have a diameter of less than one-fifth of an inch and have fibers made of thermoplastic, elastomer and thermoset polymers. The materials are solid under normal conditions and reach the environment directly or indirectly due to human activities.

THERE ISN'T JUST MICROPLASTIC IN THE OCEANS. THERE ARE ALSO HUGE EXPANSES OF GARBAGE IN THE FORM OF PLASTIC PACKAGING.

That is mainly a problem with proper disposal, especially in Asia's growth markets. Incidentally, plastic packaging often has a better ecological footprint than other materials across the entire manufacturing and logistics chain. Due to high energy use during manufacturing, a paper sack, for example, must be used at least three times before its footprint is as good as that of a plastic bag.

DO YOU SEE PLASTICS BEING REJECTED?

On the contrary. Plastics are the material for the 21st century. In 2000, global production stood at 187 million tons. Output climbed to 387 million tons by 2017.

THAT IS THE WASTE OF TOMORROW. WHAT WOULD A RATIONAL APPROACH TO RECYCLING LOOK LIKE?

In Germany, nearly 100 percent of plastic waste is collected and recycled, often into energy in combined heat and power stations and other facilities. That makes sense because it reduces the use of coal and natural gas. Incidentally, this is how we currently dispose of a large share of our production waste. After all, rubber is also known as "elastic coal."

BUT THAT IS STILL NOT A SUSTAINABLE CIRCULAR ECONOMY. DOES THAT MEAN THAT DIRECT RECYCLING IS IMPOSSIBLE?

There are technical limits, especially involving the maximum share of the old material. But the real hurdles lie elsewhere: first of all, relating to economic viability, and secondly, in the customers' specifications.

WHAT IS YOUR EXPERIENCE WITH THE USE OF PLASTIC BASED ON RENEWABLE MATERIALS?

The same approach applies in principle. A few years ago, we had a project in the United States in which one of the base materials for a type of EPDM rubber was about 50 percent sugarcane. It was designed to be an ecologically innovative material for seals in electric cars, but it was about 20 percent more expensive than other options. In the end, the customer was not prepared to bear the extra cost. Nonetheless, we continued to develop the product and requested more of the material through our purchasing department. In some cases, plastic manufacturers were very hesitant to sell it to us. The processing of renewable materials often requires changes in the companies' existing facilities and production processes.

BUT RENEWABLE DOESN'T NECESSARILY MEAN SUSTAINABLE IN ANY CASE.

That's true, too. Consider natural rubber. It can only be cultivated near the equator. Aside from the fact that it is not suitable as the basis for many technical products, its cultivation often does not meet our minimum ecological and social standards. That's why purchasing takes a close look at supplier structures.

HOW THEN DO YOU ASSESS THE ECOLOGICAL COMPATIBILITY OF INDIVIDUAL MATERIALS?

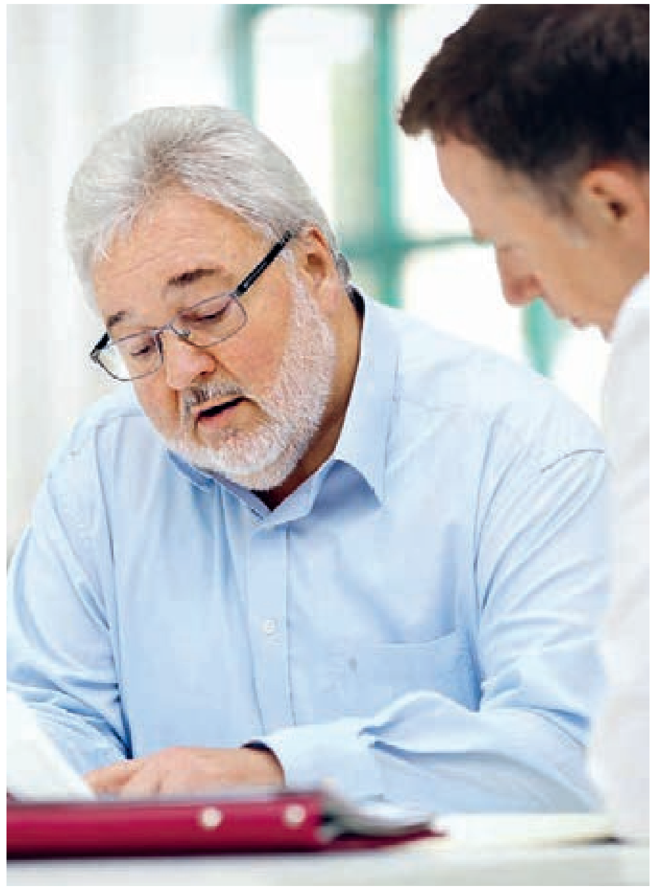
So far, our elastomer database has been the most important tool. Here all potential raw materials are linked to information on critical ingredients. It also contains information on materials whose use is prohibited – we go significantly beyond legal requirements in our guidelines. We have had an IT-supported energy and environmental management system for several years. We know precisely at what point a particular amount of waste is created and how much energy we are consuming. Every area of the company had to define five top projects that now have to be carried out. This is making it possible to substantially reduce our CO_2 footprint.

LET'S GET BACK TO MATERIALS: HOW REALISTIC IS IT TO USE CO_2 TO MAKE PLASTICS?

That would be ideal. For example, we could use the carbon dioxide that occurs as part of the cement production process or even extract it from the atmosphere. We are working on this with the renowned Institute for Plastics Processing in Aachen, Germany, among other organizations. But it is important to note that this is still at the research stage and it will be some time before plastics of this kind are available to the market.

DO YOU CONSIDER A WORLD WITHOUT PLASTICS TO BE INCONCEIVABLE?

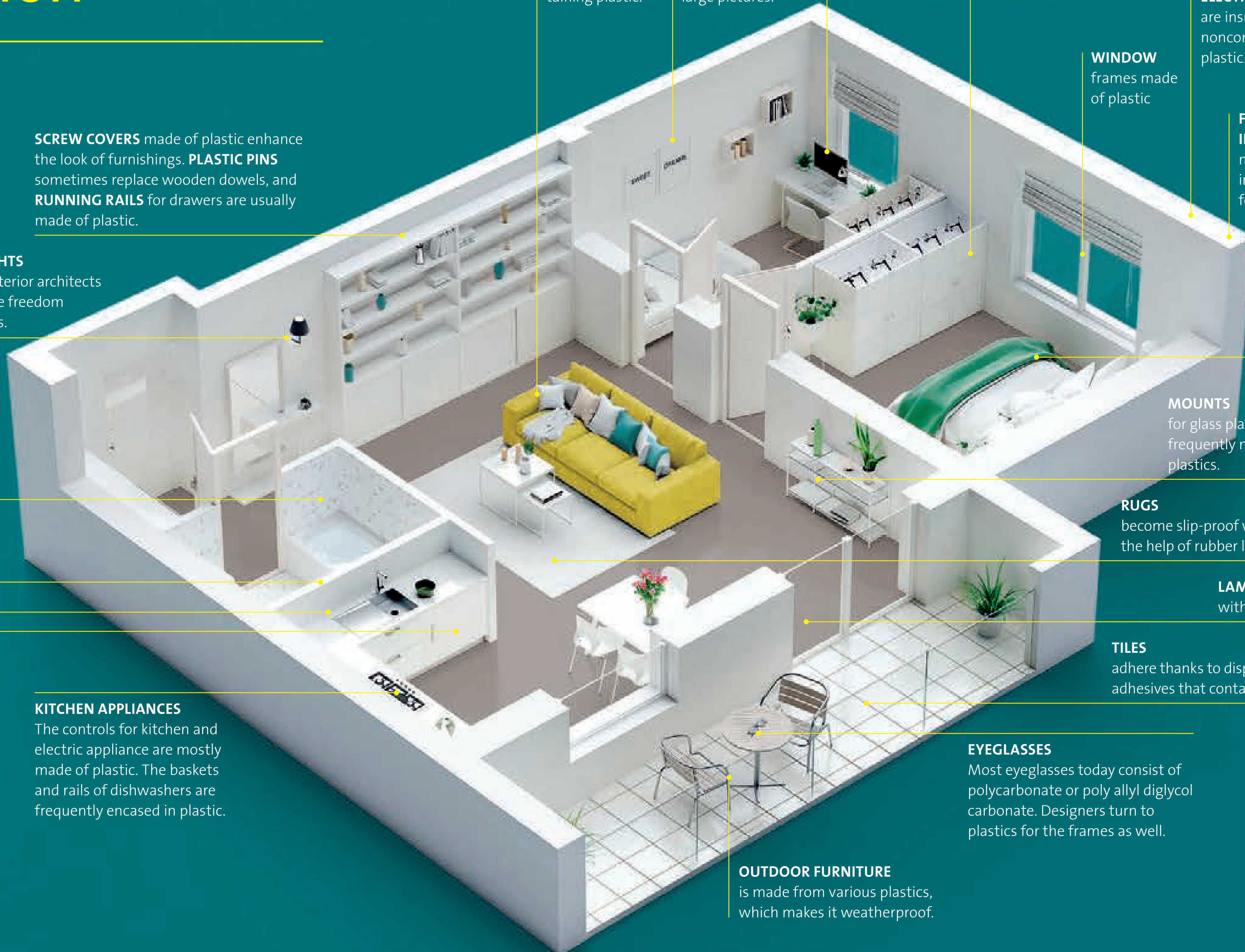
I would naturally prefer to have wood and leather in my environment instead of plastic. But many green technologies, ranging from fuel cells, to electric cars, all the way to solar cells and wind turbines, would be inconceivable without high-performance, technical plastics. And a car with an internal combustion engine would consume significantly more fuel if the roughly 2,000 plastic parts were replaced with their heavier metal counterparts.



Read more here:
https://bit.ly/2kWqhnj

Our Daily Companion

We are surrounded by plastic. In some cases, it is simply the best possible option. Its most impressive aspect is that it is everywhere, even if its presence is not always obvious.



From Climate Villain to Useful Material

Steel-making in blast furnaces has a major impact on the climate – just as the production of base materials for the chemical industry does. If you tie processes together, you can reduce emissions significantly. A tour of the Carbon2Chem Technical Center run by thyssenkrupp.

The taxi driver gets lost twice. The thyssenkrupp steel plant in Duisburg is the size of a medium-size city. Its Technical Center, on the other hand, is a small pilot facility. That spurs Dr. Markus Oles to ever-greater ambition. He is in charge of the conglomerate's innovation strategy and wants to make the steel industry more climate-friendly with the help of the "Carbon2Chem" project. But that's not easy. It turns out that coke is not just a source of energy in steel-making – it also removes oxygen from iron ore. There's no steel without coke. The equation is just that simple when the conversation turns to blast furnaces. This has consequences: Blast furnaces emit carbon dioxide as well as other smelter gases, such as carbon monoxide, nitrogen and hydrogen. Certainly, the smelter gases can still be used as a source of energy in a downstream gas power plant, but the process sends the carbon portion of the gases into the air as CO_2, contributing to the greenhouse effect. Each year, the steel industry in Germany alone emits about 37 million tons of the climate destroyer.

Carbon2Chem is a joint project drawing on the expertise of several Fraunhofer Institutes as well as the Max Planck Society, in addition to thyssenkrupp and other industrial partners. It is based on a simple idea. "We no longer consider smelter gases to be exhaust gases. Instead, we want to use them as a chemical raw material," Oles said. In the future, fuels, fertilizers and plastics are expected to be based on these materials. At the Duisburg Technical Center, which has received more than 40 million euros in investment, chemists and engineers are jointly investigating whether the process, which has already been tested in the lab, also works under real-life conditions.

Gas treatment system:
ThyssenKrupp's Duisburg steel facility
is as big as a medium-sized city.

At the Duisburg Technical Center, researchers are working on the sustainable production of hydrogen.

So far, we haven't found elements in smelter gas that we were unable to eliminate with our process."

Oles first heads into a green building where hydrogen is produced. The gas is needed in great quantities for the subsequent steps – the proportion of hydrogen in smelting gases is insufficient for the process. To this point, chemical companies have generally broken down natural gas to produce hydrogen. "That didn't make sense to us since it generated even more carbon dioxide," Oles explains. So hydrolysis, which only uses water as a raw material, is used in his facility. Using electricity from renewable sources, the water is broken down into hydrogen and oxygen. It is a familiar process, but the trick is to operate this kind of installation with high efficiency when electric current from volatile renewable sources is used. That is precisely what researchers are investigating at the installation in the Technical Center right now – the electric current load changes every 15 minutes. The equipment has been running like this since April 2018, with high-efficiency and practically without demonstrable cell aging.

1_Natural gas, plastics, fuels and fertilizers can be produced from synthesis gas.

2_Small-scale chemical plant: The synthesis gas is made from purified smelter gas.

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A small-scale chemical plant is adjacent to the building. The smelting gas is fed into it directly from a nearby blast furnace. A total of 314 standard cubic yards of the gas are prepared per hour. First, it is essential to remove water and sulfur from the gas. The latter would otherwise destroy the equipment's catalytic converters very quickly. With high resolution measurement technology, the gases are investigated for additional trace elements. "Until now, we have found no ingredient of smelting gas that we could not eliminate in this way," Oles said. The separation of the gases follows the cleaning process. The goal is for carbon monoxide, carbon dioxide, nitrogen and hydrogen to be present in a precisely defined ratio, creating what is called "synthesis gas." This gas is used to produce the precursors that are the basis for plastics, fuels and fertilizers: ammonia, methanol and high-quality alcohols. Tests on ways to separate hydrogen are underway with Linde, a thyssenkrupp partner. The hydrogen can then be fed into the process separately. The process is not only generating interest among steel manufacturers. Other industrial processes that release contaminated hydrogen – which is a much sought-after raw material in its pure form – could be improved as well.

Process technicians control the entire facility using a central master display. All processes are continually observed on monitors – even the details relating to individual cells in the electrolysis process. Part of the research project is creating control software that functions optimally with different compositions of the smelting gas and varying load profiles. It is hoped that automation technology now being developed will be used in a cross-industry network throughout the world.

After a two-year preparatory phase, the Carbon2Chem Technology Center went into operation in the spring of 2018. By September of that year, it had already succeeded in producing its first synthetic methanol. Meanwhile, the facility, which is merely container-sized, is being retrofitted for the production of high-quality alcohols. Ammonia was first produced in December 2018. "Frankly, it surprised us how stable the processes run," Oles said. The research project will continue until 2020. At its end, the participants not only expect as many scientific articles as possible to be published – but also an economical facility concept that can quickly be deployed worldwide. To put it another way: If the base materials from the Carbon2Chem are going to compete with petroleum and natural gas products, they must be cost-effective. The results so far show that the best possible sustainability and economy can be achieved when steel manufacturers and the chemical industry work together.

Greenhouse Effect in Reverse

Since 2017, a Climeworks plant in Hinwil, Switzerland, has filtered 900 tons of CO_2 per year from the air. The gas is then used as a raw material.

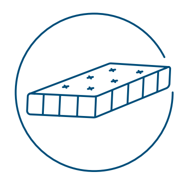
It still escapes from the smokestacks of industrial facilities and power plants and has a negative impact on the climate. But in just a few years, CO_2 will be a much sought-after raw material that will replace fossil resources such as petroleum. The reason: CO_2 contains carbon, the raw material for plastic.

1 A small, elastic thread could lead to a revolution in the textile industry. That's the message from Professor Pavan Manvi of the RWTH Aachen University and his fellow researcher Jochen Norwig of the Bayer subsidiary Covestro. In July 2019, they reported a breakthrough: In their lab in Krefeld-Uerdingen, Germany, they succeeded in producing a CO_2-based elastic thread for the textile industry. If this thread can be produced commercially, it would be no mere niche development. Synthetic fibers would then no longer have to be produced from petroleum – it would be possible through the use of CO_2, which could be obtained by scrubbing power plant exhaust gases or even by filtering it directly from the air – the greenhouse effect in reverse.

Covestro has already shown that the process can be carried out on a commercial scale. The Bayer subsidiary is working on industrial-scale production with the Institute for Textile Technology at RWTH Aachen and several textile manufacturers. "Stockings and medical textiles are due to be produced as a first step," Covestro spokesman Sergio de Salve said.

The Bayer plant in Dormagen, not far from Leverkusen, is making a novel polyol with the trade name "Cardyon." CO_2 accounts for 20 percent of the material. The polyol is a main component in the production of soft polyurethane foam used in mattresses and other products. Covestro is already ready for the market in this area. For example, the Belgian company Recticel uses the material to make foam, and it markets the mattresses under the brand name Schlaraffia. Since 2016, Covestro has produced 5,000 tons of polyol per year. The company is also working on new applications for the foam in vehicle manufacturing, the production of seals and other fields.

2 Even playing fields covered with artificial turf can be produced with CO_2 as a raw material. In October 2018 in Krefeld, this type of field was installed at the Crefeld Hockey and Tennis Club (CHTC), a national-level hockey team and Europe Cup winner where the German national hockey team plays its home games. The special feature of its new deep-blue field surface is that a CO_2-based plastic represents one-fifth of the material. The 65-by-108-yard field is no anomaly. Polytan, which produces surfaces for sports facilities, is part of Bavarian-based Sport Group, the world's largest maker of artificial turf and tracks. The company now plans to use the process to construct artificial turf worldwide.



Since 2016, Covestro has produced

5,000

tons of polyol for use in mattress manufacturing and for other purposes.

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1_By a silken thread: Prof. Pavan Manvi (RWTH Aachen, right) and his research colleague Jochen Norwig (Covestro).

2_Even artificial lawn can be produced with CO_2 as a raw material.

3_Climeworks develops filtration facilities that extract CO_2 directly from ambient air.

4_The "Sun to Liquid" research facility operated by ETH Zürich and DLR in Móstoles, Spain.

Other chemical companies such as BASF are doing research on plastics containing CO_2. For example, BASF processes carbon dioxide into urea to produce artificial fertilizer. The company has also developed a process to use CO_2 as the basis for the super-absorbers that soak up and encase urine in diapers.

3 The notion of making fuels from CO_2 is also on the brink of a breakthrough. These fuels are usually based on petroleum, but several research institutes and startups are in the process of developing pilot facilities that would use CO_2. Two pioneering Swiss researchers, Christoph Gebald and Jan Wurzbacher, are in the forefront. They studied at ETH Zürich and formed Climeworks as a spinoff. It develops filtering systems that draw CO_2 from ambient air. The CO_2 can then be further processed using chemical reactions or introduced into the air inside of greenhouses as a growth enhancer. Since 2017, for example, a Climeworks facility in Hinwil, Switzerland, has drawn 900 tons of CO_2 from the air. The gas is used in the production of fuels and in the beverage industry for carbonation.

Climeworks now plans to team up with other companies such as Sunfire (Electrolysis), Ineratec (synthesis technology) and EDL Anlagenbau (the conversion of hydrocarbons into jet fuel) to build a facility to demonstrate the production of renewable aviation fuel on the grounds of the Rotterdam airport. This raises the prospect of climate-neutral aviation. Large ventilators would filter the CO_2 from the airport's ambient air. A solar facility provides the energy for the electrolysis system that produces a synthetic gas, from which synthetic hydrocarbons are extracted – the basis for the aviation fuel. In the fall of this year, Climeworks will present the airport with a feasibility study, and a new facility is expected to go into operation by 2021.

4 Working with their colleagues at the German Aerospace Center (DLR) in Cologne, researchers at the ETH Zürich are taking a different approach. In June, after managing to produce jet fuel from CO_2 in the lab, they introduced a significantly larger "Sun to Liquid" research facility in Móstoles, Spain. It can produce a pint of jet fuel a day. "That is a breakthrough since the technology also works on a large scale," said Prof. Christian Sattler, an expert in solar processes at the DLR. "We are going to use the results to develop the technology further." It differs from the Climeworks and Sunfire technologies: The energy from the reaction is not produced with solar-generated electricity but with 169 mirrors that focus sunlight onto the reactor. The researchers estimate that a solar-based facility covering less than half a square mile could produce more than 5,000 U.S. gallons of jet fuel per day.

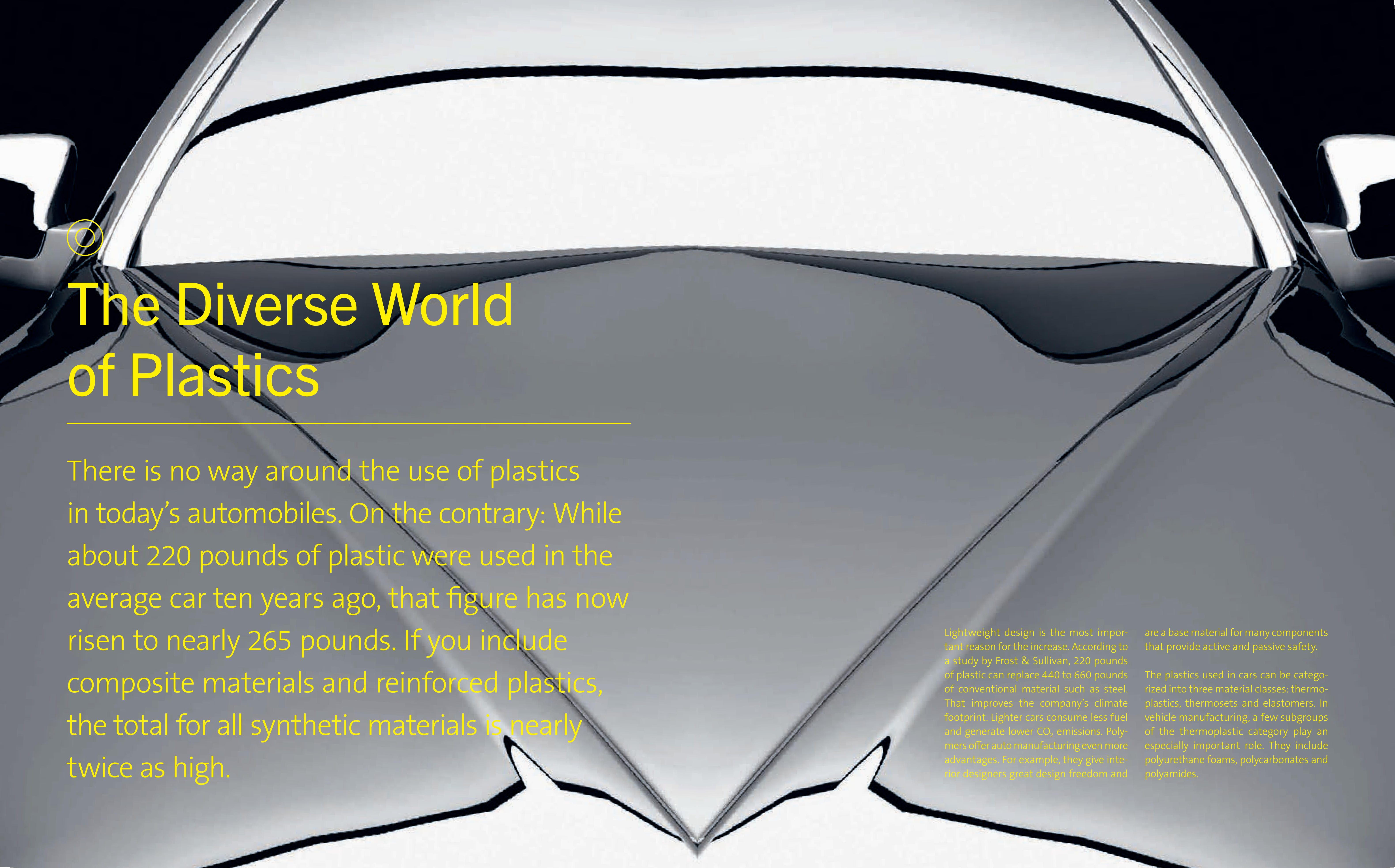
Sattler considers the production of fuel from CO_2 to be a promising option for reducing the CO_2 content of the atmosphere – and that could turn carbon dioxide into a windfall as a raw material. ◎

According to estimates, one solar facility covering about 250 acres could produce more than 5,280 gallons of kerosene per day.

THE NUMBER FOR THE TOPIC

2050

Plastic waste is a problem. On land and in the sea. Year after year, more and more of it makes its way into the world's oceans. If this trend continues, the total weight of the plastic in the ocean in 2050 would purportedly correspond to the weight of all its fish. But what's the basis for this prediction? It has its origins in an article in the journal Science in 2015. In this piece, a team of authors involved in a study assumed that between 4.8 and 12.8 million tons of plastic reached the world's oceans in 2010. The Ellen MacArthur Foundation, a British philanthropic organization, cited these figures in a study published with the World Economic Forum and McKinsey and ventured a forecast: If the ratio of plastic to fish were still 1:3 in 2025, their weights would level off at equivalent amounts in 2050. Here the number of fish in the ocean and their overall weight were based on rough estimates. No one really knows how many fish are in the sea or how their stocks will trend over time. So any comparison of plastic waste with fish has to be treated with care. But that doesn't change the basic reality: Far too much plastic ends up where it doesn't belong: in nature. ◎



The Diverse World of Plastics

There is no way around the use of plastics in today's automobiles. On the contrary: While about 220 pounds of plastic were used in the average car ten years ago, that figure has now risen to nearly 265 pounds. If you include composite materials and reinforced plastics, the total for all synthetic materials is nearly twice as high.

Lightweight design is the most important reason for the increase. According to a study by Frost & Sullivan, 220 pounds of plastic can replace 440 to 660 pounds of conventional material such as steel. That improves the company's climate footprint. Lighter cars consume less fuel and generate lower CO_2 emissions. Polymers offer auto manufacturing even more advantages. For example, they give interior designers great design freedom and are a base material for many components that provide active and passive safety.

The plastics used in cars can be categorized into three material classes: thermoplastics, thermosets and elastomers. In vehicle manufacturing, a few subgroups of the thermoplastic category play an especially important role. They include polyurethane foams, polycarbonates and polyamides.

THERMOPLASTICS

Thermoplastics are among the most successful varieties of plastic because they can be manufactured using the injection molding process, allowing considerable design freedom. During the production process, a granulate of the material is melted and introduced into a mold that determines the object's subsequent shape.

Another advantage:
Thermoplastics can be re-formed reversibly in a certain temperature range, which means the process can be repeated with successive cooling and heating as often as desired. Thermoplastics are also the only type of plastic that can be welded. They lend themselves to gluing and can be recycled.

Their disadvantage involves their resistance to extreme temperatures. If they are heated to high temperatures, the material can deteriorate. However, thermoplastic materials have now been developed for components that are exposed to extreme temperatures, including intake manifolds, housings for oil filters, cylinder head covers, engine covers and air filters.

THERMOPLASTIC SUBGROUPS

POLYURETHANES
consist of non-cross-linked polymers in chain form and are mainly used as polyurethane foams – as hard foam covering for A-, B- and C-pillars and door modules and for the soft foam components of car seats, for example. Polyurethane foams can also be used in seat shells and in soft coverings for control elements in the cockpit.

POLYCARBONATES
are hard, impact-resistant and transparent and are therefore suited for diffusers in auto headlights, glass-like roof borders and panorama roofs.

POLYAMIDES
are often reinforced with glass fibers and are increasingly replacing metallic components in cars, for example, as lamp housings and fuel tanks, thanks to their high mechanical strength. Due to their high resistance to oil, they are also used in many applications in the engine compartment.

THERMOSETS

Thermosets are made of artificial resins to which ingredients such as dyes, separating agents, fillers, and reinforcing materials are added. They are shaped into the desired form with the help of compression molding, lamination or injection molding,

Then the resins are cross-linked by heating them or exposing them to ultraviolet radiation. This makes the shape of thermoset components irreversible – they can no longer be re-formed after they are cured. They are only minimally recyclable and are more sensitive to impact than thermoplastics.

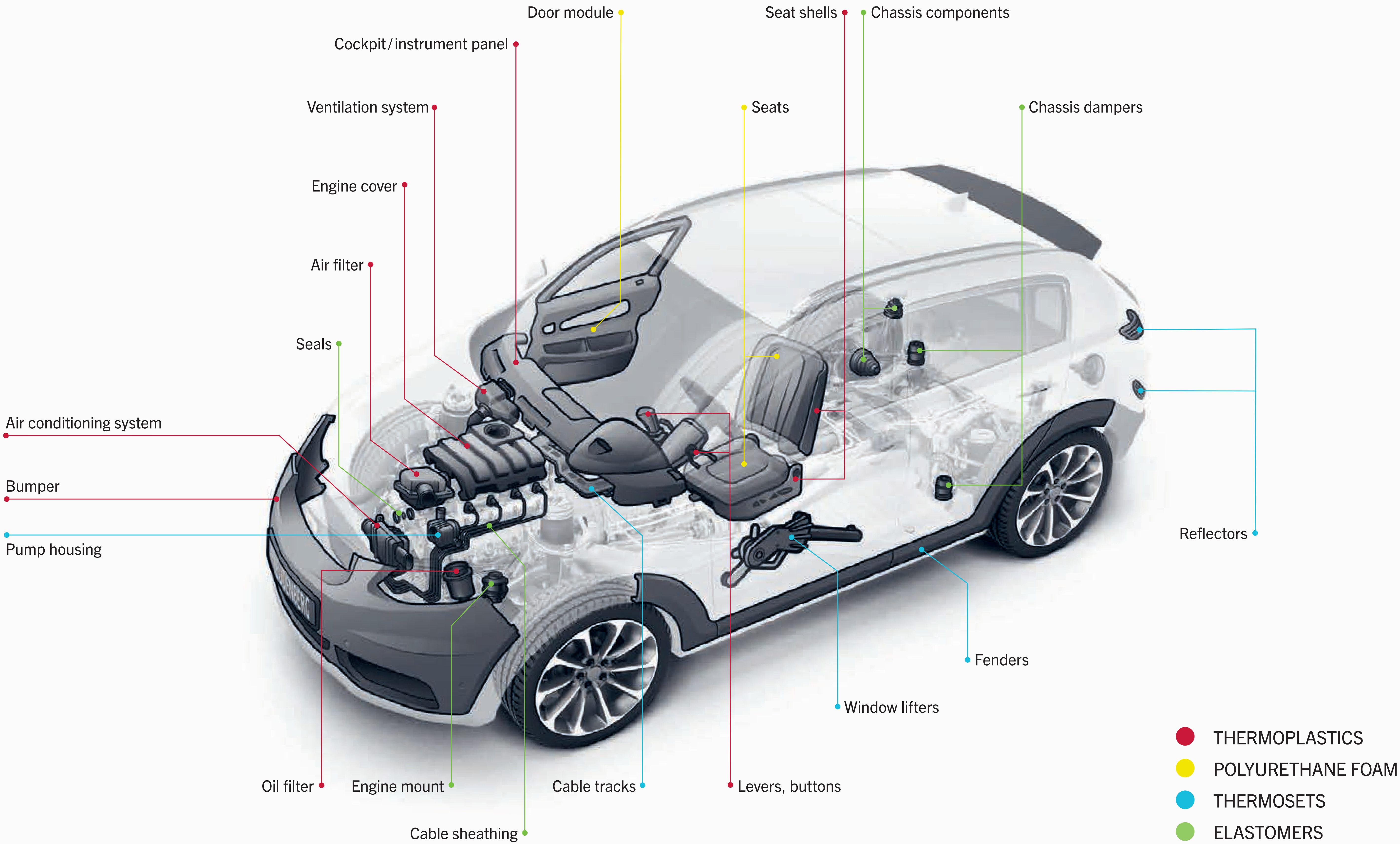
Still, they have a high degree of rigidity and hardness and are more heat resistant than other options. That's why they are mainly used in applications where thermomechanical strength is required, in housings for water pumps, cable tracks and reflectors, for example. Fiber-reinforced thermosets are also used for car body parts such as trunk lids and fenders.

ELASTOMERS

Elastomers are elastically deformable plastics that return to their original shape after tensile loading or a compressive load. During their manufacture, the elastomer mixture is vulcanized by adding sulfur. That means that its long-chain polymers are cross-linked by sulfur bridges. Depending on the base raw material used, scientists make a distinction between natural and synthetic rubber.

Natural rubber is extracted from latex, a milky sap from the bark of the tropical tree Hevea brasiliensis. It exhibits a high degree of mechanical strength and is suited for numerous products used in vibration damping in cars, including motor mounts, springs and dampers. Synthetic rubber is made from hydrocarbons and is mainly known as EPDM (ethylene propylene diene rubber).

With the help of the appropriate material mixture, the characteristics of synthetic elastomers can be shaped selectively. Among other qualities, they can be highly resistant to extreme temperatures and media and are especially suited for use in seals in automobiles.


Door module
Seat shells
Chassis components
Cockpit / instrument panel
Ventilation system
Seats
Chassis dampers
Engine cover
Air filter
Seals
Air conditioning system
Bumper
Pump housing
Reflectors
Fenders
Window lifters
Oil filter
Engine mount
Cable tracks
Levers, buttons
Cable sheathing
THERMOPLASTICS
POLYURETHANE FOAM
THERMOSETS
ELASTOMERS

Blossoms on the Eternal Ice

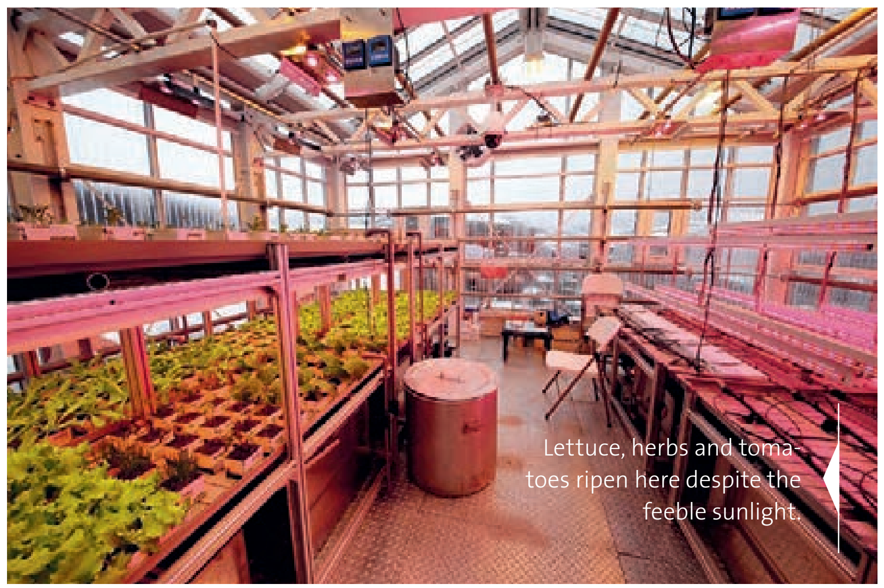
The Chinese research station "Great Wall" was established in 1985. Today it includes about a dozen buildings. A greenhouse is where fresh vegetables are grown.

A plastic that helps to promote the growth of plants: Researchers are growing vegetables in the Antarctic. They owe their success to a group of chemists who invented the all-purpose material acrylic glass nearly a century ago.

The world is gray, the air icy and the earth frozen. There is snow, scree and a barren landscape as far as the eye can see. That's no surprise at temperatures of −22 °F, complete with storms and permafrost. In summer in the Antarctic, just a small quantity of low-lying grasses and herbaceous plants grow out of the cracks in the rocks.

There is an exception to the sterility: At China's "Great Wall" research station, tomatoes are ripening, along with cucumbers, peppers and lettuce. In the middle of a barren icy desert, a greenhouse rises almost defiantly on metal stilts against the polar sky. The researchers here have been able to supply themselves with fresh vegetables since 2015. Before that, they only had frozen foods and canned goods.

Over the decades, polar researchers have longed for fresh vegetables in vain. After all, a greenhouse in the Antarctic is a challenge to planners and materials. "The extreme weather conditions have made it especially difficult to find the right materials," says Le Lu of Shanghai Dushi, the engineer who built the greenhouse.



Lettuce, herbs and tomatoes ripen here despite the feeble sunlight.

720
square yards of Plexiglas provide the 43-square-yard greenhouse with light.

86 °F
is the temperature inside. Outside, it may be as low as −22 °F.

40
people are provided with fresh vegetables.

Insulate, Keep Bad Weather Out, Let Light In

The project required a material that is both highly transparent and resistant to extreme conditions. It wasn't enough to provide the plants with the agreeable temperatures in the greenhouse's interior and to water and fertilize them: Plants need light. And during the summer months, there is light the entire day on King George Island in the South Shetland Islands archipelago – but due to the angle of the earth's axis, the sun's rays strike the ground so obliquely that they have little energy left. So the material for the greenhouse had to provide insulation, stand up to storms and allow both ultraviolet radiation and light to pass through it – and do so over a period of years.

The solution was a plastic. Polymethylmethacrylate, or just acrylic glass or PMMA for short, and even better-known by the brand-name Plexiglas, a product from Röhm GmbH. It was first produced in the form of thin transparent plates by German chemists led by Dr. Otto Röhm in 1933. But the material is capable of much more. It is highly resistant to aging and retains its robust character even when exposed to chemicals. It can also be shaped, glued or cut very easily. PMMA became a key material for designers and architects, as well as for illuminated advertising and car headlamps. Submarines depend on it during their dives, and airplane manufacturers use it in windows. Greenhouses get the benefits of ample sunlight thanks to Plexiglas, even when conditions are not as extreme as those in the Antarctic. "Of all the materials that we investigated, Plexiglas was best suited to our needs," Le Lu notes. In this case, special multi-skin sheets used in the greenhouse's construction insulate significantly better than simple glazing. And with 91 percent transparency, they ensure that the plants get enough sunlight.

Cultivating Plants Where They Are Needed

At the same time, the Antarctic project is more than just a special feat to make healthier food available to polar researchers. Indoor farming could be a good way to handle food production in the future – growing crops where people need them, whether in the middle of a city, in inhospitable regions or in harsh climates. Acrylic glass will be able to play to its strengths in these cases. This plastic can be altered to allow precisely the wavelengths that plants need to grow. It remains stable with regard to ultraviolet radiation and doesn't yellow like many other transparent plastics.

The chemists who followed in Röhm's footsteps have introduced all kinds of variations under the Plexiglas trade name. They include the especially resistant types of acrylic glass used in vehicle design elements, along with varieties that are especially good at scattering or directing light. Röhm and his research team naturally could not imagine 21st century cars or the relentless advance of LED lighting back in their day — when they actually wanted to create "transparent rubber." In 1933, acrylic glass was invented in part by accident like so many other plastics. Incidentally, 1933 was the year that American polar explorer Lincoln Ellsworth began his attempt to make the first-ever crossing of Antarctica in an aircraft. And no one was thinking about tomatoes and cucumbers growing above the eternal ice back then. ◎

There's Another Way

If you consume, you throw things away, and that includes a lot of packaging material, mostly made of plastic. But there are environmentally friendly approaches, too.

Coffee to go

Life Is Plastic …
If you need a pick-me-up on the way to work or during a stroll through the city, you're likely to resort to a coffee-to-go. The beverage can be consumed quickly, and the cup can be discarded just as fast. In Germany alone, more than 300,000 units are reportedly used – per hour, that is. Even if cups seem to be made of cardboard, they are coated with plastic and thus become another factor in the waste problem.

… But That Sounds Fantastic
More ecological solutions are now in the pipeline as substitutes, such as a cup made of bagasse. This residue of sugarcane fibers remains as a byproduct after the production of sugar. Bagasse can be easily processed and shaped. Cups made of the material are waterproof by their very nature, so an artificial coating can be dispensed with. If the use of (nonessential) plastic resin in the production is eliminated, the cups are completely biodegradable. Scientists are currently doing research on other alternatives made of purely natural materials. From algae, for example. ◎

Insulating Packaging

Life Is Plastic …
If you buy something fragile or temperature-sensitive, you will see that the volume of the packaging belies the true size of the product. Large quantities of plastic and Styrofoam® fill the space between the goods and the carton walls, providing a buffer. Styrofoam® is especially impressive for its insulating effect. But even this packaging material is usually discarded as trash immediately.

… But That Sounds Fantastic
Today there are some promising natural ways to protect sensitive goods during transport. The straw that accumulates during harvests has proven to be the equivalent of Styrofoam® when it comes to insulation and protection against impact. It is an even better moisture regulator. In the form of compact sheets, it can exploit its advantages as a filler material. After unpacking, the straw can be discarded in a garden or as organic waste. The same applies to the starch-based wrappers that hold the straw sheets together. When dry ice is added to straw cartons, fruit and vegetables not only survive the trip unscathed. They stay fresh as well. ◎

Shopping

Life Is Plastic …
When you unpack your weekend shopping purchases at home, it can be quite a shock. Many products are packaged two or three times. Take muesli, for example: You will find a plastic bag containing the contents stuffed into an oversized box. Or sweets: Chewy candy and chocolate bars are repackaged in paper or plastic within a larger bag. And it's not unusual for several packages to be held together by another outer packaging.

… But That Sounds Fantastic
Shopping without generating so much waste is already possible today. In large German, American, Danish or British cities, there are more and more stores selling unpackaged goods. Food and other everyday products are sold in large containers, glassware and dispensers. Customers can transfer them into containers that they bring from home. The storeowners have many of their goods delivered in relatively large containers, so there is waste, occasionally even the plastic variety, but less than there normally would be. Fruit and vegetables are mostly obtained from local farmers and sold in bulk. Plastic? Certainly not. ◎

A Material from the Bark of a Tree

Natural rubber, sometimes called caoutchouc, is the raw material used in making what we simply call rubber. Thailand is the world's biggest exporter of natural rubber. It is where the first plantations and producers are turning to sustainable cultivation methods – by abandoning pesticides and monoculture, for example.

During the rubber harvest, the worker carefully scratches a fine groove in a tree's outer bark using a special knife.

The night is pitch black. Only a beam of light from a worker's headlamp is visible as he makes his way through the high grass to the rows of trees. At the first rubber tree, he carefully draws a fine, diagonal gouge from the upper left to the lower right in its outer bark. The slit immediately fills with a milky fluid that circulates in the capillaries beneath the bark. It drips onto a rail and flows into a plastic bucket attached to the trunk of the tree. The milky fluid is called latex, about one-third of which is natural rubber. It only takes the worker a few seconds per tree to harvest the material using the so-called "tapping" process. That means he can handle up to 500 trees per night. Hours later, when the early mist rises over the valley at dawn, the buckets are full and the flow has ceased. Latex has to be harvested in the morning before the temperature exceeds 77 °F, explains Sudthida Thantanon, the head of the Phattalung Paratex company. Her firm doesn't just run the rubber plantation – it exports the latex as well.

The sun is shining at the collection station as the last tappers bring in their harvest – some of them on foot, others by moped from the more distant areas of the plantation. A manager weighs the barrels and draws a sample out of each of them for testing to determine the natural rubber content and quality. The company shares income with the workers, and the measurements are crucial for the tapper's compensation. Then ammonia is added to the latex to preserve it. An acrid smell immediately wafts through the open space. "Latex spoils quickly – like milk or a curry," Thantanon says. Now the tappers head off to bed as a tanker truck hauls the latex to the factory, where it is prepared for export and put in barrels.

70 Percent Is Used for Tire Production

Rubber trees grow only in the tropics, and about 80 percent of the global output of natural rubber comes from Southeast Asia. Besides Thailand, the world's largest exporter, the countries of Vietnam, Malaysia, Indonesia, Cambodia and Myanmar have relatively large market shares. About 70 percent of the global latex harvest is intended for tire production. Other products are rubber components to dampen vibrations in cars, along with mattresses, the soles of shoes, rubber boots and condoms. Under severe stresses, natural rubber is more stable and longer lasting than synthetic versions made from petroleum.

In the past, the demand for latex-based products has risen steadily. In some countries, primary rain forests have been forced to give way to rubber plantations. As a result, this natural raw material gets more attention when the topic of sustainable supplier chains comes up. The clearing of rain forests is supposed to be avoided as much as possible and the cultivation of the land is expected to become more environmentally friendly. But this isn't easy to monitor: According to the World Wide Fund for Nature (WWF), small farmers produce 85 percent of the world's natural rubber. That figure is 93 percent in Thailand, according to the natural rubber importer Weber & Schaer, who has worked with Phattalung Paratex for years. The Thai company obtains latex from a number of these small operations since its own plantation is unable to fully cover the demand.

> In some countries, primary rainforests have had to give way to rubber plantations.

Forgoing Pesticides

Sudthida Thantanon likes the idea of greater sustainability. She hasn't used pesticides at the plantation for two years. The family-owned company is working to earn a certification – a newly introduced natural rubber seal of approval from the Forest Stewardship Council (FSC). Next year, the company will be undergoing a preliminary audit to become more familiar with the requirements. She notes that the company is already meeting many of the potential conditions. Besides doing without pesticides, they include trash separation and wastewater treatment. The company recycles all usable byproducts – from latex skin to rubber foam, which is separated at the company's treatment plant. Old trees are cut down and the wood is sold to furniture-makers and other companies. Thantanon would like her suppliers to earn the FSC seal as well. Weber & Schaer also helps the plantations out financially during audits.

1

2

3

1_The milky sap drips into a rail and then flows into a plastic bucket attached to the tree trunk.

2_ Some tappers bring their harvest to the collection station by moped.

3_ At the collection station, the latex is mixed with ammonia to stabilize it.

In “rubber forest gardens,” farmers do research to determine which crops are suited for mixed cultivation.

Farewell to Monoculture

As a rule, natural rubber is cultivated as a monoculture. Using pesticides on a large scale, farmers do battle against the high grass where snakes can hide. But that displaces other plants along with the animals that feed on them. The naked ground is less effective at holding moisture and is susceptible to erosion. On Thantanon’s plantation, on the other hand, the spaces between the rubber trees are filled with small palm plants, vines, medicinal herbs and wild ginger, whose blossoms provide pollen for bees. At one time people didn’t care about pesticide use since latex is not a food, she explains. “No one was thinking about the health of the workers who are inhaling the pesticides – or the fact that rain washes pesticides into rivers.” But the conversion comes at a price. To buy pesticides, it cost the entire plantation the equivalent of 300 euros a year. But now Phattalung Paratex pays twenty times that amount to have the weeds cleared manually.

Thantanon actually has a very different goal: to bid farewell to monoculture. In the village of Tambon Kampengphect, she is standing with a group of farmers at a plantation that looks a lot like a garden. Bamboo bushes, leafy vegetables and young Hopea trees are growing among the rubber trees. The Hopea trees will one day grow nearly 150 feet into the air. Bees live in wooden boxes and produce a fine, light, tart honey. Everything is greener and moister than what you see in traditional rubber plantations. A neighbor, Niran Suwarno, was the first farmer to plant Hopea seedlings between the rubber trees, launching a village co-op for a “rubber forest garden” in the process. The government provided the seedlings at no charge. “The others saw the result. I now plant several kinds of trees for wood, peppers, herbs, vegetables and fruit,” says Suwarno, who is often invited to give presentations on his project.

Research on suitable Crops.

Thantanon would like to see the co-op supply her company, and she is learning from it in the meantime. Two months ago, in an area cleared of older trees, she began planting new seedlings further apart to create more space for other plants. The first small rubber plants, each less than two feet high, are concealed in the high grass. A soil analysis will indicate what other crops are suited to mixed cultivation here. Teaming up with Weber & Schaer, Phattalung Paratex is supporting the cooperative’s biological research project, which gives farmers insight into crop selection. Aside from an improved natural environment, the project develops additional sources of income for the farmers.

This is important since farmers are grappling with low rubber prices. The uncertain global economic outlook is again depressing demand – and thus prices on the natural rubber exchanges in Tokyo and Singapore. In 2010, the price for 2.2 pounds of field latex was still about \$3.63. It is now less than \$1.42. A price of \$1.65 is considered the minimum for small-scale farmers to get by. Despite the advantages of mixed cultivation, individual farmers face major obstacles if they want to make a switch. First of all, they have to make the initial investment. Second, it is difficult to get customers to pay a surcharge for sustainable agriculture. “It takes a great deal of persuasion,” Thantanon said. But she is convinced that a forest garden with rubber trees and numerous crops is the right path to the future. ◎

FOUR QUESTIONS FOR …

Moritz Voss,
Director of Purchasing at
Freudenberg Sealing Technologies

Elastomer products were once made from natural rubber, but that base material has now been replaced by synthetic alternatives in many applications. Is there a way back? And how environmentally friendly is natural rubber anyway?

WHAT SUPPLY CHANNELS IS FREUDENBERG SEALING TECHNOLOGIES USING TO OBTAIN NATURAL RUBBER?

Moritz Voss: The rubber tree, which belongs to the spurge family, originated in South America, but we currently get 95 percent of our supply from Asia. We mainly procure the raw material through dealers in Hamburg and Amsterdam. In some cases, it is delivered to us directly. In other cases, it comes from the warehouses of our dealers. Incidentally, the deliveries aren’t just by truck. Sometimes they come by ship on the Rhine, arriving in Mainz, where the cargo is unloaded and then delivered to Weinheim. We then process the raw material further in our mixing facility.

WHAT IS NATURAL RUBBER ESPECIALLY GOOD FOR?

It is mainly used in the tire industry. In our mixing facility, we process it for our sister company Vibracoustic, which makes products for vibration damping in cars – engine mounts, absorbers and dampers, for example. The rubber plants manage to arrange the molecular structure of the material very systematically and make it extremely long. That not only imparts a high degree of elasticity, but also great mechanical stability for dynamic applications. It is also suited to some Freudenberg Sealing Technologies products, such as diaphragms, that are exposed to high dynamic stresses and have to be very strong structurally.

WHAT ARE THE LIMITS ON THE USE OF NATURAL RUBBER?

As good as natural rubber is in the case of constant mechanical loads, it has a shortcoming: When in contact with nonpolar media such as oils and greases, it quickly swells like a sponge. That means it is usually unsuited for seals because they would lose their shape and thus their sealing function. Rubber does withstand polar media such as water better, but it quickly ages at a temperature of 212°F and develops cracks. That’s another reason it is poorly suited for sealing technologies.

HOW DOES FREUDENBERG SEALING TECHNOLOGIES TAKE SUSTAINABILITY INTO ACCOUNT WHEN IT BUYS RUBBER?

For one thing, we and our suppliers are jointly involved with the sustainability programs of the European Tyre & Rubber Manufacturers’ Association. For another, we see that the rubber tree only thrives at a few latitudes around the equator, which puts it in competition with rain forests. I am finding alternatives such as the Russian dandelion exciting because it thrives in temperate zones. In-depth research is now being carried out on these plants in the hopes of extracting natural rubber from them. ◎

Turning Four into One

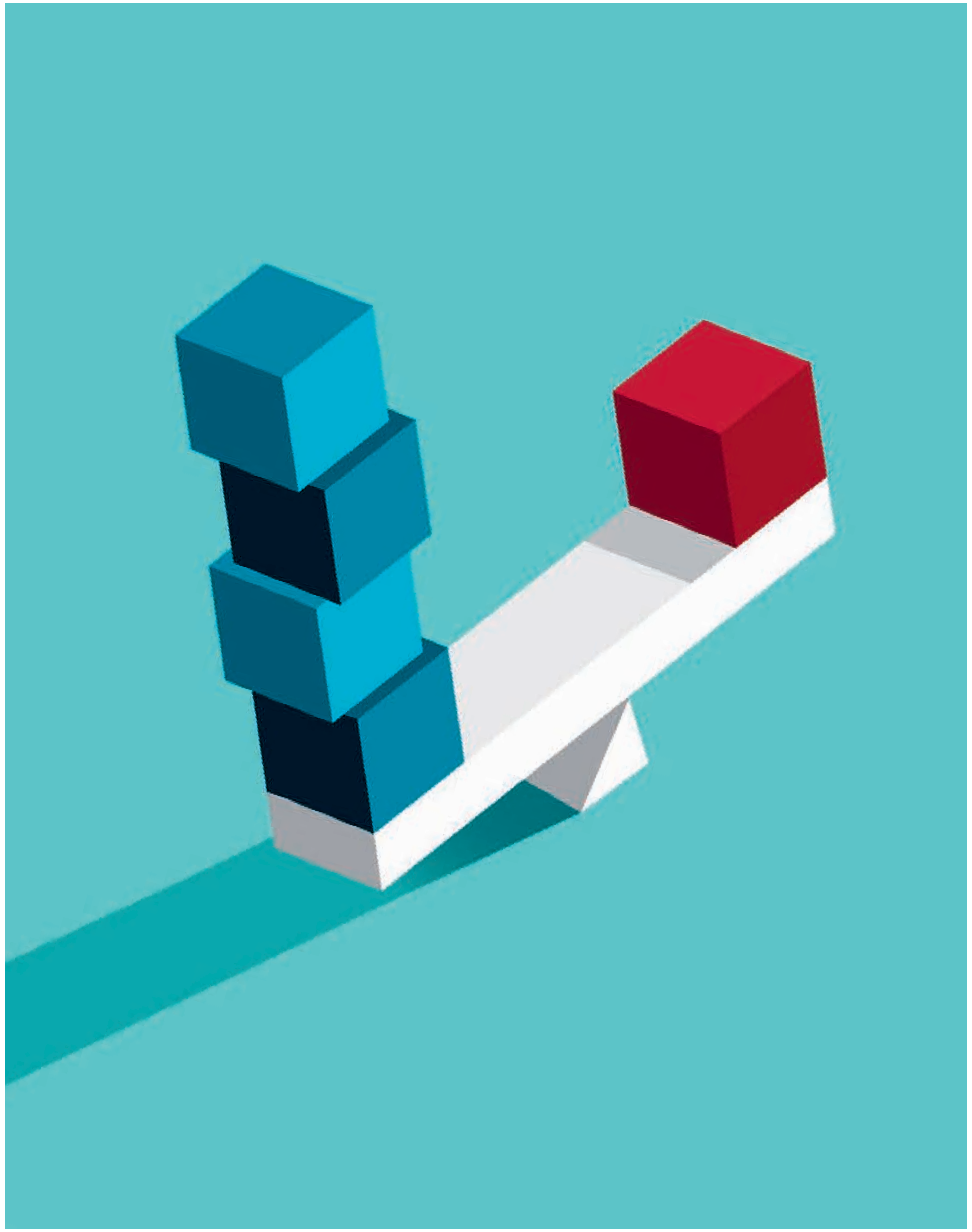
Components made of plastics are frequently lighter than those made of metal – in mobile applications, they tend to decrease CO_2 emissions. But there's more: A single component can also take over multiple functions. One example is a new plastic piston used in the transmission of a hybrid vehicle.

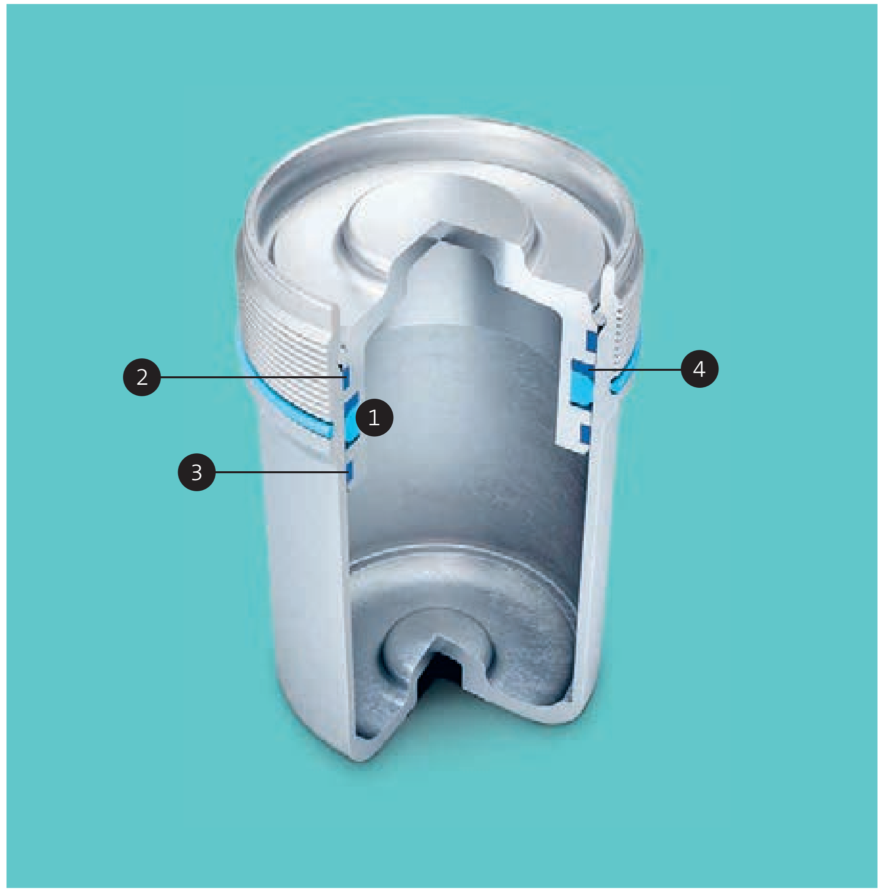
How can a plastic part perform several functions? The cap on a water bottle provides an answer. Whether it is for a PET bottle or the glass variety – which has lately seen a mild resurgence – the cap will be just one part if it is made of plastic. Plastic caps are a true all-around player. The extra ring, in the form of a breakaway part on the underside of the cap, lets a thirsty consumer know that the bottle has never been opened. The screw thread affixed inside the plastic allows the cap to be removed and re-closed multiple times. But it tightens properly thanks to the cone-shaped reinforcement in the cap's interior, which presses against the bottle's spout as it is rotated. It seals the bottle and its closure securely against one another. Neither liquid nor gas can get into the bottle or escape from it. Any additional seals become superfluous. They are, however, still needed in crown caps or screw closures made of sheet metal.

Great Freedom of Design

Functional integration – that's what experts call this approach to the use of plastic. It's possible to create just about any given shape using injection molding. Thermoplastics are an example. In the shaping process used to produce the part, the thermoplastic material in the form of a granulate is melted at about 400 °F to 600 °F in an injection molding machine and conveyed to a spray nozzle using a screw conveyor. During the injection phase, the molten mass is then introduced into the mold through an open nozzle under high pressure. The hollow space imparts the intended shape of the plastic part. Once the molten mass cools down in the mold, the shape of the plastic material is once again stable. To offset the accompanying loss of volume, the injection molder keeps feeding liquid polymer during the cooling phase. Then the injection molding process ends, and the finished part is ejected from the mold.

"Depending on how the mold is designed, the injection molding process can be used to create components with complex geometries and varying wall thicknesses," explains Matthias Hauer, a specialist in plastics processing at Freudenberg Sealing Technologies. "The plastic parts are literally all of a piece, as the saying goes – a reinforcement ring, for example,





The original hydraulic accumulator for dual clutch transmissions

1 Piston seal ring

2 + 3 Guide rings for gliding

4 Backup ring to prevent extrusion

The new lightweight hydraulic accumulator for dual clutch transmissions

1 Piston seal ring: Only one seal ring has to be installed.

> A plastic's requirements can be adjusted by using fillers and additives.

would have to be specially welded-on if the material were metallic. But the ring can be integrated right into the component with the injection molding process." Varying wall thicknesses are helpful in many cases because many plastics can be deformed to a degree even in a solid state. This quality is known as "ductility."

Integration of Multiple Functions

The plastic part can then perform many different functions if it is equipped with certain material properties and geometries. "Reinforced areas can improve the structural strength of a component or absorb mechanical stresses in dynamic components," according to Hauer. With other configurations, the part can meet its sealing responsibilities. "This is all based on the fact that the characteristics of the material can be adjusted in line with the requirements, perhaps using fillers and additives. It becomes possible to achieve high resistance to wear if a component is exposed to relatively strong friction."

Integrating functions offers many advantages. For one thing, fewer parts are needed, which can lower costs and weight. In addition, the manufacture and assembly of systems are streamlined, and combined processes are less complex and susceptible to failure.

Applications in Vehicle Transmissions

Pistons made of thermoset plastic are a good example of functional integration through the use of this class of materials. They can be produced with injection molding as well. Engineers at Freudenberg Sealing Technologies developed these pistons for dual clutch transmissions in hybrid vehicles. They replace the steel pistons that have been used until now and are deployed in so-called hydraulic accumulators, which keep hydraulic fluids under pressure in transmissions, for example, and which cushion hydraulic load peaks. As a result, a fairly small hydraulic system suffices to activate the gear changer, and the hydraulic pump requires less energy.

Hydraulic accumulators consist of a gas side and a fluid side, separated from one another by a piston. If too much hydraulic fluid is in the system in certain operating conditions, the hydraulic accumulator absorbs it, and the nitrogen used as a gas spring is compressed, storing energy. If the hydraulic pressure declines, the nitrogen expands and pushes the hydraulic fluid back into the transmission. The piston in the hydraulic accumulator had been made of steel until now and had to be equipped with a comprehensive sealing package, which consisted of no less than four individual parts. For example, two guide rings provided good guidance with low friction at the piston inside the cylinder. The actual piston sealing ring also had to be protected with an additional backup ring to prevent the sealing ring from moving into the small gap between the steel piston and housing, causing damage.

Precisely Adjusted Material Mixture

By contrast, the new piston produced using injection molding gets by with just one sealing ring. Two guide rings have been eliminated. The materials experts at Freudenberg Sealing Technologies had already ensured the proper guidance for the piston by using the right material and configuration. Aside from the material's very good slide characteristics, they adjusted the plastic's thermal characteristics so the gap between the piston and the housing can be made smaller while eliminating the need for the backup ring to protect the piston seal. By converting to the new material, the weight of the piston can be reduced by about half. And the installation of the hydraulic accumulator is now much easier since there are fewer parts to deal with.

"Plastic can be more than just a plastic bag," Hauer notes. "When its characteristics – which we can selectively influence – are skillfully combined, the material offers tremendous design possibilities." ◎

September 2019

Long-distance Buses with Fuel Cell Powertrains

Flixbus, Europe's largest provider of long-distance bus trips, plans to team up with Freudenberg Sealing Technologies to put the first long-distance bus with a fuel cell powertrain on the road. In recent decades, Freudenberg Sealing Technologies has developed numerous components for fuel cells and batteries. Thanks to the acquisition of a fuel cell manufacturer and its majority stake in the U.S. battery producer XALT Energy, the company has an outstanding market position in two key future technologies: batteries and fuel cells. It is in a position to offer complete electrical energy systems to manufacturers of heavy-duty applications, such as buses, railways, trucks and ships, from a single source. Freudenberg Sealing Technologies and Flixbus are planning to form a partnership with a bus manufacturer. Flixbus wants the acceleration of the fuel cell buses to match the performance of the popular long-distance buses today. Their range should be at least 300 miles and fill-ups should take 20 minutes at most. Claus Möhlenkamp, CEO of Freudenberg Sealing Technologies, expressed confidence in the technology. "We see fuel cells in combination with batteries as a regular fixture of future mobility. In Flixbus, we have found a new partner for this zero-emission application, and we look forward to our collaboration on this pioneering project." ©

September 2019

The Future of Mobility

On the occasion of the IAA 2019, Claus Möhlenkamp of Freudenberg Sealing Technologies talked about the future of mobility and the role that his company can play in this development. He basically sees the auto industry as a sector in the throes of an unprecedented transformation. Freudenberg Sealing Technologies has significantly expanded its business in battery-electric powertrains and fuel cells and is in the process of evolving from a component supplier into a system supplier. The company's share of value-added is now 60 percent for batteries and 80 percent for fuel cells. Möhlenkamp sees great potential in each powertrain solution – for bus, commercial vehicle and ship manufacturing, in particular, as well as for cars. Since Möhlenkamp has not written off internal combustion engines, the slogan for the future is "Continuity and Change": increasing efficiency in the internal combustion sector while building up and expanding the company's electric mobility business for the long haul. ©

July 2019

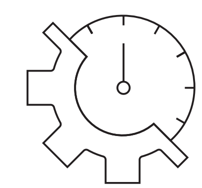
First-class Tractor Seal

There has been heavy demand for the S4 cassette seal, which is a good example of how optimal solutions can result from cooperation with customers. Working with a manufacturer, Freudenberg Sealing Technologies has spent several years developing the S4. It is suitable for highly demanding applications in the mobile work machines used in agriculture, construction and forestry. In comprehensive field tests, it proved to be four times as long-lasting as its predecessor in harsh agricultural conditions – a distinction that has impressed a number of customers in the meantime. ©

July 2019

New Composite Material

High-performance plastics such as the polymer PEEK are mostly made of standard compounds. By using additives, Freudenberg Sealing Technologies has developed PEEK compounds tailored to particular applications. Transmission seals and thrust washers (for automatic transmissions) made of the material wear less and produce less friction while resisting increases in temperatures. This shows that high-performance plastics can become even higher-performing when material and application expertise are combined. ©



95 %
less wear

April 2019

The Original Taste Guaranteed

In bottling and tapping systems, it takes the right seals to ensure that beverages taste the way they are supposed to. In times of increased beverage variety, seals keep the taste of the previously bottled or tapped drink from crossing over into the next one. Freudenberg Sealing Technologies offers its customers the best possible combination of material and components to optimize the performance of their systems, meet hygienic requirements and cope with the complex challenges relating to beverages' ingredients and flavors. ©

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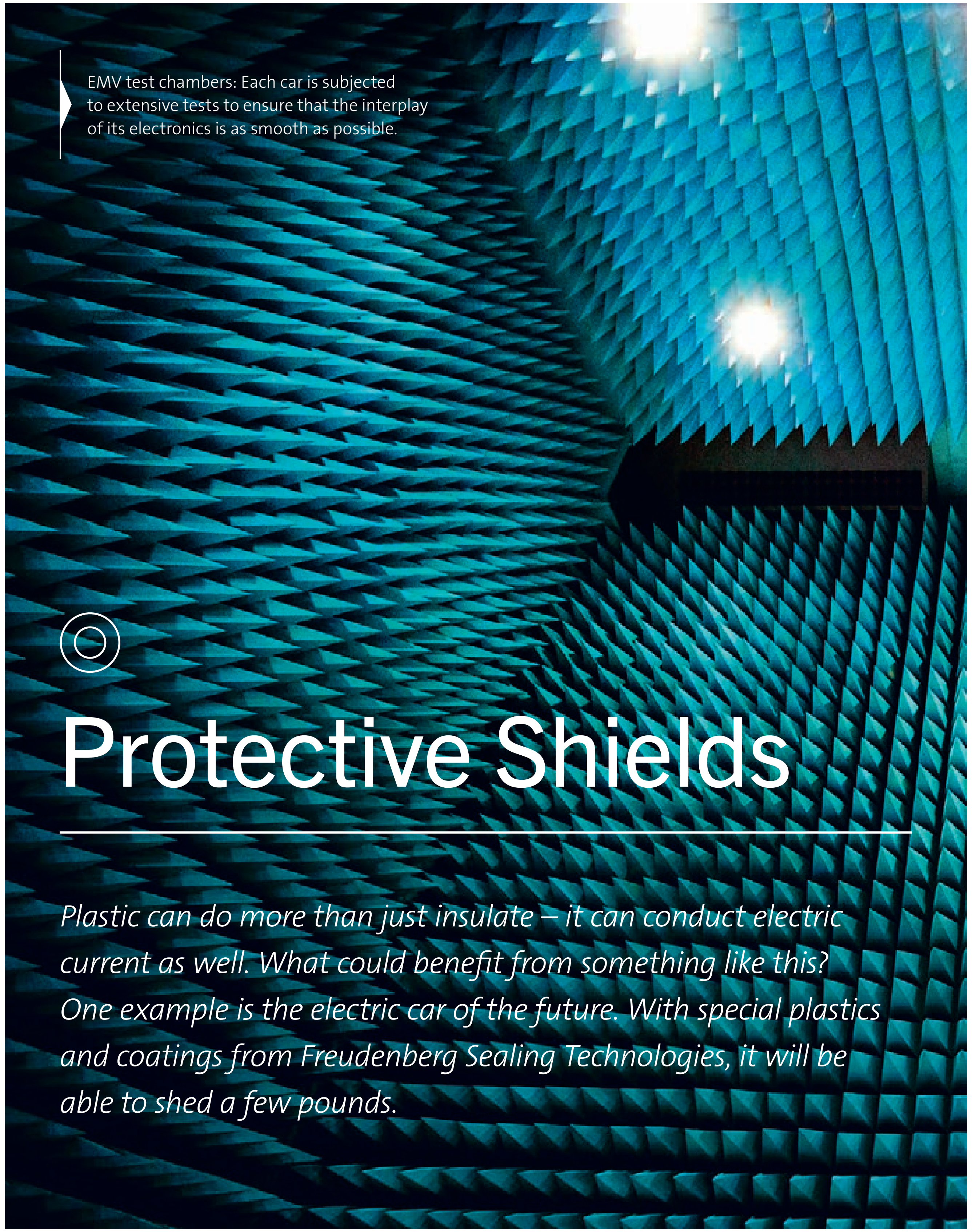


EMV test chambers: Each car is subjected to extensive tests to ensure that the interplay of its electronics is as smooth as possible.

Protective Shields

Plastic can do more than just insulate – it can conduct electric current as well. What could benefit from something like this? One example is the electric car of the future. With special plastics and coatings from Freudenberg Sealing Technologies, it will be able to shed a few pounds.

Seals are undercover agents. Their mission: to keep refrigerants, fuel, coolants and oil, which are found in nearly every automobile, from "crossing the border" into the environment. These well-trained specialists also perform well in adverse conditions. But their job description will be changing over the next few years. Electric cars certainly need reliable seals to keep coolant from escaping and to extend battery life, for example. But an electric field forms wherever electric current flows – as the "right-hand rule" memorably made clear in physics class. In an electric powertrain, however, the electricity seldom flows in one direction. (The exceptions are during certain charging processes.) The car's power electronics send alternating current at high frequencies into the veins of the electric motor, which – depending on its design – runs at rotational speeds up to 30,000 rpm. Field strengths change at a corresponding rate, producing electromagnetic waves that move through the space at the speed of light. If they are not stopped, one major result will be disruptions in the many small computers on board, and maybe even in a car stopped at the same traffic light. The only reliable measure in the battle against electromagnetic waves is to confine electric components to a housing made of an electrically conductive material or whose electrically conductive surface reflects the waves.

Plastic Replaces Aluminum

In the current generation of electric cars, the housings for batteries, motors and power electronics are made of aluminum – almost without exception. First of all, it is a good conductor of electricity. Second, it is a lightweight metal with a low specific weight. In addition, it is easily processed with pressure-casting, making it a low-cost option. To the experts at Freudenberg Sealing Technologies, all this is good – but not good enough – since every pound of excess fat has an impact on the vehicle's range. If you could replace the aluminum components with plastics, you could reduce its weight even more. But there is an obstacle: You need an electrically conductive plastic to do this. Science has only been aware of these miracle plastics since the 1980s. They are quite expensive and are almost exclusively used in the manufacture of electronics, such as displays.

One Goal, Multiple Paths

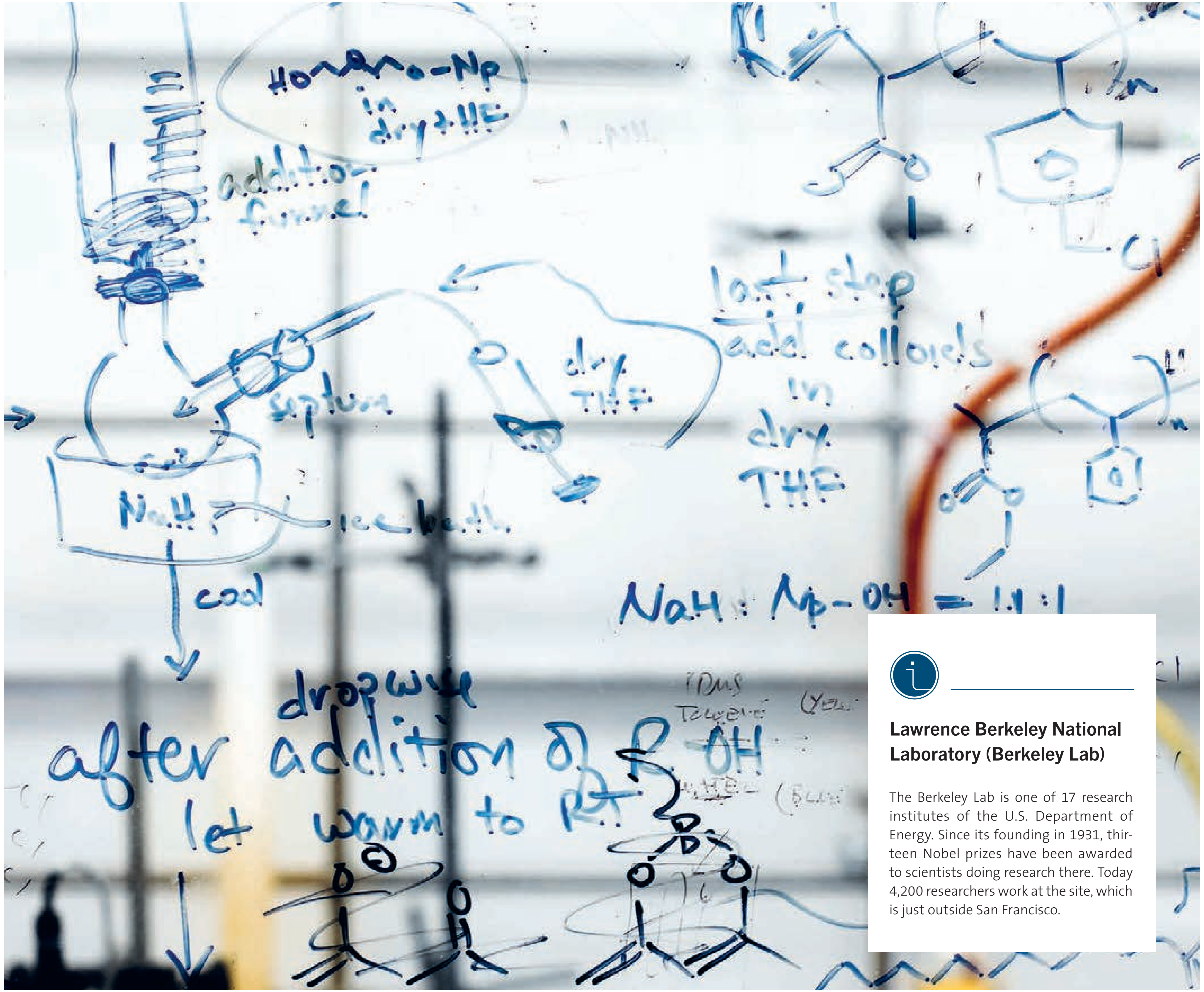
"Intrinsically conductive plastics – that is, plastics that are conductive by their very nature – have been used at our company in isolated instances," comments Volker Schroiff, who is in charge of Technology Management at Freudenberg Sealing Technologies. "But for large-scale production, we've developed various alternatives that are less expensive." The first alternative is a plastic housing with a conductive coating, that is applied like paint. The industrial implementation is far along; Schroiff is already working with his colleagues at the Special Sealing Products business unit on a production facility concept. The second alternative is to impart plastic particles of a conductive material to the nonwoven before the injection molding stage. The advantage of this approach: No additional steps are needed in the production process. This offers cost advantages, especially for relatively small components. And in the end, there is a third approach that is well-suited to large surfaces – such as the housing cover for a traction battery. After a nonwoven's fibers have been given an electrically conductive coating, the material is inserted into a mold where a thermoset part is produced. "We're working closely with the nonwovens experts at Freudenberg Performance Materials on this solution," Schroiff adds.

There were a number of findings from the first pilot projects, which involved three large, direct suppliers of electric powertrains: The ideas derived from the physics of electromagnetism perform well in practice – that is, in real-life components. And as soon as output reaches at least 30,000 components a year, the special plastics from Freudenberg Sealing Technologies have a cost advantage over aluminum, not just a weight advantage. Meanwhile, Schroiff is already moving in a new direction. In the future, the conductive layer could also consist of a razor-thin elastomer, manufactured along with the housing in a single mold, using the two-component injection molding process. The elastomer serves as a protective shield against electromagnetic waves, even as it seals against liquid and gaseous media. The process, for which a patent was filed in the summer of 2019, combines the undercover agent's old and new missions. ◎

Read more about change in the automotive industry: https://bit.ly/2m5iVOt

The Beginning of the End for the World's Plastic Woes?

A new plastic has been developed in the United States that can be completely recycled into its individual components. Then it can be used to produce an even higher-quality plastic.



Lawrence Berkeley National Laboratory (Berkeley Lab)

The Berkeley Lab is one of 17 research institutes of the U.S. Department of Energy. Since its founding in 1931, thirteen Nobel prizes have been awarded to scientists doing research there. Today 4,200 researchers work at the site, which is just outside San Francisco.

Brett Helms holds a small piece of dyed plastic in his hands. Notwithstanding its nondescript appearance, it is of enormous importance to him. And quite possibly to others in the near future. "This plastic has the potential to change the world," says Helms, 41, who leads a research group at the Molecular Foundry at the Lawrence Berkeley National Laboratory near San Francisco. The polymer in his hands is the first compounded plastic that can be totally recycled back into its separate component parts.

Recycling Pitfalls

Plastics are being produced in ever-greater amounts worldwide, and recycling them is no small task. The major problem with classic plastics involves their fillers. They make a material softer and more elastic while imparting a color and increasing its resistance to ultraviolet radiation. The fillers are so closely linked to the plastic's monomers that they stay in the material after shredding and processing. If they are melted into a new material, dark pellets with variable characteristics are often the result – at best, they can be used to make cheaper building materials. Nevertheless, a large share of plastics isn't recycled at all. They go directly into the environment, where they break down slowly and may even end up in drinking water in the form of micro plastics.

More and more chemists are tackling the problems posed by the ever-increasing use of plastic. Some are seeking new approaches to the recycling of existing plastics. One is Gregg Beckham, who is doing research in Yellowstone National Park, looking for new enzymes that break down PET plastic. Others are trying to develop completely new plastics whose structures lend themselves to recycling. Ludwik Leibler, lab chief at CRNS, a French national research institute, is chalking up the first successes: In 2011, he invented Vitrimere, a glass-like material. In 2014, Jeanette Garcia of IBM made headlines with her "Fantastic Plastic" – a new class of polymers that can be recycled.

Researchers in the mountains looming over San Francisco Bay are moving in this direction as well. At the Berkeley Lab, Brett Helms and his partners are working on recyclable thermosetting polymers, which harden when heated and whose monomers enter into stable network connections. This extremely robust material is used in packaging, tubing and screens as well as car manufacturing and airplanes. But after its processing, it can no longer be melted down. It basically ends up in landfills.

The Aha Effect

That's not the case for polydiketoenamine (PDK): "We owe our breakthrough to an accident during cleaning," Helms said. "This newly developed material adhered so securely to our glass dishes that we had to use a strong acid to remove it." The acid not only detached the PDK from the glass – it even broke down the polymer. "If we had just thrown the lab dishes away, we would have never observed this spontaneous chemical reaction," Helms notes. Suddenly curious about the phenomenon, the researchers examined the material in a test tube and discovered that the individual components were present in their initial form.

By treating the PDK with the strong acid, they found that it was also possible to filter out all its additives such as dyes and softeners. The original monomers are like new and available for use. They were also able to retrieve the additives, unchanged chemically. Some of these additives, such as flame retardants, are more costly than the plastic and therefore highly valuable on their own, which incentivizes their recovery for reuse. "PDKs make possible a circular lifecycle for plastics – the quality of the recycled material is just as good as the virgin material," Helms said. Even a higher-level material is possible: the production of a material whose quality and features are better than that of the material from which it was recycled. For example, a flexible plastic could be made from a hard plastic. "This approach is innovative, straightforward and elegant," explains the British polymer expert Rachel O'Reilly from the University of Birmingham. "There is still no single solution to the plastic problem, but this development is a very important step in that direction."

Opportunities for Use of the New Plastic

The plastic in Berkeley is produced by mixing chemicals known as triketones with amines. "This involves a click reaction at room temperature without the need for a catalyst, an additive or even a solvent – a couple of minutes in the ball mill is sufficient," Helms said. He and his team are working on a range of different material characteristics. "PDK could easily be built into a gym shoe or fibers in textiles that would replace the nylon in pantyhose, but you could also imagine the kind of hard plastic used to make bottles for cleaning fluids," he said. However, since the powdery synthetic resin in the initial material is already beige, white or transparent hues are not yet feasible. PDK currently can only be dyed darker colors.

> "If we had just thrown the lab dishes away, we would have never observed this spontaneous chemical reaction."

The Berkeley Lab has patented PDK and is now looking for major partners in the hopes of jointly developing material for industrial use. "Many details in the lifecycle of the material still have to be worked out," Helms said. "For example, the acid-based recycling process is very water-intensive." To clear the way for PDK in the market, a completely new ecosystem is needed, including recycling facilities geared to the new material. "It will likely be five to seven years before we can talk about commercialization," Helms concludes.

Brett Helms

Born in 1978, Brett Helms has worked as a scientist at the Berkeley Lab for eleven years and is also chief scientist at his startup Sepion Technologies. He studied at Harvey Mudd College in Claremont, California, and then earned a PhD at the University of California-Berkeley. He also spent a year as postdoc at the Eindhoven University of Technology, where he specialized in organic chemistry.

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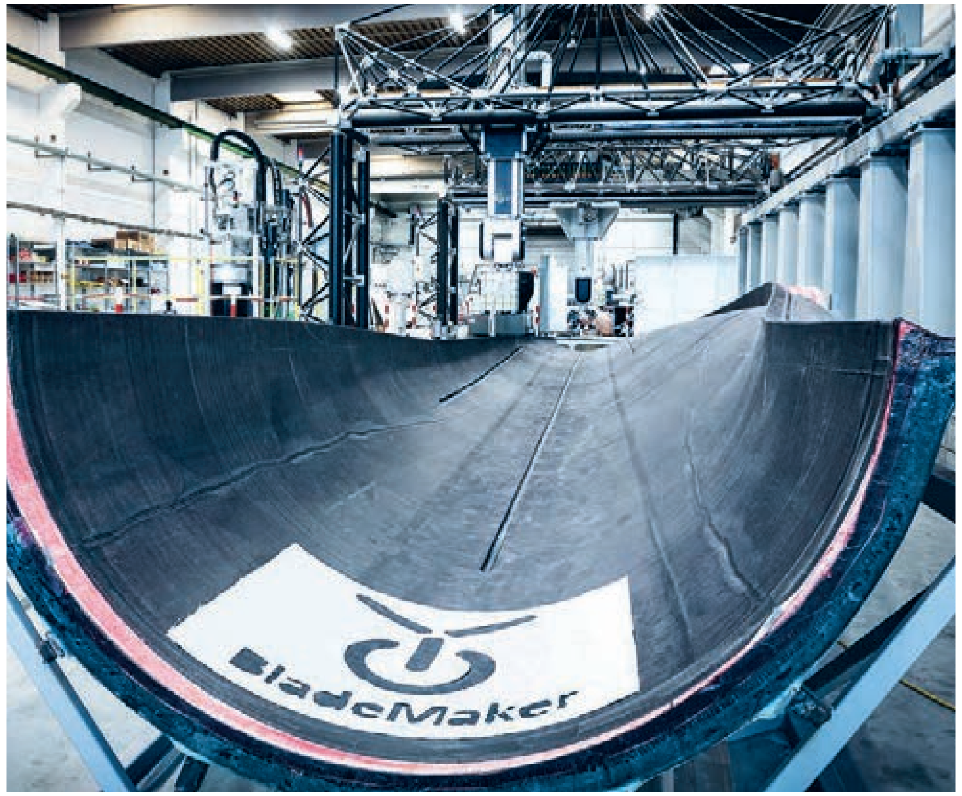

1_Giants in the sea: High-performance plastics ensure that the blades are as light as possible.

2_A foam element serves as a mounting aid for the first layer, which is made of balsa wood.

3_The second layer is made of glass-fiber mats. Then the second half shell is mounted and the hollow space filled with epoxide resin.

Light as a Feather

Wind turbines have steadily grown over the last two decades. Armed with their 117-yard-long rotor blades, the latest generation's giants stand far out in the ocean. But without composites, the blades of the turbines would be too heavy to work efficiently.

Wind energy has not just been beating solar power but brown coal as well. With a share of 20.4 percent, wind turbines were the largest net electricity producer in Germany in 2018. According to the Global Wind Energy Council (GWEC), wind turbines had an installed electric capacity of 539,581 megawatts globally at the end of 2017. That corresponds to about 1,000 conventional coal-fired plant blocks. This can be traced to the growing output per facility, and not just to an increase in the number of turbines. The latest generation of land-based wind turbines brings the average output to 3.2 megawatts – almost three times what it was two decades ago. Two factors are responsible for the rise: The average height of the hub – with every meter of height, the electric production grows by 0.5 to 1.0 percent – climbed from 78 to 144 yards today, and the rotor diameter for land-based facilities increased from 63 to 129 yards.

The largest offshore facilities, with a nominal output of 12 megawatts, show where these developments are headed. Each blade is 117 yards long. Without the development of high-performance plastics, such lengths would not be possible since the blades would be too heavy. At their tips, they reach a speed of about 200 mph. Centrifugal forces approaching 1.5 mega-newtons tear at the root of the blade. The greater the mass of the rotor blade, the greater the centrifugal force at the same rotational speed. By comparison, one meganewton corresponds to the weight force of 70 well-equipped compact cars.

Even the manufacturing involves extraordinary dimensions, since the blade is produced as a single piece. The mold used to produce it is also extremely heavy. For a 269-foot-blade, the starting point is about 500 glass-fiber mats with a thickness of about one millimeter, placed manually in the lower half shell. Then three synchronized portal cranes drive up to the prefabricated spar, which is attached inside a tubular frame. The crane driver lowers the frame onto self-centering "hold point" so the spar comes to a rest precisely in the pre-calculated position on the half shell. When the connection between the spar and the blade interior is established and the lightning conductor is fitted – manually as well – the preparations to construct the upper blade half shell begin. The portal crane lowers a foam element to the right and the left of the spar. It serves as an assembly aid for the first, balsa-wood layer, which manufacturers then cover with about 500 glass fiber mats. As soon as the upper mold shell is mounted and is airtight, an automatically controlled system produces a vacuum in the interior and then injects about three tons of epoxide resin. Once the

The rotor blade has a swept area of
226,000
square feet.

components are heated over a fairly long timeframe, they bond into a single unit.

At the end, the blade weighs nearly thirty tons. That's a huge weight, but when you figure that it has a surface of more than 26,000 square yards, it is light as a feather – and with tremendous resistance to bending and elongation to boot. It is precisely these material qualities that are crucial in rotor blades. "When the blades have a length of about 87 yards or more, there is an enormous need for rigidity," notes Tjark von Reden, Deputy Managing Director of the Carbon Composites network. "That's why a composite of carbon fibers will increasingly be used, especially in the spar." Otherwise, in certain wind conditions, rotor blades would risk striking the tower. "The use of composite material strengthened with carbon fibers is growing," adds Haras Najib, technology and innovation expert in the wind industry working group at VDMA, the German association for the mechanical engineering industry. Neither expert sees any realistic alternatives to high-tech plastics on the horizon. Titanium and aluminum are conceivable, but, compared to glass fibers, they are much too expensive or too unstable. Not long ago, there was chatter about a rotor blade made of steel sheets about seven-hundredths of an inch thick. Its contour was shaped with a hydroforming process. Still, the rotor blade, which was just a few yards long, is best viewed as a feasibility study. It is far from practical use on an industrial scale.

During the coming decade, a challenge is coming at the sector with its full force. After the phase-out of their twenty-year funding period, thousands of wind turbines in Germany are due for replacement. These wind-catchers, which have been made of thermoset plastics to this point, are difficult to recycle because glass-fiber-based composite materials cannot be broken down into their component parts economically. Thermal recovery is still playing a major role. but it poses problems for granulates containing carbon-fiber reinforced plastics (CRP). When blended with resin, CRP is not suited for co-combustion, which would damage filter systems. "We still don't have a closed material circuit, though manufacturers and national wind energy associations, along with the European Chemical Industry Council and research institutes, are working on this" Najib said.

Von Reden thinks one promising approach is to use solvolysis with supercritical water. "In a supercritical condition, water dissolves the plastics in the fiber composite. So glass fibers, carbon fibers or even metals can be dissolved out of the plastic, separating the materials. Even water separates from the plastic, which is an oil at that point, when it is no longer in its super-critical condition." Researchers from the Fraunhofer Institute ICT are tinkering with an entirely new solution: They want to fuse fiber-reinforced plastics and thermoplastic foam to one another. Unlike thermoset plastics, thermoplastics can be re-fused and shaped into new products. Moreover, the new class of materials is expected to improve on the blade's mechanical strength and longevity while reducing its weight by about 20 percent. There is also a welcome side-effect. The meltable plastic can be processed in automated production facilities. It is still up in the air whether this will work on a large scale. But without progress in plastic technology, wind power would never have become the top dog in the sector in the first place. ◎

Read more about sealing solutions in power engineering: https://bit.ly/2lXvrzR

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We cover current, entertaining and astonishing topics for you with the same passion that drives our development of high-performance products. With some success, as these awards for our company magazine Essential demonstrate.

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We look forward to a dialogue with you!
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COMPANY INFORMATION

Publisher
Freudenberg Sealing
Technologies GmbH & Co. KG
Corporate Communications
Höhnerweg 2–4, 69469 Weinheim

Responsible for the content
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Editorial Services
Profilwerkstatt GmbH,
Redaktionsbüro delta eta

Design & Conception
Profilwerkstatt GmbH

Printing
ABT Print und Medien GmbH
Bruchsaler Straße 5
69469 Weinheim

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