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The magazine for people shaping the future

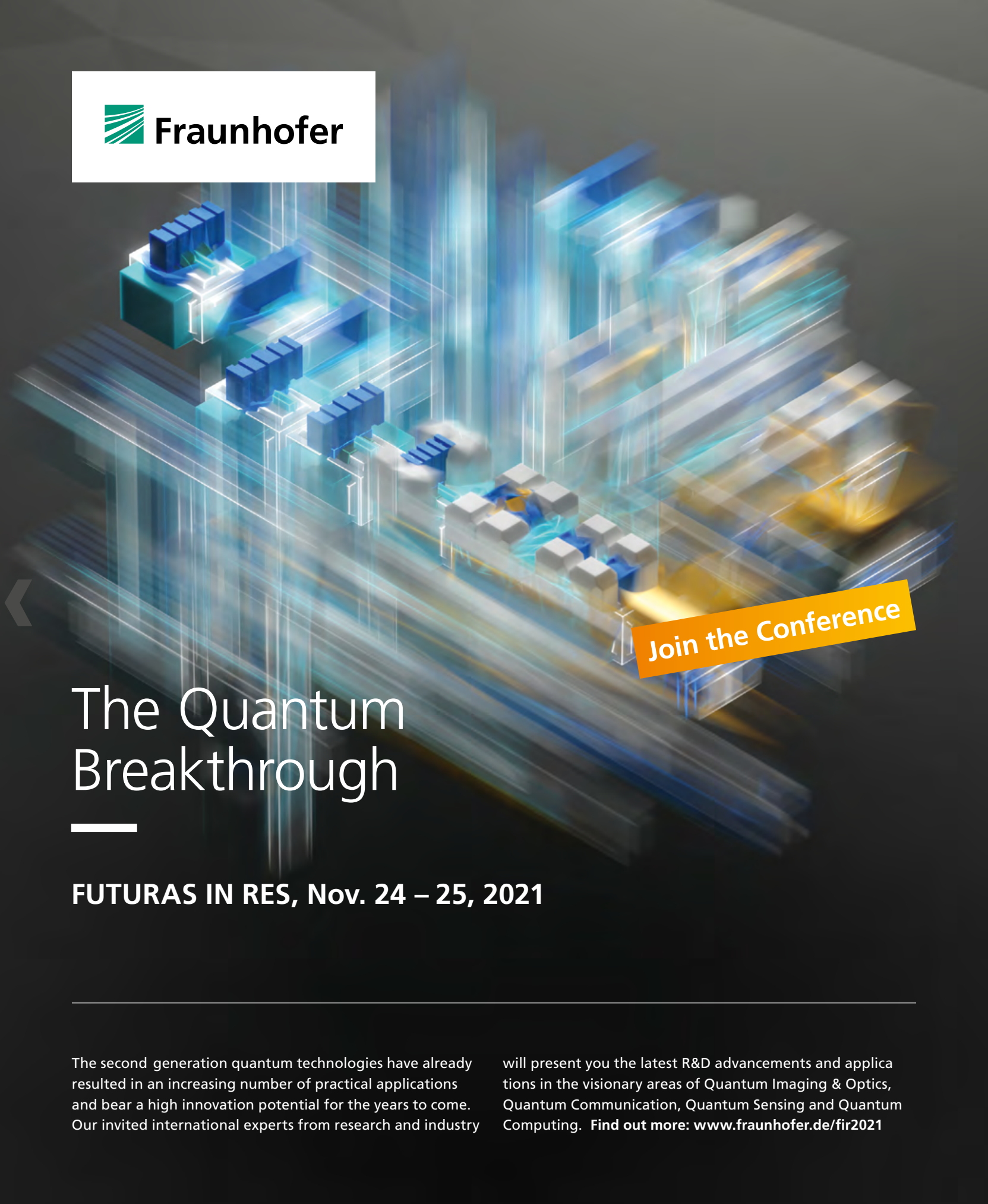
The corona expert
Portrait: Sandra Ciesek

What we're really lacking

Raw materials, supply routes, digital sovereignty

The relay of knowledge
Fraunhofer researchers provide answers

Dangers in drinking water
How drug residues are broken down



The Quantum Breakthrough

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The second generation quantum technologies have already resulted in an increasing number of practical applications and bear a high innovation potential for the years to come. Our invited international experts from research and industry will present you the latest R&D advancements and applica tions in the visionary areas of Quantum Imaging & Optics, Quantum Communication, Quantum Sensing and Quantum Computing. **Find out more: www.fraunhofer.de/fir2021**

Editorial

Affordable health care requires innovation

Prof. Reimund Neugebauer

The pandemic brought home to us all the importance of high-quality health care provision and outstanding biomedical research. Within a very short space of time, German research organizations and companies developed and made available the drugs and vaccines, practical diagnostic tests, life-saving medical devices and digital health care applications that were needed to combat the pandemic.

Due to the current wave of dynamic innovation coupled with medicine's rapid development into a high-tech discipline, technology-driven innovations for health care provide an excellent opportunity to create new jobs, harness the potential for long-term value creation and thus strengthen Germany's position as a business location. In parallel, technological sovereignty and resilience in pharma production are prerequisites for our ability to successfully manage medical crises in the future.

Personalized medicine and the associated development, production and application of pharmaceutical products for new innovative treatments are opening up entirely new opportunities. However, cost and logistics factors mean that widespread deployment of these pharmaceutical products is not yet a given. To ensure the availability of these new treatments for all patients — for the treatment of cancer or diseases of the immune system, for example — new development and production technologies based on robotics, automation and AI are required as well as cross-disciplinary collaboration between medicine, natural science, computer science and engineering.

With its network of 23 institutes, the Fraunhofer-Gesellschaft has both the medical/biological expertise to produce cell and gene therapy products and the technologies that are needed to ensure automation and flexible management. The objective is to establish a pilot facility for modular, automated production processes for Health Care 4.0. The facility will focus on the development and production of innovative technologies for use in cell and gene therapies as well as new drugs.

The intelligent integration of innovative forms of treatment with technological production methods is a key requirement for personalized, effective and affordable prevention, diagnostics, treatment and care. For Germany as a high-tech business location, it creates an enormous social and economic opportunity that we must harness to its full potential.

Sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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

Photo: Fraunhofer/Bernhard Huber

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Sandra Ciesek is "University professor of the year 2021." She has teamed up with the Fraunhofer ITMP to search for a corona drug.

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Germans consume around 30,000 tons of pharmaceuticals. Wastewater treatment plants fail to filter out any residues. Electrolysis combined with ultrasound brings new hope.

32 How can we trust AI?

Artificial intelligence is providing opportunities in more and more areas — and also creating new risks. Fraunhofer IAIS is working on certification.

#building The construction industry is said to be responsible for 38 percent of global CO_2 emissions. The potential for reductions is therefore high. According to the German Economic Institute, public procurement alone could save as much greenhouse gas as is produced by all domestic air traffic in Germany. The circular economy also offers new approaches to construction (p. 10).

38%

Cover photographs: Sonja Och (2), Tim Wegner/laif; Content: Sonja Och, Stefan-Thomas Kröger, Tobias Koch, Lena Engel, Tim Wegner/laif, Daniela Leitner

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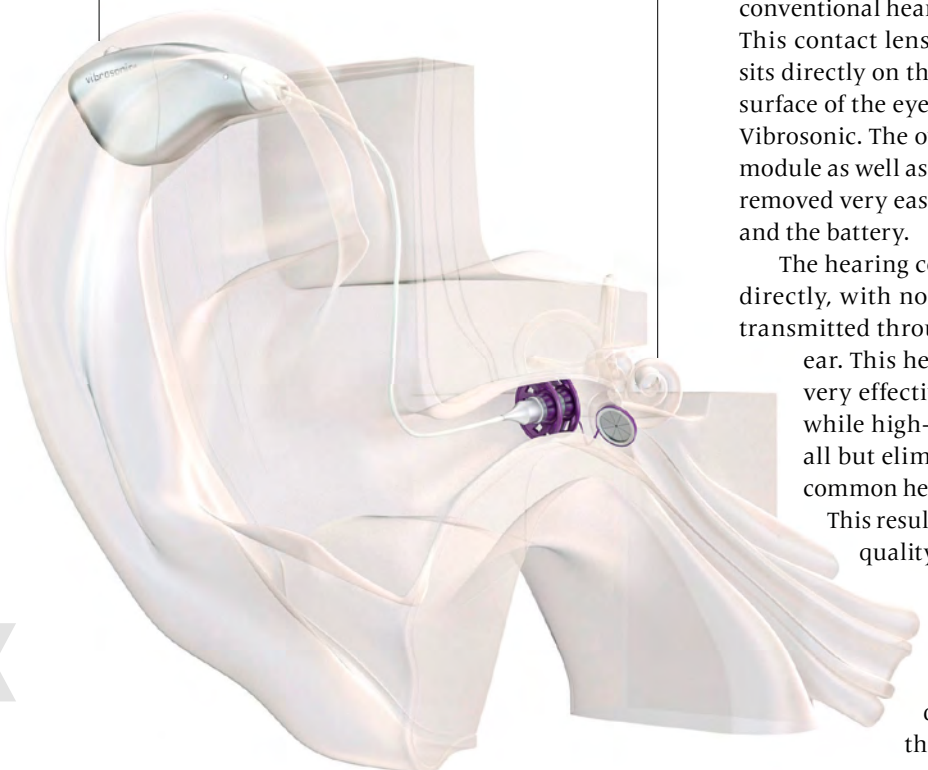
Brief report



A contact lens for the ear

An innovative new hearing aid outperforms the sound quality of conventional hearing systems — without the need for implants. This contact lens for the ear functions as a loudspeaker and sits directly on the eardrum, in the same way a lens sits on the surface of the eye. It was developed by the Fraunhofer start-up Vibrosonic. The overall system also includes an auditory canal module as well as a behind-the-ear sound processor that can be removed very easily. It houses the signal processing electronics and the battery.

The hearing contact lens transmits vibrations to the ossicle directly, with no interference from airborne noise. Sound is transmitted through the direct mechanical stimulation of the ear. This helps to reproduce the natural hearing process very effectively. Similarly, very low tones are amplified, while high-range disruptive noise caused by feedback is all but eliminated. In contrast, the loudspeaker in most common hearing devices sits inside the wearer's ear canal. This results in acoustic distortions that can impair sound quality. Because of differences in eardrum shape, the hearing contact lens is specifically manufactured for each individual patient. There are plans to miniaturize each component of this innovative hearing system so that they fit discretely deep inside the ear channel, where they are invisible from the outside. ■

Paper trumps plastic

Coated paper can be used as a replacement for plastic food packaging, and extend the shelf life of sausage, cheese and fruit. As part of the BioActiveMaterials project, researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV and the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have developed sustainable coating from plant-based proteins and waxes. The proteins act as an oxygen barrier layer while the waxes form a water vapor barrier, thus preventing fruit, for example, from drying out quickly. The formulation also contains bio-based additives — substances that influence the properties of the substrate. Here, the additives are antibacterial and thus protect the food against spoiling. The formulations can be easily applied to paper or cartons using standard coating technologies. The coated packaging is also suitable for foods that need to be chilled and for frozen foods. Once used, the packaging can simply be disposed of in a wastepaper recycling bin. ■

60 percent of Germany's fresh fruit and vegetables are sold in packaging — mostly plastic packaging.

Guilt-free guzzling — Fraunhofer researchers investigate what types of milk packaging cause the least harm to the environment.

Milk packaging put to the eco test

What is the most sustainable type of milk packaging? Cardboard cartons, plastic stand-up pouches or returnable glass bottles? The Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT has just conducted a study in order to find answers to this question. Researchers considered the production, transportation and disposal of various types of packaging. They found that returnable glass bottles are the most environmentally friendly form of packaging — but only if the return distance is short and each bottle is reused more than 20 times. At first glance, returnable glass bottles would seem to have a greater impact on the environment than cardboard drinks cartons due to their higher weight levels during transportation as well as the need to return and clean the bottles for reuse. However, the disadvantages of glass bottles are reversed once they are used on a regular basis and transported within an identified environmental radius. The higher the return rate and the shorter the return distance, the more sustainable glass bottles are. ■

More power for deep dives

Researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS are working with the research group Smart Ocean Technologies SOT to improve battery management for underwater robots. Their aim is to reduce deployment costs and enable Unmanned Underwater Vehicles (UUV) to dive for longer periods of time.

Whether inspecting oil rigs, maintaining underwater gas pipelines or detecting cracks in offshore wind farms, dive robots are being used more and more frequently, and for increased periods of time. Compared to electric vehicle batteries, for example, the robots' energy storage systems must be capable of operating in considerably tougher conditions. Some UUVs can dive to a depth of up to a kilometer. At this depth, the drop in temperature can place significant stress on the technology and accelerate battery discharge.

Using piezoceramic sensors, the researchers are collating new insights into battery discharge at the cell level. The sensors on the cells oscillate when voltage is applied externally and convert mechanical movements into measurable electrical signals. The more elastic the cell, the better charged it still is.

After a number of successful dry runs in the lab, the plan is to test the new sensor technology underwater in a mobile mini lab. Their insights are expected to feed into designs that will ensure more efficient battery management. ■

In the future, underwater robots will need to be able to operate for longer periods of time.

Photos: Vibrosonic GmbH, istockphoto (3)

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Solar modules protect apple trees while also generating electricity for the farm.

Harvesting fruit and energy

As part of the Agri-PV Obstbau project, researchers at the Fraunhofer Institute for Solar Energy Systems ISE are aiming to increase climate resilience and improve sustainability in fruit farming. To this end, they have joined with other research partners to set up an agrivoltaics (APV) system at an organic fruit farm in Rhineland-Palatinate. The farm grows apples and espalier fruit. One third of its cultivated land is to be used in parallel for the generation of solar energy. This solar energy is then used to operate the irrigation system and cold storage areas.

As part of the project, the scientists are comparing different types of crop protection systems and two kinds of solar modules with variously integrated photovoltaic cells. The researchers want to know the extent to which APV installations can protect plants and fruit against hail, heavy rains, intense sunlight, frost and extreme temperatures. They are also testing the degree to which different light management systems can influence plant growth and crop yields as a result of different PV module configurations. The APV system will also be studied in terms of landscape aesthetics, cost-effectiveness, social responsibility as well as crop cultivation. ■

In case of fire

Carbon Fiber-Reinforced Plastic (CFRP) is used in the manufacture of vehicles, aircraft and ships in order to keep weight to a minimum. It is an incredibly lightweight material, but also highly flammable. Researchers at the Fraunhofer Institute for Structural Durability and System Reliability LBF have now succeeded in developing an innovative new flame retardant for CFRPs. The flame retardant prevents the formation of fiber fragments that can be inhaled into the lungs and are a suspected source of cancer.

In collaboration with scientists from the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB), the researchers synthesized custom flame retardants from phosphorus-based polyacrylamide. Compared to conventional retardants, they have a less negative impact on the thermal stability or mechanical properties of CFRPs. In addition, phosphorus-based flame retardants are not harmful to health and release lower levels of toxic gases than halogen-based retardants, for example. Thanks to the modular design, which allows the output material and process control to be chosen during the synthesis process, the flame retardant mechanism and material properties can be customized to specific needs. ■

If components made from CFRP catch fire, the consequences can be dangerous.

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
Editorial address as above
Phone +49 89 1205-1301
magazin@zv.fraunhofer.de
www.fraunhofer.de/magazin

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publikationen@fraunhofer.de

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Layout and lithography:
Vierthaler & Braun
Cover image and cover story photography:
Sonja Och
Article image Technological sovereignty:
Stefan-Thomas Kröger
Printed by:
hofmann infocom GmbH, Nürnberg

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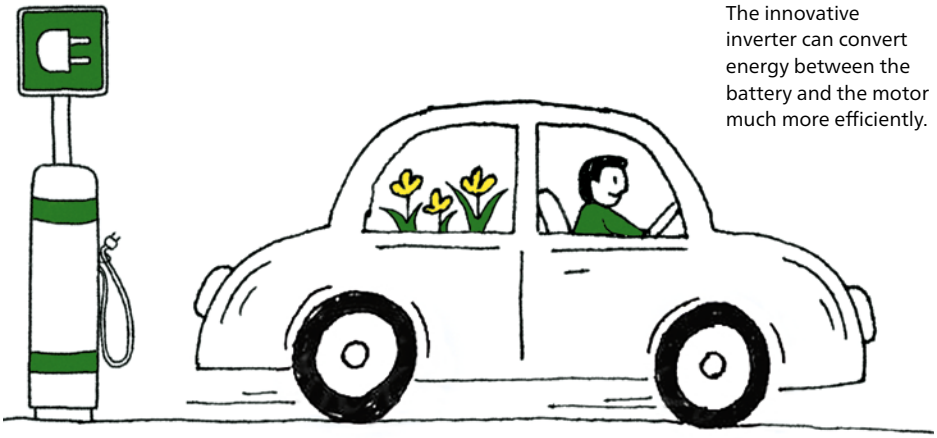

The innovative inverter can convert energy between the battery and the motor much more efficiently.

Longer ranges on the horizon for electric cars

If electric vehicles are to achieve greater distances, it is not just a matter of optimizing batteries — the entire drive chain must be improved, too.

High-performance semiconductors made from silicon carbide (SiC) help to reduce the loss that occurs in the inverter and its transistors, particularly when the vehicle is accelerating, braking and traveling at high speeds. Optimized inverters are much more efficient at converting the direct current in the battery into alternating current for the motor. These optimized inverters were developed as part of the SiCeffizient project run by a team at the Berlin-based Fraunhofer Institute for Reliability and Microintegration IZM in collaboration with industry partners.

"By optimizing the drive train in this way, we expect that ultimately the range of electric cars will be extended by up to 6 percent," says Eugen Erhardt, a research fellow at Fraunhofer IZM. It may not sound like much, but in the field of electromobility, it marks a significant increase in performance that would not otherwise be achieved without the use of additional batteries. However, the new semiconductors have a downside: they are relatively expensive. The Fraunhofer IZM team therefore cut back on the number of semiconductors used. To prevent the valuable SiC transistors from overheating due to the proportionately higher load, the team developed entirely new high-performance cooling elements.

The heat that builds up in the transistors is usually discharged through a solid cooling element. The cooling element has cooling ducts, known as fins, that dissipate the heat into water. These innovative cooling elements with comparatively thin walls were developed by the researchers using 3D printing. The transistors sit on a thin metal plate just a few millimeters thick, which causes them to move closer to the cooling water, thus intensifying the cooling effect.

The new inverter will be tested by project partner Robert Bosch over the next few months. Porsche will then install the device in a newly designed drive train, which has been precisely adapted to the SiC design. ■

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Title

What the future is made of

Raw materials are scarce. Time and again, shortages have forced companies to cut back on their production. The circular economy may be the solution — for far more than just the climate.

By Dr. Janine van Ackeren
Photography: Sonja Och

Justus von Freeden, a scientist at Fraunhofer IWU, is developing reusable structures: “Fiber-reinforced plastics with carbon fibers work really well here!”

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It takes around 25 kilograms of copper to produce a mid-range car with a combustion engine. Meanwhile, building an electronic vehicle may require as much as 80 kilograms or more. As demand increases, so do the costs. This summer, copper prices were 44 percent higher than at the start of 2020. Lithium was worse again, going up by 77 percent. Demand is growing — and so are the problems. Two thirds of German industrial companies are currently struggling with supply issues. According to a survey by the ifo Institute, the proportion of companies affected increased from 45 to 63.8 percent over April to July 2021 — the impact of the material shortage has hit the electronics and automotive industries particularly hard. Reusable materials are becoming an ever more valuable resource.

Now the German Mineral Resources Agency (DERA) has commissioned the Fraunhofer Institute for Systems and Innovation Research ISI and the Fraunhofer Institute for Reliability and Microintegration IZM to conduct its "Raw materials for emerging technologies" study for the third time. "Germany is particularly vulnerable as a high-tech hub, because it's so dependent on imports of raw materials," explains Fraunhofer IZM scientist Jana Rückschloss. "In the study, we are investigating how using new technology could change the demand for raw materials. What raw materials could become especially important on the one hand and especially scarce on the other?"

Rückschloss concentrated on data centers, one of the 33 technologies selected for the study due to their broad relevance for the market as a whole, with a particular focus on storage media like solid-state drives (SSDs), hard disk drives (HDDs) and magnetic tapes. "Platinum and ruthenium supplies in particular could become critical in the future. In 2018, world production of ruthenium amounted to 33 tons. However, in the worst-case scenario, we will use 592 tons in 2040, and that's just for the hard disk drives — it doesn't cover the demand from other technologies. Even in the most sustainable scenario, we would still need 33 tons," says the researcher in a brief summary of her results. When the remaining 32 technologies examined in the study are taken into account, demand is predicted to increase for ruthenium, scandium, dysprosium, terbium, lithium, iridium, platinum and cobalt.

> "Germany is particularly vulnerable as a high-tech hub, because it's so dependent on imports for raw materials."
>
> Jana Rückschloss, scientist at Fraunhofer IZM

The shortage of rare-earth metals is impacting the electronics and automotive industries in particular. In the electronics sector, these elements are found in LEDs, lasers and displays, while electric vehicles use them primarily in batteries and magnets. However, rare-earth metals are not as rare as the name would imply. The problem stems predominantly from dependency on the countries that produce them, with around 80 percent of our rare-earth metals coming from China. To see the kind of complications this can lead to, we need only look to the drastic jump in prices ten years ago when Beijing imposed an export ban. That is why this dependency must be reduced, to minimize the chances of shortages.

The circular economy: A ray of hope

Until now, the circular economy has primarily been viewed as an aspect of climate policy, but with the global raw material shortage, it is becoming an ever more relevant topic for industry. The Center for Responsible Research and Innovation (CeRRI) of the Fraunhofer IAO, the Fraunhofer Center for International Management and Knowledge Economy IMW and the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT have joined forces with Foundation 2° and the Foundation for Family Businesses to explore the potential that the circular economy can offer family businesses, in a study covering challenges, solutions and recommendations for further action. With a view to jump-starting the circular economy, the study made concrete recommendations for the German government, such as creating manageable standards for recycled materials. The results are promising: For example, when producing vehicle parts, one of the 21 companies surveyed has saved 85 percent on raw materials and 55 percent on its energy requirements when compared to new parts. Another manufacturer has increased its aluminum production by 20,000 tons per year, by recycling and by expanding its production plants. A further example case has proved that hot-dip galvanization can save 80 percent more zinc than conventional processes.

"If Europe wants to become independent, we need a circular economy — after all, we don't have any cobalt or nickel here, or manganese either," states Dr. Benjamin ▶

Around

80%

of our rare-earth metals come **from China.**

"Platinum and ruthenium supplies in particular could become critical," is the concern of Jana Rückschloss, scientist at Fraunhofer IZM.

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Karsten Schischke of Fraunhofer IZM is working on extending the product life of the cellphone. "Repairability and modularity are interlocking concepts."

"A smartphone contains a pure material value of **1 euro.**"

Balke. Dr. Balke, who leads a department at the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, is working on recycling basic e-mobility components that contain critical raw materials such as cobalt and rare-earth metals, as part of the HydroLIBRec project. To be precise, he's focusing on the lithium-ion batteries that are used in electric vehicles.

The first questions the Fraunhofer IWKS researchers must ask themselves is, how far do they want to break down the material? The complex intermetallic compounds are hard to separate, after all — for example, it would take a lot of energy to break the compounds all the way down to the pure elements. "That's why we prefer functional recycling," says Balke. For batteries, that means the cathode material is not separated into the individual metals, but rather is recycled as a complex compound. Disassembly is a fundamental aspect of cost-effective recycling. Shredding the batteries is not practical, as that leaves the individual fractions mixed together and it is extremely hard to extricate them again.

> "If Europe wants to become independent, we need a circular economy — after all, we don't have any cobalt or nickel here, or manganese either."
>
> Dr. Benjamin Balke, Head of Department at Fraunhofer IWKS

However, manual disassembly costs too much time and money, so the research teams developed an automated disassembly process. "To crush the entire battery by electro-hydraulic means, we place it in water and apply short high-power pulses of 40,000 volts to the liquid. That induces a shock wave in the water, which acts on the predetermined breaking points between the materials and divides them from each other," explains Dr. Balke. The individual components — copper, aluminum, plastic — are separated out in subsequent sorting steps, leaving behind the black mass, a mixture of materials from the anodes, cathodes and electrolytes. The cathode mass contains crucial elements like nickel, manganese and cobalt. "To process this mass in an eco-friendly, cost-effective way, we run through various processes to determine the best course," says Dr. Balke. At this point, it's clear that in terms of quality, the recycled cathode material is already perfectly usable. The next step is to move the recycling process toward industrialization.

Recycling can also be worthwhile in the case of neodymium-iron-boron magnets, found in electric engines, hard drives, cellphones and speakers, among other things. Because 90 percent of the energy needed to manufacture these magnets is used for mining, separating and processing the rare-earth oxides they contain — material and energy costs that can be saved by recycling. The recycling process itself is ready; however, Europe still lacks systems for bringing back used batteries, as well as customers. "There's a market for this already," affirms Fraunhofer IWKS scientist Konrad Opelt.

Under the auspices of the FUNMAG project, Opelt is working on making old magnets usable again, and above all, on demonstrating that they are still just as powerful. "We want to show that applications that use our recycled magnets have just the same properties as with new ones," says Opelt. "The recycling process can cause some losses in terms of quality, but it's possible to compensate for those, for example by changing the microstructure."

As the composition of the magnets varies depending on their applications — particularly as regards the kinds and ratios of rare-earth metals they contain — the researchers first sort them by application field and apply hydrogen to make them so brittle that they are reduced to a coarse powder. This powder can be directly used to produce new magnets. Even non-homogeneous mixtures can be used, but these are usually "downcycled," meaning they are only suitable for lower-quality use.

While FUNMAG primarily concentrates on high-performance applications for neodymium-iron-boron magnets, the Fraunhofer IWKS researchers in the RecyPer project are investigating other possible uses. "The goal is to investigate as many types of old magnets as possible — even material that can't be used for a traction motor anymore — and identify new fields of application for them, like holding magnets for whiteboards, for example," says Mario Schönfeldt, Project Manager at Fraunhofer IWKS.

Just as with magnets, it's difficult, and therefore, not cost-effective to recover pure metals from small electronic devices. "A smartphone contains a pure material value of 1 euro," reveals Karsten Schischke, Group Manager at Fraunhofer IZM. "By using metallurgical processes, we can recycle 90 cents worth of materials. The remaining 10 cents are made up of gallium, tantalum and ▶

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rare-earth metals. Recovering those materials is unlikely to become profitable for another ten to 20 years yet." Schischke was the coordinator for the project sustainablySMART; this collaborative initiative between Fraunhofer IZM and 17 other partners from eight EU member states is notable for winning the Ralf Dahrendorf award for the European Research Area. Its objective is to extend the life cycle of mobile information and communication devices by developing new product design solutions — thus saving on rare-earth metals as well. The project's targets also include device repairability. "Way back in the beginning, PCs were modular devices. Now, an exciting question is being raised: How can we apply this concept to small devices?" says Schischke.

An important factor here is continued miniaturization, which the research team is using to create space for plug-in connectors. These make it possible not only to replace defective components quickly and easily, but also to recover and reuse individual semi-conductor components from devices such as smartphones, e.g. in less complex internet-of-things applications. The Fraunhofer IZM research team took on the strategic aspect, and is analyzing which components it would make sense to recover in this way.

In the MoDeSt project, Fraunhofer IZM and the company Shift have also set their sights on extending the life cycle of small devices. "Repairability and modularity are interlocking concepts," explains Schischke. "If the devices are constructed on a modular basis, it requires a greater initial investment in certain raw materials — for example, you need gold to make the connectors." This approach pays for itself if the consumers use the devices for five years rather than three, as earlier projects have already shown, with savings of around 30 percent. "The especially exciting thing is that we got to reuse these results on behalf of the European Commission, to figure out how they can legislate for improved repairability and durability, and extended product life. Next year or the year after, we can expect the first smartphone regulations to address requirements for product design, availability of replacement parts, battery life, prevention of damage from dropping, and other measures aimed at extending product life," predicts Schischke.

> "We heat the shredder scraps up to **500 to 600 degrees Celsius** without oxygen, which converts the plastic to the vapor phase."
>
> Dr. Alexander Hofmann, Head of Department at Fraunhofer UMSICHT, Sulzbach-Rosenberg institute branch

Valuable metals and rare-earth metals can also be found in electronic waste, such as LCD panels. However, these plastic-based shredder scraps contain large quantities of impurities such as flame retardants — meaning they get incinerated as waste, with metals such as indium, gallium, palladium and silver being lost in the process. Hoping to change this, researchers in the Fraunhofer Cluster of Excellence Circular Plastics Economy CCPE — a group combining expertise from six Fraunhofer Institutes along the entire life cycle of plastic products — have developed a process for recycling plastic-based compound materials at Fraunhofer UMSICHT.

"We heat the shredder scraps up to 500 to 600 degrees Celsius without oxygen, which converts the plastic to the vapor phase," explains Dr. Alexander Hofmann, Head of the Recycling Management Department at the Sulzbach-Rosenberg institute branch of Fraunhofer UMSICHT. "Then we cool the vapor down again and condense it into pyrolysis oil. The oil is separated from the coke in the process, leaving the pyrolysis coke and the metals it contains behind." The pyrolysis coke can then be taken to copper smelting plants for further, cost-effective processing using established methods, and the metals can be recovered. A pilot plant has already been established, with a throughput capacity of 70 kilograms per hour, a rate that the Fraunhofer spin-off, Recycling Solutions Lippetal RSL, is currently scaling up — to 250 kilograms per hour. The plant is scheduled for completion in 2022.

Tackling the plastic pellet shortage

Manufacturers that depend on rare-earth metals are not the only ones suffering from shortages and high prices when it comes to raw materials. Producers of rubber and plastic goods are also feeling the pinch, with the high plastic pellet prices slowing down production for 79 percent of manufacturers. These companies' dependence on oil-producing countries and their pricing policies constitutes another strong argument for a circular plastics economy. Additionally, it's becoming more difficult to export plastic waste, as various recipient countries like China are now refusing to dispose of plastics from Germany.

Raw materials that just fall from the sky? Not quite — they still need a little push. Dr. Alexander Hofmann of Fraunhofer-UMSICHT is working on scalable solutions.

"Our goal is to establish a technology platform that will allow us to take post-consumer plastics and produce a raw material with virgin-material quality."

Dr. Alexander Hofmann

The plastics recycling solution developed by Fraunhofer UMSICHT and Fraunhofer Cluster CCPE has significant potential. "Our goal is to establish a technology platform that will allow us to take post-consumer plastics and produce a raw material with virgin-material quality," relates Dr. Hofmann. It's something they have already achieved with rotor blades from wind power plants, for example — a waste stream with high plastic content. The problem here is that the materials are fiber composites. The experts slice the rotor blades into flakes of just a few centimeters in size, and then proceed as when recovering rare metals. The fiberglass is removed from the plastic matrix and used to make foam glass. Meanwhile, the pyrolysis oil contains the basic building blocks for plastic, either as molecules or monomers, depending on the source material. The researchers then use a suitable purification process to extract pure styrene or phenol from the oil. It is impossible differentiate between the styrene and phenol and virgin material based on chemical structure, so these can be used as raw material in the plastics industry.

How can fiber composite materials be recycled? The Fraunhofer Institute for Machine Tools and Forming Technology IWU together with 21 partners from seven EU member states have been working on this question in the EU project FiberEUse since 2017. The team is focusing on three different basic principles: thermal recycling, mechanical recycling and component reuse. "Our team at Fraunhofer IWU have developed reusable structures, in collaboration with the companies EDAG and INVENT," says ▶

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Justus von Freeden, a Fraunhofer IWU scientist. "Fiber-reinforced plastics with carbon fibers work really well here. They're durable, fatigue-resistant and non-corrodible." As examples, they tested the project out on two vehicle structures of no specific make or model; they reupholstered the substructure of a car seat and produced a base frame for an electric car platform. As an interim solution for checking the quality of the composite materials, the researchers used non-destructive testing technologies, such as ultrasound and thermography.

Meanwhile, in the lighthouse project Waste4Future, seven Fraunhofer-Gesellschaft units are coming together to pursue their objective of making carbon from plastics fully recyclable. Currently only 50 percent of plastics, such as PET bottles, are recycled, while the remainder is burned. "We examine the material flows, divide them into subflows and determine the cheapest suitable processing route," says Dr. Sylvia Schattauer, Deputy Institute Director of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS, and head of the Waste4Future project. "The individual technologies needed for that do not have to be developed from scratch; they just need to be scaled up and cleverly combined."

To do this, the research team has created a kind of technology ladder — the expertise for each individual "rung" already exists at the institutes. The first step is to process everything that can be separated mechanically. Anything that cannot be taken out mechanically moves on to the next stage, namely physical-chemical separation — at this point, the recycled pellets and basic molecule chains can be produced. The final remainder moves on to the chemical-thermal processing stage, which produces pyrolysis oil and syngas; these can be processed to form new plastics using green hydrogen.

"Dumping all the material into chemical recycling makes no sense, because that requires very high quantities of energy. It's only worth using chemical processes for material flows that can't be recycled any other way," says Dr. Schattauer. Ideally, this will result in an evaluation model that companies can use to assess their material flows. A new and important aspect of the platform is that it also takes cost-effective evaluations into account. This means the calculations include factors such as source material scarcity, the price of crude oil and new plastic pellets, and the capacity of the production methods.

New demand is also arising in other areas. The last thing a layperson would expect is a gypsum shortage — after all, we see this construction material everywhere. The German industry alone requires 10 million tons a year. However, 60 percent of this gypsum comes from coal-fired power plants that are set to close in 2040. Based on present requirements, that would mean an annual shortfall of 6 million tons of gypsum.

"Recycling gypsum from building rubble would close that gap," says Dr. Volker Thome, Head of Department at the Fraunhofer Institute for Building Physics IBP. A team of researchers is working on that very issue in ENSUBA, a discovery project on the desulphation of building rubble. To date, the fine fraction of rubble, i.e. anything smaller than 2 millimeters, has been sent to landfill. Amounting to 5 million tons, or a volume 160 times that of the Berlin TV Tower, the quantities involved would definitely be worthwhile. Around 10 percent of this fine fraction is gypsum, contained in chemical compounds.

Every year, **50 billion tons** of construction sand are used for building — **40 billion tons** could form a wall 27 m wide and 27 m high around the equator.

Using a wet chemistry process, the Fraunhofer IBP researchers can remove the gypsum from the fine fraction in a cost-effective way. "First, we mix the rubble with ammonium carbonate, also known as hartshorn salt, a kind of baking powder used in German gingerbread cookies," explains Dr. Thome. This results in chalky, sulphate-free rubble, which can be processed directly at cement factories, and ammonium sulfate. If you mix chalk and ammonium sulfate, the gypsum is precipitated. Cement factories would be possible recipients for both the end products. Researchers in a large pilot project by the Central Innovation Programme for small and medium-sized enterprises aim to upscale the process and resolve some teething problems. "The method is relatively simple — and the interest in it is correspondingly high," says Dr. Thome.

With this process, 500,000 tons of gypsum could be recovered every year — a lot, but not enough. That's why Fraunhofer IBP researchers are linking up with Fraunhofer IML, Fraunhofer UMSICHT and Fraunhofer IOSB

"The method is relatively simple — and the interest in it is correspondingly high."

Dr. Volker Thome, Head of Department at the Fraunhofer Institute for Building Physics IBP

in the BauCycle joint project to develop and optimize a process for identifying larger pieces of building rubble by electro-optical means and separating them from the rest with compressed air. This would make it possible to recover fragments between 2 and 8 millimeters in size with close to full purity.

Sand: A scarce commodity even in Dubai

The sands are running out — even for construction sand. In Dubai, for example, there's a major shortage of construction sand, because desert sand is not fit for purpose, and all their construction sand has to be imported from Australia. With construction sand also at a premium elsewhere, pirates are mining sand illegally off the coast of Africa, causing irreparable ecological damage. Meanwhile, 20 Indonesian islands have vanished entirely from the face of the earth due to excessive sand mining. However, if we could recover construction sand from old concrete, this would create a gigantic source of the material. Because, after water, concrete is the most used substance in the world. However, this is no small endeavor. As yet, sand cannot be separated from its surrounding matrix. "Up to now, concrete has just been crushed mechanically. However, by using electrodynamic fragmentation, we've developed the first separation method that can be used to recover sand, gravel and steel fibers from concrete," reports Dr. Thome of Fraunhofer IBP. In the process, ultrashort pulses are generated underwater; these pulses tend to travel along the phase boundaries in the solid objects, thus breaking the concrete down into its constituent materials. "When the first predischarge alone reaches the counter electrode, it results in pressures in the region of a TNT detonation," relates Dr. Thome. While this ▶

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process allows researchers to extract and reuse the gravel in pure form and unchanged quality, and even to isolate steel fibers cleanly, some further research is still required when it comes to sand. The process still produces a mixture of sand and cement stone. Scientists are currently working to separate the sand cleanly, but until then, even the mixture can be reused — to manufacture insulation for example. The researchers have already cleared some significant hurdles in the recycling process. "In a collaborative project with a generator manufacturer, we managed to reduce the energy requirement for electrodynamic fragmentation to a tenth, so it's now within the region of mechanical processing," enthuses Dr. Thome. The team has also resolved the problem of throughputs, which had been very low until now. By the end of the year, they are aiming to have a plant running with a capacity of 3 tons an hour — previous plants could only manage one.

The process could also be very useful in recycling the ashes from waste incineration. Iron, non-iron metals such as aluminum foil, bottle caps, glass, stones and ceramic with sizes of over 2 millimeters can be fully separated and reused, thus reducing the ash volume to 50 to 60 percent. Fire-proof ceramics would be another field of application for electrodynamic fragmentation; among other things, these ceramics are used in iron and steel manufacturing or in waste incineration plants. These must be replaced once a year, with the old ceramics ending up in landfill. However, as China has a high demand for these ceramics itself, the price for ceramic aggregates is currently skyrocketing. Take high-purity bauxite for example — it now costs 800 to 1200 euros per ton. By comparison, concrete only costs 6 to 14 euro per ton. "Using electrodynamic fragmentation, we can separate out these aggregates with unchanged quality levels, so we already patented the process back in 2017," relates Dr. Thome. In FAVRE, an ongoing Fraunhofer project aimed at developing a fragmentation plant for recycling composite materials and funded by the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation), Fraunhofer IBP researchers are upscaling this technology. This will open up a new source of raw materials like bauxite, hopefully toppling prices and guaranteeing their availability in the long term. It's just one more area where reusable materials are becoming an ever more valuable resource. ■

What makes the world go 'round: Dr. Volker Thome of Fraunhofer IBP in the saturated steam autoclave used for manufacturing aerated concrete.

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Interview

“We have proven that we are capable of going digital.”

Dr. Bernd Althusmann is Minister of Economic Affairs for Lower Saxony — and an enthusiastic advocate for digitalization. However, in this interview, he also discusses its pitfalls: “Cyber espionage between political parties is an important issue, and we take it very seriously.”

Interview: Josef Oskar Seitz

Bernd Althusmann, 54, has been Minister of Economic Affairs, Employment, Transport and Digitalisation since 2017 — and deputy Minister President of Lower Saxony.

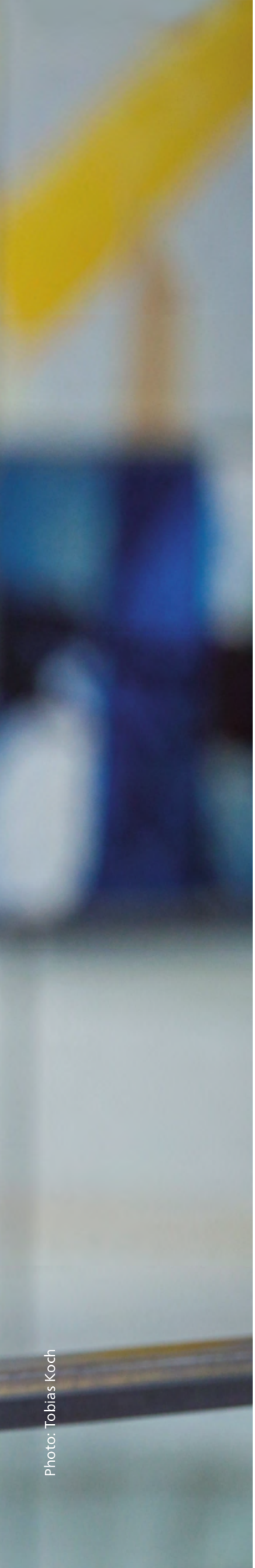


Photo: Tobias Koch

Dr. Althusmann, Germany has often been called the land of poets and thinkers. What does the expression "the land of poets" bring to mind for you?
Bernd Althusmann: My initial response would be the same association we all have with that particular expression: how lucky we are in Germany to have always had minds with the kind of brilliance that radiated across the world and shaped their respective eras. That's still true today.

Do we still have reason to call Germany "the land of thinkers" today?
Undoubtedly yes, because our greatest strengths — apart from industry — have always been and still are education, science and research. You can see that in our country's inventive spirit in particular. In Germany, 42,000 patents were filed in 2020, with more than 3300 of those coming from Lower Saxony. That's 40 patents for every 100,000 inhabitants, putting us in third place out of all the German states — after Bavaria and Baden-Württemberg. So as you can see, progressive thinking has been important to us since long before COVID.

Which brings us to your updated version of Germany's traditional nickname — the land of poets, thinkers and digitalization. Why are you calling on Germany to make digitalization a national objective?
The answer to this question is multi-layered, but I'll try to keep it short and sweet. The question is, what should a modern state look like? In the coming years, online access to public administration processes is set to replace the piles of paperwork that accompany most dealings with public authorities. We aim to create a user-friendly data infrastructure for our citizens; they will have accounts and electronic IDs. The future of up-to-date administration is digital. The term "national objective" is nothing new. Digitalization is as much a basic requirement as any other public utility or service. In plain English, this service has to be available, just like electricity and hot water, because it will also affect our lives at a fundamental level in other areas. Over the last year and a half, we saw very clearly how important digitalization is. The more digitalized a given national economy was, the better it was able to overcome the crisis.

Many people found it quite unsettling to hear that health offices had to resort to ballpoint pens, paper and fax machines in the fight against coronavirus infection chains.

Digitalization is a basic requirement: "This service is as vital as electricity and hot water!"

The pandemic showed us how long the road to implementation can be sometimes. As soon I took office, I put digitalization on the agenda. In the Lower Saxony Ministry of Economic Affairs, we have had our own dedicated state secretary and office for digitalization since 2018, and they are doing an excellent job. Since mid-2018, we have been implementing our master plan for digitalization step by step. This plan comprises over 90 measures and I'm happy to say that the majority of these have already been completed. What's more, we are raising our digitalization levels — and I'm not just talking about schools and official buildings here. With our "Digitalbonus Niedersachsen" program for promoting digitalization in Lower Saxony, we are providing up to 10,000 euros in funding for small and medium-sized enterprises that plan to invest in their digital infrastructure. This program has been a real success story. And as far as the pens, paper and fax machines are concerned, it's worth noting that people love using these terms because they sound so dramatic. But I'd like everyone to ask themselves: Do I still use a pen and paper?

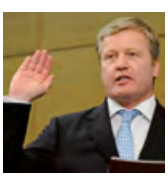
Sometimes, another topical issue gets in the way of digitalization: data protection. Can you appreciate why even Germany's coronavirus warning app was given such a hard time when it was first launched?
I would question whether data protection really gets in the way of digitalization. Because when we're talking about a national objective, that creates a particular requirement for the best data protection possible. Even data protection needs to be updated. The coronavirus app is a good example of how digital processes can function and be adapted continuously. At first, the app focused on secure risk identification. Now we know that where it can really make an impact is through its check-in and vaccine certification functions. However, as the app continues to develop, we should also keep users informed in an ever more effective way. Germany isn't the only land of poets and thinkers in the history of the world; in Ancient Greece, they had a saying that ran, "Constant dripping wears away a stone." So what can we learn from the introduction of the coronavirus app? We ▶

1960s

The son of a nurse and an Evangelical pastor, Bernd Althusmann was born on December 3, 1966.

2001

Side by side with Christian Wulff, the then chairperson of the CDU in Lower Saxony, Dr. Althusmann — as speaker on security policy and a former army officer himself — protests against the German Armed Forces' closures of locations.



2010

Dr. Althusmann is sworn in as Lower Saxony's Minister for Culture.

2010

Joining in the children's soap bubble experiments: As Minister for Culture, Dr. Althusmann presents a "Little Scientists' House" certificate to a daycare center.

need wide-ranging public relations work, and it can't wait until just when the finish line is in sight — it needs to happen right from the get-go. A crucial success factor for any digitalization measure is that our citizens see a real added value in it and accept it.

Trust is the key factor in harnessing digitalization. In the German Digitalization Index, 73 percent of those surveyed indicated that they trust the public authorities to handle their personal data. Was this praise a little premature?
That figure reminds me of vaccination rates. 73 percent is very good, but 100 percent would be better. But in all seriousness, premature praise should motivate us to work harder, not to rest on our laurels.

We're always coming up with fancy new expressions in this land of poets, thinkers and digitalization. This year's legal tongue twister is the German Register Modernization Act (RegMoG); is it a major step forward for us?
In recent times, the government has tried to spell out the objective and meaning of laws in their titles. This was undoubtedly a well-intentioned effort to improve communications between politicians and citizens, but all it produced was convoluted Frankenwords and cumbersome noun stacks. However, when it comes to the Register Modernization Act, there's an awareness among experts if no one else that it represents a definite advantage for companies in Germany. When interacting with a public authority, companies will not have to provide the same data over and over again if it has already been provided to another office. The key here is that businesses will only need their company ID to identify themselves. Meanwhile, citizens will just need their tax ID. They won't have to produce their certificate of registration or birth certificate every time. This will also reduce processing times. So yes, although the name doesn't exactly roll off the tongue, this law will lay the foundations for digitalized government action and that's a big step forward for all of us.

The Administrative Procedures Act (VwVfG) is another excellent example of the German tendency to come up with unwieldy names. Will we treat digital and paper certification as equally valid in the future?
This is a good example of a "yes, but…" answer. First, we have to clarify or establish some prerequisites — including the question of authentication in this case. The technology is there. If a digital signature can be assigned to a person in an unambiguous, tamper-proof way and long-term archiving can be guaranteed, then we can treat digital documents the same we currently treat analog records. However, it's also clear that there will always be grades and different security classifications — the security requirements for an ID card will obviously fall into a different category from a residential parking permit.

Do you believe in digital sovereignty? And how can we achieve it?
First and foremost, digital sovereignty means being able to live in accordance with our own norms and values even in a digitalized world. For example, if any US practices for monitoring telecommunications contravene European law, the answer cannot be to give up our own Charter of Fundamental Rights. Instead, when it is necessary, Europe must be in a position to switch to services that comply with European law. At present, that does not seem to be the case. But we are taking some steps in the right direction by promoting open standards, in GAIA-X, for example — the partners in this project are coming together under this futuristic name to develop collective specifications for a European data infrastructure. Because the next step will focus on the digital sovereignty of private individuals and companies, who should have the option to switch services. What's more, "digital sovereignty" is also an educational objective. I think it calls on everyone — parents, schools, universities, the media — to explain and question digital mechanisms and so to build up advanced media and digital literacy skills. And the state has obligations to fulfill here as well. Laws and regulations from the everyday reality of our analog lives must also be fit for the digital world.

You are the state chairperson for the CDU in Lower Saxony. In July, the business news magazine Wirtschaftswoche publicly revealed that the Fraunhofer-Gesellschaft had tested IT security across Germany's various political parties and warned party leaders of serious security flaws. Emails were vulnerable to interception and data was at risk of theft or deletion — meanwhile, we are being told the IT security of our political parties is especially important "for the stability of our democracy." Do you think action is needed?

Cyberattacks and cybercrime pose a growing challenge.

A qualified teacher, Dr. Althusmann hopes to use play to awaken children's interest in artificial intelligence and start-up culture — through the DigitalSTARTer competition, among other things.

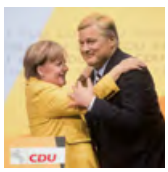
Cyberattacks and cybercrime pose a growing challenge for industry, public authorities and unfortunately, for the political sphere as well. The German Federal Returning Officer, Georg Thiel, declared just recently that he considers the risk of cyberattacks during the coming federal election to be high. The authorities are already preparing, in coordination with each other. Cyber espionage between political parties is also an important issue, and we take it very seriously. It's well known that CDU servers were hit by cyberattacks during the federal party's first digital conference in January. However, the party was prepared for this situation and was able to repel the attacks. So with this issue forming a primary concern for us as a party, we will remain vigilant and forge ahead with the continuous improvement of our infrastructure.

Anhalt-Bitterfeld, a district in Saxony-Anhalt, suffered a cyberattack that brought the administration to its knees for weeks and months. According to German IT security law, operators of critical infrastructure are obliged to report cyberattacks to the Federal Office for Information Security (BSI) immediately. After this attack on a district's administration, should the reporting obligation now apply to all 294 districts and 11,000 municipalities in Germany as well?

Unfortunately, Lower Saxony has had its own fair share of cyberattacks at this stage. And as soon as critical infrastructures are affected — I'm talking about hospitals, water supply plants and transportation companies — municipalities are also obliged to report the attacks, provided the operators are sponsored by the municipality. But as a general rule, every report filed with the BSI is another step toward increased security for all of us. If it becomes apparent in the future that municipalities are undergoing frequent, targeted attacks, it may make sense to make reporting mandatory for them as well. After all, a multi-week disruption to municipal IT infrastructure means massive restrictions on their ability to provide services.

Dr. Althusmann, we started our discussion with poets and thinkers. Can you recommend some reading material that helped you through the pandemic?

My guide in this area is a poet from Lower Saxony, Wilhelm Raabe. He once said that being a little foolish every now and again is part of wisdom. For me, this means we should look beyond our own horizons and not be afraid to seek "outside" expertise. This is why I'm recommending Martin Schallbruch's "Schwacher Staat im Netz," a book on weak states in the internet age. At first glance, it may look like a critical view of states, but Schallbruch is a respected computer scientist who spent 18 years working in various departments within the German Federal Ministry of the Interior. And his book is written in such a way as to be very readable for those without any expertise in computer science — like myself. ■



2017

Chancellor Angela Merkel fully embraces Dr. Althusmann as a front-runner in the regional elections.

2017

Dr. Althusmann with his family at the wedding of Ernst August Prinz von Hannover. He himself has been married twice.

2019

A toast to the future: As Minister for Economic Affairs, Dr. Althusmann enjoys the summer festival for Lower Saxony's state government.

Photos: private, ddp images (3), Julian Stratenschulte/dpa, imago images (3)

Really quite painful

Kidney stones hurt. The standard procedure is to break them up and remove the fragments endoscopically. But what happens to the fragments that are too small to grasp? The solution: a hydrogel — which should be commercially available very soon.

By Mehmet Toprak

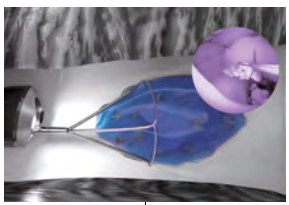
Who knew a kidney stone could look so beautiful under the microscope?

Approximately 50,000 kidney stones are removed endoscopically in Germany every year. The stones are broken up with a special laser, and a grasping tool is used to remove the larger fragments. However, there is still the question of what to do with the many tiny pieces, often smaller than one millimeter, that can't be removed this way. Previously, nobody had an effective method to resolve this problem, but the medical technology company Purenum GmbH has now come up with a solution. The Bremen-based spin-off from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM injects a transparent liquid into the kidney via a catheter that is passed through the endoscope. This fluid then surrounds the tiny stone fragments that could not be removed. A second fluid is then added, which causes a gel to form within a matter of seconds. The grasping tool can then grip the gel and remove it along with the fragments.

This technique was developed by a project group at Fraunhofer IFAM led by Dr. Ingo Grunwald, whilst his colleague Manfred Peschka was working on the business concept. "It was a call from a urologist that gave us the idea," says Grunwald. "He told us about his idea of a type of sticky liquid that could collect the stone fragments left in the kidney. After that, we got to work." The institute was able to utilize its many years of expertise in materials and, particularly, in the field of bonding. Prof. Bernd Mayer, Institute Director of Fraunhofer IFAM, supported the project. He also didn't need much convincing: "The idea is quite simply excellent. That's why we supported the project from the very beginning."

When investigations and laboratory tests showed that the concept should work, Grunwald and Peschka founded the spin-off Purenum GmbH in December 2017. The company's first mission was to develop the mediNiK hydrogel system for removing kidney stone fragments. This hydrogel system is comprised of two thin liquid components. "The catheter that passes through the endoscope and deposits the fluid inside the kidney has an inner diameter of between 0.6 and 0.7 millimeters. This means the fluid has to be very thin, like water," Peschka explains. The second liquid is only introduced after the first liquid is applied, and the two combine to form an elastic gel. It is stable enough to hold the kidney fragments, yet flexible enough to be gripped by the grasping tool and pulled out through the urethra. This frees the kidney from any remaining residues, allowing it to heal fully and painlessly.

Stone fragments encased in mediNiK are gripped by a grasping tool.



"The idea is quite simply excellent."

Prof. Bernd Mayer, Fraunhofer IFAM

"The Purenum team worked alongside 40 physicians, observing their technique when removing kidney stones and asking them about any practical requirements in order to find the most compatible solution to this problem." Peschka says, managing director of Purenum.

For example, the components must be color-coded so that the physician can use the video screen during surgery to see exactly where the fluids are in the kidney and whether they have successfully captured the small fragments. The first component is dyed blue, the second is dyed yellow. "Developing this dye caused a few problems for us," says Peschka. The dye had to meet several requirements at once: It must not stain the inside of the organ, must not change the material properties of the fluids, and it had to be transparent.

Nevertheless, they managed to overcome this hurdle as well. Authorities are confident of the quality of the hydrogel and, in particular, of its biological compatibility in humans. MediNiK is now a certified medical device and can be used for all kidney stone patients as of 2022.

And it will not be the only product to come from the Fraunhofer spin-off. Purenum is working on so-called biomimetic adhesives. These may someday be used to treat bone fractures. When dealing with the small bones in the wrist, it is often not possible to attach the splinters using wire to ensure that the bone grows together perfectly. A medical adhesive could enable precise joining of bone splinters and complicated fractures, allowing them to heal perfectly. ■

Video on the topic:
https://purenum.com/produkte.html

Photos: Science Photo Library/University of Aberdeen/Kevin Mackenzie; purenum GmbH

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Sneaking up into the brain

The blood-brain barrier protects the brain and central nervous system from harmful substances; it also makes them impenetrable to many medicines. But there is a gap in this defensive wall — could this be a possible new line of attack in the fight against Alzheimer's, Parkinson's and MS?

By Christine Broll

The brain sends a clear message to most pharmaceuticals: "Stop — no entry!" Why? Because the intricate net of blood vessels that permeate the brain are lined with a special kind of thick, vascular wall. The only substances that can pass through this wall are the ones the brain needs to function. For some nutrients, such as glucose or iron, there are even special gates in the vascular walls that examine exactly what has permission to enter. Everything else must keep out.

This "blood-brain barrier" protects the brain from undesired intruders such as bacteria, viruses and other harmful substances. Only a handful of drugs that consist of small molecules are able to pass the barrier; these include alcohol, cocaine and the painkiller diclofenac. Large molecules can't make it. Take therapeutic antibodies, for example — they could be the key to a breakthrough in treating neurodegenerative diseases such as Alzheimer's, Parkinson's and multiple sclerosis.

For decades, research teams across the world have been looking for strategies to overcome the blood-brain barrier. One promising path is through the nose, where the olfactory epithelium has a direct connection with the olfactory bulb in the brain. As part of the EU project N2B-patch, 11 partners from eight different countries developed a technology that can directly administer therapeutic antibodies in the nose; the antibodies will then be absorbed in the olfactory epithelium and transported to the brain.

"For the development of this platform technology, we have chosen an antibody that has been approved for the treatment of multiple sclerosis," explains Project Coordinator and Manager Dr. Carmen Gruber-Traub from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. Multiple sclerosis — MS for short — occurs when immune cells destroy the myelin that encases nerve fibers. The loss of this isolating blanket impairs the process of nerve conduction. Those affected experience loss of sight and feeling, in addition to pain and paralysis. The majority of antibodies that are currently used for treatment are administered intravenously and slow down the autoimmune reaction. "If the antibodies could reach the central nervous system directly through the olfactory epithelium, then their effect would be significantly stronger," explains Dr. Gruber-Traub.

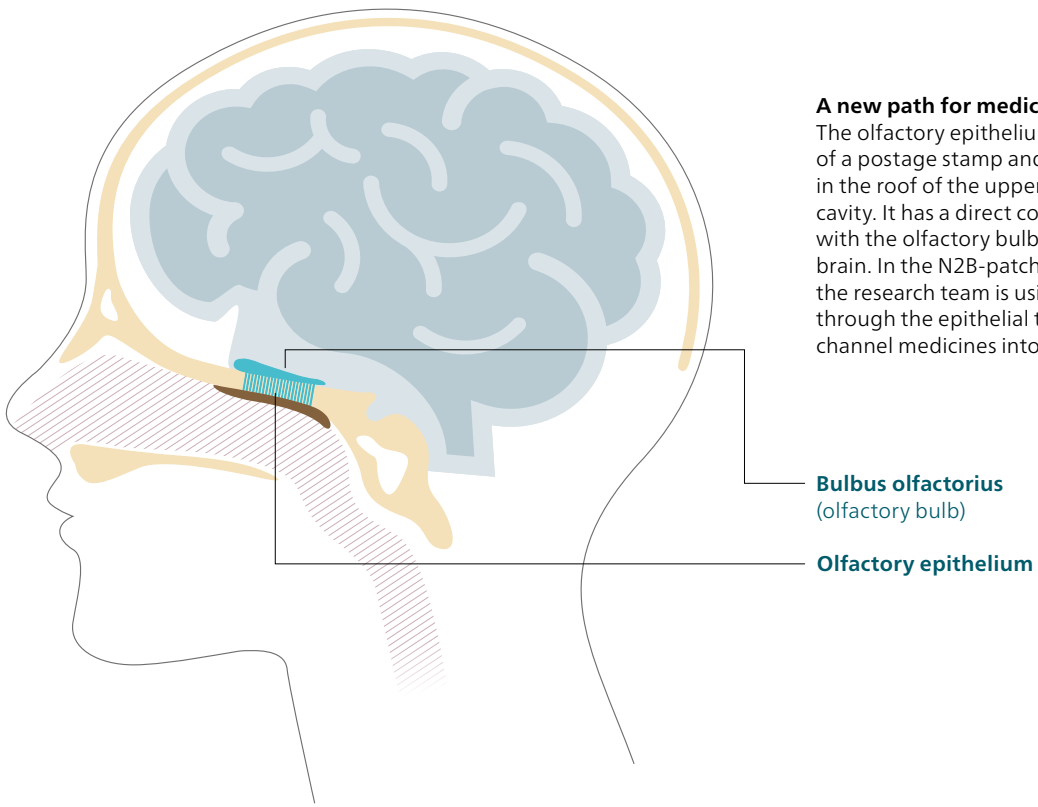
The first challenge was to wrap the antibodies correctly. Fraunhofer IGB took on this part of the job. "We successfully produced microparticles, in which the antibodies can remain stable at room temperature over the course of weeks," reports sub-project manager Lena Marie Spindler. The particles are administered together with a hydrogel that adheres to the epithelial tissue like a plaster. The project team had an unusual strategy for testing whether the antibodies had been absorbed by the tissue. "We got some pig snouts from a local butcher near Stuttgart. These are normally considered slaughterhouse waste and thrown out," reports Dr. Gruber-Traub. "We took the epithelia from these snouts and tested our formula on them." The results showed they had reached an important milestone: The antibodies had been released from the particles and absorbed by the epithelial tissue.

The next problem: How can the hydrogel and particles be administered in the nose? This is no easy task: the olfactory epithelium only has a surface area of about 5 centimeters squared and is located on the left and right sides of the roof of the upper nasal cavity. However, Beiter GmbH found a solution that works. A team led by Rolf Pfäffle designed an applicator to be attached to an endoscope. This allows trained medical professionals to apply the particles and hydrogel in the right location, and gives them a visual of the process.

The team will soon apply for a patent for the new application system. "We were able to show that the antibodies reach the brain's olfactory bulb. From there, they spread to other regions of the brain. The hydrogel plaster does not impair the sense of smell," adds Dr. Gruber-Traub. "With our technology, it could be possible to continuously and reliably administer a dose of the drugs to the brain over a one- to two-week period. After that, a new dose would have to be administered." Additional research is also taking place within the EU-wide project Bio2Brain in order to further optimize this system. The hope is that for patients, the hidden path to the brain will be uncovered as soon as possible. ■

Nose2Brain — directly to the brain through the nose

We can circumvent the blood-brain barrier through the olfactory epithelium



A new path for medicines
The olfactory epithelium is the size of a postage stamp and is located in the roof of the upper nasal cavity. It has a direct connection with the olfactory bulb in the brain. In the N2B-patch project, the research team is using the path through the epithelial tissue to channel medicines into the brain.

Porous cranial bone provides a loophole
Therapeutic antibodies are packaged inside particles in order to be channeled to the brain. The particles are administered to the olfactory epithelium together with a hydrogel. The antibodies are released from the particles and pass through the olfactory epithelium. From there, they take the path along the nerve fibers and permeate the ethmoid bone, a cranial bone with many small cavities. They continue to the olfactory nerve and then into the olfactory bulb in the brain.

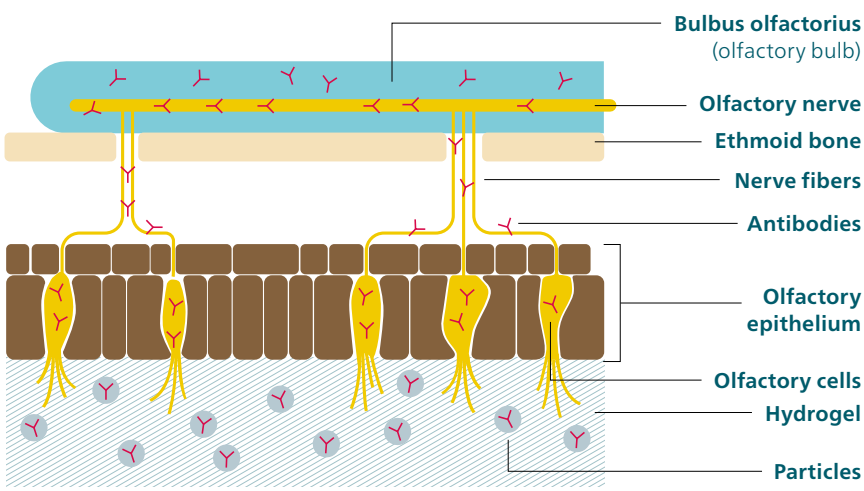


Illustration: 2issue

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A voice from the business world

Dr. Torsten Jeworrek is the master of probabilities. His area of expertise includes geohazards research.

Climate protection needs technology

The call for action could not be more urgent: In July, the Intergovernmental Panel on Climate Change issued a warning that the world risks missing its target of limiting global warming to 1.5 degrees, or 2 degrees at the most — unless we implement very strict climate protection measures very soon.

A viewpoint of Dr. Torsten Jeworrek, Member of the Board of Management of Munich Re

The recent extreme weather events seem to be a warning of what's to come. The scientific community agrees that climate change will increase the frequency of natural disasters such as heat waves, devastating flash floods and forest fires. I believe there are three key areas that we have to address in order to limit climate change and its consequences:

1. A global, or initially EU-wide, market for CO_2 emission certificates. If structured correctly, it would be the most effective way to reduce emissions whilst sending clear price signals in the process. Companies from all industries will also be in a better position to anticipate the approximate price trend, eliminating the need for ad hoc adjustments. The emission volumes in the EU trading system have been set until 2030, but now it is important to adjust this volume control quickly and in line with the politically set deadlines down to "net zero".

2. The development of new technologies for a climate-friendly economy. Transitioning to a low-carbon economy means we have to boost technologies and innovations on an exponential scale. Germany is in desperate need of an innovative and pioneering mentality, because the know-how for future technologies is already available.

3. Preventive measures to lessen the already unavoidable consequences of global warming. A comprehensive disaster management system aimed at preventing damage and building resilience will not only reduce human suffering, but will also be increasingly important in the international competition for locational advantages.

Things that cannot be reasonably prevented can generally be covered by insurance. Whether purely private or in partnership with the state, risk transfer must be linked to prices that accurately reflect the risk. This is the only way consumers, companies and communities can understand the risks and have the motivation to reduce them. It is up to insurers to use their expertise and data to provide the underlying basis.

"That's why we often cooperate with Fraunhofer, for example in the operation of test fields for photovoltaic systems or in the development of a wind energy data pool."

Dr. Torsten Jeworrek

- Has been a member of the Management Board of Munich Reinsurance Company, now called Munich Re, since 2002.
- Joined Munich Re in 1990 as an underwriter in the Fire/Treaty department. In 1997, he took over as Head of Section in the Operational Division: Property/Fire, then as Head of Financial Reinsurance and Retrocession, and in 2001 as Head of Divisional Unit: Netherlands, Nordic countries, UK and Ireland.
- Born in 1961 in Oschersleben (Saxony-Anhalt), he studied mathematics at the University of Magdeburg. After obtaining his doctorate, he worked at the university for four years as an assistant lecturer.

As a risk carrier, we take climate change very seriously. We have been dealing with the consequences for almost five decades and focus on lower emissions on both sides of the balance sheet — in investments and insurance business. We play an important role in bringing renewable energy and other climate technologies to market and scaling them up, making them easier to finance and invest in using specific risk solutions.

A few examples: We have been covering performance guarantees for photovoltaic modules for many years and similar coverage is now being provided for large-scale energy storage systems. We provide cover for the yield of offshore wind farms when there is too little or too much wind. We are actively working on insurance solutions for hydrogen technologies. In other words, we are focusing on technology trends and the specific requirements of a climate-friendly economy in order to provide know-how, experts and eventually suitable risk management solutions.

Having in-house know-how and data is an important foundation for insurers — but it's not enough. Close ties to research are also required, especially applied research, such as the research being conducted by the Fraunhofer-Gesellschaft. Their research projects on better water storage in cities during heavy rainfall through "urban greenery" or on storage systems in roads are particularly relevant for us as insurers. That's why we often cooperate with Fraunhofer, for example in the operation of test fields for photovoltaic systems or the development of a wind energy data pool. All of these projects are very close to implementation and are important for investors in future technologies.

These technologies are essential in the fight against climate change; without them, climate protection would only be possible by compromising our prosperity. New technologies also provide an invaluable advantage that goes far beyond meeting climate targets: They would dramatically increase Germany's and Europe's competitiveness in key technologies of the future. This would also enable us to take our destiny into our own hands again — something that would do this country a great deal of good. ■

Photo: Munich Re / Andreas Pohlmann

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Trust is good, control is better

People want artificial intelligence, but they're also afraid of it. Researchers at Fraunhofer IAIS are making autonomous driving, virtual assistants and other AI applications more trustworthy.

By Dr. Sonja Endres

"There are a lot of risks to consider — but there are also ways to deal with them."

Dr. Michael Mock, Fraunhofer IAIS

AI is trained using computer-generated images.

What if you could just get out at your destination and let your car find itself a parking space? Dr. Michael Mock, an associate professor and research fellow at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, estimates that this dream could become a reality in another five years thanks to artificial intelligence (AI). But who would leave their vehicle with an AI they can't trust? After all, you want to be sure your car won't get damaged as it autonomously makes its way through a city on the hunt for a parking space — or cause any damage, either.

Plenty of skepticism still. According to a survey by the German digital industry association Bitkom in September 2020, nine out of ten respondents agreed that AI systems must be tested "particularly thoroughly" before being approved. This shows there is concern. However, there is hope, too — two thirds felt the opportunities associated with the technology were enormous.

Dr. Mock and his colleagues at Fraunhofer IAIS are working on improving trust in AI. "Artificial intelligence is the key technology we can use to significantly advance digitalization — so long as we manage to foster trust in it," Dr. Mock says confidently. While conventional software works on the basis of algorithms provided by developers, AI systems are fed large amounts of sample data from which they learn and derive rules on their own ("machine learning"). But what those rules are, no one knows. Even in retrospect, they can often only be partly determined, or cannot be determined at all — the user must trust that the AI will come to the right conclusions.

As part of the Certified AI project, Dr. Mock and the Fraunhofer IAIS team are developing methods and measures to make AI systems more secure. In June, the researchers published a guide to designing trustworthy artificial intelligence, which is available for free on the Internet.

The EU also sees the need for action. In April, it proposed the world's first legal framework for AI. "When it comes to artificial intelligence, trust is a must, not an optional extra," stressed Margrethe Vestager, Vice-President of the European Commission for a Europe Fit for the Digital Age. AI that threatens the safety, livelihoods and rights of people should be banned, and systems that pose high risks must meet strict requirements before they are launched on the market. "The EU has put forward a very good proposal for regulating AI," Dr. Mock believes. "It sets out sensible requirements — although it mentions hardly any measures for meeting these requirements. Our guide is much more specific on that front." The 160-page guide aims to help developers consider all relevant criteria from the offset. "There are a lot of risks to consider — but there are also ways to deal with them," says Dr. Mock.

> "When it comes to artificial intelligence, trust is a must, not an optional extra."
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Every test begins with a risk analysis, which is carried out systematically based on essential requirements, i.e. the six dimensions of trust: fairness, reliability, autonomy and control, transparency, safety and data protection. "Not every dimension is relevant to every application," Dr. Mock emphasizes. For an AI-controlled paint-mixing machine in an industrial production context, for example, the dimension of fairness, i.e. the question of whether the AI treats all those involved fairly, is not relevant — in contrast to an automated candidate selection process. In that case, it is crucial to provide the AI with the right samples during the training phase to avoid discrimination based on gender, age, religion, skin color or ethnicity. For example, in 2018 Amazon made it public that its AI system had favored male applicants because women were underrepresented in the underlying sample data. On Twitter, its automatic image-cropping feature favored white women who conformed to certain beauty standards. The company recently shut down the software as a consequence. "That shows how important it is to carefully select training data for AI. It often conveys human prejudices," Dr. Mock warns. In addition, there are mathematical methods that can be used to ensure all affected groups are considered fairly. These methods are described in the recently developed guide, as are reviewing methods.

In the case of autonomous driving, all six dimensions of trustworthiness come into play. Together with Volkswagen, Mock is deputy head of a project for creating safe AI for automated mobility, and is also responsible for scientific coordination. As part of this project, large German car manufacturers, suppliers, technology companies and research institutes have joined forces and are funded by the German Federal Ministry for Economic Affairs and Energy. The total budget is 41 million euros.

Reliability is central to the trustworthiness of AI in cars, and it is also Mock's area of expertise. The samples you use to train the AI are important here, too. For this reason, the Fraunhofer IAIS team first defines the conditions under which the perception modules, such as pedestrian detection, are to function. Like every software system, AI requires a precisely defined operating range; in the context of autonomous driving, this is known as the operational design domain, or ODD for short. "You specify which use cases the AI has been tested for and where it works ▶

Illustrations: Daniela Leitner

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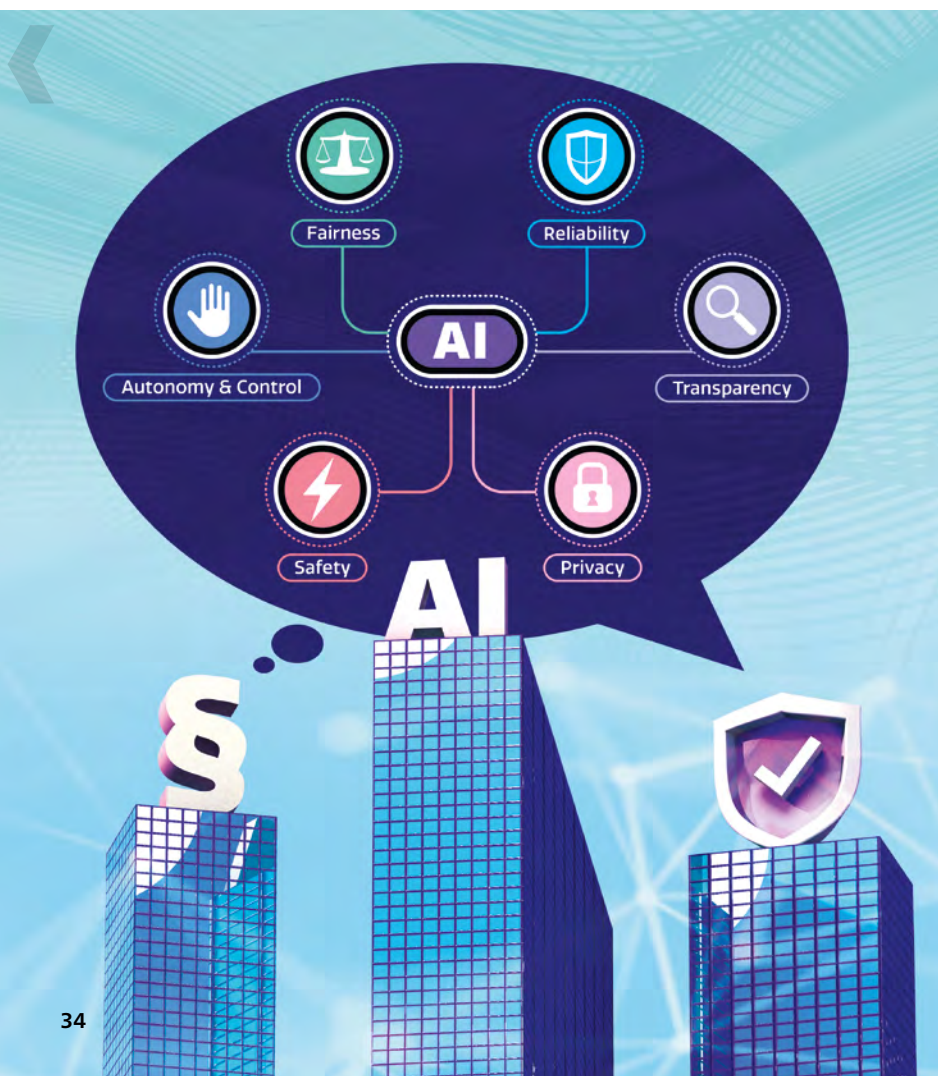
reliably," Dr. Mock explains. The sample images are then artificially generated via computer. "With this synthetic data, we can be sure we've considered a sufficient number of sufficiently varied examples within our ODD." These include children, elderly people or wheelchair users, partially obscured pedestrians, standing out in the open and in front of varied backgrounds such as advertising posters, house walls, panes of glass, in fog or rain, under different positions of the sun or at dusk. The function modules are also tested with this synthetic data later on. The AI is shown artificially generated images and must then decide whether or not they contain pedestrians. To do this, the AI must be able to apply the rules it has learned to unknown sample images and tolerate minor deviations ("robustness").

However, sometimes the AI won't make a clear decision. "After all," Dr. Mock points out, "even for a human, it's often not easy to tell if there's a pedestrian some distance away in fog or at nighttime." In this case, the AI will report that it is unsure and will warn the driver so they can take the wheel. Intervention capabilities such as this, along with other measures such as application monitoring, ensure human autonomy and control — another quality criterion for trustworthy AI. The basic premise is that human action always takes priority.

Transparency also fosters trust. As part of this dimension, the researchers are trying to make the decision-making processes within the AI transparent and offer a look inside the "black box." This is important for purposes such as troubleshooting, but also for protecting against legal claims. For example, automatically assessed creditworthiness must be verifiable if customers take legal action over a bad rating.



The dimension of security primarily focuses on the risks from malfunctions, external attacks and accidents. To minimize these risks, the Fraunhofer IAIS guide provides, among other things, protective measures against malware and extensive tests that triggers an outage within the AI application. When it comes to making AI systems trustworthy, data security in particular is hugely important. "AI systems operate based on extremely large amounts of data. When they're linked together, which we call linkage, conclusions can easily be drawn about personal or confidential training data," Dr. Mock warns. However, various procedures can be used to counter this — such as anonymizing or intentionally distorting data, for example.

The Amazon Fulfillment Center in New York City discovered how important it is to safeguard AI in spring 2020, at the start of the coronavirus pandemic. The automated HR management system assigned the night shift to employees who were seriously ill with COVID-19, sent termination notices due to absent employees and suspended benefits payments. "Of course, nobody could predict the pandemic," says Dr. Mock. Regardless, it is possible to prevent this kind of chaos — for example, by clearly establishing in advance the conditions under which the AI will operate. "If the sick leave rate is normally 3 percent, and my self-monitoring system reports 10 percent, I could make sure an alert is sent out automatically and the system is shut down."

Dr. Mock and his colleagues are now working together with the German Federal Office for Information Security BSI and other partners to further develop protective measures and methods, and to refine and standardize requirements. Their goal is to develop a guarantee seal for trustworthy AI, which is expected to be ready for use at the beginning of next year. ■

Knowledge relay

Prof. Neugebauer, what gives you hope

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Knowledge relay

*Climate*change, *renewable* energies, *industrialized region:* ***Prof. Neugebauer, what gives you hope*** that structural ***transformation*** will be successfully achieved***?***

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Climate change, renewable energies, industrialized region: Prof. Neugebauer, what gives you hope that structural transformation will be successfully achieved?

New series:
Knowledge relay

The times we live in have raised many questions — questions Fraunhofer researchers are striving to find answers to. This edition of the Fraunhofer magazine marks the launch of a new series. It starts with an expert **responding to a question.** Then they formulate a **question of their own** and **pass it on to the next expert to answer** — to create what we call a **"knowledge relay." Prof. Reimund Neugebauer,** President of the Fraunhofer-Gesellschaft, will kick things off.

Without question, the transformation to sustainable value creation comes with enormous challenges that require a new way of thinking — challenges that we must face together as a society. Nevertheless, I am convinced that this structural transformation will be implemented successfully. The efficient and sustainable transfer of scientific findings and developments into innovative applications plays a key role here. This transfer forms the backbone of our innovative culture. It will enable us to actively shape the next technological revolution and make a decisive contribution to sustainable value creation, a resilient society and technological sovereignty. It is crucial for us to understand that economics and ecology are not opposites.

Our collective success is measurable

As an economic and political partner, Fraunhofer supports companies in dealing with structural change through the adoption of new technologies and business models and through strategic repositioning within the market. Our collective success is measurable. According to a study by the Fraser of Allander Institute at the University of Strathclyde (UK),

Fraunhofer activities result in an investment in the economy of more than 15.2 billion euros and a significant increase in full-time employment. Just this year, Fraunhofer established three Hydrogen Labs in Leuna, Görlitz and Bremerhaven as collaborative platforms for research and industry. The only collaborative platforms of their kind internationally, the labs cover the entire process involved in the production and further use of green hydrogen — from carbon-neutral power generation by offshore and onshore plants, to optimization of electrolysis, to the construction of electrolysis facilities through to utilization (e.g. in the chemical industry), storage and transportation.

Pioneers of the hydrogen economy

To accelerate the market ramp-up required for green hydrogen technologies, the labs' digitally connected infrastructure provides testing and validation capacity for electrolysis and fuel cell systems of over 25 megawatts. The Hydrogen Labs are therefore important pioneers, paving the way for a future-proofed, sustainable hydrogen economy. In addition to developing new technologies, Fraunhofer has also set ambitious climate protection goals. Our aim is to achieve climate neutrality by 2030. We will do this, firstly, through the low-emission management of our buildings and a climate-friendly procurement strategy, and secondly, through carbon-neutral mobility and technology projects aimed at offsetting remaining emissions.

Close collaboration with local industry and municipal stakeholders, as is the case with the Hydrogen Labs, is crucial for technology development and thus also for successfully shaping structural transformation. According to a representative opinion poll carried out in Bautzen and Görlitz, the majority of the population considers it important to involve local people in actively shaping structural transformation in order to secure Germany's future as an energy hub. Among the factors cited as important for economic development are job creation (87 percent) and the establishment of educational and research institutions in the region (68 percent).

Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft

Close collaboration with local stakeholders ensures that technologies are systematically aligned with industry's latest needs, and that technology transfer as a concept can be integrated into the development process right from the start. By this I mean the transfer of key technologies to industry and the promotion of buy-in among the population in relation to deployment of these technologies. Both are important factors for the success of structural transformation.

One example here is the increasing level of digitalization in the health care industry and the bioeconomy; this must go hand ▶

As an economic and political partner, *Fraunhofer* supports companies in dealing with *structural change* through the adoption of new *technologies* and *business models* and their strategic repositioning in the market. Our collective success is measurable.

Photo: Bernhard Huber

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in hand with a program of education and further training that is specifically tailored to specialist target groups.

To ensure the successful integration of systems within the context of cross-sector collaboration and the circular economy, both in terms of establishing and applying standards as well as transparency, active participation will be decisive. Taking regional circumstances into account is also important here. Economic and social structures that have developed over time are driving the demand for new technologies and the rate at which these technologies are being implemented. It is therefore important to take these region-specific circumstances into account and to develop and establish innovative solutions in collaboration with the regions.

Companies of less than 250 employees play an especially important role here. According to the Stifterverband für die Deutsche Wissenschaft — a network of businesses and foundations focused on education, science and innovation — German companies employing less than 250 employees generate roughly 30 percent of Germany's overall revenue, yet spend only 8 to 12.5 percent of companies' overall R&D budget.

Interplay between all factors is key

The second step is to link up the regions and stakeholders across territories and industries and to integrate the latest developments in terms of politics, the market and society as a whole. This can include setting targets under the German Climate Protection Act, looking at current raw material prices and implementing supply and demand principles, for example. This is especially the case for solutions with a broad range of application that require infrastructure and logistics, as is the case with our hydrogen example above.

It is this interplay between all of these factors — the accelerated, efficient transfer of new technologies to the market, broad buy-in in terms of use and rapid adaption to new regional and trans-regional developments in society, politics and the market — that will be key to achieving successful structural transformation. ■

Knowledge relay 2

Prof. Welf-Guntram Drossel, *when will* electric or hydrogen-powered drive systems *allow us to cover the same distances as* combustion engines?

When it comes to travel today, it is all about flexibility and independence. A long driving range implies a high degree of independence. Breaking up a journey to fill up or charge your car puts a brake on your flexibility, too.

The range achieved by modern diesel cars is around 1000 km, yet for hydrogen-powered vehicles it is about 500 km, and for battery-powered cars, it is even less again. The main reasons for this are energy density and the technical effort involved in integrating energy storage systems into vehicles. It also explains the paradox whereby battery-powered electric vehicles with the highest drive efficiency often have the lowest range. If you compare the energy required by the various drive systems to travel a distance of 500 km, a diesel car would need 35 liters of diesel, a hydrogen-powered car would need 6 standard kgs of hydrogen, and an electric car would need roughly 90 kWh in battery charge. However, to produce 35 liters of diesel, 245 kWh of electric power is required, and to produce 6 standard kgs of hydrogen, 200 kWh of electric power is required.

Increasing energy density remains the biggest challenge

Although we can already fill up on gas, diesel and hydrogen in a matter of minutes, charging a battery-powered car usually takes quite a bit longer. To achieve roughly equivalent refill times, we would need significant electrical charging capacity. If we take our example of a battery-powered electric car a little further, in order to fill up at a charging station in 15 minutes, we would need a charging capacity of at least 360 kW. If we apply the same basic assumptions, a range of 1000 km would require roughly 180 kWh more in energy storage and 750 kW more in load capacity. If we take 150 Wh/kg as the energy density of a typical car battery system today, an equivalent battery for a range of 1000 km would weigh in at roughly 1.2 tons!

This crystallizes the main challenge we face for the future — we need to increase the energy density of batteries, from the cell level right up to the system level. This would also allow us to develop constructive alternatives in the field of vehicle architecture and create a positive impact for resource consumption during production — all prerequisites for achieving climate neutrality in the area of e-mobility. However, this does not address the issue of required charging capacity. The second challenge therefore relates to the development of our mobility infrastructure.

Germany has approximately 14,000 service stations for diesel and gas, yet only 750 charging stations with a capacity of more than 250 kW, and a mere 100 stations serving hydrogen. It is therefore clear that a car's drive system is not the only factor influencing travel speeds; the main factor is infrastructure. Today's owners of hydrogen and battery-powered electric vehicles therefore need to plan their journeys very well, and have expert knowledge of the many different apps and payment methods available. The good news is that there is already considerable investment going into building out this infrastructure.

If we assume that the ratio of rapid charging stations to overall charging stations will stay the same, Germany will have 1 million charging stations (based on federal government targets) and 18,750 rapid charging stations by 2030. If these rapid charging stations are distributed sensibly based on demand, rapid and flexible travel should become a reality, no matter what type of car you drive. ■

By 2030, we could have roughly *18,750 rapid charging stations.* *If distributed sensibly based on demand, rapid and flexible travel* should *become a reality,* no matter what type of car you drive.

Prof. Welf-Guntram Drossel, Director of the Fraunhofer Institute for Machine Tools and Forming Technology IWU

In the next issue:

When can we expect the entirety of *Germany's primary energy needs* to be met from renewable sources?

Photo: Fraunhofer IWU

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Technological sovereignty

Making industry more resilient

Coronavirus, cyberattacks, chip shortages — our vulnerabilities have recently become very clear. Fraunhofer researchers are working on the solutions.

By Tim Schröder
Photography: Stefan-Thomas Kröger

Up to now, customers have often had to "trust blindly" when buying electronics, laments Jörg Stephan from the Research Fab Microelectronics. An integrated view should result in more security — the symbols on the board stand for design, intellectual property, manufacturing, interfaces, standards, tests and analyses, delivery/supply chains and end customers.

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At the start of October, Opel had to shut down its factory in Eisenach. Its 1300 employees will likely not be called back to work until 2022. The automobile group has its reasons: "The global automobile industry is in an exceptional situation on account of the continuing pandemic and a shortage of semiconductors worldwide." Such a situation can be measured in financial loss. Business consultancy firm Alix Partners believes that car manufacturers will miss out on 178.9 billion euros in profit due to the shortage of semiconductor chips. This figure is a revision of their earlier calculations in May, when they predicted a loss of just about 94 billion euros. It is a dramatic situation — and not just for the automobile industry.

The global supply chain network is tightly knit and trimmed to the bone to ensure maximum efficiency. The example of the tiny semiconductor chips shows just how easily it can fall off course. On top of this, there are risks posed by digitalization: Companies and products are vulnerable — to attacks by hackers, manipulated chips, data leaks or production data theft, to name a few. The threat of digital attacks increases as the Internet of Things expands, and millions of control devices, sensors and cameras, both at home and in industry, become interconnected via the internet. Even the German Federal Office for Information Security admits that IT security in Germany is facing a tense situation.

The prospect of double security

Eleven Fraunhofer Institutes and two Leibniz Institutes are working together with electronics network edacentrum on the Trusted Electronics —Velektronik research project. The project, which is funded by the German Federal Ministry of Education and Research, is focused on the security of electronic components; for example, the use of intelligent sensors to prevent production data from being read as easily as it currently can be. Microchips are also indispensable to the electronics industry. The problem is that chips with integrated processors are only produced by a few large manufacturers in the USA and Asia. A variety of different companies then integrate them into modules or process them further into finished electronic components. "The customer has to blindly trust the quality and reliability of the producers," explains Jörg Stephan, coordinator of Velektronik at the Berlin business office of the Research Fab Microelectronics Germany. But the components are not always trustworthy, he says. When it comes to IT, experts make a distinction between safety and security. "Safety" means that components work reliably and can fulfill their functions by, for instance, not overheating. "Security" means that a device cannot be subject to an attack or hacked by a third party. In the past, there have been many examples of malfunctions that occurred in internationally sourced electronic components. One famous case involved Chinese-produced chips that were installed in phones and USB sticks in order to tap data. Some other components are simply substandard, and quickly become broken.

> "No individual country would be able to cover the entire supply chain, from raw materials like silicon up to the completed chip."
>
> Jörg Stephan, business office of the Research Fab Microelectronics Germany

However, the completely independent production of chips and electronic components in Europe would not be a realistic aim. "Across decades, the electronics market has developed into a gigantic, international network. No single country would be able to cover the entire supply chain, from raw materials like silicon up to the completed chip," says Stephan. This means that another methodology is required to ensure more sovereignty and security in the digital world.

Prof. Claudia Eckert and her team show how it may be done. The information scientist leads the Fraunhofer Institute for Applied and Integrated Security AISEC in Garching and is Chair of IT Security at the Technical University of Munich (TUM). "First, it is important to assess the security of software systems and understand where the possible security weaknesses and vulnerabilities are. Then, we can work to resolve these and make the software more robust," she adds. It is often too costly to redesign insecure software systems entirely from scratch so they have an appropriate level of security. "If that's the case, then we have to use additional measures to shield the weak points so they cannot be exploited by anyone." Dashcams in cars are a topical example. When an accident occurs, dashcams provide the police and insurance companies with important information about what happened. However, dashcams can be hacked as easily as other types of cameras, and their data manipulated. "Such insecure sources of data are then used in court, often in cases that involve a large amount of money," warns Eckert. That is why Eckert and her team have developed a security protocol and integrated it into the camera. It ensures that data is encrypted directly in the device, that access to the data from unreliable sources can reliably be prevented and that any attempts at launching an attack on the system are recognized and warded off, thus neutralizing the threat of an attack. This technology can be transferred to many other sensor systems in industry and the Internet of Things. ▶

"The trick is to use tamper-proof information technology to clearly demonstrate that the system is trustworthy."

Prof. Claudia Eckert, Fraunhofer AISEC

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"The challenge in our area of research is that, as technology, architectures and algorithms become more tightly intertwined, new methods of attack are always being discovered — however, we are also developing new ideas for counter-attacks."

Prof. Georg Sigl, Fraunhofer AISEC, with a system of machines for measuring the electro-magnetic radiation of embedded systems. The oscilloscope (left) captures and displays the measurements from the probe in the middle.

The information scientist is also working on completely new approaches to securely transferring, storing and processing data. This includes confidential development and production data, patient data and much more. Nowadays, all of this information is stored on servers in the cloud. "A lot of the time, the user has to blindly trust the cloud provider that stores the data. Normally, they don't know how well the data is protected, where it is processed or who exactly has access to it," adds Eckert. She is working on security solutions to put a change to this; these can be broadly referred to as "confidential computing." They involve creating monitorable areas on storage platforms where data is processed without the threat of unauthorized access. Moreover, when the system receives the user's data, it will also receive the rules for its usage and transfer. It will then monitor and ensure that these rules are complied with. Confidential computing can increase the level of trust a customer feels when they hand over their data. "The trick is to use tamper-proof information technology to clearly demonstrate that the system is trustworthy," says Eckert.

More security in split production

When a business relies on electronic components manufactured abroad, there is always a risk that somewhere along the long production line, one of the companies involved will abuse their trust. For example, it is possible to manipulate the structure of computer chips to incorporate a "Trojan horse." There is also a risk that the design of valuable chips will be copied and counterfeited. To avoid this, many businesses opt to manufacture chips across dozens of production steps; the chip is partially built by multiple different companies, with the result that nobody knows the complete design. This strategy is called split manufacturing.

This level of protection is particularly relevant for security-related components used for medical devices or banks, for example. The use of tamper-proof casing on electronic components could prevent them from being manipulated over the course of a long assembly process. Georg Sigl knows exactly how it's done. Like Eckert, Sigl is Professor of Security in Information Technology at TUM and is part of the leadership team at Fraunhofer AISEC. One of his specialties is PUFs: Physical, Unclonable Functions. This involves using the physical characteristics on the exterior of the electronic component to make the component tamper proof. Among other things, Fraunhofer AISEC has developed a protective film that encases security-related electronic components. "The film contains a double layer of fine wires," Sigl explains. "In between are small capacitors with a measurable capacity." This capacity is measured during the production process as a characteristic feature of the component and stored inside it as a security key." Later, when the device is switched on, the capacity of the film is immediately measured. The key that enables the device to decrypt the software and begin boot-up will then be derived from this. If an attacker has damaged or replaced the film during production in order to manipulate the inside of the component, the key will no longer work.

> "This allows us to adjust the chips easily, and implement various security functions for data encryption."
>
> Carsten Rolfes, Head of the "Trusted Electronics" program at Fraunhofer IMS

Sigl's first exposure to information security was in the 1990s. "For me, there was a secret, unknown element to it," he explains. "The challenge in our area of research is that, as technology, architectures and algorithms become more tightly intertwined, new methods of attack are always being discovered — however, we are also developing new ideas for counter-attacks." Ultimately, businesses and researchers are not only concerned with safety and security, but also with sovereignty over their own data and the maintenance of production. To this end, several Fraunhofer Institutes have been working on a new technology for several years: the RISC-V instruction set architecture, which defines the "brain" of the microcontroller as a computer unit. Today, the functionality of microcontrollers worldwide is largely based on one procedure, namely the instruction set architecture of the company ARM. You have to pay a license fee to use it. Imagine if an architect could choose different components from a construction kit, from the foundation, to the roof, to the interior fittings. This enables them to build a variety of houses — but the "kit" itself comes from ARM. The individual elements cannot be modified, which limits the freedom of developers.

On top of this, there are license fees to consider. That is why ten years ago, information technicians from the University of California developed an alternative that is available for free worldwide: RISC-V. "With RISC-V, we can adjust the chips easily and implement various security functions for data encryption, in particular post-quantum cryptography," explains Carsten Rolfes, program manager for "Trusted Electronics" at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS. The underlying concern is that current encryption procedures could be subverted by super-fast quantum computers ▶

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"The system is tailored directly to the container. In essence, the container itself is the 3D printer."

Markus Heilemann, Fraunhofer IAPT

in the future. Post-quantum cryptography should allow us to fight back. Processors and microcontrollers with an appropriate level of security could be manufactured with the help of RISC-V; these could then be used in medical devices, for example, and produced entirely in Germany and Europe. If global supply chains come to a standstill — as was recently the case during the pandemic — then 3D printers could be a lifeline for restoring production, at least for important components.

Up to 70 percent faster production

In the last few years, a 3D printing process has been developed at the Fraunhofer Institute for Machine Tools and Forming Technology IWU that resolves a significant disadvantage of the technology: It is considerably faster than conventional processes, which means it can enable flexible production in times of crisis. Researchers at Fraunhofer UWU had the idea to combine a plastic injection unit with 3D printing, which speeds up the process considerably. The system was equipped with a movable table that quickly moves back and forth beneath the nozzle, which ensures that the liquid plastic is assembled into a 3D component at high speed. This concept, called SEAM, has already been used by a number of manufacturers. "With this method, we can produce a strand of material about one meter long every second," says developer Christopher Schlegel. All in all, it reduces production time by up to 70 percent compared to conventional systems.

SEAM technology is especially suited to large, plastic components up to ten meters long. Large structures for vehicles and trains, for example, can be produced quickly and cheaply using this method. The same applies to tools and clamping mechanisms for the production of plastic components. Fraunhofer IWU is cooperating with numerous industry partners involved in automobile and machine construction. The system is so small that it can be packed into a container and brought to the application site in case of an emergency. Once on site, it will be able to produce plastic parts as required.

Markus Heilemann from the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT is working on these 3D printing containers together with his team. "The system is tailored directly to the container. In essence, the container itself is the 3D printer," he explains. Fraunhofer IAPT experts are deploying a variety of printing technologies, including plastic printing, printing with metal powder and printing with metal wires. Systems that produce materials by welding together different horizontal layers are of particular interest, as they can be used to repair components in emergencies. The goal of the developers was to design containers that, once fully manufactured and calibrated, would work as simply as pushing a button. "In the future, such containers could produce replacement parts for engines or turbines in factories, oil rigs and poorly developed regions," says Heilemann. This could help avoid production losses, which often run up to millions of euros. The technology has also proved its capabilities. Last year, there was a crisis when the supply of respiratory masks fell short. The team at Fraunhofer IAPT abruptly switched to producing plastic adapter units. "These enabled us to connect simple diving masks used by hobby snorkelers up to ventilators," says Heilemann. The container used for the production of medical technology components has been named "MobiMed."

> "This allows us to produce a strand of material about one meter long every second."
>
> Christopher Schlegel, developer at Fraunhofer IWU

More independence with raw materials

The Fraunhofer Innovation Program "Resilient Value Creation Systems (RESYST)" shares the goal of providing for emergencies so production can continue. A secure supply of raw materials is high on their agenda. Germany has relatively few raw materials, which means that the future will be about ensuring that recycling is as complete and high-quality as possible. The new "reProd" approach shows how this could work for metallic substances. The abbreviation stands for "resource-independent production based on secondary products." Rather than shredding scrap metal and smelting it down in an energy-intensive process, it aims to recycle secondhand components into secondary products and transform them directly into new components — for example, high-strength screws from drive shafts. Other possibilities for the secondary products are sheet metal, boards and tubes. "We want to recycle the material in a way that ensures the highest possible level of value creation," says Markus Werner from Fraunhofer IWU. But the reProd application still has a way to go. First of all, waste flows in Germany have to be digitalized for it to reach its full potential. What secondary products are available? Where? In what volumes? And what is the quality like? All of this will be captured by digital twins to make production more independent in the future. ■

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Math for any emergency

Global supply chains are complex networks, making them particularly vulnerable. Fraunhofer experts now offer solutions that make these intricately woven networks more stable.

By Franziska Sell

From earthquakes in South America to floods in Germany and political upheaval in Asia, Dr. Heiner Ackermann and his team use the same methods to manage supply chain risks. The scientists develop mathematical methods that can be used to calculate how supply chain risks can be reduced to a minimum. "Mathematically speaking," explains the deputy Head of the "Optimization — Operations Research" department at the Fraunhofer Institute for Industrial Mathematics ITWM, "these disruptive events create a complex multi-dimensional decision problem."

Specialists analyze the features of supply chains with the help of mathematical models. The simulation of failure scenarios based on these models makes it possible to identify the points with a greater need for action. The researchers' second step is to comprehensively optimize for a more robust supply chain that can reduce risks with little effort. "We put all variables into a multi-criteria optimization problem. This allows us to determine the best possible solution for balancing out the three parameters of resilience, cost and risk". Algorithms calculate the perfect balance and take the various options for raw materials, suppliers and inventories into account, including the use of alternative materials. Top priority: Make as few assumptions as possible. "We have already been able to use this to spark very beneficial discussions among entrepreneurs who had previously relied on Excel spreadsheets and their instinct," says the expert — and he adds: "Whether supply chain or supply networks, mathematics is a universal and very effective tool."

How to anticipate supply bottlenecks well in advance

The Fraunhofer Institute for Material Flow and Logistics IML offers highly effective support for checking and optimizing supply chains with its Order-To-Delivery-NETwork simulator. The tool consistently evaluates planning and material flow processes from order through to delivery. "OTD-NET fully models even highly complex supply chains on multiple levels, including the planning and information flow processes. It is possible to model cross-company and detailed cooperation on the computer using a variety of parameters," specifies Marco Motta, Head of Supply Chain Engineering at Fraunhofer IML.

The tool particularly examines networks regarding customer promises such as on-time delivery, quality, costs and ecological aspects, and also evaluates alternative scenarios with regard to resilience. "I can easily use the simulation to play with demand peaks, the collapse of a market, or scenarios that disrupt production," explains the Fraunhofer IML expert. This also makes it possible to anticipate how a supply chain will react when faced with exceptional circumstances.

Dispatchers are able to use logistics assistance systems, which combine a digital twin of the supply chain with simulation, to see which cargo ships have loaded which parts, where they are located and precisely when the cargo will be available where it is needed. This allows planners to display and examine supplies for the next 20 to 30 weeks across global networks. It also means that potential bottlenecks can be detected early on.

Tracking and tracing is a unique selling point in demand and capacity management. Planners do not only receive the number of an affected part, but can also directly see the effects on the entire production. This "forward as well as backward" from product to part has helped a German premium manufacturer in the automotive industry to significantly streamline its program planning process. By using this method, the company can look almost two

Preventing container downtime is what the Fraunhofer experts are aiming for.

> "We have already had very beneficial discussions among entrepreneurs who had previously relied on Excel spreadsheets and their instinct."
>
> Dr. Heiner Ackermann, Fraunhofer ITWM

years into the future in order to proactively configure its supply chain.

However, the automotive industry was not alone in suffering from supply bottlenecks. Medical supplies were also particularly affected. Saskia Sardesai, Senior Scientist at Fraunhofer IML, manages various research projects that use OTD-NET to increase resilience in medical product value creation networks. "Small and medium-sized companies in particular started tackling this problem with existing spreadsheet tools. But these can't be used to identify dynamics." This is where OTD-NET comes in. The dynamic simulation shows over a long period of time whether all parts are in the right place at the right time. "If all parts are available apart from the one from my transatlantic supplier and there is no delivery alternative within Europe, I would soon have a break of over a month in my chain," the specialist explains.

Using air freight as a fast remedy — a bit like a drug

Many companies are now turning to air freight, a tried and tested short-term solution that ultimately proves problematic in the long term. The expert compares it to a drug: It's fast-acting, addictive and hard to withdraw from. Saskia Sardesai: "You've eliminated the short-term bottleneck, but the reduction in pipeline filling happens with a few weeks' delay and you're suddenly tempted to revert to using the plane. The key is to pick the right moment to revert to sea freight — and our simulation depicts that very well."

In the Co-Versatile European research project, which Sardesai is overseeing, everyone is doing everything they can to strengthen the resilience of the European manufacturing industry against future pandemics. The aim is for the supply chain to be able to respond quickly and effectively to a sudden increase in demand in the area of strategic medical products. To achieve this, Fraunhofer IML experts developed a simulation model that considers demand peaks and fluctuations as well as supplier risks. Companies can immediately get an idea of what kind of effects they might face. "We have provided very simple models in order to facilitate quick feedback and application for a large number of companies," explains the project manager. There is a particular focus on capacities, lead times, transport frequencies and possible delivery restrictions. Users are able to see the interaction between the individual factors — providing an invaluable advantage over the old-fashioned Excel solution.

In another research project called ResKriVer, the Fraunhofer team is combining its simulation tool with artificial intelligence (AI). They evaluate crisis situations and different scenarios for more resilience in supply chains. Saskia Sardesai describes this using a recent example: "Consider the flooding in Hagen, which affected many businesses. The flooding gets reported on the platform. As a business, I am able to check: Are there suppliers in this area that are part of my supply chain and will I be missing parts in the future? Next, simulation comes into the picture, paired with AI algorithms: We are looking at what parameters can be changed by AI. The strength of the parameter adjustment will be determined using the AI. This will result in a range of what-if scenarios that will be tested in an automated process. The alternatives are then evaluated, fed back to the AI, and a decision is made on which one should be implemented. Again, it's important that the simulation always takes the dynamic context into account."

Head of department Motta is confident: Tools like this can be used to achieve resilience through transparency about the action mechanisms — while maintaining the same level of efficiency." ■

Photo: Raymond Forbes/Stocksy/F1online

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Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

POLAND

Printing high-tech teeth and smart hip joints

A German-Polish Fraunhofer-Gesellschaft high-performance center is researching new technologies for using 3D printing processes — also known as additive manufacturing — in medical engineering.

In the future, patients will benefit from individually customizable products and treatment options. By combining innovative materials, the researchers aim to achieve new levels of visual appeal and complexity in the production of dentures, for example. Or, when manufacturing knee and hip joints using additive processes, scientists will be able to integrate sensors that detect inflammation by reacting to higher temperatures or altered biomarkers. Another research area again is focused on 3D printing fiber-reinforced structures, e.g. for cranial implants.

In the Additive Technologies for Medicine and Health (ATeM) High-Performance Center, the Fraunhofer Institute for Material and Beam Technology IWS in Dresden and the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz have joined forces with the Faculty of Mechanical Engineering and the Center for Advanced Manufacturing Technologies (CAMT) at Wroclaw University of Science and Technology.

These hip implants are manufactured using additive processes and will be equipped with warning sensors.

Previously, carpets were not suitable for conventional recycling.

GREAT BRITAIN

Polypropylene: Making new from old

The EU alone throws out 1.6 million tons of carpets every year. Their primary constituent is petroleum-based polypropylene. The carpet materials are tightly woven together, meaning they cannot be recycled as yet. At present, waste carpets are burned or dumped in landfill in the majority of cases.

The EU project ISOPREP, led by the British research organization TWI, has succeeded in developing a solvent that can be used to recover the plastic polypropylene at a very high quality level. With 1 ton costing 12,000 euros, the Fraunhofer Institute for Building Physics IBP is now working on a recycling process that preserves this expensive ionic liquid as much as possible. If loss rates can be kept to 1 percent or less, the process will have the potential to rival the production of new polypropylene in terms of cost and the environmental impact.

The new process can separate the plastic not only from other materials, but also from additives such as colorants. The researchers believe the new process can also be applied to other polypropylene waste streams.

The upper stage is prepared for transport at the Ariane 6 tank center in Bremen.

FRANCE

Lift-off at lower prices

In 2022, Europe's newly developed Ariane 6 launcher will transport navigation and weather satellites into space. To remain competitive in the future, manufacturing costs must be reduced and production processes must be optimized. This is what the Fraunhofer Institute for Production Technology IPT in Aachen is working on, together with the Ariane Group, a joint venture between Airbus and its French partner Safran. The aim is to monitor and improve the processes for manufacturing the upper stage of the launcher by using sensors and self-learning systems. Fraunhofer IPT is largely responsible for data analysis and implementing AI algorithms.

The name speaks for itself: Medstraum means "with electricity" in Norwegian. This catamaran is being developed as part of the EU project TrAM.

NORWAY

High-speed ferries: Pushing the boat out for environment and climate alike

In spring 2022, the fully electric high-speed ferry "Medstraum" is set to commence operations in Norway. 31 meters long and 9 meters wide, the catamaran will carry up to 150 passengers from the city of Stavanger to the surrounding islands, making it the first emission-free ferry of its kind worldwide. Pollutant-free shipping is also a product of research conducted by the Fraunhofer Institute for Mechatronic Systems Design IEM, which correlates and analyzes the requirements of different ferry types. Not only can this kind of system model be used flexibly, but it also reduces development time by 70 percent and manufacturing costs by 25 percent. This holistic methodology is based on systems engineering and helps shipbuilders develop electric ferries on a modular basis, manufacture them efficiently and adapt them to customer requirements.

This lays the foundation for a whole series of environmentally friendly high-speed ferries — a market with definite future potential, with sales of fully electric and hybrid ships set to increase worldwide according to a forecast by British market research company IDTechEx. In 2027, the sales figure is predicted to reach up to 20 billion dollars.

AFRICA

Award recognizes drinking water technology

South of the Sahara, 40 percent of the population have no access to clean water — that's more than 100 million people. Coordinated by the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig, the SafeWaterAfrica project is using two demonstration plants to generate 20,000 liters of drinking water per day from river water in South Africa and Mozambique. The purification process is based on Fraunhofer IST disinfection technology, which eliminates germs with particular energy efficiency and and integrates additional technologies from Europe and South Africa. Most of the project partners are based in Africa, with local companies carrying out the design, construction and operation of the plants. The system has now progressed to a point where it can be used in other countries.

In recognition of its success, SafeWaterAfrica has now been awarded the Solar Impulse Efficient Solution Label. The Swiss Solar Impulse Foundation rewards efficient technology solutions that combat climate change in a sustainable and cost-effective way.

New disinfection technology guarantees clean drinking water aplenty.

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Art made from plastic waste collected on beaches all over the world.

Invisible and inescapable

Plastic is polluting the oceans. It does break down to microplastic over time, but that doesn't mean it disappears from the environment. Researchers at Fraunhofer IKTS are exploring how this microplastic impacts the natural world and how we can clean it up.

By Dr. Monika Offenberger

Every year, rivers, wind and sewage carry millions of tons of plastic into the oceans, resulting in the deaths of tens of thousands of animals. Seabirds and turtles end their lives in torment when they get tangled in bags or strangled by scraps of rope; fish and seals mistake bits of plastic for food and starve to death. Even when the waste is broken down into minuscule pieces, it lives on as microplastic in the material cycles of the oceans and all the Earth's other biospheres. "That's why we consider plastic pollution to be an existential threat; it's stretching the planet to its ecological limits and endangering the basis of our human existence," emphasizes Dr. Annegret Potthoff. Her team at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden is participating in MICRO-FATE, a research project investigating where microplastic goes and what impact it has, with a view to developing recommendations for handling plastics in the future.

The project kicked off with a five-week expedition in the research ship SONNE in summer 2019. The vessel carried scientists from six research institutions from Germany and Sweden. "It was a 24-hour job for us all, starting on May 30 and lasting until July 5," remembers environmental process engineer Markus Schneider who represented Fraunhofer IKTS on the voyage. The ship left Vancouver and sailed across the North Pacific to Singapore. On the way, it passed the largest island of waste in the world, the Great Pacific Garbage Patch. The patch consists of 80,000 tons of plastic strewn across an area three times the size of France. But that's not the only place: "We saw plastic waste and other rubbish all around us at sea," says Schneider.

Photos: Kari Prestgaard and Astor Andersen

Determining the origins and condition of this flotsam and jetsam is one of the many tasks the MICRO-FATE project aims to complete, under the leadership of Dr. Annika Jahnke of the Helmholtz Centre for Environmental Research in Leipzig. In particular, they are eager to find objects that can unambiguously be identified as particular products; then the objects can be compared with undamaged source materials, thus allowing researchers to draw conclusions about the decomposition process.

Although plastic is lighter than water, not all plastic waste floats on the surface, because over time, the material becomes brittle and breaks down into ever smaller pieces. Once the particles are smaller than 5 millimeters in size, they are considered to be microplastic. "We believe that a large portion of the material sinks and is deposited in the sediment as microplastic," says Dr. Potthoff. That's why the crew of the SONNE also kept a lookout for underwater plastic during their journey across the Pacific. Special bottles for collecting water and ocean floor samples were lowered to the bottom using a winch, reaching a deepest measuring point of 5700 meters. "Everyone had to pitch in when collecting the samples," recounts Schneider. His actual task was something else entirely: an experiment that simulated the decomposition of plastic under the most realistic conditions possible. To do this, he let fresh Pacific water run constantly through two stainless steel containers with a holding capacity of 800 liters each. The idea was to create something close to two mini-oceans, known as mesocosms. One of the containers was closed so as to block out the sun and its aggressive UV radiation, while the other was left open.

> "That's why we consider plastic pollution to be an existential threat; it's stretching the planet to its ecological limits."
>
> Dr. Annegret Potthoff

Four different types of plastic — pellets in the form of 5 cm beads and 10 x 10 cm pieces — were immersed in each of the mesocosms and taken back out again after hours, days or weeks. "We are interested in how these materials behave with and without the influence of UV rays," explains Schneider. "How exactly do they decompose? Does their density change? What happens to their surfaces? Do they become corroded? What is deposited on them?"

As these questions couldn't be answered on the ship, the materials from the mesocosms were preserved and brought from Singapore to Fraunhofer IKTS in Dresden, just like the sea water samples. There, the team has used a wide range of techniques to investigate the decomposition processes. In what turned out to be a decisive step, the researchers discovered that having started out as water-repellent, the surfaces became noticeably hydrophilic. "We can prove that by measuring the angles of contact," Dr. Potthoff explains. "The more strongly the surface repels a drop of water, the steeper the angle between the two will be. The more the drop clings to the surface, the flatter the angle. And we have seen that the longer the plastic stays in sea water, the flatter this angle becomes." ▶

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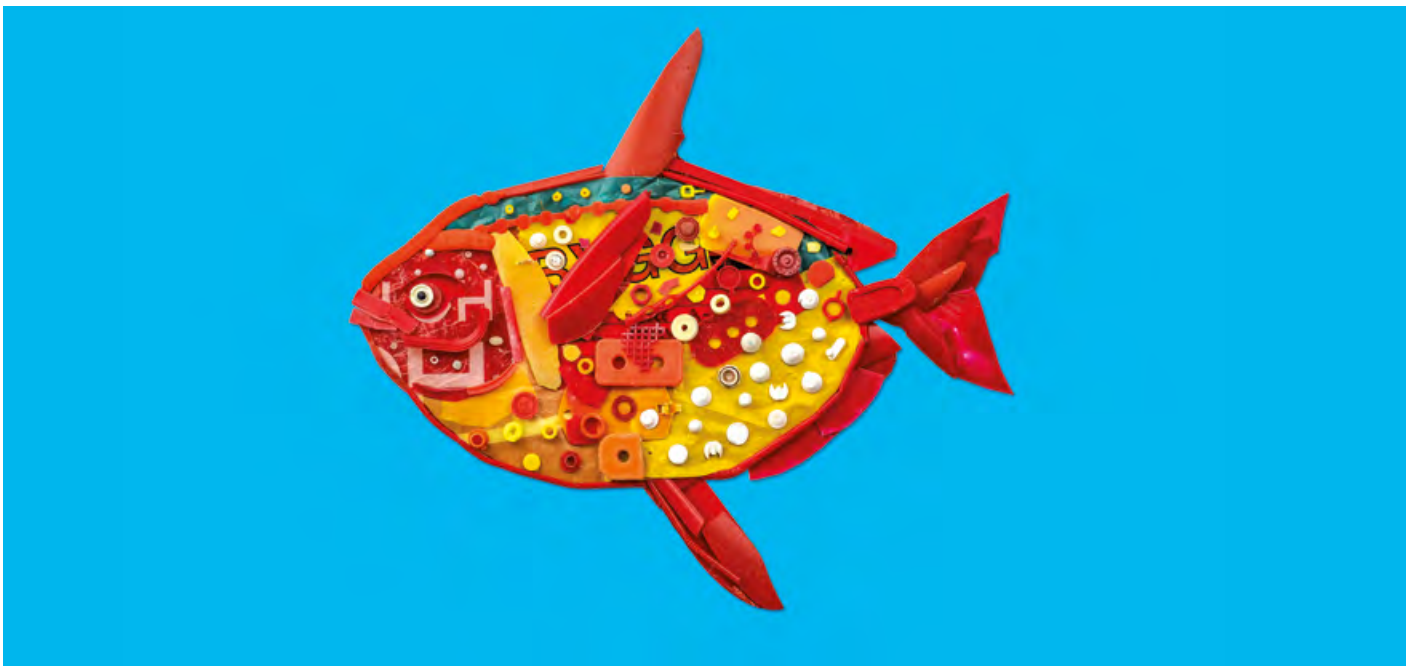

Organic substances dissolved in the sea water act as the trigger for these changes. They stick to the plastic's surface, and it's possible to prove that within hours, they have formed a fine layer on it, known as an ecocorona in scientific terms. "We don't know what this ecocorona consists of exactly, because it's so thin that even with the most delicate methods, we can't detect any individual substances," observes Dr. Potthoff. However, she does affirm that it definitely does lay the ground for bacteria and other microbes. She also explains that these then form a biofilm that makes the plastic heavier and causes it to sink. "This biofilm protects the plastic from UV light and curbs the fragmentation process the UV rays had started. On the other hand, the film itself does contribute to decomposition, because bacteria and fungi release corrosive acids that cause the plastic to break down at an accelerated pace."

Ecocoronae and biofilms only form in natural sea water. This biological factor is automatically excluded from experiments that use artificially manufactured sea water. "That's why it's so important for us to have learned what happens in reality thanks to the mesocosms — and to be able to compare that with our observations from the lab. It showed us that decomposition happens much more quickly in laboratories than in the ocean, because in our labs, we make the sun shine 24 hours a day, without the UV protection offered by the biofilm. But at a basic level, the decomposition process happens in a similar way. That puts us a good bit closer to achieving our objective of finding out what happens to plastic in the oceans," the scientist concludes.

But many questions remain unanswered. For example, what happens to all the substances that are added to plastic products as softeners, heat stabilizers or light protection agents? "I think these additives are very important, as they affect the way the plastics break down. They get washed out in the process, and end up in our ecosystems' material cycles themselves," emphasizes Dr. Potthoff. The chemist indicates that investigating these relationships is another important objective of the MICRO-FATE project. "Only when we understand plastic's decomposition process in all its complexity will we be able to estimate how critical the disruption of the ecological balance is at this point — and how we can take countermeasures to reduce the impact on a global scale." ■

Since 2010, the Norwegian artistic duo, Kari Prestgaard and Astor Andersen, have been working with plastic waste they collect on beaches all over the world. They use it to create fish and birds in workshops with children. "We use art as a teaching technique to raise awareness about plastic pollution in the oceans," says Prestgaard. They then photograph the artworks, edit the images and put them on sale in an exhibition. They donate all their profits to charity.

With its crystal-clear water, the Kreuzpullach catchment basin was built between 1933 and 1936 to supply the city of Munich with drinking water.

All at once

Pharmaceutical residues pass through wastewater treatment plants unhindered and then spread into the environment via lakes, rivers and groundwater. Intercepting them early on is a great challenge, particularly as the chemicals are very diverse and have to be completely broken down.

By Christine Broll

Photo: Lena Engel

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Hans-Jürgen Friedrich always manages to find a suitable solution when it comes to purifying heavily polluted wastewater. The graduate chemist at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden has successfully extracted heavy metals from mine wastewater, and cleaned industrial wastewater from plastics and pesticide production. Hans-Jürgen Friedrich is confident that "we can use electrochemical wastewater treatment to remove all kinds of pollutants from wastewater."

His latest development focuses on the removal of pharmaceutical residues. The process he designed combines electrolysis with ultrasound treatment to increase throughput. "This technology has the potential to clean wastewater from healthcare clinics and other medical care facilities right on site," and he adds: "It can even be used as a fourth treatment stage in wastewater treatment plants in the long term."

Absence of legal limits for pharmaceutical residues

There are currently more than 2,500 different active medical ingredients on the market in Germany. Germans consume more than 30,000 metric tons of pharmaceuticals each year. Many of these are excreted after ingestion and end up in wastewater. As most of the active ingredients do not get broken down in wastewater treatment plants, they find their way into rivers and groundwater. There are currently no legal limits regarding the concentration of pharmaceutical residues in wastewater treatment plant outflows, and therefore there is no pressure on wastewater treatment plants to remove the residues.

To date, the environmental pollution caused by pharmaceuticals has not been monitored on a nationwide scale. The only data available comes from research projects and measurement programs conducted by state authorities. A summary from the Federal Environment Agency reveals that at least 269 different active pharmaceutical ingredients and their waste products have been detected in rivers, streams and lakes in Germany. In most cases the concentrations range from 0.1 to 1 micrograms per liter. There is a huge spectrum of active ingredients. The highest concentrations have been identified in painkillers, diuretic drugs, antidiabetics and iodinated X-ray contrast dyes. Antibiotics, antiepileptics, beta-blockers and contraceptive hormonal agents are also frequently found.

The bioactive substances have an effect on other organisms, just as they do in humans. One example is 17-alpha-ethinylestradiol, the active ingredient in the contraceptive pill. Even in extremely low concentrations, it negatively affects the reproductive ability of male fish. In extreme cases, the males become female and produce eggs in their testicles. Many animals suffer kidney damage from the painkiller diclofenac, of which around 85 metric tons are consumed in Germany each year. Multi-resistant germs also pose a great threat, and they are being increasingly identified in wastewater treatment plant outflows. This is due to the widespread use of antibiotics, which are not sufficiently filtered out in wastewater treatment plants.

A fourth treatment step is a simple solution

Eliminating pharmaceutical residues in wastewater treatment plants requires an additional fourth treatment stage in addition to mechanical, biological and chemical treatment. Two processes are currently being tested and some plants are already implementing them: ozonation and activated carbon filters. Both have their drawbacks. "Ozonation produces some reactive intermediates that haven't been toxicologically characterized," stresses Hans-Jürgen Friedrich. "Whilst activated carbon filters can't capture all active pharmaceutical ingredients."

Hans-Jürgen Friedrich is able to overcome both disadvantages using his solution of electrochemical purification. This captures and destroys all organic sub-

Detecting drugs in wastewater

The largest European wastewater analysis project has investigated drug use in 73 cities in 20 European countries. Wastewater samples were analyzed for both drugs themselves and their main break-down products. The results obtained in 2020 clearly show that cocaine is preferred in western and southern Germany, while crystal meth is used more in the east.

Hamburg
Cocaine
459
Crystal meth 8

Dresden
Cocaine 42
Crystal meth
201

Data in milligrams per 1000 persons per day (mg/1000p/day)

stances in the electrolysis cell. Only CO_2, oxygen and small amounts of hydrogen remain.

The Fraunhofer IKTS team in Mecklenburg-West Pomerania has demonstrated that this method can also be used to purify large quantities of water. Here, a deep well was shut down for drinking water production because the limit value for the weed killer bentazone had been exceeded. As part of a pilot project, scientists installed a system for total electrochemical oxidation. It allows modular arrangement of the electrolysis cells so that the size of the system can be easily adapted to the amount of water to be processed. "We were able to completely eliminate the bentazone. The overall cost came to about 50 cents per cubic meter," Friedrich recounts.

The purification is more economical thanks to the combination of both electrochemistry and ultrasound. Ultrasound has long been known to destroy molecules. Processes already exist in which an ultrasound generator is incorporated into the electrolysis chamber. Hans-Jürgen Friedrich has gone one step further. He and his team have integrated the ultrasound source directly into the electrode of the electrolysis cell. This allowed him to accelerate the breakdown of the trace substances by a factor of four and thus increase the throughput, all with only a modest increase in the energy required.

Friedrich estimates that operating such a large-scale plant would cost around 30 cents per cubic meter of wastewater. By the time the government adopts the long overdue limits for trace substance levels and wastewater treatment plant operators start looking for a suitable solution, the technology will be in place. ■

Munich
Cocaine
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Crystal meth 9

Chemnitz
Cocaine 27
Crystal meth
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How can antibiotics, beta-blockers or hormonal agents be removed from wastewater? An interview with Hans-Jürgen Friedrich from Fraunhofer IKTS:

Click here for the podcast

Front-runner in Europe

Cocaine
1175
Antwerp, Belgium

Crystal meth
703
Ostrava, Czech Republic

Photos: AdobeStock (2), iStock, pixabay, Malte Jäger/Berliner Wasserbetriebe; Source: European Monitoring Centre for Drugs and Drug Addiction

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Sandra Ciesek

- Born in 1978 in Goslar.
- Head of the Institute of Medical Virology at Frankfurt University Hospital since 2019.
- Named Professor of the Year 2021 alongside Christian Drosten for their NDR podcast “Corona Update”.
- On the quest for a drug to treat coronavirus in conjunction with Fraunhofer ITMP.
- Married, mother of one daughter.

The woman who clarifies the coronavirus

She was one of the first people in Germany to see the novel virus under an electron microscope. Sandra Ciesek, Head of the Institute of Medical Virology at Frankfurt University, has been on the search for a drug to treat SARS-CoV-2 ever since an aircraft first carried the pathogen into the city.

By Beate Strobel

The woman sitting across from me is Germany's Professor of the Year 2021, an accolade bestowed by the German Association of University Professors and Lecturers. She received the honor for her podcast "Coronavirus Update" on German radio station NDR where she shares hosting duties with virologist Christian Drosten to explain the pandemic to the people of Germany.

She is sitting on the third floor of the virological institute at Frankfurt University Hospital, explaining things in her distinctly calm manner; just as she did in times of upheaval. Professor Sandra Ciesek reports on the latest developments of the virus we know as SARS-CoV-2. The 43-year-old's reports also cover why there are sometimes no new developments. "It became clear early on that the coronavirus carries so-called spike proteins in their envelope, and that a vaccine would have to induce the production of the appropriate antibodies. Once we had that information, the technical aspects of developing a vaccine became relatively simple. On the other hand," she continues, "it will take much longer to develop a drug to treat coronavirus." "A lot of substances look promising when applied to cell cultures, but fall through when it comes to animals or humans. The fail rate is immense. If one substance out of one thousand reaches market maturity, then that's actually a very good result." The process is like finding a needle in a haystack — as is often the case in research.

Prof. Ciesek is a physician and has qualified as a professor. She serves as Director of the Institute of Medical Virology at Frankfurt University Hospital and numbers among the leading coronavirus researchers in Germany. When the first evacuation flight from Wuhan carried 126 passengers home to Frankfurt at the beginning of February, Ciesek and her team were on standby at the airport to test all arrivals for the new SARS virus. None of those who suspected they were sick carried the virus. However, two entirely asymptomatic people tested positive for SARS-CoV-2. "That's when it became clear to us that this virus could grow into a much bigger problem," Prof. Ciesek recalls.

Using the samples taken from swabs given to the arrivals from Wuhan, Prof. Ciesek's team was able to cultivate the virus for the first time in an intestinal cell line. They were then able to observe their new opponent under an electron microscope. Soon, they discovered the extent to which SARS-CoV-2 alters the host cell. Many other viruses stop the production of protein in their host cell so they can produce their own, viral protein; however, the new coronavirus pathogens actually increase the original protein synthesis. Was this a gateway to a possible drug treatment? Prof. Ciesek's research team in Frankfurt was indeed able to successfully stop virus proliferation in a cell culture by inhibiting the production of protein within the cells. Media headlines from May 2020 optimistically read: "COVID-19: A breakthrough in treatment."

We have the vaccine. When will we have the cure?

Over a year later, a variety of coronavirus vaccines are in use. But the world is still waiting for a convincing drug to treat the diverse range of symptoms we call COVID-19.

On account of the multi-level process for approving new drugs, a possible shortcut would ▶

Developing a vaccine? "Relatively simple, technically speaking."

Developing a drug? "That will take much longer."

Photo: Tim Wegner/laif

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be to use a drug that has already received approval and has also been proven to be successful in combating SARS-CoV-2. This process is referred to as drug repurposing. Prof. Ciesek undertook the search for just such a positive side-effect in collaboration with the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP. Together, the partners are working through the "repurposing library" at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Hamburg, where more than 6000 substances are stored. They are testing the substances against cells that are infected with SARS-CoV-2 from Prof. Ciesek's safety labs. Some substances have made it from the screening stage to preclinical trials. However, Prof. Ciesek offers a sobering counterpoint: "So far, none of the substances have been convincing."

Several Fraunhofer Institutes are working on new strategies

As the vaccination campaign in Germany stalls and the incidence rates begin to climb again, there is a growing desire for drugs to treat COVID-19. The search for new therapeutic treatments — substances that intercept the virus early on in the upper respiratory tract or prevent their entry into somatic cells, or that halt the multiplication of the virus in the cells — is keeping pace accordingly. Alternatively, there is still the option of strengthening the body's own immune defense system with drugs so that it can deal with the intrusion of the coronavirus on its own terms. Currently, two substances have been approved within the EU: the antiviral drug remdesivir and the immunosuppressant dexamethasone. However, neither have shown completely convincing results in practice. Three more substances are currently in the process of receiving approval. As part of the BEAT-COVID project coordinated by the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM, a number of Fraunhofer Institutes are working on innovative strategies for treating both SARS-CoV-2 and future pathogens that are as yet unknown.

Wouldn't it be great if in addition to a vaccine, Germany also produced a cure for COVID-19? It is, after all, the country once celebrated as the pharmacy of the world.

But Prof. Ciesek has her doubts. She says that during the pandemic, it was clear that Germany thwarted its own efforts with a litany of laws and guidelines. For example, the German Act on Dis-

"I have never worked as much as I have since the beginning of the pandemic," says Sandra Ciesek, 43, mother of one daughter.

pensing Medicinal Products (Medizinprodukte-Abgabeverordnung — MPAV) almost prevented rapid COVID tests from taking place outside the presence of professionals; or the stipulation that tenders for major research acquisitions must always extend across Europe. "Certain bureaucratic structures do not function well during a pandemic. A lot of things must be done differently," asserts the professor from Frankfurt.

Almost two years of research into SARS-CoV-2 has resulted in many, many hours of overtime for Prof. Ciesek and her colleagues at the institute. "I have never worked so much as I have since the outbreak of the pandemic," says the mother to one daughter. But that's just part of the job for the woman who took on the task of explaining the coronavirus to Germany. Because of the coronavirus, virologists from across the country are in high demand for interviews; they have become a new kind of celebrity. Prof. Ciesek tries to shy away from the limelight. "I was never really eager to be a public figure," she assures us. The physician grants interviews in homeopathic doses; and in contrast to other representatives of her field, she never appears on talk shows. "The format doesn't suit me," she says, "too many sound bites, and not enough time to explain — not to mention all the self-promotion."

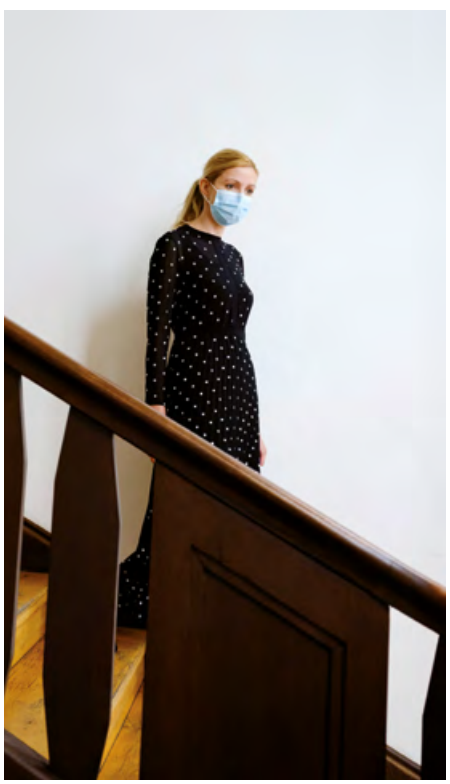
Prof. Ciesek is not the type to make quips or get into the headlines with bold assertions. She considers her job as Institute Director to be "not very sensational." At the end of the day, she says, she spends most of her time leading operations from the desk in her office. She ties back her long, blond hair into a low ponytail, and keeps her words and emotions under similarly tight control. For example, she was adamant that her 2020 study on the risk of infection in daycare centers would not be misinterpreted as a prompt for politicians to leave them open. "I am a scientist. Political consequences are up to politicians."

"I am irritated by how aggressive some people are."

However, with "Corona Update," the NDR podcast that she co-hosts with Berlin expert virologist Christian Drosten, Prof. Ciesek sees the chance to inform people in relative detail about the daily work undertaken by scientists the world over since the start of the pandemic — spreading science. "For me, the deciding factor in accepting the job was my ability to speak as someone who both works directly with the virus and represents expert opinion — being, as I am, a board member for the German Society for Virology. That meant I wasn't just offering an individual opinion and creating false equivalences between arguments. No drivel."

Nevertheless, following research developments in (almost) real-time is not for impatient people — nor for anyone who looks to experts to provide clear answers wrapped in a bow. "People with a scientific background understand that uncertainties and inconsistencies are the life force of research; but other people aren't always the same." This is something that Prof. Ciesek has learned during the two years of the pandemic. Does she despair about the contrarians and anti-vaxxers? "I don't despair," she replies gently. "At most, I am irritated by how aggressive some people are." She says we must accept that a portion of people will think differently. "All we can do is clarify things honestly — including when the science is uncertain. We can't do anything more than that." ■

She wears a face mask. But in her role as a podcaster, her message comes through loud and clear. That is why she was named Professor of the Year 2021.



"I represent specialist opinion as a board member of the German Society for Virology — no false equivalence. No drivel."

Prof. Sandra Ciesek

Photos: Katrin Binner/laif

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Series: **Founding companies with Fraunhofer**

Bright prospects

Creating one from the other — the new simple process for manufacturing wafers for photovoltaic systems. The Fraunhofer spin-off NexWafe has succeeded in making wafer production significantly cheaper, more effective and more environmentally friendly — and thus in rapidly advancing the energy transition.

By Marina Babl

The heart of NexWafe production: the epitaxy facility.

Things looked pretty gloomy for the solar industry in Europe for a while. High production costs, a lack of innovative spirit and an overly generous exchange of information on processing methods meant that knowledge and capital seemed to be drifting towards China. It was at this time, around six years ago, that Dr. Frank Siebke and Dr. Stefan Reber founded the Fraunhofer spin-off NexWafe with the goal of producing better and cheaper silicon wafers for photovoltaic systems.

Reber had worked at the Fraunhofer Institute for Solar Energy Systems ISE for many years focusing intensively on silicon and its processing, while Siebke came with many years of business experience from the solar industry. A powerful team. Nevertheless, finding European investors was no mean feat, recalls Siebke, who is now the company's CFO: "The investment market was quite skeptical at the time." But the co-founders didn't let that faze them. Today, NexWafe has around 30 employees and aims to revolutionize global silicon wafer production with an innovative, patent-protected process.

Wafers are thin slices of silicon and a core component of every photovoltaic cell.

Photo: NexWafe GmbH

"The many years of intensive research at Fraunhofer ISE provide an incredibly strong scientific foundation that our competitors lack."

Dr. Davor Sutija, Managing Director of NexWafe GmbH

They account for around 70 percent of the cost of a cell in conventional production techniques. This is partly due to the many steps which are needed to produce them: A high-purity polycrystalline form of silicon is produced from the chemical chlorosilane. This is then melted down and large individual crystals, known as ingots, are extracted from the melted mass. These can be cut into individual wafers using fine wire saws. The drawbacks: These production steps consume a lot of energy. During the melting of the silicon, the ingots become contaminated with oxygen, which in turn hinders the efficiency of the photovoltaic cells. A lot of silicon is lost in the form of dust during sawing. If the wafers are too thin, they break.

Low emissions lead directly to success

In contrast, NexWafe works with a technology called epitaxy that allows chlorosilane to be processed into wafers without any additional steps. It all starts with a single wafer. This is then etched using acid and electricity, resulting in a highly porous thin layer. Subsequent heating up then seals the surface again. "The structure is like a Gothic cathedral," Siebke explains. "It has a stable roof, is held up by a few columns and is otherwise open." In high-temperature processes, silicon grows on this roof layer by layer, and a new wafer is created that is a perfect copy of the initial wafer. Both wafers are then separated at the columns and the original wafer can be reused. Fraunhofer ISE has been researching silicon epitaxy for many years and has successfully developed a continuous process, which is now used by NexWafe. Every wafer that is produced is identical, can be thinner than is possible with conventional production methods, and has fewer impurities. This saves a great deal of time and money. Around 70 percent less CO_2 is emitted in comparison with conventional production.

The manufacturing technology is now undergoing further testing and optimization at a prototype plant in Freiburg, Germany, where NexWafe's headquarters are located. The NexWafe team is continuing to work closely on the process with Fraunhofer ISE. The plan is then to start mass production in Bitterfeld in 2024. The company brought additional valuable expertise on board last year in the form of Dr. Davor Sutija in order to successfully navigate the transition from the laboratory to the commercial world. Sutija has years of experience in leading technology companies. Under his leadership, NexWafe acquired ten million euros in new investor funding in December. One million of this came from the Fraunhofer-Gesellschaft.

It has generated a great deal of interest from potential customers and investors from all over the world. Now, even the "Silicon Module Super League", the group of the largest producers in the solar industry, is backing high-efficiency n-type monocrystalline wafers like those NexWafe wants to manufacture. "This confirms that we are working on the right technology and gives us the opportunity to play a vital role in shaping the photovoltaic market of the future. Now we need to stay on the ball, identify future trends and implement them," says Sutija. For example, the current industry trend is for larger wafers. NexWafe is therefore planning to modify some of its systems accordingly within the next year.

Two U.S. companies are also working on new ways to produce wafers which differ significantly from the conventional melt-in-saw process, although these technologies are far less advanced: "The many years of intensive research at Fraunhofer ISE provide an incredibly strong scientific foundation for our company that our competitors lack. We wouldn't be where we are today without Fraunhofer's support" Sutija emphasizes, "I am extremely grateful of our collaboration. Particularly because it's not just about the success of our company, but rather something much bigger — the success of the global energy transition." ■

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Little equipment, lots of know-how: Christian Brandt from Fraunhofer SIT has uncovered the security gaps in a Bluetooth lock using two chip cans as directional antennass.

The chip container hack

Wireless mice, keyboards and smartphones are convenient, and sometimes dangerously so: Fraunhofer researchers have just discovered a new security breach — in a Bluetooth padlock.

By Mehmet Toprak

Bluetooth padlocks are practical. There isn't a key to loose. They can be opened using a fingerprint or a smartphone app that connects to the lock via Bluetooth Low Energy (BLE). Very convenient. But not always very secure. Researchers at the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt have managed to crack the Bluetooth connection on one manufacturer's lock — with just two cans of potato chips and a lot of know-how.

Christian Brandt and Matthias Cäsar, IT and crypto experts in the Cyberphysical Systems Security department, initially launched a man-in-the-middle attack. This involves attackers placing themselves between the user's smartphone and the lock. Any data that is exchanged between the lock and the smartphone passes through the attacker's computer undetected. Once the user leaves, the connection remains in place and the attacker can open the lock. The second security flaw was even more severe. In a so-called replay attack, the data exchange between the smartphone and the lock is recorded, and attackers can use this data to open the lock as often as they like. The attack was only successful due to a poorly implemented random number generator integrated into the security protocol.

Two potato chip cans, which were transformed into a directional antenna with a wire, were all that the hacker needed. On top of that, two Raspberry Pi mini-computers were used, one for the connection to the lock, the other for the connection to the victim's smartphone. "Of course, it's not quite as simple as it sounds," Brandt says. "Uncovering the vulnerabilities was complex and called on our considerable expertise." The researchers had to use so-called reverse engineering, which requires know-how in IT security, computer science and electrical engineering.

However, the security flaw is not a problem with the Bluetooth standard. It was rather that the manufacturer had failed to implement the Bluetooth functionality correctly. "A separate, in-house protocol was developed by this company for the padlock on the application layer of Bluetooth LE, which was simply not secure," Brandt explains.

For those who value security: Bluetooth should remain disabled on notebooks, smartphones or tablets when it is not needed.

Christian Brandt, IT and crypto expert at Fraunhofer SIT

Responsible disclosure: The manufacturers are given time to rectify the situation

Fraunhofer SIT notified the manufacturer of the flaw and gave them several weeks to rectify it. "This is the tried-and-tested procedure in a responsible disclosure process," says Andreas Fuchs, Head of the Cyberphysical Systems Security department. The SIT team only issued a public warning after the company provided an update resolving the issue for one of the two models in which the problem had surfaced.

Always be aware, as Bluetooth padlocks are by no means the only example of IT devices that can be cracked easily. The Fraunhofer SIT team of experts frequently uncovers security flaws, particularly in wireless devices such as mice, keyboards or presenters, that their owners are not aware of.

The researchers do not only get involved when manufacturers ask them to evaluate the security of a product before it goes on the market. They often spend their time buying devices, disassembling them, reading memory, detecting signal paths and decoding program codes implemented in the firmware. "Some manufacturers lack IT security awareness, and some are also worryingly sloppy in their work," comments Christian Brandt.

Dangerous convenience

Another problem lies in an all-too-human trait. "Many people, including employees, are too lazy to use encryption methods or comply with security measures they consider to be a nuisance," says Brandt. This complacency can be particularly dangerous when you take the bus or train, pull out your work cell phone with Bluetooth activated, and read emails that are unencrypted.

If security is important to you, Bluetooth should remain disabled on notebooks, smartphones or tablets when it is not needed. This eliminates a potential source of danger. Although it may not be as convenient, it is safer to connect your headphones, keyboards and mice using a cable rather than wirelessly. ■

Photos: Fraunhofer SIT

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In the past, it was common for munitions on the seabed to be simply blown up.

Ticking time bombs at the bottom of the sea

It's a race against time. 1.6 million tons of munitions from the Second World War are rusting away in the North and Baltic Seas. The more holes there are in the metal layers, the more toxic TNT escapes into the sea — endangering the health of both humans and animals.

By Mandy Bartel

Nienhagen, located on the Baltic Sea, is known for its rocky coastline, its spooky forest, and its recreational value, as certified by the Mecklenburg-Schwerin Ministry of the Interior in 1929 with the "concession to operate a seaside resort". Peter Menzel also enjoys the peace and tranquility when he takes his boat on the short ride to the offshore research platform off Nienhagen. Shining yellow before him, the platform, built in 2010 and operated cooperatively by the Mecklenburg-West Pomerania Federal Research Institute for Agriculture and Fishing (LFA) and the Fraunhofer Institute for Computer Graphics Research IGD Rostock, has just been upgraded with the latest technology: a wind turbine, solar panel, a modern weather station, a current gage, all kinds of sensors and a broadband connection. It provides real-time data from Germany's first underwater test site, the Digital Ocean Lab. It was commissioned in summer and will play an important role in the fight against contaminated Second World War sites.

Shellfish with TNT

1.6 million tons of mines and explosives, most of which were discarded in the sea by the Allies after the end of the war, are the

ticking time bombs of the North and Baltic Seas, releasing toxic TNT, nitroaromatics and mercury into the water as they rust. Even to this day, traces of toxic explosives can be detected in many fish and shellfish. And humans have only made the problem worse. Due to the lack of suitable salvage methods for the munitions on the seabed in the past, it was quite common to simply detonate the explosives in order to protect busy sea routes or to avoid endangering the construction of wind turbines. However, seashells found close to detonated explosives contain 50 times higher concentration of these hazardous substances, which not only poses a threat to the marine ecosystem, fish and shellfish stocks, but also to humans via the food chain.

This problem of underwater contaminated sites is not a new discovery. The German Federal Parliament is now also looking into the issue, a topic of both ecological and economic importance. Experts stood before the Environment Committee and called for a fund of at least 100 million euros. The EU has also already expressed its intention to contribute financially to the search for and disposal of World War II munitions, due to the urgency of the task at hand.

From underwater garden to digital reef

The challenge is to locate and classify these fragile and dangerous contaminated materials, and to salvage and disassemble them in the safest and most eco-friendly way. While there are already many ideas regarding technologies and processes, opportunities to test them extensively under real conditions — poor visibility, strong currents, loose sediment — are often lacking. "Companies and research organizations will be able to test new technology on the underwater test site's artificial reef without posing any risk to munitions buried at different depths. It will be possible to test image recognition and measurement systems in our munitions garden, as well as crawlers, underwater robots or transport procedures," explains Peter Menzel, who heads the Digital Ocean Lab. However, these are not the only test scenarios: New materials, corrosion or anti-fouling systems are tested in other areas. Underwater cables can also be laid and maintained, or autonomous underwater vehicles tested. "The requests we have received are broad: some want to test buoys equipped with sensors, some want to lay cables, while others want to establish artificial coral reefs from 3D printers. But salvaging unexploded ordnance (UXO) will play the biggest role in the foreseeable future," the marine researcher is certain. The Digital Ocean Lab not only provides companies with the infrastructure, "For each experiment, we also arrange the necessary permits with authorities and provide accurate information on the conditions on site," says Menzel.

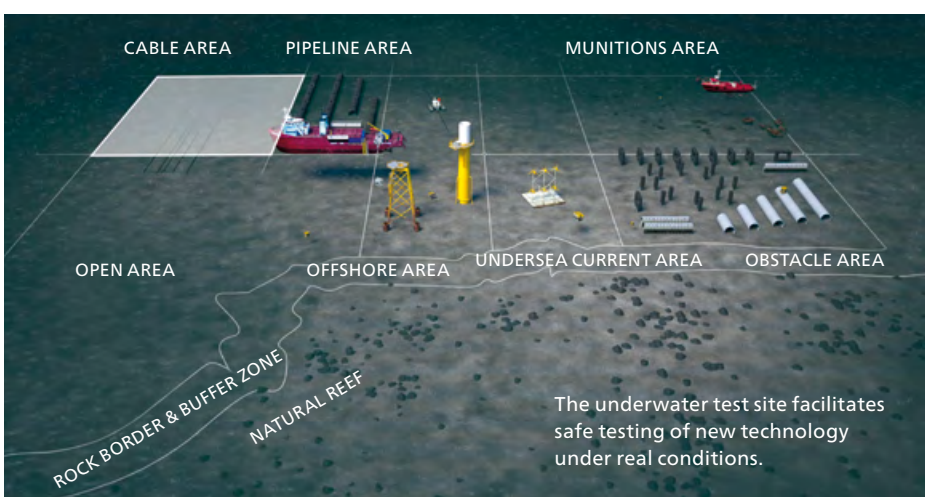
This precise data is also the basis for the Digital Ocean Lab's business model: "Our goal is to have a complete digital model with real-time data from the reef within three years — from currents and salt content to sediment structure and temporary ship traffic. This would allow fully virtual simulations of experiments, regardless of location and without the need for costly permits and preparations. The whole system would also be scalable and could be used by several companies simultaneously," says Menzel. This could boost global research in the field of munitions solutions, as the problem is by no means unique to Germany. According to nature conservation organizations, dangerous contaminated sites can be found in almost all of the world's oceans. ■

Protection of divers

Until unmanned alternatives are technologically refined, professional divers will have to perform the dangerous task of recovering explosive devices. To protect them, Fraunhofer IGD, in cooperation with research partners, has developed a safety concept: Different sensors will warn divers of toxic substances and will help them communicate with the surface in real time, which is essential in poor visibility conditions and when assessing hazards. Augmented reality diving goggles are being developed to display safety-related information, such as current readings.

Research diver Florian Huber regularly encounters the dangerous legacy left behind by the world wars during his scientific expeditions. We talked about his experiences.

Click here for the podcast:



The underwater test site facilitates safe testing of new technology under real conditions.

Photos: Carsten Rehder/dpa, Fraunhofer IGD

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Photo & Fraunhofer

Simply unstoppable? Miniaturized radio technology in the ball, shoes and jerseys is helping to optimize movement in modern soccer training, so players like Evan N'Dicka (2) and Djibril Sow (8) no longer need to just watch others score goals.

Fraunhofer on the ball

The 2021/22 soccer season kicked the first weekend off in style — largely thanks to Erling Haaland in his black and yellow jersey. The 21-year-old played a spectacular game against Eintracht Frankfurt (5:2): Scoring two goals for Borussia Dortmund and setting up at least two more, Haaland was always on the ball.

Always on the ball when it comes to modern soccer: Fraunhofer technology. High-frequency technology has been a core area of expertise at Fraunhofer IIS for more than 20 years. The researchers have also been working with partners on intelligent sensors in the ball itself. This involves developing a small and lightweight sensor module that does not impair flight characteristics. Kicks, passes and information on ball possession are determined using statistical methods, and player speeds are estimated with the help of machine learning to optimize performance in both training and matches. To ensure that the ball game is even more dynamic in the future.

Photo: ddp images

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5th Fraunhofer Alumni Summit 2021

»Future of logistics«
In cooperation with Fraunhofer IML
November 5, 2021, digital

+ Fraunhofer Evening program

Charity wine tasting and beer tasting, digital
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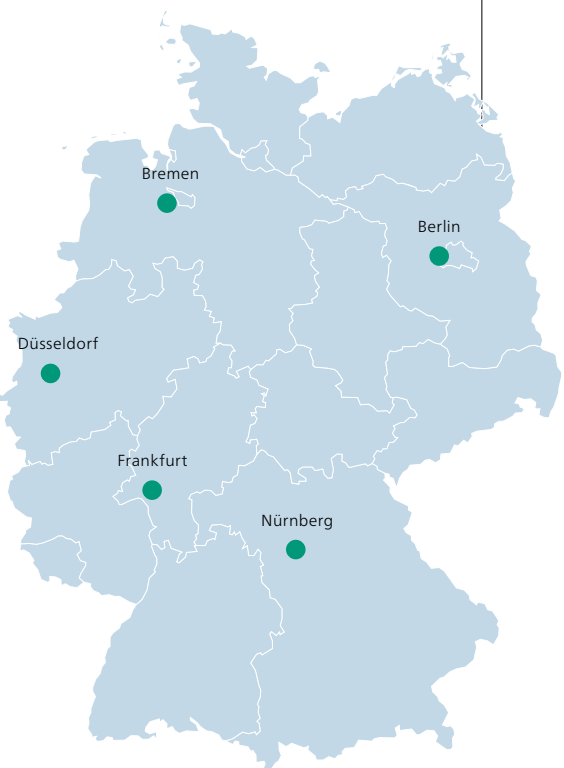
www.fraunhofer-alumni-summit.de

Fraunhofer on the road



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

Virtual
October 26–27, 2021
Smart Country Convention
Congress for E-Government and Smart City

Düsseldorf
November 15–18, 2021
Medica
International trade fair for medical engineering

Düsseldorf
November 15–18, 2021
Compamed
International trade fair for the supplier market for medical manufacturing

Bremen
November 16–18, 2021
Space Tech Expo
Trade fair and conference for space technologies

Frankfurt am Main
November 16–19, 2021
Formnext
Trade fair for additive manufacturing technologies and their upstream and downstream processes

Nürnberg
November 23–25, 2021
SPS drives
Trade fair for electric automation, systems & components

Berlin
November 23–25, 2021
Futuras in Res
Fraunhofer-Gesellschaft international conference series for science and technology, this time on the topic of "Quantum Technologies"

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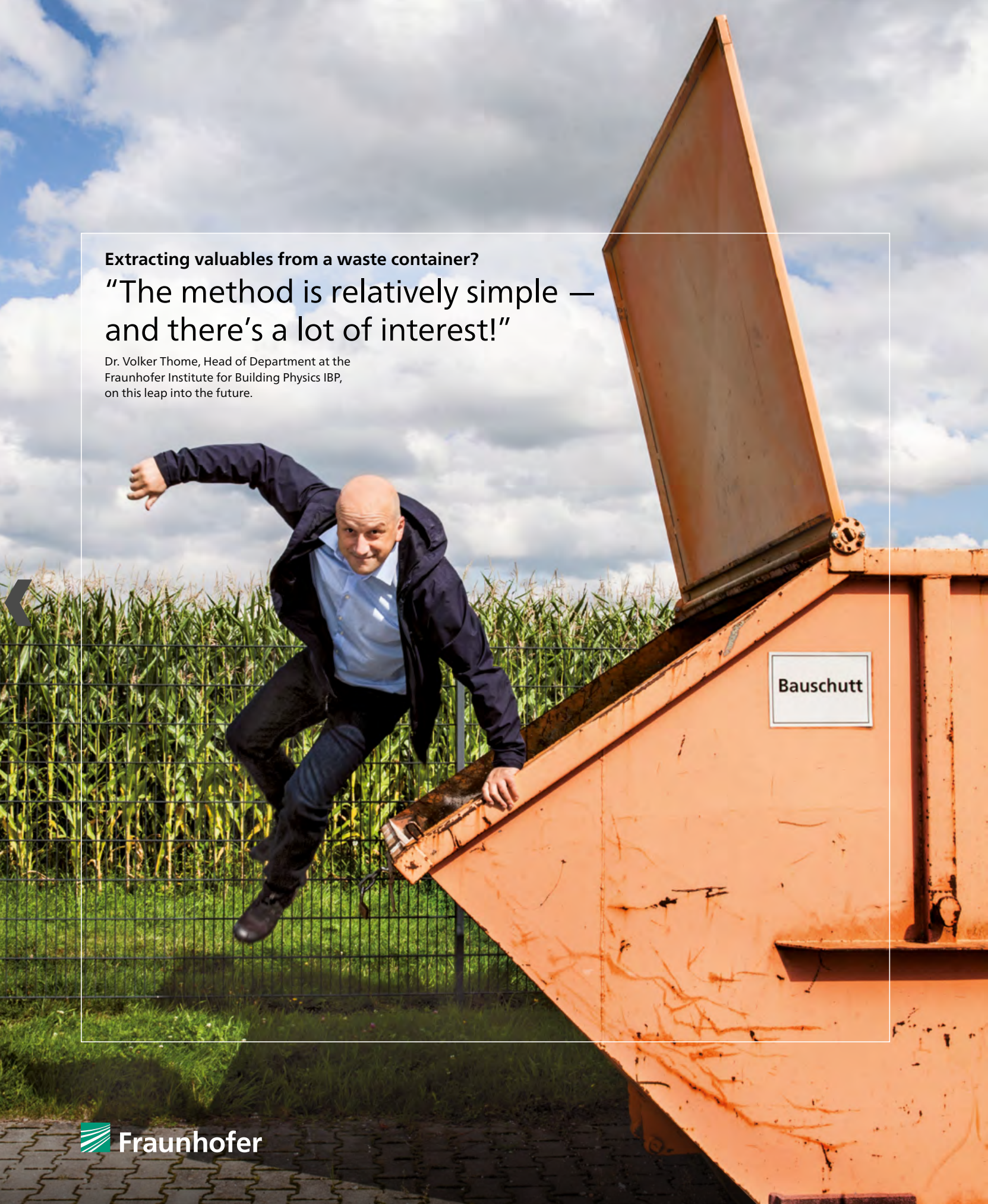

Extracting valuables from a waste container?

“The method is relatively simple — and there’s a lot of interest!”

Dr. Volker Thome, Head of Department at the Fraunhofer Institute for Building Physics IBP, on this leap into the future.

Fraunhofer