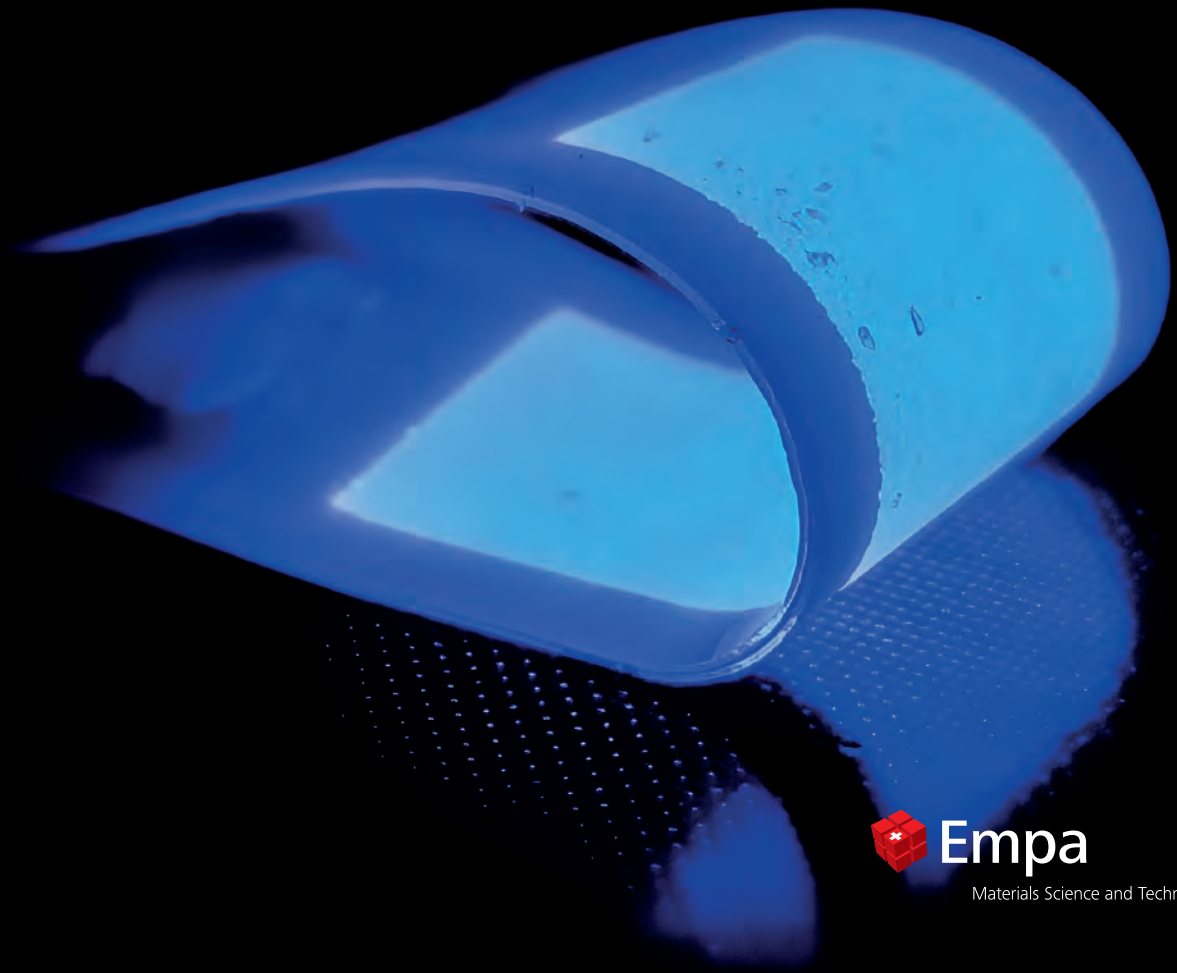
Annual Report 2022



Empa

Materials Science and Technology

Our Vision.
Materials and Technologies for a Sustainable Future.

Cover Image:
Stretchable AC electroluminescent device for application in flexible electronics (e.g. flexible displays).

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Research with an impact – thanks to focus and cooperation

2022 was a year of many changes, around the globe, in Switzerland and at Empa. After 13 extremely successful years under the helm of Gian-Luca Bona, I took over the leadership of Empa in June with great enthusiasm and a zest for action, but also with a lot of respect. I was very pleased to experience a great deal of support from our stakeholders in industry, research, politics and administration as well as from our staff.

Empa has turned into a veritable hotbed of innovation for Swiss industry over the past decade. So we are not setting a radically new course, but instead will be working to achieve an even greater impact for our partners as well as for society as a whole with our outstanding research as "The Place where Innovation Starts".

One of our approaches to achieve this is through increased agility, which we in turn want to enhance by cross-linking our internal competencies considerably more across all organizational units, in order to more efficiently develop practical solutions to the challenges of our time. In future, we will thus focus on four Research Focus Areas: Nanoscale Materials and Technologies; Energy, Resources and Emissions; Built Environment; and Health and Performance.

Moreover, we will establish a dynamic hub structure in order to pool the expertise of our different laboratories on specific current topics such as post-lithium batteries or quantum materials. These hubs represent dynamic, flexible, adaptive "tag teams" that come together to address specific issues and will be discontinued once the goals have been achieved – only to reform again with a new configuration to tackle another problem.

All these measures have one goal: to address the complex challenges in a comprehensive, inter- and transdisciplinary way. One example is the field of energy: Our guiding principle here is to view the Earth's atmosphere and its components, such as the greenhouse gas CO_2, as a valuable source of raw materials. These need to be extracted and processed into products such as synthetic fuels or starting materials for the chemical industry. For one thing, this provides us with (storable and transportable) energy carriers, but also with products and materials for our daily lives.

Things get really exciting when the synthetic hydrocarbons produced in this way are broken down again into the energy carrier hydrogen (H_2) and into (solid) carbon. Energy losses are the price for this, but the bottom line is that CO_2 is removed permanently from the atmosphere and can be stored in the form of solid carbon for an unlimited period of time, for instance in building materials such as concrete and asphalt, where it can even replace any limited raw materials. This is a crucial step towards the decarbonization of our society, which we all can only achieve by joining our forces.

In addition to increased in-house collaboration, we also want to further strengthen the cooperation with our external partners, for example within the ETH Domain, through various Joint Initiatives, as well as among the four research institutes as part of the ENRICH initiative. Of course, we also want to boost cooperation beyond the academic sphere, especially when it comes to the practical implementation of our research. After all, given the complexity of the tasks at hand, even an outstanding research institution will eventually reach its limits. Together, however, we can keep pushing boundaries and find solutions for a sustainable and liveable future.

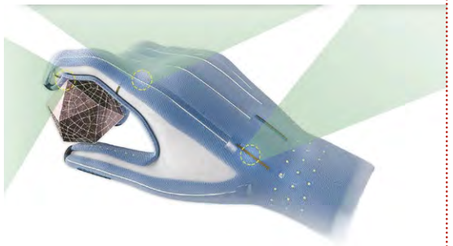
Thank you all for your cooperation and support. And enjoy reading our current Annual Report!

Tanja Zimmermann

***Prof. Dr. Tanja Zimmermann**, Director*

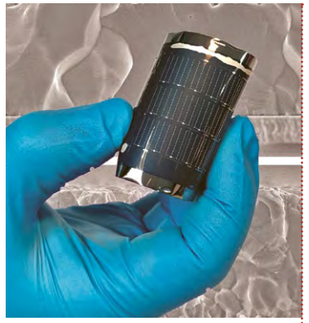
Year at a Glance

Tanja Zimmermann – Empa's first woman CEO
In February, the Federal Council appointed Tanja Zimmermann as Empa's new CEO. She assumed her new office on 1 June. Previously, the internationally renowned materials scientist was a member of the institute's Directorate and head of the Functional Materials department, as well as co-head of the Built Environment Research Focus Area. Tanja Zimmermann is the first woman in Empa's over 140 years of history to take over as head of the materials research institute.

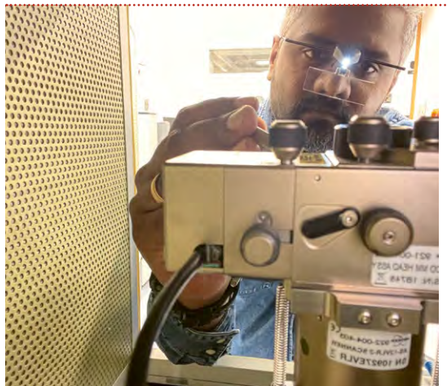


A 3D-printed VR glove
Together with colleagues at EPFL and ETH Zurich, an Empa team is developing next-generation VR gloves that will make virtual worlds in the metaverse tangible. The glove is to be tailored to each user and capable of being produced largely automatically – using a 3D printing process. Hydraulically amplified electrostatic actuators only millimeters in size provide a sense of touch and texture. Electrostatic clutch actuators allow for high force that can make virtual objects feel solid. Illustration: Herbert Shea/EPFL

Engineering award for Empa's pioneering work
A light and elegant rail bridge near Stuttgart was awarded the German Civil Engineering Award 2022 for its innovative design as a network arch bridge with carbon fiber-reinforced polymer (CFRP) cables. Around 40 years ago, using CFRP in construction was revolutionary. The former CEO of Empa in Dübendorf, Urs Meier, came up with this idea and contributed significantly to its implementation through his research and developments. On 8 January 2023, he celebrated his 80th birthday. During his career, Meier obtained several patents, published around 300 scientific and technical publications, and was awarded many distinctions. Image: sbp/Andreas Schnubel



Energy output increased – once again
One year after announcing their last efficiency record, Empa scientists have achieved yet another record figure of 22.2 percent for flexible CIGS solar cells on polymer film. Bifacial solar cells can potentially generate even more solar electricity as they collect solar energy on both their front and their rear side. The Empa team has now developed a production process that results in record efficiencies of 19.8 percent for the front and 10.9 percent for the rear side. Moreover, they also produced the first bifacial perovskite-CIGS tandem solar cell, which opens up the possibility of even higher energy yields in future.



Parkinson's: Is copper a possible cause?
Copper exposure in the environment and the protein alpha-synuclein in the human brain could play an important role in the pathogenesis of Parkinson's disease. A team of researchers at Empa and the University of Limerick was able to show how the protein takes on an unusual shape when exposed to high concentrations of copper ions. Their findings might help in the development of new strategies for the treatment of neurodegenerative diseases.

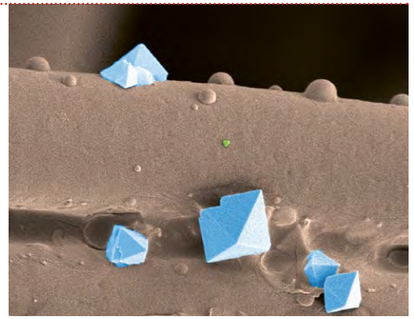
Concrete as a carbon sink?
The cement industry emits large amounts of climate-damaging carbon dioxide – but alternative binders based on magnesium carbonate could even bind CO_2. For her research project, which aims to lay the foundations and prepare practical applications for this revolutionary idea, Barbara Lothenbach has received the first Advanced Grant from the Swiss National Science Foundation (SNSF) for Empa.

Early warning system for dementia
Alzheimer's and other types of dementia are among the most widespread diseases today. Diagnosing these is complex; a reliable diagnosis can often only be established late in the course of the disease. A team of Empa researchers, together with clinical partners, is now developing a new diagnostic tool that can detect the first signs of neurodegenerative changes using a sensor belt. In a study, the researchers showed that altered skin temperature readings measured with the belt provide an indication of the cognitive performance of test subjects – and can do so well before the first signs of dementia develop.

A swarm of drones for construction and repair
An international team of researchers from Empa and Imperial College London looked to bees as an example in order to develop a swarm of cooperative drones. Under human control, these flying robots work as a team to print 3D materials for building or repairing structures, as scientists reported in the cover story of the September issue of Nature.
Image: Yusuf Furkan KAYA, Aerial Robotics Laboratory, Imperial College London/Empa

Batteries for a circular economy
The CircuBAT research project aims to create a circular business model for the production, application and recycling of lithium-ion batteries used for mobility. Seven Swiss research institutions, including Empa, and 24 companies are joining forces to look for ways to boost sustainability in all stages of a battery's life cycle. The project is part of the newly launched Flagship Initiative of Innosuisse, the Swiss Innovation Agency. Image: CircuBAT

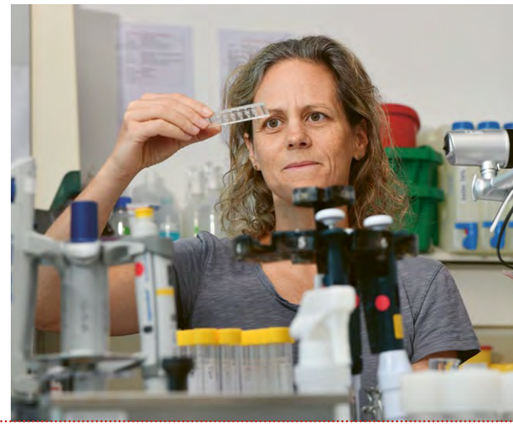
Viruses caught in the act
Using a new analytical method, Empa researchers have tracked viruses as they pass through face masks and compared their failure to pass the filter layers of different types of masks. The new method is intended to accelerate the development of surfaces that can kill viruses.



Making plane approaches quieter and more climate-friendly
A joint project of Empa researchers and partners in Switzerland, Germany and France is paving the way for airplane approaches that cause less noise and CO_2 emissions – thanks to intelligent assistance systems for the pilots. The team developed new on-board functionalities that support pilots during the approach, including optimized flap and landing gear settings to reduce noise and fuel consumption.

A paper battery, switched on by a drop of water
An Empa team has developed a water-activated biodegradable paper battery. According to the researchers, it could be used to power a wide range of small, low-power electronics – such as smart labels for tracking objects, environmental sensors and medical diagnostic devices – and minimize their environmental impact. This idea was even included on a list of the most important inventions of the year published by the US magazine TIME.

A chip to replace animal testing
Using a polymer chip and human placenta and stem cells, Empa researchers are developing a system for the investigation of developmental toxicity in collaboration with ETH Zurich and the Cantonal Hospital of St. Gallen. The assay system is intended to be an alternative to animal testing in future. The chip will allow studies to be conducted about placental transport and the effects of substances on unborn babies. What is needed is just such a test system for the development of new medication or for risk assessment, for example of nanoparticles in the environment. Zurich-based ProCare Foundation is funding the project.



Virtual cold chains against food waste
Together with Empa, the non-profit organization Basel Agency for Sustainable Energy (BASE) is working to prevent food waste – with the help of a newly developed mobile app that helps to minimize losses in food production, particularly in warmer climate zones, as well as lower greenhouse gas emissions. The app provides market information before and after the harvest in order to ensure the right handling, storage and protection of goods and to enable smallholders to monitor the quality of their products. Image: BASE

Selected Projects

Investigating new materials and accelerating the development of innovative technologies; supplying the stimulus for the sustainable development of our society; providing the scientific basis for political and societal decisions – these are Empa's core objectives, which it pursues through research and development, cooperation, networks and partnerships as well as services, expertise and consulting activities. The following snapshots from the institute's laboratories give an insight into Empa's multifaceted research activities.

A sensitive drill

Dr. Kerstin Thorwarth, kerstin.thorwarth@empa.ch

Hearing-impaired people whose auditory nerve is still intact can often be helped with a cochlear implant. However, 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 this risk by automatically shutting off when it comes into close proximity with nerves.

Together with a team led by Stefan Weber of the University of Bern's ARTORG Center for Biomedical Engineering Research, the researchers drew upon advanced manufacturing (AM) methods to create an intelligent drill for use in surgery. Ultimately, the drill is wielded by a surgical robot. The goal is to insert cochlear implants more gently than even a surgeon could, as a human surgeon has to remove relatively large areas of the skull bone during the intervention and cannot use the drill until the position of the nerves has become visible. Surgeons cannot simply drill at random, because the hole for the cochlear implant must be made between the gustatory and the facial nerve. These nerves must be protected at all costs. This is a very delicate operation, as the two nerves are only three millimeters apart in one spot. Until now, surgeons proceeded as follows: Just before the constriction, they stopped drilling and stimulated the facial nerve using an electric tip. If the twitching in the patient's face was not too strong, they could continue drilling carefully.

Drilling and stimulating at the same time

The physicians at the ARTORG Center approached Empa with the following question: Could a drill be developed that would also electrically stimulate the facial nerve, i.e. a drill that would indicate its position in the patient's skull by itself? Kerstin Thorwarth and her team from Empa's Surface Science and Coating Technologies lab developed a drill with a conductive tip as part of an Innosuisse project. The conductive and insulating hard coatings of titanium nitride (TiN) and silicon nitride (Si_3N_4) were applied to the drill tip by way of magnetron sputtering. For this, the individual windings of the drill had to be covered with special masks.

Not yet certified for medical applications

Ultimately, the drill with a special surface developed at Empa exhibited the suitable electrical characteristics and also passed drill tests of bone material in the lab. Another advantage is that the robot drills only a 1.8-millimeter-wide channel, the course of which is determined on the basis of a previously created computed tomography image. The partners were satisfied and see possible applications for the smart drill, not only in cochlear implants but also in spinal surgery.

Now, the Empa researchers are working with the surgeons in Bern to find an industrial partner who can manufacture the smart drill in accordance with the legal requirements for medical devices, as the further development effort still needs the appropriate financial support. //

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A sensitive drill for cochlear implants.

2
Kerstin Thorwarth developed the special drill with conductive and insulating hard coatings.

How data processing can heat buildings: micro data centers in the neighborhood

Philipp Heer, philipp.heer@empa.ch

A click on the internet leaves traces behind. Not only on the web itself, but also in the form of an ecological footprint. Because even though all our data is supposedly floating in the cloud, physical data centers are required to process and store it, and these consume huge amounts of energy – a significant proportion of which is used to cool the facilities. The latest digital trends such as artificial intelligence (AI), augmented reality (AR) and the Internet of Things (IoT), pose further challenges: The volumes of data to be processed are increasing to an overwhelming degree, and at the same time, reactions are required in real time – without delay. To achieve this, the data must be processed much closer to the place where it is generated. For instance, in the form of an edge data center in the neighborhood. In the best case, however, this local data center will not only be used for data processing, but – connected to the energy system – will also be used to heat the buildings. A field test with edge data centers in the NEST research building at Empa and at two other locations in Turkey and the Netherlands aims to explore the potential of this idea.

Intelligent cooling

The project, called ECO-Qube, is supported by the EU's Horizon 2020 funding program and brings together research and industry partners from Switzerland, Turkey, Spain, Germany, the Netherlands and Sweden. Its goal is to reduce both the energy demand and CO_2 emissions of small data centers by one-fifth each. Conventional data centers often operate at only about 15 percent of their capacity. Despite this, the servers need power and must be cooled constantly. To counter this problem, the cooling of the ECO-Qube data centers is made intelligent: Sensor data from the individual IT components is accumulated into Big Data structures and helps to ensure that the heat distribution within the components is accurately recorded at all times. AI combines this data with airflow simulations so that cooling can be specifically targeted. At the same time, the computing loads in the three test data centers are distributed in such a way that all three facilities can be operated as energy-efficiently as possible.

Reusing waste heat

The three data centers are also directly integrated in the energy systems of the surrounding neighborhoods and are intended to be powered with renewable energy as far as possible. At NEST, this power is supplied by the photovoltaic systems of the NEST units and the Empa mobility demonstrator move, among others. The data center's waste heat is fed into the existing medium or low-temperature network. In this way, it directly feeds the building's heating systems in winter and also acts as a source for a heat pump year-round that provides domestic hot water. Coupling the electrical and thermal systems with IT infrastructure and data processing offers a great potential for optimization, up to the fully sustainable operation of these systems.

The project is due to run for three years. After its completion, the team intends to provide guidelines for planners and building operators in order to support them in the energy-efficient integration of data centers into buildings and neighborhoods. //

1
Using artificial intelligence (AI) and accumulated sensor data, only those locations inside the data center that currently require it can be cooled.

2
The ECO-Qube data center at NEST is both part of the IT infrastructure and part of the building technology.

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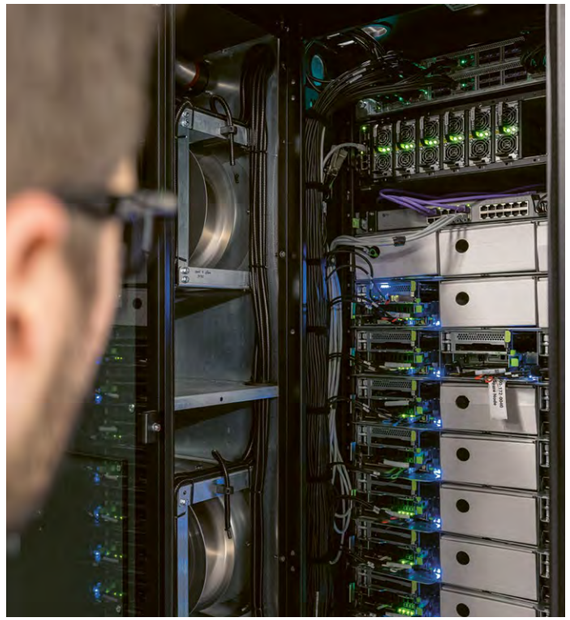

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Rail pads against railroad noise and vibrations

Dr. Bart Van Damme, bart.vandamme@empa.ch

Railroad noise is often a nuisance for residents living near railroad tracks. Hundreds of millions of Swiss francs have already been invested in noise barriers, quieter braking systems and other measures with the goal of protecting at least 80 percent of the Swiss population from railroad noise by the year 2025 – but because rail traffic will continue to increase, a lot remains to be done.

To further reduce noise, researchers at Empa and the Haute École d'Ingénierie et de Gestion du Canton de Vaud, under the leadership of EPFL, have redesigned an inconspicuous component of the rail system: rail pads. These components are made of elastic polymers and are placed between the rails and concrete ties. They serve to protect the track made of compacted ballast and concrete ties, which is subject to high loads, by allowing the rails to move imperceptibly. But it is precisely this freedom to move that makes the rails generate more noise – and this noise is the decisive factor at the most frequent speeds of 60 to 160 km/h.

Tailor-made composite material

In Switzerland, rail pads are usually made of the hard polymer ethylene vinyl acetate (EVA). It is true that a softer material would provide better protection for the tracks, but at the cost of higher noise pollution. To solve this tricky problem and create a quieter alternative, the research team developed novel rail pads made of a composite material in the past few years on behalf of the Federal Office for the Environment (FOEN) and the Federal Office of Transport (FOT) in collaboration with SBB, the Swiss Federal Railways.

As a first step, the experts turned to a combination of the hard material EVA and the soft material polyisobutylene (PIB), the damping qualities of which can be precisely tuned to the frequency range from about 200 to 2,000 Hertz, at which vibrations are particularly noisy. They then designed dozens of variants: sandwich structures made of flat layers – with and without a lid made of EVA, zigzag-shaped fillings made of PIB, surfaces with incisions and all sorts of other alternatives.

Practical test on real rail tracks

Ultimately, computer calculations and laboratory measurements of newly developed components resulted in another good solution: a soft material with a high degree of damping and exactly specified geometry. The researchers produced the first prototypes together with the plastics manufacturer Semperit. And finally, in March of 2022, they tested their rail pads in practice together with SBB experts – on a 100-meter section of track near Nottwil in the canton of Lucerne. Measurements of the vibrations of track ties and rails, sound levels and other data were used to precisely record their effects during real train runs.

The results were positive. The analysis of the data showed that the new rail pads noticeably dampened both train noise and vibrations. Thanks to these results, the researchers are now optimistic that the novel components will be used in practice in the future, if the production of the intermediate layers would not lead to significant additional costs. //

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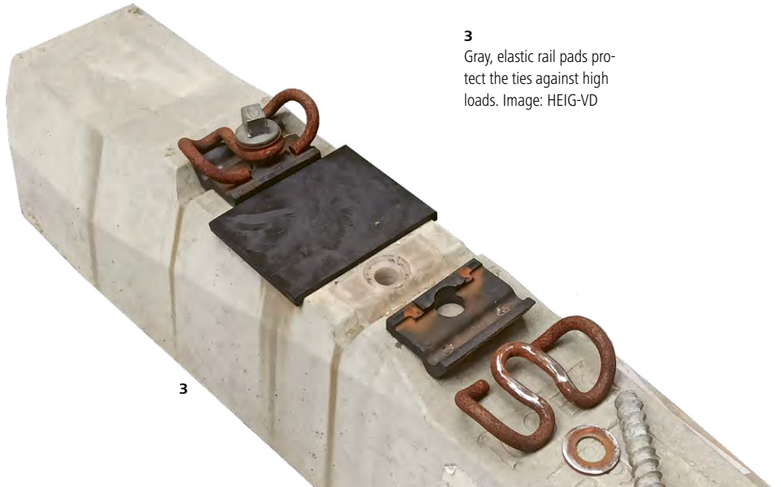

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Researchers measure the noise emissions of the new rail pads on a 100-meter-long stretch near Nottwil.

2
Train noise in focus: Empa researcher Bart Van Damme with a new type of rail pad that has been tested in train service.

3
Gray, elastic rail pads protect the ties against high loads. Image: HEIG-VD

Meeting the challenge of mixing rubber and cellulose

Dr. Thomas Geiger, thomas.geiger@empa.ch

The substitution of petrochemical materials with substances obtained from renewable raw materials is an important step toward increasing sustainability. Materials derived from plant cellulose are promising candidates for this application area as they are renewable, abundant and have a low environmental impact. In the rubber industry, microfibrillated cellulose (MFC) is receiving a lot of attention due to its high degree of rigidity, the morphology of its fibrils, its low density and its mechanical properties. Thus, it has a high potential to improve the properties of rubber compounds.

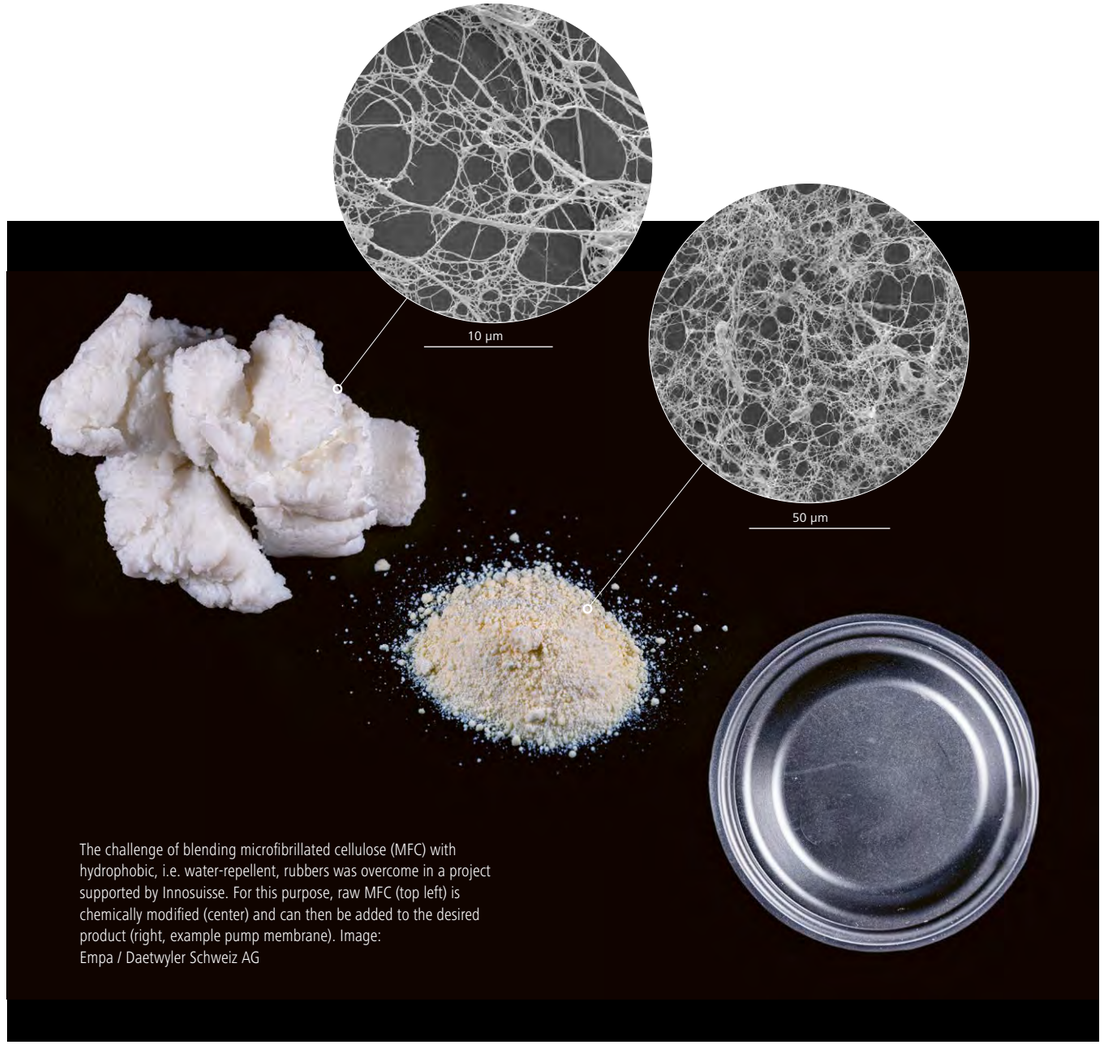
However, it is a challenge to blend MFC with hydrophobic, i.e. water-repellent, rubbers. Together with its development partner Empa, the internationally active Swiss industrial group Dätwyler has developed a process for the surface modification of MFC to solve this challenge. Initial trials involved replacing petrochemical aramid fibers with modified MFCs. The results showed good compatibility between the MFC filler and the rubber matrix, which reinforced the compound even more than conventional petroleum-based aramid fibers. The development of these novel fillers will be an important step toward increasing the sustainability of rubber products such as pump diaphragms.

From research to industrial implementation

In just two years of intensive and open collaboration between Empa and Dätwyler Schweiz AG as part of a project supported by Innosuisse, the Swiss Innovation Agency, a process was successfully developed that brought together the disparate materials cellulose and rubber. The process has since been patented.

However, further steps are needed until the technology can be implemented. Manufacturing the cellulose-based filler must be made possible at an industrial scale of more than 30 kilograms per batch, and further test series are necessary with regard to processing and molding. In order to maximize the potential of the new filler, research on the elastomer compound continues together with important industry users. The newly developed filler should be of interest for various industrial application areas, including the automotive industry. Until development is complete, due to the required validations of the components, it will take another two to five years until products with this technology arrive on the market.

The project is a good example of how valuable Innosuisse's support is for such innovation projects, which not only strengthen and economically advance the companies themselves through novel products and processes, but ultimately also Switzerland as an industry location. //



The challenge of blending microfibrillated cellulose (MFC) with hydrophobic, i.e. water-repellent, rubbers was overcome in a project supported by Innosuisse. For this purpose, raw MFC (top left) is chemically modified (center) and can then be added to the desired product (right, example pump membrane). Image: Empa / Daetwyler Schweiz AG

Smart wound treatment

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Poorly healing wounds pose a major challenge to medicine, particularly after operations on the digestive tract. For this reason, researchers at Empa have developed a polymer patch for the intestine that can be used to stably bond and seal internal or surgical injuries. The hydrogel material prevents germ-laden digestive juices from escaping the intestinal tract and causing peritonitis or even life-threatening blood poisoning (sepsis).

Now, further features have been integrated into the technology: The rubber-like composite material reacts selectively with digestive secretions that could escape from internal wounds, swells and closes all the more tightly. In addition, the hydrogel patch features antibiotic substances and chemical sensors that react within a very short time if a suture begins to leak. This makes early intervention possible before the health of the patient can deteriorate. In this way, the inexpensive, biocompatible super glue is intended to shorten hospital stays and save healthcare costs.

Alexandre Anthis is working on the fundamentals of this new sealing technology as part of a team led by Inge Herrmann at laboratories at Empa and ETH Zurich, together with clinical partners at the Cantonal Hospital of St. Gallen, the Queen Elizabeth University Hospital in Birmingham and the Charles University Biomedical Center in Pilsen in the Czech Republic. Their work is supported by several foundations, which include the Evi Diethelm-Winteler-Stiftung, Hans Gröber-Stiftung and Peter Bockhoff-Stiftung.
Empa awarded the young researcher Anthis the 2022 research award for his work, also due to its high relevance for applications in medical technology. In addition, Anthis received one of the coveted ETH Pioneer Fellowships. His work earned him his own place on the Forbes 30 Under 30 list in the Science & Healthcare category.

Currently, Anthis is founding the start-up Veltist. As a spin-off of Empa and ETH Zurich, the future biomed company aims to develop and bring to market materials that will contribute to optimal wound closure and improved healing in surgery, thus helping to prevent the dreaded complications.

Smart skin dressing

Empa researchers are working in interdisciplinary teams on further approaches to improve wound treatment. These include a smart dressing made of polymer fibers that releases antimicrobial drugs as soon as the environment heats up due to an infection. This is because it is often impossible to tell from the outside whether a wound will heal without problems under the dressing or whether bacteria will cause an inflammation. In this case, using prophylactic antibiotics promotes the emergence of multi-resistant germs, which are an immense problem in global healthcare. The novel dressing is intended to autonomously administer antibacterial drugs, but only when they are really needed. For this purpose, researchers produced a fine membrane made of a skin-compatible polymer mixture by means of electrospinning. This composite's material design results in the fibers softening and releasing the integrated medication when the wound temperature increases due to infection. In this way, wounds can be treated as needed at the right moment. //

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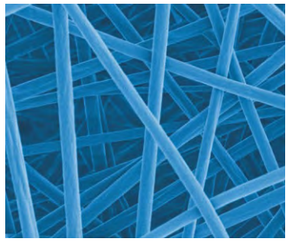

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1
Empa researcher Fei Pan is working on a smart dressing that releases medication only when a wound becomes inflamed.

2
These nanofibers, which are made of a polymer mixture (seen here enlarged 6,000 times on a colorized scanning electron microscopy image), release an antimicrobial agent when they get too warm.

3
Alexandre Anthis developed the hydrogel composite material during his dissertation at Empa.
Image: Schwarz Pictures/Empa

Building bridges for technology transfer

Dr. Lars Sommerhäuser, lars.sommerhaeuser@empa.ch

In addition to research itself, the transfer of newly developed materials and technologies to industrial applications is a task to which Empa has dedicated itself intensively for many years. A successful transfer always requires two sides: research institutes like Empa as the starting point for technological innovation and industry partners who want to test, implement and bring to market new technologies. This is why Empa and its industry partners build bridges to allow new technologies to be implemented in industrial applications.

The technology transfer centers that are being created as part of the AM TTC initiative launched by Empa are examples of just such bridges. The abbreviation AM TTC stands for Advanced Manufacturing Technology Transfer Centers. Individual AM TTCs feature infrastructures such as pilot production facilities that enable Swiss industry – especially local SMEs – to learn about, try out and transfer new manufacturing technologies into their production.

Two new centers for Swiss industry

In 2019, the Swiss m4m Center for 3D-printed implants in Bettlach, Solothurn, in which Empa is significantly involved, and the ANAXAM center at the Paul Scherrer Institute (PSI) were founded as part of the first AM TTC call for proposals. At the end of 2022, the Federal Department of Economic Affairs, Education and Research (EAER) and the AM TTC Alliance, the umbrella organization of the initiative, decided to fund two more centers: one in the field of collaborative robotics and one in the field of photonics. Until the end of 2024, funding in the amount of 6.5 million Swiss francs will be provided, on the one hand, by the ETH Board, which has defined the development of AM TTCs in Switzerland as a measure of its strategic planning 2021-2024. On the other hand, as "research institutions of national importance", the centers also receive funding from the federal government (according to Art. 15 of the Swiss Law on the Promotion of Research and Innovation, RIPA).

The Swiss Cobotics Competence Center (S3C) at the Innovation Park in Biel aims to demonstrate the opportunities of collaboration between humans and robots. Its goal is to close the gap between the theoretical capabilities of robots and industrial reality and thus to bring more collaborative robots into industrial applications. With the S3C, Swiss companies gain access to know-how and a demonstration and test platform for innovative cobotic solutions.

The second newly founded AM TTC, the Swiss Photonics Integration Center (Swiss PIC), is located in the Swiss Innovation Park InnovAare. Its focus is on optical components and systems that transport and process light particles called photons. The Swiss PIC will build facilities that will make it possible to integrate even the smallest optical components into larger systems or devices and test them. In Switzerland, there are many companies as well as research groups that develop and manufacture new innovative photonic components. Often, they do not have access to such facilities. Swiss PIC is intended to close this gap. //

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Collaborative robotics for industrial applications – this is the focus of the newly funded "Swiss Cobotics Competence Center" (S3C) in Biel. Image: Envato

2
Integration and test of photonic components – the Swiss Photonics Integration Center (Swiss PIC) provides access to the necessary facilities. Image: Polariton

NEST – the meeting point for innovation and inspiration in construction

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Once the Swiss Federal Council had declared an end to the exceptional situation in the spring of 2022, many meetings were held back in the real world again instead of in the Zoom universe. At NEST, the resurgent enthusiasm for meeting face to face was palpable, since the research and innovation building thrives on the daily exchange between researchers and experts from the construction and energy sectors. On the occasion of a summer festival, the partner network met at NEST again for the first time in a long while, looked back on its achievements and discussed future plans. The new units HiLo and Sprint were the center of a great deal of interest, even reaching far beyond the network itself. Several thousand visitors – mainly from the construction industry – again participated in tours and events at NEST and were fascinated to learn about material-saving construction design and circular building methods.

The NEST team continued to actively promote circular construction. Together with ETH Zurich, Switzerland Innovation Park Central and further partners, several pitching sessions were held for an Innosuisse Innovation Booster. The same partners welcomed attendees to the first Circular Building UnConference, held at the Dübendorf Innovation Park, in the autumn of 2022. At NEST itself, there were multiple workshops on the topic with public sector clients.

The implementation of the next unit, STEP2, which features innovations in the areas of digital manufacturing, building envelope, energy systems and circular economy, made significant progress in the meantime. The energy and thermal comfort concept has been finalized, and the first prototype tests for the digitally manufactured ribbed filigree slab and the concrete staircase in the shape of a spine showed positive results. The planning application has been submitted and the start of construction is planned for this year.

Three new start-ups around NEST

viboo, MESH and Zurich Soft Robotics are three new start-ups that were founded in 2022, and NEST played a significant role in this. With its predictive heating controller that can save up to 40 percent of heating energy, the Empa spin-off viboo received a lot of attention, multiple awards and a great deal of funding last year. The first experiments were conducted in the Urban Mining & Recycling unit. MESH, a spin-off of ETH Zurich, brings the robotic manufacturing of concrete structures without formwork to market. This technology was developed at ETH Zurich and first implemented in a construction project in 2018 in the DFAB HOUSE unit. Zurich Soft Robotics was founded by researchers at Empa and ETH Zurich. With the product Solskin, the start-up has set itself the objective of placing the adaptive solar façade, which was developed at ETH Zurich and implemented in the HiLo unit, on the market this year. The start-up has an optimistic view of the future since the façade received the Watt d'Or energy award by the Swiss Federal Office of Energy (SFOE) in January 2023.

In November, the creators of the HiLo unit received the Arc Award for architecture in the Digitalization category, which represents further acknowledgement of the spirit of innovation at NEST that is fueled every day by the exchange of ideas between research and industry. //

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2

1
Circular construction, which is demonstrated in the Urban Mining & Recycling and Sprint units, continued to arouse a great deal of interest, also with public sector clients.

2
The solar façade of the NEST HiLo unit received the Watt d'Or energy award in January 2023. Image: Roman Keller

Milestones of post-fossil mobility

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The most recent upheavals in the energy sector have shown once again that our energy system has to change and that the discussion about a shift to renewable energy sources has to be intensified. This eventful year also kicked off quite a few things at move, Empa's mobility demonstrator.

Driving with synfuels

A visible sign of this is the integration of a Direct Air Capturing (DAC) system by Climeworks at move. This system can remove up to 200 kg of CO_2 from the atmosphere per day in future. This CO_2 is used to produce synthetic fuels in combination with hydrogen (H_2). The first demonstrator for producing synthetic methane (CH_4) was implemented as a laboratory unit and put into operation in 2022. It consisted of a conventional first stage and a second stage developed at Empa with sorption enhancement. The sorption-enhanced process enables the water generated during the reaction to be continuously absorbed by the catalyst support, resulting in only pure methane as a product. This eliminates the need for further treatment of the product gas.

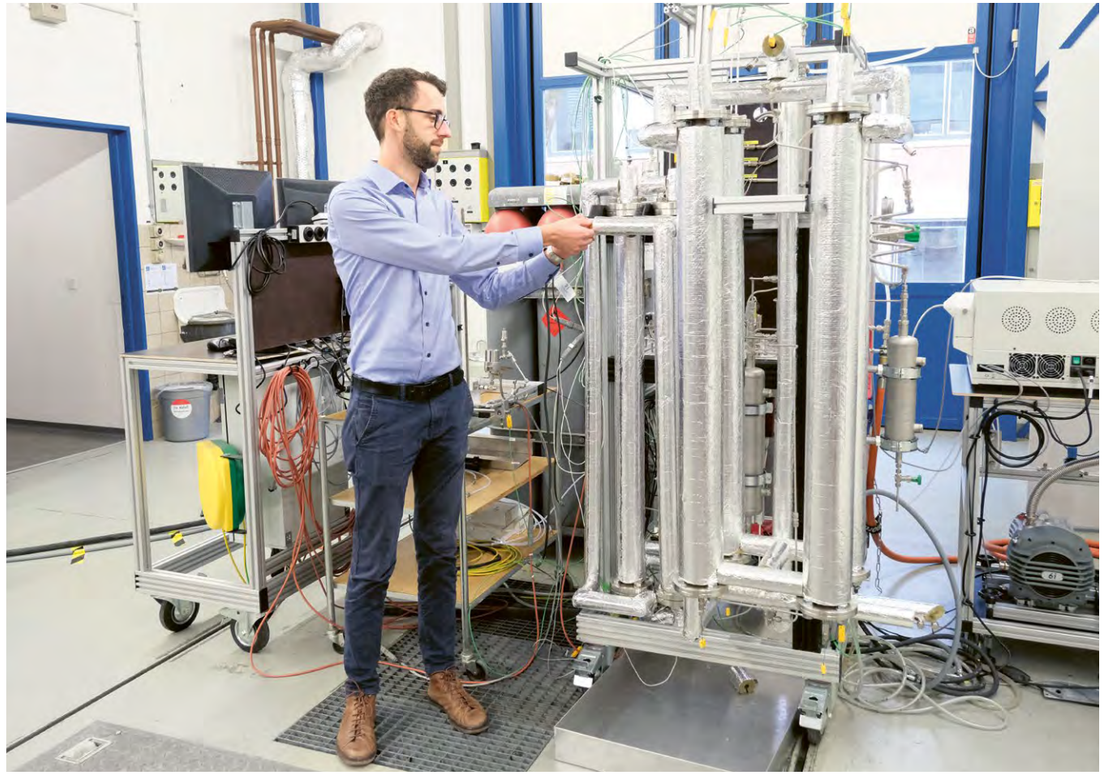
In addition, a system was implemented that uses the waste heat of the electrolysis plant generated during hydrogen production. This heat is increased from 60°C to about 120°C by a heat pump and can then be used for CO_2 desorption in the DAC system. The project is supported by the ETH Board, the Canton of Zurich, Glattwerk AG, Avenergy Suisse, Migros, Lidl, Armasuisse and Swisspower.

Running on hydrogen

In the field of hydrogen mobility, researching the heat generated when refueling H_2 pressure vessels is paramount. Without the appropriate measures, the temperature in such a pressure vessel in a passenger vehicle would increase up by 100°C when refueling, which would cause the pressure vessel to wear out faster. This is why the hydrogen is precooled to -40°C. However, it is still unclear whether this is sufficient for larger pressure vessels, for example in trucks. As a first step, an experimental setup was therefore implemented as part of a doctoral thesis in order to measure the temperature distribution in and on the pressure vessel during refueling. The researchers also developed flow and heat transfer models to simulate the various physical effects in detail. The project is being implemented in cooperation with ETH Zurich and is financed by the Swiss Federal Office of Energy (SFOE) and the EU research program Horizon 2020.

Running on electricity

In the field of electric mobility, preparations are currently underway for the enhancement of the current (monodirectional) charging station. An Empa study last year showed that a system-serving charging of electric vehicles can make a significant contribution to the transformation of the energy system. A current vehicle operating study is now investigating in detail how various individual vehicles are used in reality. This data will be used, among other things, to further substantiate the implementation of ancillary charging. //



The findings from the newly developed reactor concept can be implemented for large-scale plants: Florian Kiefer, project manager for sorption-enhanced methanation, next to the test plant.

The way to a resilient energy system

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The topic of energy supply was omnipresent in 2022. Fear of an energy shortage in the winter characterized the public discourse. It is clear that we need new approaches to make the Swiss energy system more resilient in future and keep the impact of shortages as low as possible. As an energy demonstrator, the Energy Hub (ehub) at Empa makes a key contribution to developing such approaches and putting them into practice. By combining the two demonstrators NEST (see page 24) and move (see page 26), the ehub provides important insights for energy management at the neighborhood level as well as for sector coupling and provides a real-world environment to develop and validate new ideas and concepts.

Research towards an energy transition

In the PATHFNDR project, which is funded by the Swiss Federal Office of Energy (SFOE), researchers are working with other institutes to investigate how the integration of renewable energies into the Swiss energy system and the coupling of different sectors can be accelerated. This would increase the flexibility of the overall energy system.

In 2022, the team was able to make important progress, one example of which was Empa's collaboration with the Paul Scherrer Institute (PSI), the Lucerne University of Applied Sciences and Arts (HSLU) and EPFL to develop a standard for describing and modeling the technical components. This provides all members of the consortium with uniform digital models of the technical infrastructure for their research work.

The SWEET Lantern project, which is also funded by the SFOE, was launched in April. The eight-year project aims to develop energy solutions that will enable Switzerland to achieve its net zero target. In addition to technical institutes, social science partners are also involved in the project for the first time. This is to ensure that the central human factor is also taken into account as part of the decarbonization of the energy system, as this factor plays a decisive role in shaping the transition. At the ehub, these "sociotechnical" approaches are developed and contrasted with purely technical solutions.

A net-zero campus

Decarbonization is also a key topic on the Empa campus. The new campus, which is currently under construction, is intended to have a neutral carbon footprint in future. To do this, the ehub team will create a digital twin for each new building, based on its experience from previous NEST projects. These models make it possible to further optimize operations to achieve net zero.

In addition to the new campus, the plan is also to optimize the operation of the existing buildings at Empa. Here is where the innovative solution of the Empa spin-off viboo applies. The company was founded in March 2022 after several years of research in the Urban Energy Systems Lab and in the ehub team. viboo has developed an algorithm using data from the Digital Hub (dhub) that makes it possible to operate even older buildings relatively easily with around 25 percent less energy. The important factor here is that user comfort remains the same or even improves. Following a successful pilot project with thermostat manufacturer Danfoss in an office building at Empa, other buildings on the campus are now being equipped with the smart thermostats. //

To increase the flexibility of the energy system, the expansion and integration of renewable energies and sector coupling must be accelerated. The ehub team is involved in various projects in order to advance this goal. Image: Adobe Stock

Building a modern research campus

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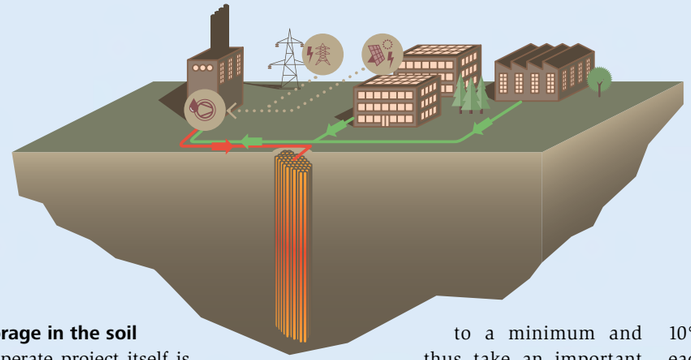
The expansion “co-operate” of the joint Empa and Eawag campus in Dübendorf is progressing apace: After construction began with the groundbreaking ceremony in May 2021 and the foundation was laid in September 2021, the next milestone was reached on 14 July 2022: The shell of the laboratory building was completed and the building reached its full height. A small tree is then placed on the roof as a clearly visible sign of the completion of the shell. Traditionally, this is when the topping-out ceremony is held. For once, however, the focus of the ceremony was not on those in charge, but on the construction workers who actually carried out the work. With the ceremony, the building owners thanked them for their valuable work.

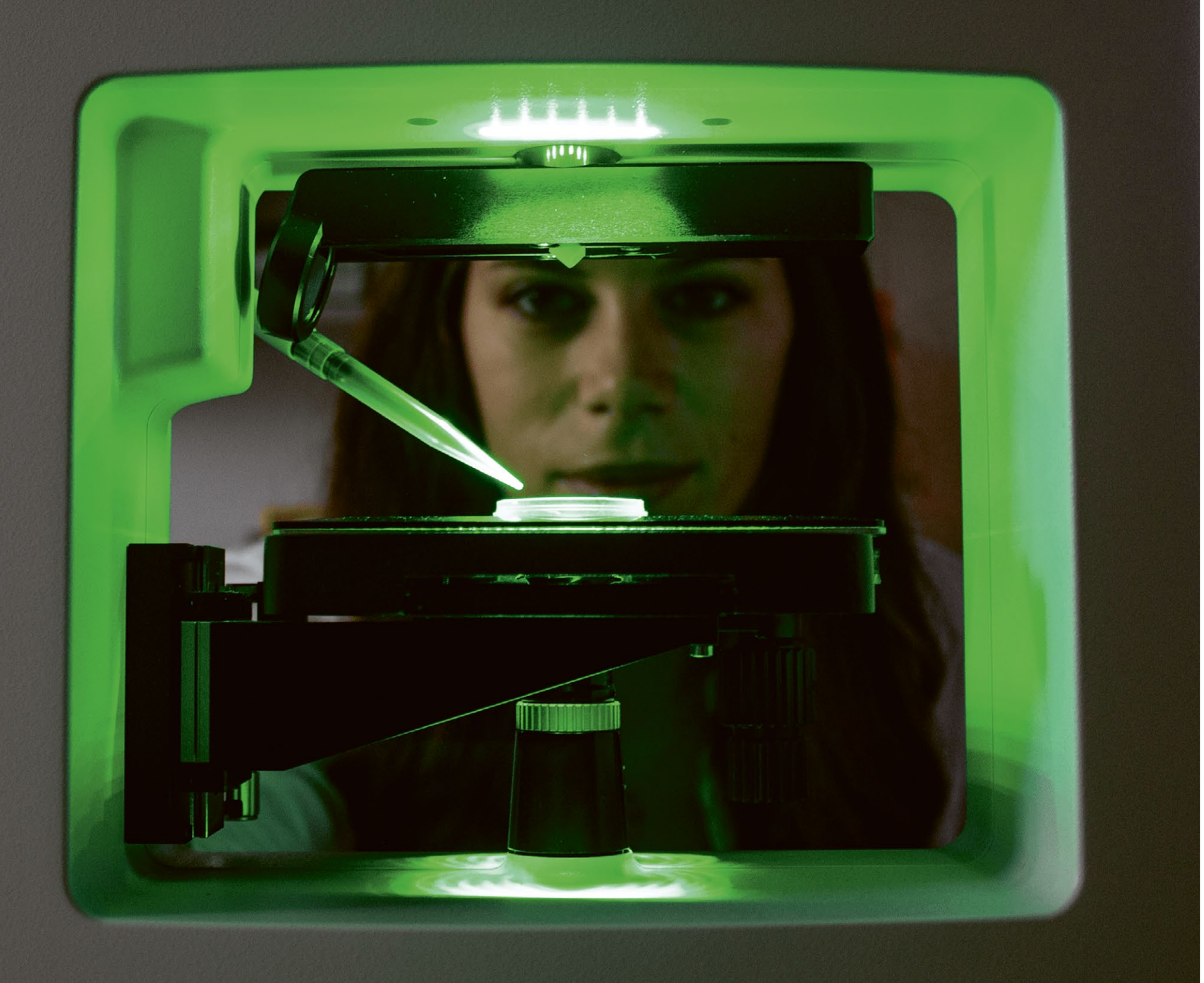
The laboratory building, which from spring 2024 provides space for around 30 offices and 30 laboratories, will house highly sensitive research instruments. Therefore, 48 piles of a combined pile-slab foundation transfers the loads to a more stable layer of soil at a depth of up to 18 meters.



Heat storage in the soil

The co-operate project itself is also a subject of research. This is because an experimental, seasonal energy storage facility is being built under the site, which will supply energy not only to the new buildings but to the entire Empa-Eawag campus. In summer, the waste heat, for example from the chillers, will be stored in order to use it in winter for heating or for the production of domestic hot water. The aim is to either use around 90 percent of waste heat directly or to store it temporarily in the underground storage system. In this way, Empa aims to reduce the CO_2 emissions of its buildings to a minimum and thus take an important step towards a future of sustainable energy.

The heat reservoir – a field of geothermal probes with a temperature gradient – comprises 144 probes extending up to 100 meters deep into the ground. At this depth, the storage unit works particularly effectively, emitting only a small proportion of the stored heat to the environment. In the center of the geothermal probe field, the maximum temperatures can reach 50 °C, and the values are around 10 °C at the edges. Via the pipe system, each individual pipe of the geothermal probes or defined areas can be controlled to achieve the optimum mix between temperature, efficiency level and energy storage. Although such an underground storage system is very effective, it is also sluggish due to its large mass. The Empa researchers assume that the final operating temperature will be reached after about three to four years. //



Research Focus Areas

Where do the major challenges of our time lie? Undoubtedly in the fields of human health and well-being, climate and the environment, dwindling raw materials, a safe and sustainable energy supply and the renovation of our infrastructure. In its five research focus areas, Empa pools the expertise of its 30-plus research labs and centers and develops practical solutions for industry and society.

High resolution material analytics for future technologies

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The concept of matter consisting of minute particles is over 2,000 years old. Atomism was first formulated in ancient Greece and later taken up and developed further by many eminent thinkers. Certainly, all these theories remained philosophical in nature and were not translated into scientific formulas until the nineteenth and twentieth century by modern atomic physics. In 1974, the Japanese scientist Norio Taniguchi coined the phrase nanotechnology, defining it as the ability to change materials at the atomic scale. To make this possible, it is however necessary to make atoms visible at the nanoscale.

Heinrich Rohrer and Gerd Binnig took the first big step in this direction when they developed the scanning tunneling microscope around 40 years ago at the IBM research lab in Rüschlikon, thus opening the door to the nanocosmos though experiments. With further methods such as atomic force microscopy and X-ray spectroscopy, atoms and molecules were made "visible" all at once and material parameters could suddenly be measured at the micro and nanoscales.

From still image to in situ diagnostics with time resolution

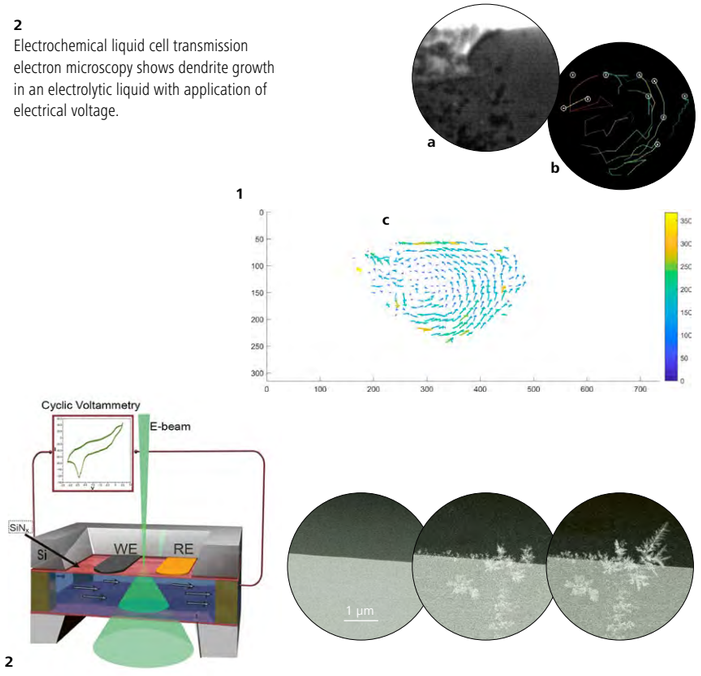
Currently, the next developmental stage is to shift from static research to analyses with time resolution. With time resolution methods, it is now possible to follow and research processes on and in materials. However, this involves new challenges: Speaking in highly generalized terms, spatial and temporal resolution compete when studying effects at the nanoscale. High spatial resolution requires an excellent ratio of measuring signal to noise. Nevertheless, noise cannot be completely suppressed, so a good spatial resolution requires the measurement signals to be averaged, which in turn takes time and thus limits the temporal resolution. Often, a compromise between temporal and spatial resolution is inevitable.

New developments based on better detectors and the option of processing large amounts of data in real time have recently created new possibilities to combine high spatial and temporal resolution in one experiment. Two examples that show this in an especially impressive manner are synchrotron X-ray computed tomography and transmission electron microscopy. In a single experiment, a process with high spatial and temporal resolution can now be researched *in situ*. This allows for snapshots of a melting bath in a single beam during a 3D printing process, which are recorded at the TOMCAT beamline of the Swiss Light Source (SLS) in cooperation with partners at EPFL. A miniature laser powder bed facility developed at the Paul Scherrer Institute (PSI) was used for this. To improve contrast, tungsten particles that do not dissolve during the process were added. With the help of machine learning algorithms, it is possible to track the movement of the tungsten particles in the melting bath over a large number of images with high temporal resolution and to derive the melting bath dynamics during the 3D printing process. The findings obtained in this process promote a better understanding of the formation of defects such as pores or cracks that can occur during 3D printing, and thus help to optimize additive manufacturing processes with a view to improving component quality.

Using electrochemical liquid cell transmission electron microscopy, Empa researchers investigated dendrite growth in an electrolytic liquid with application of electrical voltage. This process, simulated in a model system, is decisive for the failure of battery materials, because such nanoscale dendrites can cause short circuits in batteries.

1
Radiography of a melting bath with tungsten particles during a 3D-printing process (a); movement paths of tungsten particles (b); convection velocity distribution in the melting bath, calculated from 2,000 individual images (c)

2
Electrochemical liquid cell transmission electron microscopy shows dendrite growth in an electrolytic liquid with application of electrical voltage.



Analytics on the right length scale

These examples show how important material analytics at the nanoscale will be in the future. This makes a better understanding of physical and electrochemical processes possible on the essential appropriate length scale. This could open the doors for future technological breakthroughs. //

Sustainability relies on durability

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One of the key aspects in reducing the consumption of resources and related emissions is securing the long service life of built environment. This issue is addressed by different teams at Empa that focus on durability of building materials. By understanding the ageing and degradation processes, appropriate strategies can be devised for the future of the existing structures, e.g. repair, retrofitting, reuse, etc. On the other hand, for newly created materials the durability characteristics can be enhanced, ensuring safe and reliable service with minimum repair.

Reduce Alkali Silica Reaction to secure long service of concrete dams

Alkali Silica Reaction (ASR) occurs when siliceous aggregates react with the alkaline solution present in concrete. The formation of ASR reaction products causes buildup of stresses and eventually cracking of concrete. In Switzerland and worldwide, the ASR-induced cracks cause serious damage and limit service life in concrete infrastructure of major importance. In fact, around 25 percent of the 130 concrete dams in Switzerland suffer from the ASR cracking. Due to its multi-scale nature, ASR still remains one of the most complex open questions in the field. The major recent achievements were reached thanks to the contributions of Empa's scientist under the lead of Andreas Leemann from the Concrete and Asphalt Laboratory, notably in the recently concluded SNF Sinergia grant (collaboration of Empa, PSI and EPFL). Empa's scientist were able to show the dependence of the structure of ASR products upon temperature and developed contrast-enhancing methods for X-ray microtomography that enable following the propagation of ASR product formation and crack development in 4D. Both are a break-through in ASR research.

In addition to the cutting-edge laboratory work, field studies at different exposure sites are an important tool in predicting the possible ASR damage in realistic conditions. In a current project funded by cemsuisse and the Swiss Federal Office of Energy, the team led by Andreas Leemann and Mateusz Wyrzykowski studies concrete samples exposed to natural weathering at the construction site of the Spitallamm dam on Lake Grimsel. These studies will enable designing concretes with reduced ASR propensity for durable and hence sustainable infrastructure of major significance. Moreover, they will empower the prognosis of damage development in affected structures.

Durability and Reuse of CFRP wires for bridge cables

What to do with valuable carbon fiber reinforced polymer (CFRP) parallel-wire prestressing cables of a decommissioned bridge? This question arose when the Canton of Lucerne department for traffic and infrastructure, Vif, led by Gregor Schwegler, decommissioned the "Kleine Emme" bridge in April 2016. The pedestrian and cyclist bridge, completed in 1998, was a world-first as a steel-concrete-composite bridge post-tensioned with parallel-wire CFRP cables and was decommissioned not due to deterioration, but rather due to a new concept for flood protection in the city of Lucerne which made the bridge redundant. The cables were monitored in service by integrated fiber optics (developed by Empa's Transport at Nanoscale Interfaces Laboratory) during their 18 year in-service life and showed that no discernible prestress losses had occurred. During the decommissioning, Urs Meier of Empa was given the two CFRP cables, containing about 8.7 km of CFRP wires with a market value of 45,000 Swiss francs. Given their financial value and apparent excellent condition they are being considered for reuse in other structures. Tensile tests of the CFRP wires have been performed in the Mechanical Systems Engineering Lab at Empa (Giovanni Terrasi, Christian Affolter and Valentin Ott), and evaluated for their post-service tensile properties by distributed fiber optic sensors and strain gauges; this work has been done in collaboration with the University of Edinburgh. Initial results have confirmed the exceptional durability of CFRP; after 25 years (of which 18 under high prestress and subject to weather cycles) the CFRP wires show tensile strength of 92 percent of the original tensile strength of 3'250 MPa, still corresponding to 100 percent of the original design strength of 3'000 MPa. The Lab of Giovanni Terrasi and Carbo-Link are currently working in a project with Vif, where they plan to reuse some of the CFRP wires for two new CFRP cables with novel resin cast CFRP anchor sleeves in order to strengthen an ageing prestressed concrete bridge. //

1
Construction site of the new Spitallamm dam at Lake Grimsel where the concrete samples for studying ASR cracking are exposed to natural weathering. The old dam (behind) finalized in 1932 suffers from considerable ASR cracking and needs to be replaced.
Image: David Birri, Meiringen.

2
Decommissioning of Kleine Emme Bridge in April 2016. The CFRP wires reclaimed from this bridge still show an excellent performance even after 18 years of service and could be thus reused in future projects.

Circular economy – the key to sustainable development

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Closed cycles play a key role in terms of sustainable development as many resources for the production of goods are finite and their production requires large amounts of energy. This applies in particular to the energy- and material-intensive construction sector, but also to the production of consumer goods and energy supply and storage. In order to achieve the climate objectives of the Paris Agreement, to which Switzerland is committed, it is therefore imperative that we as a society give much greater priority to the sustainable use of resources and the closing of material cycles.

"CircuBAT" – sustainability for electric mobility

Sustainable electric mobility requires that the ingredients of lithium-ion batteries also be restored to the economic cycle to the greatest possible extent. Seven Swiss research institutions, which are the Bern University of Applied Sciences (BFH), the Swiss Center for Electronics and Microtechnology (CSEM), the Swiss Federal Institute of Technology (EPFL), the Eastern Switzerland University of Applied Sciences (FH OST), the Switzerland Innovation Park Biel/Bienne (SIPBB), and the University of St. Gallen in addition to Empa, as well as 24 companies have joined forces in the CircuBAT research project to search for options to close the material cycles for lithium-ion batteries. Science and business work closely together to cover the entire life cycle of batteries, from production and application to recycling, and develop strategies for translating new findings from research into practical applications as directly as possible.

By maximizing metal recovery and resource efficiency, materials are provided for future manufacturing processes and batteries are prevented from ending up in landfills or being disposed of elsewhere. For this purpose, the project partners are looking for solutions for the disassembly of batteries and material recovery that enable large quantities of high-quality secondary raw materials to be used to produce new batteries.

Another important factor is extending the battery life cycle. The project partners hope to achieve this by developing optimal charging and discharging strategies as well as new concepts for battery assembly that make repairs easy. In addition, batteries could be put to use as stationary energy storage systems after they are retired from their first mobility-related application. The project is therefore also investigating how these can be integrated into the power grid safely and efficiently. On top of these technical aspects, the project also examines socio-economic aspects and develops future comprehensive business models.

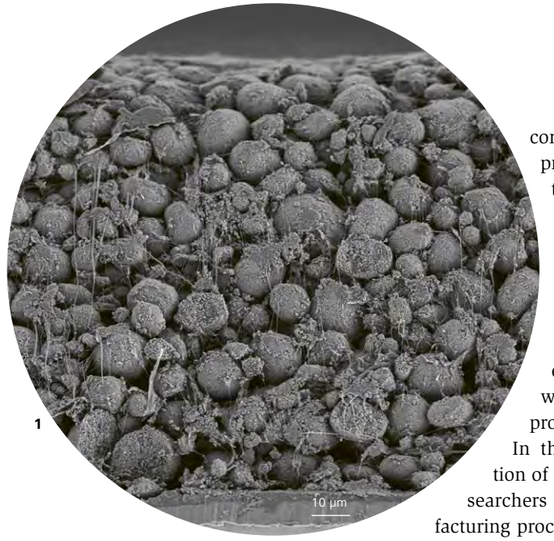
Step by step towards a circular economy

Of the seven CircuBAT subprojects, three are led by Empa researchers. The subproject Material Recovery aims to optimize a recycling process developed by the Swiss company Kyburz. In this process, the coatings of the anode and cathode are separated in a water bath. Among other things, copper, aluminum and lithium iron phosphate of the best quality can be recovered in this process, which can be used to produce new batteries.

In the subproject Production of Battery Cells, Empa researchers are developing manufacturing processes that require considerably less energy. By far the most energy-intensive step in the production of a lithium-ion battery – the drying of the battery electrode after coating – is changed significantly in the process: For electrode coatings, a novel dry method without solvents is being investigated so that subsequent drying can be omitted in future. Empa studies show that up to 25 percent of the energy consumed in battery cell production could be saved if the drying stage of electrode manufacture were left out. In this project, the Empa researchers are working together closely with the Swiss technology corporation Bühler.

In the subproject Sustainable Business Model, experts from the University of St. Gallen and Empa are working with other partners to research what viable business models for the sustainable handling of (car) batteries could look like in the future. To do this, they consider not only the costs but also the environmental and social impacts along the entire value chain. The main objective is to identify suitable, economically advantageous business models in order to implement these innovations as quickly as possible.

CircuBAT, one of the 15 projects in the newly launched Flagship Initiative of Innosuisse, the Swiss Innovation Agency, will therefore play a key role in decarbonizing mobility in Switzerland and promoting the use of renewable energy. //



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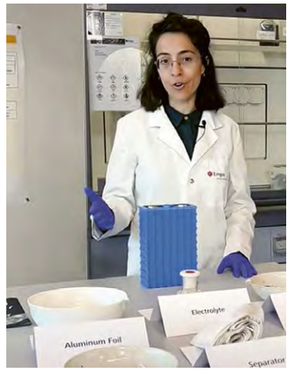

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1
Scanning electron microscopy image of a dry-processed electrode for lithium-ion battery cells. This new process can save up to 25 percent of the energy during battery production. Image: Empa/Bühler

2
Empa researcher Nora Bartolomé is looking for new recycling methods for lithium-ion batteries.

Word of the year: power shortage

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The choice of "power shortage" (Strommangellage) as word of the year 2022 for German-speaking Switzerland shows that energy-related topics have entered the public consciousness for good. In fact, since the start of the war of aggression on Ukraine, we have had to deal with the possibility of a general energy shortage, which primarily pertains to natural gas in addition to electricity. Multiple different crises and challenges in the energy sector actually seem to be overlapping at the moment: extreme increases in energy prices, shortages of computer chips and skilled workers, interrupted supply chains and still no progress in the negotiations with the EU on an electricity agreement. What contribution can a research institute like Empa make in such a crisis?

In the short term: reducing energy demand

To counter the threat of energy shortages in the winters of 2023 and 2024, we have to resort to measures that can be implemented quickly. A great potential to reduce energy demand lies in space heating for buildings. However, major construction measures would take too long. In building operation, on the other hand, major effects can be achieved with minimal structural adjustments. For example, Empa has developed an algorithm for the predictive control of room temperature that independently adapts to building behavior thanks to artificial intelligence. In successful pilot studies, energy savings of 20-40 percent were achieved. Now, in the summer of 2022, the newly founded Empa spin-off viboo has begun to bring an easy-to-install system to market. Since the newly developed control via cloud service is compatible with various smart thermostat products, Empa's innovation can quickly achieve widespread use via established sales channels and available or even already installed hardware.

In the medium term: bringing innovations to market more quickly

In the medium term, i.e. in the next two to five years, the focus will be on bringing innovative technologies in the energy sector to market more quickly to support the urgently needed transformation of our energy system. One example of Empa's close collaboration with industry partners is the establishment of the Association for the Decarbonization of Industry in June 2022. One of its goals is to decarbonize high-temperature industrial processes by using hydrogen. In this context, the association focuses on methane pyrolysis, a technology for hydrogen production that is on the threshold of commercialization. A demonstration plant in Zug is intended to test methane pyrolysis in practice. In addition to hydrogen, methane pyrolysis generates solid carbon, which can be used as a raw material in the construction industry, for example. If synthetic methane or biogas is used as a source material, this technology even promises negative emissions, i.e. CO_2 would permanently be removed from the atmosphere.

In the long term: transition paths, materials and technologies for improved resilience

And what about the coming decades? The main objective here is to build an energy system that simultaneously ensures security of supply, affordable energy prices and climate neutrality. And not only for "fair weather", but also during future crises. So, we need to find ways to combine sustainability with resilience. Empa makes various contributions to this goal, including scenarios and transition paths for the Swiss energy sector, as shown in the "Energy Future 2050" study, which was recently carried out by Empa and the University of St. Gallen on behalf of the Association of Swiss Electricity Companies. This is the first scientific model to simulate Switzerland's overall energy system across sectors up to the year 2050, taking into account neighboring countries as well. It shows various scenarios, including costs and necessary framework conditions, for achieving energy and climate policy goals.

Other Empa research projects aim to use sustainable materials and technologies to make our energy system as a whole more resilient and robust. In the field of batteries, for example, Empa is researching technologies that use the abundantly available metal sodium instead of the rather scarce lithium, as well as processes to recycle batteries – with the aim to reducing Switzerland's dependence on raw materials through closed material cycles. //

The Association for the Decarbonization of Industry has set itself the goal of developing easy-to-implement, comprehensive approaches for CO_2 reduction in industrial processes. The focus is on industrial high-temperature applications. V-ZUG AG's enameling furnaces are to be operated without fossil natural gas in the future.
Image: V-ZUG AG

A comprehensive approach in medical materials research

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In order to succeed in medical materials research, a comprehensive approach that can meet the complex medical requirements is absolutely indispensable. Hence, collaboration between physicians, who require innovative materials, and scientists, who develop such materials, is essential. In-depth cooperation is possible thanks to an interdisciplinary approach and the comprehensive expertise Empa researchers possess in fields such as material synthesis and processing, bio-analytics, computational modelling and simulations, bioinformatics, imaging and life science.

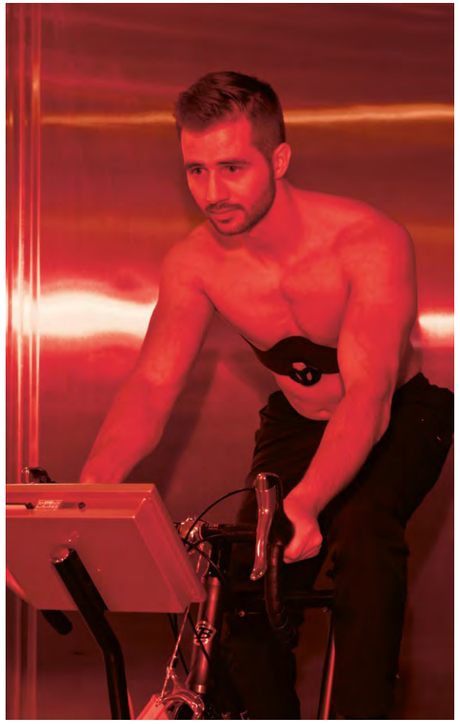
The aim of the innovations developed at Empa is to reduce the future burden on hospitals, which is already becoming increasingly acute. For instance, the situation in intensive care units is critical. Here, the primary concern is to maintain the health of patients and to shorten treatment time.

Nowadays, wearables (e.g. wearable sensors or functional textile composites) and digital twins can provide diagnoses of life-threatening or chronic illnesses at an early stage. Specifically, such systems are employed both for body monitoring as physical, chemical and biological sensors, as well as for the controlled delivery of medication. Predictively estimating the reactions of patients to the therapeutic agents with the help of digital twins means that more accurate dosages can be administered.

Biomedical imaging technologies

Multilevel and multimodal data integration through machine learning methods allows for the improved early detection of illnesses, which is often a prerequisite for efficient treatment. A combination of high-resolution 3D X-ray tomography images and different microscopy techniques, complemented by genetic and molecular analyses, also known as multi-omics data, enable completely new approaches in early detection. For example, a pilot study conducted in collaboration with the clinic for neurology at the Cantonal Hospital of St. Gallen successfully obtained photographs of proteins with unprecedented precision, thus allowing new insights into the molecular pathogenesis of Alzheimer's. These findings are intended to facilitate earlier diagnosis of dementia through a simple blood test.

Various label-free analytical techniques allow for simultaneous digital pathology without requiring additional tissue samples. For this purpose, Empa researchers are developing 3D and 4D imaging techniques to track and monitor processes relevant for diagnostics and follow-up examinations. These 3D imaging methods provide new opportunities for non-invasive digital precision pathology, such as for tumor tissue or blood clots, for example in the case of stroke.



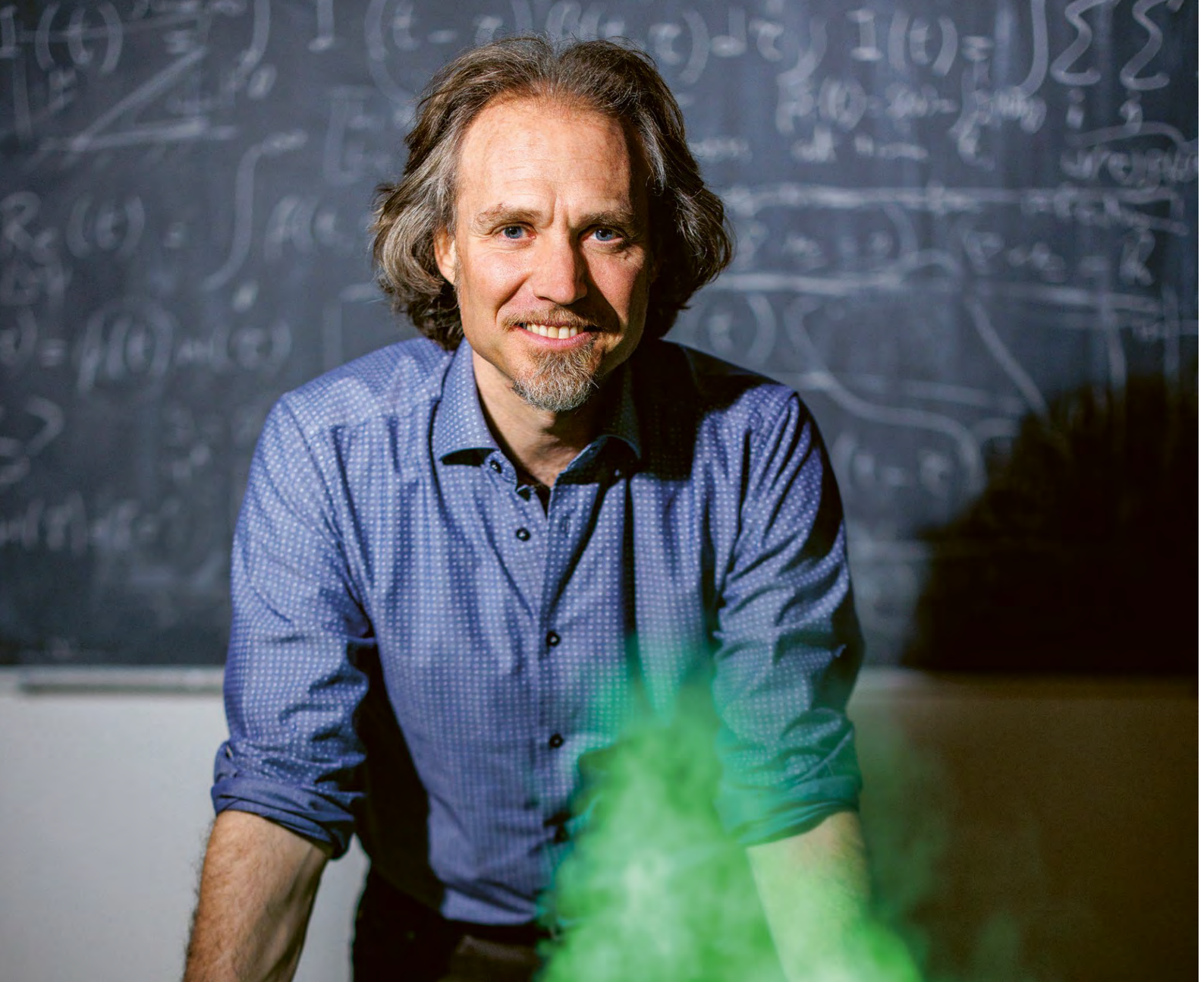
With the cardio belt made of comfortable fabric and embroidered electrodes, physiologically important parameters can be measured comfortably over a longer period of time.
Image: Robert Stürmer / Empa

Nanomedical systems

Current therapies are often only effective in comparatively small patient groups. To improve this situation, each individual patient would have to be treated in a personalized manner, requiring new approaches in materials research. While personalized diagnosis and treatment concepts are increasingly integrated into clinical routine, there is still room for improvement regarding adoption of the precision medicine approach in the medical device and materials design community. Through computer models, which simulate the interaction of new materials with multicellular tissue models, Empa researchers aim to better understand the human physiological processes, complex interactions, signaling pathways and healing processes. For instance, the tailored modification of surfaces can influence protein adhesion, leading to a change in biological cell response. Empa's contribution, both in materials design and analytics, aims to accelerate the establishment of precision medicine in Switzerland.

Implants and biological interfaces

An aging society is generating a growing demand for implants and novel regenerative material concepts in the biomedical field. The goal of Empa's materials research in areas such as coatings, tribology, corrosion, biomechanics and additive manufacturing is to understand and control the response of different cell and tissue types, as well as their specific adaptations and changes at the material surface level. Subsequently, these findings are intended to support the repair, regeneration and function of impaired tissue and organs. Such interdisciplinary approaches in materials research, in collaboration with industry and clinical partners, are fundamental to important discoveries for clinical applications. //



From Research to Innovation

Top-flight research and a proximity to industry – the two poles between which Empa operates. The institute is able to offer its partners tailored solutions thanks to efficient and individual forms of collaboration and a broad spectrum of services. Whether it be with a view to developing new products and applications, optimizing technologies, solving concrete problems or bringing technical specialists up to the state of the art – with almost 600 highly qualified scientists and top-class infrastructure, Empa is the place to be.

Shaping the future with research and innovation

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Cooperation with industry is in Empa's DNA and forms an integral part of the institute's culture. Together with its industrial partners, Empa researches new materials and develops technologies that address the technological changes and the challenges facing society and that strengthen Switzerland as a business location. Implementing these ideas together with industrial partners and transferring the results and technologies to the economic sector as quickly as possible is one of the central tasks of technology transfer.

The year 2022 again saw the launch of over 200 new research projects, the majority of which were joint projects with industry partners. In addition, patent applications were filed for 18 inventions and 10 new licensing and technology transfer agreements were concluded with business partners. The Empa spin-off CTsystems AG was acquired by Dätwyler (also see p. 48).

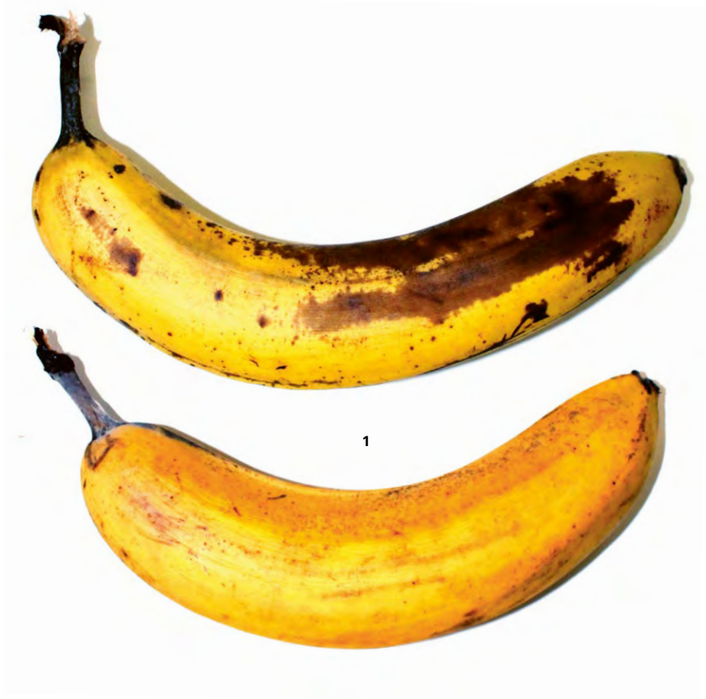
Drill coating for medical technology

In collaboration with the ARTORG Center for Biomedical Engineering Research of the University of Bern, Empa researchers from the Surface Science & Coating Technologies department developed a hard-coated drill bit that features two electrodes that are isolated from each other at the tip. In the process, electrically conductive and insulating hard coatings of titanium nitride (TiN) and silicon nitride (Si_3N_4) were alternately applied to the drill by way of magnetron sputtering. The drill is installed in a robot developed by the ARTORG Center that can insert cochlear implants more gently than a surgeon. With this drill, an electrical signal can be used to check in real time whether the necessary distance to the facial nerve is being maintained during drilling (see also p. 12).
The drill coating technology was jointly patented in 2017 by Empa and the ARTORG Center, and a patent has already been granted in several countries. At the end of 2021, an exclusive license agreement was concluded with CAScination AG, a company based in Bern. CAScination was founded in 2009 as a spin-off of the ARTORG Center and won the Swiss Medtech Award for its cochlear implant robot in 2019. The license to the coating technology for the drill now rounds off the advantages of the overall system.

Ecological packaging for fresh fruit and vegetables

Plastic packaging in grocery stores protects fruits and vegetables from spoilage, but also creates significant amounts of waste. Together with the retailer Lidl Switzerland, Empa researchers have developed a protective covering for fruit and vegetables based on renewable raw materials. The novel cellulose coating was developed at Empa's Cellulose & Wood Materials department under the leadership of Gustav Nyström and is made of pomace – fruit and vegetable peels which have had their juices pressed out. The coating is either sprayed onto the fruit or applied to the produce in a dipping bath and is easy to wash off before eating. As it is harmless to the consumer, it could also be consumed without any issues. Coated fruits and vegetables stay fresh significantly longer. For example, the shelf life of bananas was extended by a week.

The cellulose coating is currently being further improved together with a fruit and vegetable supplier as part of an Innosuisse project. After a successful completion of the project, the aim is to implement the new technology in grocery stores in order to reduce packaging materials and prevent food waste at the same time.



1
Yellow is the new brown: The lower of these 10-day-old bananas is protected by a cellulose coating. Image: Empa, Lidl Switzerland

2
The conversion from analogue to smart thermostats connected to the viboo cloud solution is easy to implement in existing buildings and achieves energy savings of between 20 and 40 percent.

Empa Innovation Award 2022 goes to viboo AG

Every two years, Empa presents the Empa Innovation Award to honour outstanding innovation projects with successful technology transfer onto the market. In 2022, the Empa spin-off viboo AG won this award. During their years of research at the Urban Energy Systems Lab, Felix Bünning und Benjamin Huber developed a control algorithm that can calculate and optimize a building's ideal energy use several hours in advance based on weather forecasts and building data. The conversion from analogue to smart thermostats connected to the viboo cloud solution is easy to implement in existing buildings and achieves energy savings of between 20 and 40 percent. With the goal of launching the technology on the market, Empa researchers founded the company viboo AG and are already working with manufacturers such as Danfoss, ABB and Schneider Electric in various pilot projects. //

Successful industrialization

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The objective of the business incubators at Empa is to support the transfer of research findings into industrial applications by way of start-ups. This was shown using the example of three successful Empa spin-offs in the past year.

Dätwyler acquires Empa spin-off CTsystems

In the reporting year, the internationally active industrial corporation Dätwyler, based in the canton of Uri, took over CTsystems, a spin-off at Empa and tenant of glatec. CTsystems' patents for electroactive polymers were thus transferred to Dätwyler. For the first time, Dätwyler can produce stackable electroactive polymers on an industrial scale. Electroactive polymers convert electrical power into precise and multifunctional mechanical movement through elastic deformation. Thanks to the unique stack design, this more attractive technical solution can replace conventional actuator technologies in various areas of application, as well as enabling completely new applications, for example in the car of the future. The two companies have been working closely together since 2018.

Basel-based energy provider acquires stake in Sympheny

A large number of factors come into play when planning the energy use of individual buildings or entire developments. In order to identify and evaluate the various energy solutions, the Empa spin-off Sympheny, founded in 2020, has developed energy planning software. Using algorithms, a digital twin of the energy system and now also geographical information system (GIS) data, the software can simulate the local production, storage and consumption of energy.

Sympheny's software has already been used in over 20 major planning projects. Customers include energy suppliers and general contractors from all over Switzerland. In 2022, the Basel-based electricity supplier Industrielle Werke Basel (IWB) announced its investment in the CleanTech startup. IWB took over 30 percent of the shares. The fresh capital will be used in particular to further develop the energy planning software.

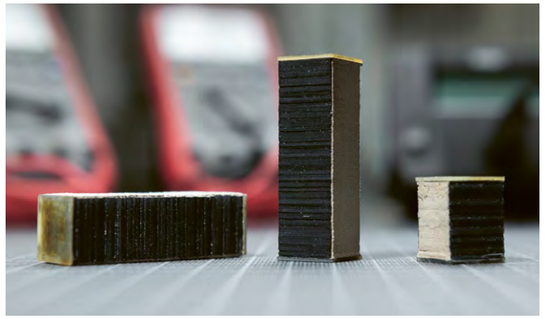
Empa spin-off Nahtlos receives one million Swiss francs

The company Nahtlos, another Empa spin-off, has received one million Swiss francs in a first round of financing from a network of business angels from Switzerland and Liechtenstein as well as from the Startfeld Foundation. Over the past two years, Nahtlos has developed novel textile-based electrodes for recording heart activity (electrocardiogram, ECG) – for example, to detect atrial fibrillation – and for electrostimulation therapies, in order to preserve the muscle mass in paralyzed patients, for example. Textile-based electrodes allow for gentle and skin-friendly application, even if the electrodes have to be worn for several days or even weeks. The textile electrode is thus the first alternative to the gel electrode, which was developed 60 years ago and is still considered the standard for medical applications today.

Merger of Startfeld and Switzerland Innovation Park Ost

After the Federal Council determined that Switzerland Innovation Park Ost (SIP Ost) would join the network of Switzerland Innovation as the sixth site in 2021, Switzerland Innovation Park Ost merged with Startfeld, the network for innovations and start-ups in Eastern Switzerland, in June 2022. The two organizations were not only located in the same building, but also have significant overlap with Empa, the Canton and City of St. Gallen, the University of St. Gallen (HSG) and the University of Applied Sciences of Eastern Switzerland (OST) with regard to their sponsoring organizations. For Startfeld, this represents an increase in the possible sphere of influence in view of the secondary location Buchs and the area covered by the innovation park. //

1
Promising for industrial applications: electroactive polymers in a unique stacked construction. Image: Dätwyler Holding Inc.



2
The founders of Nahtlos AG, José Näf and Michel Schmid, with the textile-based electrodes for long-term ECGs in their laboratory at SIP Ost. Image: Marlies Thurnheer

Many new funding partnerships

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As a research institute in the ETH Domain, Empa receives about 60 percent of its basic funding from the Swiss government. The remaining 40 percent comes from third-party funding in Switzerland and the EU as well as from research projects with and services for Swiss industry players. In 2022, many valuable partnerships were established with charitable foundations, grants from which can now be used to realize important research projects.

Personalized tumor therapy
Glioblastoma is the most common and dangerous primary brain tumor. Empa researcher Peter Wick is now pursuing a new research approach with his team. 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 type of tumor, which remains mysterious, and hope to develop a personalized therapy for glioblastomas. Their work is made possible by the support of the Dr. Hans Altschüler Foundation, the Elgin Foundation, the Hanne Liebermann Foundation, the Mirto Foundation, the stiftup Foundation, the VSM Foundation, the Werner Geissberger Foundation and other charitable foundations.

A chip to replace animal testing
New drugs made from nanoparticles that can easily penetrate any barrier within our bodies are a great hope in medicine. The safety of such promising drugs must be ensured before they can reach the market. In this context, the following question must also be answered: What happens if, in the body of a pregnant woman, a substance manages to penetrate the natural barrier between baby and mother, the placenta? 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. A team from Empa and ETH Zurich, headed by Empa researcher Tina Bürki at the Particles-Biology Interactions laboratory in St. Gallen, has been working for some time on the question of how the so-called embryotoxicity of substances can be determined precisely, simply and reliably. The team, together with the Cantonal Hospital of St. Gallen and ETH Zurich, is now developing a new system that aims to detect embryo-damaging substances without the need for animal testing. This work is made possible by the support of the ProCare foundation.

Intelligent intestinal patch
Although surgical interventions in the gastrointestinal tract have become routine nowadays, the blood poisoning that can ensue during the repair of the intestinal passage is one of the most dreaded surgical complications. Approximately five to 15 percent of intestinal passages do not heal properly and leak contents of the digestive tract into the abdomen, which can lead to sepsis resulting in death. Treating such a problem, known as anastomosis insufficiency, is lengthy and complex since they are often discovered much too late. In a new project, Empa researchers led by Inge Herrmann, are developing a novel, functional intestinal patch to successfully combat anastomosis insufficiency and, for the first time ever, enable monitoring of the healing process through non-invasive ultrasonic measurement. The technology is based on a new bonding technology that anchors the intestinal patch in the tissue and can thus efficiently absorb any leaking digestive fluids and contents of the digestive tract. Sensors in the intestinal patch display possible leaks early on and can therefore prevent a severe course of disease. This project is made possible thanks to the support of the Evi Diethelm-Winteler Foundation, the Hans Gröber Foundation, the Peter Bockhoff Foundation and one other charitable foundation. //

1
The X-ray images show a glioblastoma, the most common and dangerous primary brain tumor.
Image: Tonpor Kasa, iStockphoto

2
Patented: The team led by Inge Herrmann and Alex Anthis has developed a hydrogel patch that stably seals surgical wounds.

Partnerships for innovation across borders

Prof. Dr. Tanja Zimmermann, tanja.zimmermann@empa.ch

Despite – or precisely because of – Switzerland's exclusion from EU research programs and bodies, which is by the way disadvantageous for all sides, maintaining international contacts and networks is all the more important. Therefore, Empa's Directorate exchanged ideas with various foreign delegations last year with the aim of exploring possibilities for future collaboration, among other things.

The focus was primarily on promoting innovation in an international – largely European – context. At the beginning of September, for example, a delegation from the Swedish innovation agency Vinnova – which has a similar role to Innosuisse in Switzerland – led by Director General Darja Isaksson, focused on improving technology transfer, promoting entrepreneurship and the role of public-private partnerships, such as in the area of Advanced Manufacturing (AM). In November, this was followed by a meeting of the Swedish-Swiss Innovation Initiative on digitalization in industry, at which just under 80 representatives from research and industry from Switzerland and Sweden, as well as from the host country Germany, exchanged ideas on the topics of sustainability and energy as well as – again – AM. There were also match-making opportunities to find project partners, for example for the new EUREKA/EUROSTAR calls launched at the event.

Visitors from the fields of business and politics

Several business delegations paid a visit to Empa, for example from Austria as part of a "Zukunftsreise" (journey to the future), an initiative of the Austrian Federal Ministry for Digital and Economic Affairs and the Austrian Federal Economic Chamber. Among the topics discussed were future alternatives in the construction industry – particularly regarding building materials such as concrete and asphalt – and innovative materials made of wood, a natural (and renewable) raw material that both countries have in large quantities.

The UK is a logical partner for Switzerland in terms of science and technology for several reasons: Firstly, the UK is also excluded from the EU research alliance – due to Brexit – and secondly, ten of the top 20 universities in Europe are based in one of the two countries. A group of British members of parliament visited Empa in April to discuss precisely this in-depth cooperation. Drone researcher Mirko Kovac, who heads both a research lab at Empa and a group at Imperial College London, demonstrated at NEST how such a cooperation can look in practice. This, incidentally, is entirely in line with the Memorandum of Understanding signed in London in November by the research ministers of both countries regarding in-depth cooperation in science and innovation.

Focus on major challenges

NEST and the sustainable building and energy solutions developed there were also the reason for the visit by representatives of the German Federal Institute for Research on Building, Urban Affairs and Spatial Development and various German universities in late May, as they are pursuing concepts in Germany that are similar to the Plug-and-Play innovation building on the Empa campus. Another key topic at NEST, circular economy in the construction industry, was the focus of a meeting with representatives of the Dutch Ministry of the Interior and the Dutch government's Central Property Administration in July. The Digital Technologies Forum of the German Federal Ministry for Economic Affairs and Climate Action, in turn, visited Empa in September to learn about the latest trends in quantum computing and digital construction, among other things.

1
A delegation of British members of parliament visited Empa in April.

2
In Empa's mobility demonstrator, move, Christian Bach (second from left) shows representatives of the Qatar Ministry of Finance and Federal Councilor, Ueli Maurer, ways and ideas for a closed carbon cycle, for instance using by fuels.

3
In mid-May, representatives of Swissnex – the global network of the State Secretariat for Education, Research and Innovation (SERI) – marveled at the NEST unit DFAB HOUSE.

1

2

3

That same month, the Finance Minister of Qatar, Ali bin Ahmed Al Kuwari, joined his Swiss counterpart Federal Councilor Ueli Maurer at Empa's mobility demonstrator, move, to learn about sustainable energy sources and the mobility of the future. Empa researcher Christian Bach and Empa Deputy CEO Peter Richner presented ways and ideas for a closed carbon cycle, for example by synthetic fuels.

And last but not least, a truly multinational group found its way to Dübendorf in mid-May: Representatives of Swissnex – the worldwide network of the State Secretariat for Education, Research and Innovation (SERI) – held their annual meeting on the Empa campus and learned about current Empa research projects and the latest trends in sustainable construction and digital fabrication. //

Exchange and dialog – live and in person again, at last!

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After the COVID restrictions were lifted in March 2022, Empa was finally able to welcome real visitors in customary – i.e. pre-Corona – numbers back at its sites. On tours of the Empa labs and NEST as well as at the more than 60 events, just under 12,000 interested visitors took the opportunity to learn more about Empa's research and the innovations. Moreover, there were several thousand virtual visitors and participants.

In order to further strengthen the dialog with the public, Empa also launched a new event format this past October called "wissen2go" (knowledge2go). At these compact, approximately 90-minute evening events, interested parties can hear about scientific "tidbits" on current technology topics – the first event covered climate-friendly mobility – with easy-to-understand, snappy presentations. In the subsequent Q&A, ideas, questions and suggestions can be discussed directly with the researchers and continued in more depth in the concluding drinks reception.

Shortly before the launch of wissen-2go, Empa researcher Roman Fasel was named one of the ten winners of the Science Breakthrough of the Year at the Falling Walls science festival, which takes place annually in Berlin, for his atomically precise quantum materials based on graphene. Empa also reached a broad public during the Digital Days – both live at the opening event on the Bundesplatz in Bern, where visitors could marvel at drones from Empa's Sustainability Robotics Lab, and virtually via livestreams on the topic of energy management of the future. In addition, the Empa spin-off viboo won the GreenTech Startup Battle at the Digital Days with its AI-controlled technology that can reduce the energy consumption for the heating of buildings by 20 to 40 percent.

A great deal of interest by politicians and the administration

Last year, Empa's Directorate was able to exchange views with several Federal Councilors on current research and innovation policy topics, for example on the fringes of the WEF, which was held, for once, in May 2022 with the motto "How to best serve Switzerland" and to which the ETH Domain had invited Federal Councilor Guy Parmelin as well as around 60 other high-ranking guests from politics, research and business to the WSL Institute SLF in Davos. At the end of August, Federal Councilor Ueli Maurer paid a two-day visit to Empa with all the head officials of the Federal Department of Finance, with the goals of strengthening cooperation, for instance with the Federal Office for Buildings and Logistics (BBL) – one of the country's largest real estate operators – putting the energy and building technologies developed at Empa into practice, and thus serving as a role model for the Swiss real estate industry in terms of sustainability.

At the end of September, the annual parliamentary group visits saw "Die Mitte" touring Empa in Thun, with representatives including Party President Gerhard Pfister, and brought the Social Democrats with Federal Councilor Simonetta Sommaruga to the Innovation Park Zurich in Dübendorf. And finally, in October, the President of the Swiss Confederation Ignazio Cassis, together with St. Gallen Cantonal Councilors Beat Tinner and Marc Mächer and Mayor of St. Gallen Maria Pappa, paid a visit to the joint stand of Empa and the Innovation Park Ost on the subject of digital twins at OLMA in St. Gallen. In addition, various federal offices such as the Federal Office for the Environment (FOEN), the Federal Roads Office (FEDRO) and the Swiss Federal Audit Office (SFAO) exchanged information with the Empa directorate.

1

2

One of the best inventions of the year

One example that highlights the fact that innovations from Empa are certainly "suitable for the masses" is the biodegradable paper battery that can be activated by a drop of water from Gustav Nyström's lab: It was featured on the list of the 100 best inventions of the year of the US magazine TIME. Media interest in Empa's research was also enormous in other respects, with (for the first time) more than 9,000 articles in 39 languages just this past year; a fact also evidenced by various visits by journalists from Japan, the USA, Germany and Austria, to name just a few.

And last but not least, Empa has also sought contact with its youngest stakeholder group, children and young people, with the goal of inspiring them to enter careers in natural sciences, research and technology – certainly not an insignificant undertaking in view of the universally lamented shortage of skilled workers. On the National Future Day and at its summer camp, Empa was thus able to give more than 130 enthusiastic children exciting insights into the world of researchers, scientists and engineers. The children conducted experiments themselves, assembled electric cars and computers, isolated the DNA of a tomato and played hide-and-seek in the dark with infrared goggles. In addition, Empa researchers again participated in several TecDays at cantonal schools hosted by the Swiss Academy of Engineering Sciences (SATW). //

3

1
In order to further strengthen the dialog with the public, Empa launched a new event format this past October called "wissen2go" (knowledge2go).

2
A tête-à-tête at OLMA in St. Gallen at the joint stand of Empa and the Switzerland Innovation Park Ost (from left): Empa researcher René Rossi, Cantonal Councilor Beat Tinner, Roland Ledergerber, President of the Board of Directors of Innovation Park Ost, President of the Swiss Confederation Ignazio Cassis, Cantonal Councilor Marc Mächler, Mayor Maria Pappa, Paola Cassis, Empa CEO Tanja Zimmermann, Hans Ebinger, CEO Switzerland Innovation Park Ost.

3
Every year, TIME publishes a list of the most important inventions of the year. This year, Gustav Nyström and his team from Empa's Cellulose & Wood Materials Laboratory made it onto the list with their biodegradable disposable battery, which points the way to the future of environmentally friendly electronics.

Diversity and inclusion remains a key topic

Melina Spycher, melina.spycher@empa.ch

In general, diversity is enormously important – I myself have had the best experiences in mixed teams," Tanja Zimmermann said in her interview in December 2022. The topic of diversity, equity and inclusion thus remains a key concern at Empa under its new management.

Further strengthening of diversity, equal opportunities and inclusion

The equal opportunities and diversity action plan for the 2021-2024 period also accompanied employees this year. One focus was to further strengthen the topic of diversity and inclusion at Empa. The Expert for Diversity & Inclusion visited departments and divisions for this purpose. The plan is to continue this in the coming year. Furthermore, the Newsletter for Equity was established in cooperation with the Paul Scherrer Institute (PSI) and WSL. Every two months, this newsletter provides information on various diversity-related topics, events and campaigns as well as other news. Its target audience are employees who regularly engage with the topic as well as those who are newly interested.

Are you interested in networking events or skill building courses? Also as part of this action plan, Empa continues its membership in Advance, the leading business association for gender equality in Switzerland. This network is comprised of over 120 Swiss companies committed to increasing the proportion of women in management positions. The association offers exciting skill-building and best practice workshops as well as networking events.

Kick-off for the new mentoring programme feM-LEAD

2022 saw the first call for applications for the new mentoring programme feM-LEAD (female Mentoring: Leadership for Equity And Diversity). It addresses women who want to take on a leadership position or want to find out whether leadership is the right fit for them. The programme, which has its origins at the PSI, starts in March 2023 with nine participants from Empa and will run for a year. The selected women from the fields of science, technology and communication will participate in a versatile framework programme in addition to the mentoring. The goal is a future with more women in leadership positions at Empa as well as throughout Switzerland.

CONNECTing academia and industry

In 2022, the CONNECT (connecting women's careers in academia and industry) program started its fourth round. As part of a motivated group of women scientists, Empa staff members visited companies such as McKinsey, DETEC, Bystronic and Siegfried and learned about exceptional women and their careers from academia to industry.

Big research for small scientists

After the difficult circumstances of the past years, the National Future Day was finally held in full again at Empa. A total of 89 children visited the Empa sites in St. Gallen and Dübendorf. In various workshops, they were given the opportunity to conduct experiments, assemble electric cars or computers, isolate the DNA of a tomato, play hide-and-seek in the dark or challenge each other in a Bobby Car race. In St. Gallen, the children added their own toppings to pizza for lunch, which was a big hit and ensured that food waste never became an issue.

And the Summer Camp was also held again. 16 motivated children of Empa staff members learned, among other things, how to make batteries, build rockets and use infrared cameras in a playful way. The children themselves captured these moments as budding paparazzi. //

The Summer Camp and the National Future Day gave children the opportunity to immerse themselves in the world of research and development and to handle materials in a playful way.

Challenges after the pandemic

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Following the sharp decline in business air travel in the wake of the COVID19 pandemic, greenhouse gas emissions from business travel rebounded sharply in 2022. This trend reversal was to be expected, but the extent is surprising. With a share of about one third of Empa's total emissions, business travel remains only slightly below pre-pandemic levels. Despite significantly higher use of digital communication tools, there seems to be some kind of pent-up demand for face-to-face contact and travel.

Energy future in implementation

The heating of buildings is one of Empa's main sources of greenhouse gases, accounting for around 50 percent of the total. To reduce emissions in this area, existing energy flows must be used efficiently. The heating network at the Dübendorf site is now fully operational, enabling heat generated from ventilation, equipment and servers on campus to be exchanged. A visionary underground storage facility is currently being implemented. 144 geothermal probes under the emerging "co-operate" research campus will enable the underground to be heated locally and this surplus energy to be used as a heating source in winter. It is planned to use this seasonal heat storage for research purposes as well as for building operation.

A pond for more biodiversity

The gravel area upgraded in 2021 at Empa in St. Gallen received a biodiversity update last year. As part of the national Clean-Up Day, an insect and amphibian pond was dug by the Grassroot Group. Despite rainy weather, employees and family members were pleased with the effort.

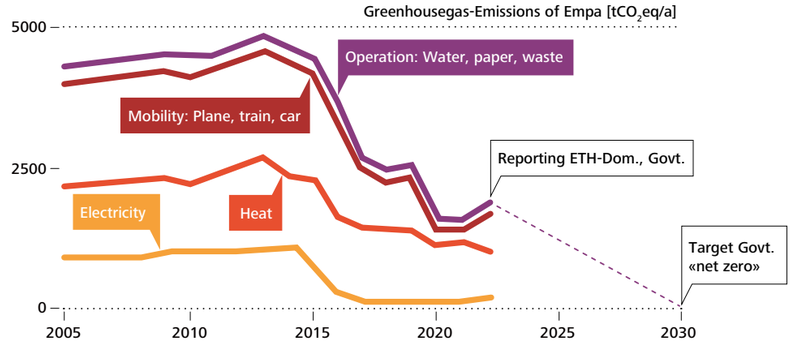
"Watt" is happening under my desk

The energy crisis was an ongoing socio-political issue in 2022. In response to this, various savings measures were implemented at the Empa sites, both large and small. For example, heating output was reduced and the provision of hot water (where not absolutely necessary) was dispensed with. In St. Gallen, power guzzlers were banished from the offices through the re-use of e-waste: Power supplies for older versions of electrically adjustable desks have a standby consumption of 7 watts. In contrast, the standby consumption of e-waste computer power supplies that have become obsolete is barely measurable. Since both power supplies have otherwise similar specifications, employees replaced the power supplies on dozens of desks. As a result, 62 kWh of electrical energy can be saved per console per year in the future, which is roughly equivalent to the energy requirements of a laptop. //

1
For more biodiversity, the Grassroot Group created an insect and amphibian pond.

2
The rebound in greenhouse gas emissions cannot be ignored, posing a major challenge to achieving the "net zero" target by 2030. Strong measures in the area of heat are being implemented, business travel remains a challenge.

1



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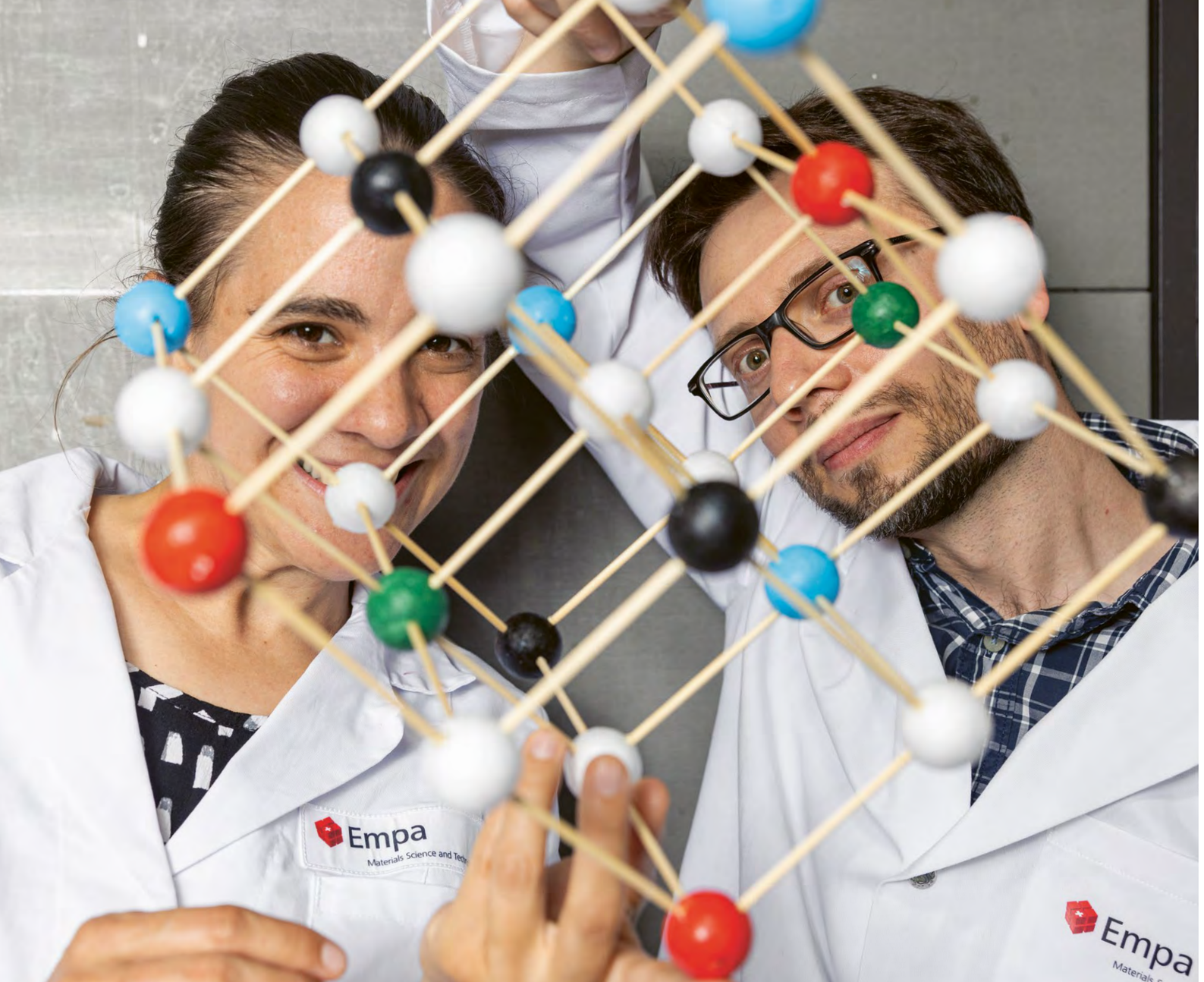

Facts and Figures

Researchers like measuring, including their own performance: In 2022, Empa researchers and engineers published 869 academic papers and filed patent applications for 18 developments. At the end of the year, 104 projects funded by the Swiss National Science Foundation (SNSF), 86 projects backed by Innosuisse and 76 EU projects were underway at Empa. Together with other start-ups in Empa's two business incubators, the 34 spin-offs employed a total of 1,082 people.
Empa's annual financial statement has been compiled, as at all institutions in the ETH Domain, based on IPSAS (International Public Sector Accounting Standards). It is available at *www.empa.ch/web/s604/annual-reports.*

Risk management

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The objective of risk management at Empa is to identify potential risks for the company and its employees at an early stage and to take appropriate measures to mitigate them. This system contributes to a culture of health and safety and thus constantly improves the safety situation at Empa.

Principles for dealing with risks

Empa has based its regulations in this area on the risk management guidelines for the ETH Domain and the Swiss federal government. Its safety and risk policy lays down binding rules for the homogeneous, systematic handling of the wide range of risks. The top priority of all measures is the protection of the health and lives of employees, guests and all persons within Empa's sphere of influence. Further objectives are the protection of material assets and the environment from negative impacts, the protection of know-how and intellectual property and the protection of Empa's reputation. The focus of these efforts is on prevention.

Risk management follows a standardized process, which starts with a periodic inventory of risks. Each risk is evaluated according to its possible impact and probability of occurrence and assessed in the categories of financial and reputational risk. Finally, measures to contain the risks are defined and implemented. In risk controlling, the risk management process is regularly reviewed and – if necessary – adjusted.

From the pandemic to a potential energy shortage

Fortunately, by spring 2022, the situation regarding COVID-19 had largely improved, and normal operations at Empa resumed in early summer. However, instead of the pandemic, the forecast energy shortage very quickly became a new focus for risk management. A task force tackled this complex issue. Efforts to determine energy consumption as precisely as possible on a temporal and spatial basis were stepped up. These findings formed the basis for the development of necessary and realistic emergency scenarios. To prepare for repeated and prolonged power outages, emergency power generators were rented for the sites to supplement the infrastructure already in place for operating the ICT systems. The purpose of these generators is to ensure emergency operation in order to prevent major damage to the equipment and instruments, some of which are extremely expensive.

However, the most important initiative was focused on saving energy and increasing energy efficiency. Energy-saving measures that had already been considered were implemented, such as reducing and modernizing indoor and outdoor lighting, replacing conventional heating valves with modern systems supported by artificial intelligence (AI), avoiding standby operation, and implementing power-saving settings on all printers. These measures were accompanied by awareness-raising campaigns.

Saving energy has been an important topic at Empa for some time now. In the past, the construction sector in particular already attached great importance to energy efficiency when planning building renovations and new buildings. As part of the construction or Empa and Eawag's new "co-operate" campus, for example, a seasonal geothermal energy storage system in the form of a geothermal probe field with a diameter of around 60 meters will be put into operation in 2023/24. In its final state, this high-temperature geothermal probe field will contribute around 1,700 MWh per year to the heating energy requirements of the campus. Assuming an annual consumption of around 6,000 MWh (as of 2018), this means that the geothermal probe system, including the heat pump, will supply around 28 percent of heating energy on campus. Major steps such as this one are of great importance in order to achieve the federal government's CO_2 targets.

Developing the security organization

A central aspect of prevention at Empa is the training of staff – with more than 500 staff members joining or leaving per year, this is a major challenge. The risk management division offers a wide range of training courses in the fields of chemical, nanotechnological and laser safety, etc. for different user levels.

The in-house rescue team, as well as the fire and chemical response team, also maintained their drill regime throughout 2022. The level of training was raised even further through selective advanced training. Interdisciplinary exercises were conducted and provided important input for further process improvements. Joint exercises with emergency services are in preparation.

The topic of information security gained even more relevance in view of the increased number of cyber attacks in the past year. An information security team developed a security concept and various instructions and started gathering information assets as a basis for defining the rules for handling specific information. Its aim is to protect the information based on a business risk analysis regarding confidentiality, integrity and availability. Systematic development of this issue will continue in the future in line with the standard and optimized for the institution. //

Human resources development

(previous year's figures in brackets)

André Schmid, andre.schmid@empa.ch

At the end of 2022, 1,021 (1,012) people, including trainees, were working at Empa. This corresponds to a full-time equivalent (FTE) of 959.50 (948.3) positions, due to numerous part-time employments.

Scientific staff, including PhD and postdoctoral students, comprises 577 (574) individuals. Of these, 102 (101) are Senior Scientists. Technical and administrative staff comprised 401 (395) persons in the year under review. The proportion of women, at 29.5 (28.2) percent, reflects the gender distribution among graduates from Swiss universities and ETH in the scientific disciplines represented at Empa.

The proportion of foreign citizens was 467 (457), or 45.7 (45.2) percent of the total staff. The EU accounts for 279 (268) persons, or 59.7 (58.6) percent of all foreign employees. Empa offers vocational training for a number of professions and currently employs 43 (43) apprentices. As in previous years, all Empa apprentices successfully passed their final exams in 2022. //

STAFF END OF 2022

	2021	2022
Scientific staff	**574**	**577**
Technical and administrative staff	**395**	**401**
Apprentices	43	43
Total	**1,012**	**1,021**

Key Figures

SCIENTIFIC OUTPUT

	2021	2022
ISI publications	**850**	**869**
Conference contributions	**942**	**1,103**
Doctoral studies completed	**34**	**54**
Doctoral studies in progress	**226**	**226**
Teaching activities (in hours)	**4,529**	**5,390**
Prizes and awards	**50**	**52**

EMPA-ACADEMY

	2021	2022
Empa events	**70**	**64**
Participants	4,490	4,038
On-site visits / online	1,266 / 3,224	3,011 / 1,027
Scientific conferences	18	19
Events for industry	14	20

KNOWLEDGE DISSEMINATION & TECHNOLOGY TRANSFER

	2021	2022
New R&D Agreements	**232**	**196**
Active exploitation contracts	**54**	**45**
New exploitation contracts	**14**	**9**
New patent applications	**13**	**18**

MEDIA EXPOSURE

	2021	2022
Radio	143	150
TV	57	45
Print	1,370	1,200
Online	6,880	7,700
Total	**8,450**	**9,100**
Languages	39	39

SPIN-OFFS & START-UPS (Startfeld & glaTec)

	2021	2022
Companies total	**107**	**112**
thereof spin-offs	28	34
Employees total	**1,097**	**1,082**
thereof employees of spin-offs	173	196

CURRENT PROJECTS

	2021	2022
Swiss National Science Foundation (SNSF)	**112**	**104**
Innosuisse	**98**	**86**
EU projects	**71**	**76**

Bodies of Empa

ETH Board

The ETH Board has overall responsibility for the management of the ETH Domain, which incorporates the two Federal Institutes of Technology (ETHZ, EPFL) and the four federal research institutes (PSI, WSL, Eawag and Empa).

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Michael O. Hengartner Prof. Dr.

VICE-CHAIRWOMAN

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Beatrice Fasana Dipl. lng. Lm, Sandro Vanini SA
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Christiane Leister Leister AG
Joël Mesot Prof. Dr., ETH Zürich
Cornelia Ritz Bossicard
Christian Rüegg Prof. Dr., Paul Scherrer Institut PSI
Martin Vetterli Prof. Dr., EPF Lausanne

Industrial Advisory Board

A body of leading personalities which advises the Empa management on fundamental concerns.

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Christian Koitzsch Dr., Robert Bosch GmbH
Katharina Lehmann Blumer-Lehmann AG
Chris Luebkeman Dr., ETH Zürich
Céline Mahieux Shell (Switzerland) AG

Research Commission

The Commission advises Empa's Board of Directors on questions of research, the choice of R&D spectrum and the evaluation of internal R&D projects.

CHAIRMAN

Andrea Bergamini Dr., Empa

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Marcus Textor Prof. em. Dr., ETH Zürich
Alexander Wokaun Prof. em. Dr.

Organizational chart

as of May 2023

RESEARCH FOCUS AREAS (Research priorities)

Nanoscale Materials and Technologies
Dr. Lorenz Herrmann

Built Environment
Dr. Peter Richner

Health and Performance
Prof. Dr. René Rossi a.i.

Energy, Resources and Emissions
Dr. Brigitte Buchmann

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Dr. Urs Leemann

RESEARCH, KNOWLEDGE AND TECHNOLOGY TRANSFER PLATFORMS

NEST
Reto Largo

move
Dr. Brigitte Buchmann

ehub
Philipp Heer

Coating Competence Center
Dr. Lars Sommerhäuser

Empa-Academy
Claudia Gonzalez

Business Incubators glaTec
Mario Jenni
Startfeld / SIP Ost
Peter Frischknecht

International Research Cooperations
Prof. Dr. Tanja Zimmermann

DEPARTMENTS

Advanced Materials and Surfaces
Dr. Lorenz Herrmann

Engineering Sciences
Dr. Peter Richner

Materials Meet Life
Prof. Dr. René Rossi a.i.

Energy, Mobility and Environment
Dr. Brigitte Buchmann

Corporate Services
Dr. Urs Leemann

LABORATORIES

High Performance Ceramics
Prof. Dr. Thomas Graule

Joining Technologies and Corrosion
Dr. Lars Jeurgens

Advanced Materials Processing
Prof. Dr. Patrik Hoffmann

nanotech@surfaces
Prof. Dr. Roman Fasel

Mechanics of Materials and Nanostructures
Prof. Dr. Johann Michler

Thin Films and Photovoltaics
Prof. Dr. Ayodhya N. Tiwari

Surface Science and Coating Technologies
Dr. Lars Sommerhäuser a.i.

Functional Polymers
Prof. Dr. Frank Nüesch

Structural Engineering
Prof. Dr. Masoud Motavalli

Mechanical Systems Engineering
Prof. Dr. Giovanni Terrasi

Multiscale Studies in Building Physics
Dr. Ivan Fabrizio Lunati

Experimental Continuum Mechanics
Prof. Dr. Edoardo Mazza

Concrete and Asphalt
Prof. Dr. Pietro Lura

Urban Energy Systems
Dr. Kristina Orehounig

Sustainability Robotics
Prof. Dr. Mirko Kovac

Magnetic and Functional Thin Films
Prof. Dr. Hans Josef Hug

Cellulose & Wood Materials
Dr. Gustav Nyström

Biomimetic Membranes and Textiles
Prof. Dr. René Rossi

Advanced Fibers
Prof. Dr. Manfred Heuberger

Particles-Biology Interactions
Dr. Peter Wick

Biointerfaces
Prof. Dr. Katharina Maniura

Transport at Nanoscale Interfaces
Prof. Dr. Michel Calame

Building Energy Materials and Components
Dr. Wim Malfait

Materials for Energy Conversion
Dr. Corsin Battaglia

Advanced Analytical Technologies
PD Dr. Davide Bleiner

Air Pollution / Environmental Technology
Dr. Lukas Emmenegger

Automotive Powertrain Technologies
Christian Bach

Materials for Renewable Energy
Prof. Dr. Andreas Züttel (Antenna Sion)

Technology and Society
Dr. Patrick Wäger

Acoustics / Noise Control
Dr. Jean Marc Wunderli

ICT-Services
Stephan Koch

Mechanical Engineering / Workshop
Stefan Hösli

Finances / Controlling / Purchasing
Susann Hug a.i.

Communication
Dr. Michael Hagmann

Human Resources
André Schmid

Knowledge and Technology Transfer / Legal
Marlen Müller

Real Estate Management
Kevin Olas

CENTERS

Electron Microscopy Center
Prof. Dr. Rolf Erni

Center for Synergetic Structures
Dr. Cédric Galliot

Center for X-ray Analytics
Prof. Dr. Antonia Neels

Library (Lib4RI)
Dr. Lothar Nunnenmacher

Entrepreneurship / Industry Relations
Gabriele Dobenecker

Fundraising
Dr. Martin Gubser

Scientific IT
Prof. Dr. Eleni Pratsini

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A complete overview of the vested interests can be found at: *https://www.empa.ch/web/empa/vested-interests*

Empa – The Place where Innovation Starts

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