1/2026

EVONIK
Leading Beyond Chemistry

ELEMENTS

Research. Knowledge. The future.

Making Material

How fermentation makes the industrial production of spider silk possible → p. 10

Glass bottles: sustainably coated with silanes → p. 22

Lipid nanoparticles: On the road in North America's research hotspots → p. 36

Bionics

Using natural models for technical developments

The term bionics is a blend of the words "biology" and "electronics." This field of research develops technical solutions modeled on natural systems. Bionics follows two approaches. On the one hand, it imitates biological principles and translates them into technical applications such as removable fasteners based on the burdock or particularly aerodynamic aircraft surfaces that are modeled on the structure of shark skin. On the other hand, it recreates or synthesizes biological structures, processes, and materials. The principle of photosynthesis, in which plants use sunlight, water, and carbon dioxide to produce energy-rich substances, is also used in the production of fuels. Another example is the biotechnological production of silk threads using spiders as a model. As an interdisciplinary field, bionics combines biology, electronics, physics, chemistry, engineering, and materials science as well as architecture and design.

Natural system A system that arises without human intervention in nature and organizes itself. This makes it particularly dynamic and adaptable.
Synthesized Artificially manufactured or deliberately produced by a chemical or technical process.
Interdisciplinary Encompassing different subject areas or scientific disciplines that contribute to the solution of a shared problem.

DEAR READERS,

People who talk about the achievements of the chemical industry often meet with a specific response: "Well, personally I prefer organic products." On the one hand, a certain lack of awareness is involved—after all, without chemistry over 90 percent of the products in our lives would not exist. These products often owe their good properties to chemistry. On the other hand, such a statement suggests that "biochemistry" is a contradiction in terms—but that's not the case.

Biochemical processes are one of Evonik's specialties. And when biology comes into play as a source of ideas, that's when things get really innovative. Just like at AMSilk—a company based in Munich that has made bacteria produce the protein that spiders use to build their webs. It's an extremely tear-resistant, extremely light, and extremely flexible material. Fashion houses, car manufacturers, and other companies are now snapping up this fine yarn. Evonik's expertise in the area of fermentation ensures that they get it. Together, the two partners have succeeded in enabling production on an industrial scale and with consistent quality. Fabric that seems natural—only better.

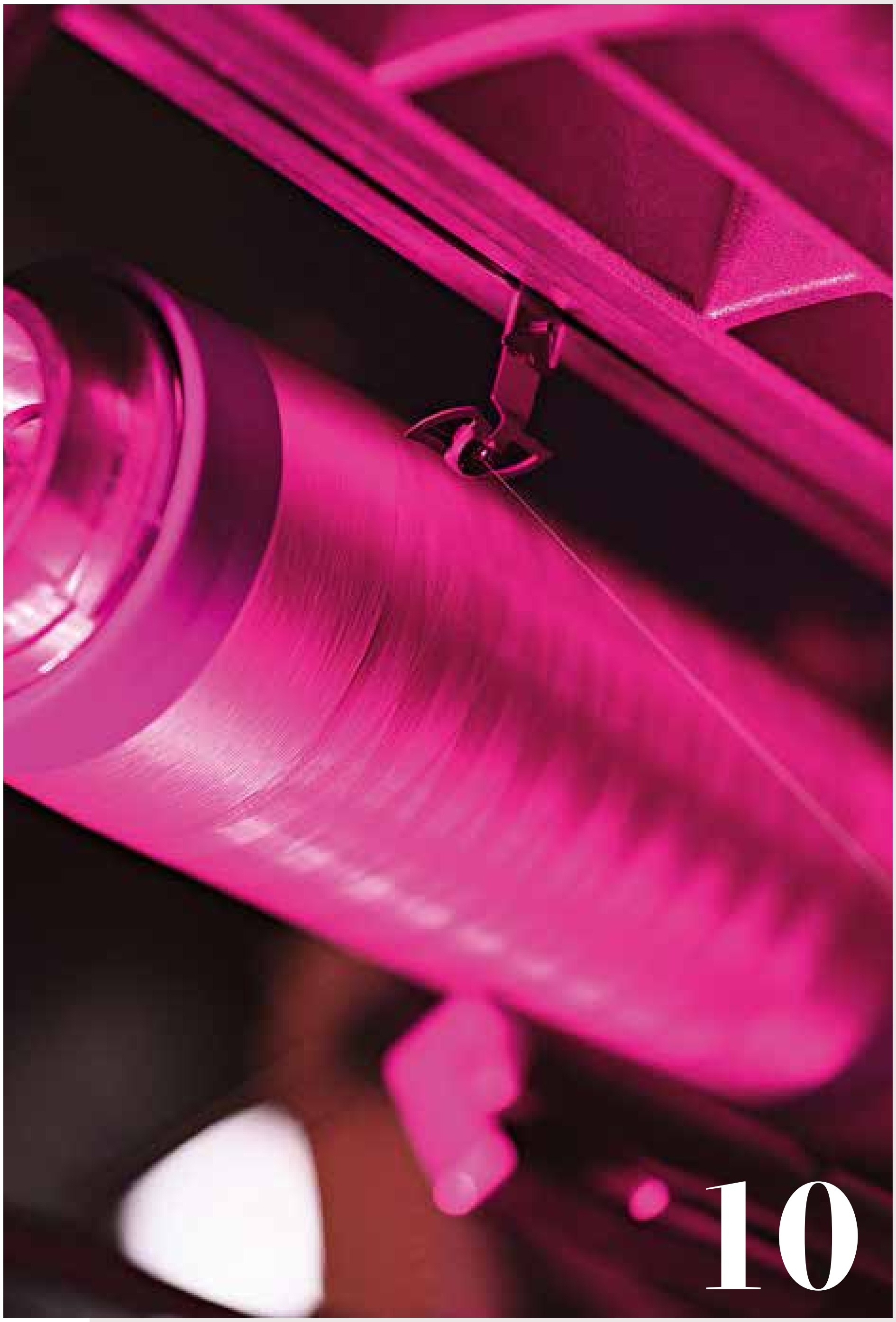
The beverage bottles that are the subject of another story in this issue are also better. In that article, you can find out how much innovation goes into giving a beer bottle its shine and scratch resistance, and into making the coating required for this as safe and environmentally friendly as possible. After reading it, you'll look at your after-work drink with different eyes—that's a promise.

In this issue we also show what's happening with the medical miracle mRNA. The US government has drastically reduced its funding for mRNA research. Nonetheless, a wide range of innovations that goes well beyond pandemic vaccines is developing in the USA, and at least as strongly in Canada. Evonik has research and production locations in both countries.

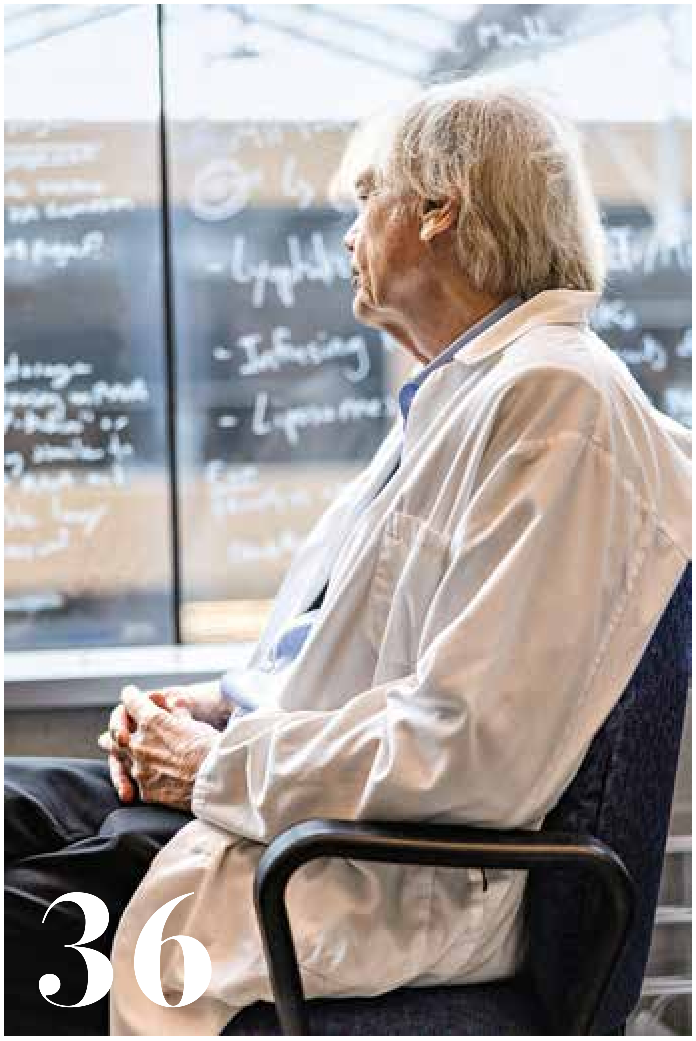
I wish you fascinating insights. If you have any questions, recommendations or criticisms about this issue, please write to me at elements@evonik.com

Jörg Wagner
Editor in Chief

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



A fine thread with a tensile strength greater than steel—spider silk is one of the most exclusive materials anywhere. Together with AMSilk, Evonik uses fermentation to produce it for luxury companies, the automotive industry, and the medical sector



Luminaries such as Professor Pieter Cullis in Vancouver are gathering mRNA expertise around them. Evonik is also part of the biotech cluster in this coastal city in Canada

Shine and protection: Silanes enable bottles and other glass containers to be coated more sustainably than was previously possible

The world is full of challenges. Evonik is working on innovative solutions that are both economical and sustainable. We present them here.

The problem: Millions of people around the world wear contact lenses. However, symptoms such as reddened eyes or a feeling that there's something in your eye can significantly impair wearing comfort. These complaints are often related to the lens material. If the lens does not allow enough oxygen to pass through to the cornea, cannot store sufficient moisture or is not dimensionally stable, this can lead to redness and irritation, and even impair vision.

The solution: High-purity raw materials and advanced synthesis processes can help to avoid such undesirable side effects. Contact lenses consist of a polymer network that is held together by so-called crosslinkers. This is precisely where Evonik plays a key role. The company offers high-purity specialty monomers and crosslinkers that give hydrogel lenses high oxygen permeability, dimensional stability, and a great ability to retain moisture. Evonik's portfolio also includes bio-based monomers that enable more sustainable product solutions. The result is contact lenses that combine sharp vision with high wearing comfort.

The human iris is protected by the cornea. As it has no blood vessels, the cornea is dependent on oxygen from outside. Contact lenses must therefore ensure a sufficient supply of oxygen while remaining soft and dimensionally stable.

Made from milk

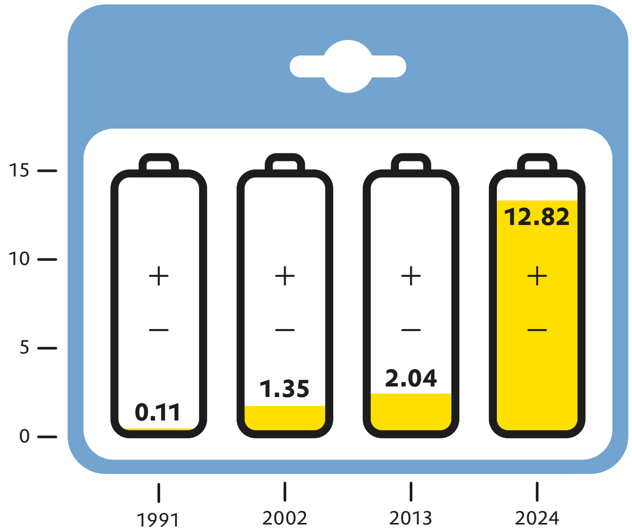
Researchers from the USA are transforming casein and whey proteins into a more sustainable plastic for additive manufacturing

Worldwide, around 116 million tons of dairy products are wasted or disposed of every year. Dr. John Obielodan and Dr. Joseph Wu from the University of Wisconsin-Platteville have developed an innovative solution to make these residual materials usable. Their patented process converts dairy waste into a biodegradable plastic for 3D printing. The basis is casein and whey proteins, which are extracted from spoiled milk and combined with polymers. Butanol first removes unwanted fat from the proteins to improve printability. The purified proteins are then mixed with conventional polymers. Crucially, the formulation must be precisely balanced, because the mixing ratio largely determines mechanical characteristics such as strength, flexibility, and resistance to pressure. The result is a printable material with bio-based content as a more environmentally friendly alternative to conventional plastics.

THAT'S BETTER

Cheaper charging

Number of kilowatt hours that can be generated with 1,000 US dollars



Lithium-ion battery cells for electric vehicles, consumer electronics, and energy storage systems are becoming increasingly affordable. Mass production, optimized production lines, and advances in battery technology and cell chemistry have ensured that today around 13 kilowatt hours of electricity can be generated with an investment of US$1,000, 116 times more than 35 years ago.

Source: www.ourworldindata.org, Rupert Way (2026) based on Ziegler and Trancik (2021), BloombergNEF, and Avicenne Energy

90

PERCENT

of the starting materials are recovered by researchers at the Swiss Federal Laboratories for Materials Science and Technology in St. Gallen through the chemical dissolution of an epoxy resin containing a phosphorus-based polymer additive. Conventional epoxy can no longer be recycled after curing due to its irreversibly crosslinked polymer chains. However, the phosphorus compounds form hinges in the polymer chains and thus enable recycling. They also serve as integrated flame protection. The new epoxy resin is suitable for coatings and adhesives with high stability and fire protection requirements.

RIFF DIFF...

...stands for Rotamer Inverted Fragment Finder-Diffusion, an AI-supported technology for the design of artificial enzymes. Instead of modifying existing proteins as was previously the case, researchers from Graz, Austria, are using generative machine learning models and the computer-aided simulation of atoms and molecules to build enzymes from scratch. In the active center of the enzyme, they first position the structural elements that are crucial for the desired reaction and then generate the complete protein molecule structure using AI. This results in particularly fast and stable biocatalysts for industry, medicine, and the environment.

PEOPLE & VISIONS

"I want to make the adhesives and sealants industry more sustainable and empower farmers"

THE PERSON

Engr. Mark Kennedy Bantugon developed a feel for the value of natural resources early on. "I grew up on a farm," says the 27-year-old Filipino. "That's how I came across plants and trees from which valuable raw materials can be extracted." The native pili tree has shaped the young researcher's path to this day. After earning a bachelor's degree in aeronautical engineering from the Philippine State College of Aeronautics, Bantugon is currently finishing his master's degree in materials science and engineering at Mapúa University. Here he pushed ahead with his invention Pili Seal and at the same time established his start-up Pili AdheSeal.

THE VISION

Bantugon uses resin residues from the pili tree that are a byproduct of the perfume industry. With its good adhesive properties, this waste forms the basis of a non-toxic, environmentally friendly, and high-performance sealant and adhesive—for the aerospace industry, for example. The residues from Bantugon's production can be converted into fertilizer. "This creates a cycle that makes the sealant and adhesive industry more sustainable and empowers local agriculture." He is implementing his first project in cooperation with the Philippines' Department of National Defense: "Now I want to see my invention grow beyond the country's borders."

Mark Kennedy Bantugon with Pili Seal, a sustainable multipurpose adhesive and sealant that sticks to all materials

New for nitrate wastes

Copper-palladium hybrid interfaces enable a highly efficient electrochemical ammonia synthesis

A research team led by Professor Xinhe Bao from the Dalian Institute of Chemical Physics has developed a copper-palladium bimetallic catalyst that efficiently converts nitrate waste into ammonia. Its highly active interfaces, at which copper and palladium atoms are in direct contact with each other, specifically control the electrochemical nitrate reduction and increase the formation of ammonia. This method is a gentle alternative to the Haber-Bosch process, which requires fossil raw materials as well as high temperatures and pressures. If renewable electricity is used, the electrochemical synthesis produces "green" ammonia with an improved carbon footprint, which can be used as a raw material for fertilizers, for example. The catalyst opens up prospects for sustainable agriculture, nitrogen recovery from wastewater, and low-carbon energy systems in which ammonia serves as an energy source or hydrogen store.

GOOD QUESTION

Mr. Güsken, what can we learn from the octopus?

Together with researchers at Stanford University, we have developed an ultra-thin photonic skin that can change its surface structure and color independently of each other, like an octopus skin. In the laboratory, the adaptation to different colored backgrounds can already be demonstrated on five to ten square millimeters. The technology could be used in sensors for soft robotics or smart textiles, for example. It combines methods from semiconductor manufacturing, biological polymers, and physical concepts such as optical resonances in thin films. Before the first displays with an octopus surface can be used, we still need solutions for the scalability and controllability of the photonic skin. In the long term, AI-controlled systems could adapt materials autonomously in real time—a step towards living, adaptive technology.

Junior Professor Nicholas Güsken researches and teaches in the Department of Quantumphotonics & Optoelectronics at Paderborn University.

SMOOTH

The “magic moment”: The silk protein solidifies in a liquid to form fine filaments (above). When stretched out, they become a thread of spider silk (right)

AS SILK

Silk has fascinated mankind for thousands of years. Now the precious fiber can be redefined biotechnologically. Together with the company AMSilk, Evonik uses fermentation to manufacture the precursor for a high-performance fiber modeled on nature

TEXT **SINA HORSTHEMKE**

The thread runs over heated rollers for drying (top). The subsequent quality control also includes measuring the tensile strength directly in the spinning mill (left)

The building southwest of Munich's city limits may look like nothing special from the outside, but inside you can marvel at a fascinating process. A viscous mass is being extruded under pressure through 40 tiny holes in a faucet-sized nozzle into a flask full of transparent fluid. Suddenly, thin threads are forming and sinking to the bottom of the glass as if in slow motion. Only a few get to see this spectacle live. The two chemical engineers who are in attendance wear protective clothing while presenting the effect, which they call the "magic moment."

What the employees in the spinning mill of the biotech company AMSilk in Planegg are demonstrating so vividly is otherwise done in secret. So just how the 40 filaments inside the machine are stretched up to 80 times their length and spun into a fine thread remains a secret. What can be seen is the spinning facility, in which this thread runs through a water bath, then over heated rollers to dry, before finally being wound by machine onto a bobbin the length of a forearm. At the end of this spinning process, the bobbin will carry one kilometer of thread that weighs just nine grams. The thread shimmers like mother-of-pearl, is as fine as hair and as soft as silk—spider silk, to be precise. AMSilk's product is based on the thread that spiders weave into webs to catch their prey.

LUXURY COMPANIES AS FIRST CUSTOMERS

"It's the strongest natural protein in the world—the thread has a tensile strength two and a half times that of steel," enthuses AMSilk CEO Ulrich Scherbel. "No wonder the Spiderman story fascinates people. However, for a long time no one had succeeded in producing significant quantities of spider silk from proteins." AMSilk has—initially on a small scale in the laboratory, and now, together with Evonik, on an industrial scale.

There is a great deal of interest in this innovative material, and the customers who are already using it are well known worldwide. The fiber can be found in blouses from this year's spring collection of the Parisian fashion group Balenciaga. It is used in watch straps for the luxury brand Omega. And in 2022, AMSilk announced a collaboration with Mercedes-Benz. The in-

The genetically modified coliform bacteria multiply on a culture medium in petri dishes. The colonies are recognizable as droplets

“Bringing our protein into large-scale production was a challenge”

ULRICH SCHERBEL, CEO OF AMSILK

terior of the Vision EQXX concept car now features door handles that contain silk fibers. Spider silk threads are now playing a role in more and more applications. Demand is increasing, and that is why Evonik and AMSilk expanded their existing cooperation—which had been in place since 2021—in the fall of last year.

BENEFITS FOR THE CLIMATE AND THE ENVIRONMENT

The use of biotechnologically produced spider silk is conceivable in more than 20 sectors, for example in the cosmetics industry as a substitute for silicones in shampoos, in the health sector, and in agriculture. “We know, for example, that implants coated with spider silk are tolerated better by the body,” says AMSilk CEO Scherbel. “And if we coat plant seeds with it, their shelf life doubles.” AMSilk’s high-performance fiber was the first to be used in the textile industry as an alternative to natural silk and other materials. The industry urgently needs innovative solutions. According to the European Environment Agency, it is the third-largest cause of water pollution and land use. The EU’s plan to achieve a circular economy by 2050 is also clearly aimed at the textile industry.

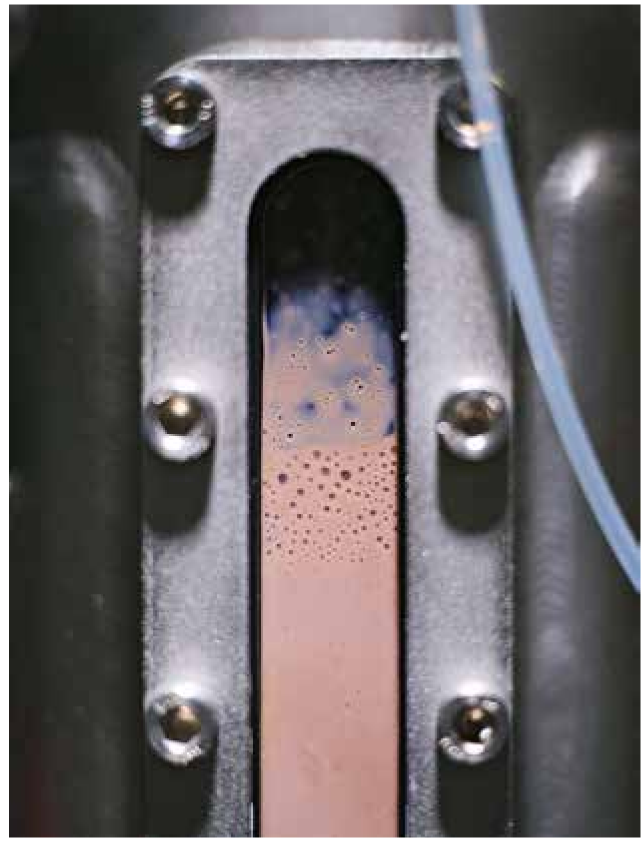
91,765

TONS

of silk were produced worldwide in 2020.

The AMSilk material is more sustainable than many other textiles. Because the composition of the threads corresponds to that of their natural model, they are completely biodegradable—unlike polyester fibers, for example. Their production is better for both the climate and the environment than conventionally produced silk. This comes mainly from the cocoons of the caterpillars of the mulberry moth, which is native to China. Real spider silk, the model for the AMSilk product, can indeed be obtained from cultivated spiders and has been experimentally tried in silk production. However, the process is extremely labor-intensive, and the quantities produced are negligible (see box on p. 15).

According to AMSilk, the biotechnological production of spider silk requires 97 percent less water and 92 percent less land area than the laborious natural extraction and production of traditional mulberry silk, and the carbon footprint is around 81 percent smaller. In addi- →



In the AMSilk laboratory, process engineer Nadine Ersig takes a sample from the ongoing cultivation in a fermenter. The bacteria produce the silk protein as they grow in a nutrient solution

tion, the AMSilk process allows the production of silk thread in far greater quantities than nature can provide. To make one kilo of silk with the help of mulberry silkworms, you need the cocoons of around 15,000 caterpillars. In just one working day, AMSilk's technology produces a hundred times this amount of protein, which can be processed into almost as much fiber material. "The textile industry urgently needs sustainable solutions like these," says CEO Scherbel.

BACTERIA REPLACE SPIDERS

At AMSilk, the source of the silk thread is not a spider but a microorganism. Ever since science has been able to precisely analyze and modify genes, it has been possible to turn such single-celled organisms into tiny factories. To do this, a segment of DNA containing the code for the desired molecule is introduced into the interior of the bacteria by means of electrical pulses. All that the genetically modified microorganisms then need to multiply and produce the silk protein in bulk is a lot of sugar, a supply of the right amino acids from Evonik's own production, and optimal living conditions (see diagram, pp. 20–21).

96

PERCENT

of the silk on the world market comes from China and India.

This is a fermentation process like those used for centuries to preserve food and produce beer and wine. For a long time it was not known that microorganisms play the decisive role in this process. In the 19th century, the French biochemist Louis Pasteur was the first to show that bacteria are responsible for what is known as lactic acid fermentation. Modern precision fermentation with genetically modified microorganisms has been gaining momentum for around 40 years and is now an integral part of biotechnology. Forecasts predict average annual sales growth of 43 percent for fermentation-based products by 2030—to a market value of more than 35 billion US dollars. →

DEADLY LUXURY

Silk is one of the finest fabrics, but the animal producers pay for its production with their lives

Silk was already considered a luxury good in China under Emperor Wu in the 3rd century. The empire made a good living from the trade.

Cool in summer, warm in winter, almost weightless on the skin, yet shiny and soft—silk has been considered a precious commodity for thousands of years. How it is made was long a closely guarded secret in China, and wearing it was reserved for the emperor and other nobles. The silk business began during the Han dynasty, when the first trade routes extended to Central Asia.

Chinese silk is the product of the caterpillars of two moths, the mulberry silkworm and the tussar moth. People are said to have bred them for the production of silk yarn as early as around 2800 BC: The larvae pupate in a cocoon, from which the moth later emerges. The berry-sized cocoon consists of an 800 to 3,000-meter-long silk thread. In order to obtain this intact, the pupae must be killed in boiling water. Six kilograms of cocoons from around 15,000 caterpillars are needed for one kilogram of raw silk—enough for around six scarves. It is no wonder that this fine material is considered a luxury good and was once worth its weight in gold when it was carried to Europe on caravans via the Silk Road. China is still the stronghold of silk production today; with around 200,000 tons per year, the country accounts for more than 70 percent of the global market.

Today, China produces around 80 percent of the silk used worldwide. It usually comes from the cocoons of silkworms.

Spider silk never came close to such quantities—it is virtually impossible to obtain enough of it to make textiles. But that didn't stop people from trying: At the beginning of the 18th century, attention was initially focused on the cocoons in which spiders lay their eggs to protect their offspring from predators. A Frenchman from Montpellier is said to have been the first to collect, boil, and comb out the feather-light cocoons to make a fabric for stockings and gloves from the thread. Raimondo Maria de Termeyer made the first attempts to extract silk directly from spiders in 1796. The Spaniard secured spiders in a frame to pull the silk directly from the spinneret and wind it onto a bobbin.

At the end of the 19th century, larger quantities were successfully produced in a similar way in an experimental facility run by the French colonial government in Madagascar. The thread was taken from twelve spiders at the same time, twisted into yarn and woven into a cloth that could be admired at the World Exhibition in Paris in 1900. But even then, it was clear that making textiles from spider threads is not really effective.

It was not until 2004 that textile artist Simon Peer and entrepreneur Nicholas Godley took up the idea again. They had more than a million golden orb spiders produce threads, and after five years had enough for a cloak weighing one and a half kilograms. The gold-colored robe has been on loan to various museums since 2012, most recently to the Museum of Islamic Art in Doha, Qatar, until 2024.

The Britons Simon Peers and Nicholas Godley created a gown from golden silk spider threads.

At Evonik Fermas in Slovakia, fermentation is carried out on an industrial scale: The fermenters in the production hall hold 50,000 liters of biomass

“The silk protein required some technical changes in our plant”

RICHARD VEREŠ, HEAD OF TECHNOLOGY AND PROCESS DEVELOPMENT AT EVONIK FERMAS

However, getting genetically modified microorganisms to produce silk protein through fermentation sounds easier than it is—at least if you need large quantities, as AMSilk does. What works well in a two-liter tank in the laboratory does not necessarily work smoothly in a 50,000-liter tank. “Fermenting the protein in suitable yields and bringing it into large-scale production was a challenge,” reports AMSilk CEO Scherbel about the early days of the company, which was founded in 2008 as a spin-off from the Technical University of Munich.

Evonik’s experience as a production partner therefore comes in handy: The chemical company’s biotech hub has specialized in the industrial fermentation of bioproducts for animal feed, cosmetics, and medicine for many years. An Evonik plant was the first to produce large quantities of silk protein. Scherbel has to smile when he thinks back to the start of the collaboration: “It quickly became clear that although we at AMSilk know a lot about how our product behaves in the laboratory, we knew about as much about fermentation on an industrial scale as we do about rocket science. The experts at Evonik always believed in the silk protein and contributed their knowledge so that we were finally able to make the process industrially viable.”

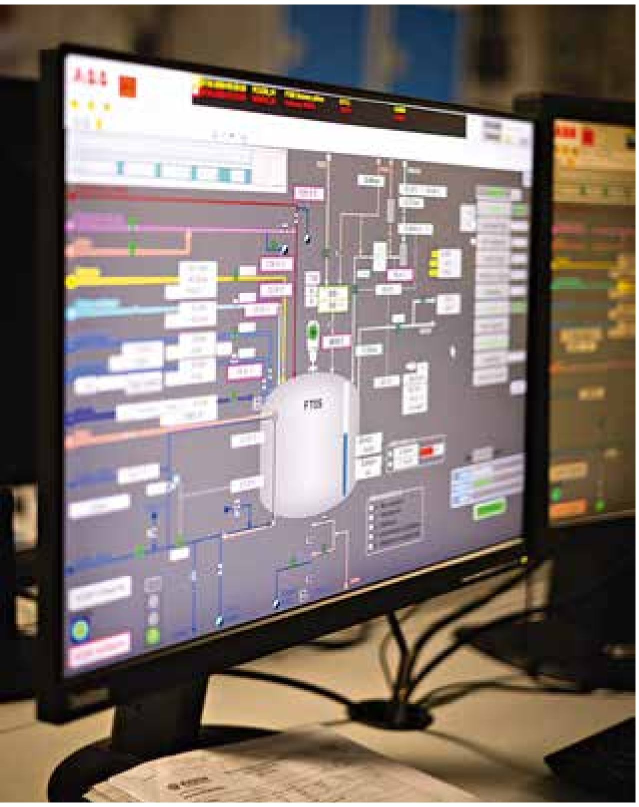
90

PERCENT

of the silk traded worldwide comes from the mulberry silkworm.

FROM LAB TO INDUSTRY

If you want to see this for yourself, you should drive 750 kilometers east from Scherbel’s office in Bavaria, into the heart of Slovakia, where the village of Slovenská Ľupča lies at the foot of the Low Tatras in the shadow of a castle. The Evonik Fermas chemical plant is an important employer for the people who live here, and an internationally significant production site for the biotechnology industry. A total of 23 tanks, each with a capacity of 50 cubic meters, are located in the huge fermentation hall, in which pumps and motors hum sonorously,



Temperature, pH, sugar content, and other values are monitored around the clock (above). Large centrifuges (right) are then used to isolate the silk protein from the biomass

warm temperatures prevail even in winter, and it smells like a bakery.

Yellow lines mark the safe routes. Safety goggles, ear muffs, and safety shoes are mandatory for everyone here. In the control center, specialists work in shifts around the clock to monitor the fermentation process, checking parameters such as pressure, pH, temperature, and sugar content. Directly in front of it is a truck-high tank reserved for AMSilk alone. Inside it, billions of microorganisms produce silk protein.

The process, which was developed in the Munich laboratory, was transferred to an industrial scale here in 2020. Since then, it has been continuously optimized to produce even larger quantities, reports Richard Vereš, Head of Technology and Process Development at Evonik Fermas. “Here, we start with individual laboratory experiments to familiarize ourselves with a new product. Then we start the upscaling process.” Evonik sometimes advises the customer to adapt the genetic make-up of the bacteria, the ingredients or the sequence of the isolation steps for industrial production. It can take weeks or even months to produce a protein in a large tank with the same quality as in the laboratory.

32

KILOGRAMS

of mulberry leaves have to be fed to caterpillars to produce a T-shirt.

The biggest challenge in the production of silk protein is to isolate and purify the target molecules from the bacterial solution—only then can they be spun into a thread later on. To ensure the necessary quality, AMSilk’s and Evonik’s experts have developed a multi-stage process. “The silk protein required some technical changes in our plant,” says Vereš. “For example, we needed new specialized equipment for cell disruption.” This unit is located in a container outside the hall and is responsible for a decisive step in the separation process: It breaks open the bacterial cells, causing them to release the protein. The solution is then centrifuged several times until only spider silk protein remains. During processing, the →

In the Evonik Fermas laboratory, lab technician Kristina Gabonova checks the purity of the protein using liquid chromatography (left). After drying, a white powder—spider silk protein—remains (above)

mixture undergoes several clarification and concentration stages, gradually transitioning into a more refined and concentrated protein solution. After the water has been evaporated in a drying unit, what remains is protein powder, which is delivered to the spinning mill in 20-kilogram barrels.

The fact that Evonik purchased new equipment specifically for AMSilk doubled the capacity and significantly improved the efficiency of the process.

BETTER AND BETTER

Because even the smallest change in parameters can affect the quality of the silk protein, its purity is strictly monitored in Slovenská Ľupča. Employees take samples on a regular basis during the downstream process—hundreds per batch, which are meticulously checked in the in-house laboratory. The measurement results are transmitted to AMSilk several times a week. The finished powder must have sufficient purity for the thread to be spun later. “The samples from today had much higher purity compared to previous years, which is safely above the required level,” reports laboratory manager Juraj Kasala after looking at the screen. “It took years to optimize the process so that the quality remains stable.”

1

KILOGRAM

of silk is enough for six scarves.

Tim Pohlmann and Ronald Mathä accompanied this process. The two men, a chemist and a biotechnologist, regularly travel to Slovenská Ľupča from Germany. They handle contract manufacturing in the field of microbial fermentation. They enable customers to manufacture their products economically at Evonik and open doors to global partners for startups. “We look forward to continuing on this path with AMSilk and further improving the process,” says Pohlmann, for whom close cooperation between both partners is essential. “Evonik ensures transparency and whenever challenges arise, we solve them as a team.” This works so well that the capacity of the plant in Slovenská Ľupča, which runs on green electricity, has quadrupled since the start of production in 2023—several tons of silk protein are now produced in Slovakia every month.

Ronald Mathä is particularly fascinated by the sustainability of the process: “We don’t need any dangerous chemicals for fermentation. Sugar, in this case glucose

In the spinning mill, the powder is turned into a shimmering thread of spider silk, which is finer or coarser depending on the customer's wishes and the end product

"We look forward to continuing to improve the process together with AMSilk"

TIM POHLMANN, HEAD OF GLOBAL BUSINESS SEGMENT CDMO FERMENTATION OF EVONIK

syrup, is the most important ingredient for producing almost any desired product with the help of bacteria in a living system." One example is the powder made from protein molecules that are otherwise only produced in the abdomens of spiders.

But how is this powder turned into a high-tensile thread that could later be used in a silk blouse, a watch strap or a car door handle? As soon as the barrels arrive at the AMSilk pilot spinning mill near Munich, the protein is first gradually stirred into a solvent. The powder must not be allowed to form clumps or the proteins in the honey-like liquid will never line up to form a stable thread, preventing that "magic moment." A lot can go wrong, from cultivation to spinning, but the process now runs smoothly. The machine in the inconspicuous building reliably pulls a silvery spider thread out of the solution around the clock and wraps it around bobbin after bobbin.

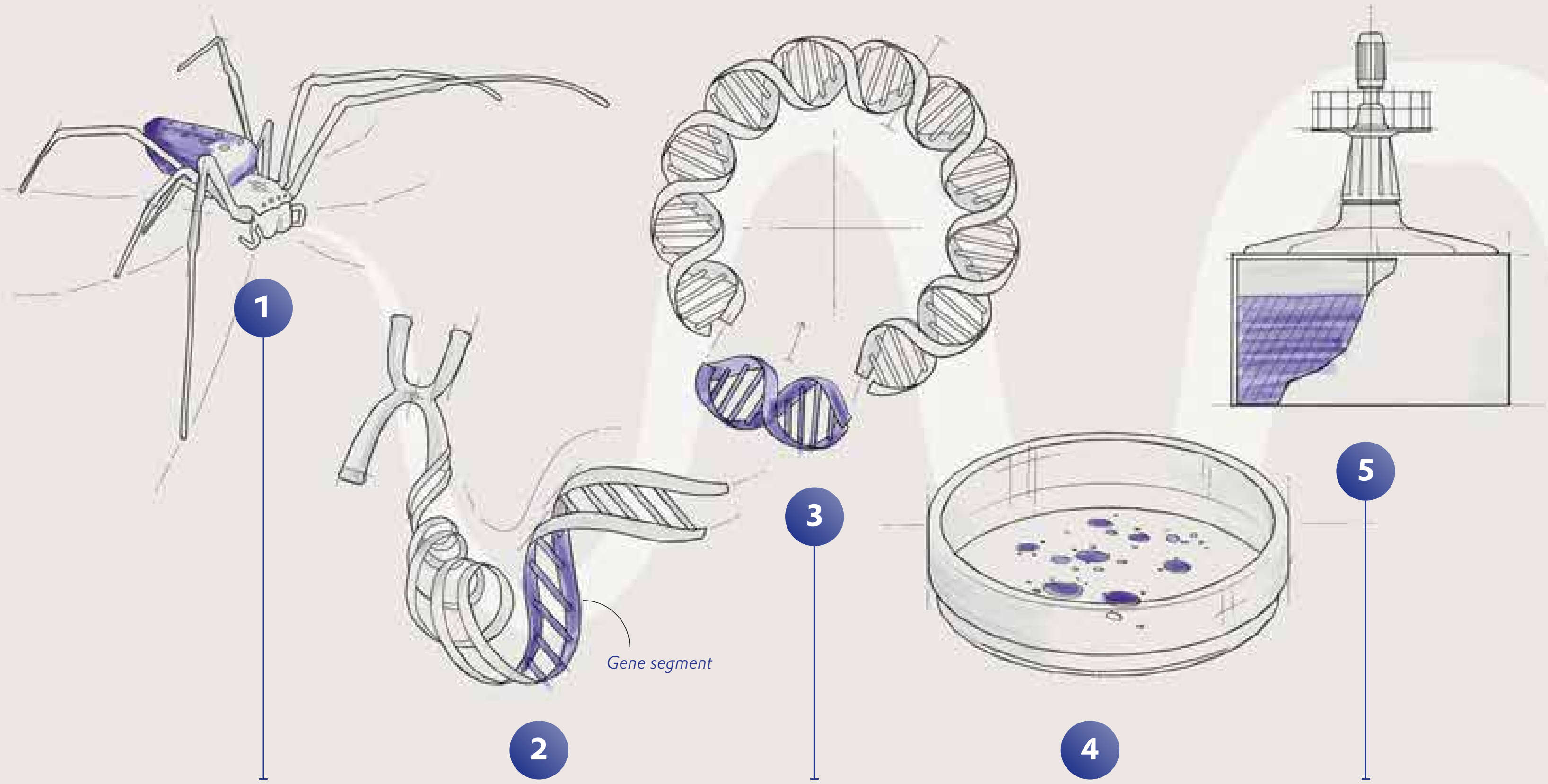
Depending on customer requirements and the intended use, AMSilk is now able to produce thinner or thicker threads. All of them are as light as a feather, very resilient, less sticky—and yet close to nature's model. "I'm certain that we will become one of the leading suppliers of high-performance fibers," says Scherbel enthusiastically. "Great things can happen when the innovative strength of new companies like AMSilk meets the expertise of experienced industrial partners like Evonik." The feeling of magic, for example, when a viscous mass becomes a delicate, silvery thread.

Sina Horsthemke is a science journalist based in Munich. She has a degree in biology and writes primarily about health-related topics and bioengineering

From a spider gene to a silken thread

AMSilk has developed a process that enables bacteria to produce the protein that spiders use to spin their threads. These ten steps can turn spider silk into a blouse

INFOGRAPHIC **MAXIMILIAN NERTINGER**



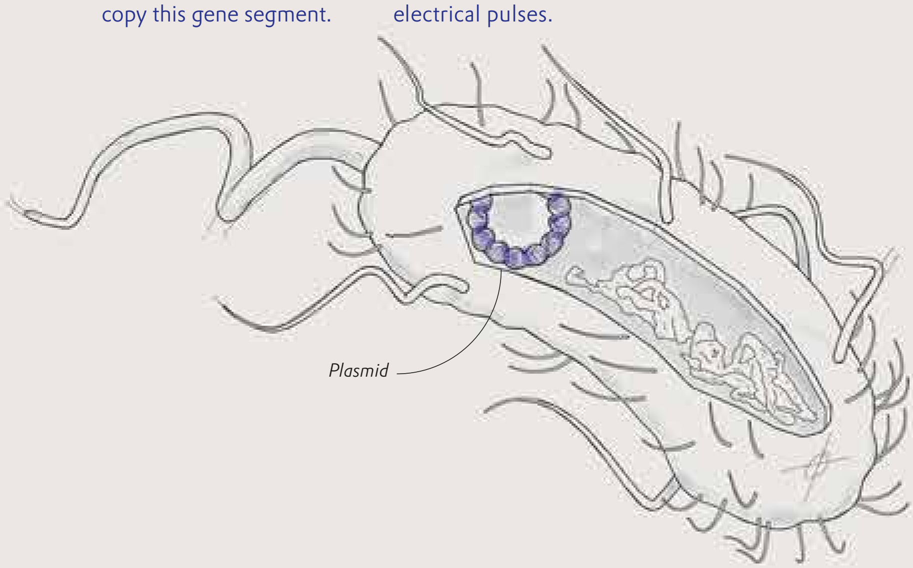
NATURE'S MODEL
The spinnerets in the abdomen of the spider produce a fine, strong thread. The spider weaves this into a web, uses it to abseil, or forms it into a cocoon for egg deposition.

GENETIC ANALYSIS
Researchers identify the specific segment of the spider's genome that contains the genetic blueprint for the silk protein used to spin its thread. The aim is to copy this gene segment.

PLASMID DESIGN
A plasmid is created, first on the computer, then in the laboratory. This ring-shaped DNA molecule containing the blueprint for the protein is introduced into coliform bacteria using electrical pulses.

CULTIVATION
The bacteria that have successfully taken up the plasmid and its protein blueprint are placed onto a nutrient medium in Petri dishes. The bacteria multiply rapidly in the warmth of an incubator.

FERMENTATION
In a bioreactor, the bacteria are fed with nutrients and sugar and continue to multiply. Adding a specific substance initiates the production of silk protein.



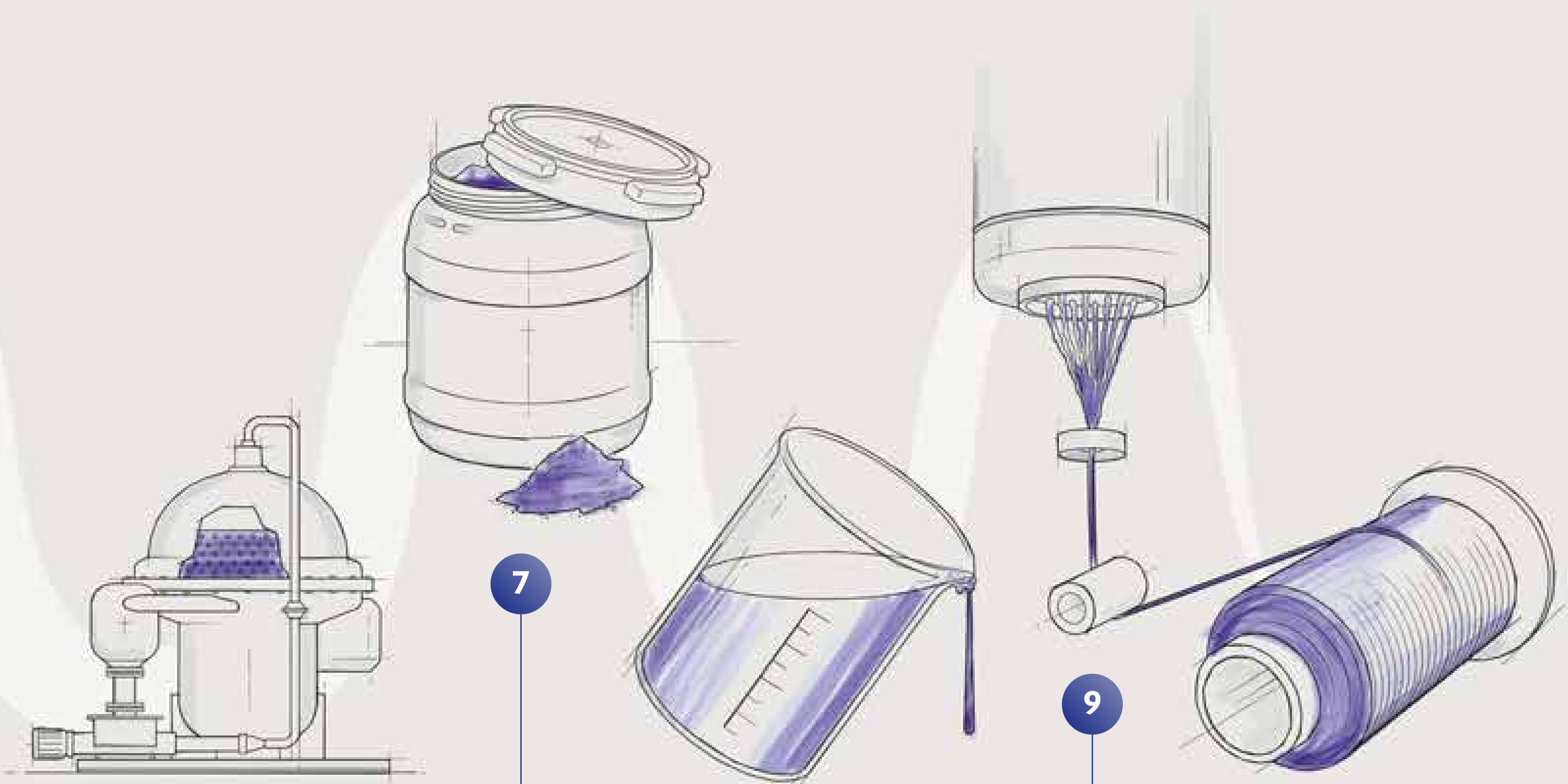
Coliform bacterium
In addition to its own DNA, the bacterium's cell interior now contains the plasmid with the blueprint for the silk protein.

81%
smaller: the carbon footprint of biotechnologically produced silk compared to that of spider silk.

92%
less land is needed because no mulberry trees are required to grow caterpillar food.

97%
less water is used when the silk protein is produced by fermentation.

(Compared to conventional silk production from mulberry silkworm cocoons; source: AMSilk)



6 PURIFICATION
The silk protein must now be isolated from the biomass in a downstream process. Through multiple separation steps, the silk protein is enriched and the latte-colored liquid gradually becomes lighter.

7 DRYING
After the last purification step, the protein must be dried. This takes place in a spray dryer in which the water evaporates. What's left is a white powder.

8 PREPARATION
In the spinning mill, the protein powder is stirred into a solvent. The mass, which resembles viscous honey, must be degassed and filtered to exclude impurities.

9 THREAD FORMATION
The solution is pressed through a spinneret into an agglomeration bath, causing the protein to solidify and the molecules to align. The fine filaments are stretched and combined to form a thread.

10 WINDING
The silk thread is passed through a water bath, dried on heated rollers and wound onto a bobbin. Fully wound, the bobbin holds one kilometer of thread, which weighs just nine grams.

PRODUCTS

The biotechnologically produced silk thread has a wide range of applications and has so far mainly been used in the textile industry—either as an innovative new fiber or as a more sustainable alternative to conventionally produced silk from Asia. For example, the material is currently used in the door handles that are installed in the interior of the Mercedes-Benz VISION EQXX concept car. The Parisian luxury brand Balenciaga produces blouses made from fermented spider silk. And the Omega watch brand is already weaving the AMSilk thread into some of its watch straps. In the future, the protein could also be useful in medicine and agriculture as well as in laundry and dishwashing detergents.

Silanes from a spray gun: In the laboratories in Rheinfelden, new mixtures are first applied by hand in order to test them for properties such as scratch resistance

A CLEAR IMPROVEMENT

Scratch-resistance, durability, and smoothness—these are the qualities consumers expect from bottles and jars. To achieve them, glass containers need a protective coating. Using silanes as the foundation, Evonik and its partner TotalEnergies have developed a safer and more environmentally friendly alternative to conventional methods

TEXT **TIM SCHRÖDER**

Where would we be without glass? We buy pickles, red cabbage, and mustard in jars. We pour beer, sparkling wine, and spritzers from bottles. At Christmas, elegant glass perfume flacons find their way under the tree. According to the industry association FEVE, around 80 million glass bottles and jars enter the European market each year, filled with food, beverages, creams or other cosmetics. Millions more circulate as returnable bottles, traveling between customers and bottlers up to 25 times before eventually being recycled. Besides metal cans, glass is the only packaging material that can be recycled endlessly without losing quality—it can always be reshaped.

Because it's so ubiquitous, glass rarely gets the appreciation it deserves. Most of us focus on what's inside, not on the container itself. But that container has a long list of duties. Bottles and jars need to offer a firm grip, even when condensation forms. They also need to be robust. They must withstand impacts without shattering, ensuring safety. Labels and prints must adhere reliably. For premium products, a flawless appearance is key. A champagne bottle shouldn't show scratches; a €100 perfume flacon must look immaculate. "Glass manufacturers therefore need to deliver a perfect look and feel—it can make a real difference at the point of sale," says Dr. Stefan Hilf, Head of Research & Development for the Smart Effects business line at Evonik's Rheinfelden site.

TWO LAYERS FOR THE FINAL FINISH

To meet these demands, glass containers receive a special coating that is just a few nanometers thick, yet extremely robust. It makes the surface scratch-resistant, gives it a pleasant grip, and enhances its overall quality. For returnable bottles, it also prevents the material from becoming dull and worn too quickly.

For decades, the industry has relied on a tried and tested two-step process. First, bottles are sprayed with butyltin trichloride, which forms a smooth tin oxide layer on the hot glass. This layer fills microscopic cracks and acts as an adhesion promoter for the second step: →

a film of polyethylene wax, which links with tin oxide across the entire surface, providing grip, scratch resistance, and a smooth finish.

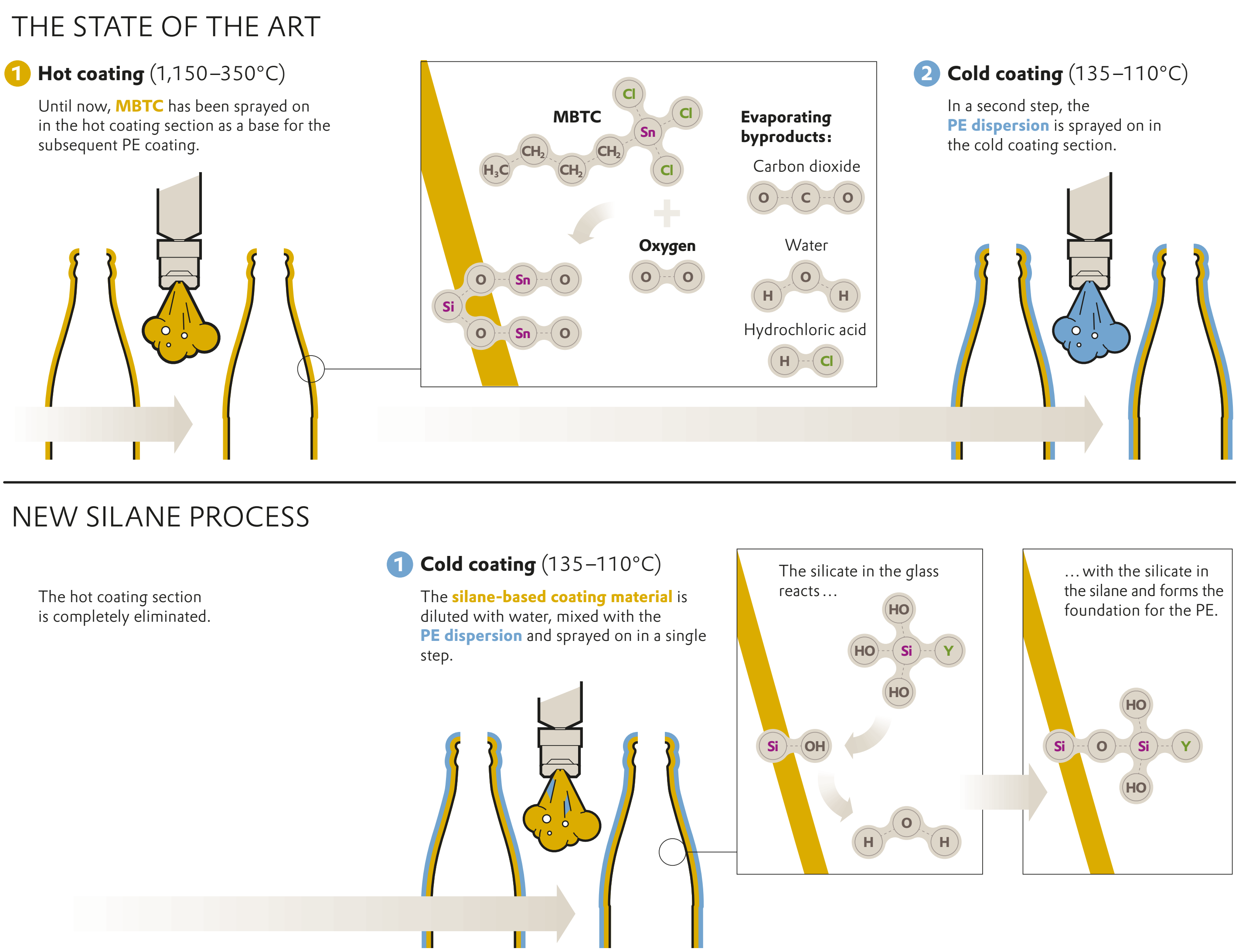
The method is globally established but problematic. Butyltin trichloride is corrosive and toxic to aquatic organisms. In addition, the substance degrades only slowly, meaning it can persist in the environment for a long time and accumulate in living organisms. Since only the harmless tin oxide layer remains on the glass after the reaction, the process is still suitable for the food industry. However, glass manufacturers are only allowed to apply the butyltin trichloride under strict safety precautions. That makes occupational safety costlier and the whole production process more complex. That's why Evonik and French company TotalEnergies jointly developed an entirely new, nontoxic coating approach. It's scheduled for market launch in late 2027, when TotalEnergies intends to deliver the new product—named Glasskote Base 1—to its customers in the glass industry.

TAILOR-MADE SILANES

This new coating is based on silanes—a completely different chemical class of substances than butyltin trichloride. Silanes consist of a silicon framework to which molecular appendages with various chemical functions, known as functional groups, can be attached. "This allows you

COATING IN ONE GO

Until now, glass bottles have been coated with PE in a two-stage process.
The new silane process eliminates the need for hot coating



Many years of experience: Chemical engineering specialist Eckhard Just has been working on silanes for decades and knows how to tailor them. Right: The friction test shows how abrasion-resistant the coating is

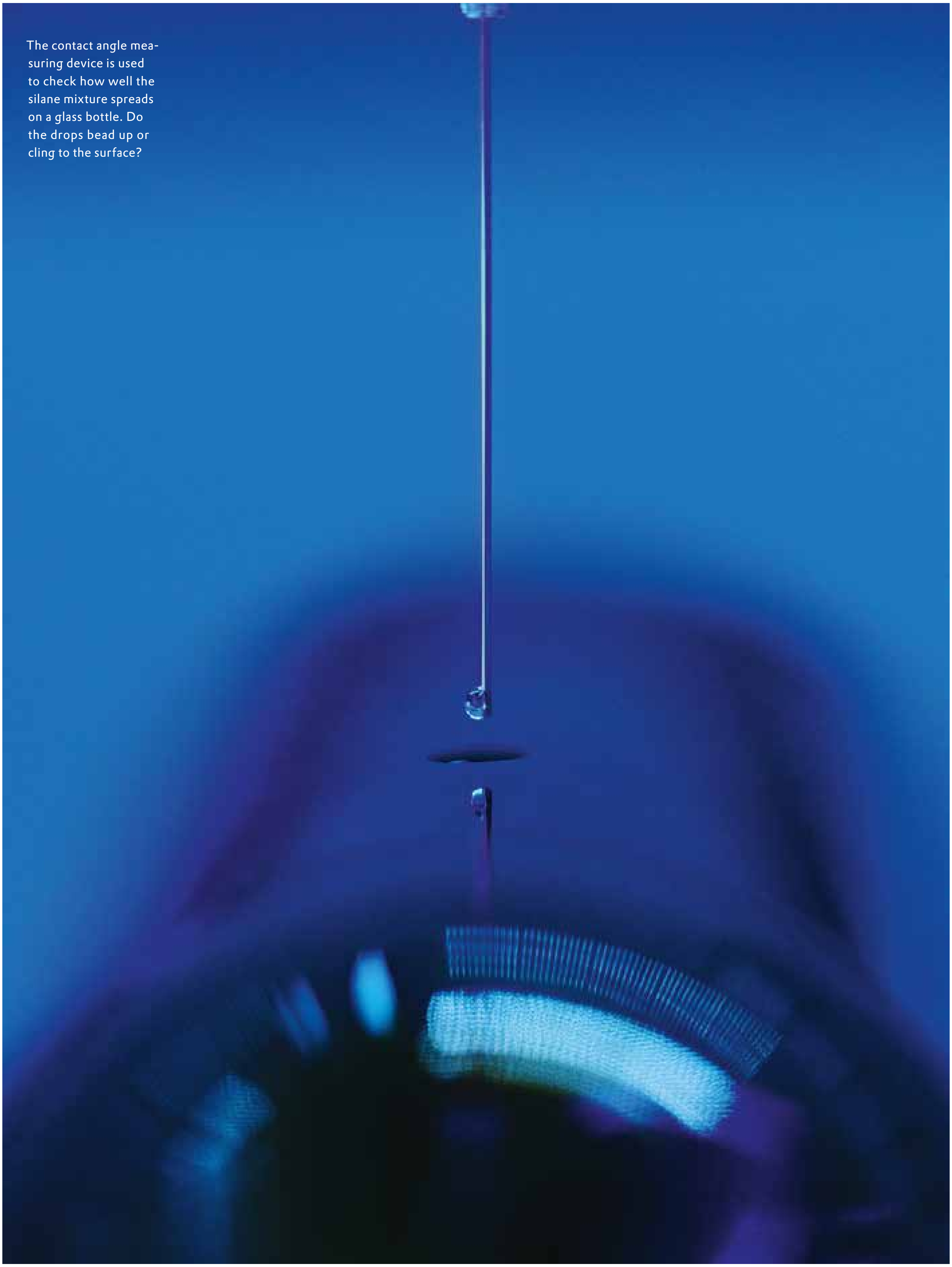
to tailor surfaces with a wide range of effects," says Stefan Hilf. Metals can be made resistant to corrosion; walls can be treated to repel water and prevent moisture and moss formation. "With this new silane coating, Evonik is now entering a new segment of the glass industry," Hilf emphasizes.

It took a long time to reach this point. The team needed a solution that matched the performance of the long-established tin oxide-polyethylene system. Development began in 2019, when TotalEnergies' US division approached Evonik. Having supplied the glass industry with lubricants and release agents for years, their teams were well aware of the challenges surrounding butyltin trichloride. "We reached out to several companies in the United States that had attempted to create an alternative—but none could meet the industry's requirements," says Manuel Keller, Sales Director at TotalEnergies Glass Lubricants Europe. "Evonik was the first partner with the technical understanding and chemistry expertise needed to tailor suitable materials for this use."

THE GOAL: A PERFECT FILM

The breakthrough came largely thanks to the experience of the Rheinfelden team—especially Eckhard Just, who has worked at Evonik in Rheinfelden since 1987. As a chemical engineering specialist, he knows how to give silanes the needed properties and how to handle them—because they can be somewhat capricious. Silanes are predominantly delivered to customers in liquid form. However, the molecules tend to crosslink with one another when exposed to moisture. They form viscous gels, precipitate out of the liquid as flakes, or even clump together. Developing a silane solution that remains stable over a long period of time and only forms a fine, even film on bottles at the very end of the glass production process requires experience. "It's truly a challenge," says Just. "If the liquid ends up clumping in the hoses or spray nozzles of the system, you have a huge problem."

The team had to identify the right acid for processing the silanes, determine the correct pH and the ideal solids content in the aqueous solution, and perfectly →



The contact angle measuring device is used to check how well the silane mixture spreads on a glass bottle. Do the drops bead up or cling to the surface?

“Perfect look and feel make a real difference at the point of sale”

STEFAN HILF, HEAD OF RESEARCH & DEVELOPMENT AT EVONIK SMART EFFECTS

adjust many other parameters. And of course, the right ingredients also mattered. Silanes are assembled from small individual silicon building blocks known as monomers. These monomers join together in pairs or trios to form larger molecules—the dimers or trimers. Whether a silane ultimately forms a thin uniform layer on the surface of a bottle depends, not least, on the mixing ratio of these oligomers.

TESTING IN REAL WORLD CONDITIONS

Eventually, the team found the perfect recipe. Initial spray tests in the lab looked excellent. When Eckhard Just sprayed glass bottles with a spray gun, a thin, even film formed. Then it was time for the first practical trial at a large test facility in the USA. As soon as the bottles had cooled to between 130 and 100 degrees Celsius, the silane—polyethylene mixture was applied—and it formed a flawless film on the bottles.

And the experts achieved something else as well; the silane and the polyethylene wax could be applied to the bottles in a single step. “That was a huge success,” says Hilf, Head of Research, “because it significantly simplifies the coating process compared to the conventional method.” Butyltin trichloride and polyethylene have to be applied separately at two different points in glass production, with butyltin trichloride coming first. It is deposited as a vapor onto the bottles while they are still hot. They pass through a chamber in which a fine mist of butyltin trichloride settles on them. After that, the bottles cool down on the conveyor belt to around 90 degrees Celsius. Only then can they be sprayed with the polyethylene wax. →

Drops in close-up: Joachim Beetz, an expert in inorganic analysis, uses a camera image to analyze how well the liquid adheres to the glass surface. He can measure the curvature of the drop on the screen at the click of a mouse

Laboratory employee Ivonne Gallazzini uses a nuclear magnetic resonance (NMR) spectrometer to check whether the mixture is correct. A perfect coating can only be achieved if the silane monomers, dimers, and trimers are present in the correct ratio

“For high-quality champagne bottles, the layer still needs to become even more scratch resistant”

FABIAN ZSCHOCKE, PROJECT MANAGER GLASS LUBRICANTS AT TOTALENERGIES

EVERYTHING IN ONE GO

Not so with the silane coating. Customers simply mix the silane solution with the polyethylene emulsion of their choice at the plant and then fill the mixture into the spraying system—and that’s it. In recent months, TotalEnergies has carried out additional production tests together with glass manufacturers. Their results are also promising. “With Glasskote Base 1, we produce surfaces that reach 80 to 90 percent of the quality of a butyltin trichloride coating,” says Fabian Zschocke, a project manager and glass production expert at TotalEnergies. “For beer bottles and food jars, that is more than sufficient. But for champagne bottles, for example, the layer still needs to become even more scratch resistant.” He is confident that the quality will continue to increase, as every plant still has the potential to be optimized. “No production facility is like any other,” Zschocke explains. “A new process first needs to be fine-tuned and run in.”

Dr. Karsten Korth, Technical Manager at Evonik in Rheinfelden, is confident that the new technology will match the conventional system. “We will enter the market at the beginning of 2027 and will continue optimizing together with TotalEnergies and the customers—either by adjusting the production facilities or by modifying the silane with further additives,” he says. “What is crucial is that glass manufacturers can switch to the new coating without making major changes to their production equipment.” Fabian Zschocke is currently working with glass manufacturers to further optimize the spray-nozzle technology so that the bottles truly receive a uniform, perfect layer.

Fully automatic filling: The lids of the transport drums are positioned and screwed down under computer control. A filling nozzle is then inserted into the hole and the liquid silane mixture is pumped into the drum

For glass manufacturers, the new technology offers a major advantage: They hardly need to make any modifications to their production lines in order to apply the silane coating. In addition, Glasskote Base 1 facilitates the transition from gas-fired furnaces to electric furnaces. Like many other industries, glassmakers will have to comply with stricter limits on carbon dioxide emissions in the future. Until now, melting furnaces have been heated with natural gas, releasing large amounts of CO_2. In the future, they are to be powered by electricity. The conventional coating process creates problems here: When the tin oxide layer forms on the hot glass surface from the butyltin trichloride, hydrochloric acid is released. Up to now, this acid has been mixed with the exhaust gases from the gas furnaces and thereby heavily diluted. When electric furnaces are used, these exhaust gases are no longer available, and the concentra- →

MILESTONES OF SILANE CHEMISTRY

Silanes have been helping to improve sustainability for many decades. At the forefront of research: Evonik and its predecessor companies.

1857 The chemists Friedrich Wöhler and Heinrich Buff are the first to produce a **gaseous silicon hydrogen compound**. In the same year, Wöhler succeeds in synthesizing the first chlorosilanes.

1942 Chemische Werke Griesheim Elektron AG commissions the first plant for the production of silicon tetrachloride ($SiCl_4$) in the southern part of today's Evonik facility in Rheinfelden. It marks the **birth of industrial silicon chemistry** at the site.

1992 The **"green tire"** reduces fuel consumption by up to eight percent. This is made possible by special silicas and silanes from Evonik's predecessor company Degussa, which are added to the rubber compound.

2006 The first rubber silane that emits virtually **no volatile organic compounds** after processing is launched on the market. Si 466® is a milestone in occupational safety and environmental friendliness.

2026 **PROTECTOSIL® Antigraffiti** has been reliably protecting facades from soiling for decades. In the new variant **Ecotrete** this is done without fluorine compounds for the first time, making it even more environmentally friendly.

Before filling, chemical technician André Schumacher checks the hose lines. Stacked four high on a pallet, the drums can then be shipped to the customer

tion of hydrochloric acid in the air stream reaches critical levels. “For this reason, the authorities prohibited one of our customers from using monobutyltin trichloride,” Zschocke explains. “With Glasskote Base 1, the problem disappears.”

Beyond that, the shift to silanes offers yet another advantage, adds Evonik RD&I manager Hilf. Under the European Union’s new supply chain regulations, companies must ensure that not only they themselves, but also their suppliers comply with environmental protection standards. “This means it also becomes important for bottlers and the food industry whether the glass was produced in a more environmentally friendly way,” says Hilf.

Evonik and TotalEnergies have high expectations for the new technology. The further the performance of the silane improves in an industrial environment, the greater the interest among glass manufacturers is likely to become. One major strength is that, by eliminating the use of butyltin trichloride, it makes production safer and more sustainable in terms of occupational health and environmental protection. Glass is already an environmentally friendly material. Because it can be melted down endlessly, it offers an excellent basis for a true circular economy. And with the transition from gas to electric furnaces, its carbon footprint will shrink even further. The silanes are paving the way for such a future.

Tim Schröder is a science journalist who lives in Oldenburg

TRANSPARENT BUSINESS

Glass is easy to recycle, leaves no taste, and has a high-quality appearance. That's why it enjoys great popularity as a packaging material—all over the world

Sources: FMI, Statista

INFOGRAPHIC **MAXIMILIAN NERTINGER**

Clear course for growth
Sales of glass bottles and containers
in billions of US dollars

Well packaged
Share of materials in the global packaging market
in percent

Bottles and jars
Share of types of glass packaging
in percent

From seltzer to sunscreen
Which products are packaged in glass bottles and containers
in percent

Dirk Diederich is the founder and CEO of the Institute for Glass and Raw Materials Technology (IGR) in Göttingen. He has more than 20 years of experience in glass technology and has been a publicly appointed expert in this field since 2020. He also identifies and analyzes foreign bodies such as glass, plastics, and metals for the Lower Saxony State Office for Consumer Protection and Food Safety

"There are many ways to make glass more sustainable"

As a packaging material, glass faces tough competition from plastic, tinplate, and cardboard—and offers clear advantages when it comes to recycling. Dirk Diederich, CEO of the Institute for Glass and Raw Materials Technology in Göttingen, explains in which applications glass can perform particularly well—and how it can be optimized even further

INTERVIEW **NADINE ALBACH**

At the IGR, cullet mixtures are examined to determine how the mixture affects further processing into recycled glass

Mr. Diederich, why is glass so suitable for food packaging?
It is infinitely malleable and therefore offers all kinds of possibilities for designing packaging. It's also practically infinitely recyclable because it can be melted down again and again without compromising quality. Glass is practically inert, so it hardly reacts chemically: It neither releases substances nor changes itself. This inertness is a top priority for the food industry and the pharmaceutical sector. Glass is also gas-tight. This is important for medicines, but that's not all. If you leave a plastic mineral water bottle in the car in the sun, for example, it swells and carbon dioxide escapes.

Nevertheless, there is competition from other forms of packaging such as plastic, cans, and drink cartons. They outperform glass, especially in terms of weight.
That's right. Plastic bottles, for example, are actually lighter and cause less carbon dioxide emissions during transportation. But plastic can't be recycled at will. I can't easily make a new product from a batch of 100% recycled plastic, because the molecular chains have become shorter. I need new polymers every time, and most of them are made from crude oil. Plastic also has the disadvantage that substances can migrate from the plastic into the product and change the taste, for example. In the EU, many plastic additives are subject to strict limits that are regularly reviewed. Glass therefore comes into its own with sensitive foods, because it is practically inert.

And how does glass compare with cans or drink cartons?
Metal cans are not inert. That's why they are provided with thin polymer coatings on the inside for corrosion protection—for tomato paste, for example. Substances can then be released from the coating. And as for the drink cartons, some time ago, the Federal Environment Agency came to the conclusion that they are very environmentally friendly because they weigh less. But that's only half of the story. It's important to remember that cardboard is made up of different composite materials that are difficult to separate. And if I want to make something new out of the paper, I have to add new fibers. Furthermore, as far as I know, the old carton, without the current plastic closure, was used for the life cycle assessment. →

Before the actual measurement series starts in the laboratory, sample solutions are prepared in volumetric flasks

“Because I can produce glass entirely from cullet, this alone can save up to 30 percent of the primary energy”

Despite their advantages, bottles and other glass containers are under pressure. In recent years, global production has shrunk by around 20 percent. Production sites in Germany have been closed. What’s the explanation?
We don’t yet know all the reasons for this trend. This is because all packaging in the food sector has lost ground—cardboard and PET bottles have lost a lot, while glass has only lost a moderate amount. We suspect that consumption has changed, because we’re seeing this development in all packaging materials. It’s clear that the beverage can is currently “in,” especially among young people—with energy drinks, for example. From a marketing point of view, glass is probably more “old school” here at the moment. In addition, glass bottles are no longer permitted at mass events due to political regulations, because people could injure themselves. In South America and South Africa, on the other hand, the glass market is growing significantly.

How can the industry strengthen glass packaging in the future?
Clearly by focusing more on sustainability. There are many levers, starting with the material. For example, you can increase the proportion of cullet from recycling during production, because this greatly reduces energy consumption compared to new glass—for every ten percent of cullet, I save three percent of the energy. Because I can produce glass entirely from cullet, this alone can save up to 30 percent of the primary energy. Packaging material accounts for up to 50 percent of the carbon footprint of food. In this respect, the food industry is thinking very carefully about which packaging it should use. For high-class products, where the color of the glass is also important, we can achieve a cullet content of around 40 percent. For other products, up to 100 percent.

And what can be done about the weight?
Thin walls really are a major topic. They save raw materials and energy during production and make the packaging lighter—which in turn saves fuel during transport. Thin walls are of particular interest for disposable containers, which are often transported over long distances. Forty-eight percent of all glass containers in Germany are disposable, so saving material is an effective lever. Glass has already become thinner over the decades, thanks to new technical processes. In addition, the wall thickness has become more and more uniform. But we’re still a long way from the end. In the meantime, reusable beer bottles that are significantly lighter than conventional ones have also been introduced.

How can that be implemented technically? After all, bottles and glasses aren’t supposed to break.
New forming processes, targeted temperature control along the production process, and better monitoring with the help of AI and camera technology can all make thinner glass stronger. Of course, there must be no unintentional glass breakage. Contamination with foreign bodies and glass splinters during the filling process must be prevented. New coatings such as those from TotalEnergies and Evonik can also help here, as they are able to protect the glass even better against scratches and damage. In addition, this reduces the consumption of tin.

Glass expert Dirk Diederich in conversation with *Elements* editor Nadine Albach

What other measures can be taken to make glass even more sustainable?
Increasing recycling rates even further—not just in Germany and Europe, but worldwide. Germany, Austria, and the Netherlands were the first to establish glass recycling in the 1970s. In Germany today, more than 80 percent of glass is recycled rather than thrown away. In the meantime, however, other countries such as Switzerland, Norway, and Sweden have overtaken us. It's also good to know that other countries have caught up massively. Hardly any recycling used to take place in Spain or Italy. Today, these nations are also reaching high values—unlike the United States, where the figure is less than 30 percent. There, but also here in Germany, it's important to continue encouraging people to dispose of used glass correctly.

Recycling is one thing. But can you still tease something out of the material itself?
Of course, through further energy savings in production or through alternative sources of raw materials. Glass is made from the primary raw materials sand and soda—i.e. silicon dioxide and sodium carbonate—as well as dolomite or lime—magnesium or calcium carbonate. It has a relatively high CO_2 load due to the carbonates. In the future, lime could alternatively be separated from drinking water, for example, in order to conserve other lime deposits. The salt obtained in seawater desalination plants could be converted into soda. This sodium chloride could be broken down into its components via electrolysis—the sodium could then be used with water and CO_2 from industry for soda production, and the chlorine could be used to disinfect drinking water.

You just mentioned carbon dioxide emissions. Could the glass industry distinguish itself here in the future by making savings?
Clearly yes, it must. This is because the entire industry in Europe is under massive pressure as a result of trading in CO_2 certificates. I see a multi-stage process here. We need to recycle more and use CO_2-neutral raw materials. We have to reduce weight and also work on the coating of the glass surface in order to optimize the whole thing. There are also alternative energy sources—wind, solar, and hydropower. Then we can actually melt glass in the future without natural gas or oil. Whether we use the electricity directly or turn it into hydrogen first remains to be seen. Incidentally, the idea of using electricity is nothing new—it has been done this way for many decades. Glass is melted in furnaces that are normally heated from above with gas. For dark glass, I also have to use electrodes to supply radiant heat from below, because I can't get enough energy into the area at the bottom of the tub via the tub vault alone. The key factors are that the electricity is affordable and comes from renewable sources.

What opportunities do you see for glass in the future?
The use of this material will increase massively—in very different areas. In the future, specially equipped window panes will produce electricity. Buildings can also be heated by radiant heat, as in a conservatory. In general, glass will continue to gain importance in insulation, house construction, and building technology. Because we are now able to produce increasingly thinner glass, we can also save a lot of material. The automotive industry is tending to go back to glass for certain plastic parts, such as lenses for LED headlights, because of the high quality. And then there's even the idea of storing data in glass, in huge quantities. For the food sector, I expect to see a return to glass in some areas because of its unique properties.

Vancouver on Canada's West Coast is home to numerous research institutions and companies specializing in biotechnology (top). Kendall Square in Cambridge, Massachusetts, with its renowned MIT is considered "the most innovative square mile on the planet" (below)

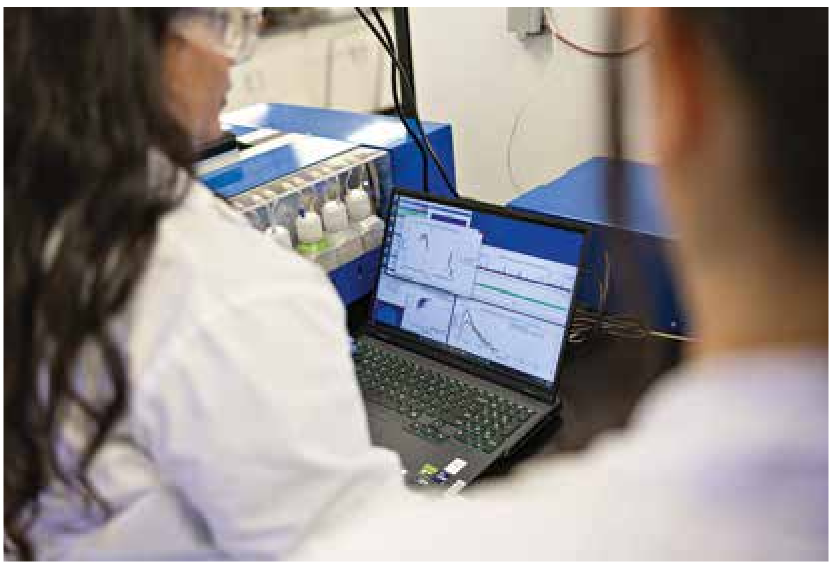
AN ECOSYSTEM FOR LIPID NANOPARTICLES

Why Evonik established a presence in Vancouver and Cambridge: to be close to cutting-edge science, innovative startups, and the next breakthroughs in RNA delivery

TEXT **NORBERT KULS**

Pieter Cullis often dons dark blue suits for official events, but in his University of British Columbia lab, white takes center stage. His unruly white hair and bright white lab coat lend him a professorial air, while ideas for papers and projects are scrawled in white marker on the large fifth-floor window overlooking the atrium of the Life Sciences Centre. Amid this setting, a small snowflake-shaped lapel pin might go unnoticed, but it serves as a subtle emblem of great distinction. Adorned with a golden maple leaf, the white pin marks Cullis as an Officer of the Order of Canada, one of the nation's highest civilian honors.

Recognized for his pioneering work in lipid nanoparticle technology—a key component of the Pfizer-BioNTech and Moderna COVID-19 vaccines—the Professor of Biochemistry and Molecular Biology is far more →



Lipid solutions used for the formulation of lipid nanoparticles (LNPs) in Evonik's Vancouver Labs (top). Innovation Projects Manager Zahra Merchant is testing LNP formulations on specialized lab equipment and reviews the results on a computer screen (middle). An impingement jet mixer creates LNPs by rapidly combining lipids with a nucleic acid payload (bottom)

“We’ve been working since the 1980s on getting cancer drugs as specifically to the tumor as possible”

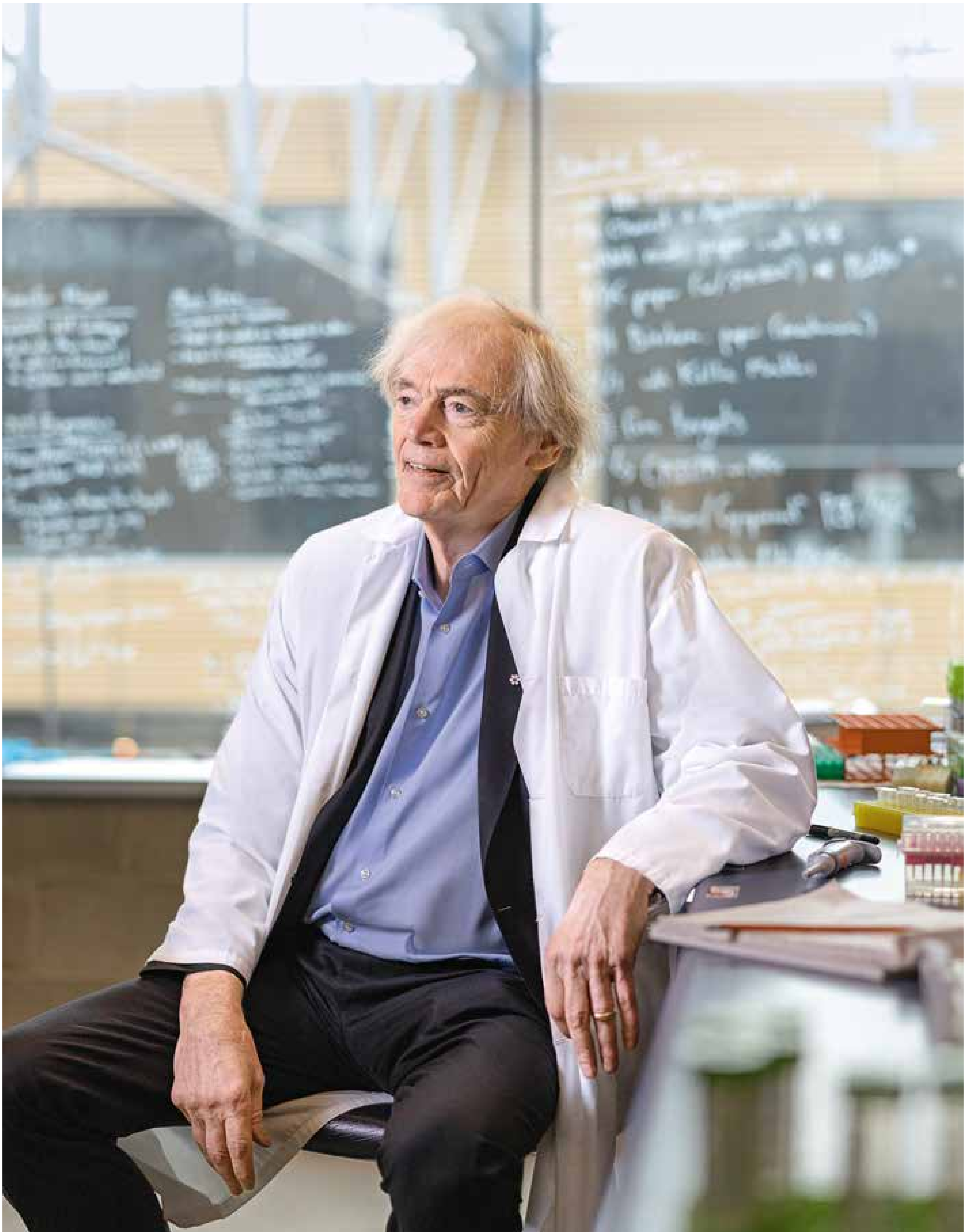
PIETER CULLIS, SCIENTIFIC ENTREPRENEUR AND PROFESSOR FOR BIOCHEMISTRY AND MOLECULAR BIOLOGY AT THE UNIVERSITY OF BRITISH COLUMBIA

than a typical academic. Cullis is a serial entrepreneur whose four decades of perseverance have supported the rise of nucleic acid-based medicines and the technologies for their precise delivery. Preferring the term “scientific entrepreneur”, Cullis is widely regarded as the driving force behind Vancouver’s emergence as a biotech and life sciences hub, rivaling established industry centers like Boston and San Francisco.

MESSENGER RNA TAKES CENTER STAGE

For years, nucleic acid-based therapeutics and the lipid nanoparticles (LNPs) that deliver them into human cells were primarily known to scientists—despite successful clinical trials, new drugs targeting rare diseases, and breakthroughs addressing adverse reactions in LNP formulations. The COVID-19 pandemic changed that, thrusting mRNA into the public spotlight as a global acronym for hope.

Messenger ribonucleic acid (RNA) carries instructions for the body to produce proteins, while LNPs—little bubbles of lipids—encapsulate and protect the genetic material. As the world learned this new scientific vocabulary in 2020, the focus has since shifted to the vast future potential of RNA therapeutics and LNPs. →



Fully suited operators monitor vial fill stations for LNPs in the clean room of Vancouver Labs. Phase 1 and 2 clinical production runs take place in Vancouver, while larger Phase 3 and commercial manufacturing are conducted at Evonik's site in Birmingham, Alabama

FROM VACCINES TO A WIDENING THERAPEUTIC FIELD

Potential applications span cancer, HIV, malaria, tuberculosis, brain diseases, cardiovascular conditions, and genetic disorders. "For now, cancer applications look particularly interesting," says Cullis, pointing to personalized cancer vaccines nearing clinical trials with the promise of much higher cure rates than chemotherapy. That has been his long-time goal. "Since the 1980s, we've been working on getting cancer drugs as specifically to the tumor as possible," Cullis says.

Beyond cancer, there are many rare diseases. "Imagine a child born unable to produce a specific protein. You could save that child's life by using medicines that instruct the liver to produce the missing protein—medicines that could be developed in just a few months. It is enormously exciting."

AN EARLY SHIFT TO A PROMISING TECHNOLOGY

Evonik positioned itself early for the shift to nucleic acid-based medicines. In 2016, the company acquired Transferra Nanosciences—formerly Northern Lipids, one of Cullis' early commercial ventures—thereby securing a foothold in Vancouver's lipid-delivery ecosystem and expanding its capabilities in injectable drug delivery services. The strategy was straightforward: Be where science meets entrepreneurialism, so ideas can move quickly from bench to process to clinic.

"We are on the cusp of a revolution," says Mike Parr, Global Head, Strategic and Technical Marketing at Evonik's Vancouver Labs, who studied under Cullis in the 1990s and later did postdoctoral work at Harvard Medical School. "The pandemic has accelerated the promise of nucleic acids delivered via LNPs."

One active program supported by Evonik's Vancouver Labs is ETH47, an mRNA-based antiviral designed to prevent virus-induced asthma attacks by bolstering innate defenses in the airways. Last year, the Munich-based biotech company Ethris announced a Phase 2a trial for the therapeutic which is administered as an intranasal spray.

"The pandemic has accelerated the promise of nucleic acids delivered via LNPs"

MIKE PARR, GLOBAL HEAD, STRATEGIC AND TECHNICAL MARKETING, AT EVONIK'S VANCOUVER LABS

Dermot Kelleher, Dean Emeritus of the Faculty of Medicine at the University of British Columbia, emphasizes the need for pandemic preparedness

To help eliminate potential side effects to LNPs, Evonik is also developing and testing a novel type of structure for PEG lipids, one of the four main lipids in LNPs.

Inside Evonik's Vancouver Labs—two unassuming buildings a 45-minute drive from downtown—scientists combine lipids with a nucleic acid payload in high-velocity impingement jet mixers to form nanoparticles. Behind thick windows and sealed doors, fully suited operators monitor vial fill stations in the site's clean room. "That's the material that goes into humans," Parr says. "At that stage, mistakes are not an option." Phase 1 and 2 clinical production runs take place here, while larger Phase 3 and commercial manufacturing is conducted at Evonik's site in Birmingham, Alabama.

LNPs hold the key to the future success of RNA technology. "If there is one message that captures the state of the field, it is that delivery remains both the critical step and the defining opportunity," says Robert Langer, Institute Professor at the Massachusetts Institute of Technology (MIT) in Cambridge, a pioneer of modern biomaterials and drug delivery and the co-founder of the biotech firm Moderna. (See essay p. 42)

Evonik partnered with Vancouver-based Acuitas Therapeutics during the pandemic. Acuitas, also co-founded by Cullis, provided the LNP delivery technology for the Pfizer-BioNTech vaccine. Within months, Evonik scaled up production to manufacture two lipids used in the vaccine—a clear reminder that delivery science and robust supply chains turn bench breakthroughs into reality.

FROM UNIVERSITY LABS TO STARTUP CULTURE

At the outbreak of the pandemic, Cullis was already a seasoned expert in LNP technology. A physicist by training, he began studying lipid structures in biological membranes in the late 1970s after joining UBC as an assistant professor. Over time, he learned to manipulate these structures and envisioned their potential as drug delivery vehicles. Becoming a scientific entrepreneur seemed to happen almost by chance. He and his lab collabo- →

rators had invented a device to produce liposomes that attracted commercial interest. "I wanted to keep my team together, and the only way I could figure out how to do that was starting a company."

In Vancouver's biotech scene, the names of Cullis' original research group and early startup co-founders are revered, much like the founders of Google or Apple in Silicon Valley. "Over four decades, we started umpteen companies in the liposome and LNP space, with a revolving door of people doing graduate or undergraduate work in Pieter's lab and then joining these companies," says Tom Madden, co-founder and Chief Executive Officer (CEO) of Acuitas. Madden was one of Cullis' original collaborators and later served as CEO of Northern Lipids. A large-scale graphic panel in an Acuitas conference room, illustrating the company's journey since 2009, captures their vision: "mRNA is the future. THERE ARE NO LIMITS." Another declaration reads: "We are SAVING the WORLD."

Personal connections run deep in Vancouver's startup world. "Pieter cultivated a group of younger entrepreneurs who absorbed his way of thinking and acting," says Evonik's Parr, who also ran a startup for a while. "That's why it's so important for Evonik to have a physical presence in Vancouver—to stay connected to the startups emerging from the university."

THE MASSACHUSETTS CONNECTION

Research institutions and companies in the Greater Boston life sciences cluster

Wendy Hurlburt, CEO of Life Sciences British Columbia, credits a go-getter attitude shaped by immigration, collaboration, and a self-reliant outpost mentality for Vancouver's entrepreneurial spirit

Vancouver's location in Canada's westernmost province seems to shape its entrepreneurial spirit as well. "World-class research is always the foundation, and the University of British Columbia has been a biotech engine for decades," says Wendy Hurlburt, CEO of Life Sciences British Columbia, an industry association. She also credits the industry's growth to a distinct West Coast mindset—a go-getter attitude shaped by immigration, collaboration, resourcefulness, and a self-reliant outpost mentality.

British Columbia now boasts the fastest-growing life sciences sector in Canada, with over 2,000 companies employing close to 20,000 people, the majority of whom are based in Greater Vancouver.

"Vancouver has always been an entrepreneurial and innovative place," agrees Dermot Kelleher, Dean Emeritus of the Faculty of Medicine at UBC. "But it still lacks the critical mass of life sciences hubs like Boston."

EVONIK'S VANCOUVER-BOSTON CONNECTION

To complement what Vancouver offers, Evonik looked eastward. In 2024, Evonik established a foothold in the Greater Boston biotech cluster, tapping into its critical mass. Evonik's Cambridge Innovation Satellite specializes in LNPs as well and features a modern life sciences lab space located on MIT's campus in Kendall Square, often called "the most innovative square mile on the planet."

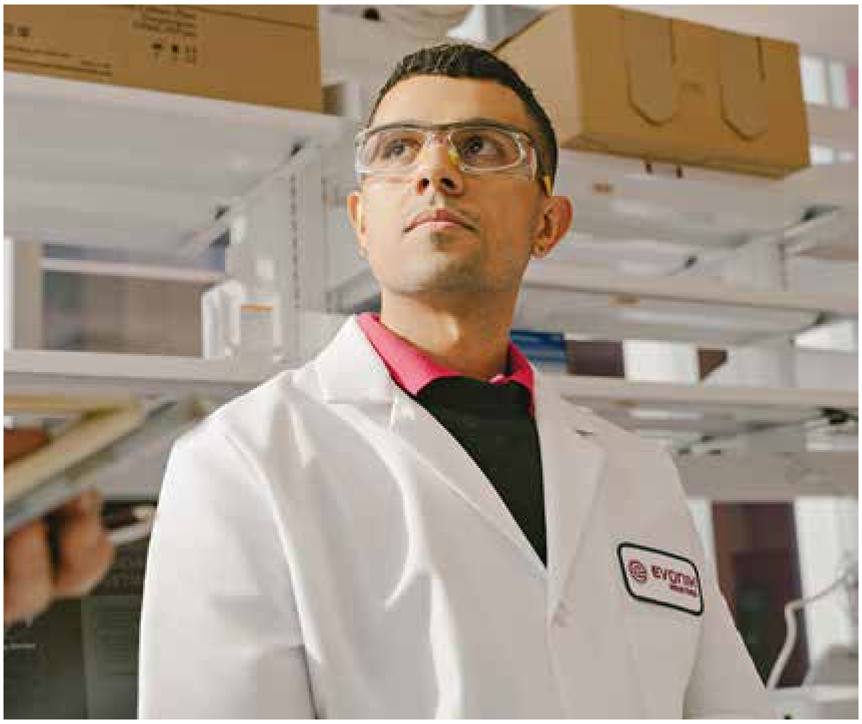
Like Vancouver, Evonik's Cambridge presence fosters collaboration with a vibrant cluster of startups, academic institutes, and hospitals. "In Cambridge, we are part of an extraordinary ecosystem where science, innovation, and business drive seamlessly converge. This unique environment allows us to remain at the forefront of scientific advancements, with a strong focus on early-stage research and development," says Andrea Engel, Senior Director of Cell and Delivery Systems at Evonik. Cutting-edge ideas are exchanged casually in Cambridge—even at the local coffee shop. "The community is incredibly open and supportive. Researchers from neighboring organizations can easily connect, sometimes just by crossing the street, and collaborate on formulations," Engel says.

In the lab, Daniel Costa, Senior Scientist for Nucleic Acid Delivery and an MIT postdoc alum, uses a nebulizer to test LNP formulations for lung diseases like asthma—administered via inhalation instead of injection, enabling the direct delivery to the mucosal surfaces of the airway.

Another focus of the Innovation Satellite is in vitro testing of formulations in cell-based systems. On a computer screen, cellular compartments appear as striking blue and red blobs, reminiscent of an impressionist painting. →

“We are part of an extra-ordinary ecosystem where science, innovation, and business drive seamlessly converge”

ANDREA ENGEL, SENIOR DIRECTOR OF CELL AND DELIVERY SYSTEMS AT EVONIK’S CAMBRIDGE INNOVATION SATELLITE



Daniel Costa, Senior Scientist for Nucleic Acid Delivery in Evonik's Cambridge Innovation Satellite, uses nebulizers (right) to test LNP formulations for lung diseases like asthma

PANDEMIC PREPAREDNESS IN CANADA

Despite the focus on new medical applications, the toll of the pandemic has not been forgotten. "We must maintain our focus on pandemics," says UBC's Kelleher, who helps lead the University's Immuno-Engineering and Biomanufacturing Hub (CIEBH). Established in 2023, CIEBH is one of five national research hubs created by the Canadian government to bolster biodefense. Its relevance has grown since U.S. Health and Human Services Secretary Robert F. Kennedy Jr. announced the cancellation of approximately $500 million in federal funding for mRNA vaccine research last year.

"Canada has strong capabilities in RNA and lipid nanoparticles, and we aim to have the capacity to rapidly manufacture products based on these technologies during a pandemic for early stage clinical trials," says Kelleher. "Partnering with companies like Evonik will be key to scaling up production." Evonik's Mike Parr serves as the industry representative on CIEBH's governance committee.

A key initiative of the CIEBH is the Avenger program, co-led by Cullis. The program focuses on developing mRNA LNP vaccine formulations to protect against viral and bacterial pathogens, while also advancing personalized cancer vaccine research and clinical trials.

That could lead to yet more awards for Cullis, who, in addition to receiving the Order of Canada has been honored with numerous other prestigious accolades both pre- and post-pandemic. Like his American colleague Langer, Cullis is considered a candidate for a future Nobel Prize.

At the beginning of his career, he couldn't have envisioned that his work would lead to 400 published articles, 100 patents, and a formidable biotech ecosystem in Vancouver. Yet Cullis never doubted the potential of his research. "I just knew it was going to work out," he says.

Norbert Kuls is Evonik's Communications Manager in North America and a former US correspondent for German newspapers.

Perspective on RNA therapeutics, LNPs, and what comes next

Synthetic messenger RNA has revolutionized the development of medicines. While the focus has so far been infectious diseases, attention is now also turning to cancer and rare diseases. A key factor lies in the delivery systems

By Robert S. Langer

Prof. Robert S. Langer is an MIT professor in Cambridge and a pioneer in biomaterials and drug delivery. His research has enabled safe, effective RNA delivery systems, helping advance mRNA therapeutics. He co-founded the biotech company Moderna, contributing to vaccines and innovative RNA-based treatments

RNA medicines, particularly messenger RNA (mRNA), have illustrated how the combination of engineering and biology can reshape what is possible in human health. mRNA is a naturally occurring molecule that cells use to carry genetic instructions from DNA to the ribosome, where proteins are synthesized. In therapeutic applications, synthetic mRNA follows the same principle: once delivered into cells, it provides a temporary blueprint for producing a specific protein that can perform such functions as trigger an immune response, or replace a missing protein, or modulate cellular activity. Although mRNA entered public awareness during the COVID-19 pandemic, the foundational science spans more than 60 years. The COVID-19 vaccines demonstrated the full maturation of this technology: highly effective immunizations can be developed, manufactured, and deployed at unprecedented speed, with Moderna's roughly 94 percent efficacy underscoring how far the field has advanced. For comparison, the flu vaccine typically achieves approximately 40–50 percent efficacy. At the same time, key challenges remain, including extending the durability of protection, improving tolerability, and expanding delivery beyond the traditional intramuscular route to more patient convenient application routes like inhalation.

Looking ahead, the potential of RNA extends far beyond infectious diseases. Personalized cancer vaccines are already producing encouraging clinical results and are likely to become increasingly central to oncology care. In addition, nucleic acid delivery opens the door to areas such as protein replacement, gene editing, and cell-specific modulation, provided we can reach the correct cells reliably and consistently. Achieving tissue- and cell-targeted delivery remains one of the central bottlenecks in the field and, at the same time, one of its greatest opportunities.

> "Delivery systems must become more tunable so that RNA reaches the intended cells with sufficient potency and durability while avoiding adverse drug reactions"

Lipid nanoparticles have been essential for RNA therapeutics, providing stability and facilitating cellular uptake. Yet no single formulation can serve every therapeutic need. The ideal delivery system depends on cell type, tissue architecture, and disease biology. This is why combining rational design with high-throughput experimental screening is essential, and why the integration of machine learning and other AI-guided approaches is accelerating progress. These tools can now propose lipid combinations and formulation parameters that may offer faster routes toward extrahepatic and cell-specific delivery, while also helping establish emerging design principles that improve safety and tolerability.

Equally important is recognizing that what we deliver must be matched by how we deliver it. Microneedle systems offer one minimally invasive way of administering RNA, with the promise of enabling more consistent vaccination and greater global reach. In parallel, mucosal delivery is advancing rapidly, supported by material-based strategies aimed at provoking strong immune responses directly at respiratory surfaces. Both approaches represent meaningful steps toward broadening access, improving patient experience, and aligning delivery with the natural biology of infection.

IMPROVEMENTS FOR ONCOLOGY AND RARE DISEASES

As RNA platforms mature, progress is likely to unfold across several domains at once. Oncology will continue to benefit from more refined personalized vaccines and therapeutic combinations. Genetic and rare diseases will see improvements through targeted RNA and gene-editing strategies that expand beyond the liver. Respiratory pathogens may increasingly be addressed through intranasal or pulmonary formulations that establish strong mucosal immunity. Immune and inflammatory disorders could benefit from RNA medicines capable of directing therapeutic signals to specific cell types.

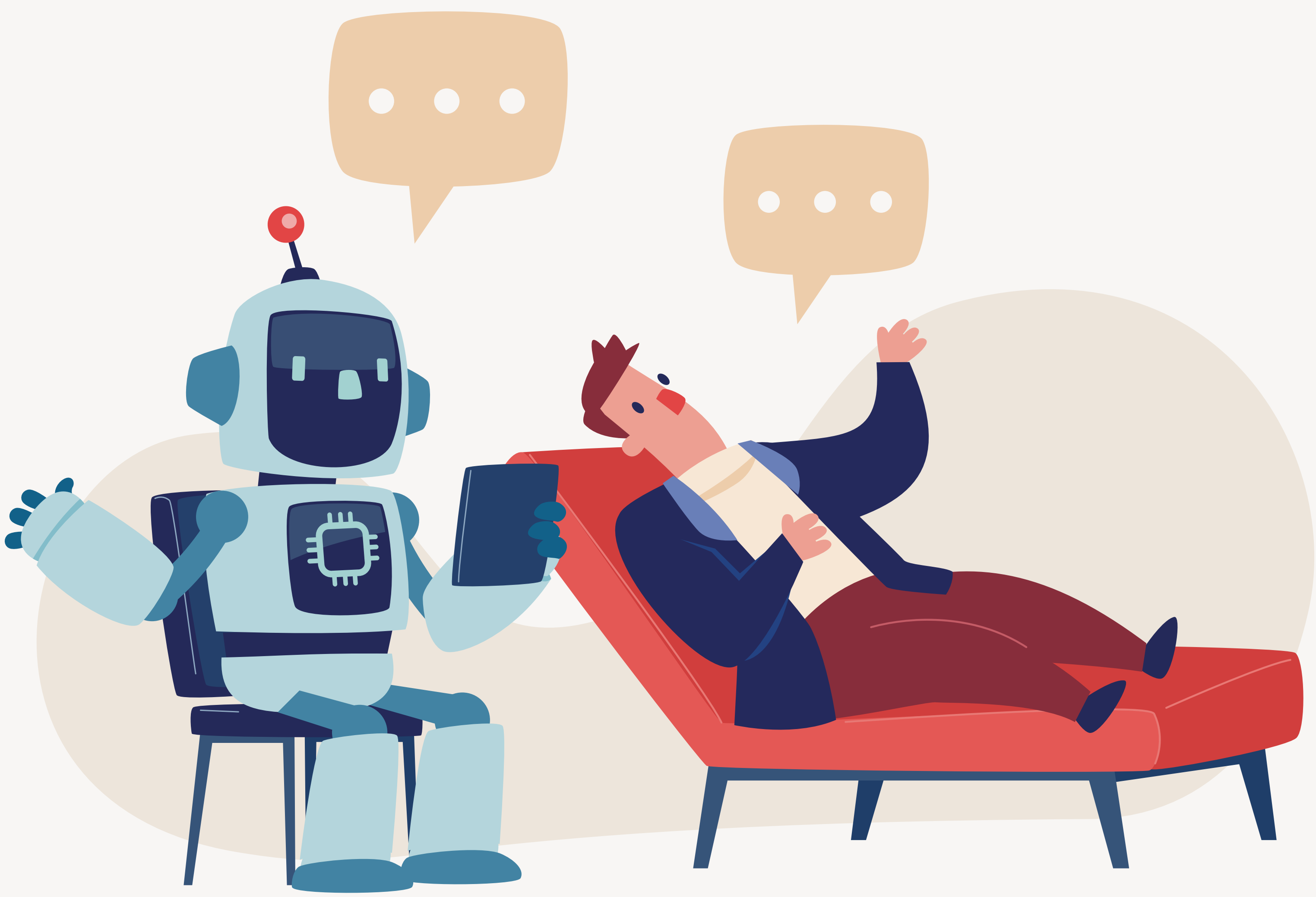
Realizing this vision will require continued engineering innovation. Delivery systems must become more tunable so that RNA reaches the intended cells with sufficient potency and durability while avoiding adverse drug reactions. Safety profiles must continue to improve, even as existing mRNA vaccines already compare favorably with many traditional vaccines. Manufacturing and stability will play an equally important role: robust, scalable processes and formulations that maintain integrity at room temperature or in dry-powder formats will be essential for global access. Finally, the field will continue to expand beyond LNPs alone. Polymers, hybrid systems, and device-based solutions such as microneedles will complement, rather than replace, lipid nanoparticles, creating a broader toolkit that can be matched to diverse biological problems.

THE IMPORTANCE OF THE "BUMP EFFECT"

None of this progress occurs in isolation. The Boston-Cambridge ecosystem, anchored by leading research universities, world class hospitals, and a dense network of entrepreneurs and investors, has been instrumental in accelerating the translation of fundamental discoveries into approved medicines. The "bump effect" of Kendall Square, where proximity promotes unexpected encounters, idea exchange, and the rapid formation of new teams and companies, remains a defining engine of innovation. A culture that embraces academic entrepreneurship continues to help breakthrough concepts transition from the lab to the clinic at remarkable speed.

If there is one message that captures the state of the field, it is that delivery remains both the critical step and the defining opportunity. As we invent better nanoparticles, smarter materials, and new administration routes, and as ecosystems like Boston-Cambridge continue to catalyze progress, RNA therapeutics can move from proofs of concept to widely used treatments across infectious disease, oncology, and many other areas of medicine.

ON THE COUCH WITH AI



And how do you feel about it? AI is now even being used in psychotherapy

Artificial intelligence is penetrating ever deeper into our everyday lives. It is changing jobs, politics, and even psychology. In the future, it will permeate all areas of society. The Evonik Foresight team has therefore analyzed the effects of this game changer

TEXT **BJÖRN THEIS**

Sometimes progress is very expensive: At the beginning of February, the US company Anthropic, one of the leading start-ups in the field of artificial intelligence (AI), presented new functions of its Cowork assistance software. For the first time, they can take on entire task packages more or less independently: for example, programming, monitoring compliance processes, or preparing legal opinions. As a result, around 285 billion US dollars were wiped out on the stock market within one day, as investors sold shares in companies that could loose their customers to Cowork.

Instead of merely assisting people, Cowork aims to replace demanding activities. This is something that worries even the head of Anthropic: Dario Amodei warns that AI applications could make around 50 percent of all entry-level jobs in offices and administration redundant in just a few years.

The rapid evolution of artificial intelligence is one of the developments that Evonik's Foresight team has analyzed in depth as part of the GameChanger 2035 project. The focus is on disruptive developments and inventions with the potential to fundamentally change economic, military, and social structures. That certainly applies to AI.

Artificial intelligence is already occupying prestigious jobs today. For example, the Albanian chatbot Diella 1.0 was appointed Minister for Artificial Intelligence at the beginning of 2025. The follow-up version Diella 2.0, which not only understands text but also voice and whose avatar appears in Albanian costume, is more than just a PR stunt. It will gradually assume responsibility for public tenders and ensure that procurement procedures are free from corruption. However, the fact that the introduction of new technologies sometimes causes friction is shown by the lawsuit filed by actress Anila Bisha, who says she was not asked for permission to use her voice and likeness for Diella.

DIRTY TALK WITH THE AI?

AI is even finding its way into sensitive areas such as psychology. So far not directly with the patient, but in trials with recorded conversations, the machines have already come up with answers and results that deeply impressed the human therapists—because they were better. Artificial intelligence is also making inroads into the bedroom: ChatGPT is about to introduce an "adult mode." This should make it possible for adults to have erotic conversations with the chatbot—according to ChatGPT operator Open AI, more and more customers want such a feature.

These examples show that AI applications are a real game changer that is spreading rapidly into all areas of life. AI systems will soon also be used on a large scale in the chemical industry—for example in research, as demonstrated by the A-Lab at Lawrence Berkeley National Laboratory. The A stands for "autonomous." In order to accelerate the synthesis of new materials, an artificial intelligence is used to independently manage an entire laboratory. It devises experiments, carries them out, and analyzes the results—around the clock, without human intervention, and 50 to 100 times faster than humans.

The Foresight Team is evaluating when and for which tasks such systems can increase Evonik's innovative prowess in the future. Because one thing is certain: AI will also change the rules of the game in research.

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

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Mercury

“Our mirrors encompass the room”

LOG **ENRICO GERHARTH**
PHOTOGRAPHY **JONAS HOLTHAUS**

Steffen Noack is the managing director of a specialist company in Weißwasser, Saxony. In 1989 Noack, a trained mechanic, was working in a mirror factory. After Germany’s reunification, the factory was closed. He then set up his own business as a dealer and started to grow his company. Today, at his company he and his ten employees produce mirrors, glazing, doors, and canopies

The call came two decades ago, but I remember it well. A professor from the State Office for the Preservation of Monuments in Saxony told us that the Green Vault in Dresden was to be restored. Around 80 percent of the historic mirrors inside had been destroyed. For me as a child of the GDR, this collection of rare, world-class exhibits has great personal significance. The professor asked if I could make new mirrors with mercury according to the original process. “That’s crazy,” I thought.

We normally make mirror glass by spraying on silver nitrate—a process that’s modern and clean. For the Green Vault, everything was to be produced in the same way as in the 1720s: with a tin-mercury amalgam. This is a tricky process, and the heritage conservation department had not found anyone who could still master the technique. It was the same for me—I started from scratch, researched in books that were two centuries old, set up a laboratory, and procured protective equipment. Then I worked on my first samples and had my blood tested regularly because of the contact with mercury.

This element is contradictory. It flows without wetting surfaces; it evaporates easily, although it is heavy; it shines, but does not give off any light. The steps of the process are the same as in the 18th century. Spread the tin foil on a marble plate and add a little mercury. Wait until the amalgam forms. Then frame the plate and flood it with a larger amount of mercury. The glass is then carefully slid onto this layer from the side. The thin layer of amalgam adheres to the glass, and the excess mercury runs off again. Every step demands its own pace; if you push too hard, you lose. But this creates a surface that no modern mirror can match. The reflectance is lower, the colors of the mirror image are true.

Today, the Green Vault once again has over 600 square meters of mirrors. They don’t open up the space—rather, they encompass it. When I’m there, I can feel their effect: soft light, authentic colors. The history of the exhibited objects comes to the fore, and the mirrors set the stage for this.

It makes me proud to see my mercury mirrors in places that tell a story. In the Green Vault, but also here in the parade rooms of the Residenzschloss, I think of my first reaction: “Crazy.” Maybe it was—but it was worth it.”

Masthead

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“Fortunately, my web has the tensile strength of steel”

The hero of Stan Lee’s comic *The Amazing Spider-Man* made this boast about the quality of his climbing aid back in 1963. In most of the stories in the series, the web is formed from a liquid that is shot from the wrist and polymerizes into an extremely strong, elastic fiber. Evonik’s cooperation with the company AMSilk shows that science fiction can become real innovation. Biotechnologically produced silk protein powder is turned into spider silk, which is lighter than cotton, as elastic as rubber—and stronger than steel.