



The magazine for people shaping the future

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## This is not an egg

Our diet is changing radically. What does the future taste like?

Verónica García-Arteaga,  
Fraunhofer researcher  
and start-up founder

**How safe are the autobahns?** Bridges at the breaking point: A sensor system to detect defects

**“Changes that affect 83 million people.”** An interview with German Federal Minister of Food and Agriculture Cem Özdemir



# The Quantum Breakthrough

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## Editorial

# To be free, we need technology

The morning of Thursday February 24, 2022 may have opened some people's eyes in more ways than one. That was the day Russia began its war of aggression against Ukraine. Suddenly, it became clear that even in Europe, we can't take peace, freedom and sovereignty for granted.

Freedom comes with a price. According to the German Federal Ministry for Economic Affairs and Energy, Russian imports account for about 55 percent of fossil gas imported into Germany, about 50 percent of coal imports and about 35 percent of crude oil imports. However, economic dependencies must not supersede freedom. Freedom is an indispensable part of our democratic culture and our continuing success. The price of freedom is one we can afford. It is true that in 2021, Germany exported goods and services worth 26 billion euros to Russia; however, this only amounts to 1.9 percent of all German exports. In contrast, Germany is Russia's most important trading partner after China.

In response to the invasion of Ukraine by Russian troops, the Fraunhofer-Gesellschaft joined forces with other members of the Alliance of Science Organizations in Germany and decided to temporarily freeze all ongoing projects and interactions with Russia; this decision was later extended to include Belarus. This is a necessary hiatus. It is explicitly not directed against the Russian people, nor against the Russian scientific sector, the development of which we continue to support.

**Increasing sovereignty** has been a focus point for the Fraunhofer-Gesellschaft for many years — not just in the energy sector, but also in terms of technological sovereignty and digital sovereignty. It is an "immensely important topic," as Federal Minister of Education and Research Bettina Stark-Watzinger confirmed at the Alliance of Science Organizations in Germany. For this reason, we welcome the determination that the Euro-



Prof. Reimund  
Neugebauer

pean Commission has recently shown in launching the European Chips Act. Around 43 billion euros will be made available for semiconductor production in the EU, so that in 2030, Europe will be producing a fifth of the chips manufactured worldwide. That the impact of the European Chips Act has become evident so quickly with such clarity, and that the Intel semiconductor plant, "the largest investment in history" as Minister President Reiner Haseloff has put it, is coming to Magdeburg, is good news — not only for Saxony-Anhalt, but for Germany and Europe as a whole.

**Freedom requires collaboration.** Freedom requires close ties. But freedom also requires resilience and independence in key areas of supply and development. This means the technologies needed in these areas are also key to our freedom. The Fraunhofer-Gesellschaft is determined to play its part.

Sincerely,

Reimund Neugebauer  
President of the Fraunhofer-Gesellschaft

Learn more about the main research topics of the Fraunhofer-Gesellschaft:  
**Prof. Reimund Neugebauer on LinkedIn**



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**91 percent** of all farms in Germany with more than 100 hectares were using smart farming technology such as GPS-controlled agricultural machinery as of 2020, according to the digital association Bitkom. The figure was 71 percent for farms with at least 50 hectares, and 64 percent for smaller farms.

# 91%

## Brief report



SusLight\_works adapts to individual light requirements.

## Improving well-being with light

Health, motivation and performance are all influenced by lighting. To ensure that employees are working under the right kind of light, researchers at the Fraunhofer Institute for Applied Solid State Physics IAF, together with industry partners, have been developing smart and sustainable workplace lighting.

SusLight\_works saves energy and, on account of its durability, also saves raw materials and production costs. This innovative LED lighting has a luminous efficacy of up to 210 lumens per watt. The dynamic light source offers functions such as dimming without energy loss, variable color temperatures and adaptive light panels. To take full advantage of these benefits, the researchers have integrated a light sensor that mimics the human eye and constantly monitors the color temperature and illumination level of the available ambient light.

SusLight\_works has the potential to support workers in terms of ergonomics and biorhythms by generating light in varying degrees of brightness and color temperature, as required,” explains Dr. Michael Kunzer, project coordinator at Fraunhofer IAF. ■

## Self-sufficient houses

Are environmentally friendly buildings that power, heat, cool and ventilate themselves just a pipe dream? Not anymore, thanks to an innovative modular facade developed by researchers at the Fraunhofer Institute for Building Physics IBP and the Fraunhofer Institute for Energy Economics and Energy Systems IEE. The system makes it easy to not only refurbish existing facades, but also to fit out new buildings in sustainable and energy-efficient ways.

At the heart of the module is a photovoltaic system combined with a heat pump that acts as a highly efficient heat and cold generator, as well as a decentralized ventilation unit with heat recovery. All of the necessary components are housed in the modular facade itself.

Jan Kaiser, project manager at Fraunhofer IEE, explains: “We’re not renovating the entire building, just the facade. In future, the old facade will be replaced with industrially prefabricated modules with integrated systems technology, providing a

multifunctional solution that meets the latest energy standards.” Since the modules can be prefabricated, they can be produced for “out of the box” use. Replacing the old facade takes just a few hours; the new floor-to-ceiling modules are simply fitted to the front of the building structure. ■

Each floor-to-ceiling module can supply a room approximately 24 m<sup>2</sup> in size.



## Checking the immune response in the lungs

Chip cytometry is eliminating the need to manually count different cell types under the microscope.



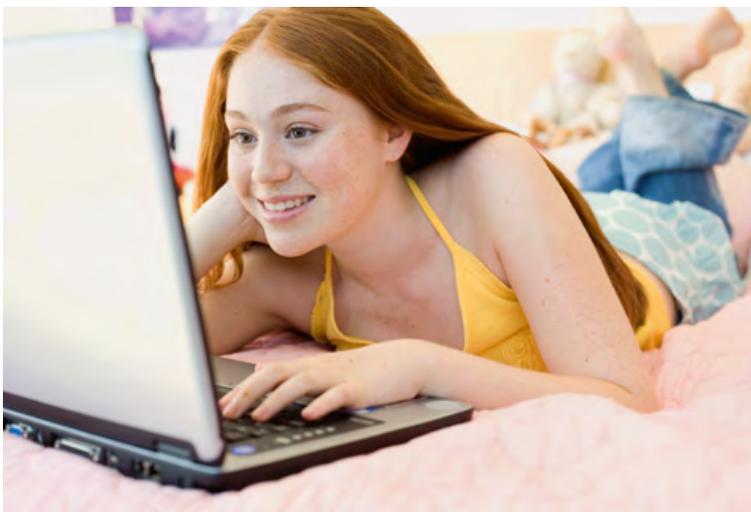
Researchers at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM have not only succeeded in accurately characterizing the lung's immune cells for clinical studies, but also in making them available for longer. With the help of the innovative chip cytometry method, valuable patient samples can be stored in the refrigerator for months and examined for additional parameters if new aspects become relevant in the course of a study.

With chip cytometry, patient samples are examined on special object slides, referred to as chips. These consist of a transparent chamber, and

the cells attach themselves to the bottom. The sample is then stained with fluorescent antibodies that bind very specifically to a certain type of immune cell. The analysis of the microscopic images is conducted automatically for the most part; the results show the proportions of the various immune cells that were being searched for in the sample.

Chip cytometry was developed and validated on blood cells by the start-up company Zellkraftwerk, which has since merged with the US company Canopy Bioscience. Fraunhofer researchers have now adapted the technique for the first time for use with immune cells from the lungs. ■

## Using AI to protect children



The European law enforcement agency Europol is warning of a significant increase in cybergrooming since the start of the pandemic.

Artificial intelligence and multimedia forensics can be used to protect children against sexual abuse on the internet. This is according to a feasibility study conducted by the Fraunhofer Institute for Secure Information Technology SIT. The study placed particular emphasis on practical feasibility. For example, forensic text profiling technology can be used to estimate the age of chat participants, thereby preventing cybergrooming. Cybergrooming occurs when adults make contact with minors via chatrooms, forums or online games with the intention of sexually abusing them. Forum moderators could be notified if a user's stated age does not match their style of writing, indicating that they are actually an adult. Even if people who previously aroused suspicion and were blocked use new profiles to log in to forums, forensic text analysis techniques are capable of detecting this with a certain degree of probability. The study is freely available at [www.sit.fraunhofer.de/jugendschutz](http://www.sit.fraunhofer.de/jugendschutz) ■



Eliminating herbicides from organic fruit production with the AMU-Bot robot system.

## Mobile weedkiller

A new robot system can remove weeds mechanically, cost-effectively and in an environmentally friendly manner, without the use of chemicals. Researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, together with industry partners, initially developed the AMU-Bot for use in tree nurseries and orchards. The autonomous caterpillar vehicle moves between the rows of trees, using rotary harrows to remove weeds. The rotating blades are attached to a height-adjustable manipulator, which is the moving part of the robot that performs the mechanical work. Even the weeds growing in the spaces between the trees are reliably destroyed. At the end of a row of trees, the caterpillar vehicle turns around and autonomously moves on to the next row.

The project team uses optical sensors to assist with navigation. The built-in LiDAR scanners continuously emit laser pulses while the vehicle is in motion, which are then reflected by the objects in the surrounding area. The distances to these objects can be calculated based on the time it takes for the reflected laser pulses to reach the sensor again. This data is then used to produce a 3D point cloud of the environment, which the robot system uses to find its way around and to determine the position of plants or trees. ■

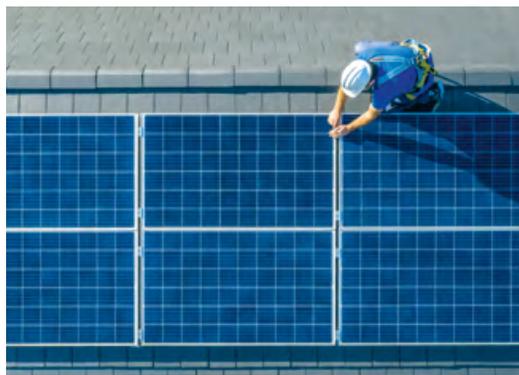
## Solar cell recycling

Researchers at the Fraunhofer Center for Silicon Photovoltaics CSP and the Fraunhofer Institute for Solar Energy Systems ISE, together with an industry partner, have developed a process for recovering valuable silicon from old solar cells. This will make it possible to recycle all crystalline silicon photovoltaic modules, regardless of manufacturer and origin.

The process involves separating and collecting solar cell fragments from by-products of the already established mechanical recycling process. In the first step, the cell fragments are separated from glass and plastic at Fraunhofer CSP using various sorting processes. This is followed by wet chemical etching to gradually remove the rear contact, silver contacts, anti-reflective layer and finally the emitter. Once the silicon has been purified in this way, it is used to produce wafers using standard processes.

Crystallization is then carried out using this 100 percent recycled silicon. The wafers were

processed into PERC solar cells at Fraunhofer ISE and achieved a cell efficiency rating of 19.7 percent in the first trial. “This is below the efficiency of today’s premium PERC solar cells, which is approximately 22.2 percent, but is certainly above that of the solar cells in the old, decommissioned modules,” says Prof. Peter Dold, project manager at Fraunhofer CSP. ■



Currently, only aluminum, glass and copper are being recycled from old photovoltaic modules.

**Editorial notes**

Fraunhofer. The magazine, magazine for research, technology and innovation.  
ISSN 1868-3428 (print edition)  
ISSN 1868-3436 (online edition)

**Published by:**

Fraunhofer-Gesellschaft  
Hansastraße 27c, 80686 München, Germany  
Editorial address as above  
Phone +49 89 1205-1301  
magazin@zv.fraunhofer.de  
www.fraunhofer.de/magazin

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**Layout and lithography:**

Vierthaler & Braun

**Cover image and cover story****photography:**

Ragnar Schmuck

**Photo for hydrogen article:**

Christian Burkert

**Printed by:**

hofmann infocom GmbH, Nuremberg

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Munich 2022

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Filter-feeding fish swim with their mouths open to ingest small particles from the water.

## What do fish and washing machines have in common?

The gill arch systems in fish are the source of inspiration for new microplastic filters in washing machines. For every kilogram of laundry, several hundred milligrams of tiny plastic fibers are released from synthetic textiles as a result of abrasion.

**P**rof. Alexander Blanke is passionate about washing machines... and fish! “There are many filter-feeding animals,” says the biologist from the Institute of Evolutionary Biology and Ecology at the University of Bonn, “but the mechanism used by fish bears the greatest resemblance to the conditions in a washing machine”. Prof. Blanke is referring to gill arches and the movement of food in the digestive tract. In the FishFlow project, he and his team are working with researchers from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and industry partners to design innovative filters that will capture the fibers abraded in washing machines — and thus protect the environment from plastic pollution.

To this end, the scientists have measured the gill arch structures in various fish. They use this data to generate computer models of gills, carry out simulations and recreate them on a 3D printer to establish which filter structures are most efficient.

The biomimetic models of the gill arch structures are then tested in a flow channel and ultimately in a washing machine.

The members of the interdisciplinary research team come from the fields of biology, materials science and engineering. Since the filters are designed to protect the environment, the sustainability of the filter production process itself is also key. “We will conduct a life cycle assessment early on in the product development process,” says Dr. Ilka Gehrke from Fraunhofer UMSICHT.

Leandra Hamann, who is completing her doctorate on Prof. Blanke’s team, has been researching suspension feeders for years. Ranging from sponges to fish and flamingos, these organisms feed on particles suspended in water using a variety of filter mechanisms. Hamann has identified over 35 different types of filter function, but it was fish that showed the greatest promise. The research team is now aiming to develop a filter with a retention efficiency of more than 90 percent. ■

# Title

Baking a tasty cake without eggs? The Fraunhofer spin-off Bettr Egg is making it happen.



# This is what the future tastes like

Which came first, the chicken or the egg? This age-old question has become outdated. Now, you can rule out the chicken altogether and just have the egg. And our diet is undergoing other radical changes, too.

By Dr. Janine van Ackeren, photos: Ragnar Schmuck

Appetizing —  
and yet gluten-,  
cholesterol- and  
allergen-free.



“The egg yolk is  
made of plant  
proteins from peas  
and/or fava beans,  
sweet potatoes,  
high-quality  
omega-3 fatty  
acids and calcium.”

Verónica García-Arteaga

Convincing, both  
outside and in.





A varied diet without eggs: 85 percent of testers could not tell which dishes were made with vegan eggs and which with chicken eggs.



Dr. Siegfried Fürtauer has used a new generation of bioplastic for the eggshell. Calcium carbonate is mixed in to make it crackable.

A complex interplay between ions and algae-based hydrocolloids transforms the yellow liquid into a spherical egg yolk with a vitelline membrane.

**A** weekend breakfast without eggs? For many people, that would be a real sacrifice — especially at Easter. However, large numbers of consumers are turning against factory farming and are resolving to consume fewer animal products, if only out of concern for climate change. “Things can’t go on as they are,” says German Federal Minister of Food and Agriculture Cem Özdemir in an interview with Fraunhofer (p. 20). That’s why people are urgently looking for alternatives that allow them to enjoy their food with a clear conscience — real solutions like Bettr Egg.

It looks like an egg. It tastes like an egg. But this is not an egg. Not only can Bettr Eggs be used as a primary ingredient in vegan cakes, quiches and other egg-based dishes, but you can also use them to make hard- or soft-boiled eggs, fry them or scramble them — whatever you prefer. This development from Fraunhofer has almost no competition: so far, the only products to come on the domestic market have been vegan egg powders, which are very different from chicken eggs in terms of taste. A

vegan hard-boiled egg was recently launched in Switzerland, but a liquid vegan egg with a yolk, white and shell is a completely new phenomenon in Europe.

“The egg yolk is made of plant proteins from peas and/or fava beans, sweet potatoes, high-quality omega-3 fatty acids and calcium,”

Verónica García-Arteaga reveals. On her social media profile, García-Arteaga, a native of Mexico who studied nutritional sciences in Munich, promises that “Egg-citing things are coming.” At the suggestion of an industry partner, she started developing vegan egg whites and egg yolks at the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising. In May 2021, the VEgg GmbH start-up

was launched, with García-Arteaga as the co-founder and CTO. Dr. Patrick Deufel joined the company as co-founder and CEO in November 2021. The young entrepreneurs have set up their office in Berlin, and are working hard to bring a healthy egg alternative to the market, without animal farming. In their Bettr Egg, ions and algae-based hydrocolloids interact in a complex way to form a spherical yellow yolk, complete with a vitelline membrane. This approach is already being used in molecular gastronomy, such as in bubble tea. The egg white mainly consists of proteins and hydrocolloids — polysaccharides that easily cross-link to form a gel. These can even cause the transparent egg white to turn white and solidify when cooked, just like a chicken egg. The egg flavor is created using kala namak, a black salt with a high sulfur content. “We keep the list of ingredients as simple as possible for both the egg whites and yolks: plant-based ingredients with no preservatives, no artificial flavorings and no artificial colorings,” García-Arteaga says. The vegan egg scores some further points for consumer health — it doesn’t contain any cholesterol or allergens, and is also gluten-free.

### The eggshell

According to an Estonian proverb, the wise look at the core, fools look at the shell. But at Easter in particular, the shell is important — even if it’s essentially just superfluous packaging material. So that consumers can get the full “experience” of having a boiled egg at breakfast or even cracking eggs when baking a cake, the researchers at Fraunhofer IVV have also developed a suitable eggshell. “Our goal was a biodegradable eggshell that can be thrown into the compost, can be produced on an industrial scale and is just as brittle as a real eggshell — and can be cracked open with a spoon,” explains Dr. Siegfried Fürtauer, who collaborated on developing the shell at Fraunhofer IVV and now heads the packaging development department at VEgg GmbH. But all that isn’t enough — the shell also needs to protect the egg. “While a natural eggshell must be porous in order to ensure the growing chick gets enough air, the egg as a food product needs to be protected from air and germs and from drying out. So we replicated the shape of the natural eggshell, but not the material itself,” says Dr. Fürtauer.

To achieve this ambitious goal, they put a biodegradable thermoplastic through an injection molding process. The thermoplastic itself is not derived from petroleum — instead, it is obtained from special bacteria using a fermentation process. “We’ve developed a completely new generation of bioplastics for the eggshell,” Dr. Fürtauer

“Egg-citing things are coming.”

Verónica García-Arteaga

explains. The research team has mixed calcium carbonate into the bioplastic to make the egg crackable. The material development stage is largely complete, and eggshells are already in production on a pilot scale.

### How does the egg get into the shell?

There are still a few challenges to be overcome before the egg can go into industrial production. There are two main options. The first is to produce the complete eggshell, but leave a small filling hole so that the white and yolk can be injected in liquid form. They must not be mixed at this initial stage — unless they are being shaken or stirred — because they have different viscosities. However, the yolk sphere doesn't form on its own. This is the difficult part — in order for it to form, the diameter of the hole, the geometry of the eggshell, the nozzle, and the filling time and pressure all need to be exactly right. The yolk sphere is stabilized by the complex interaction between the ingredients of the egg white and yolk, and the distinctive vitelline membrane forms. García-Arteaga and Dr. Fürtauer are confident that the machine suppliers they have found so far will be able to make this approach work. The second option involves placing the pre-encapsulated round egg yolk in an open eggshell, which is sealed with the other half of the shell, i.e. the lid of the packaging. The egg white is then poured in through the filling hole. While the first method can only be carried out using suitable industrial equipment, the second method has already been proven to work in the lab. However, this method now needs to be scaled up to the industrial level.

The team aims to reach this stage by the end of 2023, when the vegan egg, complete with its “eggshell packaging,” should be hitting the supermarket shelves. But in the meantime, the founders at VEgg GmbH are hatching another plan — in the interim, they're going to fill bags and containers with liquid scrambled eggs, where the egg whites and yolks are already mixed, and market them to buyers such as bakeries, restaurants and other B2B customers. The retail sector will be able to sell the vegan scrambled egg, or even the individual components of the egg yolk and white, in jars, tetrapaks, bottles or yogurt cups. In addition to the technical feasibility of filling this packaging, and its user-friendliness, its sustainability will also be very important. García-Arteaga and Dr. Fürtauer hope these scrambled egg variants could be on the market as early as 2022. Vegans are by no means the only target group that the VEgg team has in mind. “An egg substitute that tastes like an egg and looks like an egg is sure to be widely accepted — as opposed to tofu, for exam-

ple, which is used as a meat substitute but bears no resemblance to the animal product,” says Dr. Fürtauer. This is good news for people who want to cut down their egg consumption, but are not prepared to make any major compromises when it comes to taste.

### Thinking outside the egg

On its own, the Bettr Egg is no magic bullet for the future of nutrition. There's more to it than that. “When it comes to the issue of food, we don't just look at individual, standalone developments,” says Prof. Andrea Büttner, Director of Fraunhofer IVV. Instead, she looks at the big picture. “We need to see a change in industry and a change in consumers — otherwise we'll keep running into huge problems.”

Many vegans decide not to consume any animal products out of concern for animal welfare. However, as problems with our climate and resources loom, it's inevitable that the need to switch from animal products to plant-based foods will increase. Raw materials are also running out. German companies are already complaining of major supply issues for raw materials for food manufacturing and packaging — and the situation may worsen in the future. “In Germany, we cannot ▶

“Our goal was a biodegradable eggshell that can be thrown into the compost, produced on an industrial scale — and cracked open with a spoon.”

Dr. Siegfried Fürtauer from Fraunhofer IVV is working on Bettr Egg.



“There’s more to it than just developing eggs or individual products — Fraunhofer has whole project maps that fit together like a puzzle.”



Prof. Andrea Büttner,  
Executive Director  
of Fraunhofer IVV

maintain the supply for our population on our own without overcoming major challenges,” Prof. Büttner believes.

However, new alternatives also create new challenges. Take oat drinks, for example.

Where can we get the required quantity of oats from? How do we avoid monoculture? What do we do if the oat crop fails in a region, e.g. due to flooding? Cows produce milk all year round, but oats can only be harvested at certain times — what’s the best way to store them? “We need to rethink entire logistics chains and processing systems,” Prof. Büttner insists. This is why Fraunhofer not only works on individual projects and products, but acts as a systems provider to help develop regional supply chains as well as new economic systems and business models. Or, as Prof. Büttner puts it, “There’s more to it than just developing eggs or individual products — Fraunhofer has whole project maps that fit together like a puzzle.”

### Cheese — Vegan and fermented

Cheese is another important item on the menu. The need for new food products doesn’t stop at eggs — it extends to cheese, too. You can already find a whole range of vegan milk substitutes in supermarkets and health food stores. However, when it comes to plant-based cheese, the current selection is extremely limited. What’s more, with the exception of cream cheese, vegan cheese is usually not fermented. Instead, it’s made of a mixture

of fat and starch that contains hardly any protein and doesn’t have much nutritional value. In many cases, these cheeses contain the controversial ingredient palm oil, as well as additives that have to be declared, and flavorings to give them a “cheesy” taste. Consumers tend to be wary of these kinds of ingredients.

In the Kerbse project researchers at Fraunhofer IVV are taking a different approach — they’re developing a semi-hard cheese, which is produced from pea protein using a fermentation process, just like cheese from cow’s milk. The advantages here are that peas have a high protein content of 20 to 25 percent, can be grown locally, are easily obtainable and are not genetically modified like soybeans — which have a positive effect on consumer acceptance. “We produce plant-based milk from pea protein, rapeseed oil and a sugar source,” explains Dr. Andrea Hickisch, Group Manager at Fraunhofer IVV. “This plant based milk is inoculated with lactic acid bacteria before being fermented, pressed, salted and matured.” Although the individual steps of this process have been around for hundreds of years, a lot of work needed to be done to adapt them for this purpose.

The researchers had to source suitable bacteria, remove as much bitterness as possible, reduce beany off-flavour and introduce cheesy flavours. It was also important to identify the optimal conditions for the pressing, salting and maturing processes: on the one hand, mould formation must be avoided, but at the same time, the plant-based cheese needs to mature to allow the development of the appealing flavour. The researchers are already on the right track in all these areas. The prototype cheese is already very appealing, in terms of texture as well as sensory perception and flavor. However, it may take another one to two years before this vegan cheese appears on the market.

### Eating fish with a clear conscience

Then there’s fish. Oceans are highly polluted with microplastics and heavy metals, which end up on our plates when we eat fish. In addition, 90 percent of all fish stocks are considered to be fully exploited or overfished. On the other hand, as the world’s population continues to grow, more and more people are relying on fish as a source of protein. These problems could be solved by cultivating fish directly from cells instead of taking them from the sea. Bluu Seafood, a spin-off of the Fraunhofer Research and Development Center for Marine and Cellular Biotechnology EMB has the right technology. “We produce fish from real fish cells, which we grow on scaffolds in the bioreactor,” explains Dr. Sebastian Rakers, founder and Managing Director

of Bluu Seafood. This means that no fish need to die for our food supply. Moreover, the fish product is not genetically engineered and is free from antibiotics and environmental toxins. The team have developed their own growth media, so they also don't need to use the fetal bovine serum that gave the practice of cell-based meat and fish farming something of a bad name initially. To begin with, hybrid products such as fish balls, fish sticks and fish tartare will be produced from cell components and plant proteins and sold to restaurants; they will make their way to supermarkets later. In the long term, the team aims to include fish fillets in their range. In carrying out its research, Bluu Seafood is continuing to collaborate closely with Fraunhofer EMB, which is affiliated with the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Lübeck.

Aquaculture and mariculture can also be sustainable forms of fish farming. But of course, diseases must not be allowed to develop in the water and the fish. As part of the EU Rasopta project, researchers at Fraunhofer IVV are therefore working on feeding techniques, suitable sensors and filter systems to detect diseases early and take steps to prevent them. These technological developments help to avoid off-flavors such as a musty taste. The researchers at Fraunhofer EMB are working on improving the sustainability of fish products. In many cases, just the fillet is sold, rather than the whole fish. A lot of good fish is left behind in the process, and ends up in the garbage. The research team takes these leftovers and processes them into healthy high-protein chip snacks that you can munch on from the comfort of your couch, just like potato chips. These chips are much healthier than conventional kinds — they contain high-quality omega-3 fatty acids, for example. Fraunhofer is continuing to expand its research in the growth sector of aquaculture. As of January 1, 2022, the research team at Gesellschaft für Marine Aquakultur mbH has been integrated into Fraunhofer IMTE. By joining forces, the researchers aim to develop new solutions for environmentally responsible aquaculture methods.

### Algae in beer?

Let's not forget about algae. Chia seeds, nettles and kale are known as superfoods. But seaweed also contains valuable nutrients that should earn them a spot on the superfood list — they have a lot of fiber, proteins and minerals, for example. What's more, seaweed is collected or cultivated in the ocean, so it doesn't require farmland, fertilizer or large amounts of energy. It also removes the

excess nutrients from fertilizer run-off from fields, which cause problems when they end up in the sea. In contrast to other superfood products, up until now, seaweed has mainly been available in tablet form as a food supplement. "We want seaweed — especially European seaweed — to be a more common entry on German menus," explains Elke Böhme, group manager at Fraunhofer EMB. "And what better way to do that than with beer, one of the Germans' favorite drinks?" With its distinctive flavor and interesting colors, seaweed can really give beers that certain something. Fraunhofer EMB has developed the manufacturing process — the seaweed beer can be produced in a standard brewery, and the seaweed is simply added during the brewing process. And if you'd prefer an alcohol-free version, the researchers have that covered, too: they've developed a brewed seaweed lemonade. But seaweed such as dulse and sugar kelp can be used in more than just beverages — they can also be made into seaweed ice cream and pesto, as various projects by Fraunhofer EMB have shown.

Microalgae, the smaller members of the sugar kelp family, also contain substances that offer health benefits: proteins, omega-3 fatty acids, various pigments with antioxidant effects, and phyosterols. In numerous projects, including the internal Future Proteins lighthouse project where ▶

"We produce fish from real fish cells, which we grow on scaffolds in the bioreactor."

Dr. Sebastian Rakers,  
founder and  
Managing Director  
of Bluu Seafood.



they are collaborating with five other Fraunhofer institutes, researchers at Fraunhofer IGB are investigating how microalgae can be cultivated in a photobioreactor and processed into high-quality, healthy food. “In each case, we look at the entire chain from production to turning the microalgae into a food product, whether it’s a vegan sausage spread, a milkshake or shot,” explains Dr. Ulrike Schmid-Staiger, group manager at Fraunhofer IGB. One of the challenges here is the high energy requirement, as the algae need artificial lighting — sunlight alone is not enough. And as the green coloring in algae is less desirable for food products, the research team is developing new processes to remove the chlorophyll that creates this color. When the project comes to an end in December 2023, the team will have developed a healthy, new algae-based food product.

**Fruit smoothies to nibble on**

And last but not least, there’s fruit. Every year, 12 million tons of food ends up in the garbage in Germany — and in many cases, it’s just because of non-standard shape or coloring. But crooked cucumbers and unusually shaped apples and tomatoes taste just as good as their cookie-cutter counterparts. “We urgently need new business models and alternative utilization

strategies — both to limit waste and to give food back the value it deserves,” Prof. Büttner says. To this end, researchers at Fraunhofer IVV are working with the Berlin-based start-up Sprk GmbH to produce high-quality products from misshapen produce. Their method is based around drying fruit using a microwave-vacuum process developed by Fraunhofer IVV. “Unlike freeze-drying, which usually produces boring, soft products, we get a crispy product that can be eaten as a snack, similar to potato chips,” explains Prof. Peter Eisner, Deputy Director of Fraunhofer IVV. While around 80 percent of production expenses usually go toward raw materials, at a cost of 10 to 20 euros per kilo, this is reduced down to nothing when your raw material is a by-product. “By focusing on food that would otherwise be thrown away, not only do costs go down, but sustainability and value creation increase at the same time — and you get a great flavor and crunch,” Prof. Eisner promises. Seeing as these fruits may often have brown spots, or unripe white patches in the case of strawberries, the researchers crush the different fruits together and produce a sort of puffed smoothie snack you can munch on. This more gentle processing method means that 50 to 80 percent of the fruits’ vitamins are retained — and as much as 100 percent of the proteins and minerals. The

**85 %**  
of testers could not tell which dish was made with vegan eggs and which with chicken eggs.

**100 %**  
of testers preferred the taste of the vegan quiche: it was moister, and smelled nicer, too.

team has also found a use for the press cakes that are left after juicing the fruits. For example, pineapple press cakes are very nutritious due to the high fiber content and can be seasoned with mint and ginger or mango and paprika. The healthy snacks made from misshapen produce are scheduled to hit the market in early 2023.

Preventing food loss is also the goal of Fraunhofer IVV researchers working in the SHIELD project, which is focused on using sensory detection methods to produce safe, domestic, organic food. When it comes to rapidly perishable organic goods in particular, the sensory detection methods they develop should make it easier to produce quality forecasts and optimize logistics chains — and so respond to the actual needs of the food industry and consumers. “Just as we humans have multiple senses, we don’t rely on a single channel when it comes to our technological solution. Instead, we combine sensor technologies, optical methods and smart algorithms,” says Büttner. “The result is handheld devices and smart software that even small enterprises can use. We also want to establish methods that can be used to authenticate both raw materials and foods products,” explains Dr. Susann Vierbauch, who is coordinating the interdisciplinary consortium project.

### How do new foods change our tastes?

From vegan eggs and petri-dish fish to pea cheese and seaweed beer, our diets are clearly changing. But what will the future taste like? “The future will have a much more regional flavor,” Prof. Büttner answers. “We’ll need to reinvent a lot of things produced domestically, and establish new means of value creation to avoid long transport chains that cause CO<sub>2</sub> emissions. And we will rediscover lots of old ideas on a large scale.” The Fraunhofer institute director recalls the renaissance of processing and refining techniques such as fermentation. “What we eat today came about by chance. In times of crisis, people ate things that had actually gone off — and realized they tasted better and were more nourishing than their usual food.” Prof. Büttner explains that this is how bread, dairy products, cured sausages, vinegar and alcoholic beverages came into being. “We are continuing this process and developing it further, especially when it comes to plant-based raw materials. This way, we’re creating new textures and new foods that will shape our consumer behavior and tastes in the future.”

Not only can fermentation be used to produce imitations of familiar foods based on different raw mate-

rials, it can also help develop entirely new flavors. This brings up an exciting question: How can we pique consumers’ curiosity so that they try new types of food that might taste better to them and also protect the climate, animals and their health? After all, our tastes are by no means fixed and unchangeable. “What we like changes all the time,” notes Prof. Jessica Freiherr, Group Manager at Fraunhofer IVV. “The more often we eat things, the better they taste to us.” This has been shown in a study whereby babies that initially refused to eat broccoli puree were offered it again and again — not in a forceful way, but tenderly and in a relaxed environment. After eight days, they liked the broccoli puree as much as carrot puree. Researchers at the institute are currently investigating the extent to which familiarity with certain foods will increase their acceptance by adults. One of their results showed that if adults drank special milkshakes with an unfamiliar flavor over seven days, they started to like the drink more.

So, can an egg developed entirely by humans actually taste good? García-Arteaga and Dr. Fürtauer have been investigating this in their first blind taste tests. Around 100 testers tried muffins and quiches made with Bettr Egg, as well as conventional versions made with chicken eggs. The results showed that 85 percent of testers could not tell which dish was made with vegan eggs and which with chicken eggs. 100 percent of testers thought the vegan quiche tasted better — they found it was moister and smelled nicer. When it comes to vegan eggs, at least, our tastes seem to be ready for the future — even if the egg can’t be dyed for Easter yet. ■

“The more often we eat things, the better they taste to us.”

Jessica Freiherr,  
Fraunhofer IVV

## Interview

# “What we need to change...”

He sees agricultural policy as propping up an “exploitative system” and strongly believes that “things can’t go on as they are.” Germany’s new agriculture minister Cem Özdemir talks to us about what he wants to improve — and how Fraunhofer technology is helping him achieving these goals.

**Interview: Josef Oskar Seitz**

Initially tipped as Minister of Transport or Foreign Affairs, Cem Özdemir, 56, was appointed German Federal Minister for Food and Agriculture on December 8, 2021.



\_\_\_\_\_ **Meat production in Germany is decreasing, Mr Özdemir. Is this good news for our country?**

If meat is produced abroad under worse environmental and animal welfare conditions and exported to Germany, it is of no benefit to the climate, animals or domestic agricultural production here. If there was a systematic focus on quality in terms of supply and demand in Germany, that would be good news. During the current legislation period, we are aiming to achieve real progress on the supply side and drive the conversion of livestock farming. Because things can't go on as they are — the current system is a burden on animals, the environment and agriculture itself. One core element that we are currently working on is mandatory livestock farming identification. This will provide transparency on the actual housing conditions in which the animals are kept. Origin identification is a further key element.

\_\_\_\_\_ **What plans are in place here?**

We want to increase transparency in terms of food origin at a European level. Consumers want to know where their food comes from — and our domestic farmers will be at an advantage there. If a product is advertised on a supermarket flyer based on its origin rather than a discounted price, everyone benefits. After all, this is also about appreciating our farmers. An important aspect for me is that origin identification also makes transport routes visible, which contributes to climate friendly consumption.

\_\_\_\_\_ **The German Federal Statistical Office has recorded a reduction in meat consumption for the fifth year in a row, with the number of pigs slaughtered falling by 2.9 percent to 51.8 million in 2021. Would you still advise a young person today to take over their parents' farm?**

The number of animals going to the butchers is just one side of the coin; there's also a flip-side. Over the past ten years, the number of pig farms has almost halved, but the number of pigs is nearly the same as before. We are in the midst of a process that concentrates production into a smaller number of farms that are ever

“Our ministry has the fourth-largest research budget. Research and innovation can help resolve any ostensible conflicts of interests.”

Cem Özdemir

increasing in size. Many family-run farms can't contend with these. From each euro that a customer pays for meat at the checkout, the farmers receive a mere 21 cents. This is the result of a one-sided agricultural policy, and I'm not willing to let this exploitative system continue. We want to offer the farms a future that is both ecologically and economically sustainable so that young people are keen to take over family farms and they have the chance to make a living. This is also connected to a greater social goal: Wherever there are farmers, they work in, and for the good of, the countryside. This holds together communities and fosters rural culture.

\_\_\_\_\_ **You were initially tipped as Minister of Transport, or Foreign Affairs due to your family heritage. You are now the Minister of Agriculture. What are your ties with the proud people of the farming community?**

In political terms, I haven't actually worked this field before. My father's parents were ▶



## 1965

### Car know-how

Born and raised in Bad Urach, Baden-Württemberg, the young Cem displayed a deep interest in cars. His father came to Germany in 1963, his mother in 1964. "My parents only spoke with me in Turkish," recalls Özdemir. "It was better that way — otherwise I would have learned a lot of mistakes."



## 1998

After high school, training in child care, a diploma from a vocational school and studies in social education, he entered the German Federal Parliament (Bundestag) in 1994. In 1998, he was elected co-chair of the Green Party.



## 1999

### Visiting mom

The owner of a nail salon, she arranged for a tutor for Cem when he was in school. "I always got an F in German until the fifth grade," he recalls. "I was the worst in the class."

farmers in Turkey and I always went there on summer vacation. Now things have come full circle, in a way. Above all else, serving our country as Federal Minister of Agriculture is a huge honor. Naturally, I was delighted that my party entrusted me with this important portfolio. I now have the opportunity to work together with my colleagues to plan and drive important changes that will ultimately affect 83 million people. For me, it's important that we tackle these tasks together and put an end to the sense of one group working against another. To answer your question, I think farmers can rightly be proud of their work, and we should be too. I have also witnessed a high level of innovation in the sector as well as a certain perseverance, which has earned my deep respect. Being honest and talking about what is effective and what we need to change is important to me. For far too long, farmers were told there were no problems — for instance regarding high nitrate levels resulting from overfertilization, an issue on which the EU has been calling for improvements for years and where we have recently only just averted massive fines.

\_\_\_\_\_ **Your call for an end to "junk prices" for food has naturally provoked some angry responses. Is this your recipe for the future: less, but more expensive?**

That version is too simplified — my recipe has more ingredients than that. First of all, farmers in Germany must be able to make a living. Secondly, what we spend on food must factor in the ecological truth, that is, the costs for people, animals and the environment. And thirdly, we require food that is high-quality, but still affordable. I want shape these three goals into one interconnected whole. We clearly need to restore the balance between the number of animals and the space they have. And it's also important that farmers do not lose out as a result of this transformation. If they make improvements to their livestock farming practices, it must pay off in the long term. The responsibility for this must be shared jointly by politics, the food industry, commerce and consumers.

\_\_\_\_\_ **"For my mother, giving candy to her child was a sign of love," you once said. Drawing on your background in education, Mr. Özdemir, how long do you think it will take to make healthier, more environmentally friendly nutrition part of everyday life?**

When love and calories go hand in hand, there's going to be a big, fat shock at some point — in the most literal sense of the word. It's obviously good that the issue of healthy and sustainable nutrition is now so topical — there's definitely been a shift here. However, it is not always easy for consumers to figure out what food is actually healthy and whether it was produced in a way that conserves resources. For this reason, our coalition has decided to develop the Nutri-Score labeling scheme further. I'm referring to the five-color nutritional value rating label found on a lot of food packaging. We need a uniform solution for this at the European level. Plus, as already mentioned, we are working on livestock farming identification and origin identification.

\_\_\_\_\_ **This also brings us to the issue of demand that you talked about earlier...**

Exactly. We want to ensure that food is produced in a healthier, more humane and sustainable manner and naturally, we also want to make it easier for consumers to be able to recognize this from packaging. This labeling system will definitely provide the right support to help consumers make animal-friendly and eco-friendly choices.

\_\_\_\_\_ **What do you expect from the dual-use initiatives for arable land that involve constructing solar panels over it?**

Our goal is to drive the expansion of renewable energy production. With agrivoltaics, it's a win-win-win situation. Our farmers can contribute to the renewable energy supply while earning money. Simultaneously, they can still use the land underneath the panels for agricultural activities. And finally, this also represents an important contribution to combating the climate crisis.

\_\_\_\_\_ **There are still some obstacles, however. The dual use of arable land is simply not yet provided for by law, so farmers cannot claim EU agricultural grants and electricity feed-in remuneration is unregulated. How do you plan on overcoming these hurdles?**

We are aiming to take advantage of the synergies to enable both food and sustainable energy to be produced using the same area of land. That's why the new regulations for agricultural support funding will allow this kind of land to be considered for direct payments from the EU from 2023 onward. These dual systems will

“This Fraunhofer spin-off aims to enable high-precision, and thus more sustainable farming in our fields. Agriculture is more modern, digital and technologically advanced than people think.”

Cem Özdemir



also be funded in accordance with the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG).

\_\_\_\_\_ **How can research help combine economic and ecological factors in agriculture?**

Our ministry has the fourth-largest research budget of all departments, and our subordinate agencies are also conducting research in this area. Combining economic and ecological factors is the only way of ensuring a positive future for agriculture in Germany. Research and innovation can help resolve any ostensible conflicts of interests.

\_\_\_\_\_ **Could you give us some examples?**

Digitalization in agriculture is one particular example I'm thinking of. It offers almost endless possibilities for making agriculture more environmentally friendly and resource-efficient. For instance, we are currently providing funding for ConstellR — a startup that measures soil health from space using its own satellite fleet. This Fraunhofer spin-off aims to enable

high-precision, and thus more sustainable farming in our fields. There are also technologies that significantly reduce pesticide use or even make it unnecessary, such as robots that target weeds using AI-driven image recognition and remove them mechanically using heat, lasers or electricity. This allows us to protect biodiversity, too. There are many other examples of similar measures. At any rate, agriculture is more modern, digital and technologically advanced than people think.

\_\_\_\_\_ **“As a teenager”, you once confessed, “I shattered my parents’ dreams.” What would your parents be proud of today?**

Well, as an environmentally conscious vegetarian who listened to rock music, wore ripped jeans and studied child care, I didn't always conform to their ideal image of a son. But my parents were always proud of me and supported me. I think they would be especially proud of the fact that I'm now a federal minister. It would certainly have been hard to predict my path here. ■



## 2002

### The frequent-flier

#### **mile affair:**

Özdemir used parliamentary frequent-flier miles for personal purposes and took out a cheap loan with a lobbyist. Following criticism, he resigned as a member of the Bundestag and took up a fellowship in the USA. “I was done with politics,” he recalls. In 2004, he returned to politics and became a member of the European parliament.



## 2016

### Yoga practitioner

Özdemir angered several members of his party with his support for the use of weapons, saying “We can't fight the Islamic State with yoga mats!”



## 2018

### Extending a hand

Özdemir attempts to shake hands with Turkish president Erdogan, who hesitates. This moment is symbolic of a fragmented relationship. Erdogan has accused Özdemir of being “a so-called Turk” with tainted blood.

# I could use a pig-me-up!

Pigs are sensitive. Fraunhofer researchers plan to use a special sensor system in piggens to monitor the animals' emotional state — and keep them playfully engaged if they become restless or show signs of aggression, to prevent them from injuring themselves or others.

By Marina Babil

SmartPigHome is looking to sniff out trouble in the pigpen.

**P**igs are intelligent and sensitive animals. When they feel uneasy, they start to get bitey — both with themselves and with their pigpen pals. They often nibble on each other's curly tails and injure each other in the process, sometimes seriously. In this way, animal welfare can quickly become an economic factor in agriculture. Dr. Sarah Fischer has set herself the task of giving these animals a "pig-me-up."

The head of the Electronics for NDT Systems department at the Fraunhofer Institute for Nondestructive Testing IZFP in Saarbrücken is an expert in techniques for characterizing complex materials. Usually, this is in relation to specific components. She still sometimes marvels at her current field of work: "I never would have imagined that the materials I'd be investigating would be as complex as pigs in a pigpen."

SmartPigHome is the first of several planned projects to be approved in the field of Smart Farming at Fraunhofer IZFP. The institute, which usually deals with industry-focused sensor research, hopes to make the leap to the agricultural sector through this project. "If we manage to bridge this gap, I believe we can make a very valuable contribution in terms of animal welfare," says Fischer. The project kicked off in October and is being funded by the Federal

Ministry for Food and Agriculture to the tune of 1.6 million euros. Under the leadership of the Lower Saxony Agricultural Transformation Research Association (Verbund Transformationsforschung agrar Niedersachsen), the project group includes Fraunhofer IZFP and various other partners with expertise on the subjects of animals, artificial intelligence and sensors.

The aim of SmartPigHome is to support farmers in their work and to assist them with decision-making. Sensors record the temperature, humidity and the levels of certain gases. However, they also use sound and image data to record the pigs' behavior. AI models are then used to draw conclusions regarding the animals' moods, taking all data sources into account. If the algorithms detect that the pigs are restless or aggressive, the farmer receives a push notification on his cell phone. In critical situations, an interactive activity tool with moving spots of light triggers the pigs' play instinct and distracts them until the farmer can intervene on site. "This way, our sensor systems can be the farmers' eyes and ears when they're not in the pen, and provide additional support by detecting situations and trends that would otherwise not be recognized in time," says Fischer.

### Sustainability and transparency in the pigpen

You only need to look at the current pig farming situation in Germany to see how the idea of SmartPigHome is socially relevant. Although meat consumption in Germany has fallen in recent years, a study by the Federal Information Center for Agriculture showed that 57.3 kilograms of meat per capita were still served up in 2020. Almost 60 percent of this was pork. To meet this demand, over 55 million pigs were slaughtered in Germany in 2019 according to the Meat Atlas 2021. Consumers are increasingly calling for greater sustainability and transparency from agriculture in general and the meat industry in particular. At the same time, the price a farmer receives for a single fat-

tening pig at slaughter fluctuates a great deal, and has recently been on a downward trajectory. This means a single pig falling ill or dying prematurely can result in significant financial loss.

Animal welfare is therefore worth the investment. When it comes to the mood in the pen, the pigs themselves provide the most important data. To be of real benefit in practice, the sensors must analyze and transfer data in real time, if possible. Previous research projects in this area have mainly focused on developing new algorithms, explains Fischer. "Vast quantities of data, especially images, have often been recorded over several weeks in an idealized pen environment. Then, after an elaborate evaluation process, researchers are able to say, 'Oh, something remarkable happened in the second week.' However, this information arrives too late for the farmer."

One of the SmartPigHome project partners mainly works with image data, and analyzes how the animals move and lie down, for example. At Fraunhofer IZFP, however, the project is primarily focused on sound data. According to Fischer, "This data can be analyzed with comparatively little computing capacity. We want to evaluate how it can best be put into practice. What's more, the sounds pigs make are very informative, particularly when it comes to detecting stressful situations." If pigs are relaxed, their grunts tend to be at lower frequencies, but they become more shrill when problems arise. When a person enters the pen, pigs also often make a kind of barking sound.

The algorithms that will ultimately be able to correctly determine the animals' moods are being trained based on knowledge from farmers. Fischer goes on to say, "As an engineer, I find it fascinating how well a farmer can use the slightest cues to ascertain the level of well-being of their animals. We can only hope that our sensor systems will become almost as reliable as farmers."

To record the image and sound data, the researchers plan to use the most inexpensive existing sensors that they can find. The activity tool, which is being developed

by another partner involved in the collaboration, is to be installed on the ceiling of the pen. Projector systems on rails will travel over the various pigpens and aim toward animals in areas where the sensor system has identified stress or signs of imminent stress. The idea is that the animals can then move spots of light similar to soccer balls with their noses, for example, and will be rewarded with food after playing.

### Two pens, one goal

The first sensor systems should be installed by summer at the latest, and the first data will then be generated. This will involve working with two different pigpens. The first is a conventional pig fattening farm for testing under real-life conditions, and the other is an idealized test pen at the University of Veterinary Medicine Hannover. There, investigations will be carried out into how pigs respond to different light and color conditions, for example. The results will be used to develop the activity tool.

The project has been scheduled to run for three years to start with. Sarah Fischer is already very much looking forward to progressing it further. "I'm optimistic that our work will help us better understand and improve the welfare of pigs on pig fattening farms." Her long-term vision is for the new data they collect to be included in official requirements for husbandry practices and animal welfare labels. "This would quantify animal welfare in a more animal-centered way and would make the factors influencing animal welfare visible all the way to the consumer, which would also add value for farmers. I believe this is the only way to guarantee sustainable agriculture in Germany." ■

How is a contented grunt different from a restless or aggressive one? Scan here for the podcast:



# Much ado about mossing

It was used during wars to dress wounds because of its antiseptic properties and by the ancient Romans as toilet paper due to its absorbent properties. Today, moss facades are bringing nature right to the doorsteps of stressed city inhabitants and filtering fine particulates out of the air.

By Mandy Bartel

**W**hen the mummy Ötzi was discovered in an Ötztal Alp glacier in 1991, 75 different moss varieties were found in and around the body. The “Iceman” may have used these to wrap up food or tools and to dress wounds. For bryologists, or people who research mosses, this find was a real windfall, because it provided information about the flora that existed 5000 years ago and the versatility of these fleecy plants.

One person who made a significant contribution to studying the “Ötzi moss” is Dr. Wolfgang Hofbauer, Chief Scientist at the Fraunhofer Institute for Building Physics IBP in Valley, Bavaria. A renowned expert on mosses, microbiology and botany, he has been working on these multi-talented plants and their benefits since writing his thesis 30 years ago. The idea of using moss to create biointelligent facades inspired him right from the beginning. Because mosses have some astonishing properties. Not only can they absorb 12 to 20 times their own weight in water, they filter fine particulates and pollutants out of the air and break them down. Mosses can completely dry out and remain that way for years, only to fully rehydrate with the next shower of rain. In addition, they possess special acoustic properties, have positive effects on human psychological wellbeing and produce antiseptic substances.

## Sticky business: Plant mucilage as wall glue

In recent years, there have been several green facade initiatives focused on moss, but most were ultimately unsuccessful. Often, the mosses simply didn't become established. “Selecting the right plants is an important factor for success. Of the 20,000 known types of

moss, only several hundred are suitable for creating a facade,” explains Dr. Hofbauer. Fraunhofer IBP is researching suitable varieties for moss walls at its outdoor area near Munich. “Achieving homogeneous vegetation growth over a large area is especially difficult. The first months of growth are particularly critical,” adds Dr. Hofbauer.

Together with his team, the biologist developed a new, patent-pending method based on a mix of biopolymers with good swelling properties, nutrients and moss particles. These mucilaginous “moss starters” can be directly applied onto building surfaces. Alternatively, due to the risk that heavy rain could wash it away, the starter layer can be applied to panels and these can then be attached to the facade once the plants become established. The biopolymers harden on the walls or panels and provide the moss with moisture and nutrients. Spraying the starter with fine water mist can also accelerate growth. Instead of taking fully grown plants from natural habitats such as forests, the research team has invested its time in cultivating its own moss. “While this takes longer, it offers more chance of success and it's more sustainable, too,” affirms Dr. Hofbauer.

Having proven that it works, the researchers are currently working on scaling their concept. After all, transferring the vegetation to a larger area must be possible in order for the benefits of moss to come to the fore. Several facade designers have already registered their interest, and implementation projects are set to start soon. So in the future, the earthy scent of a forest floor might be more likely to pervade our urban landscapes than the smell of exhaust fumes, as gray building facades are transformed into green, sustainable urban biotopes. ■

Photo: Twilight Show/istockphoto



Mosses can  
absorb

**12 to  
20 times**

their ownweight  
in water.

Moss functions as natural air conditioning — just one of the reasons why we may see it running riot across building facades in the future.

# Happiness is when the bass drops in sync

Pounding beats, a thrilling live show, a sea of bobbing heads and thousands of dancing feet — a live concert is a feast for all the senses. But these past two years have been more of a famine. A team of Fraunhofer researchers had the same thought — and ventured an experiment.

By Mandy Bartel

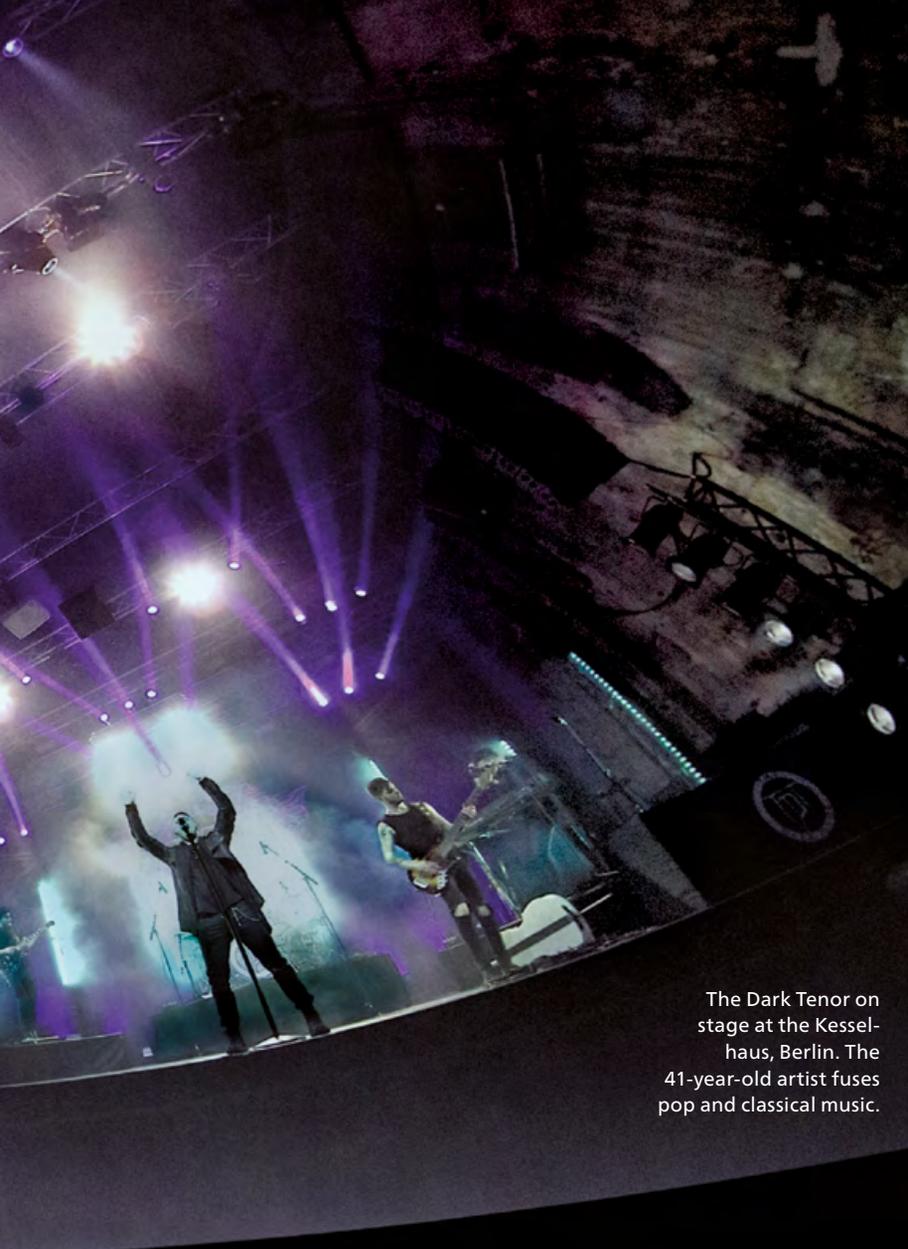
**B**illy Andrews was feeling the tension. The artist known as The Dark Tenor had not stood under stage lights for many long months. The technical team of 15 researchers from three Fraunhofer institutes were experiencing some stage fright too. After all, they were aiming for no less than a milestone in event technology: the first hybrid live concert to bring together artists and audience members at various locations for a shared experience using the latest technology. For months, they had been honing the perfect concert experience that blurred the lines between real and digital perception. For weeks, they'd been on tenterhooks about whether the event could actually go ahead, due to the increasing uncertainty posed by the coronavirus crisis.

The place was Berlin, the Kesselhaus venue in the Kulturbrauerei to be precise. The date was December 11, 2021. That Saturday night, 300 fans experienced The Dark Tenor and his band. The stage show was filmed using a 360° camera and projected onto the enormous dome screen of the

Zeiss planetarium in Bochum, 500 kilometers away. Exhilarating 3D sound helped create an immersive experience for the 50 other fans enjoying the show from there. The Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI looked after the 360° camera technology, while the Fraunhofer Institute for Integrated Circuits IIS, at whose digital cinema in Erlangen the show was also broadcast, delivered the MPEG-H audio system. The Fraunhofer Institute for Open Communication Systems FOKUS was in charge of broadcasting and projecting the stream. Over 600 people from 16 countries also tuned in via a low-latency internet live stream. They were also able to participate in a virtual fan chat and send digital applause and their own camera images to a screen directly in the Kesselhaus.

## A lag-free virtual duet

The highlight of the show was a real-time switch to a recording studio in Treptow. From this location, the artists



The Dark Tenor on stage at the Kesselhaus, Berlin. The 41-year-old artist fuses pop and classical music.

**5**  
milliseconds  
to play  
together  
across  
different  
locations.

Queenz of Piano played the song “When You Roar” live together with The Dark Tenor in the Kesselhaus. For the audience, it was just a well-rehearsed performance, but for the scientists, it was a real technical challenge. “The latency of the audio connection was crucial for the duet — after all, the idea was that the musicians would be able to play together live. But even with the commonly used low-latency streaming of today, there is generally a lag of between 3 to 8 seconds, which was much too long for us,” explains Robert Seeliger, production manager for the event and VirtualLive sub-project manager at Fraunhofer FOKUS. So his team had to pull out no small number of stops: As well as the Digital Stage platform, they used fiber optic connectors and the latest 5G technology, separated IP connections for audio and video transmission using dedicated network configurations, tinkered with the streaming parameters and optimized the entire effect chain for latency.

“During the initial tests in October, we finally got close to the required latency of 30 milliseconds for transmitting the audio to the studio,” recalls Seeliger. However, a lot of interference occurred in the process as the result of other services on the IP connection. “That was disappointing. In order for the musicians to play together in synchronization, we had to reduce the lag further and remove interference in particular.” In the end, they used two specially configured streaming devices that could transmit the audio tracks from the location with as little processing and compression as possible. The technical team also worked together with internet service provider K-tel to split the audio and video track for the internet broadcast so that they could be transmitted via two different virtual networks, and removed all interference variables. In this way, they finally managed to achieve a minimal lag of only 5 milliseconds by the dress rehearsal, a week before the concert.

### Huge interest from the events industry

Although the artists were in separate locations, to the audience, it sounded as if they were playing together in the Kesselhaus. Billy Andrews, aka The Dark Tenor, was impressed with the results too. “The Classic RoXX tour premiere was a huge success and the collaboration with the Fraunhofer institutes opened up new possibilities for music and art to coexist over the internet despite physical distances. I’m excited that this technology is helping artists interact. It will definitely form an integral component of our work down the line,” the singer added.

As a model for future events that go beyond physical boundaries, the concert did indeed attract a huge level of interest. The Fraunhofer team received a number of inquiries from the events industry, as well as from music colleges. This comes as no surprise, since event organizers have been desperately searching for new solutions to deal with uncertainties posed by the pandemic, such as limited numbers of attendees, travel restrictions, and so on. They won’t have to wait for long. “Since it’s based on a combination of existing, tried-and-trusted technology with innovative technologies, this new toolbox can basically be used right away,” says Selliger. “The only limiting factor is the on-site conditions — due to their internet connections, not all locations are suitable for this hybrid format. A good IT partner can be an advantage here.”

Pounding beats, thrilling live shows, bobbing heads and dancing feet — suddenly, the magic of a live concert can stretch across cities, countries, continents and pandemics. This Fraunhofer technology opens up a new world of possibilities and expression for creatives, without compromising on sound or vision. And it brings the same adrenaline rush as the heady, pre-COVID days. ■

The wasp spider gets its name from its black and yellow coloring. It can reach up to 2.5 centimeters in size, and can be found in almost all European countries.



# Spider venom for medicinal use

Spiders make a lot of people nervous, but they are welcome at Fraunhofer IME. Here, researchers are analyzing spider venom — a largely unexplored bioresource that has great potential for medicinal use.

By Britta Widmann

**V**enomous animals are Dr. Tim Lüddecke's passion. He keeps spiders and scorpions as pets. In his work, too, he's involved with these eight-legged creatures: he and his team from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen are primarily focusing

on native spiders and their highly complex mix of toxins, which have been given little attention until now. Researchers at the Justus Liebig University in Giessen are also lending a helping hand here.

The venom of a single spider contains up to 3000 components. Hardly any research has been

done in this area — due to this very diversity. After all, there are 50,000 known species of spider. “Spider venom has a lot of potential for medicine, for example in researching disease mechanisms,” says Dr. Lüddecke. The head of the new Animal Venomics working group at the Bioresources institute branch of Fraunhofer IME in Giessen believes that these components, chiefly peptides, can be used to develop promising drug candidates for treating numerous diseases. For example, scientists hope to use the venom cocktail of the Australian funnel-web spider to treat neuronal damage after strokes and to make hearts for organ transplants last longer. Other drug candidates could function as antibiotics or as pain relievers.

Research so far has focused on the toxins of the very large or potentially dangerous species that live in the tropics. Little thought has been given to the small, harmless native varieties. “Most spiders in Central Europe are no more than 2 centimeters in size, and the amount of venom they produce is insufficient for experiments. However, now we have precise analysis methods that enable us to examine the small amounts of venom produced by the previously neglected majority of spiders,” explains Dr. Lüddecke.

### Decoding wasp spider venom

Currently, the scientists are particularly interested in the wasp spider (*Argiope bruennichi*), which owes its name to its striking wasp-like coloring. They have succeeded in decoding its venom, identifying numerous new biomolecules in the process. The advantage of wasp spider venom is that it only contains around 53 biomolecules. It consists predominantly of components with a high molecular weight, including catabolite activator proteins (CAPs) and other enzymes. As with other spiders, the venom contains knottins, but these make up only a small part of the total mixture.

Knottins are a group of neurotoxic peptides that can resist chemical, enzymatic and thermal degradation due to their robust, knot-like structure. These molecules could therefore be administered orally as a medicinal component without being digested in the gastrointestinal tract. In addition, knottins bind specifically to ion channels. “The more specifically a molecule docks onto its target molecule, attacking only a single type of ion

channel, the fewer side effects it triggers,” explains Dr. Lüddecke. Furthermore, even small amounts of the knottins influence the activity of the ion channels. As a result, medicines derived from these compounds can be administered in low doses. The combination of these properties makes spider venoms extremely interesting for scientists.

The project partners have also discovered molecules in the venom of the wasp spider that resemble neuropeptides in structure. These are responsible for transporting information between nerve cells. “We have found new families of neuropeptides that we had not seen before in other spiders. We suspect that the wasp spider uses them to attack insects’ nervous systems,” the researcher speculates.

### Gender influences biochemical repertoire

The venom profile of the wasp spider has now been fully decoded. So, what’s the next step? “We’re building genetically modified bacteria that produce the toxin on a large scale.” Dr. Lüddecke and his team have successfully mass-produced CAP, the main component of the wasp spider venom. The first functional studies are already underway. The scientists are already familiar with CAPs from many other animal toxins. In snakes, they take the form of neurotoxins that act on the central nervous system and paralyze the victim. In ticks and parasitic fish, they affect blood clotting. In cone snails, they act as enzymes. “But the mechanism of action of the wasp spider’s CAPs is completely unknown,” relates Dr. Lüddecke, “so we need to mass-produce them.”

Until now, the dynamics of spider venom have been completely underestimated. “The biochemical repertoire is decisively influenced by the stage of life, habitat and, above all, gender. The interactions between the components increase their effectiveness.” ■

**Spider venom: A beacon of hope in the fight against central nervous system disorders.**  
Scan here to watch a video:



“We’re building genetically modified bacteria that produce the toxin on a large scale.”

Dr. Tim Lüddecke,  
Fraunhofer IME



Dr. Tim Lüddecke at work. The head of the Animal Venomics working group believes that spider venoms have huge potential as drug candidates for medicinal use.

# A virus turned cure-all

A virus joining forces with the body's immune system to combat cancer? It sounds a little crazy. But this unlikely alliance is proving successful — and researchers are pinning their hopes on it for tumor treatment.

By Dr. Sonja Endres

It takes an electron microscope to make them out: herpes viruses (blue and yellow) infect a cell (yellow and brown, bottom right). The viral DNA takes over the cell and turns it into a production factory for viruses.



**W**hen it comes to simplicity, viruses are hard to beat: they're just a smidgen of genetic material wrapped in proteins and lipids, 20 to 200 nanometers in size, and only visible with an electron microscope. But what makes viruses unique is their ability to invade living cells and force them to help the virus multiply. They often destroy the host cell in the process, causing humans and animals to get sick — or healthy. Prof. Susanne Bailer and her team at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB has successfully genetically modified the herpes simplex virus type 1 so that it can be used as an effective weapon against tumor cells.

The herpes virus is known for the painful, unsightly blisters that it causes on the lips. However, for people with weakened immune systems, herpes viruses can also cause encephalitis. Prof. Bailer, who leads the Virus-based technologies innovation field at Fraunhofer IGB, has pulled off quite a feat. She turned off the gene in the virus that causes disease — making it available as a tool for medical treatment.

### A virus with plenty of memory capacity

The herpes virus' genetic material consists of DNA, rather than the RNA found in the coronavirus SARS-CoV-2, for example. "The DNA genome is significantly larger than the RNA genome, so it can accommodate a lot of additional genes. This means that if we want to reprogram a virus, there's a lot of memory available," explains Prof. Bailer, who has been researching the herpes virus for 20 years. A further advantage here is that the basic technologies needed to genetically modify the herpes virus already exist. The process of developing vaccines for the coronavirus has brought about major advancements in this area in recent years. The AstraZeneca vaccine is based on adenoviruses that trigger colds in chimpanzees but are harmless for humans. The modified viruses carry the information needed to

synthesize vaccine antigens into human cells, which then start producing antibodies that specifically target SARS-CoV-2. According to Prof. Bailer, AstraZeneca's success has strengthened research into genetically modified viruses across the board and dispelled a lot of the existing reservations about the field.

Prof. Bailer and her team managed to improve the genetic engineering process for manipulating herpes viruses, allowing them to program a targeting system into the virus. "This ensures that when we inject our viruses directly into the tumor, they will infiltrate cancer cells, but not healthy cells. They start multiplying in the cancer cells and make them burst." This then

"The immune system is our strongest weapon against cancer. We hope to stimulate it in a targeted way using our virus and the tumor markers it releases, so that the body can treat itself in a way."



Prof. Susanne Bailer,  
Fraunhofer IGB

releases tumor markers, which bring the body's own immune system into the battle against the cancer. "We also activate the immune defenses using specific proteins that our viruses emit when they reproduce. These cause the immune system to detect the tumor cells and eliminate them." Prof. Bailer hopes that this will allow doctors to treat undetected metastatic

growths outside the tumor mass. "The immune system is our strongest weapon against cancer. We hope to stimulate it in a targeted way using our virus and the tumor markers it releases, so that the body can treat itself in a way."

### Initial victories in the fight against lung cancer

The Fraunhofer IGB team conducted their first preclinical tests with the oncolytic virus in the project TheraVision, in collaboration with the Fraunhofer Institute for Cell Therapy and Immunology IZI, the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM and the Fraunhofer Institute for Silicate Research ISC. The researchers fine-tuned the virus to treat non-small cell lung carcinoma. This variety of cancer has a high fatality rate. Only 22 percent of all female patients and 17 percent of all male patients survive the first five years after a lung cancer diagnosis. Non-small cell carcinoma tends to metastasize at an early stage, meaning that the prognosis is even worse.

The results of the studies are promising. The tumor cells were consistently destroyed, and the viral immunotherapy also appeared to have a positive effect on metastatic growths. "However, we must conduct further research on that," Prof. Bailer acknowledges. It's still too early for a clinical trial. However, the herpes simplex does fulfill the requirements for clinical testing, as it offers another decisive advantage over other viruses — a kind of "emergency break." If the viral treatment causes unexpected side effects in the already debilitated cancer patients, the scientists can stop the replication of the virus with a highly effective virostatic agent that has proven its reliability over almost 50 years.

However, further studies are needed before the treatment can see clinical use. "To unlock the full potential of viral immunotherapy, we need a better understanding of the mechanisms of action. In any case, we have now developed a virus platform technology, that can also be used for other types of tumor in the future." ■

# 80,000 revolutions for the energy transition

Geothermal energy promises an unlimited, environmentally friendly source of heat, all from the earth's interior. But there is a high risk of drilling incorrectly, making the technology expensive — until now.

By Mehmet Toprak

**A**t only around 10 centimeters in length and 3.6 centimeters in width, the micro drilling turbine still has what it takes to persuade investors to fund geothermal applications. But so far, there has been a stumbling block: Almost a third of deep geothermal wells do not make a strike. Now, a turbine developed at the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG in Bochum is making it possible to explore the area around a borehole for deposits of hot thermal water at a depth of several thousand meters, significantly reducing the risk of not finding anything. This water can be as hot as 200 degrees Celsius, making it particularly worthwhile to drill for. Once carried upward, it can supply entire districts with heat and even electricity. "Drilling at a depth of up to 5000 meters can cost several million euros. If a drill operator misses the mark at first, micro turbine drilling can save the day," says Niklas Geißler, a researcher at Fraunhofer IEG. Together with his team, he has developed a method called micro turbine drilling, or MTD for short, based around a new micro drilling turbine.

**The idea is that** the micro-turbine is equipped with a special drill bit, and is guided down the borehole on a tube via a rod system. A deflection saddle at the end of the rod system guides the small turbine outward at an angle of 45 degrees. The turbine then revolves at up to 80,000 times

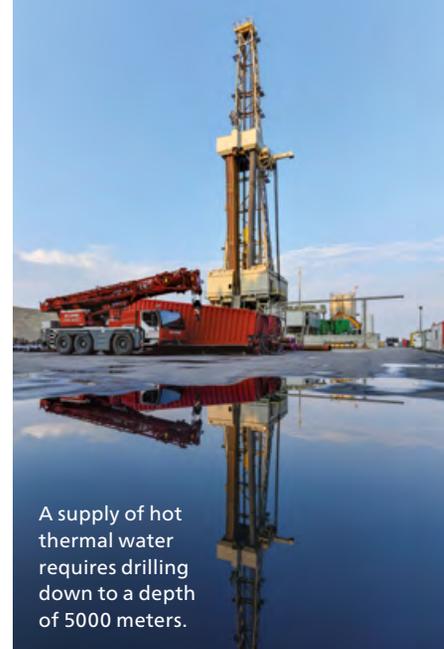
per minute, penetrating both the steel casing of the borehole and hard rock such as granite. Acoustic signals are set off by trigger elements in the borehole, among other things, and travel through the rod system and up to the surface, allowing the technical team to monitor the process.

In the future, the turbine will be able to cut through rock for up to 50 meters.

According to estimates, the total demand for thermal energy in Germany will be around 1400 terawatt hours per year in the coming years.

The operator will also be able to drill several boreholes around the primary well in a star formation, allowing a full investigation of the surrounding area and an even higher yield of thermal water.

In 2020, around 9 percent of the heat generated from renewable sources came from near-surface geothermal energy. In the future, as infrastructure for deep thermal energy expands, this share will



A supply of hot thermal water requires drilling down to a depth of 5000 meters.

increase significantly, in turn accelerating the energy transition. Geothermal energy has a decisive advantage here: It is dispatchable. "This means that regardless of the weather, the position of the sun or the time of year, the systems can deliver a constant stream of hot water — 365 days a year, day and night," explains Geißler. On top of that, the systems are small. They can be accommodated in unobtrusive buildings that fit nicely into the neighborhood. After all, the essential parts of the process all happen underground.

**According to estimates,** the total demand for thermal energy in Germany will be around 1400 terawatt hours per year in the coming years. "If we succeed in tapping hydrothermal deposits even more effectively and integrating them into district heating systems and industrial processes, for example, then geothermal energy could cover at least 300 terawatt hours in these areas alone. Additionally, near-surface geothermal energy has an equally high potential for supplying individual properties and city districts," says Prof. Rolf Bracke, Director of Fraunhofer IEG. ■

**Geothermal energy: Taking drilling to a new dimension**  
Fraunhofer researchers Niklas Geißler and Prof. Rolf Bracke have brought along an audio recording, captured at a depth of more than 300 meters.  
**Scan here for the podcast:**



## **Knowledge relay**

***resource strategies***

***energy  
transition***

# 80,000 revolutions for the energy transition

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## Knowledge relay

***Prof. Anke Weidenkaff, what resource strategies are necessary for the global energy transition?***

## Knowledge relay, episode 4

# Prof. Anke Weidenkaff, what resource strategies are necessary for the global energy transition?

### **Series:**

### **Knowledge relay**

The times we live in are raising **lots of questions** – Fraunhofer researchers are working hard to find the **answers**. A specialist **answers a question**, then poses a **question of their own** for the **next expert** to answer – it's a **"knowledge relay."** In this edition, **Prof. Anke Weidenkaff**, Director of the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, responds to a question posed by **Prof. Hans-Martin Henning**, Director of the Fraunhofer Institute for Solar Energy Systems ISE.

**T**he global energy transition means establishing accessible, safe, emission-free and sustainable energy supplies across the whole world. The goal is to reduce emissions drastically by 2050. The global temperature increase must be limited to 1.5 °C.

This requires renewable energy sources and the transformation of every economic sector (automotive, real estate, production). The transition also calls for high-end technologies, with demand of raw materials set to triple by 2050. Many of these substances are already on the critical raw materials list today, and even more will join their ranks over the course of the energy transition. There will be no new resources, so we must be economical with the materials available to us on Earth. We need to focus more on reusing materials. This means we must recycle and funnel our resources into a closed loop in order to secure our supply of raw materials. But where should we start?

Recycling rates must increase even further. Analyzing the entire life cycle of a product is an important step here. Extraction and exploitation of raw materials must be taken into account within one holistic system. In such a system, materials would be evaluated from a technical, environmental and economic perspective right from the development phase.



Prof. Anke Weidenkaff is Director of the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS.

Then, in the production stage, we can use material flow analyses to identify areas where resources could potentially be saved. We should also start considering how to close the product loop through recycling as early as the design and development phase and make it possible to reclaim secondary raw materials in an effective way.

### Green hydrogen will play a key role

We also need to achieve fully closed material loops in terms of the substances emitted into the environment. Even the earliest production phases result in harmful emissions and byproducts that can cause major damage to our environment. The planetary boundary for chemical pollution, one of nine planetary boundaries, has probably already been exceeded. It is hard to establish precise values, because measuring concentration levels in humans and the environment is a com-

plex process. The planetary boundaries are mutually dependent, so for example, chemical pollution is related to climate change, which in turn is closely connected to the energy and transport transition.

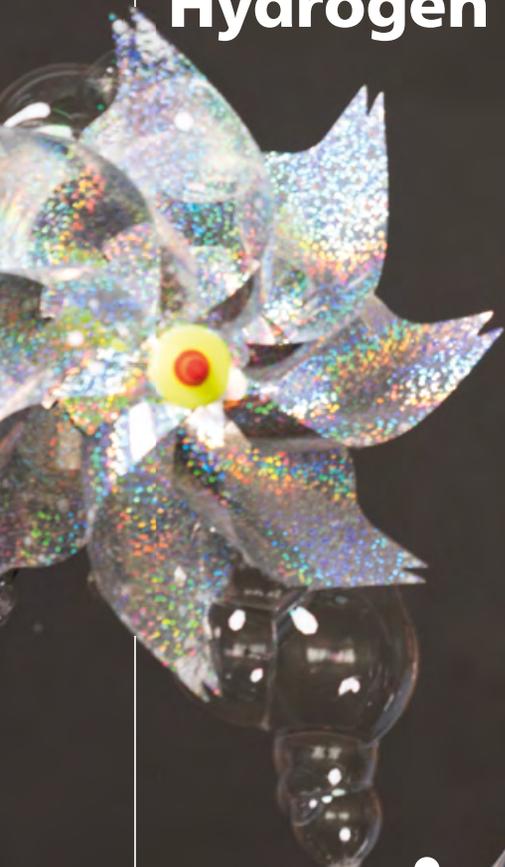
Green hydrogen will have a key role to play in the global energy transition, as it's a suitable storage medium for volatile wind and solar energy, and can also be used directly as a fuel. This means that hydrogen is in a position to make a vital contribution to decarbonizing industry, transport and even heat generation. Even now, we are already deploying many technologies that can produce green hydrogen using renewable energy sources. We are already moving toward developing sustainable solutions for storing and transporting the gas safely. The energy stored as hydrogen can then in turn be released via fuel cells. It is not enough for new materials to simply fulfill new functions in energy converters and applications aimed at ensuring sustainability; they must also be sustainable and safe themselves. ■

There will be **no new resources**, so we must be economical with the **materials available to us on Earth**. We need to focus more on **reusing materials**.

#### In the next issue:

When it comes to **hydrogen**, many people are concerned about the **Knallgas reaction** — how safe are these new technologies?

## Hydrogen



# Winds of change

As Germany sets its sights on climate neutrality, green hydrogen is set to make decisive contribution. However, the production of gas is still not “green” enough. Researchers from several Fraunhofer institutes hope to change this. As part of the H<sub>2</sub>Wind project, they are developing electrolyzers that can produce hydrogen where wind is abundant: at sea.

By Beate Strobel, photography: Christian Burkert



Hydrogen: an energy drink for industry. Dr. Ulrike Beyer heads up the Hydrogen Task Force at Fraunhofer IWU and Mark Richter leads the Climate-Neutral Factory Operation business area.

# 1. The project

Harnessing offshore winds and converting their energy into electricity is a promising idea on multiple levels. Offshore winds have some advantages over winds on land — out at sea, the wind not only blows stronger, but also at a more consistent rate. That is why offshore facilities produce twice as much energy on average as their land-based counterparts, contributing significantly to the reliability of renewable energies in the process. On top of that, there are no residents at sea to complain about the noise of the rotors, and no citizens' groups to demand that facilities are kept far away from town centers. It also means fewer legal proceedings to put the brakes on the expansion of wind energy. All this makes wind energy an attractive option — but it isn't the full picture. There is also the technical challenge of connecting offshore wind farms to the electricity network. The long distances that electricity must travel to reach the shore are reflected in transmission losses. However, if green hydrogen (H<sub>2</sub>) will play a key role in the German energy transition, as the German federal government's National Hydrogen Strategy asserts, why not move hydrogen production to a place where water and wind energy come together?

**The H<sub>2</sub>Mare lighthouse project** from the German Federal Ministry of Education and Research (BMBF) is exploring just this avenue. Directly combining wind turbines and electrolyzers (the devices that break water down into its components, hydrogen and oxygen) can potentially bring about a considerable reduction in the cost of H<sub>2</sub> production. This would make hydrogen a more appealing option for a number of possible applications from both a financial and an environmental perspective.

The Fraunhofer-Gesellschaft, alongside Siemens Energy, is a main coordinator of the large-scale H<sub>2</sub>Mare project. One of the four sub-projects is H<sub>2</sub>Wind, which is funded by the federal government to the

tune of 3.5 million euros. The project focuses on a compact electrolyzer that can be directly integrated into a wind turbine. However, before this can be realized, there are still many questions to answer. How do you design an electrolyzer to withstand a harsh offshore environment? Where is the best place in the system to install it? How do you treat seawater so that it can be used as a raw material for producing hydrogen? How can the hydrogen produced offshore be stored and then transported to land later?

Dr. Ulrike Beyer has been heading up the Hydrogen Task Force at the Fraunhofer Institute for Machine Tools and Forming

“Fraunhofer is able to ensure a rapid launch to market.”

Dr. Ulrike Beyer,  
Fraunhofer IWU

Technology IWU for two years. “Fraunhofer is positioned at the intersection between fundamental university research and industry. This means, above all, that Fraunhofer can understand the current state of research, modify it for its own goals and ensure a rapid launch to market,” says the doctor of industrial and mechanical engineering.

**Time is a key factor** for H<sub>2</sub>Wind. Although the project was only launched in 2021, researchers plan to present solutions for offshore electrolyzers as early as 2025.

Dr. Beyer considers this deadline to be ambitious, but doable: “At Fraunhofer, the topic of hydrogen drives us both professionally and personally. Sometimes, you have to push yourself right to your limits.” However, the 51-year-old welcomes the challenge. And she sees the benefits for more than just her own institute, which has locations in Chemnitz, Dresden, Wolfsburg and Zittau. “In the Saxony region, we're seeing many small and medium-sized companies that, until now, have been active as suppliers in the automotive sector. They're all looking for new business areas with a view toward entering the future sector of e-mobility. The responsibility falls to us here, as we're preparing these fields for industry.”

Hydrogen has long been considered the champagne of the energy transition. The aim now is to turn it into an energy drink for industry. “Currently, in the field of electrolyzers, almost everything is manufactured manually,” says Mark Richter, Head of Climate-Neutral Factory Operation at Fraunhofer IWU. “That's why we must be able to produce complete systems on an industrial scale in a way that suits the mass market. Only then will we see prices drop, and from there, hydrogen will become a real option for industry.” Dr. Beyer adds that the aim is to create a “people's electrolyzer,” namely one that is functional and inexpensive.

To Fraunhofer, H<sub>2</sub> is far more than just a trendy topic, explains Mark Richter. “It is a strategically important and sustainable research field that not only allows us to shape the future, but also to constantly develop ourselves.” Aside from Fraunhofer IWU, the Fraunhofer Institutes for Wind Energy Systems IWES, for Microstructure of Materials and Systems IMWS, for Interfacial Engineering and Biotechnology IGB and for Chemical Technology ICT are also involved in H<sub>2</sub>Wind. “The topic of hydrogen extends across almost the entire Fraunhofer ecosystem. This means nearly everyone can make a contribution,” says Dr. Beyer. And that, adds Mark Richter, “is a cool driving force, something fun. That's also important to recognize.”

## 2. The material

The principle of using electricity to split water into hydrogen and oxygen goes back more than 200 years. Today, it is usually achieved using something known as PEM (proton-exchange membrane) electrolysis. The core components of this process are electrolytic cells layered into stacks, which in turn consist of two central components: bipolar plates (BPs) and the membrane electrode assembly (MEA). BPs ensure an electrical connection and transport both between cells and to and from the MEA, where the water is split.

Bipolar plates are usually made of a special stainless steel, graphite and titanium, and are further protected against corrosion by means of a precious metal coating such as gold or platinum. The material and design of the bipolar plates are also decisive factors for the electrolyzer's efficiency, maintenance requirements, functionality and service life. All of this, in turn, is essential for a future offshore electrolyzer to function and turn a profit while far away from land and under extreme conditions.

**The question of materials** is central to Wolfram Münchgesang's role in H<sub>2</sub>Wind. The doctor of physics from Fraunhofer IWES acts as a go-between, coordinating the correlations between stack properties and special offshore requirements discovered at the laboratory level, the development of a research stack at the test level and, finally, the transfer of laboratory and test results to industrial application. Or, as Dr. Münchgesang puts it: "I gather information, consolidate it and try to develop an overall scientific picture on that basis."

Although we have long been aware of the principle of electrolyzers, and their individual components, the development of an offshore electrolyzer represents a new frontier for science. If wind power is used to directly provide the energy to split water, what impact will this have? What particular stresses will the material need to withstand offshore? How will vibrations

or mechanical stress, for example, affect the service life of the various components? After desalinating the seawater, will it still contain ions? Could these potentially accumulate in the stack (or elsewhere in

device for splitting water into hydrogen and oxygen. In principle, it will be the same as it was two centuries ago, only this time it's at sea. And that's the new frontier.



"We design functional models for offshore operations and scale them for industrial application,"

Wolfram Münchgesang, Fraunhofer IWES

the electrolyzer) and impair its function? There are no standardized test profiles or valid measurement scales for any of these questions. And as it's impossible for technicians to quickly service the system on the high seas, it needs superior-quality materials to help it withstand the conditions of its offshore location.

**Researchers aren't planning to reinvent the wheel here** — if only for reasons of time and money. Münchgesang sums it up pragmatically: "We design functional models for offshore operations, test them and, finally, scale them for industrial application." By 2025 at the latest, we should be as close as possible to the ideal

## 3. The storage

In Germany, offshore wind farms are located 58 kilometers from the coast on average. The electricity is usually transported to land via submarine cables that have been laid in the seabed. In the future, how can hydrogen produced offshore be taken where it is needed?

Sebastian Schmidt, project manager at the Fraunhofer Hydrogen Lab in Görlitz, and project partners Siemens, Mannesmann and other Fraunhofer institutes are developing a pipe storage system suitable for offshore use, specifically for H<sub>2</sub>Wind. They will then test various usage ►

“We are setting standards and shaping the future.”

Sebastian Schmidt,  
Fraunhofer Hydrogen Lab, Görlitz



scenarios on the system. “During the tests, the primary aim will be to simulate aging behavior by charging and discharging the storage device in quick succession,” explains the qualified mechatronics engineer. In other words: “Filling the device with compressed hydrogen, compressing it further and draining the device again.” And again and again — this is an endurance test for the future.

**A pipe storage system** is actually little more than a special variety of pipeline, says Sebastian Schmidt: “You take a pipe from a pipeline that’s already proven its ability to transport  $H_2$ , increase the diameter and weld a cover on the left and right sides.” It may sound simple, but it’s not — to ensure the longest functionality possible and store the gas safely, the individual parts of this storage system will likely need to be welded together

offshore and underwater, with maximum precision. As a qualified welder, Schmidt knows that this will be no easy task.

In addition, the environmental conditions at sea are different from those on land. The material that makes up the pipe storage system and the way the system is manufactured must also be designed for this environment. A particular concern is corrosion from salt water. Of course, quality and safety are not the only considerations when storing hydrogen and transporting it to land, be it by ship or pipeline — there is also the matter of cost. Every consumer is currently seeing how important this factor is as they heat their homes or refuel their cars. The energy of the future must be affordable. “Any new technology being developed for offshore use should not only be as highly automated as possible, but should also be robust, straightforward and inexpensive,” says

Schmidt in summary. If the cost associated with hydrogen production cannot be reduced soon, “the German government’s greater plans for hydrogen are in danger, since the industry would not be able to finance a large-scale transition.”

Even if there are still many uncertainties when it comes to hydrogen, Schmidt believes that for a scientist, it is a “real stroke of luck” to be involved at this stage. “We are setting standards and shaping the future.” What more could a researcher ask for?

## 4. The water

To produce green hydrogen, you need water and green energy. This is yet another thing that makes offshore electrolysis so appealing — after all, there is no shortage of these resources at sea. This means we wouldn’t have to use precious freshwater reserves to produce hydrogen at the scale required by industry. However, the devil is in the details: Salty seawater could permanently damage the stack, which is essentially the heart of the electrolyzer. This would not only noticeably reduce the quality of the hydrogen produced, but could also exacerbate the problems associated with maintaining offshore systems, significantly shortening the lifespan of the electrolyzer.

In an ideal scenario, the abundant seawater would therefore need to be treated before use. However, this would consume a lot of energy, reducing the sustainability and efficiency of hydrogen production. What can be done?

**Questions like these** brought chemical engineer Henner Heyen to the Fraunhofer Institute for Wind Energy Systems IWES right after he completed his studies at TU Berlin. The prospect of using wind energy to produce green hydrogen attracted him to work at the Hydrogen Lab Bremerhaven. Two locations have now been added to Fraunhofer IWES in Leuna and Görlitz, both of which conduct research along the

hydrogen value chain. This opens new exciting opportunities to collaborate on future research questions.

As a project manager, Heyen is now responsible for a work package within the H<sub>2</sub>Wind project that focuses on extracting heat from the electrolyzers. This could solve the problem of energy in seawater treatment. "Until now, the waste heat generated when water is split has reduced the efficiency of electrolyzers," explains Heyen. "But if we could at least partially intercept this energy and use it to treat seawater, things would look very different." The scientist is already thinking beyond H<sub>2</sub>Wind: "The solutions that we are developing here for offshore plants could also one day be used for water treatment in regions where there is a shortage of drinking water."

**Heyen has already set his sights** on another "waste product" of electrolysis: the oxygen that results from hydrogen production. "There are already people

interested in this on land, for example in hospitals or sewage treatment plants. We are still looking for viable applications offshore."

## 5. The simulation

At 28, Tom Schwarting is probably the greenest Fraunhofer employee on the H<sub>2</sub>Wind project. Until mid-2021, the information and communications engineer still thought his professional future would be in aerospace technology, and even completed his master's degree at TU Braunschweig in this research field. As a research assistant at the Institute of Flight Guidance, he was involved in the MOSAiC polar expedition, a research expedition that saw the Polarstern icebreaker and its crew drift across the Arctic Ocean for a year, documenting the dramatic melting rate of the sea ice. It became clear to Schwarting that in the future, he would

rather work for people that prevent CO<sub>2</sub> emissions rather than those that cause them.

**Since April 2021**, Tom Schwarting has been part of the Factory of the Future team at Fraunhofer IWU. Within the H<sub>2</sub>Wind project, he is one of the researchers focusing on the question of what changes must be made in order to advance the production and use of green offshore hydrogen, in both environmental and economic terms.

**Using simulation models**, he is trying to map the entire value chain for offshore hydrogen electrolysis as realistically as possible. He uses digital twins to develop, compare and finally evaluate different scenarios. "It's a bit like a kid's game where you have to move marbles back and forth as efficiently as possible," says Schwarting.

But of course, it's anything but a kid's game. There are a huge number of potential influencing factors, not to mention the enormous challenge of properly considering the major developments in the field: How are different forms of renewable energy developing? How much will energy cost in 2025? And in the world of tomorrow, what role will hydrogen play as an industrial raw material? As energy storage? Or even as a heat source? "Our simulations are based on reliable studies, so the numbers are thoroughly substantiated," explains Schwarting. Nevertheless, the fact remains: "It's better to work with estimates than to start with digital simulations too late." Otherwise, you run the risk of a chicken and egg problem: No company will opt to produce hydrogen as long as the cost and benefits are unclear. But if no one produces hydrogen, the financial aspect remains fuzzy. A simulation can help break this vicious cycle.

"Right now, many people consider hydrogen to be a savior, so to speak. But it can only save us if we first generate enough green electricity for hydrogen production," warns Schwarting. "But with every wind turbine we set up, we move a little closer to our goal." ■

"The solutions that we are developing here for offshore plants could also one day be used for water treatment."

Henner Heyen, Fraunhofer IWES



## A voice from the business world



Kerstin Andreae, 53, made the move from politics to industry. As chair of the German Association of Energy and Water Industries (BDEW), she advocates establishing a trading system for renewable gases.

# Hydrogen — A real all-rounder

Germany already has a 500,000 kilometer gas infrastructure and the largest gas storage capacity in the European Union — and these are by no means the only advantages to using hydrogen as its ticket to climate neutrality.

**Kerstin Andreae, Chair of the Executive Board at the German Association of Energy and Water Industries (BDEW), shares her thoughts**

**W**e are facing a great task: to achieve climate neutrality in Germany by 2045. It's an ambitious goal, but nevertheless, it can be done. To be able to make the energy transition a reality, we need to use renewable and decarbonized gases. Hydrogen, in particular, offers considerable potential in this regard, as it can store energy and release it again without emitting CO<sub>2</sub>. Given its wide range of possible uses, it also has a particularly versatile skillset, ranging from climate friendly heat and energy production for industry and private households to environmentally friendly mobility.

### Existing potential

One major advantage of hydrogen is its ability to store electricity over long periods of time without loss — this makes it a key building block for the energy transition. As a result, the use of hydrogen enables energy to be transported and released again at a later point in time without emitting CO<sub>2</sub>. To fully realize the potential of hydrogen, we absolutely must make use of existing infrastructure — specifically Germany's gas storage capacity, the largest in the European Union. Some of the existing capacity for natural gas storage could also be used for climate-neutral gases in the future, making an important contribution to a flexible energy transition in the process. For example, up to 100 percent of the capacity of underground cavern storage facilities, which account for almost two-thirds of the volume of German gas storage facilities, could be used to store hydrogen. This means that in the future, electricity from wind and solar energy could be stored in the form of hydrogen, for example, to compensate for seasonal fluctuations in electricity generation and heating requirements.

In addition, Germany already has a gas infrastructure comprising a 500,000 kilometer network. This infrastructure will be the basis for building a hydrogen economy that extends across sectors and national borders. Distribution networks, in particular, are of great importance here. The task now is to upgrade networks, storage systems and end devices to make them hydrogen-compatible. At the BDEW, we are advocating making use

“Hydrogen is one of the keys to achieving climate neutrality in Germany. That is why it is now all the more important for the German government to promptly follow up its National Hydrogen Strategy with concrete action.”

### Kerstin Andreae

- ▶ has been chair of the executive board of the German Association of Energy and Water Industries since November 1, 2019. The 53-year-old is also a member of the presidential council. The BDEW represents the interests of more than 1900 companies, including major energy suppliers like RWE, E.ON., EnBW and Vattenfall.
- ▶ In 2002, Andreae became a member of the German Federal Parliament (Bundestag) as a representative for Alliance 90/The Greens in Baden-Württemberg. She was a member of the Finance Committee until 2007 and the Greens' spokesperson for economic policy until 2012. Until 2018, she was one of five deputy chairs of the Alliance 90/The Greens parliamentary group. She resigned from the German Federal Parliament before moving to the BDEW.
- ▶ Kerstin Andreae was born in Schramberg, a town in the Black Forest. She studied in Freiburg and graduated with a degree in economics. She is married and has two children.

of the tried and tested regulatory framework for gas networks by integrating hydrogen networks within it. In addition to gas networks, pure hydrogen networks will also be required, for example, in industry. The first regulatory basis for this was created with the last amendment to the German Energy Industry Act (Energiewirtschaftsgesetz, EnWG).

We also require a trading system for renewable and decarbonized gases such as hydrogen. The BDEW has put forward a concrete proposal for this. From our perspective at the BDEW, an important element here will be a standardized source determination system that can be used by end consumers, as well as in industry and trade to clearly trace the sources of renewable and decarbonized gas. This way, consumers can make a transparent choice about what form they want to purchase these gases in (“clean choices”). Production for the market would take place in Europe initially, then shift to non-European supplier countries in the future.

### The urgent need to remove investment blockers

Hydrogen should be produced in a way that is both climate-neutral and increasingly renewable, so that its high potential for climate protection can be fully exploited. The energy industry has a central role to play here in supplying the green electricity that could produce a significant portion of our hydrogen requirements in the future. This green hydrogen could then make a major contribution to substantially reducing CO<sub>2</sub> emissions. Expanding our use of renewable energy sources is a vital factor in enabling this. However, to achieve this expansion, we must remove the remaining investment blockers, and overcome obstacles to the use of wind and photovoltaic energy. After all, obstacles that hinder expansion in the field of renewable energies also hinder the production of renewable gases. As a beacon of hope for carbon-neutral energy production, hydrogen is also one of the keys to achieving a climate-neutral Germany by 2045. That is why it is now all the more important for the German government to promptly follow up its National Hydrogen Strategy with concrete action. ■

# Hydrogen from the compost heap

Until now, the most common way to get rid of green waste and sewage sludge has been to compost or incinerate it. However, using these materials to produce valuable hydrogen would make far more sense.

By Tim Schröder

**T**here is no shortage of organic waste in Germany. According to the German Environment Agency, last year, approximately 4.6 million tons of it ended up in the compost bins of German households. This doesn't include waste from public parks and gardens, agriculture and food production, as well as sewage sludge and leftovers from canteens — all in all, it comes to a good 15 million tons. Most of it is brought to composting plants, or incinerated to generate heat and electricity. This creates carbon dioxide (CO<sub>2</sub>) emissions, which harm our climate. But according to Johannes Full from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, organic waste is far too good for that. "It would make more sense to use the material to generate hydrogen. The CO<sub>2</sub> that results from the process could then be separated, stored or used in the long term." Many people consider hydrogen to be the clean energy carrier of the future. Upon burning, it only releases water. But as it stands, hydrogen is still largely produced from natural gas, although a plant-residue-based production process would be much more climate friendly.

The past few years have seen the development of a wide variety of processes for converting biomass into hydrogen. In their analysis, Full and his colleagues took a closer look at which of these processes are technologically mature and could be

operated efficiently in the future. The new conversion methods must also help compensate for a certain weakness in conventional organic waste management, namely that biomass always releases carbon dioxide regardless of whether it is composted or burned. This is because the plants have absorbed it from the air beforehand via photosynthesis. It would make more sense to capture this greenhouse gas from the plants with the intention to either use it as a raw material in the chemical industry or store it underground in disused natural gas fields. "That way, we kill two birds with one stone," says Full. "We contribute to reducing the amount of carbon dioxide in the atmosphere, while also using plant residue to produce green hydrogen in the process."

## Using biomass to its full potential

To show how this can work, Fraunhofer IPA is conducting a project with a company in the metal industry, where waste produced by local fruit farmers and vintners, cardboard waste, waste wood and canteen waste can be converted into hydrogen. This hydrogen can then directly be put to use in metal processing. What's exciting about the project is that the participants compare various methods of hydrogen production. The leftover fruit and canteen waste can first be fermented with the help of bacteria in dark containers, producing hydrogen and carbon

Organic waste has been collected separately in Germany since 1985. The amount of waste has increased significantly since then.

**15**  
million tons  
of biomass  
are produced  
annually in  
Germany





Photo: Gina Baschant

dioxide in the process. The fermented mass can then be converted to methane through another fermentation process at a conventional biogas plant. The methane can also be converted to hydrogen and CO<sub>2</sub>. By contrast, wood and paper fibers are difficult to ferment in this way. They can be split into CO<sub>2</sub> and hydrogen using a wood gasifier.

Purple bacteria are particularly efficient at producing hydrogen from fruit and dairy waste. Researchers at the University of Stuttgart have succeeded in modifying the bacterium in such a way that it hardly requires light. Together with Fraunhofer IPA, they are investigating financially viable methods of producing hydrogen with purple bacteria on a larger scale in the future. As part of the H2Wood project, the team at Fraunhofer IPA, together with the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, is also exploring how microbes can break down wood waste from the Black Forest to form hydrogen, CO<sub>2</sub> and other valuable molecules for the chemical industry in an economic way.

### Solving problems for cities

Hydrogen or valuable gas mixtures can also be obtained from municipal organic waste and sewage sludge with the help of a pyrolysis plant. They could then be used to operate combined heat and power units or the municipal fleet. On behalf of the hydrogen systems manufacturer BHYO, the Fraunhofer Institute for Systems and Innovation

Research ISI in Karlsruhe conducted a study to determine when purchasing such a system would be worthwhile for cities. Spreading sewage sludge on fields was prohibited several years ago, due to contamination with pollutants. Some municipalities have no choice but to pay high sums to dispose of it, at up to 150 euros per ton. However, if sewage sludge could be converted into hydrogen in the future, it would become a valuable commodity. A single ton of organic waste amounts to about 100 kilograms of hydrogen.

“We contribute to reducing the amount of carbon dioxide in the atmosphere, while also using plant residue to produce green hydrogen in the process.”

Johannes Full, Fraunhofer IPA

Researchers from Fraunhofer ISI found that for medium-sized cities, the system is already worth the cost. A particular strength of the BHYO system is that it can supply either hydrogen or gas mixtures, depending on the particular mode of operation. In winter, the operators could concentrate on producing the gas mixture in order to supply combined heat and power units (CHP). In summer, they could switch providing more hydrogen to fuel the municipal fleet.

Martin Pudlik, a research fellow at Fraunhofer ISI and professor at the Bingen Technical University of Applied Sciences, says that this dual use means the systems pay for themselves very quickly. Depending on what's needed, they can be installed as a module directly at CHPs or sewage treatment plants, allowing the sewage sludge to be used on site. Cities could then very easily switch from fossil fuels such as natural gas, fuel oil and diesel to renewable raw materials. It's a pragmatic strategy, and it seems to be working. Bernhard Seyfang, Pudlik's colleague at the university says: “We've only presented the system at a few conferences in the region, but municipalities are already banging down our doors here and at BHYO.” ■



# Eye candy

Nowadays, we often treat eye diseases with drops. However, these are quickly washed out of the eye. To help solve this problem, researchers have developed a new contact lens with a sugar coating for the slow release of active agents.

By Tim Schröder



**S**ugar: For most of us, it's an indulgent treat that causes love handles and tooth decay.

Dr. Ruben R. Rosencrantz has a different perspective. He is head of the Biofunctionalized Materials and (Glyco) Biotechnology department at the Fraunhofer Institute for Applied Polymer Research IAP, located in the Potsdam Science Park, and finds sugar quite simply fascinating.

"The body's own sugars form the substance that keeps the joints and eyes as supple as they are. These sugars line the trachea and lungs to keep germs out." For more than three years, Dr. Rosencrantz coordinated a project to develop a sugar-coated contact lens that could help treat eye diseases.

Eye drops are commonly used to treat irritated and inflamed eyes. However, fluids from tears wash out the drugs so quickly that only around 5 percent of the active agent reaches the area suffering from pain or inflammation. This means that treatments often take a long time. That is why Dr. Rosencrantz and his German-Israeli research team have developed therapeutic contact lenses, an alternative method that is better equipped apply drugs to the eye. Active agents are chemically bound to the surface of the lens and released gradually. As a result, the eye receives a continuous supply of medicine.

### Lubricating lenses with sugar

Dr. Rosencrantz is an expert on sugar molecules, the key ingredient of the therapeutic contact lenses. Together with researchers from the Israel-based Weizmann Institute of Science, Dr. Rosencrantz had the idea of coating the therapeutic contact lenses with sugar molecules to allow for active agents to be embedded in the lenses. It also ensures that the lenses are highly lubricated and do not place an additional strain on irritated eyes. The team chose liposomes to carry their active agents. These microbubbles

consist of a fatty shell that can encapsulate liquids. Liposomes have already been used for a number of years to transport active agents. Most recently, they have been used to carry mRNA vaccines into the body to protect against the coronavirus and other pathogens.

The German-Israeli team has succeeded in finding suitable sugar molecules known as glycopolymers, which are very good at binding the liposomes. The challenge is to create a bond strong enough for the liposomes to securely adhere to the coating on the contact lens, but weak enough that they can gradually detach from the lens and spread throughout the eye.

Surflay Nanotec, a Berlin-based company that, among other things, specializes in applying molecules to surfaces, was also part of the research team. The Berlin scientists applied the glycopolymers to the contact lenses layer by layer, while simultaneously embedding the liposomes in the matrix. The project group was supported by the Israeli company EyeYon Medical, which manufactures individually customized contact lenses. What's more, EyeYon Medical already has plenty of practice in using contact lenses to administer medicines.

These contact lenses are equipped with small holes to which the liquid adheres for a while. "The contact lenses previously ensured that the active agent had a dwell time of around 20 minutes," says Dr. Rosencrantz. "That's a longer period than you achieve by dropping the liquid directly into the eye. However, we wanted to go much further."

And they've succeeded in doing so. Initial tests have shown that contact lenses coated with glycopolymers can release active agents across a period of several hours.

"We have now gathered all the elements needed for a future product: the contact lenses, the glycopolymers and the liposomes," says Dr. Rosencrantz in summary. The project has since ended, but the team still has work to do: They are now carrying

out biological tests in collaboration with the Rostock university hospital. Because therapeutic contact lenses are a future medical product, they must go through the mandatory clinical studies in order to be approved. At the moment, the team is carrying out tests to determine how well the eye tissue will tolerate the lenses in the long term. "There shouldn't be any complications, since we've chosen a very natural substance for the coating, namely the glycopolymers," explains Dr. Rosencrantz.

### The importance of sugar in communication

Glycopolymers have a lot of potential. Cells in tissue groups recognize each other based on the sugar molecules on their surface, meaning that these molecules play an important role in cell communication. This sugar structure transforms in cancerous cells, as the cells slip out of the cell group and metastasize in the body. That is why research on sugar structures can contribute to developing medicines to fight cancer.

Dr. Rosencrantz's group at Fraunhofer IAP has already taken advantage of the fact that pathogens and germs adhere very easily to glycopolymers: The team uses glycopolymers to encase small particles, which, in the future, could be administered as a spray to remove germs from the respiratory tract. Because the germs bind easily to glycopolymers, it is possible that the particles could actually pull them out of the lung tissue. The loaded particles could then be removed from the respiratory tract when the patient clears their throat and coughs up mucus.

But Dr. Rosencrantz isn't just thinking in terms of medicine. He also has the mass market in mind, in the truest sense of the word: "People who wear contact lenses often complain about eye irritation," says the researcher. "With a sugar coating, their lenses could be significantly more comfortable to wear." ■

# Duisburg harbor: From coal haven to climate hero

It's called Kohleninsel — because this little island on the Rhine used to be home to mountains of coal. But now this part of the world's largest inland harbor has fallen into disuse, and Duisburg is developing the free space into Europe's first climate-neutral container terminal — all powered by hydrogen technology.

By Dr. Janine van Ackeren

**D**espite the island's historic name, its time as a coal hot spot has come to an end. The "Kohleninsel" at Duisburg's Inner Harbour is set to become the largest climate-neutral container terminal in Germany: the hydrogen-powered, intelligent, connected facility will offer the perspective of supplying neighboring residential districts with energy in the future. On its 240,000 square meters, the Duisburg Gateway Terminal, or DGT for short, will house six gantry cranes, 12 block train rails stretching for 730 meters each and multiple berths for barges. The facility will need sustainable green energy — enerPort II, a project running in parallel to the terminal's construction, aims to provide it with an innovative energy model. With funding from the German Federal Ministry for Economic Affairs and Climate Action (BMWK), the harbor operator duisport and the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT are collaborating on the project with other partners.

## Constructing a new container terminal in Duisburg: From theory...

To begin with, the researchers worked out the theory behind a climate-neutral container terminal in their initial project, enerPort. "First, we analyzed inland harbors in general: What standardized features from the field of settlement typology can be found at the harbor? What's the situation regarding its industrial importance, its structure and its integration with the city's infrastructure? We wanted to start by understanding how a harbor functions as a district," explains Anna Grevé, head of department at Fraunhofer UMSICHT in the neighboring city of Oberhausen. "Ultimately, inland harbors are a very specific type of district. They combine industrial, commercial,

administrative and residential spaces, and they can be located in either urban or rural areas." The team summarized their results on maps, allowing them to compare Germany's 170 inland harbors and group them into clusters based on their features.

## ... to practice

Although construction work on the DGT only started in spring 2022, the four-year enerPort II project kicked off back in December 2021. Fraunhofer UMSICHT is in on the action, right alongside Rolls-Royce Power Systems AG, Westenergie Netzservice GmbH, Netze Duisburg GmbH, Stadtwerke Duisburg AG and Stadtwerke Duisburg Energiehandel GmbH. The primary focus for the research team is on connecting photovoltaics, fuel cells and a hydrogen-based combined heat and power unit, as well as various electrical and thermal storage facilities, to form one optimized, intelligent energy system for the terminal. The challenge here is that the terminal requires as much energy as around 1000 family homes. "First of all, we want to show that it's possible to get the energy supply for something as large and complex as a container terminal from renewable sources — after all, we don't have any experiential data to work with here," Grevé points out. The Fraunhofer UMSICHT team has developed a mathematical optimization model that they hope will help cover the extensive list of requirements. Energy from the photovoltaic system is subject to natural fluctuations depending on the levels of sunshine, and consumption fluctuates too — for example, large quantities of shore-to-ship power are mainly needed when a ship is moored in the harbor. And what's the situation in terms of demand and grid networks for hydrogen? Would there be customers for the oxygen that would be produced in the process? Could the



Illustration: duisport

facility supply the neighboring residential district with heat in the future?

Using this model as a basis, the team develops operating strategies that could achieve different goals depending on what the operator wanted — such as the lowest possible CO<sub>2</sub> emissions, for example, or a high level of self-sufficiency. Fraunhofer UMSICHT is also planning to develop business models. What's more, the results from the mathematical modeling will be built into the monitoring system and real-time control system for the facilities.

The dirt may still be fresh on the shovels from the ground-breaking ceremony, but the new terminal is already considered a test site and model for climate-neutral inland harbors all over the world. “The

container terminal will act as a foundation where we can build many other projects — like supplying the surrounding districts or other terminals with energy and heat, producing hydrogen in the harbor area or setting up a hydrogen fueling station at the harbor,” relates Grevé. Plans for these satellite projects include a hydrogen-powered switcher. Until now, switchers have always had diesel engines, as overhead wiring for electric vehicles would get in the way in harbor environments. Now, the climate-neutral terminal is becoming both the anchor and the foundation for the transformation of Duisburg's entire harbor. And what's more, this model will serve as an example for other inland harbors; its effects will be felt far beyond the boundaries of Duisburg harbor. ■

The terminal requires as much energy as **1000** family homes.

This is what 240,000 square meters looks like. The illustration gives some idea of the sheer scale of the Duisburg Gateway Terminal.



# Bridges at the breaking point

With half of all German autobahn bridges aging and overloaded, road closures and traffic jams are an inevitability. Fraunhofer IZFP is hoping to lighten the burden with a new system for continuous condition monitoring.

By Dr. Sonja Endres

At 185 meters, the Kocher viaduct on the A6 near Geislingen is the highest bridge of its kind in Germany. It is one of the few autobahn bridges built in the 70s that has already undergone comprehensive renovation work.

Every day, individual sections of the autobahn must bear axial loads of more than **200,000 tons.**

**30 %**  
of all autobahn bridges were in a condition deemed adequate or worse in a 2021 assessment.

**60 %**  
of bridges on German highways are between 35 and 60 years old.

Starting this year, Autobahn GmbH aims to annually renovate at least

**400**  
bridges, up from 200.

“It is vital that we make the switch from reactive to proactive maintenance management.”

Prof. Hans-Georg Herrmann, Fraunhofer IZFP



Since the start of December, noisy, smelly heavy-goods vehicles have been clogging the streets of Lüdenschaid in western Germany. Every day, around 25,000 vehicles are diverted from the A45 and through the once tranquil town, because they can't use the autobahn anymore — the nearby Rahmede viaduct had to be closed entirely due to serious damage. With renovation out of the question, the only option is to tear down and rebuild the 53-year-old bridge — and that's no one-off.

Around half of the 28,000 bridges on the German autobahn were built in the period between the 60s and 80s. Since the beginning of the 80s alone, traffic volumes have almost doubled, with heavy-goods vehicles in particular showing a significant increase. But the problem is not just that there are more trucks on the roads, it's that the vehicles themselves have grown to gigantic proportions. Trucks with a total weight of 40 tons and 11 tons of axial load are by no means rare. Dr. Jürgen Krieger, director and professor at the German Federal Highway Research Institute (BAST), lays out the facts clearly: “Our current traffic situation is incompatible with old bridges,” he says. The civil engineer heads the BAST's Bridges and Structural Technology department. However, if traffic is to keep flowing, renovation and rebuilding work must be carried out in stages. “This means we have to ensure that these older bridges continue to function for as long as possible,” Dr. Krieger warns.

### Continuous monitoring cuts costs

Prof. Hans-Georg Herrmann and his team at the Fraunhofer Institute for Nondestructive Testing IZFP in Saarbrücken hope to lend a hand here. The deputy institute director, engineer and sensor expert is working on a sensor system that will continuously monitor bridge conditions. “It is vital that we make the switch from reactive to predictive or proactive maintenance management, so that we can keep the costs and consequences for traffic as low as possible,” Prof. Herrmann affirms. Prof. Krieger agrees wholeheartedly. In the future, intelligent sensors will help detect problematic changes in the bridge structure at an early stage — before any visible damage occurs.

Previously, bridges were surveyed by specially trained civil engineers, with primary and second-

ary — almost exclusively visual — inspections taking place at three-year intervals. In a primary inspection in line with DIN 1076 requirements, the bridge is checked all over from touching distance. In other words, every square meter must be inspected with great precision, with the inspector close enough to reach out and touch the structure at any time — for example, to tap it. They must document and assess cracks and any other damage. If they are unsure, they must arrange for a more in-depth analysis. At that point, they can also call on established non-destructive testing methods, such as the ultrasound and georadar systems developed by Fraunhofer IZFP. “We use a multimodal approach to solve the problems that the civil engineers bring to us. This means we combine different, sometimes newly designed sensors and measurement and condition variables. The system will draw on a variety of information sources, just as a human being would with their own senses,” explains Prof. Herrmann. This would offer many possibilities for inspections. For example, it could be used to measure the thickness of concrete structures or assess corrosion of embedded steel elements — a characteristic weakness of prestressed concrete bridges, which make up around 70 percent of the German highway bridges. Bridges from the 70s and 80s are a particular risk for stress corrosion cracking, which can cause cracks to form unexpectedly in prestressed steel and, in extreme cases, can cause bridges to collapse. “We have made enormous progress in terms of construction materials. Back then, concrete was far less durable and thick than it is today,” says Prof. Krieger. It all boils down to one thing: old concrete is delicate and prone to cracking. Water and road salt find their way into the cracks and start wearing down the aged structural steel. Prof. Krieger sighs. “There's actually nothing more you can do at that point.”

To prevent bridges from reaching that stage, it's important to continuously monitor — and if necessary, repair — the concrete road surfaces and the underlying steel mats that reinforce them. “We are working on miniaturizing our inspection systems so that they can be installed on site as permanent sensors,” says Prof. Herrmann. His plan is that the efficient, intelligent sensors will generate their own energy supply, ideally via solar cells and that the system will also be able to detect the bridge condition in real time. The data from



500 meters long and 70 meters high, the Rinsdorf viaduct on the A45 imploded on February 6, just as planned — right down to the centimeter level. Under no circumstances could the demolition be allowed to damage the first part of the new bridge, which stood directly alongside.

the sensors can be read on site by means of wireless transmission to a cellphone or automatic transfer to a cloud. An initial subcomponent of the system has already been developed and is currently undergoing testing.

Having been responsible for bridge planning, construction and operation since the start of 2021, Carsten Chassard of Autobahn GmbH des Bundes would also welcome a sensor system that could serve as an additional tool for structural monitoring and sustainable maintenance. The civil engineer, who heads up the autobahn company's Neunkirchen branch, looks after a 334 kilometer autobahn route network with 527 bridges. He also has a tale of woe to tell when it comes to corroded reinforcement steel and cracked concrete structures. However, his hope is that continuous monitoring will make it possible to take more targeted action at an earlier stage. "But the measurement program will always have to be adapted to each specific bridge and its unique static characteristics."

"Our current traffic situation is incompatible with old bridges."

Prof. Jürgen Krieger,  
German Federal Highway Research  
Institute (BASt)

And it's important to take the findings of structural inspections, any damage that has already been identified and the characteristic weaknesses of various bridge types into account in the process. Crucial variables such as traffic impact and air and structure temperature must also be measured. Without them, the data cannot be classified and

correctly interpreted. Above all, the sensors have to be installed at the points that experience the greatest level of stress. These must be calculated individually for each bridge. "We don't have any standard 'construction kit' bridges in Germany. Placing a sensor at a point where nothing happens is a waste of time," cautions Prof. Krieger. However, he adds that continuous monitoring of every single problematic element is not a realistic option. Instead, experts will have to choose representative objects and apply the results to similar bridges and structural elements — to avoid closures like Lüdenscheid and the accompanying financial losses, which reach well into the millions. ■

# 60

## viaducts

on the A45 alone will have to be renovated due to their advanced age, including the 55-year-old Rinsdorf viaduct and 53-year-old Rahmede viaduct in North Rhine-Westphalia.



For more information, see:  
<https://s.fhg.de/izfp>

# From coal to blockchain

A living lab for blockchain technology in an old film studio is aiming to simplify the digital transformation process for companies, and to increase the attractiveness of the coal mining region in the Rhineland as an innovation hub.

By Markus Borgmann

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Find out what's in the pipeline at the new European Blockchain Institute in Dortmund and how technology can drive progress for companies in an interview with Prof. Michael Henke and Prof. Wolfgang Prinz.

Scan here for the podcast:



In 2038, coal will finally be phased out. The Rhineland mining region needs new options for the future now.

**T**wo experts, one development, two points of view: “In the coming five to ten years at the latest, there won’t be a single business in the B2B sector that isn’t using blockchain technology.” There’s a touch of euphoria to this firm pronouncement by Prof. Michael Henke. By contrast, according to Prof. Wolfgang Prinz, “Far too many promises were made in the past; nowadays, when it comes to the practical implementation of blockchain, we tend to focus much more on the obvious, low-hanging fruit.” For example, blockchain could be used as a reliable means of verifying the origin of medicines or food and checking whether refrigeration was provided throughout transportation.

Prof. Henke is director of the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund, while Prof. Prinz is deputy director of the Fraunhofer Institute for Applied Information Technology FIT in Birlinghoven, North Rhine-Westphalia. Both institutes have been working closely together in this field for many years.

Blockchain has had a turbulent past. The concept of a decentralized system for breaking down data into blocks, interlinking them and encrypting them cryptographically was first written about in the public domain in 2008 under the pseudonym of Satoshi Nakamoto. To date, it is unclear if the name refers to a single person or a group of people. What is clear, however, is that the hype surrounding blockchain, bitcoin and smart contracts started there. Fraunhofer IML and FIT have been working on this topic since 2015. In 2017, the first Fraunhofer position paper dedicated to research questions and potential applications of this technology was published.

For Fraunhofer, the living lab for blockchain technology in Hürth near Cologne has become a core element of its blockchain strategy in North Rhine-Westphalia. The film studio, where Hans Meiser and Ilona Christen once hosted talk shows, is being converted into a blockchain environment. “The idea is that interested parties can come to us to learn about blockchain. We use various demos to

Prinz. “The drivers of the tank vehicles receive digital certificates, which are verified on a mobile device, for example, by scanning a QR code. This provides tamper-proof evidence that the tank has not only been cleaned, but also that the cleaning has been checked.”

Prof. Prinz’s team presents examples such as these in the living lab and uses demos to explain to interested parties how

Prof. Michael Henke,  
Director of  
Fraunhofer IML



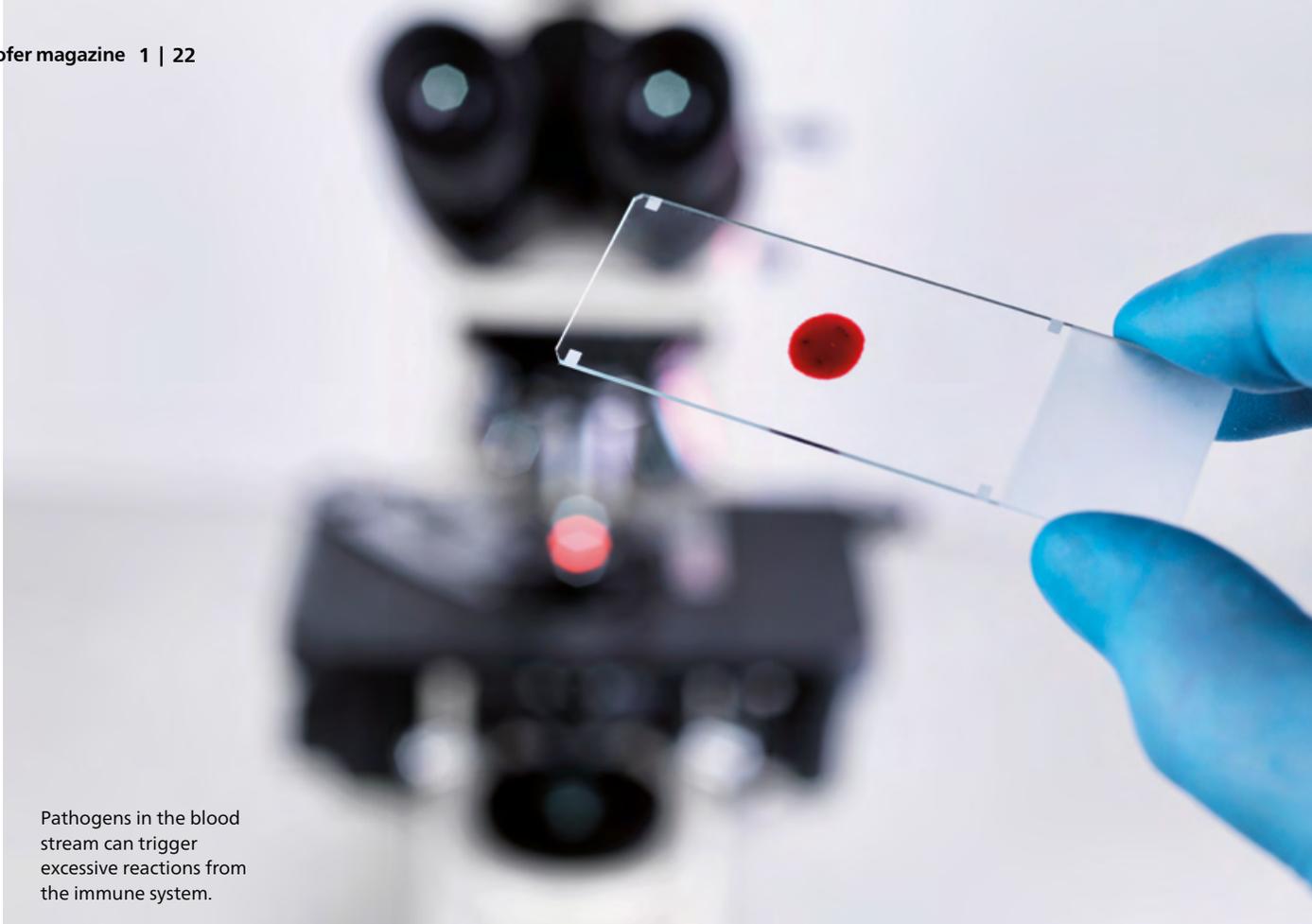
Prof. Wolfgang Prinz,  
Deputy Director of  
Fraunhofer FIT



explain the use and benefits of the technology”, explains Prof. Prinz, who heads up the living lab. “It goes without saying that the visitor pass is also on a blockchain.” The project, which has received five million euros in funding from the state of North Rhine-Westphalia, is designed to drive structural transformation in the Rhineland mining region following the phasing out of coal — and has long since reached the application stage. The experts at the living lab help companies in the region to familiarize themselves with the technology, show them possible applications and work with them to develop ideas for new digital services. Prototypes for initial use cases have already been implemented with a local logistics service provider specializing in the transport of chemicals. For safety reasons, the cleaning of the company’s tank vehicles must be carefully documented. Paper documentation seemed too unreliable to the managing director. “So we quickly arrived at a blockchain solution,” according to Prof.

data is stored on a blockchain. In the future, each step of a process, along with all of the associated data and documents, can be securely and irreversibly recorded on the blockchain, making it ideal for numerous applications, such as tamper-proof certificates of origin, internal company documentation or international trade. “Not everyone needs to understand exactly how blockchains work”, says Prof. Prinz. “Hardly anyone knows how the gears of a car work, and yet everybody uses them.”

While manual transmission will become less important in the years ahead due to electromobility, Profs. Henke and Prinz are certain that the future belongs to blockchain, especially when it comes to transaction-based businesses. Prof. Henke cites the electronic waybill and customs documents as examples. “A digital blockchain-based folder will replace paper documents, making customs transactions, for example, not only more secure and transparent, but also more sustainable due to the savings in paper.” ■



Pathogens in the blood stream can trigger excessive reactions from the immune system.

# Racing the clock to save lives

Every year, 11 million people worldwide are struck by sepsis — and many do not survive. Fraunhofer IGB is looking for a quicker and more reliable method of finding the trigger pathogens — within the space of a hospital shift.

By Dr. Monika Offenberger

**B**lood poisoning is an old name for a very topical illness: Every year, around 11 million people worldwide suffer from sepsis, with 280,000 of them in Germany alone.

Sepsis comes on suddenly. Once triggered by an infection, it causes an uncontrollable immune response. If untreated, the condition will cause multi-organ failure, circulatory shock and, ultimately, death. It's caused by pathogens entering the bloodstream. Doctors try to fight the unknown enemy with broad-spectrum antibiotics,

but one in four patients lose the race against time. Now, there's a new method for identifying the pathogens quickly and accurately. Is it bacteria — and if so, which one? Or is it a virus, fungus or parasite?

The standard procedure when sniffing out the culprit starts with a blood sample from the patient. The sample is enriched with a growth medium and placed in an incubator so that the unknown germs will multiply. Then they can be identified using a microscope or based on their molecular and biochemical characteristics. "This conventional diagnostic process usually

takes several days and works for at most 30 percent of cases, but generally even less. We've got to make this process faster and more reliable," emphasizes Dr. Kai Sohn of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. Dr. Sohn has a PhD in biology and heads up the In-vitro diagnostics innovation field. Since 2014, he's been on the hunt for biomarkers that can also be found in blood samples, but deliver far better detection rates than the conventional incubator methods. He struck gold with a particular class of nucleic acid — cell-free

DNA or cfDNA for short. It consists of a variety of DNA fragments released by cells that have died or been destroyed by the immune system. These fragments then circulate in the blood stream for a short period of time. Cell-free DNA can be isolated from the blood and sequenced overnight using commercially standard high-throughput techniques. “We analyze up to 30 million different DNA fragments in a single blood sample. Then we use bioinformatic methods to compare each individual fragment with known sequences from publicly accessible databases,” explains Dr. Sohn. In the process, they discovered that 95 to 99 percent of the cfDNA comes from the patients themselves. The remaining 1 to 5 percent is of non-human origin, meaning that it has to come from a germ or germs. “We take these fragments too and compare them one by one to reference genomes from the databases,” the researcher recounts. “Then at the end, we can say what microorganism we’re dealing with. And what’s more, we know what quantities of it are there. From that, we can deduce how relevant they are for the infection and the sepsis — and work out what medications can be used to fight them most effectively.”

**An additional benefit of this approach** is that the number of cfDNA fragments in the blood is generally many times higher than the number of intact microbes that are needed for cultivation in incubators. What’s more, it’s easy to multiply even tiny amounts of nucleic acid. As a result, the chances of identifying the cause of the patient’s sepsis with a much greater degree of reliability are good. Dr. Sohn tested his method on more than 250 blood samples from 48 patients at Heidelberg University Hospital — and confirmed that it works. The standard diagnostic procedure could only identify specific bacteria in 29 blood samples. Meanwhile, the Fraunhofer team succeeded in pinpointing the relevant pathogen in 169 samples using cfDNA. “This means our process is at least five times more sensitive than the conventional method, and also much quicker,” concludes the biologist.

All the patients involved in the study were treated with broad-spectrum antibi-

otics as quickly as possible, in line with good medical practice. However, if a diagnosis had been made based on cfDNA, more than half of them would have been able to receive more specific — meaning more effective — medications. The team are currently conducting comparative testing on the method using samples from 500 patients suffering from sepsis and 50 healthy test subjects at 20 German university hospitals. This elaborate, multi-centric study and another research project at the university hospitals of Essen and

One in four  
patients lose  
the race  
against time.

Heidelberg have been funded by the Dietmar Hopp Foundation (Dietmar Hopp Stiftung). “There, we hope to test our improved diagnostic process with severely ill newborn and premature babies and small children. Because in addition to the elderly, sepsis primarily affects the very young,” explains Dr. Sohn. In the future, the team intends to use nanopore DNA sequencing to analyze DNA molecules of any length in real time. Even today, conventional high-throughput sequencers can process all the cfDNA in a sample in just 16 hours. When you add in the subsequent data analysis step, that means you can make a diagnosis within 24 hours. “But there’s room to improve here, too, when it comes to treating sepsis,” emphasizes Dr. Sohn. He has ambitious goals: “Our aim is to use nanopore technology to cut this timeframe down to six to eight hours — that is, the duration of a hospital shift.”

In addition to research labs, quite a number of university hospitals are now equipped with high-throughput sequencers. The key thing is knowing the right way to prepare each sample in order to filter out the relevant information for a medical diagnosis out of the massive quantities of sequencing data. “This is exactly where our area of expertise lies,” Dr. Sohn points

out. “We cover the entire process, offering a one-stop shop for everything from sampling and processing to analyzing and interpreting the nucleic acids in question. This allows for extremely high levels of speed and efficiency.” Sepsis diagnostics is just one of many fields that call for quick, accurate identification of nucleic acids. Unknown germs can attack a wide variety of tissues and organs, so their DNA not only circulates in the bloodstream, but in other bodily fluids as well, such as in the joints and the brain.

**Even for diseases** that are not caused by foreign pathogens, DNA analysis can prove useful. Dr. Sohn describes how it could be brought to bear in tumor diagnostics: “With patients experiencing painful symptoms relating to the pancreas, you always have to ask yourself: is that pancreatic cancer or just inflammation? The latter can be treated with medication. But if it’s a tumor, that has to be removed completely at the earliest stage possible. Otherwise, the patient’s chances of survival will be slim.” At present, the only way to shed any light on the situation is to take a tissue sample from the patient, but that requires a biopsy. In the future, Dr. Sohn believes it will be possible to replace this unpleasant and possibly risky surgical intervention with a blood sample analysis.

The Fraunhofer IGB team is collaborating with the Universitätsklinikum Erlangen university hospital and a Swiss bioinformatics company to look for suitable biomarkers. “We isolate the cfDNA of patients with pancreas problems and check what sections have undergone chemical alterations. These epigenetic signatures tell us whether a gene is active or turned off. If a tumor is developing, certain genes will be shut down, while the activity of other genes will change in the case of inflammation. By comparing the samples with healthy people, we can identify signatures that allow us to make a conclusive diagnosis. And we already have some very promising candidates,” reveals Dr. Sohn. He has a clear vision for the future. “When a pancreatic patient comes into a hospital, we want to be able to tell them what’s going on straight away. A test that delivers quick, unambiguous results could save lives.” ■

## Hugo Geiger Prize

# Prize for talented young scientists

Every year, the state of Bavaria and the Fraunhofer-Gesellschaft award the Hugo Geiger Prize to three young scientists that have produced outstanding doctoral work in the field of applied research.

By **Laura Rottensteiner-Wick**

A helping hand for the energy transition:  
Dr. Markus Feifel at work.

“Markus Feifel has successfully increased the efficiency rate of silicon-substrate-based III-V solar cells from

**19.7** to  
**25.9**  
**percent,**

a major technological advancement.”

Prof. Andreas Bett,  
Fraunhofer ISE



## FIRST prize: Dr. Markus Feifel, Fraunhofer ISE

# Solar power from small spaces

### High-efficiency III-V multi-junction solar cells on silicon

Dr. Markus Feifel is playing an active role in the energy transition. “It’s very satisfying to conduct research in an area that can offer significant added value for humanity in the near future,” says the young physicist.

**F**or his dissertation on high-efficiency III-V multi-junction solar cells on silicon at the Fraunhofer Institute for Solar Energy Systems ISE, Dr. Feifel developed a high-powered, complex, III-V solar cell structure based on a silicon substrate that has already broken multiple efficiency records. The results of his research earned him first place in the Hugo Geiger Prize 2021. “This award is the best form of recognition I could receive for the work, time and even stress that have gone into this dissertation over the years,” says Dr. Feifel.

Smartphones beep, servers hum and machines rattle away in factories. Without electricity, our modern world would collapse. But energy comes with a price — and not just a financial one. The energy sector still produces a major portion of global CO<sub>2</sub> emissions. The political will to expand our use of renewable energy has never been greater — and the need has never been more dire. “Renewable energy frees us from dependencies. That makes renewable energy a kind of freedom,” announced Christian Lindner, the German Minister of Finance on February 27, 2022, at a special sitting of the German Federal Parliament (Bundestag) on the war in Ukraine. But with a lack of suitable locations and efficiency rates of existing technologies stretched to the utmost, the options are limited. Dr. Markus Feifel set out to tackle this problem by developing a new kind of solar cell. “In conventional silicon solar cells, you just use an absorber material to convert the sunlight into electrical power,”

explains Dr. Feifel. Silicon is the second-most common element in the earth’s crust and the market for it is well developed. But at the moment, silicon cells only reach an efficiency rate of up to 24 percent in production. “The goal is to produce significantly more power with a comparable cost level and using the same surface area, while also opening up the possibility of producing solar energy in small spaces where it’s currently not viable, such as in the automotive field,” relates Dr. Feifel.

**Tandem photovoltaic cells** offer a possible solution to this problem. These cells consist of multiple absorber layers stacked one on top of another, so that they can take in a greater spectrum of sunlight. The sub-components of the cells are mere micrometers thick and only harness the wavelengths of light that they can convert into electricity with a comparatively low level of loss. The technology exists and III-V multi-junction solar cells are already reaching efficiency levels of up to 39.2 percent. Previously, instead of silicon, multi-junction solar cells were exclusively based on III-V compound semiconductors, a combination of materials from Group III (earth metals/boron group) and Group V (nitrogen family) of the periodic table, which are much rarer than silicon. This makes III-V semiconductors too expensive for conventional flat solar modules, so they are used almost exclusively in space technology. Dr. Feifel’s solution combines the best of both technologies. “In my silicon-substrate-based III-V solar cell structures, two III-V sub-components



Dr. Markus Feifel

are ‘grown’ directly on a cheap silicon substrate by means of epitaxy,” says Dr. Feifel.

**The big challenge** with this combination is that silicon and gallium phosphide, the first III-V semiconductor grown in this way, have differing lattice structures. “This causes defects in the crystals, which drastically reduce performance,” Dr. Feifel explains. He started with an efficiency rate of only 19.7 percent as a result. Detecting the defects was an arduous process, but the breakthrough came when he tried detecting and analyzing the defects with electron channeling contrast imaging (ECCI) — the first time the method had been applied with this material system. “Previously, this method had primarily been used with metals and it can analyze a much larger area at one time.” Dr. Feifel then came across a particular type of defect and was able to adjust the III-V growth conditions accordingly.

“Markus Feifel has successfully increased the efficiency rate of silicon-substrate-based solar cells from 19.7 to 25.9 percent, a major technological advancement,” says Prof. Andreas Bett, Director of Fraunhofer ISE. “We certainly still have some way to go with improving the materials and processes before the results can be transferred to industrial production. But his dissertation has laid the foundations for this development.” ■

**Read on for second and third prize** ▶



Prize winner Dr. Miriam Strangl, 28.

## SECOND prize: Dr. Miriam Strangl, Fraunhofer IVV

### A nose for recycling

#### Analyzing and evaluating odor-active properties in plastic waste and recycled materials

In her research, Dr. Miriam Strangl of the Fraunhofer Institute for Process Engineering and Packaging IVV has focused on our sense of smell. The 28-year-old food chemist analyzed odor contamination of recycled plastics for her dissertation and was awarded second place in the Hugo Geiger Prize 2021 as a result.

**H**andling our resources carelessly is a dirty business — in fact, it quite literally stinks. When it comes to plastic recycling, science and industry have made major progress in terms of visual appearance and mechanical properties. However, undesirable smells remain a major obstacle to the widespread use of recycled plastic. Dr. Miriam Strangl lays out the problem: “Imagine you pick up a bottle of shampoo in the supermarket and the packaging smells like cheese, for example. I’m pretty sure that most customers would put the product right back on the shelf.” Now, the chemist has won second place in the Hugo Geiger Prize 2021 for analyzing this issue in her dissertation on the characterization of odor-active compounds in post-consumer polyolefins.

**Plastic is everywhere.** However, the global recycling rate for plastic packaging is only around 14 percent. The remainder ends up in incinerators or landfills, or is dumped

in the environment. Conserving resources and handling plastic waste in a sustainable way are two of the central challenges of our time.

But the unpleasant smells lingering on recycled plastics are throwing a spanner in the works when it comes to using them in consumer products. During processing, new smells can develop or existing smells can be transferred to plastics; removing them afterward can be quite tricky. This results in a phenomenon known as down-cycling, where recycled products can only be used in limited circumstances. The physical and chemical properties of the polyolefines most often used in the packaging industry are particularly conducive to smell transfer. What’s more, failure to properly separate trash and pure plastic waste, even in dedicated plastic waste collections, means that plastic often comes into contact with a wide variety of garbage components and sources of smells. And analyzing the various objectionable smells is a complex affair. “We still can’t detect and analyze smells with machines as

precisely as we can with visual appearance and mechanical properties,” explains Prof. Andrea Büttner, Dr. Strangl’s dissertation advisor and Director of Fraunhofer IVV. “The research is heading in that direction — at Fraunhofer IVV, for example — but we have a long way to go yet. Analytic sensor technology is still no match for the human nose.”

**To analyze odorants,** Dr. Strangl therefore had to adopt an approach that combined chemical analysis and human sensory perception, so as to bring together the respective advantages of humans and machines. “Once the volatile fractions from the material specimens have been isolated and subjected to chromatography separation techniques, the different smells are characterized by trained personnel using ‘sniffing ports.’ At the same time, instrumental analysis is used to detect the odors,” Dr. Strangl explains. When combined with her knowledge of typical smell sources and formation mechanisms, her research lays the foun-



Dr. Miriam Strangl analyzes odor contamination.

“We still can’t mechanically detect and analyze smells with machines as precisely as we can with visual appearance and mechanical properties.”

Prof. Andrea Büttner,  
Director of Fraunhofer IVV

dations for the development of targeted, innovative decontamination solutions focused especially on smell minimization. “That brings us another step closer to sustainable closed-loop recycling.” But as consumers, we must also literally learn to see further than the end of our own noses. “We basically need to reflect on whether we actually need so many odorous substances in our products. That would allow us to cut off at least part of the problem at the root.”

**For Dr. Strangl**, receiving second place in the Hugo Geiger Prize 2021 is more than just an honor. “That shows me that the massive importance of this issue has been recognized. Because it’s not just about being aware the smell issue — there are other contaminants that need to be eliminated as well. For everyone involved in the value chain, it’s becoming ever clearer that we have to tackle the question of a circular plastics economy in a holistic, interdisciplinary way, in order to sustainably conserve resources.” ■



Fighting for sustainability in lab work:

“For everyone involved, it’s becoming ever clearer that we have to tackle the question of a circular economy in a holistic way.”

Dr. Miriam Strangl

## **THIRD prize: Dr. Jessica Schwarz, Fraunhofer FKIE**

# Focusing on people

### **Real-time assessment of multidimensional user states for adaptive human-computer interaction**

For Dr. Jessica Schwarz, it's all about people. "In human-machine interactions, the technology has to support the people — not the other way around," insists the scientist. "Both humans and machines are prone to errors," she reasons. "For reasons of ethics and liability, if nothing else, humans must continue to bear ultimate responsibility, particularly in safety-critical applications."



How does the brain respond under stress? Dr. Jessica Schwarz is using sensors to test the mental state of a test subject as they carry out complex monitoring tasks on a computer.

In her dissertation on real-time assessment of multidimensional user states for adaptive human-computer interaction at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, Dr. Jessica Schwarz developed RASMUS, a diagnostic framework for user states. As the framework enables multidimensional, and consequently holistic detection and evaluation of mental states and influencing factors affecting workers even as they are working on their tasks, it forms a basis for tailored adaptation strategies. Now, Dr. Schwarz has won third place in the Hugo Geiger Prize 2021 for the results of her work.

**The digital transformation** is turning the working world upside down, and bringing both new possibilities and new challenges in its wake. As an intersection point between the digital and the personal, adaptive human-computer interaction represents an opportunity to offer people the optimal support from their machines in their work. Dr. Schwarz, who has recently taken over leadership of the Human Factors Analysis research group in the Human Systems Engineering department at Fraunhofer FKIE, very consciously focuses on that goal in her research. "As a psychologist, I predominantly concentrate on human factors in the area of human-computer interaction," she explains.

This is why her work is focused on human-centered design. "The technology must support the people, not the other way around."

But adaptively adjusting technical systems to suit people requires continuous detection of the user's mental condition. Because what the researchers call critical user states are often at the root of accidents

in safety critical human-machine systems, for example, in the automotive and aviation sectors. "The crash involving an Air France aircraft in 2009, which resulted in the death of all onboard, is a particularly tragic example," Dr. Schwarz comments. "The pilots were caught off guard when the autopilot failed and did not have sufficient support from the technical systems to overcome their extreme emotional strain

"She uses performance breakdowns to trigger the technical adaptation process. Then she attempts to determine the cause of the decrease in performance quality based on physiological and behavioral metrics."

Prof. Gerhard Rinkenauer, IfADo

and inaccurate situational awareness in time." These human performance breakdowns form the exact jumping-off point for Dr. Schwarz's research. Previous efforts mainly focused on determining the need for adaption based on critical changes in physiological metrics, but she is trying a different approach. "She uses performance breakdowns to trigger the technical adaptation process. Then she attempts to deter-

mine the cause of the decrease in performance quality based on physiological and behavioral metrics," clarifies her dissertation advisor, Prof. Gerhard Rinkenauer, who is also principle investigator for Human Machine Interaction at the Leibniz Research Centre for Working Environment and Human Factors (IfADo) in TU Dortmund University.

**In her dissertation**, Dr. Schwarz developed the multidimensional real-time diagnostic framework RASMUS for optimal user-state detection. Her holistic diagnostic approach takes into account both the interaction between different dimensions of the user state, such as tiredness, distraction and situational awareness, and external influencing factors. Based on her findings, the technology can offer tailored support without counteracting the user's productive self-regulation strategies. "Based on this holistic state detection process, the adaptive system can select highly targeted strategies to restore human performance capacity," says Dr. Schwarz. The adaptation strategies include concrete assistance in the form of visual or auditory instructions or even reduction of the stress, with the technology taking over certain aspects of the task. Dr. Schwarz's colleague, Sven Fuchs used her real-time diagnostic framework to develop this dynamic adaptation management process further in his own dissertation. "Together, we have created a functional adaptive system that's ready for application," Dr. Schwarz affirms.

"I'm very pleased and honored to receive such an award for working in psychology and ergonomics, a rather unusual research field for the Fraunhofer-Gesellschaft," she adds. "It's a wonderful show of appreciation, particularly for the field of ergonomics." ■

# A high-intensity X-ray

With the BM18 beamline, the electron synchrotron in Grenoble is establishing an X-ray facility like no other on Earth. It can scan large objects with a level of detail never seen before — and it works as well for industrial components as it does for human organs.

By Christine Broll



**W**hen Prof. Simon Zabler describes the X-ray system at the European Synchrotron Radiation Facility in Grenoble, he tends to talk in superlatives. The BM18 beamline produces some of the most brilliant X-rays in the world. It's ten trillion times more brilliant than the X-rays used in medicine. "The facility is the only measuring station of its kind worldwide for non-destructive testing of large components. We can scan objects of up to 70 centimeters in width and up to 180 centimeters in height at a resolution of 25 micrometers," explains Prof. Zabler, who is head of department at the

Development Center X-ray Technology EZRT within the Fraunhofer Institute for Integrated Circuits IIS and leads the BM18 project.

He is delighted that the unique facility will soon be able to offer computed tomography (CT) measurement services for industry customers. The requirements for component testing keep on mounting and the demand stems from a wide range of industries, from automotive construction and the aviation sector right up to wind turbine manufacturers. The firms want CT testing to evaluate joining seams in car bodywork, for example, or to assess the structure of a fiber composite material. As

customers keep calling for even higher resolution, lab-based CT facilities are coming up against physical limits. These limits can only be surpassed by means of X-ray facilities that are powered by an electron synchrotron, like the one in the European Synchrotron Radiation Facility (ESRF) in Grenoble, at the foot of the French Alps. The ESRF was founded in 1994 and is funded by 22 partner states.

When viewed from above, the ESRF looks like an enormous, ring-shaped UFO that has landed at the concourse of two rivers. The ring has a circumference of almost a kilometer. Inside, electrons circulate at close to the speed of light — 24

The electron synchrotron in Grenoble has a circumference of around a kilometer. Within the concrete ring, electrons circulate at 99.99 percent of the speed of light.

The X-ray detector can produce resolutions of **0.025** millimeters for large objects, an unparalleled achievement.

hours a day, seven days a week. The enormous energy of these electrons is used to generate X-rays. The storage ring has around 50 units that act as a source of X-rays. At these units, the rays enter straight tubes, known as beamlines, and set at a tangent to the ring, where they can then be used for a wide variety of experimental purposes.

### Setting new standards for industrial CT

“When renovating the electron storage ring, the ESRF also built new beamlines. This included the BM18 beamline, which

we are converting into a unique industrial CT facility,” recounts Prof. Zabler. He is an established expert in synchrotron imaging, having completed his master’s and doctoral dissertations in Grenoble more than 20 years ago. “In conjunction with the University of Passau and the University of Würzburg, Fraunhofer is setting out to develop detection technology and data processing techniques, while the ESRF constructs the remaining hardware,” the physicist reports. The BMBF is contributing 6.3 million euros in funding for the collaborative project.

In the BM18 beamline, the X-rays generated by the electron storage ring must travel 200 meters through a vacuum tube before they reach the enormous experiment room. Here, they hit the test object, which turns on a podium and is scanned in stages. After passing through the object, the X-rays hit the detector, positioned up to 40 meters away. “The great length of the distance between the objects, the X-ray source and the detector allows us to obtain sharp images with exceptional phase contrast,” Prof. Zabler enthuses. To record these images, the Development Center X-ray Technology EZRT at Fraunhofer IIS developed an X-ray detector that has set new standards. It can produce resolutions of 0.025 millimeters for large objects, an unparalleled achievement.

The X-ray cameras generate enormous volumes of data. “When operating at full capacity, we produce two gigabytes of tomography data per second,” says Prof. Zabler. To handle this deluge of data, the Development Center X-ray Technology EZRT is working with Prof. Tomas Sauer in Passau and Prof. Randolph Hanke in Würzburg and their respective faculties. The first step here involves reconstructing a 3D image of the object from the individual scan data.

“If we were just to store the raw data on the ESRF’s servers, we would use up this massive research institution’s entire storage capacity within a month,” Prof. Zabler points out. That’s why the project team is working on visually lossless compression for the image data. The enormous 3D images are compressed in such a way

that any section of the image can be decompressed and viewed on a laptop in real-time.

### Official commencement of measuring operations set for December

Although the project was impacted by the pandemic right after its start in early 2020, the first test measurements were conducted toward the end of 2021. To showcase the incredibly sharp level of detail achieved in the scans, the team has already released images of a smartphone. More sample scans will follow in the course of the year, before measuring operations commence for industry customers in December. “With our set-up in Grenoble, we can carry out tests in just a few hours that would take a week in a lab CT facility — and produce better quality too,” reveals Prof. Zabler. “Naturally, Fraunhofer is taking on the task of implementing the complete measuring process.”

One eighth of BM18’s beam time will be set aside for industry customers. The remaining time will be available for scientific experimentation. However, the number of researchers that have applied for beam time allotments already significantly exceeds availability. An independent jury is selecting the successful applicants. One project has already received approval: the Human Organ Atlas. This project will take human organs from hospital pathology departments, scan them with incredible precision and make the images available to the general public. The project team has already produced some initial scans at another beamline. The most fascinating thing about the images is that it’s possible to zoom in on the organs, all the way to the cell structure level. Soon, the international team hopes to use the BM18 to scan the torso of a deceased person in 3D so they can provide the world with a unique 3D atlas of anatomy. ■

For more information, see:



<https://s.fhg.de/x-ray>



SINGAPORE

## Clearing a path through the legislative jungle

For foreign automotive manufacturers, understanding Chinese regulations on cybersecurity, cryptography and data security is an almost impossible task. But a new study by the Fraunhofer Institute for Secure Information Technology SIT and Fraunhofer Singapore is clearing a path through the legislative jungle. The study lists all the relevant laws and regulations together with the responsible Chinese institutions, authorities, research and development institutes, councils and contact points. And it's important for more than just automotive manufacturers and suppliers — technology suppliers and interested parties from the world of research and development will find it useful too. In addition, the study outlines predictions regarding the future of electromobility security in China and analyzes relevant publications by the government, industry and NGOs. The survey will be regularly updated and can be downloaded for free at [www.sit.fraunhofer.de/NEVChinaSurvey](http://www.sit.fraunhofer.de/NEVChinaSurvey).



In the last five years, e-vehicle sales in China have more than quadrupled, going from 652,000 to 2,734,000 vehicles.

# Fraunhofer worldwide



NETHERLANDS

## Cleaning house at the bottom of the ocean

Millions of tons of waste lie on the sea floors. Until now, diving has been the only way to retrieve it — a costly, time-consuming process. But soon, an autonomous robot system could take over this arduous task. SeaClear will be able to identify and classify up to 80 percent of underwater waste, and collect up to 90 percent.

The Fraunhofer Center for Maritime Logistics and Services CML and six partners are developing the garbage collector under the leadership of the Delft University of Technology. The system is made up of an unmanned search vessel, a diving and collection robot and a drone. It maps the waste on the ocean floor, distin-

guishes it from marine vegetation and collects it.

The Fraunhofer CML researchers are designing and implementing the hardware and software infrastructure, together with the interfaces for exchanging data between the robots and a land-based control center. In addition to technical coordination, Fraunhofer CML is also working on developing the collection basket where the waste will be deposited. It contains electronics that help locate the waste. SeaClear has passed its initial practical trial run with flying colors by retrieving plastic waste from sea floors along the coast of Croatia. Tests in Hamburg harbor are soon to follow.



Plastic waste costs around 135,000 marine mammals their lives every year.



## EUROPE

## Quicker charging with smart sensors



From smartphones to e-vehicles: The EU research project SPARTACUS aims to achieve quicker charging for lithium-ion batteries, as well as extended range and service life. Researchers have now taken a major step toward this goal. With the Fraunhofer Institute for Silicate Research ISC at the helm of the project, the participants developed new types of sensor and models for predicting battery status and optimal charging control. Now these indi-

Acoustic-mechanical and thermal sensors enable optimized adjustments to charging and draining cycles.

vidual components have been combined to form one innovative monitoring system that unlocks previously unexploited reserves in battery management. The result is a reduction in charging times of up to 20 percent, without any impact on the reliability or service life of the battery.

Fraunhofer ISC is primarily working on developing sensors for monitoring the battery cells. The data from the sensors is transmitted to the battery management system, allowing for optimal, status-dependent charging and draining. Defects and negative influences on the battery service life and performance are detected at an early stage.

As though lost in a thick fog — dementia patients can often be cut off from the world.



## EUROPE

## Hot on dementia's trail

The objective of the EU research project DEBBIE is to reliably detect Alzheimer's disease at an early stage. In many cases, the disease is only discovered when clear clinical symptoms appear. But by that point, the incurable brain disorder is already quite advanced and the nerve damage is irreversible. Researchers at the Fraunhofer Institute for Digital Medicine MEVIS are developing a new control software, known as a measurement sequence, that allows doctors to conduct detailed magnetic resonance imaging (MRI) processes and makes pathological alterations visible at an earlier stage.

The software gives MRI scanners the ability to map changes in the blood-brain barrier (BBB) with a high level of precision, without any need for contrast agents that could potentially harm patients. If the BBB is impaired, harmful substances can pass into brain cells or damage or change the tissue before the first symptoms of Alzheimer's disease appear. If treatment begins at that point, the patient's memory capacity can be preserved for longer. Side effects of the illness, such as disorientation and the breakdown of speech or perception could then most likely be alleviated.



## CHILE

## Eco-friendly insulation

Researchers from the Fraunhofer Institute for Wood Research Wilhelm-Klauditz-Institut WKI have taken plant waste from the Chilean agriculture, forestry and lumber sectors and created insulating materials for residential construction. Working in close collaboration with Chilean industry partners, the team successfully manufactured an environmentally and climate friendly alternative to the mineral- and petroleum-based products the construction industry had commonly used in the past. Insulation made from renewable raw materials has yet to become widely established in Chile. The researchers mostly used grasses and



So far, plant waste has hardly been used in Chile.

wheat and oat straw. These can be made into sustainable insulation that not only conserves heat but also complies with soundproofing and fire protection standards.

These innovative construction materials bind CO<sub>2</sub> from the atmosphere and can also be reused as a raw material for a wide range of consumer goods, such as thin molded parts in the automotive industry. At the end of the value chain, the plant-based fibers can be burned or composted.

## Ready-to-wear algae: From bioreactor to fashion statement

Whether it's a water-proof jacket, a pair of comfy stretch jeans or a figure-hugging summer dress, consumers looking to ban petroleum-based synthetic fiber from their wardrobes can expect a 75 percent drop in the range of garments available to them. As fossil fuel resources become increasingly scarce, the textile industry has been looking for alternatives. They've now found one — in the form of algae.

By Mandy Bartel

**W**hen the call came in from Adidas, Dr. Ulrike Schmid-Staiger and Gordon Brinitzer were immediately excited. The sporting goods manufacturer is the first textile company with plans to manufacture textile fibers from algae. Based in Herzogenaurach, the company already has plenty of experience under its belt from previous sustainability projects involving synthetic fibers made from plastic flotsam, for example. The

great response to these initiatives demonstrated that sustainable, environmentally friendly fashion is a long-term trend that customers are ready and willing to spend more money on. While searching for new bio-based source materials for their clothing items, Adidas came across research on algae biotechnology that had been carried out by Brinitzer and Dr. Schmid-Staiger at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart.

For the two researchers, the inquiry from Adidas AG opened up the possibility of a new application for the versatile fatty acids that are produced in the cells of micro algae under certain conditions. Ten years previously, they had worked on a project to manufacture biodiesel from a species of algae rich in fatty acids called *Chlorella vulgaris*. However, initial hype around the sustainable fuel was tempered by high manufacturing costs and a political preference for electric vehicles.



## From algae to synthetic fiber

The AlgaeTex project will now focus on the manufacture of various biopolymers for textile fibers made from algae fatty acids and the widespread application of these biopolymers in the textile industry. “In terms of a sustainable circular economy, algae are a really suitable raw material,” says Brinitzer. “They not only recycle CO<sub>2</sub>, algae by-products from the processing step such as proteins can also be reused in other industries.” When preparing the algae, and right throughout the process chain, the research team consistently focuses on green chemistry principles such as waste prevention and less hazardous chemical syntheses. This is also important for Adidas AG, which puts each step in the process to the test in terms of sustainability.

Producing fashionable items of clothing from microscopic green cell “factories” is the result of closely coordinated team work. First, Fraunhofer IGB cultivates the microalgae in photobioreactors. By limiting the supply of nitrogen, the algae can produce greater quantities of the required fatty acids, which can reach up to 50 percent of the biomass. Once extracted via pressure, heat and green chemicals, the

fatty acids are ready for use as source materials for the manufacture of polymers. In the next process step, a team based at the University of Bayreuth develops polyamides and polyester suitable for spinning. Another team at the Institute of Textile Technology at RWTH Aachen University then spins the generated biopolymers into synthetic fibers via melt spinning. Finally, in conjunction with Adidas AG, they assess whether the materials can be processed to form a woven textile.

### Yield increased ten fold by LED light

In previous experiences of open-air algae cultivation using natural sunlight, yield was a key issue. Fraunhofer IGB are therefore testing the use of LED light and a new stack-based photobioreactor, and the results are already promising. Flat-panel bioreactors providing a volume of up to 250 liters are closely packed in alongside each other over an area of one square meter. “With this system, artificial light can increase yield by a factor of 10. In contrast to natural sunlight, which is very volatile, artificial light illuminates the bioreactor continuously, which means the algae can continue to photosynthesize

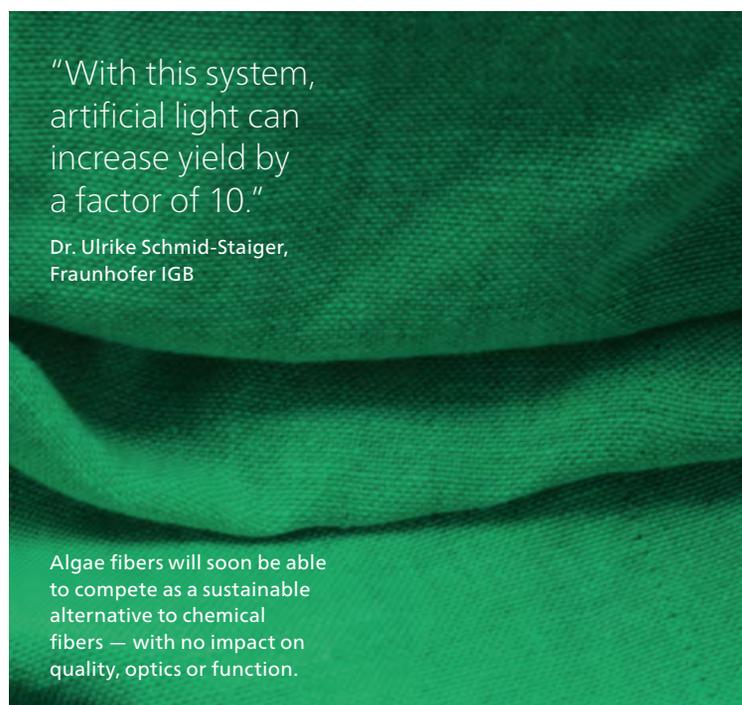
around the clock,” explains Dr. Schmid-Staiger. The researchers ensure that the resulting increase in energy required is met through renewable energies. Because of the extremely compact design, artificial light allows the same quantity of biomass to be produced from a few square meters as an entire hectare under natural sunlight.

As part of the AlgaeTex project, the partners are also involved in the Biotext-future innovation space — an initiative funded by the German Federal Ministry of Education and Research (BMBF), aimed at opening up new sustainable sources of raw materials for the textile industry. For now, the process is restricted to laboratory scale. The goal is to provide approximately 20 kilos of algae biomass for further processing by early summer 2022. This will allow the production of a textile prototype in which biopolymer accounts for 50 percent of the textile initially, with this proportion increasing even further over time. In theory, algae fibers can be used to produce any kind of textile. In terms of appearance, haptics and function, bio-based materials provide the same benefits as their regular petroleum-based cousins. With the added benefit of easing the wearer’s environmental conscience. ■



The microalgae *Chlorella vulgaris* forms fatty acids that can be used to produce biopolymers for textile fibers.

Photos: Chokniti Khongchum/shutterstock, BIOTEXFUTURE



“With this system, artificial light can increase yield by a factor of 10.”

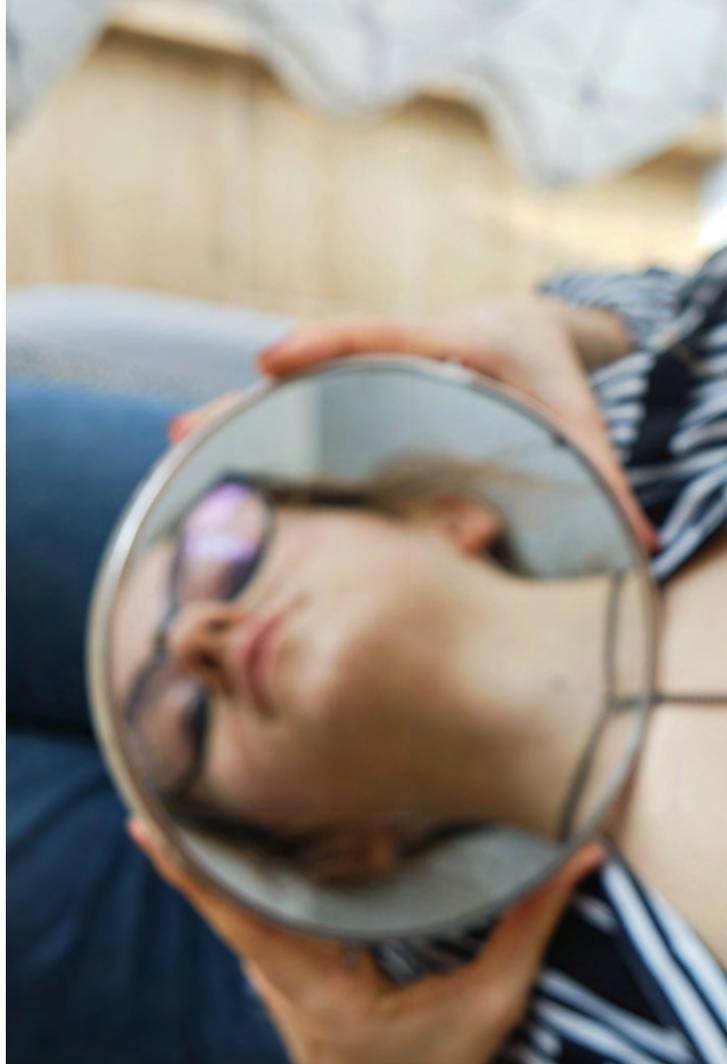
Dr. Ulrike Schmid-Staiger,  
Fraunhofer IGB

Algae fibers will soon be able to compete as a sustainable alternative to chemical fibers — with no impact on quality, optics or function.

# Fighting skin cancer with AI

Harmless mole or dangerous skin cancer? In the future, an AI-based full body scanner will enable rapid decision-making with improved accuracy.

By Meike Grewe



**J**ust six minutes is all it takes for the innovative scanner to screen 98 percent of a person's total body surface area. This is followed by an individualized risk analysis and diagnosis driven by AI technology. This revolution in the early detection of cancer has been developed by researchers at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI and international partners as part of the IToBoS project.

**Skin cancer is not only the most common tumor disease worldwide**, it is particularly insidious. At the early stages, it can easily be taken for a harmless mole or birthmark and doesn't cause any pain. However, the earlier it is detected and treated, the better the chances of it being cured. Accurate and regular diagnostic testing is therefore critical.

Currently, everyone in Germany over the age of 35 with statutory health insurance is offered an early detection exam every two years. This exam is carried out by a physician via visual inspection, or in the case of skin areas that look suspicious, using an incident light microscope. The checkup generally lasts 15 minutes. However, even if the screening lasted one hour, it would only be possible to examine a maximum of 20 percent of the person's body surface area. This screening also needs to be carried out regularly, since changes in individual skin areas can be an important indicator of skin cancer. Irregularities therefore need to be documented precisely, which is a time-consuming and error-prone task. Thankfully, the new full body scanner will make this a thing of the past. The entire scan is transferred to a 3D avatar and stored in a patient database.

This not only allows monitoring of alterations to individual lesions, but also

changes in overall skin appearance. The system will also be capable of detecting whether the skin already has underlying UV damage — this type of diagnosis is just not possible with a regular exam. A cognitive AI assistant uses a variety of data sources to detect the UV damage. Algorithms retrieve all available patient information such as medical history, personal circumstances, hereditary predisposition and the position of each individual mole. The AI assistant then uses this information to determine the risk of skin cancer. Each risk assessment is accompanied by an explanation that will enable medical experts to understand the AI assessment and interpret that assessment in a substantiated way.

"The more data provided to the machine learning models, the more accurate the prognosis," explains Dr. Sebastian Lapuschkin, who heads up the IToBoS project at Fraunhofer HHI. Dr. Lapuschkin, who views his "Explainable AI" (XAI) research



The earlier it is detected and treated, the better the chances of it being cured.

Anyone with a large number of skin moles should examine their bodies carefully. When checking a mole, it can be helpful to apply the ABCDE rule which focuses on characteristics such as the asymmetry, border, color, diameter and evolving nature of the mole.

team as essentially a technical partner, hopes to develop a system that delivers really meaningful results. It's not just about using AI to detect cancer risk, it's about being able to explain the result. According to Dr. Lapuschkin, the AI can be viewed as a black box that is fed large volumes of data; it then uses this data to learn independently and to define rules based on what it has learned. But there is no way of knowing why it reaches these conclusions. For the XAI team, the task is simply to lift the lid on the AI's decision-making process.

**Before it can conduct its analysis, the AI must be read and process the data,** extract various characteristics and make countless decisions. "We need information about all of these partial decisions, so we can question and understand them," says Dr. Lapuschkin. If the AI draws the wrong conclusion from a series of images of a cancer patient with lots of body hair, for

example, the researchers must be able to respond. "If we know that the correlation between hair indicators and a positive diagnosis is too strong, we can take this into account in the next AI training process," Dr. Lapuschkin explains.

Researchers at Fraunhofer HHI must find out which internal features are responsible for this error behavior, and then remove or suppress these features so the AI can work in a way that is reliable and safe. "Our role is to ensure a new level of explainability," says Dr. Lapuschkin. The physician still has responsibility for the final diagnosis. And if the system interprets a patient's tattoo as skin cancer, it must be possible to demonstrate that this is what has happened. The researchers aim to manufacture the full body scanner on a large scale, so that as much data as possible can be collected. The more the AI knows, the less likely the possibility of erroneous conclusions.

The models are still trained using skin cancer images in databases as currently the scanner is not able to capture images. This will be possible at a later stage, and will incorporate the use of special fluid lens cameras. Based on two immiscible liquids that refract light differently, the lens in these cameras produce unprecedented image quality. They are capable of generating subcutaneous images by pretty much "seeing through" the first layer of skin, which means that bodily hair is no longer a problem. Polarizing light emitted from multiple directions prevents reflection and illuminates the relevant skin layer only.

Manufacture of the scanner is currently experiencing delays. Global supply bottlenecks are affecting the mechatronic components and cameras, for example, that are needed to build the prototypes. The first prototypes are set to be put into operation at three hospitals in Spain, Italy and Australia. ■

5500 coffee mugs,  
stacked as part of the  
Cup Cube art project.

## Photo & Fraunhofer

# A sustainable caffeine fix

Germans love drinking coffee — often from disposable cups. According to figures from the German Federal Ministry for the Environment, Germans use 320,000 disposable cups per hour. This amounts to almost three billion a year. For just ten minutes of use, they create lasting, mostly non-recyclable waste and are responsible for a total of 48,000 tons in CO<sub>2</sub> emissions.

In January, Fraunhofer and its partners opened a digitally supported, sustainable plastics production plant at SmartFactoryOWL in Lemgo, a facility belonging to Fraunhofer IOSB-INA and the Ostwestfalen-Lippe University of Applied Sciences. In an AI living laboratory,

the team are working with the start-up CUNA Products GmbH to produce reusable, recyclable cups from sustainable, bio-based plastic, all without the use of oil. Here, under realistic production conditions, the scientists are conducting collaborative research on Industrie 4.0 technologies. Prof. Jürgen Jasperneite likens the data-driven production at SmartFactoryOWL to “open-heart surgery.” As director of Fraunhofer IOSB-INA, he promises to deliver high speed first and foremost: “This approach offers the fastest maturation process for digital and sustainable innovations.”



# Hybrid timber to edge out reinforced concrete

In the future, hybrid-timber construction systems may be able to compete with reinforced concrete, not only in terms of sustainability but also because of significant strides made in terms of stability.

By Dr. Janine van Ackeren

**T**imber is vastly more environmentally friendly than reinforced concrete — it regrows quickly, absorbs CO<sub>2</sub> and is available locally. Living in a timber home also gives a greater sense of comfort than a home encased in concrete walls. It's not all good news, though. From a stability perspective, reinforced concrete performs better than timber — whose tensile and compressive strength perpendicular to the grain is lower by comparison. Yet, when timber is combined with other materials, the mechanical properties of the overall structure are greatly improved. Combining the timber with fiber-reinforced plastics or concrete means that new types and classifications of timber previously unsuited to the construction industry can now be used — this increases the playing field for climate-conscious, environmentally friendly forestry.

## Reduce weight, accelerate production

Although several recent studies have looked into the short-term behavior of such hybrid-timber materials, little is known about their long-term behavior. However, when it comes to construction materials, long-term behavior is key. A group of young researchers led by the Fraunhofer Institute for Wood Research Wilhelm-Klauditz-Institut WKI now set on closing this gap by investigating the long-term behavior and durability of these hybrid-timber construction systems. The project is funded by the German Federal Ministry for Food and Agriculture and supervised by the German environmental agency Fachagentur für Nachwachsende Rohstoffe e.V. "So far, timber construction accounts for a small portion of between 10 and 15 percent of the German construction market. We aim to increase this significantly," says Prof. Libo Yan, Senior Scientist and Junior Research Group Leader at Fraunhofer WKI. If we can ensure that hybrid construction materials are able to withstand all kinds of weather conditions over extended periods of time, these construction materials will almost certainly see a surge in popularity. Researchers all over the world are investigating different combinations of timber and concrete as well as timbers in which carbon fibers or polymer-matrix flax increase stability. As for the combination of sawn timber and concrete, the team began by developing a new way to combine these materials.

Typically this is done mechanically — using steel nails, steel plates and steel mesh, for example. "By using polyurethane or epoxy resin to join the materials, we can reduce the weight of timber hybrids and speed up production by up to 15 percent," Yan explains.

## Through hail, rain and snow...

It may sound a little contradictory — we're talking about long-term tests after all — but the first step in the study is to carry out a series of short-term tests. This is because long-term tests over a 20-year period are not only too expensive, they are also not very practicable; ultimately, the aim is to facilitate use of the new construction materials as quickly as possible. For short-term tests lasting several hours or days, the researchers join materials such as concrete and timber. They then clamp the outer timber sections and apply a defined force to the concrete. They determine how much force is required to damage the adhesive layer and break apart the composite material. The research team uses these and other measurements to develop a theoretical model. This involves examining the microstructure of the adhesive joint via microscope. "Our goal is to establish a correlation between the macroscopic behavior and the microstructure," says Yan. "We also go right down to the chemical level — for example, we look at how the chemical components change at the interface between the two materials. This allows us to systematically improve the properties of the hybrid materials."

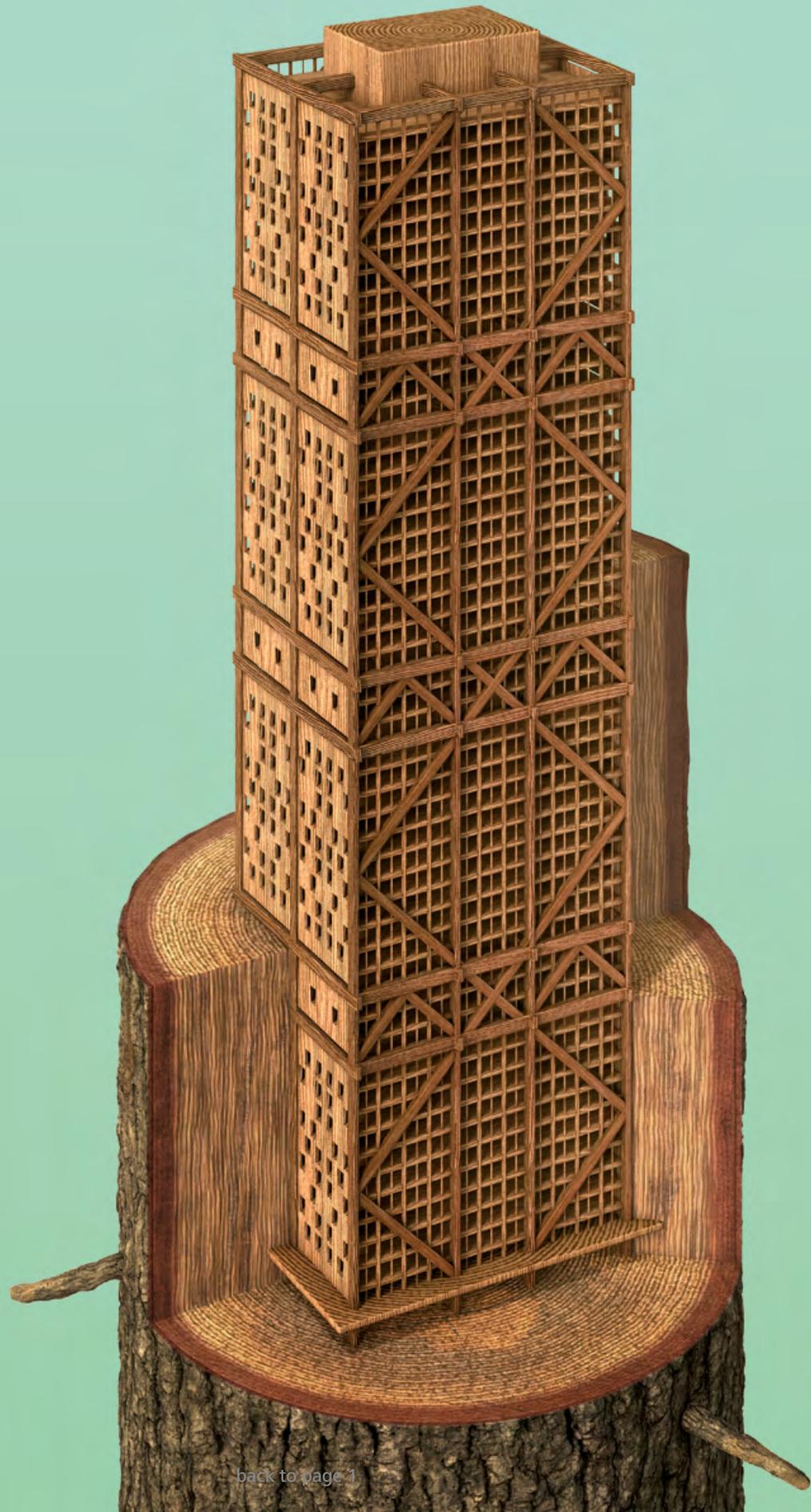
To validate the model they have created and capture reality as accurately as possible, the researchers are now following up their short-term tests with longer-term studies. This involves exposing 5 to 6 meter hybrid panels to the open elements for a period of two years. What level of impact will this have on the panels? Does the model predict this correctly? "We can use the results to optimize the model even further," explains Yan. This means they can work out how hybrid-timber materials will behave over a 50-year period, so that they can be used as construction materials in the future. ■



<http://s.fhg.de/holz-hybrid>

“Up to now, timber construction accounts for a small portion of between **10 and 15 percent** of the German construction market. We aim to increase this significantly.”

Prof. Libo Yan,  
Fraunhofer WKI



Every cubic meter of wood can permanently store about one ton of CO<sub>2</sub>. When used as a construction material, timber retains this CO<sub>2</sub>, while also freeing up space for the growth of new trees.

# The future is quantum internet

A quick, secure and stable network between quantum computers in different locations opens up completely new possibilities for the future.

By Mandy Bartel



Laboratory prototype for a low-noise quantum frequency converter.

In 2021, 38 exabytes of data was exchanged over the internet worldwide. That's more than ever before, amounting to 38 trillion bites — a number with 18 zeros. 52 years earlier, the internet was born when four mainframe computers were connected with each other for the first time in the US. But hardly anyone could have guessed how much this innovation would shape the world. Now, data volumes are growing beyond the possibilities of conventional computer architectures. This is why we're pinning our hopes on quantum computers. Connecting these computers to form a network would further increase computing capacity and ensure secure communication. Not only that, it would also expand the range of application areas and create space for innovations, much like the internet before it.

## Faced with a big task

Quantum computers use qubits as their smallest computing unit, but these cannot be transmitted as easily as conventional bits. Together with their Dutch colleagues at QuTech, a collaboration between the Delft University of Technology and the TNO research organization, Fraunhofer researchers have set themselves a major task: to lay the technological foundations for the quantum internet in Europe.

“The key is photonics,” says Prof. Constantin Häfner, Director of the Fraunhofer Institute for Laser Technology ILT in Aachen. “We use the properties of individual photons, as well as quantum effects such as superposition and entanglement, to transfer quantum information in a targeted way and connect quantum processors at different locations,” he explains. In contrast to other quantum systems such as superconducting qubits, the light particles remain stable even without cryogenic conditions, and can be transmitted over greater distances without the loss of relevant information. The problem is that the entangled photons have a different wavelength from the one required for low-loss transmission in existing telecommunication lines.

Fraunhofer ILT has found a solution by optimizing what are known as quantum frequency converters, devices that adjust the wavelengths of the photons using sophisticated optical systems — this represents a milestone on the path to a stable quantum network. “These quantum frequency converters enable efficient, low-noise transmission of fragile quantum information over long distances through telecommunications service providers' existing fiber optic lines. They translate the light frequency of the quantum processors to the frequency suitable for the

existing fiber optic networks,” explains Prof. Häfner. “With this development, we at Fraunhofer ILT have set our first world record for a low-noise converter and we hope to set records for signal-to-noise ratio in the future.”

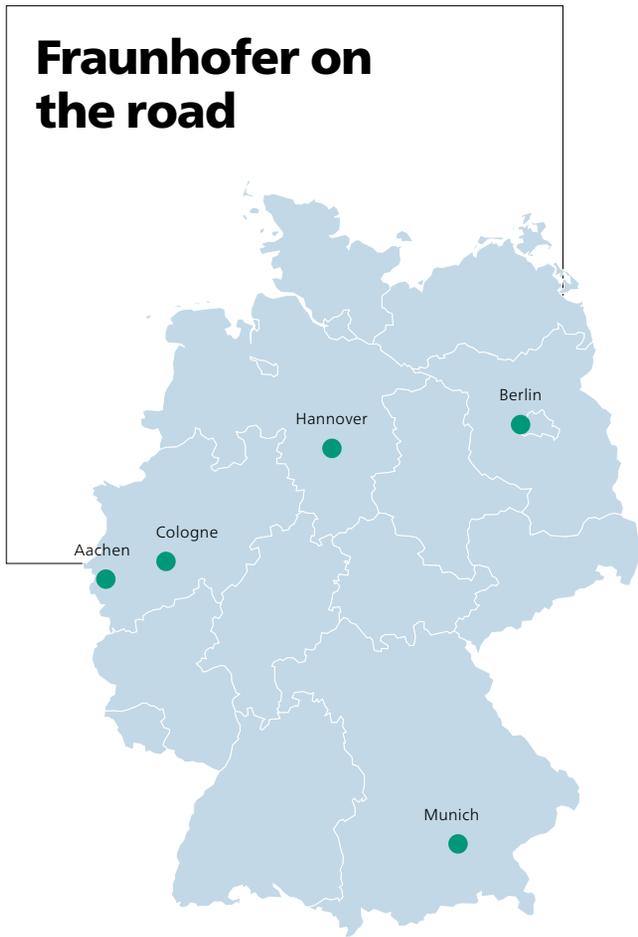
## The first German quantum node

Now, Aachen-based Fraunhofer ILT has set its sights on the first German quantum node in an international quantum network, all coordinated by QuTech. The plan is to connect quantum processors in Aachen with computers in the Dutch cities of Delft, Leiden, The Hague and Amsterdam. “Cross-border initiatives like these are particularly important for positioning ourselves well in terms of international competition in the field of quantum technology, especially against the USA and China,” argues Prof. Häfner. Establishing the quantum node will mark the birth of the quantum internet in Europe — we can only wonder what other possibilities this will bring. ■

Listen to the quantum internet podcast here:



# Fraunhofer on the road



- Berlin**  
**April 26–28, 2022**  
**DMEA**  
 The leading event on the digital transformation of health care
- Munich**  
**April 26–29, 2022**  
**LASER World of PHOTONICS**  
 Fraunhofer ILT presents its research on the quantum internet and other quantum technologies
- Cologne**  
**April 26–29, 2022**  
**Anuga Foodtec**  
 International supplier trade fair for the food and drink industry
- Aachen**  
**May 4–6, 2022**  
**AKL'22 – 13th International Laser Technology Congress**  
 A leading forum for applied laser technology in production
- Hannover**  
**May 30–June 2, 2022**  
**Hannover Messe**  
 The world's leading industrial trade fair
- Berlin**  
**June 22–23, 2022**  
**HUB Berlin**  
 Business festival by the Bitkom digital association
- Berlin**  
**June 22–26, 2022**  
**ILA Berlin**  
 International trade fair for the aerospace industry

**Last updated: March.** Changes may occur due to the pandemic. Please keep an eye out for information from the event organizers.

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“We need to see a change in industry  
and a change in consumers.”

Prof. Andrea Büttner, Executive Director of Fraunhofer IVV



A lab-produced egg, with no hens in sight — and gluten-, cholesterol- and allergen-free.  
Even the shell is biodegradable and can be composted.