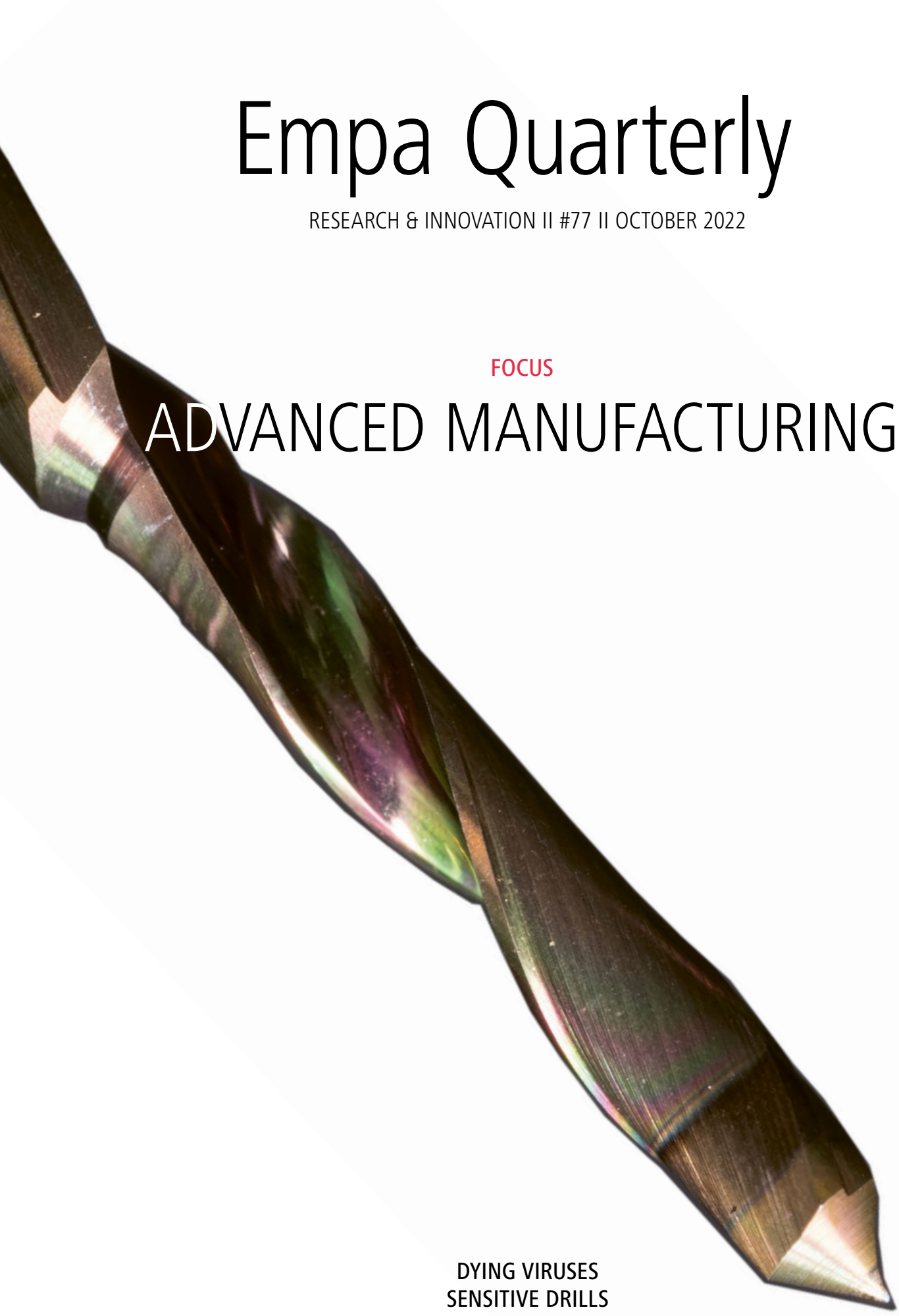
Empa Quarterly

RESEARCH & INNOVATION II #77 II OCTOBER 2022



FOCUS

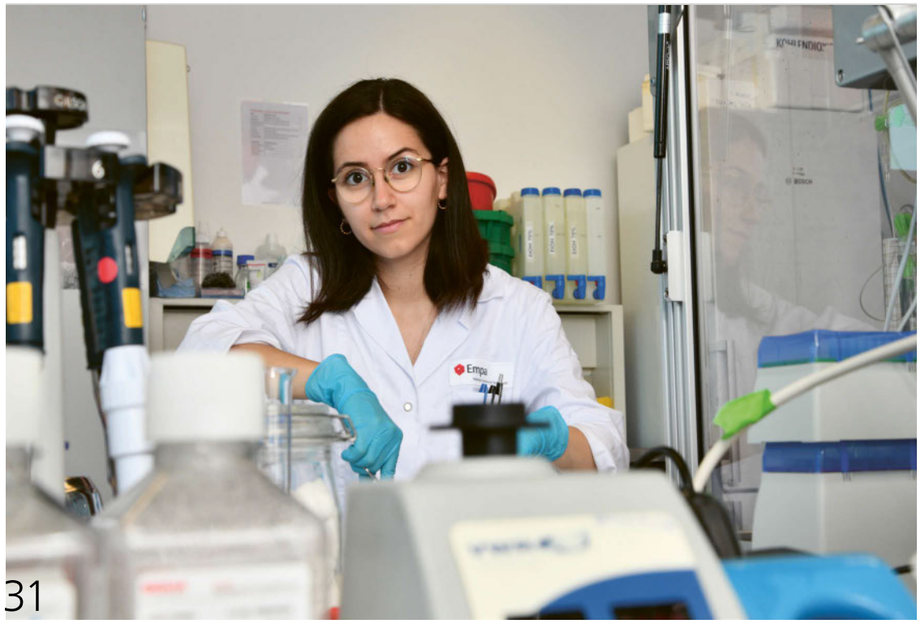
ADVANCED MANUFACTURING

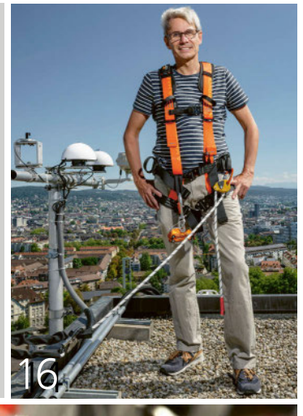
DYING VIRUSES
SENSITIVE DRILLS
VIRTUAL COLD CHAINS

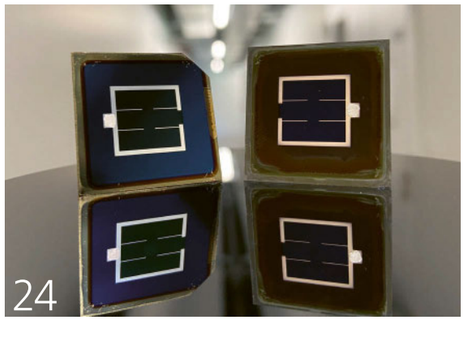
www.empaquarterly.ch

[CONTENT]

[FOCUS: ADVANCED MANUFACTURING]







Photos: Empa (3), Christian Wolff (EPFL), Tazio Plej (ETH Zürich)

[COVER]

Advanced manufacturing methods are also helping surgery. Together with the ARTORG Center for Biomedical Engineering Research at the University of Bern, Empa developed a sensitive drill for head surgery that can indicate when it is coming dangerously close to facial nerves. (See p. 26). Image: Empa

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PUBLISHER Empa
Überlandstrasse 129
8600 Dübendorf,Schweiz
www.empa.ch
EDITORIAL Empa Kommunikation
LAYOUT PAUL AND CAT.
www.paul-and-cat.com
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PUBLISHING SEQUENCE
quarterly
PRODUCTION
norbert.raabe@empa.ch

myclimate neutral Imprimé
myclimate.org/01-22-468620

ISSN 2297-7414
Empa Quarterly (English edition)

MATERIALS SCIENCE GOES DIGITAL

Dear Readers

What does a materials scientist actually do, day in, day out? Well, they deal with methods for producing novel materials and exploring their (hopefully promising) properties. So far, so good. For some time now, however, materials science has increasingly been taking place in silico – that is, using high-performance computers. Data science, computer simulations, machine learning and AI have thus opened up numerous new possibilities.

For instance, in the area of Advanced Manufacturing (AM), the focus of the current issue: The aim here is to understand these new, advanced manufacturing processes such as 3D printing down to the very last detail, i.e. so well that one can simulate them – and thus eventually vary and adapt them. Only then can AM be successfully put into practice, as Pierangelo Gröning, member of Empa's Directorate, explains in an interview (p. 19).

3D printing also plays a crucial role in another project that involves making the virtual worlds of the metaverse tangible – with the help of a Virtual Reality (VR) glove, tailor-made and largely automated (p. 22).

Empa researchers are also developing an app called «Your Virtual Cold Chain Assistant» to avoid food waste (p. 8), using a self-learning algorithm to save around a quarter of heating energy (p. 6), and modeling our atmosphere to track down problems such as climate change or urban air pollution (p. 16).

Enjoy reading!
Your MICHAEL HAGMANN

PAVING THE WAY FOR SOLAR FUELS

In August 2022 the ETH Zurich spin-off Synhelion has become the first company in the world to succeed in producing syngas on an industrial scale using only solar heat as an energy source. The successful demonstration took place at the multifocus solar tower of the German Aerospace Center (DLR) in Jülich. Synhelion's technology uses high-temperature solar heat to produce syngas, which is then used in standard industrial processes to synthesize liquid fuels, such as kerosene, gasoline, or diesel, that are compatible with conventional jet engines and internal combustion engines. To enable the chemical reactors for solar fuel production to operate 24/7, a cost-effective, high-temperature thermal energy storage is developed together with Empa's Laboratory for High Performance Ceramics in a project funded by Innosuisse.

Further information on the topic is available at:
www.empa.ch/web/s604/synhelion-energiespeicher

Photo: Synhelion

A SELF-LEARNING ALGORITHM SAVES ENERGY

SIMPLE SWAP
Replacing conventional radiator thermostat sensors with Danfoss Ally smart thermostats is simple and can be done in just a few seconds.

With energy prices soaring, heating costs will also inevitably rise in the coming winter. In order to mitigate this, solutions for operating buildings more efficiently are needed. The Empa spin-off viboo has developed an algorithm that makes it possible to operate even older buildings with around 25 percent less energy – while user comfort remains the same or even improves.

www.empa.ch/web/s604/viboo-danfoss

A ROBOT LANDS LIKE A GECKO

Empa researcher Ardian Jusufi has studied geckos that land on trees. He found that it is not only the gecko's "sticky" feet that are responsible for a successful landing, but the gecko's tail, which must be a certain length and cushions the impact. Without the right tail, which has evolved over the course of evolution, a gecko cannot land successfully.

Jusufi, together with his research group at the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, has recreated geckos as replicas and thrown them at the wall with a catapult. In this way, he has deciphered the systematics of gecko landing and calculated it physically. Jusufi now wants to develop this basic knowledge further at Empa and build robots that can land on vertical surfaces on the basis of their geometry alone – without any microprocessor or real-time correction calculation.

www.empa.ch/web/s799

THE TAIL ASSISTS
A robot for hard landings on vertical walls – inspired by geckos

Photos: Empa, Max Planck Institute for Intelligent Systems

AEROGEL FOR HISTORIC BUILDINGS

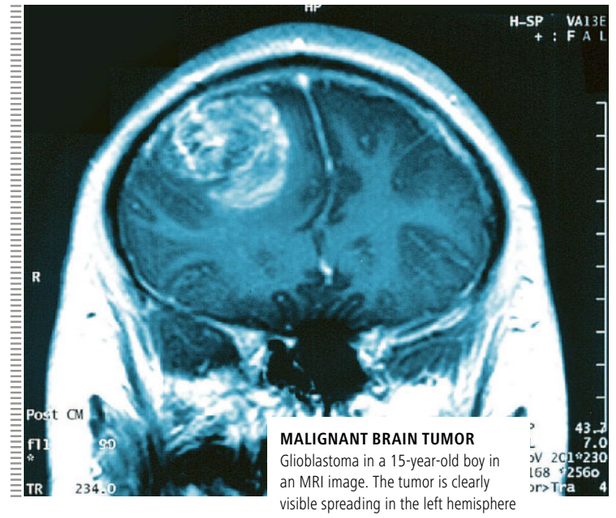
Award ceremony of the Aerogel Architecture Award in August 2022 at NEST: (from left to right) organizer Michal Ganobjak (Empa), architect Astrid Wuttke (schneider+schumacher), architects team Christoph Allenbach, Maren Zinke, and Beat Kämpfen (Kämpfen Zinke + Partner) with the representative of the client Paul Ott, jury member Michael O'Connor (Advapor, front), Marco Biondi (Agitec), jury member Matthias Koebel (Siloxene AG), co-organizer Samuel Brunner (Empa).

www.empa.ch/s604/aerogel-architecture-award-2022

PERSONALIZED TUMOR THERAPY

Glioblastoma is the most common and deadly primary brain tumor. Supported by the Dr. Hans Altschüler Foundation, the Elgin Foundation, the Mirto Foundation and the Werner Geissberger Foundation, Empa researcher Peter Wick and his team are now pursuing a new research approach. Tissue samples from the tumor, obtained with the patients' consent, are to be used to create glioblastoma organoid cultures, which will be cultivated on biochips, characterized and examined microscopically. In this way, the researchers hope to learn more about this still mysterious type of tumor and to be able to develop a personalized therapy for glioblastomas.

www.empa.ch/web/s403



MALIGNANT BRAIN TUMOR
Glioblastoma in a 15-year-old boy in an MRI image. The tumor is clearly visible spreading in the left hemisphere of the brain.

Photos: Empa, de.wikipedia.org/wiki/Glioblastom

ON THE SMARTPHONE
In a pilot project in India, the team tested the app which informs farmers' wives about the condition of their refrigerated produce.

PAY PER USE
Small farmers and traders gain access to reliable, off-grid refrigeration and pay only for the amount of food they store.

VIRTUAL COLD CHAINS SAVE FOOD

Text: data.org

Photos: Basel Agency for Sustainable Energy (BASE)

Nearly half of all fruit and vegetables produced globally are wasted each year, according to the United Nations. This has implications for food insecurity, climate change, and for economic security and mobility of the world's agricultural workforce.

Fighting food waste, in other words, has the potential to be a force multiplier for social impact. And that's exactly what the Basel Agency for Sustainable Energy (BASE), together with Empa is working to accomplish through data science for social good – working with communities to fight food waste while lifting the livelihoods of small farmers and simultaneously driving investment in climate change solutions.

THE CHALLENGE

BASE is a Switzerland-based nonprofit that develops business models to unlock investments in clean energy. For more than 20 years, they have worked across sectors at the intersection of climate solutions, finance, and international development. In recent years, the BASE team has taken an interest in cooling, starting in 2018 with commercial air conditioning and industrial refrigeration. With many cooling users opting for less energy-efficient solutions to save on the upfront investment despite higher operational costs, BASE helped choreograph a shift to a subscription model instead, where the burden of ensuring efficient operation falls

▶

on the provider and individual users can purchase cooling as they use it.

DIGITALIZATION

The success of that effort, known as the Cooling as a Service Initiative, sparked new ideas and illustrated new challenges. "There's a lot we can do beyond the business model. We realized that tailoring this to the agricultural cold chain is a key piece of the puzzle to address food security. By integrating digitalization, we facilitate the adoption of the model by local entrepreneurs as well as its scaling-up", says Thomas Motmans, senior sustainable energy finance specialist and the project lead at BASE.

The extensive experience of Empa researchers, led by Thijs Defraeye, with analyzing and reducing food loss in post-harvest supply chains as well as with physics-based modeling to predict fresh produce shelf life showed to be highly synergetic to extend the solution to the agricultural cold chain.

Thus, BASE and their partners at Empa launched an interdisciplinary consortium for a deep dive into the problem of food waste, starting in India, one of the world's largest food producers. As much as 35 percent of the fresh food produced in India is wasted, largely due to a lack of proper refrigeration. In fact, only 6 percent of the country's food moves through the cold chain, compared to about 60 percent in developed countries.

Through the project, Your Virtual Cold-Chain Assistant, BASE and Empa are enabling a business model in which farmers can access cooling services on a pay-per-use basis, and have developed a mobile application, that facilitates the implementation of the model. The open-access, data science-based mobile application uses machine learning and physics-based food modeling to provide smallholder farmers with actionable post-harvest and market intelligence.

OPERATORS OF COLD ROOMS

While initially, BASE and Empa conceptualized the solution to be used by farmers only, it became clear in early, local conversations that the operators of cold rooms would become important users of the app and that some farmers without access to smartphone technology might be excluded. They started to rethink the approach and co-create the solution together with the users.

This resulted on the one hand in adding the operators of cold rooms as primary users and on the other hand in enabling the communication of data by these cold room operators to the cold room users via SMS messages for those farmers, or members of farmers' households, having access only to feature phones. "It's really important to understand who will be using the app, engage with them to collect feedback, and ensure the solution is tailored to technical capability and infrastructure," says Roberta Evangelista, sustainability data science and digitalization specialist for BASE.

BASE's used their connections with cold room operators to roll out the pay-per-use model in partnership with three local cooling providers – CoolCrop in Himachal Pradesh, Koel Fresh in Odisha, and Oorja in Bihar. Under this business model, farmers gain access to solar-powered cooling while only paying for the amount of food they store per day in the cold rooms. This makes cold chain storage more affordable for smallholder farmers in the process. Service providers who own, maintain, and operate the cooling facilities are incentivized to think long-term and use efficient systems.

TRACKING SHELF LIFE FROM REMOTE

With the post-harvest and market intelligence that it provides, the application makes data science actionable for farmers. "We call it upcycling," says Thijs Defraeye, leader of the Simulating Biologgical Systems group at Empa's Biomimetic Membranes and Textiles lab. "We translate the data into useful recommendations for the people on the ground."

The app sensors capture data points like temperature and humidity – information that on its own may not be helpful to a farmer – and transforms them into usable indicators. For instance, the solution helps smallholder farmers remotely track the shelf life of their crops in storage based on real-time sensor data. In future, the app will even be able to forecast daily market prices for different commodities using open-source data from markets across India. "From the perspective of the farmer, the main benefit of the app is that they will receive real-time information about when the produce in storage is reaching the end of life, which combined with market price forecasts means that they can better leverage cooling to achieve better prices in the markets," explains BASE's Roberta Evangelista.

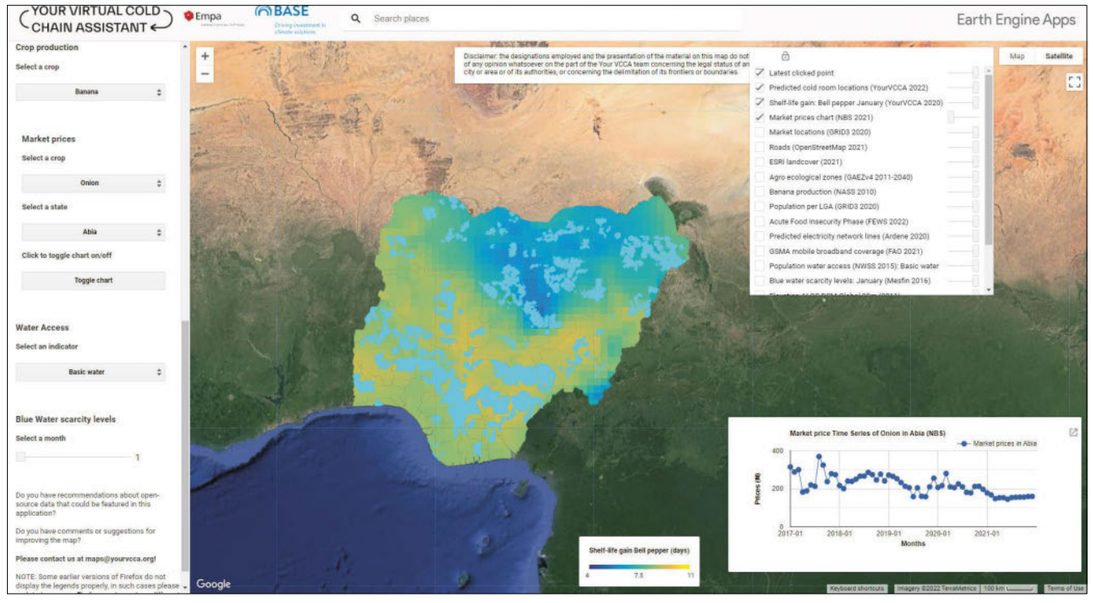
Currently, when food outside of the cold chain is reaching the end of its shelf life, farmers are often forced to distress sell it at significantly reduced prices or waste it, a financial hit to their business. Your Virtual Cold Chain Assistant enables them to leverage cooling as a solution to delay the decay of perishable produce, store leftover products overnight before they can sell at full price the next day, and better plan when and where to sell their produce to maximize their income.

Pilot projects were launched in India in partnership with the three local cooling companies, and the efforts are already being expanded to Nigeria, with plans to expand to yet further geographies. ■

This Story was originally published on data.org: https://data.org/stories/virtual-cold-chain/

PILOT PLANT
One of the cold rooms was set up by Koel Fresh in Keonjhar, India.

Photo: Basel Agency for Sustainable Energy (BASE)



Grafic: Basel Agency for Sustainable Energy (BASE)

WHERE VIRUSES REACH THEIR LIMITS

Using a new analytical method, Empa researchers have tracked viruses as they pass through face masks and compared their failure on the filter layers of different types of masks. The new method should now accelerate the development of surfaces that can kill viruses, the team writes in the journal Scientific Reports.

Text: Andrea Six

Richtiger Link?

> "Electron microscope images reveal that a few virus particles manage to make their way into the innermost mask layer close to the face."

Using high pressure, the apparatus pushes artificial saliva fluid, colored in red, with test particles through a stretched mask. This is how the researchers simulate the process of a droplet infection. The new method established at Empa ((https://www.youtube.com/watch?v=clF4MTcUheA)) is currently used by certified test centers to ensure the quality of textile face masks because a safe and effective protective mask must meet demanding requirements: It must keep out germs, withstand splashing drops of saliva, and at the same time allow air to pass through.

Now Empa researchers are going one step further: "Images taken using a transmission electron microscope show that a few virus particles manage to make their way into the innermost layer of the mask, close to the face. However, the images do not always reveal whether these viruses are still infectious," says Peter Wick of Empa's Particles-Biology Interactions lab in St. Gallen. The researchers' goal: They want to find out where exactly a virus particle is held back within a multilayer face mask during droplet infection, and which mask components should be more efficient. "We needed new analytical methods to precisely understand the protective function of newly developed technologies such as virus-killing coatings," says Empa researcher René Rossi of the Biomimetic Membranes and Textiles lab in St. Gallen.

After all, this is precisely one of the goals of the ReMask project, in which research, industry and healthcare experts are teaming up with Empa in the fight against the pandemic to develop new concepts for better, more comfortable and more sustainable face masks.

DYING BEAUTY

The new process relies on a dye, rhodamine R18, which emits colored light. Non-hazardous, inactivated test viruses are used, which are coupled to R18 and thus become dying beauties: They light up as soon as they are damaged. "The fluorescence indicates reliably, quickly and inexpensively when viruses have been killed," Wick says.

Based on the intensity with which a mask layer glows, the team found that for fabric and hygiene masks, most viruses fail in the mid layer between the inner and outer layers of the mask. In FFP2 masks, the third of six layers glowed the most – again, the central layer trapped a particularly large number of viruses. The researchers recently published their findings in the journal Scientific Reports ((Link: https://plus.empa.ch\images\scientificreports-wick-2022.pdf)). These findings can now be used to optimize facial masks.

In addition, the new process can accelerate the development of virus-killing surfaces. "Surfaces with antiviral properties must comply with certain ISO standards, which entail laborious standard tests," Wick explains. The Empa researchers' fluorescence method, on the other hand, could be a simpler, faster and more cost-effective way of determining whether a new type of coating can reliably kill viruses, as a supplement to current standards. This would be of interest both for smooth surfaces, such as on worktops or handles, and for coatings on textiles with a porous surface, such as masks or filter systems.

And with the new method, this knowledge could already be integrated into the development process of technical and medical applications at a very early stage. According to Wick, this will speed up the introduction of new products, as only promising candidates will have to undergo the time-consuming and cost-intensive standardization tests. ■

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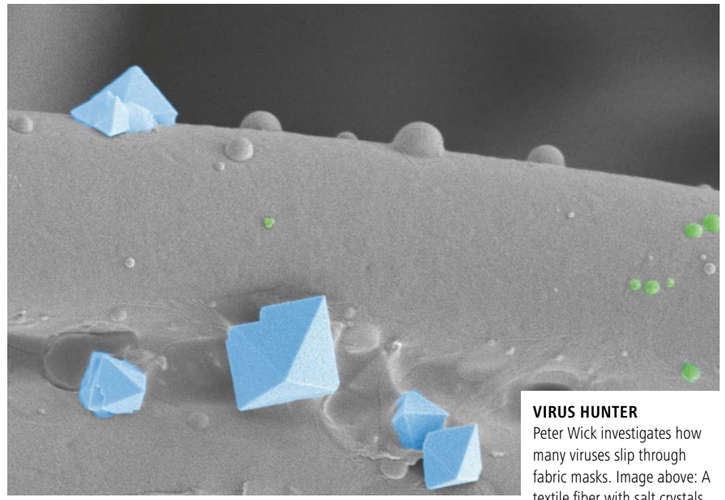
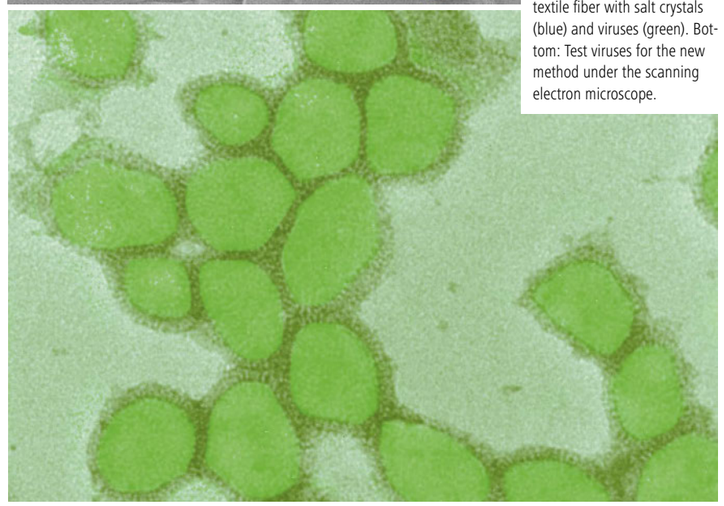
Further information on the topic is available at: www.empa.ch/de/web/s403





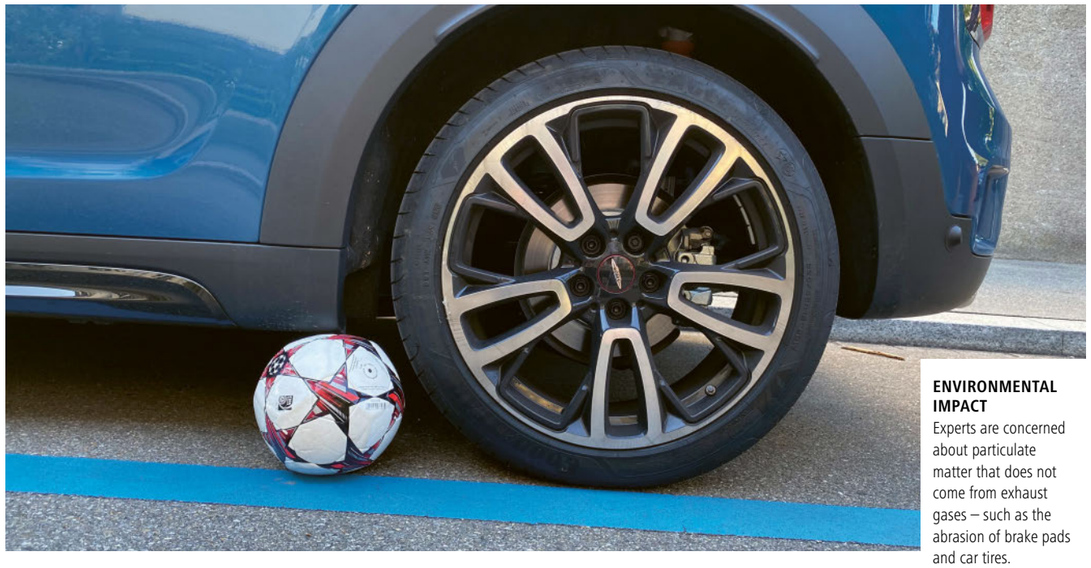
VIRUS HUNTER
Peter Wick investigates how many viruses slip through fabric masks. Image above: A textile fiber with salt crystals (blue) and viruses (green). Bottom: Test viruses for the new method under the scanning electron microscope.

Photos: Empa

WHAT MAKES PARTICULATE MATTER SO DANGEROUS?

Large amounts of particulate matter in the air are known to be harmful to human health. But many questions remain unanswered: Which components are particularly dangerous? At what concentrations? The "oxidative potential" of particulate matter could serve as a criterion for assessing risks in the future – and Empa researchers have explored it for Switzerland.

Text: Norbert Raabe



ENVIRONMENTAL IMPACT
Experts are concerned about particulate matter that does not come from exhaust gases – such as the abrasion of brake pads and car tires.

Inflammation, bronchitis, asthma attacks, cardiovascular problems – an excerpt from the list of possible health problems caused by high concentrations of particulate matter: particles with a diameter of ten micrometers or less – called PM10 – and even smaller PM2.5 particles that can enter our lungs from car exhaust, heating systems, industrial operations and natural sources. Although strict monitoring and abatement measures have reduced pollution levels in Switzerland since the 1990s, the problem persists in many places, especially in cities

Particle size, composition, sources and effects of particulate matter are not easy to determine. One thing is certain: the smaller the particles, the deeper they reach the human lungs. But which fractions are particularly dangerous? And in what combinations and concentrations? To describe this, a new criterion termed oxidative potential had been developed a few years ago: a term intended to describe the ability of inhaled particles to trigger the formation of so-called free radicals in the body, which can ultimately lead to inflammation.

FIVE LOCATIONS

Empa researchers Stuart Grange and Christoph Hüglin from the Air Pollutants/Environmental Technology lab have investigated the suitability of this criterion for the assessment of health risks with samples collected Switzerland in greater detail – with an elaborate measurement campaign supported by the French Université Grenoble Alpes. With the help of the National Air Pollutant Monitoring Network (NABEL), which Empa operates together with the Federal Office for the Environment (FOEN), they collected particulate matter samples in the PM2.5 and PM10 categories around the clock between June 2018 and May 2019. The measuring stations covered the entire range of particulate pollution levels and were located in cities, the agglomeration and in rural areas south and north of the Alps.

In total, the experts analyzed around 900 samples in the laboratory – using test methods for oxidative potential that work with different analysis substances: ascorbic acid (AA for short), dithiothreitol (DTT) and dichlorofluorescein (DFCH).

SAMPLES
Air was drawn through these quartz fiber filters for 24 hours – in principle like in a vacuum cleaner.

Photos: Empa

In the AA test, the consumption of ascorbic acid, an important antioxidant, allows conclusions to be drawn about the oxidative toxicity of the sample under investigation, for example due to metals contained therein. The other two methods work in a similar way. Put simply, says Christoph Hüglin, the three methods offer different perspectives on similar biological processes.

MACHINE LEARNING

In addition to the oxidative potential, a large number of chemical constituents of fine dust were analyzed. This resulted in a large amount of data on the elements, ions and organic substances that make up fine dust in Switzerland. In order to identify the suspicious substances with the greatest oxidative potential in these masses of data, the Empa researchers used machine learning methods. More precisely, they used the Random Forest algorithm, which, metaphorically speaking, allows a forest of countless trees to grow; each tree then makes decisions about relationships in the data – such as, in this case, the ingredients of particulate matter and the associated oxidative potential. In the end, a mean model is formed from the decisions of the entire forest.

In this way, the experts reduced the number of suspicious constituents to about a dozen, which they in turn analyzed using conventional computational methods and models to finally track down the most important health hazards – different metals or even organic substances, which in turn provide clues to their origin.

The results confirm known facts such as a clear urban-rural divide in particulate matter and its associated health consequences, as well as higher pollution in winter than in summer. Admittedly, there are exceptions: The oxidative potential, related to the air volume, had increased particularly significantly in Southern Switzerland during the cold season – in areas that were polluted by smoke from wood burning during this period.

Rural areas showed the lowest mean values, while the highest values throughout the period came from an urban measuring station exposed to heavy traffic. At busy intersections in cities, other emissions besides exhaust gases are a cause for concern: Metals such as copper, zinc and manganese indicate particulate matter components that may originate from the abrasion of car tires or brake pads, for example.

How exactly the criterion of oxidative potential can describe health hazards is currently the subject of controversial debates among experts. After all, even the most precise measurements and analyses of air pollutants do not answer open questions about inflammatory processes in the human body. But Empa researcher Hüglin assumes that sensible measures can be derived from their analyses: Although all fine dust particles could affect health, with regard to the oxidative potential, particles from road traffic, which do not originate from exhaust gases, as well as those from wood combustion should be given special attention in measures to protect public health. ■

HARMFUL PARTICLES

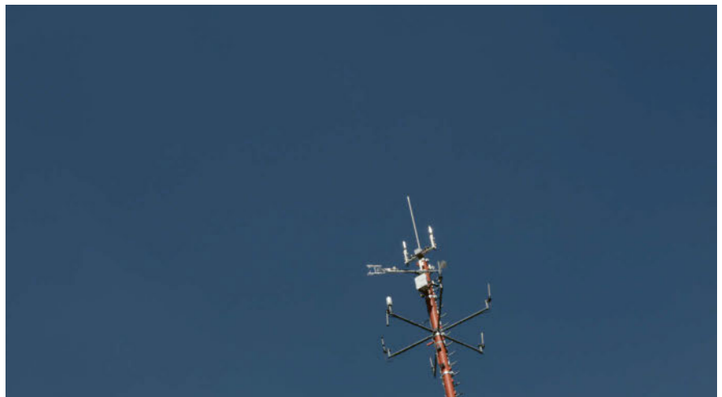
Particulate matter can be described as a mixture of solid and liquid particles in the air – from anthropogenic sources such as engines or industrial exhaust gases or also natural sources such as volcanoes. While many particles enter the air directly through emissions (primary particles), secondary particles are only formed in the atmosphere through chemical reactions of gaseous compounds. Of particular importance to human health is respirable particulate matter with particle aerodynamic diameters of less than ten micrometers. Particulate matter also includes so-called ultrafine particles, such as those from diesel engine exhaust, which can penetrate deep into the lungs and can cause severe damage.

Further information on the topic is available at:
www.empa.ch/de/web/s503

A SCOUT OF THE ATMOSPHERE

Internationally recognized atmospheric scientist and Distinguished Senior Researcher at Empa: Dominik Brunner is a renowned scientist who has explored his subject area from many angles – with a weatherproof motivation and curiosity that drives him to this day.

Text: Norbert Raabe



OVER THE ROOFTOPS
Dominik Brunner on the "Hardau II" tower block. The measuring instruments in the background are collecting data for the "ICOS Cities" research project.

Photo: Felix Wey / Empa

If you read an article about air pollution in Switzerland, about greenhouse gases or climate change, you are most likely to find thoughts and ideas from Dominik Brunner, head of the Atmospheric Modeling and Remote Sensing group at Empa since 2006, professor of tropospheric chemistry at ETH Zurich. Involved in satellite missions of the European Space Agency ESA and in numerous international research projects, co-founder of the Swiss measurement network for greenhouse gases and much more. And honored several times for his research, including as one of Empa's very few Distinguished Senior Researcher.

How did that come about? Steadily and patiently. The topic of the environment had already interested Dominik Brunner in his youth in the 1980s, when the environmental movement emerged – with the slogan "jute instead of plastic," as he recounts with a smile, with waste avoidance, green initiatives and the attempt by "activists" at the time to join forces to put Migros – one of the largest retail companies in Switzerland and organized as a cooperative –, as cooperative members, more firmly on an environmentally friendly course.

Nevertheless, Brunner did not become a treehugger with political ambitions,

DOMINIK BRUNNER

CAREER: After studying physics at ETH Zurich, Dominik Brunner devoted himself to atmospheric research in the field of nitrogen oxides, climate gases and other areas. He completed a post-doctorate at the Royal Netherlands Meteorological Institute in De Bilt and was a research assistant at the Institute for Atmospheric Science at ETH Zurich.
RESEARCH: Since 2006, he has headed the Atmospheric Modeling and Remote Sensing Group at Empa. Brunner published papers on modeling and measurement technologies and participated in satellite missions of the European Space Agency (ESA). He is professor of tropospheric chemistry at ETH Zurich and a member of numerous expert committees. Brunner received several awards, for instance, for his PhD thesis, as reviewer for ERC research grant proposals and as a Distinguished Senior Researcher at Empa.

but studied physics at the ETH Zurich. In his diploma thesis, he built a device for measuring hydrogen peroxide (H_2O_2) in ambient air; as a PhD student he continued with this topic – a fully automatic measuring system that was used on board a Swissair aircraft. The focus of the atmospheric scout: nitrogen oxides and ozone, which were already important environmental factors at the time.

They were to prove a door opener. The result was a publication in the renowned journal Science and an award from ETH Zurich – for the discovery that some phenomena are more widespread than previously assumed. For example, large-scale nitrogen oxide plumes in the region of the tropopause, the boundary layer above the near-Earth troposphere – caused by lightning and upward transport of air pollutants from the Earth's surface into thunderclouds.

TOWERS, AIRCRAFT, SATELLITES ...

Since new insights always raise new questions, several aircraft measurement campaigns followed during two postdoctoral positions at the Royal Netherlands Meteorological Institute (KNMI) and ETH Zurich – in Canada, Brazil and Australia, where a former Russian spy plane was used that flew at altitudes of up to 20 kilometers. "We were also concerned with nitrogen oxide production by lightning," Brunner recounts, "the planes flew into thunderclouds; that surely had a certain adventurous twist to it."

A highlight in his career. As was, later on, the CarboCount-CH project, in which a Swiss team led by Brunner equipped the Beromünster tower – the former radio station, which is far away from major sources of pollution – with innovative measuring equipment. "That was Switzerland's first greenhouse gas monitoring network," the researcher recounts, "the station is still up and running and is now even part of the National Air Pollutant Monitoring Network, NABEL." Together with research stations such as Jungfraujoch and others, NABEL is the Swiss "hardware" for exploring environmental hazards and climate risks.

Opportunities for pioneering work, it seems, frequently came Dominik Brunner's way. And he seized them – out of sheer curiosity. An important virtue for a researcher, he reckons – as is the courage to pursue completely original ideas. Take satellites, for example: Brunner got his first inspiration back at the KNMI in Holland, which was developing the OMI satellite (Ozone Monitoring Instrument) at the time. "There I saw how elegantly you can combine modeling and satellite measurements," he says. And so he delved deeper into the subject and tried to improve the measurements with the help of new algorithms that took into account the fact that different soils, such as grassy areas, reflect sunlight differently to the sensors in the satellite.

SIMULATED STREET CANYONS

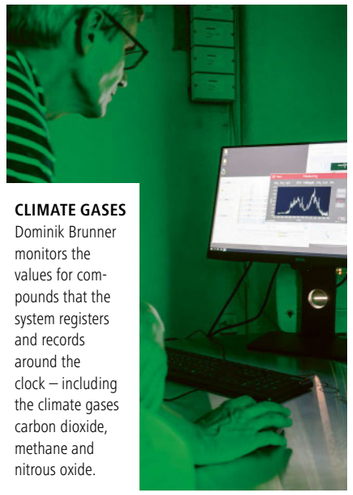
It shouldn't stop at this global perspective, though. Since joining Empa, Brunner has increasingly turned his attention to regional and small-scale problems, such as urban air pollution and heat islands: the climate in Zurich. And because the ever-increasing computing power of supercomputers allows ever finer weather models, simulations have been developed right down to individual street canyons.

From orbit to the sidewalk ... – yes, nods Brunner: "I have covered a great many topics and scales." An accumulation of knowledge and experience that he is happy to pass on – whether in lectures, in supervising PhD theses and also as head of a research group. "Working with motivated PhD students is always great, of course," he says, "but actually being the boss doesn't really suit me, especially when it comes to making unpleasant decisions. However, I've grown into this role and now feel quite comfortable with it."

IS THERE ANY ANNOYANCE AT ALL?

Well, he certainly dislikes some aspects in the debate about climate change: "It's often said that researchers are just stirring up panic to get more research funding," says Dominik Brunner, "that's something that annoys me." After all, the major trends in global warming are now well confirmed – and the fact that there are unanswered questions is by no means disputed. As an example, ▶

SAMPLING
After intermediate storage in gas containers, the air samples are stored in 24 glass containers according to predefined.



CLIMATE GASES
Dominik Brunner monitors the values for compounds that the system registers and records around the clock – including the climate gases carbon dioxide, methane and nitrous oxide.

CONTROL
The distribution of the air samples is controlled and monitored by a computer.

the climate scientist mentions feedback effects: As it gets warmer, the snow and ice regions melt, especially in the Arctic – more dark surfaces, in other words, which absorb more sunlight and thus in turn accelerate global warming.

On the other hand, as temperatures rise, trees will grow in higher altitudes. The tree line in Switzerland is rising, Brunner says, and the bottom line is that vegetation is growing worldwide – and thus also sequestering more carbon dioxide. But whether such effects will balance things out in the longer term? "After all, vegetation can't migrate at will," he says, "which really worries me: We might even be underestimating the consequences of global warming."

Wouldn't that require more aggressive communication? Also speak plain language politically, like some other climate researchers? Brunner prefers to focus on his research and not to expose himself too much in public – and he doesn't enjoy arguing anyway. Press interviews, well, he gives them – "if they have to be...", he adds with a smile.

PRECISE MEASUREMENTS

He'd rather kick off more exciting projects like a Europe-wide measurement campaign that has just started. The EU-funded project ICOS-Cities will take a close look at climate gas emissions in large cities – in Zurich, and later also in Munich and Paris. After all, metropolises are responsible for around 70 percent of climate gas emissions worldwide, according to rough estimates. For the three European cities of different sizes, ICOS-Cities will provide helpful data – also with the help of measurements on a residential tower of Zurich's Hardau II estate, almost 100 meters high, once the city's tallest building. In addition to conventional measurements of CO_2 concentrations, from which emissions are then calculated backwards, another method called eddy covariance is used. Thanks to extremely fast sensors, this allows records of climate gases such as CO_2, methane and nitrous oxide to be correlated with measurements of upwind and downwind conditions. This allows the "breathing" of the city to be recorded – and thus conclusions to be drawn about the causes of the emissions. And this data could in turn also reveal how road traffic, for example, affects the city on workdays or on weekends.

> "We might even be underestimating the consequences of global warming."

An appealing project for the atmospheric scout that will require ideas, curiosity and perseverance until 2025 – in the small circle of environmental scientists, not on the public stage of climate policy. And yet with practical value for people in big cities. "Climate change is certainly the Number 1 topic in atmospheric research," says Dominik Brunner, "and for me, one that is truly dear to my heart." ■

Further information on the topic is available at:
www.empa.ch/de/web/s503/team-modelling

Photos: Felix Wey / Empa

Der Satz ist unvollständig

"KEEPING AN EYE ON PROCESSES"

Pierangelo Gröning, President of the Advanced Manufacturing Technology Transfer Center (AM-TTC) Alliance and Empa's Research Commission and member of Empa's Directorate, explains the research institute's role in AM research.

Interview: Rainer Klose

PIONEER
Pierangelo Gröning is a member of Empa's Directorate and established research into Advanced Manufacturing at Empa.

Photo: Empa

What does the buzzword Advanced Manufacturing actually mean? What is so new about it?
Today, modern materials science involves more than just the development of materials. As long as the novel material cannot be processed, it has no technological significance. Empa is conducting research on a number of novel materials that can hardly or not at all be processed using well-known standard processes. Hence, we devote a great deal of attention to developing and refining manufacturing processes and processing methods – and in this respect we have achieved quite a lot in recent years.

How did this all begin?
Originally, nanomaterials triggered this thought in me. When you hear the keyword "nano", it quickly becomes clear that there simply aren't any processing machines there yet, and also that industry can't build on existing knowledge and simply further develop established processes in this area. So we had to look at process technology even then and show ways of generating added value with the help of these new materials. The second trigger was digitalization and the question of how to make the most of the possibilities of digitalization in manufacturing.

Do you mean automation for mass production?
No. I'm not thinking primarily about optimizing supply chains and manufacturing processes, but really about optimizing the product and its quality. There is an illustrative example from coating technology: We use plasmas for the deposition of hard coatings. Thanks to modern power electronics, we can now use pulse modulation to control the composition of the reactive particles, i.e. ions and radicals in the plasma, and thus directly influence the composition and structure of the coated layer, i.e. its physical properties. Compared to conventional plasmas, the coating process is virtually digitized by pulse modulation. This opens up completely new possibilities for optimizing the coating properties. This then begs the question: How do I find the right solution in this vast jungle of possibilities? We can't leave the product engineers out in the cold here – we need scientists who understand these processes from the bottom up. And in the age of digitalization, in-depth understanding means: I have to be capable of simulating the deposition process on the computer. Only in this way is it possible to compile a kind of book of recipes that suggests the right parameters to process engineers, with which they can achieve optimum results.

So digitalization alone is still no help?
No. Many people think that I now have lots of data and a neural network, and I'll just let it calculate until a suitable solution will pop up. But you can't take it that easy. That would just be trial-and-error with a little help from digital tools. To fully exploit the potential of digitalization, you have to physically understand the manufacturing processes much better, at a level where you can simulate them. Simulation can then be used to quickly and reliably determine the optimal process parameters. However, we are still a long way from achieving this, as it requires highly complex multiscale modeling that is computationally very intensive.

What is so special about AM?
The manufacturing processes we are talking about are additive processes. This means, material synthesis and production of the final product are combined in an integral manufacturing process. This, of course, increases complexity and poses completely new challenges for quality management, since the material quality of the product must now be ensured in addition to dimensional accuracy. A very clear-cut example is 3D metal printing. The material properties of the geometrically complex workpieces that can be produced by 3D printing processes are not isotropic, in other words uniform in all spatial directions. This is due to the sequential build-up process of 3D printing and the way the laser is guided. Various laser parameters such as laser power or scan speed can be used to influence the melting and recrystallization process, which in turn affects the properties of the material. In short, mastering 3D printing as a manufacturing process requires a in-depth understanding of materials and processes. Knowledge that is not available even in larger companies. And SMEs quickly reach their limits in this respect. You can clearly see the need for close cooperation between research and industry – in order to establish these new technologies on the market and thus give Swiss companies an innovative edge.

How will AM technologies play out in everyday life?
That's a tricky question. Perhaps the best way is to look at the trends and needs of industrial production. These are, on the one hand, individualization – customized products – and, as we have experienced in the last two years, improved resilience in production. This can be solved by high agility and short supply chains, and this is exactly what AM enables. What's more, AM has the potential to significantly change the production landscape by replacing centralized mass production with decentralized small-scale production – a huge opportunity for Switzerland as a production site.

What is Empa's role in the introduction of these technologies?
In addition to researching and developing new materials optimized for manufacturing technology, we also have research projects aimed at making technologies suitable for everyday use in industry. That is, to develop and provide the necessary tools to ensure robust, reliable use of the technology. As already mentioned, we develop simulation software to quickly and reliably determine optimal process parameters, but also to train and improve process understanding. Moreover, we develop measurement systems for monitoring production processes in real time. The development of such complex systems requires close cooperation between specialists from numerous fields. This is a great strength that we can exploit here at Empa, but also a strength of the entire ETH Domain. ■

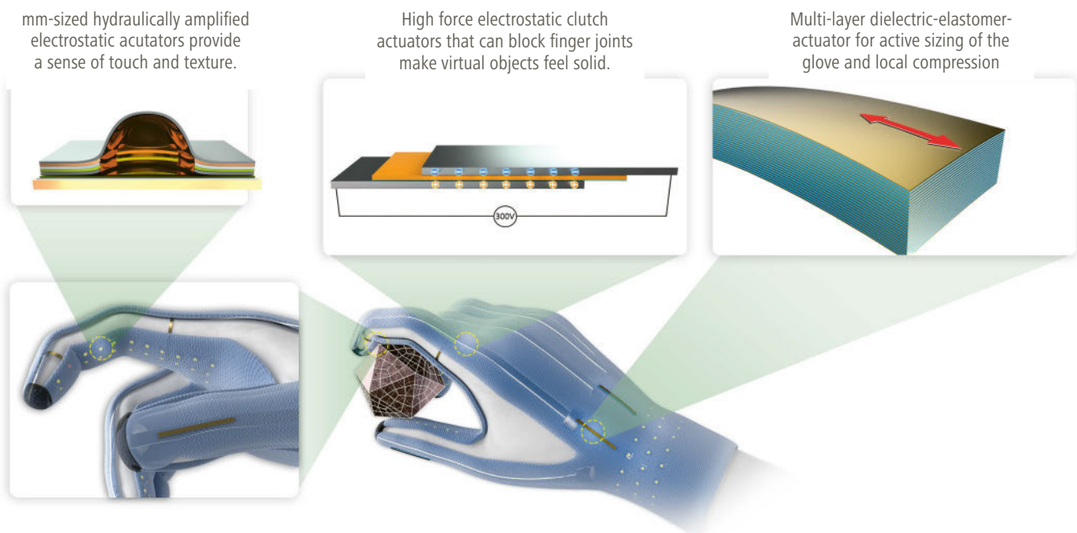
Grafic: Empa

Further information on the topic is available at: www.sfa-am.ch

THE VR GLOVE FROM THE 3D PRINTER

Together with EPFL and ETH Zurich collegues, an Empa team is developing next-generation VR gloves that will make virtual worlds tangible. The glove is to be tailored to each user and capable of being produced largely automatically – using a 3D printing process.

Text: Rainer Klose



Grafic: Herbert Shea / EPFL (2021)

Research sometimes needs a sacrifice. Empa researcher Patrick Danner has just made one – and filmed it. "When I applied a good 2000 volts to the sample, it caught fire," he reports drily in the debriefing. The mishap is clearly visible in his cell phone video: First it smokes, then flames erupt from the experimentally created polymer. "Hopefully, you were still able to save a piece of it," counters Dorina Opris, head of the "Functional Polymeric Materials" research group. A piece of evidence is important to learn from the result and draw conclusions.

With their research on electroactive polymers, Dorina Opris and Patrick Danner are part of a large-scale project called "Manufhaptics". The goal of the four-year project, led by Herbert Shea of the Soft Transducers Lab at EPFL, is a glove that makes virtual worlds tangible. Crucially, all of the glove's components, which exert various forces on the surface of the hand, are to be producible in a 3D printer. So this is about research into new materials, with the production method being considered from the very start.

THREE TYPES OF ACTUATORS

To make virtual surfaces feel real and objects tangible at the right size, the research teams from EPFL, ETH Zurich and Empa want to integrate three different types of actuators into the glove: Underneath the fingers, nubs can grow up to replicate a specific texture of a surface. In the area of the finger joints, electrostatic brakes are mounted that stiffen the glove and block the joints. This simulates larger, solid objects that offer resistance when touched. The third type of actuators that complete the virtual experience are called DEA's (Dielectric Elastomer Actuator). These DEA's are used on the back of the hand; they tighten the outer skin of the glove so that it fits perfectly at all points. During the VR experience, they can also apply pressure to the surface of the hand. The DEA's are Empa's topic.

INDUSTRY-READY
The desired electroactive polymer should have a consistency similar to hand cream so that the artificial muscles can be produced automatically in a 3D printer.

Photo: Empa

ARTIFICIAL MUSCLES FROM THE 3D PRINTER

Dorina Opris, the head of the research group, has years of experience with such electroactive polymers. "They react to electric fields and contract like a muscle," the researcher explains. "But they can also serve as a sensor, absorbing an external force and generating an electrical pulse from it. We're also thinking of using them to harvest energy locally: From movement, electricity can thus be generated anywhere."

The Manufhaptics project presents new challenges for Opris and her colleague Patrick Danner. "Until now, we have produced our polymers using solvents through a chemical synthesis," explains Opris. Now everything has to work without solvents: The plan is to superimpose up to 1000 fine layers from the 3D printer, always alternating between the electroactive polymer and a current-conducting layer. "Solvent has to be avoided in such a process" says Opris. Patrick Danner explains the next difficulty: The two inks needed for making the layers must have the exact right consistency to flow out of the 3D printer's nozzle. "Our project partner Jan Vermant from ETH Zurich wants something with similar properties to a hand cream. It should come out of the printer easily and then remain dimensionally stable on the base." And after that, this "creamy" layered structure still needs to crosslink into the appropriate polymer.

After a long series of tests, Patrick Danner found a promising formulation – a cream that is liquid enough and at the same time dimensionally stable, and from which electroactive polymers can be created in a single step. His colleague Tazio Pleji at ETH Zurich, a member of Jan Vermont's team, has successfully processed the material in his 3D printer into several layers – always alternating between polymer and electrode material. There are not yet 1,000 layers, but only about 10, and the artificial muscle from the 3D printer does not yet function satisfactorily.

THE COMPETITION IS AT HARVARD

But Opris and Danner are confident of mastering the task together with the printing specialists at ETH Zurich – possibly as the first team in the world. The only scientific competitors in this field are based at the renowned Harvard University in Massachusetts. "I know the colleagues there from some congresses," says Dorina Opris. "We watch very closely what they are upt to. And they're certainly watching our work, too." ■

Further information on the topic is available at: https://www.sfa-am.ch/manufhaptics.html

CRYSTALLINE LIGHT CATCHERS

GREEN PRODUCTION
Perovskite expert Fan Fu is looking for fabrication methods without toxic solvents.

Photo: Empa

Three institutes in the ETH Domain are conducting research on so-called perovskite-based optoelectronics, such as solar cells, photodetectors, and light-emitting diodes (LEDs). In a project called AMYS, labs of EPFL, ETH Zurich and Empa have now joined forces for four years to explore new chemical compositions, but also simple and scalable low cost production methods.

Text: Rainer Klose

Various solutions are available for converting sunlight directly into electricity. The best known are silicon solar cells, which are based on silicon single crystals. Solar cells of this type are relatively thick and fragile.

As a further variant, so-called thin-film solar cells have emerged, which are about 100 times thinner than crystalline silicon cells. This cell structure is flexible and can be vapor-deposited onto flexible substrates such as plastic films or metal foils. The thin-film cells made of the semiconductors gallium arsenide (GaAs), cadmium telluride (CdTe) or copper indium gallium sulfur selenium (CIGS), which have been known for some time, have now been joined by a new class: organic-inorganic perovskites. The term perovskite describes the common crystal structure of the materials in these thin films.

The interesting thing is that perovskites can not only be used as solar cells, but conversely can also serve as illuminators or as a basis for photodetectors, for example in X-ray devices or sensors for smartwatches. For this reason, this class of materials is currently attracting a lot of research activity worldwide. But there is a problem: Many of these perovskite crystals contain so-called organic ions as building blocks. These are crystal building blocks that contain carbon, nitrogen and hydrogen. They melt and evaporate at much lower temperatures than silicon or GaAs, CdTe or CIGS. As a result, many well-proven production methods are not well-suited for these materials.

INDUSTRIAL MANUFACTURING

The AMYS project (Advanced Manufacturability of Hybrid Organic-inorganic Semiconductors for Large Area Optoelectronics), which was launched as part of the Strategic Focus Area Advanced Manufacturing (SFA-AM), is now trying to solve precisely these problems. What is needed is an industrial manufacturing method for perovskite thin-films, which have so far been produced mainly in "wet" spray processes in laboratories.

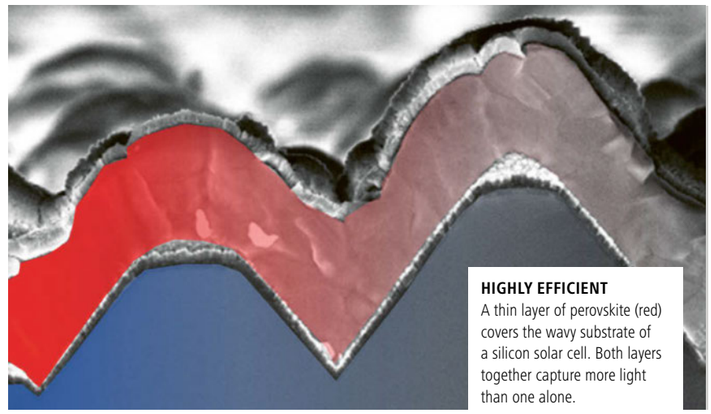
The tasks of the research partners are carefully distributed: Perovskite specialists Ayodhya N. Tiwari and Fan Fu's team from Empa's "Thin Films and Photovoltaics Laboratory" is looking for a flexible perovskite photodetector and solar cells; Chih-Jen Shih's team from ETH Zurich's Nanomaterials Engineering Research Group wants to build perovskite LEDs that produce light with particularly high color accuracy. And Christophe Ballif of EPFL and his team are on the hunt for particularly efficient tandem solar cells that consist of silicon on the bottom and a semi-transparent perovskite layer on top.

All the researchers have already done preliminary work: The EPFL team set a new world record in July: EPFL solar cells made of thick, crystalline silicon with a thin layer of perovskite on top achieved more than 31 percent efficiency. Such a value has already been achieved with other semiconductor cells, but these are about a thousand times more expensive to produce. So this opens a gateway to low-cost photovoltaics. "We have developed a two-step process to apply the organic ingredients of our perovskites gently and homogenously, on medium sized solar cells" explains Christian Wolff, who works on the EPFL team. "We now want to extend this process to a newly developed dry vapor-based method, which will enable to homogeneously cover even larger areas on the one hand, and at the same time see if there aren't even better chemical combinations."

Sebastian Siol at Empa is helping him with this. He is a specialist in coating processes and in the analysis of industrially produced thin films. He will use automated high-throughput experiments to screen a large number of different chemical compositions and process parameters with the goal to create a "library" of promising perovskite mixtures. This will give Wolff and his colleagues in all working groups crucial tips on where to look. That speeds up the journey to the goal of cheap, stable and large-area optoelectronic devices with a manifold of applications.

NON-TOXIC SOLVENTS

Empa researcher Fan Fu is a specialist in perovskites and is also part of the research consortium. He has taken on two tasks at once: On the one hand, he is looking for new photodetectors and solar cells based on perovskites. On the other, he also wants to find a "green path" for the industrial production of perovskite cells. "While the EPFL team has found a dry process, we at Empa have further developed the wet process," the researcher explains. "We no longer need any toxic solvents, which you can use in the lab but are a handicap in the industrial process. We now work with isopropanol – which is also used in every hair dresser's store." Fan Fu now wants to adapt his wet process to industrial processes such as slot-die coating. His Empa colleague Sebastian Siol is also helping him in his search for the optimal process. He will map the test specimens from Fu's test series and help find the optimal process parameters.



HIGHLY EFFICIENT
A thin layer of perovskite (red) covers the wavy substrate of a silicon solar cell. Both layers together capture more light than one alone.

Photo: Christian Wolff (EPFL)

SENSORS FOR SMARTWATCHES

Fan Fu has a second project that he is pursuing as part of AMYS: Perovskite cells could potentially also serve as photodetectors in cameras or X-ray detectors for medical imaging - and would have two key advantages: they are far cheaper and easier to produce than the silicon camera chips commonly used today. And they are flexible and can adapt to body shapes. Fan Fu uses an example to explain how interesting this could become: "Blood oxygen and pulse rate sensors in smartwatches are partly based on optical detection of blood flow." With flexible, optical sensors, such readings could be obtained much cheaper and at the same time more accurately in the future, says Fu. "Measurement devices that rest directly on the skin are a key technology for future interaction between humans and machines." ■

Further information on the topic is available at:
www.sfa-am.ch/amys.html

SENSITIVE DRILLS

Hearing-impaired people whose auditory nerve is still intact can often be helped with a cochlear implant. But inserting the implant into the inner ear is not without risks, as facial nerves can be damaged in the process. Empa researchers have developed a novel smart drill that minimizes the risk by automatically shutting off when it comes near nerves.

Text: Rainer Klose

COATING EXPERT
Kerstin Thorwarth developed the special drill with conductive and insulating hard coatings.

Photo: Empa / Grafic: NZZ-Infografik

Methods of Advanced Manufacturing can lead to remarkable advances in surgery. A group of researchers led by Stefan Weber of the University of Bern's ARTORG Center for Biomedical Engineering Research has developed a robot that can insert cochlear implants more gently than a surgeon. "When a surgeon performs the procedure, he has to remove relatively large areas of the skull bone," Weber explained in an article in the NZZ. Only when he can see where the nerves are located will he use the drill, he said. The robot, on the other hand, drills only a 1.8 millimeter wide channel, the course of which is determined on the basis of a previously created CT image.

But the surgeons must not drill at random, because the hole for the cochlear implant must lie exactly between the taste nerve and the facial nerve. At one point, these nerves are only three millimeters apart and must not be damaged under any circumstances. Until now, surgeons proceeded like this: Just before the constriction, they stopped drilling and irritated the facial nerve with an electric tip. If the twitching in the patient's face is not too strong, drilling can continue carefully.

DRILL AND STIMULATOR AT THE SAME TIME

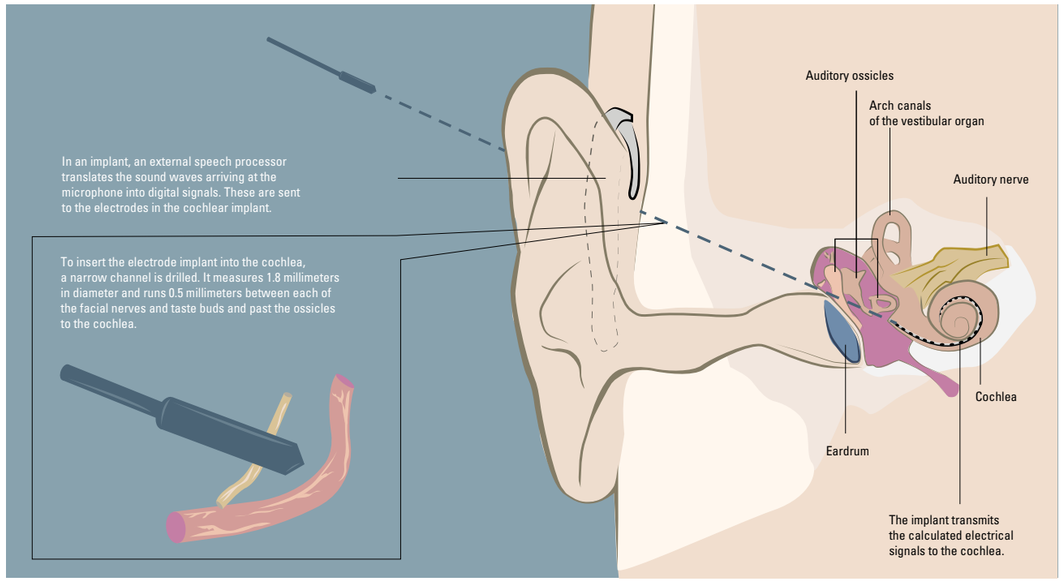
The physicians at the ARTOG Center approached Empa with the question: Couldn't we develop a drill that would also electrically stimulate the facial nerve, i.e. a drill that would indicate its position in the patient's skull? Kerstin Thorwarth from Empa's Surface Science and Coating Technologies lab went to work. Together with a colleague, she developed a drill with a conductive tip as part of a master's thesis and an Innosuisse project. The conductive and insulating hard coatings of titanium nitride (TiN) and silicon nitride (Si3N4) were applied to the drill tip by magnetron sputtering. For this, the individual windings of the drill had to be covered with special masks.

NOT YET CERTIFIED FOR MEDICAL APPLICATIONS

The drill with the special surface developed at Empa finally exhibited the appropriate electrical properties and also passed drilling tests in bone material carried out in the laboratory. The partners in Bern were pleased. "The smart drill for cochlear surgery could also be used for spinal surgery, for example," says project leader Stefan Weber.

Now the Empa researchers are working with the surgeons to find an industrial partner who can manufacture the smart drill in accordance with the legal requirements for medical devices. "This will require further significant development effort," says Weber. And that still needs to be funded. ■

Further information on the topic is available at:
www.empa.ch/web/208



STEEL WHEEL FOR BIODIVERSITY

Farmers once ensured rich harvests of hay by systematically irrigating meadows. In the canton of Zurich, environmentalists are bringing these methods back to life to create a valuable idyll with high biodiversity – using the historic technology of a water scoop wheel, which Empa-researchers helped to develop.

Text: Norbert Raabe

Dragonflies buzz through the sunny plain; blue butterflies and other colorful moths flutter from flower to flower. Midwife toads in search of females let out their call, while a grass snake looks for prey in the damp grass: a verse biotope for endangered species that is to be created in the former floodplain called Hundig near Glattfelden in the Zurich lowlands – thanks to an agricultural method that was common here long ago. Watering meadows probably originated in the Middle Ages and could more than double the hay harvest at the time. And to divert water from rivers and streams, farmers in German Franconia used nearly 200 water-scooping wheels around 1800.

This environmentally friendly technology is being revived here. "So it's an ecological and cultural-historical project," says project manager Daniela Eichenberger of the association "Wässerwiesen im Hundig". But this also required help from experts such as Silvain Michel from Empa's Mechanical Systems Engineering lab: He helped to implement the scoop wheel – based on a 1:5 model designed and built by metal construction entrepreneur Bernhard Krismer in Wallisellen. "The first tests with this scoop wheel showed that it would work in principle," Michel recalls.

But the work was only about to begin, because there were many question marks: How deep should the steel wheel, with a diameter of six meters after all, project into the Glatt? Would the water power of the shallow river at the planned location be sufficient to drive it? And to lift the necessary volume of water, which would then flow from the scoop cups into a channel leading to the meadows?

PROJECT WITH MANY HELPERS

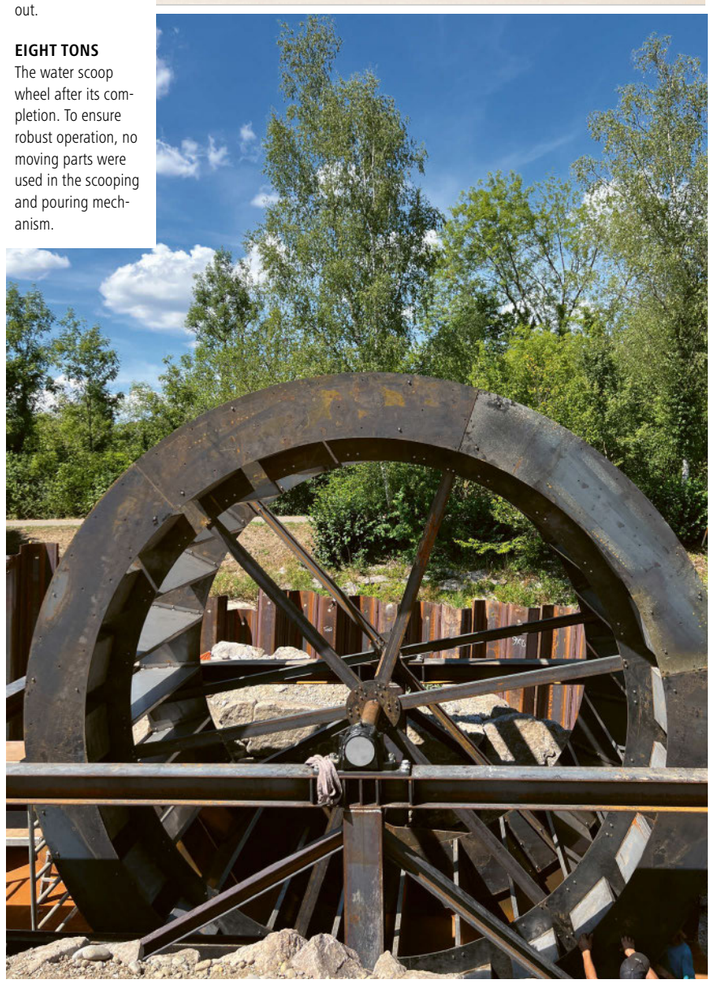
The operation of the water meadows in Hundig with the scoop wheel and the supply line via canals is to start next year after a long planning and implementation phase. The wheel alone costs around 300,000 Swiss francs; the total for the entire project amounts to 2.4 million. Funding comes from Zurich Airport – as one of its ecological replacement measures, to which it is obliged – and from numerous sponsors, including the lottery fund of the Canton of Zurich and the electricity company of the City of Zurich EWZ, as well as numerous foundations. The project sponsors are the Wässerwiesen im Hundig association and the Nature Conservation Department of the Office for Landscape and Nature of the Canton of Zurich.

NEW MEASUREMENT OF RIVER AND BED

The initial research showed that the hydraulic data on the Glatt at this location were partially contradictory. Therefore, experts remeasured the river with its water levels at the planned location – and finally decided to change the thresholds of the river bottom. Above the scoop wheel, the threshold was raised by 30 centimeters, below it it was lowered by 30 centimeters. Two "steps", over which the Glatt flows towards the Rhine, were thus combined into one larger one – a gradient of almost one meter that could be used to increase the potential energy of the water for driving the wheel.

Nevertheless, initial analyses showed that hydropower could be in short supply; especially since the draw from the river is limited. The Glatt's prescribed residual flow of 1070 cubic meters per second must be maintained at all times – and withdrawal has been limited to a maximum of 120 liters per second. This is what preliminary tests had shown was needed in the meadows in 2019. At temperatures above 20 degrees, however, the quantity is gradually reduced – down to a quarter, depending on the discharge rate of the Glatt into the Rhine, which is recorded around the clock.

MADE IN 1895
A historical photo shows how irrigation channels were laid out.



EIGHT TONS
The water scoop wheel after its completion. To ensure robust operation, no moving parts were used in the scooping and pouring mechanism.

Photos: Empa, AWEL

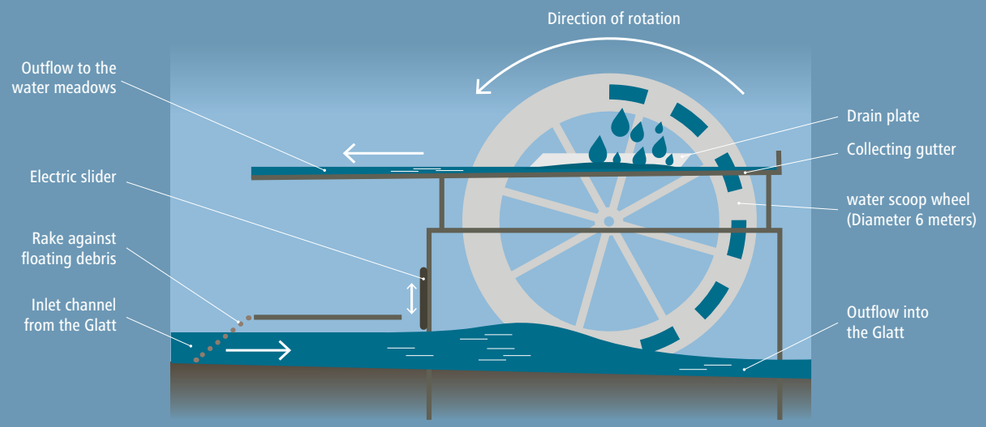
Ultimately, everyone wants to keep long-term climate protection in mind – as well as the interests of the local fishing club, which was concerned about the water level and its catch, including coveted trout, and objected to the building concession. "I have full understanding for this," says master metalworker Krismer, designer of the bailer, who is, after all, an angler himself. And project manager Daniela Eichenberger is also glad that a sensible solution could be found through successful negotiations. "Now it's time for implementation!" says the biologist, who has been in charge of the project since 2016.

DRIVE WITH PITFALLS AND TRICKS

Ensuring the reliable drive of the eight-ton scoop wheel under these conditions proved to be a real challenge for Empa researcher Silvain Michel. Initial calculations had assumed an efficiency of 90 percent – an extremely favorable ratio of energy supplied to energy used. But literature research showed that such an "undershot" water wheel, which is driven by water from below, usually achieves only up to 40 percent efficiency. "The maximum is 50 to 60 percent," Michel says, "so the original assumption was way too optimistic."

What to do? Michel sought advice from an expert: The experienced hydraulics expert and emeritus professor Michel Dubas from the Valais University ▶

How the water scoop wheel works



The water scoop wheel weighs around eight tons and is designed to extract a maximum of 120 liters of water per second from the river Glatt. From the scoop cups, the collected water falls over an inclined drainage plate into the collection channel. From there, it is finally directed via a canal near the Glattfelden train station to two target areas. The meadows are irrigated via detour structures that can be opened and closed. Excess water is returned to the Glatt.

of Applied Sciences in Sion made his knowledge and experience available – free of charge, by the way, as the Empa researcher points out. And after joint deliberations, Dubas proposed a simple but efficient solution: a goiter in the steel sole below the scoop wheel – in other words, a targeted downward bulge that ensures that the water accelerates significantly once again before it presses into the scoops of the wheel.

With this idea and other details, the hydraulics experts calculated, the pumping capacity of the wheel just about reaches the required values. And they are convinced that the performance is sufficient even despite some technical brakes on the water flow: After all, a rake in front of the wheel has to keep out floating material such as branches. Moreover, a curtain of steel chains in the water generates noise to ensure that fish stay in the Glatt and do not stray into the branch channel to the scoop wheel.

Two video cameras in the water will film whether this strategy actually works. And when the operation of the meadow watering system starts for the first time next year, not only the local fishermen will keep an eye on the scoop wheel, but also the Empa expert and the designers – to make sure water quantities are controlled reliably and the scoop wheel runs smoothly. After all, it is necessary to regularly look after things, check the rake and inflow gate valves, and also regularly lubricate the rotating axle of the steel wheel – the job for a water wheel keeper who is soon to be recruited. ■

Further information on the topic is available at: www.waesserwiesen-hundig.ch

Grafic: Empa

PROGRESS
Tina Bürki sees the placenta-embryo chip as the future for developmental toxicity tests.

Photo: Empa

A CHIP TO REPLACE ANIMAL TESTING

Empa researchers are developing a medical chip in collaboration with the ETH Zurich and the Cantonal Hospital of St. Gallen that will allow statements to be made about the effect of substances on babies in the womb. The Zurich-based ProCare Foundation is funding the project, which was recently launched.

Text: Andrea Six

New drugs made from nanoparticles that can easily penetrate any interface within our bodies are a great hope in medicine. For such hopefuls to reach the market, their safety must be ensured. In this context, it must also be clarified what happens if a substance manages to penetrate the natural barrier between baby and mother, the placenta, in the body of pregnant women. "Environmental toxins can also pose a major threat to the sensitive fetus if they penetrate the placental barrier or disrupt the development and function of the placenta, thus indirectly harming the fetus," explains Tina Bürki, Empa researcher at the Particles-Biology Interactions lab in St. Gallen. A team from Empa and ETH Zurich has been working for some time on the question of how this so-called embryotoxicity of substances can be determined precisely, simply and reliably. Now the team is developing a new system that will detect embryo-damaging substances

without the need for animal testing. The recently launched project is funded by the Zurich-based ProCare Foundation.

A UNIVERSE IN A POLYMER CASE

At the heart of the process will be a polymer chip, about the length of a human finger, that houses a small universe: Human cells grow on the chip that are to model the placental barrier and the embryo under conditions that are as close to reality as possible. For this purpose, cells of the placenta are cultivated on a porous membrane to form a dense barrier, and embryonic stem cells are formed into a tiny tissue sphere in a drop of nutrient solution. To simulate blood circulation, a shaker continuously tilts the chip back and forth. Test substances can be added to the maternal side of the placenta. This allows the researchers to study the transport of the test substance and the effects on both tissues. "We already know that such a test system can work, as a simplified prototype was developed during a preliminary study with the Bio-engineering lab at ETH Zurich," says Bürki.

RESEARCH FUNDING

Empa's "Zukunftsfonds" supports outstanding research projects that are not (yet) supported elsewhere. For the present project, the ProCare Foundation will be covering the entire project costs. The foundation supports projects that can particularly advance applied research in the field of animal welfare and environmental protection.

What is special about this new chip is that the researchers want to improve the cell models by replacing the previously used laboratory cell lines or mouse cells with so-called primary human cells and a human stem cell line. "We are working closely with the gynecological clinic of the Cantonal Hospital of St. Gallen and can isolate the cells we are looking for from placental tissue that would otherwise be discarded after birth," Bürki explains. The cells will be used to develop an improved three-dimensional placenta model. Ultimately, the embryo-placenta chip will allow the interaction of placenta and embryo to be reproduced and transport processes at the placenta as well as direct and indirect harmful effects of a substance on embryonic development to be investigated.

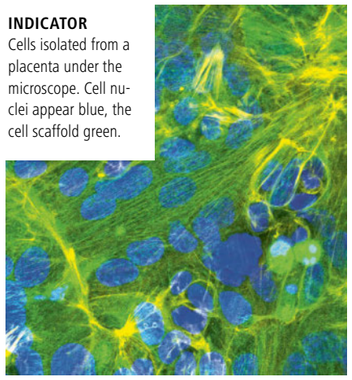
ALTERNATIVE MODEL ADVANTAGEOUS

Studies on the developmental toxicity of drugs and environmental toxins currently rely on animal experiments with pregnant mice. In the EU, for example, 840,000 animals were used in toxicity and safety research in 2017, of which nearly 100,000 were used for developmental toxicity. Thanks to the new chip, the number of these animal experiments could be significantly reduced.

This is not only an important goal from an ethical point of view, because the significance of a test with pregnant mice is not optimal for assessing drug safety in humans: "The placenta has a very specific structure in each species – and in mice it is correspondingly different from that in humans," says Empa researcher Bürki. Better insights can be gained from the alternative in vitro model, i.e. the new system "in the test tube", because the new chip technology with primary human cells can more reliably map what happens at the interface between mother and child.

ACCELERATING NEW THERAPIES

The new test system is intended as a simple and precise way to check the safety of a substance early in the development of new drugs and thus accelerate the application of new therapies. In this way, the chip supports the safe-by-design principle, which envisions the early integration of safety aspects into the innovation process.



INDICATOR
Cells isolated from a placenta under the microscope. Cell nuclei appear blue, the cell scaffold green.

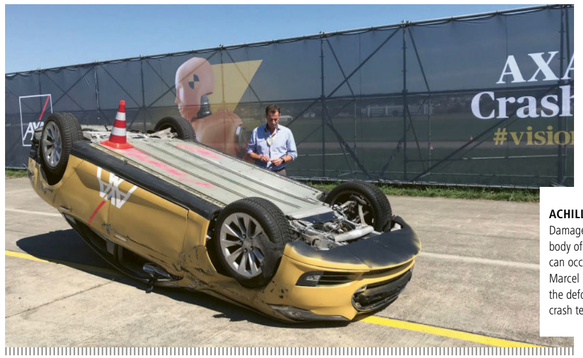
The need for developmental toxicity studies in industry is also increasing for another reason: The safety of chemicals and particles in the environment needs to be clarified, as required by the current REACH chemicals regulation. "The placenta embryo chip should ultimately be a user-friendly test kit that can provide important data on potential health risks during pregnancy," she said.

The project's results are also expected to help fill knowledge gaps in understanding the placental barrier. "The chip will be a model that brings together the processes at the placenta and in the embryo. In this way, we hope to better understand the complex interactions that take place by means of signaling substances in the future," says Tina Bürki. ■

Further information on the topic is available at:
www.empa.ch/web/s403

Photo: ETH Zurich/Julia Boss

BATTERY EXPERT ACCOMPANIES CRASH TEST



ACHILLES' HEEL
Damage to the underbody of electric cars can occur. Empa expert Marcel Held looks at the deformation after a crash test.

This year's crash test by the AXA insurance group on 25 August at the Dübendorf airfield focused on the growing number of electric cars. The experts caused a Tesla Model S to roll over on a ramp, damaging the car's underbody. In the subsequent panel discussion, Empa battery expert Marcel Held explained the potential dangers of such an accident. The danger stems from the so-called thermal runaway that can occur after battery cells are damaged. The battery overheats, and moves out of safe operating condition. The process is self-reinforcing, and the pressure in the cell increases until the case finally bursts. Flammable gases leak out, and later high pitched flames. Firefighter Michael Derungs of Schutz & Rettung Zurich pointed out that his colleagues are well prepared and practiced for such situations. Michael Pfäffli, Head of Accident Research & Prevention AXA Switzerland said that – contrary to public perception – fires involving electric cars would not occur more frequently than those involving cars with combustion engines. He also said that rescuing passengers from an electric car involved in an accident generally poses no problems.

www.axa.ch/de/ueber-axa/medien/medienmitteilungen/aktuelle-medienmitteilungen/20220825-crashtests-2022.html

WOODEN CREDIT CARDS MADE IN URI

In July 2022, Swiss Wood Solutions AG, a spin-off of Empa and ETH Zurich, moved to Altdorf in the canton of Uri. There, the young company and its ten employees will start producing sustainable credit cards made of wood. "Swiss Wood Cards" are made from veneers of local woods such as maple, curly maple, cherry, oak, spruce and many others. Each card is unique with personalized laser engraving or color printing and functions like any other traditional credit card. The location was chosen in favor of the canton of Uri in April 2022 after evaluating several sites.

https://swisswoodcards.swisswoodsolutions.ch/en/

SCRATCHPROOF
Bank cards made from native wood species are hardened using a patented process.

Photos: Empa / Swiss Wood Solutions

GREEN ECONOMY – HOW DOES THAT WORK?

CONVERSATION
Peter Richner discusses with Andreas Kuhlmann from the German Energy Agency (DENA).

Photo: Thomas Oehrli

For the tenth time, the Swiss Green Economy Symposium in Winterthur brought together experts from industry, research and politics to promote dialog, innovation and practical implementation – this year with a focus on circular economy. At a panel discussion on the future of energy, Peter Richner, Deputy Director of Empa, indicated that regarding the impending energy crisis, behavioral changes will have the greatest impact in the short term. He also pointed out that many of the solutions developed by Empa for a decarbonized energy system now have a better chance of being implemented, and gave an outlook on future research priorities at Empa: solutions that are CO_2-negative, i.e. that lead to a reduction in the CO_2 concentration in the atmosphere. Kurt Bisang from the Federal Office of Energy (SFOE), Alexander Keberle from economiesuisse, Andreas Kuhlmann from the German Energy Agency GmbH and Gerd Scheller from Siemens Switzerland and swisscleantech participated in the discussion.

https://sges.ch/

EVENTS
(IN GERMAN AND ENGLISH)

11. OKTOBER 2022
Live Stream: Energiemanagement der Zukunft
Zielpublikum: Öffentlichkeit
https://digitaltag.empa.ch/
online

04. NOVEMBER 2022
Kurs: Tribologie
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/tribologie
Empa, Dübendorf

08. NOVEMBER 2022
Technology Briefing:
Advanced Manufacturing at Empa
Zielpublikum: Industrie, Wirtschaft, Wissenschaft
www.empa.ch/web/tb
Empa, Dübendorf

17. NOVEMBER 2022
Seminar: Digital fabrication in the construction industry
Zielpublikum: Industrie und Wissenschaft
www.empa-akademie.ch/rfa
Empa, Dübendorf

01. DEZEMBER 2022
Technology Briefing: Photovoltaics
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