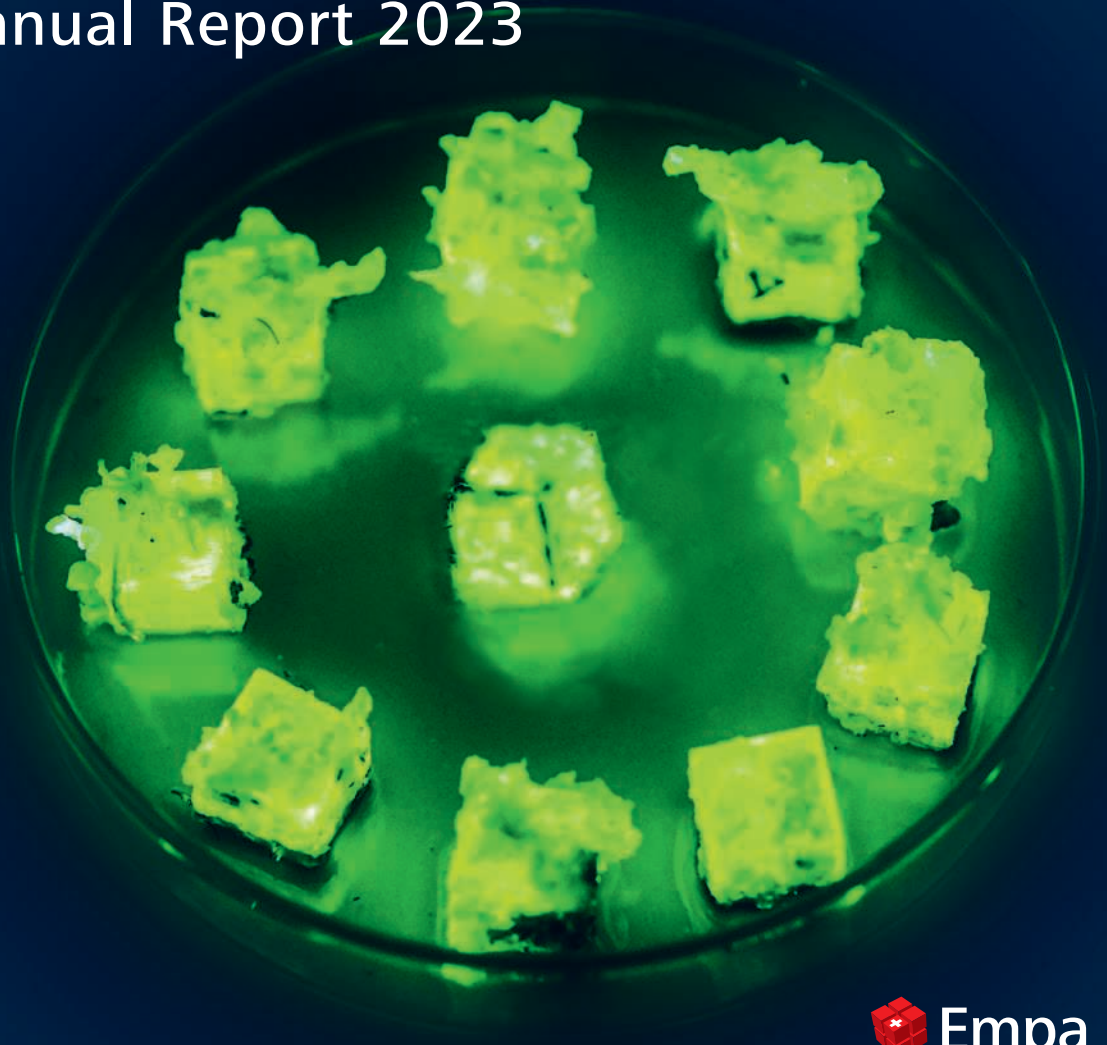
Annual Report 2023



Empa
Materials Science and Technology

Our Vision.
Materials and Technologies for a Sustainable Future.

Cover image:
Empa researcher Francis Schwarze has developed a process for producing bioluminescent wood using fungi. The fungal filaments of a white rot fungus penetrate the wood and feed on wood components, producing the light-generating substance luciferin. Similar to fireflies, the functionalized wood emits a greenish light in the dark thanks to the glowing fungal filaments.

Publisher: Empa
Concept/design/layout: Empa
Production: Neidhart+Schön Print AG, Zürich
Images: © Empa, unless otherwise stated

ClimatePartner klimaneutral
Druck | ID: 53232-1504-1011

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Giving innovation a major boost

The past year was characterized by major progress and some groundbreaking initiatives that we launched, in many cases in close cooperation with our partners. I would like to give you an overview of the latest developments and an insight into the many exciting prospects that lie ahead.

Our aim to boost innovation has inspired us to introduce new internal tools and processes to help us develop groundbreaking ideas faster and initiate new, forward-looking research activities. The first two of our newly launched "Research Boosters", this time in the fields of biomedicine and 2D materials, are a case in point. We are concentrating on new institute-wide initiatives such as Mining the Atmosphere (see p. 28), which enable us to focus our interdisciplinary research even more on a clear objective.

Interdisciplinarity, which is at the heart of our research philosophy, is also reflected in our partly renewed senior management team. Over the past 18 months, four new department heads with extremely diverse backgrounds – from large corporations to start-ups and application-oriented, translational research – have taken on their roles at Empa. This diversity fuels creativity and strengthens our ability to find innovative solutions to the complex challenges of our time.

The close partnership with our sister institute Eawag focuses on pooling our strengths. Under the heading of Climate Solutions, we are working together on solutions for dealing with and counteracting climate change; we will, for instance, be chipping in our Mining the Atmosphere activities. More specifically and in the context of Beyond Zero and circularity, we are already planning several NEST units that will demonstrate solutions for a sustainable, resource-conserving future. Our new Empa-Eawag campus co-operate, which will go into operation later this year, will support us with various innovative approaches such as a large geothermal probe field to take us a significant step closer to our on-campus goal of net zero.

Of course, the challenges we face are enormous. We are convinced that we can only master them successfully through comprehensive cooperation across the entire ETH Domain and beyond. We are therefore actively involved in various joint initiatives within the ETH Domain, whether in the field of energy or other topics. Our goal is clear-cut: We want to achieve maximum impact by further advancing our research through an increased focus and a joining of forces – both internally and in collaboration with our numerous partners from research and industry.

With this in mind, I look forward to taking the next steps in Empa's exciting journey with you and thank you for your continued interest and support. I hope you enjoy reading this Annual Report!

Tanja Zimmermann

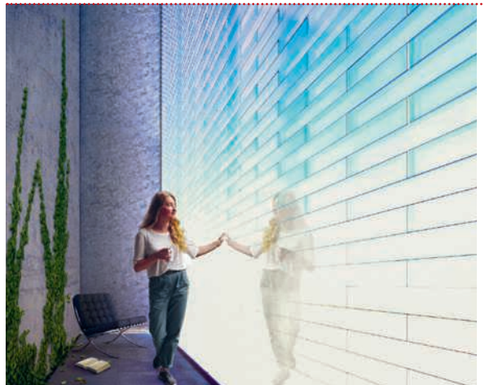
***Prof. Dr Tanja Zimmermann**, Director*

Year at a Glance

Partial renewal at senior management level
Since October 2023, Empa's Energy, Mobility and Environment department has had a new head: Chemical and bioengineer Nathalie Casas, an expert in CO_2 capture, succeeded Brigitte Buchmann in this role. Casas was Head of Research and Development at the ETH spin-off and cleantech company Climeworks. She is also a member of the Innosuisse Innovation Council. Following the retirement of Alex Dommann, Empa's Materials meet Life department is now managed in the form of a co-lead: René Rossi and Manfred Heuberger took over jointly and rep-resent the department as co-heads.

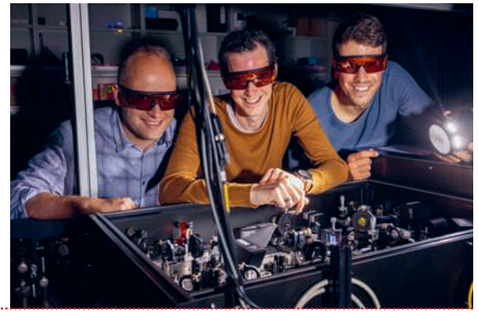
Asphalt: from old to new
Switzerland is largely built, at least as far as the road network is concerned. As a result, despite recycling, significantly more reclaimed asphalt is produced than can be reinstalled in new roads. It is thus all the more important to try and keep the proportion of recycled asphalt as high as possible whenever repairs and renewals are carried out. Empa researchers have set themselves the goal of increasing the share of recycled asphalt – with adapted production methods and simple instructions. Two test tracks with recycled asphalt in Uster and on the Lukmanier Pass are very promising.

Rapid test for blood poisoning
In case of blood poisoning, the bacteria in the blood must be identified as fast as possible in order to initiate life-saving therapies. Empa researchers have now developed "sepsis sensors" with magnetic nanoparticles that recognize germs within a short time and identify candidates for effective antibiotic therapy. The magnetic nanoparticles bind to the bacteria in a urine sample and can be isolated using a magnetic field. If resistant Pseudomonas pathogens are present, this can be made visible using a chemiluminescence reaction.



Light brickwork
Glass blocks have long been popular in architecture to bring more light into buildings. Until now, however, they were not suitable for load-bearing walls and were poor insulators. An Empa team has now developed a translucent and, thanks to aerogel, well-insulating glass block that can even be used for load-bearing elements. This makes it possible to build aesthetic, translucent walls that reduce the need for artificial lighting inside the building.

Green electronics
Can cellulose fibers be used to produce sustainable circuit boards for the electronics industry? Empa researcher Thomas Geiger investigated this and produced housing parts for computer mice from cellulose fibers. The surfaces shine like precious ivory; the components are completely biodegradable. Geiger is now part of the multinational EU project Hypeligum. Its goal: biodegradable electronics.



A quantum computer based on atomic defects
Empa physicist Bruno Schuler (center) and his team are embarking on an ambitious research project: They want to add targeted defects to atomic layers of semiconductor materials and attempt to measure and control their quantum properties with both picosecond temporal resolution and atomic precision. The aim is to generate fundamental knowledge for future quantum computers. The Empa researcher is supported by a grant from the European Research Council (ERC).

Empa components on the way to Jupiter
The European space probe JUICE, launched in April, is to explore Jupiter and its icy moons. The instruments for this have to survive the rocket launch and the long journey through space – and still function precisely and reliably afterwards. Also on board: Components manufactured at Empa using a specially developed soldering process.

New plastic protects against flames – and prevents waste
Empa researchers have developed an epoxy resin that can be repaired and recycled – and is also flame-retardant and mechanically resistant. At the same time, it retains the favorable thermomechanical properties of epoxy resins. Possible applications range from coatings for parquet flooring to composite materials for trains and airplanes. Image: Adobe Stock

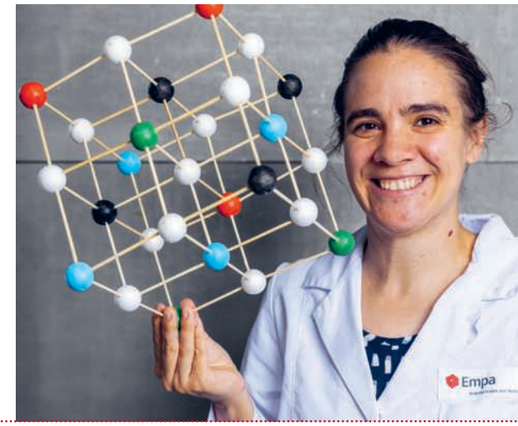
Special award for Empa apprentices at national research competition
New horizons open up for anyone achieving a special mention in the national "Schweizer Jugend forscht" competition. This is what Sofie Gnannt and Nick Cáceres, physics laboratory technician apprentices at Empa's Transport at Nanoscale Interfaces lab, have achieved. With their project, Plastic Separation with Terahertz Radiation, which was rated "outstanding", they represented Switzerland at MILSET, the international young researchers' conference in Mexico, in October.

Virtual railroad noise – close to reality
For years, acoustics experts at Empa have been investigating how noise is generated by passenger and cargo trains – and which technical and structural measures are particularly effective against it. Their findings have now been incorporated into the SILVARSTAR project. The result is a simulation tool for railroad noise that can also help in practice. It can be used to playfully experience a cargo train passing by, for instance: The monitor shows what the users see in virtual reality – with the realistic railroad noise exactly in their position.

New technology for analyzing old ice
Ice cores are a unique climate archive. Thanks to a new method jointly developed by researchers at the University of Bern and Empa, greenhouse gas concentrations in 1.5 million-year-old ice can now be measured more accurately. This requires a new laser spectrometer with an automatic inlet system for ice core air samples. The air extracted from the ice cores is not lost during measurements and can be used for further analyses. Image: PNRA/IPEV

3D-printed insoles measure sole pressure directly in the shoe
Researchers at ETH Zurich, Empa and EPFL have developed a 3D-printed insole with integrated sensors that allows the sole pressure to be measured in the shoe and thus during any activity. This helps athletes and patients to determine progress in performance and therapy.

When disorder contributes to solving our energy problems
Empa researcher Amy Knorpp wants to bring a systematic approach to the rather new field of high-entropy oxides. These are crystals whose specialty is not order but disorder. By using these crystals, the researcher hopes to develop new, more robust and more efficient catalysts and thus make an important contribution to the transition away from fossil fuels towards CO_2-neutral solutions. In 2023, Knorpp was awarded an Empa Young Scientist Fellowship.



Empa research as a basis for new EU regulations
New vehicles are responsible for around 10 percent of the EU's demand for plastics, and the automotive sector is the main consumer of raw materials such as aluminum, magnesium, platinum group metals and rare earth elements. A new set of rules proposed by the European Commission to revise the EU End-of-Life Vehicles Directive is intended to strengthen circular economy in the automotive sector. Empa researchers played a key role in developing the scientific basis as part of a science-for-policy study. Image: Adobe Stock

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.

Success with “snake polymers”

Dr Dorina Opris, dorina.opris@empa.ch

An area of research with potential: Novel dielectric polymers stretch under electrical voltage and can be used as wafer-thin layers in actuators – for example for artificial muscles, which have been the subject of research for years, or for generating electricity. The “Functional Polymeric Materials” research group at Empa, led by chemist Dorina Opris, is working in this field – with success, as demonstrated by the award and funding of an “ERC Consolidator Grant” worth around 2 million euros.

Of course, the chemist had to overcome hurdles when starting out in materials research: Ideas failed, funding was not approved. Funding from the Swiss National Science Foundation and the Sciex scholarship program finally provided support. In 2020, Opris received the “ERC Consolidator Grant” for the “TRANS” project (“Synthesis of novel stimuli responsive dielectric polymers and their use in powerful transducers”) – for printable dielectric polymers that convert electrical voltage into strain or movements and temperature changes into electricity.

The fact that Opris and her creative colleagues have mastered this field is also thanks to know-how that originated at Empa – such as that of engineer Gabor Kovac, who pioneered the production of stack actuators with silicone disks. Unlike her colleagues, however, the chemist works less on printing such components and more on the synthesis of polymers for non-conductive layers for stacked transistors or elastic films.

The desired profile: As thin as possible, easy to stretch, sensitive to low voltage and robust at the same time. And above all: Printable, i.e. without solvents for the conductive layers between which the polymers lie. Compounds that raise hopes are polysiloxanes: They are easy to synthesize; the “backbone” of their strands is very flexible – and they can be easily manipulated with polar groups, i.e. plus-minus charged molecules.

In layman’s terms, Opris explains them with an image: “You can imagine the polysiloxanes as a pot full of snakes that constantly want to move.” The polar groups act on them in two ways. Firstly, they make these snakes more sensitive to electric fields so that they react to low voltages. Secondly, they act as a kind of glue between the molecules. Both effects need to be fine-tuned. For practical application, the transition from a solid to an elastic state at low temperatures is also important so that the technology can later be used at room temperature.
In addition, such polymer structures must be chemically “cross-linked” – for example by UV light and with the help of so-called end groups: Quasi molecular “hats” that the snakes wear at their ends. However, in laboratory practice, it has so far proved tricky to reliably provide these polymers with defined end groups. The chemist herself calls the TRANS project “very, very ambitious”.

Her team is optimistic about previous work, such as a polysiloxane elastomer that deformed at a voltage of just 300 volts – an extremely low value. Printing capacitor layers without solvents was also successful. Nevertheless, there are still many steps to be taken – and qualities that have brought Dorina Opris to Empa and ETH Zurich: The ability to turn failed attempts into progress and to create an inspiring environment for employees that also allows failed attempts so that good ideas can emerge. //

Teamwork: Together with doctoral student Malte Beccard, Dorina Opris inspects a liquid used to produce the dye spiropyran.

Building with clay: a clean mud fight

Dr Ellina Bernard, ellina.bernard@empa.ch

The built environment is, on the one hand, the structural foundation of a society and, on the other, one of the biggest climate sinners. Cement production alone is responsible for around 7 percent of all greenhouse gas emissions worldwide. Empa researchers are therefore working on ways to reduce these emissions with innovative building materials and technologies. One of these paths to clean building is a muddy one: Ellina Bernard from Empa's "Concrete & Asphalt" laboratory and the Chair of Sustainable Building at ETH Zurich is currently investigating the potential of clay as a sustainable building material. Compared to concrete, clay should release significantly less CO_2. It is also available in almost unlimited quantities, can be recycled and is easy to process – even together with other "hipsters" of modern building culture such as organic waste materials from hemp processing.

Earth-based paste for residential buildings

The potential of this concrete alternative would be enormous. Concrete could not be replaced by clay for all purposes. However, in addition to a variety of non-load-bearing constructions, load-bearing walls of residential buildings are possible. And after all, more than half of all building permits in Switzerland are issued for residential buildings.

A true miracle cure? Unfortunately not yet, because although clay is one of the more original building materials in human history, the earthy paste has yet to be properly mastered. On the one hand, the composition of the natural material varies all over the world, which makes standardized production and use difficult. Secondly, conventional cement is currently added to the clay to create a stable and durable building material. However, this addition pushes the ecological footprint of clay back into the red zone. Ellina Bernard and her team therefore want to explore the earth-based material, define standards for its composition and mechanical strength and at the same time develop a clean alternative building material for industrial use. She was awarded one of the coveted "Ambizione" grants from the Swiss National Science Foundation (SNSF) for this ambitious project.

The gentle power of magnesium

Magnesium-based cement is a promising candidate in the search for a suitable stabilizing binder. When extracted sustainably, it has an excellent carbon footprint compared to calcium-containing cement, whose chemical reaction releases large amounts of CO_2. In addition, magnesium-based cement shortens the drying time and yet only gently interferes with the advantageous micro- and nanostructure of the clay elementary particles.

In the first laboratory experiments, the team has already achieved a compressive strength of up to 15 megapascals with various clay formulations – many times higher than untreated clay. A good start for Ellina Bernard. As she wants to assess the sustainability of building materials holistically, the laboratory experiments must also be accompanied by life cycle analyses that record the durability, deconstruction and recycling of the materials. //

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1
The geological composition of the earths is different all over the world. Ellina Bernard wants to develop standards for their use in the construction industry.

2
Earthy raw materials: Loam consists of clay minerals, sand and fine-grained silt sediments. To develop a water-resistant material with concrete-like properties, other additives need to be added.

Building the electronics of the future

Prof. Dr Mickael Lucien Perrin, mickael.perrin@empa.ch

Quantum technology it is expected to provide us with various technological breakthroughs in the coming decades: Smaller and more precise sensors, highly secure communication networks and powerful computers. To achieve this, we need so-called quantum materials: Substances that exhibit pronounced quantum physical effects. One such material is graphene. This two-dimensional structural form of carbon has unusual properties, such as extraordinarily high tensile strength, thermal and electrical conductivity. Restricting the already two-dimensional material even further, for instance, by giving it a ribbon-like shape, gives rise to a range of controllable quantum effects.

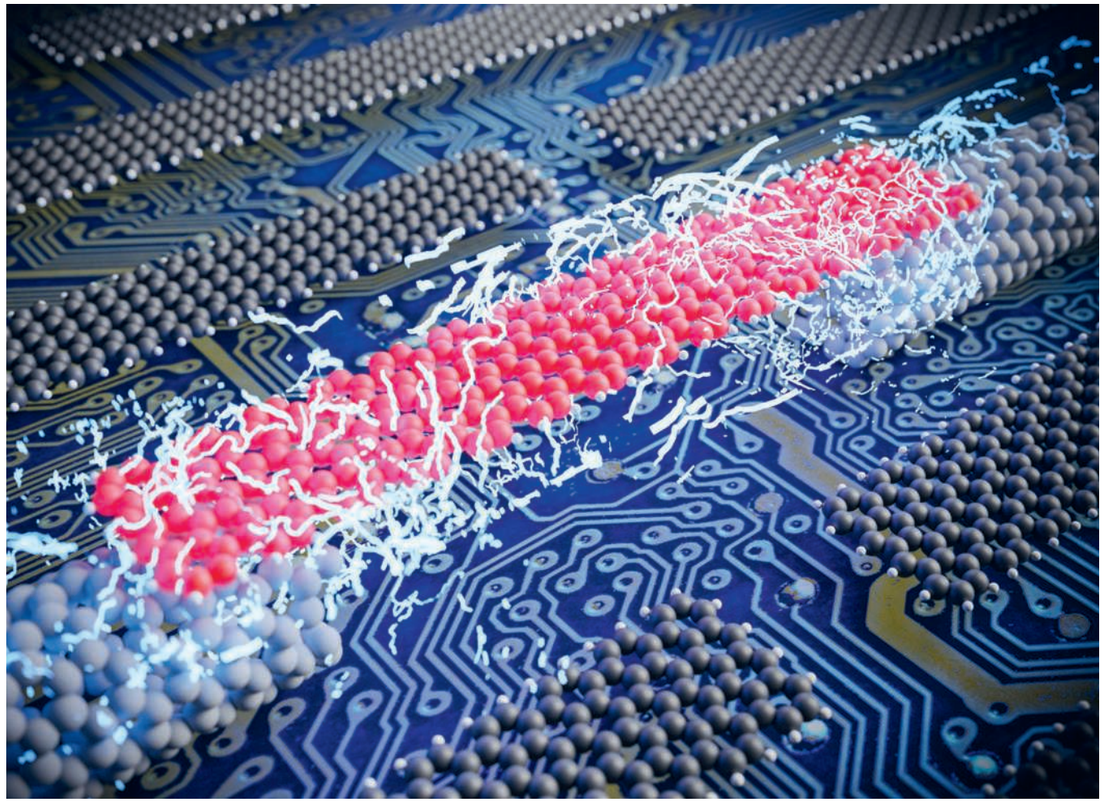
This is precisely what Mickael Perrin's team leverage in their work: For several years now, scientists in Empa's Transport at Nanoscale Interfaces laboratory, headed by Michel Calame, have been conducting research on graphene nanoribbons under Perrin's leadership. By varying the length and width of the ribbons, as well as the shape of their edges, and by adding other atoms to them, the researchers are able to give them all kinds of electrical, magnetic and optical properties. The precision manufacturing of these nanoribbons is carried out by Empa's nanotech@surfaces laboratory.

Ultimate precision – down to single atoms

In a new study published in August in the journal Nature Electronics, Perrin and his team have succeeded for the first time in contacting individual long and atomically precise graphene nanoribbons. Not a trivial task, since the ribbons only measure 1 nanometer in width. To ensure that only a single nanoribbon is contacted, the researchers employed electrodes of a similar size: They used carbon nanotubes that were also only 1 nanometer in diameter. Precision was key every step of the way, from synthesizing the source materials to connecting the ribbons and the nanotubes and measuring their properties. Interdisciplinarity and international collaboration were equally essential: Scientists from various institutions in Germany, China and the United Kingdom contributed to the study.

Where theory becomes practice

Graphene nanoribbons are not ready for commercial applications just yet, but Empa and its partners aim to pave the way for this in the coming years with the new research initiative Materials to Devices. The goal is to increasingly process promising materials such as graphene nanoribbons into devices, i.e. electronic components for new kinds of sensors or quantum computers. Another aim of the initiative is to develop and scale up the production processes for such devices, enabling a first step from basic research towards practical application. In the future, these technologies could facilitate breakthroughs, such as the production of quantum computers that do not require an energy-intensive cooling infrastructure. //



An atomically precise graphene nanoribbon with carbon nanotube electrodes: A first step on the way to novel electronic devices.

A close look at plastic pollution

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Dr Zhanyun Wang, zhanyun.wang@empa.ch

Most Swiss citizens are aware that plastic is a problem for the environment. Plastic bags and PET bottles are not biodegradable and can be fatal for animals. But not all plastic pollution is visible to the naked eye. Empa researchers are investigating and modeling the invisible environmental impact of microplastics.

Microplastics in Swiss rivers and lakes

Every year, approximately 15 tons of microplastic – particles in the micrometer to millimeter range – end up in Swiss rivers and lakes. Microplastics comes from many sources, such as cosmetics or synthetic fiber clothing. The tiny particles are also produced by abrasion and decomposition of larger pieces of plastic. Due to their small size, microplastics particles readily enter waterways. Measuring their concentration in water is not an easy task, because the tiny polymer pieces are often difficult to distinguish from particles of natural origin, and their quantity varies greatly with the time and place of measurement as well as with the measurement method.

Empa researchers David Mennekes and Bernd Nowack have developed a model for the Federal Office for the Environment (FOEN) that can predict the concentration of microplastics in waterbodies nationwide. It also allows researchers and policy makers to estimate what effects behavioral changes or government measures would have on microplastics concentrations. The scientists published their findings in June in the new journal Nature Water. The model can also be applied to other countries and areas.

An unknown risk: chemicals in plastics

The plastic itself is not the only threat to the environment: Plastics contain thousands of chemicals, and many others are used in their manufacturing. A technical report from the United Nations Environment Programme (UNEP), co-authored by Empa researchers Narain Ashta and Zhanyun Wang from Empa's "Energy, Mobility and Environment" department, has found that over 13,000 different chemicals are found in plastics or used in their manufacture. A quarter of these have been shown to be problematic, and for about another 50 percent or so, little is known to make an assessment of their safety. The report also prioritizes ten sectors where chemicals of concern are particularly likely to endanger people and the environment. This is the case, for example, with plastic products for agriculture and fishing, as well as toys, food packaging, electronic devices, furniture, textiles, vehicles, building materials and many more. The researchers propose a number of measures to reduce chemical pollution, especially in these products. //

1
Some of the sectors where chemicals of concern in plastics are particularly problematic include toys, furniture, textiles and food packaging.
Image: Adobe Stock

2
Microplastics: Pieces of plastics less than 5 millimeters in size easily end up in bodies of water.

3
One of the ways microplastics gets into the environment is by degradation and abrasion of larger pieces of plastic.

How can manufacturing technologies be scaled up?

Dr Lars Sommerhäuser, lars.sommerhaeuser@empa.ch

In our day-to-day research, we encounter technical challenges as well as scientific questions: How can we improve the properties of a product, e.g. increase the efficiency of a solar cell? Or how can we manufacture a product more efficiently, e.g. print electronic components on foils instead of producing them on silicon wafers using complex lithography and coating processes?

From the idea to CCC to production

It usually starts with a new idea. Then we have to prove that this idea works: We develop models and calculate them with the help of computers. We go to the laboratory, prepare samples and examine them. Finally – if we are successful – we have a demonstrator. This allows us to show that our idea works – at least in the laboratory.

This demonstrator is usually not enough for industry. They need proof that it not only works on a laboratory scale, but also with industrial processes and on large systems. We therefore have to demonstrate the scalability of the new production technology, usually together with our industrial partners. Empa's Coating Competence Center (CCC) in Dübendorf is the perfect place for this.

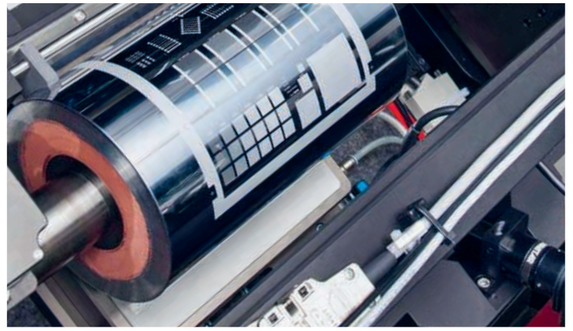
On the one hand, the CCC is equipped with smaller production facilities like those used in industry. On the other hand, there are pilot plants. These are used to manufacture products with similar process parameters to those used on production systems, but in smaller quantities. This allows materials to be used that are not yet available in large quantities. And many process or product variants can be tested.

The CCC is also a place for technology development, where partners with different areas of expertise work together. One example of such cooperation is the "SCALAR" project. In addition to the research groups at Empa, ETH Zurich, EPFL and the Paul Scherrer Institute (PSI), numerous industrial partners such as Norbert Schläfli Maschinen, 3D AG and Hilti are also involved in this project, which is funded by the ETH Board in the Strategic Focus Area "Advanced Manufacturing".

Gravure printing for electronic circuits

The aim of the project is to further develop the widely used gravure printing process so that it can be used to print complex electronic circuits. The technical goal of the project is to be able to print micrometer-sized structures at a speed of 1 meter per second. Until now, such fine structures could only be printed very slowly. If the printing speed is increased, the minimum structure size increases to 10 micrometers. This resolution is not sufficient to be able to produce electronic circuits competitively.

The goal of the project is to understand exactly what mechanisms are at work when the ink is transferred from the very small cells of the cylinder to the substrate to be printed. This depends on numerous factors. These include the material properties such as the flow properties of the ink, the geometry of the printing cylinder or the surface properties of the substrate. At the same time, the process phenomena must be understood, i.e. factors such as adhesion, pressure, shear rates and stresses. SCALAR uses the high-precision printer at the CCC. The project has shown that printing the smallest structures at high speeds not only works in the laboratory, but also with industrial processes on a pilot system. //



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1
View into the printing unit: The elements to be printed can be seen on the gravure cylinder.

2
Preparation of the machine for the printing process. Clean room conditions prevail.

NEST – taking big steps forward towards new projects

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Almost 400 guided tours and around 9,000 visitors: 2023 was a busy year at NEST. As construction for its next unit "STEP2" started, the innovation and research building also visibly came alive again from an outside point of view. From the beginning of October, visitors were able to follow the development process live and make new discoveries every week. After around three years of development, construction is now progressing rapidly and STEP2 will open in 2024. The main focus of the unit lies in its co-creation by all involved parties throughout the entire development process and also in bringing various innovations to a market-ready state. As a result, a strategic partnership with Stahlton Betonteile AG and zirkulit AG was initiated even before the construction work began. Together, the two companies will continue to pursue the vision of recyclable concrete buildings.

Two further units on the horizon

Besides the construction of STEP2, the team started developing and planning further projects. As a result, two new units will complete NEST: In the style of an aviary, the "DroneHub" will soon provide a testing ground for drones to carry out measurement, construction and maintenance work. This will enable airborne testing in the field of additive manufacturing (AM) under realistic conditions. At the same time, the "cage" of the "DroneHub" enables test flights without having to obtain individual permits. Overall, this gives drone research at Empa a major boost and opens up new, promising possibilities.

The latest NEST unit, "Beyond Zero", is intended to investigate the extent to which CO_2-negative materials from the Empa laboratories can be used in buildings that would function as actual carbon sinks in the future. Empa researches and partners are driving forward the development of the unit, which fits seamlessly into the new "Mining the Atmosphere" research initiative. Said initiative aims to "extract" CO_2 from the air and convert it into solid carbon and hydrogen using chemical conversion processes. The resulting products will lend themselves to potential application in the mobility and construction sectors and reduce the overall CO_2 in the atmosphere.

Committing to a circular economy

However, NEST has an inspiring effect outside of its walls, too: On the initiative of NEST and the Canton of Zurich, twelve of the largest public and private construction partners in Switzerland signed up to the "circular construction" charter in summer 2023. Thereby, they confirm their intention to reduce the use of non-renewable primary raw materials in construction to a maximum of 50 percent of the total mass by 2030. Additionally, they intend to record and significantly reduce gray energy emissions as well as to measure and significantly improve the circularity of renovations and new buildings. Together, the involved parties are responsible for an annual investment volume of around 4 billion Swiss francs in the building sector. The charter therefore sends out a clear signal in the ongoing struggle against energy and resource scarcity. It also tackles the current challenges in the construction sector and aids efforts towards a circular economy in Switzerland. //

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1
As a kind of aviary, the "DroneHub" will enable a wide range of research with drones at NEST in the future.

2
The modular ceiling of the STEP2 unit was prefabricated by Stahlton Bauteile AG and assembled on site.
Image: ROK Architekten

2

The path to negative emissions

Christian Bach, christian.bach@empa.ch

2023 was marked by the new Empa research initiative: "Mining the Atmosphere". The aim is to use hydrogen to convert CO_2 extracted from the atmosphere into short- or longer-chain hydrocarbons. These can replace fossil fuels in aviation, in high-temperature industrial processes or in long-distance freight transportation. Move plays a central role in the implementation of this vision, as the mobility demonstrator provides important findings, for example on catalytic processes and efficient energy management, networks relevant players and shows how the mobility and industry of the future could function without fossil fuels.

Optimizing technologies

The production of circular energy sources such as synthetic methane is forward-looking – but has its pitfalls, as it is associated with relatively high energy losses. In addition, the load flexibility of existing processes is not yet fully developed. This is important because renewable electricity – the energy basis for the production of hydrogen and synthetic energy sources – fluctuates. Empa researchers have therefore developed a new reactor concept for methanation that is optimized for load flexibility. A laboratory reactor has been running since last year and a demonstrator is currently under construction. This will enable methane to be produced in move in line with the cycle. The CO_2 required comes from a "Direct Air Capturing" system from Climeworks in move.

Not only mobility, but also industrial high-temperature processes should be decarbonized. The Association for the Decarbonization of Industry (VzDI) is committed to this, with Empa as a founding member. The VzDI is currently building a demonstration plant in the Tech Cluster Zug, in which methane used as fuel gas for the enameling furnace of V-ZUG AG is split into the components hydrogen and solid carbon by means of pyrolysis. The separated carbon is then to be developed into a raw material for construction and agriculture, for example as an admixture in building materials or for the enrichment of humus. Empa laboratories have already carried out initial spectroscopic analyses of the methane plasma and have started to lay the foundations for carbon processing

Establishing cooperation

However, the potential for domestic production of renewable hydrogen or synthetic methane is not sufficient to cover Switzerland's needs. The situation is different in the Earth's sun belt. The "reFuel.ch" consortium, which consists of nine Swiss universities, universities and research institutes – including Empa – as well as an industrial partner, is convinced of this. It is funded by the Swiss Federal Office of Energy (SFOE) as part of the SWEET funding program and aims to develop robust supply paths for sustainable fuels and basic chemicals. Both Swiss and foreign potentials are being investigated. Against this backdrop, the Omani ambassador has already presented Empa, as co-coordinator of reFuel.ch, with a letter of interest for cooperation.

An initial project for wireless charging of electric vehicles was launched at the end of the year. The project team is investigating the technical feasibility of inductive charging, determining the advantages and disadvantages compared to conventional charging systems and clarifying the approval process. Empa is part of the project team led by Eniwa, which is also supported by the SFOE. //

1
Switzerland and Oman are pulling together: Omani Ambassador to Switzerland H.E. Mahmood Al Hassani (right) presents Empa researcher Christian Bach (left) with a "letter of interest" for cooperation in the reFuel.ch project.

2
The majority of sustainable energy sources will come from countries in the Earth's sun belt, as twice as much electricity can be generated per square meter of PV area there than in Switzerland. Image: Adobe Stock Photo

Storage and flexibility: the major challenges of the energy transition

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With the expansion of renewable energy resources, storage systems are becoming increasingly relevant. As a large proportion of renewable energy – especially from solar and wind – is intermittent, ways and means must be found to make this energy "flexible". Since its opening in 2016, Empa's Energy Hub (ehub for short) has been an important platform for evaluating and further developing storage solutions, conversion technologies and the control of energy flows in a real-life environment. The ehub connects the two demonstration platforms NEST and move – and thus also links the building and mobility sectors.

Over the past year, the ehub team has been working on expanding its own infrastructure, among other things. Additional thermal energy storages were installed, practically doubling the buffer capacity. This means that the low-, medium- and high-temperature grids can be operated more robustly and flexibly. The reasons for the expansion lie on the one hand in the ongoing expansion of the NEST Units, but also in the desire for more flexibility in the use of thermal energy.

In addition, the new buildings on the Empa campus will also integrate the underlying geothermal borehole field into Empa's energy system. With around 144 geothermal probes that reach down to a depth of 100 meters, waste heat is fed into the ground in summer. In winter, the energy is extracted from the ground used directly for heating. The geothermal borehole field is being used by the ehub team and Empa's "Urban Energy Systems" Laboratory to investigate the experimental design of such seasonal storage systems and the interaction with other thermal systems. Initial results show that it can make a valuable contribution to the decarbonization of a local energy system.

Heating and cooling with foresight

In addition to storage, flexibility in operation is a focal point in the optimization of energy systems. Last year, a research project at the ehub therefore investigated the potential of predictive control for heat pumps and cooling systems in neighborhoods – with the aim of stabilizing the electricity grid. Due to the inertia of buildings with regard to heat or cooling losses, electrified heating and cooling systems can be controlled in such a way that they are beneficial to the grid. Data from the two NEST units "DFAB HOUSE" and "UMAR" were used to develop a control algorithm. Information on the presence of people is also helpful for greater flexibility within a building. Together with the industrial partner Oxygen at Work and supported by Innosuisse, Empa researchers have investigated which sensor technology and which calculation models are suitable for using the CO_2 concentration in rooms for presence control, validated in NEST and other buildings.

In addition to the activities on the Empa campus, the ehub team also makes its expertise available in many national and international research projects. In addition to the SWEET projects "PATHFNDR", "LANTERN" and now also "reFuel.ch" funded by the Swiss Federal Office of Energy (SFOE), the ehub is part of the EU project "REFORMERS". The project focuses on the realization of resilient, regional multi-energy systems that are intended to increase energy security and at the same time accelerate the energy transition in Europe. In addition, NEST will become a pilot district from 2024 onwards as part of the "HEATWISE" project, which is also funded by the EU. The aim of this project is to make better use of waste heat from IT infrastructures in buildings and integrate it into the energy system. //

View of the construction site of the co-operate campus extension, under whose building a geothermal borehole field with 144 geothermal probes reaching down to a depth of 100 meters is being built (left in the picture).

Out of thin air: using CO_2 as a resource

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To prevent irreversible changes to the Earth's climate system, we need to remove excess man-made CO_2 from the atmosphere. This is the aim of a large-scale Empa research initiative: Mining the Atmosphere.

The threat of climate collapse

2

Fossil fuels are simply ingenious: Easy to handle, with a high energy density, versatile and available in large quantities. They are the foundation of our technological progress and prosperity over the last 200 years. However, we are paying a high price for this: The Earth is heading for climate collapse. Every year, we "pump" around 9.4 billion tons of carbon (in the form of CO_2) into the atmosphere. Natural processes, particularly through vegetation and the world's oceans, partially compensate for these gigantic emissions. However, the bottom line is that there is a "surplus" of around 5.1 billion tons of atmospheric carbon – every year… The CO_2 concentration in the atmosphere has been exceeding 350 ppm (parts per million), the threshold value for climate stability, since 1988. If this is exceeded over a longer period of time, the Earth's climate system threatens to tip over – with partially irreversible consequences.

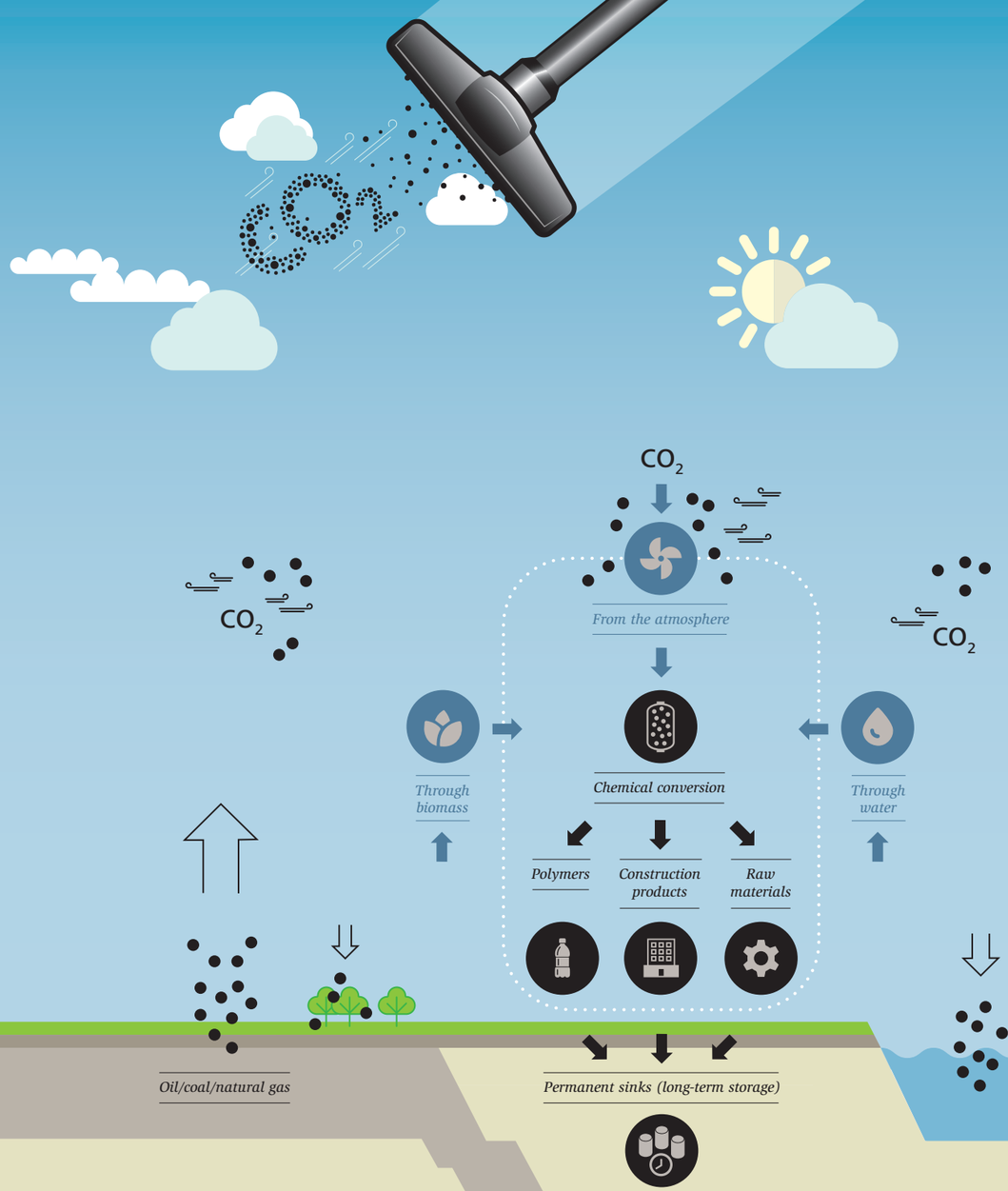
"Business as usual" is therefore not an option, and net zero can only be an interim goal. What is required is a holistic approach that can be implemented technically – and also financed. Which is where Mining the Atmosphere comes in. In contrast to just capturing CO_2 and storing it underground – the necessary first step – the "mining" approach goes much further: The goal is to develop an entirely new global economic model and the associated industrial sector that converts CO_2 as the raw material of the future into valuable materials to replace conventional building materials and petrochemicals.

The task of the century

The approach thus postulates a change of perspective: Where raw materials were previously extracted in underground mines, the focus is now shifting towards the atmospheric "mine". At the same time, this shift affects society as a whole, which must transition from a CO_2-emitting society to a CO_2-binding society in the next 20 years via the energy transition towards net zero.

So much for the idea – the implementation of which is the task of the century that will require countless players from research and industry to join forces and work together. After all, an estimated 400 billion tons of carbon (i.e. around 1,500 billion tons of CO_2) need to be removed from the atmosphere.

And this is just the beginning. The next step is to convert this carbon into value-adding materials, polymers, building materials, etc. The construction sector in particular has a key role to play here, as concrete and the like could bind an enormous amount of atmospheric carbon due to their mass. After being recycled several times, the carbon-containing materials could be deposited as a final carbon sink at the end of their "life" (see also p. 34). //



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The Mining the Atmosphere approach: The aim is to develop a completely new global economic model and the associated industrial sector that converts CO_2 as the raw material of the future into valuable materials to replace conventional building materials and petrochemicals.

2
While biochar (left) is to be used as an insulating material in construction, thus removing CO_2 from the atmosphere in the long term, pellets made from biochar are replacing conventional aggregates in concrete (right). In this way, the potential of CO_2-neutral or even CO_2-negative concrete can be explored.

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.

From small crystals and innovative displays

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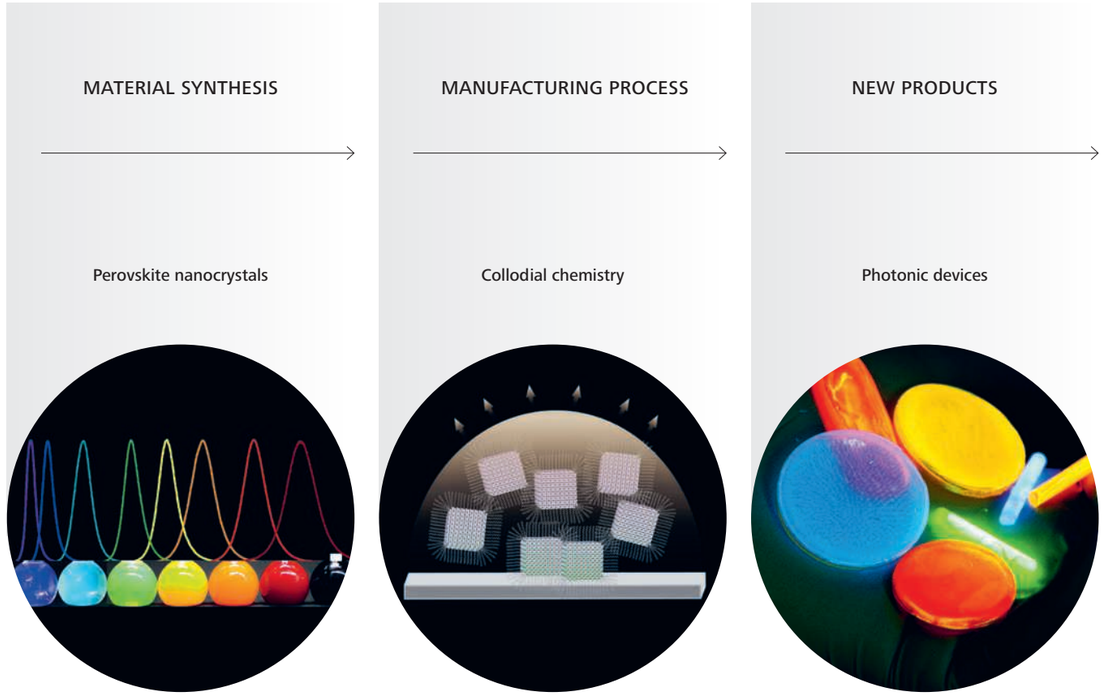
Last year, Moungi Bawendi, Louis Brus and Alexei I. Ekimov were awarded the Nobel Prize in Chemistry for their work in the field of quantum dots. Quantum dots are tiny, mostly semiconducting nanocrystals, only a few nanometers in size and with amazing properties that can only be explained by quantum mechanics. Empa is also conducting intensive research in this field, namely in the group led by Maksym Kovalenko and Maryna Bodnarschuk in the "Thin Films & Photovoltaics" laboratory. The researchers are currently working primarily on nanocrystals made of metal halide perovskites, a further development of the substances originally synthesized by the Nobel Prize winners. The focus here is primarily on the optical properties of the nanocrystals: Their optical emission spectra are adjustable because individual elements in the material composition can be replaced. At the same time, the nanocrystals offer an extremely narrow-band emission spectrum.

This means that the energy supplied is used very efficiently. This makes the nanocrystals ideal for use in future displays. A further application could arise in novel photon sources in photonic integrated circuits, a field of research that is currently coming into focus in collaboration with other institutions in the ETH Domain (ETH Zurich and PSI), international partners (Karlsruhe Institute of Technology, KIT) and the new Swiss Photonic Integration Center (Swiss PIC) in the context of the "Advanced Manufacturing Technology Transfer Centers".

"Materials to Devices": from material synthesis to the finished product

This example vividly illustrates the main task of Empa's research focus area "Nanoscale Materials and Technologies": Building on a broad knowledge of materials science, new materials are produced and characterized on the nanoscale. The focus is on materials with great application potential for industry and society. This means that the production of the new materials must be scalable as well as ecologically and economically interesting. If these conditions are met, we invest in the next stage of research into suitable production techniques and develop new processes to produce the materials in larger quantities, ideally with partners from industry.

In the coming years, we will be taking a closer look at the MXenes class of materials, among others. MXene is an umbrella term for two-dimensional, inorganic compounds that consist of atomically thin layers of transition metal carbides, nitrides or carbonitrides. Here too, the material properties can be decisively influenced by a targeted variation in the chemical composition of the materials. Following initial promising results regarding the application of such MXenenes in Jakob Heier's group in the "Functional Polymers" laboratory, we would like to focus in future on the first part of the process route, namely synthesis and characterization. It should therefore soon become clear whether this new class of materials has a similar application potential to the perovskites mentioned at the beginning. //



The new "Materials to Devices" concept, here using the example of nanocrystals for innovative optical applications, aims to accelerate the adaptation of innovative nanomaterials in products.

Increasing sustainability and safety in construction

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The building and construction sector is currently one of the major sources of greenhouse gas emissions both in Switzerland and globally. This trend could be reversed by turning building materials into effective carbon sinks.

1

Concrete as a carbon sink

One practical solution that could enable this is by incorporating biochar or other types of pyrolyzed carbon – based on captured atmospheric CO_2 – into concrete. In this way, the original emissions (stemming mainly from cement production) can be compensated for with the negative emissions from the pyrolyzed carbon. The acceptance of this approach is limited in large part by challenges related to the handling of the raw biochar. Biochar is usually very light and porous, which impairs the workability of concrete. Moreover, it is highly variable from batch to batch and difficult to handle at a concrete plant or a construction site, mainly due to the fine black dust it produces. In an Internal Research Call 2021 project, researchers at Empa's Concrete and Asphalt lab under the leadershipof Pietro Lura studied the feasibility of incorporating biochar into concrete and developed new methods to address the main challenges. They developed a method to pre-process biochar into lightweight pellets and use them to replace conventional aggregates in concrete. These pellets are much easier to handle in construction practice compared to raw biochar. Concrete with biochar-rich pellets at a volume proportion of 20 percent can achieve net-zero emissions. Further developments of this concept include manufacturing aggregates with pyrogenic carbon from methane pyrolysis, in collaboration with teams at Empa and PSI within the ETH Domain Center of Excellence, SCENE.

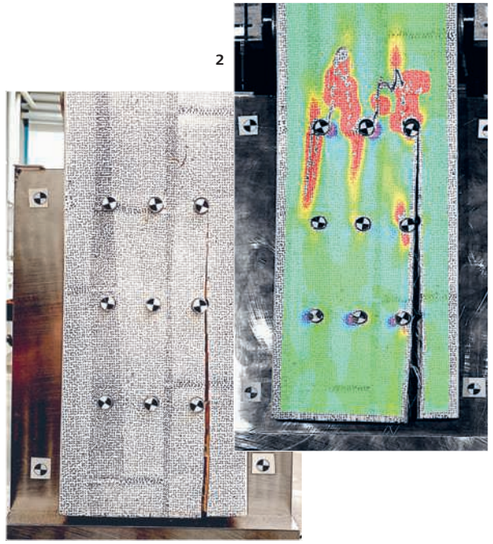
Connections in timber structures

Unlike concrete structures, which are cast into monolithic shapes, timber structures consist of multiple individual components that are assembled using structural connections. The role of these connections is to provide continuity to the components and, whenever possible, to improve the global structural behavior, by adding deformation and energy-dissipation capacity. Structural connections are, therefore, as important as the individual components and critical from a structural design perspective.

The most common types of structural connections comprise metallic parts inserted into the connected timber components. Steel dowel-type fasteners and slotted-in plates are in common use, because of their ease of assembly and disassembly, high load capacity, ductility and energy-dissipation capabilities. However, their behavior exhibits high variability, mostly due to the natural variability of the timber components, and brittle failures, which in turn limits the reliability of analyses based on simple connection models. These challenging topics are studied by a team lead by René Steiger and Pedro Palma at Empa's Structural Engineering laboratory. New modelling approaches for connections are being developed. To address new requirements regarding reusability of timber components and structures, connection systems that allow for disassembly and re-use are being studied in the scope of an Innosuisse flagship project "Think Earth – Regenerative Building".

1
Carbon-rich lightweight aggregates enable negative emissions to be incorporated into concrete.

2
The state-of-the-art experimental techniques and advanced modeling tools enable Empa experts to develop new connection systems for reusable timber structures.



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Empa as a key center of expertise

As in previous years, our laboratories continue to serve as an important source of expertise to Swiss and global industry and the public at large. A prominent example is the failure analysis of the tensioning system of the electrical railway line in the Gotthard tunnel. It was performed under the lead of Gabor Piskoty from the Mechanical Systems Engineering lab in cooperation with experts of the Joining Technologies and Corrosion lab. Within the scope of this analysis, the physical background of the early rope damage was identified based on challenging onsite measurements and laboratory analyses of the damaged ropes. Based on the results, recommendations for a reliable future tensioning system could be derived.

Another example is a failure analysis carried out by a team led by Andreas Leemann from the Concrete and Asphalt lab that studied the reasons for the crumbling of concrete structures occurring in thousands of houses in Ireland, with the overall damage amounting to billions of euros. They discovered that the damage occurs primarily due to the presence of the mineral pyrrhotite in the aggregates and not, like previously believed, due to frost damage of mica-containing aggregates. Thanks to the activities of our world-renowned experts, serious failures of the built environment can thus be avoided in future. //

Booster projects for health and performance

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Prof. Dr Katharina Maniura, katharina.maniura@empa.ch

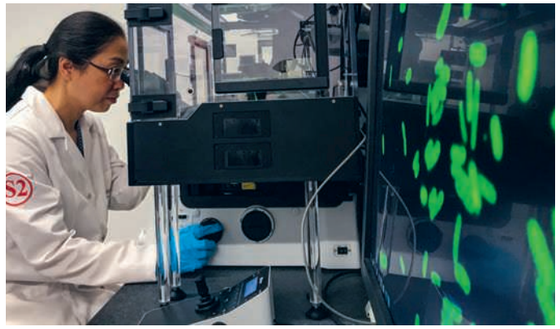
Research for health at Empa aims at maintaining health and accelerating regeneration and recovery through the development of novel diagnostics tools, innovative implants and materials-based therapeutic concepts. A close collaboration with hospitals, as exemplified with new partnerships with Inselspital in Bern and Balgrist in Zurich, ensures the identification of pressing clinical challenges and translation of the newest research findings into clinical practice. As the time from basic research to the implementation of a novel technology in clinical practice can easily take 10 to 15 years, it is imperative to focus on a limited number of topics with the greatest possible impact. In 2023, Empa launched so-called booster projects that are financed both through internal and external means. These interdisciplinary projects will promote the collaboration of several PhD students, postdocs and scientists by combining the knowledge of different research groups to accelerate the innovation process. In our Research Focus Area Health and Performance, two booster projects on integrated wound management and musculoskeletal biodynamics could be started this year.

Integrated wound management

New materials for wound healing has been a key research topic at Empa for some years. In 2023, a lab-on-a-fiber wearable multisensor for the monitoring of wound healing has been developed to simultaneously detect several biomarkers present in wound exudate. The sensor can measure the pH, the level of glucose and the concentration of a specific enzyme called matrix metalloproteinase, important parameters to discriminate between healing and chronic wounds. For the treatment of chronically infected wounds, a new wound dressing material containing probiotic bacteria is currently under development. In laboratory tests, we could show that the material loaded with probiotics was able to prevent infections and to even kill skin pathogens. For the new Empa wound booster project, six different labs are now joining forces to develop an integrated system that will monitor the precise pathophysiological state of a skin wound based on proteomics data. The newly discovered biomarkers will allow online monitoring of wounds via novel wearables and finally a precise and patient-specific wound treatment.

Musculoskeletal biodynamics

Last year, the close collaboration between Inselspital Bern and Empa led to the launch of a new center for dynamic imaging at sitem-insel, the Swiss Institute for Translational Medicine and Entrepreneurship, that combines medical knowledge with expertise in biomechanical modeling and image processing. This perfectly exemplifies how the combination of different analytical methods can lead to the development of new and more precise diagnostics methods. Musculoskeletal disorders are the second most common cause of disability worldwide and are very difficult to diagnose precisely without considering the motion patterns of a patient. Thanks to the combination of infrared motion capture cameras with radiographic imaging, rolling and sliding movements in the joints of the patients can be assessed accurately. Within a new Empa booster project involving three laboratories, this novel kinematic information will be combined with data from "classical" imaging methods like computer tomography (CT) and magnetic resonance imaging (MRI) as well as patient anthropometric data and subjective pain perception. Machine learning and AI tools will be employed to improve diagnostic and prognostic capabilities of musculoskeletal joint diseases and will have a tremendous impact on clinical decision making.



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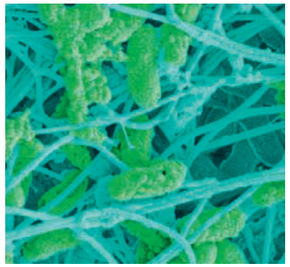

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1
Good bacteria for bad wounds: Empa researcher Qun Ren is looking for new ways to combat persistent biofilms.

2
Wound bacteria (Pseudomonas aeruginosa, light green) between connective tissue fibers of the human skin (blue gray) can cause serious chronic wound infection (Scanning Electron Microscopy, recolored).

3
Empa is one of the partners who established the new Dynamic Imaging Center (DIC) in Bern.
Image: sitem

A new partnership with Balgrist University Hospital Zurich

A new collaboration with Balgrist University Hospital and the University of Zurich has started with the establishment of a joint research laboratory under the leadership of Inge Herrmann, a group leader at Empa. The close collaboration with Balgrist's clinical teams will speed up technology transfer from bench to bedside, for instance the development of novel surgical adhesives with integrated sensors to detect infections or other complications at an early stage. The work of Herrmann's team received high visibility last year with two prestigious awards: Inge Herrmann received the ETH Zurich Latsis Prize 2023, while her colleague Alexandre Anthis, a postdoctoral researcher, has been awarded the Lopez-Loreta Prize 2023. //

Net zero CO_2 emissions by 2050

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In 2023, important environmental and energy policy milestones were reached; the Climate and Innovation Act was approved by the electorate and the Federal Act on a Secure Electricity Supply from Renewable Energy Sources was passed by Parliament. These laws also show how closely the topics of energy, environment and climate are interlinked: Switzerland's ambitious climate target – net zero emissions by 2050 – can only be achieved by phasing out fossil fuels while at the same time securing the supply of both energy and critical raw materials. To take account of this close link, Empa merged the research focus areas Energy and Resources and Pollutants into the new focus area Energy, Resources & Emissions at the beginning of 2023.

Basis for political decisions

In this political environment, Empa, as an applied research institute, is in close contact with stakeholders from politics and public administration in order to develop the scientific basis for fact-based decisions. Last year, this led to a number of important results, for example in the field of electromobility: Researchers from the Technology and Society laboratory worked with partners on behalf of the Swiss Federal Office of Energy to develop guidelines that identify issues along the life cycle of traction batteries for electric cars and resolve them based on the current state of knowledge. Important aspects include the availability of raw materials, energy and material requirements, safety and environmental and social impacts.

As members of the Swiss Federal Commission for Air Hygiene (FCAH), Empa researchers Brigitte Buchmann and Lukas Emmenegger evaluated the significance of the new air quality guidelines of the World Health Organization for the Swiss Ordinance on Air Pollution Control. In doing so, the FCAH relied primarily on measurements from the National Monitoring Network for Air Pollutants, which is operated by Empa and the Federal Office for the Environment. Based on these measurements and current scientific studies, the FCAH recommends a reduction in important immission limits, for example in the area of nitrogen oxides and particulate matter.

Excellent materials research

Scientific excellence led to numerous Empa publications in scientific journals in the field of energy and environmental research in 2023, such as in the January issue of the renowned journal Nature Energy: The study illustrates how a deeper understanding of material properties can help achieve a breakthrough. Solar cells based on copper indium gallium diselenide (CIGS) enable lightweight, flexible solar modules. However, it has not yet been possible to produce them in a bifacial configuration with high efficiency. Bifacial solar cells can produce electricity from sunlight on both sides, which is interesting, for example, for vertical modules on flat roofs or in alpine ground-mounted systems. Both types of system generate a significant proportion of their electricity in the winter months and will therefore play an important role in Switzerland's year-round energy supply in the future. Researchers from the Thin Films and Photovoltaics laboratory have adapted the coating process and the chemical composition of the layers within the bifacial CIGS solar cell, which are only a few micrometers thick, to achieve a high efficiency of almost 20 percent. When used in snow-covered environments, its rear side can even increase electricity production by over 50 percent.

Joint initiatives in the ETH Domain

Many of Empa's research activities are carried out in collaboration with other research institutes or universities.

1
Battery-powered vehicles are seen as the key to decarbonizing transport. By recycling traction batteries, important raw materials such as lithium, cobalt, nickel and graphite can be recovered after any secondary use. Image: istock

2
Empa and the Federal Office for the Environment jointly operate the National Air Pollution Monitoring Network, which will continue to be central to the assessment of Swiss air quality in the future.

3
Bifacial CIGS solar cells consist of extremely thin active layers, only around 3 micrometers "thick" in total. The polycrystalline CIGS layer is applied to a transparent electrical contact and absorbs the light from both the front and the back.

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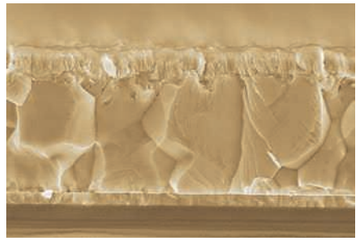

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Within the ETH Domain, this collaboration is promoted through joint initiatives. In 2023, various such initiatives were launched in the fields of energy and the environment. One of these is the "Swiss Center of Excellence on Net-Zero Emissions" (SCENE), in which over 30 research groups from all six institutions of the ETH Domain work together and deal with issues related to net zero. This concerns, among other things, optimal forest management and the use of wood as a building material and energy source, a cross-sector model of all Swiss greenhouse gas emissions and the development of approaches for circular infrastructure.

Sometimes, however, it is also worth taking the first step alone with visionary topics. For example, Empa launched the "Mining the Atmosphere" initiative in 2023. The aim is to use various approaches to extract CO_2 from the atmosphere in order to produce durable materials. This should lead to "negative" emissions and thus counteract global warming (see also page 28). //

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 specific problems or bringing technical specialists up to the state of the art – with slightly more than 600 highly qualified scientists and a top-class infrastructure, Empa is the place to be.

Shaping the future with research and innovation

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Synergies can be exploited through cooperation – which is why numerous companies cooperate with Empa. Product ideas are developed, evaluated and advanced together. The start of an innovative adventure with our partners begins with technical questions. In creative, interdisciplinary, unconventional discussions, ideas and solutions are discussed and summarized in a project description. The appropriate model for the collaboration is selected jointly and funding applications are written. Empa researchers support companies in the development of new materials and technologies or optimize processes and products – always with the aim of transferring results and technologies to industry as quickly as possible.

More than 230 new research projects were launched in 2023, many of them with industrial partners. In addition, ten patent applications were filed for inventions and twelve new license and technology transfer agreements were concluded with business partners. In 2023, another Empa spin-off was acquired: Bruker AG has a majority stake in MIRO Analytical AG (see also p. 44).

Innovative sportswear

Sportswear places high demands on materials, design and manufacturing methods in order to provide athletes with the best possible support during their activities and ensure a good body climate. Special requirements arise when athletes switch between land and water activities without changing clothes, for example during triathlons or "swimruns". What at first glance appears to be a relatively simple requirement has turned out to be extremely complex. As part of an Innosuisse project by the Swiss TechTex start-up Swijin and Empa's Biomimetic Membranes and Textiles department, the requirements for the material and cut of a sports bra were defined. The development was a threefold challenge: On the one hand, the product had to meet the requirements of a heavy-duty sports bra on land. At the same time, however, it had to provide the compression of a swimsuit in the water – and with a very short drying time.

As no comparable clothing was yet available on the market, the team developed tests to realistically assess the high-performance textile. A measuring mannequin was also designed: A model of the female upper body on which the mechanical properties of bras can be measured. In addition to scientific findings, the expertise of the team, which consisted of sports physiologists, textile engineers, material scientists, industry specialists, designers and, of course, female athletes, was also incorporated.

In summer 2023, Swijin was able to launch the first product from this collaboration: The SwimRunner, a sports bra with bottoms that are suitable for both swimming and running and dry at lightning speed. Thanks to this innovation, female athletes can switch between land and water sports for the first time without having to change clothes. Female stand-up paddlers can also enjoy unrestricted freedom of movement with the SwimRunner, with sufficient fit, both on the board and in the water.

A piece of Empa on your wrist

Hardly any other watch has traveled as far as this one: The Omega Speedmaster Professional, also known as the "Moonwatch" NASA astronaut Buzz Aldrin wore it on his wrist when he became the second man to walk on the surface of the moon on 20 July 1969. Over 50 years later, the MoonSwatch collection from Swatch and Omega makes the iconic design more affordable. Although the MoonSwatch is not approved for use in space, it contains a piece of Empa research: The hands and hour markers are coated with the Swiss Super-LumiNova luminescent material. From 2013 to 2015, it was jointly developed by the Appenzell-based company RC Tritec AG, Empa and the University of Geneva as part of a project funded by the Commission for Technology and Innovation (CTI; now Innosuisse). The luminescent material is not only used in the MoonSwatch, but also in numerous other watch brands and models. So if you look at your watch at night, you might see Empa know-how shining through.

Digitally printed perovskite solar cells

Perovskia Solar, an Empa spin-off, develops and manufactures digitally printed, customizable perovskite solar cells for OEMs, working at the interface between printed electronics, photovoltaics and materials science. The solar cells are tailored so that they can be seamlessly integrated into electronic devices and sensors. They also work efficiently in poor lighting conditions such as in homes and offices. Company founder Anand Verma researched printing processes for flexible, inorganic perovskite solar cells at Empa from 2015 to 2020 before setting up his own company. //

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1
During a swimrun, athletes switch several times between swimming and trail running, which places increased demands on their sportswear.
Image: Swijin

2
The fact that the MoonSwatch shines so brightly in the dark is partly thanks to Empa research.

3
Customized, digitally printed solar cells from Perovskia Solar: The solar cells are cut in such a way that they can be seamlessly integrated into electronic devices and sensors.
Image: Perovskia Solar AG

Investor focus on Empa spin-offs and start-ups

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In 2023, the spin-offs and start-ups supported by Empa's and Eawag's Business Incubator glatec raised a total of close to 4 million Swiss francs from investors and funding agencies. After IRsweep and CT Systems, yet another Empa spin-off – MIRO Analytical – was also acquired by an industry leader last year. And the Empa spin-off BTRY had barely been founded when it was accepted to the Business Incubation Center of the European Space Agency ESA.

viboo raises 1.5 million Swiss francs
The Empa spin-off viboo has received a total of 1.5 million Swiss francs in a seed round financing from a group of investors, the High-Tech Gründerfonds, Swisscom Ventures and Rainmaking Impact. The start-up has developed a platform for energy-efficient control of the indoor climate in buildings. The funds will be used for the technology's commercialization.

Bruker acquires majority stake in MIRO Analytical
The Empa spin-off MIRO Analytical based in Wallisellen has been majority-owned by the Bruker Corporation since last fall. The company, which has its headquarters in Massachusetts, USA, and a Swiss site in Fällanden, complements its gas analysis spectroscopy portfolio with MIRO's fast, mobile and high-precision multi-gas analyzers. MIRO's trace gas analyzers are based on quantum cascade lasers. They can measure up to ten trace gases simultaneously with a sensitivity in the ppt (parts per thousand) range and are used in atmospheric research and in industry.

Fellowship for neo-entrepreneur – BTRY, the battery revolutionaries
Shortly after the start of his Empa Entrepreneur Fellowship, which supports young researchers for one year in founding a company, Empa researcher Abdessalem Aribia founded the Empa spin-off BTRY, together with Moritz Futscher. Its thin-film batteries are not only safer and more durable than conventional lithium-ion batteries, they are also much more environmentally friendly to produce and can be charged and discharged in just one minute. The battery is still small, but the founders have big plans.

Start-ups supported by the St. Gallen-based start-up incubator, Startfeld, were able to raise more than 13 million Swiss francs in investor funding in 2023.

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The Startfeld Foundation plays an important role in the funding process. It is often the first investor providing a financing commitment, thus helping the start-ups to attract further investors. Of the 13 million Swiss francs, 1.2 million came from the Startfeld Foundation. Fortunately, the Startfeld Foundation was able to further increase the foundation capital by another 2.5 million Swiss francs. In addition to the St. Galler Kantonalbank as the main donor, the Thurgauer Kantonalbank is now co-funding the foundation.

Vigilitech – contactless measurements of vital parameters
Vigilitech AG also completed a successful financing round in 2023; it is developing a highly sensitive and precise technology for animal monitoring that complies with animal welfare guidelines in research. The first product, MARTA, is a novel monitoring system in preclinical research. It works remotely through the fur, without electrodes or cables. Vital parameters such as heart and respiratory rate are continuously monitored and the animals' normal body temperature is maintained during all steps of an experiment. MARTA is fully sterilizable and complies with CE conformity 60601 for medical devices. The data obtained by MARTA is stored in the cloud and is available to researchers for further use. //

1
Thermostat manufacturers can integrate the viboo algorithm into their smart thermostats via cloud connection. Image: Adobe Stock

2
The two founders of MIRO Analytical AG Oleg Aseev (l.), CTO, and Morten Hundt, CEO. Image: MIRO

3
The successful BTRY founders: Moritz Futscher, Abdessalem Aribia and Yaroslav Romanyuk (from left to right).

4
Marc Zünd, CEO of Vigilitech, with the MARTA Pad. Image: Vililitech

Project financing is also talent development

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Loris Pandiani, loris.pandiani@empa.ch

In 2023, donations of over CHF 2.5 million were made to fund various research projects, including a substantial contribution from the Walter Fischli Foundation. All these funds were used to employ seven doctoral students and three postdocs at Empa. One of them is Selina Camenisch. The young Swiss researcher obtained her Bachelor's and Master's degrees in cell biology at ETH Zurich and took up her PhD position in the "Particles-Biology Interactions" department in February 2023.

Diagnosis of kidney and bladder stones

Around five percent of the total population suffer from urinary or kidney stones. Clinical treatment and patient management vary from person to person and depend heavily on patient-specific factors such as the composition of the stone. The aim of a project led by Empa researcher Robert Zboray, together with the Cantonal Hospital of Fribourg and the Vetsuisse Faculty of the University of Zurich, is to analyze the chemical and structural differences in the composition of urinary and kidney stones using dark-field X-rays, a novel, non-invasive imaging method. In an interdisciplinary collaboration between imaging experts and doctors from veterinary and human medicine, the team wants to develop an innovative technology from basic research through to potential clinical application in a translational approach. The hoped-for gain in knowledge could be used to modify conventional X-ray equipment in order to accelerate the clinical use of the speckle imaging method and establish it cost-effectively.

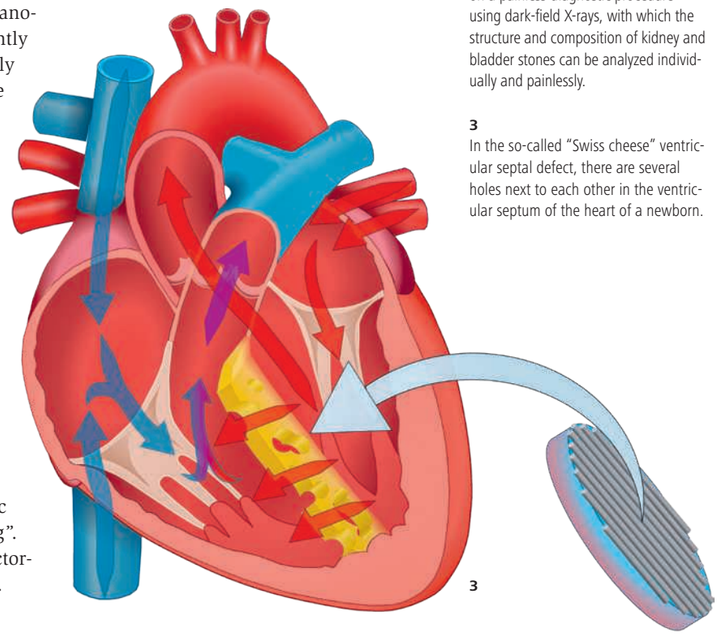
The benefits for patients lie in the precise, personalized and non-invasive analysis of stone types and in the reduction of unnecessary surgical interventions. The associated time and cost savings for the healthcare system underline the social relevance of the project. The project could be launched thanks to the support of the Maiores Foundation and the Max and Hedwig Niedermaier Foundation

Innovative patch for "Swiss Cheese" defects

Congenital heart diseases are the most common congenital anomalies in newborns and the main cause of death in infants in connection with congenital diseases. The so-called "Swiss cheese" ventricular septal defects are characterized by the coexistence of several holes in the ventricular septum. Current treatment methods still have numerous side effects. The aim of the project led by Empa researcher Kongchang Wei is to develop, in close collaboration with the University Children's Hospital Zurich, a biocompatible patch for these ventricular septal holes that does not impair heart function and significantly improves the child's life expectancy. Hybrid membranes that combine tissue-adherent hydrogels and electrospun nanofibers are being developed to efficiently close the defects and subsequently enable tissue regeneration. In the first phase, the focus is on the development and ex vivo validation of such hybrid membrane materials. The project was made possible thanks to the support of the Stiftung des Ärztevereins Klinik Stephanshorn, the Immanuel und Ilse Straub Stiftung and two other foundations.

Walter Fischli Foundation Fund

Following a visit by the Board of Trustees to Empa in August, the Walter Fischli Foundation decided to open a fund at Empa for the strategic research topic of "wound healing". This fund will be used to support doctoral students over the next eight years.

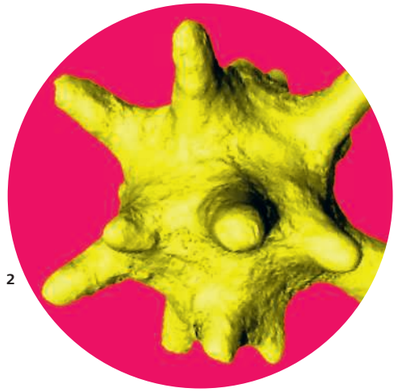


1
PhD student Selina Camenisch was able to take up her position at Empa thanks to donations.

2
What looks like a "battle star" is a kidney stone in a 3D visualization based on multimodal dark-field X-ray technology. Empa researchers are currently working on a painless diagnostic procedure using dark-field X-rays, with which the structure and composition of kidney and bladder stones can be analyzed individually and painlessly.

3
In the so-called "Swiss cheese" ventricular septal defect, there are several holes next to each other in the ventricular septum of the heart of a newborn.

1



2

Walter Fischli is a patron who has already supported various institutions with his foundation, including a biotech project at Empa. He is a co-founder of the pharmaceutical company Actelion in Allschwil, which today belongs to the Johnson & Johnson Group. //

Research and innovation knows no boundaries

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

Research and innovation are inherently international endeavors. Last year, Empa researchers worked with partners from 57 countries. And: The greater the challenge, the more important a huge network is – both on a national and international level. In December, for example, a Swiss delegation – including Empa researcher Christian Bach – visited Oman to discuss with government representatives the possibility of closer cooperation within the reFuel.ch consortium, which is co-coordinated by Bach and funded by the Swiss Federal Office of Energy (SFOE) as part of the SWEET (SWiss Energy research for the Energy Transition) research program, and the Empa research initiative Mining the Atmosphere (see p. 28). The aim is to "harvest" solar energy in the Earth's sun belt and use it to produce sustainable energy sources and basic chemicals for Switzerland.

In October, Empa Director Tanja Zimmermann visited Empa's Japanese sister institute, the National Institute for Materials Science (NIMS) in Tsukuba, to discuss even closer cooperation in materials and technology development with the institute's senior management. She also took part in a panel discussion on Breakthrough Innovation and Trends in Sustainability at the opening of the new swissnex offices in Osaka. Empa also signed a new Memorandum of Understanding (MoU) with the University of Osaka, which provides for closer cooperation, including in the area of doctoral training.

Empa – a good address when it comes to innovation

Conversely, numerous international delegations once again visited Empa last year, mostly to discuss innovation promotion and a more efficient technology transfer with Empa's senior management and the institute's researchers. In June, for example, a delegation from Innovate UK, the British innovation promotion agency and thus the counterpart to Innosuisse, visited to learn about the "Swiss way" of technology transfer based on successful transfer projects and to explore potential synergies. The study trip of US transportation experts, mainly but not only from California, who also visited Empa in June, had a similar goal, focusing on the area of mobility. Two business delegations came from Austria. Organized by Advantage Austria, the foreign trade organization of the Austrian Federal Economic Chamber, the focus was on innovations made of wood in March and Smart Cities – Swiss Drone Technology in June.

As in previous years, NEST was also a major attraction for visitors from abroad. In May, Peter Richner, Empa's Deputy Director, welcomed a high-ranking delegation from Singapore, led by Desmond Lee, Minister for National Development, and Andrew Toh, Singapore's Ambassador to Switzerland, to Empa's innovation building. The talks focused on the challenges in the construction and energy sectors as well as concepts for a successful transfer of knowledge from research to industry. And in September, the EFTA working group of the European Council was a guest at NEST to discuss circular and resource-efficient construction methods with Richner.

A truly international group finally arrived on the Empa campus in July: The mentors of the 55th International Chemistry Olympiad, which was held in Switzerland for the first time last year, took the opportunity to visit Empa and Eawag and got to know the two research institutes better through lab tours and lectures.

The importance of EU research

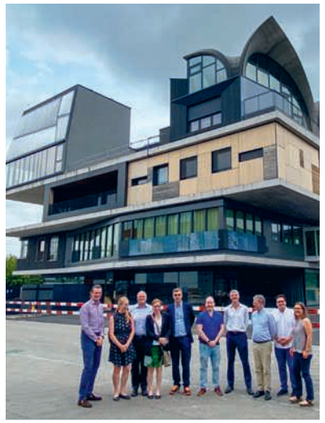
The EU's Graphene Flagship project was successfully completed in 2023 after ten years. More than 150 academic and industrial research groups from 23 countries – including several Empa research teams – and numerous other associated members were involved in the largest EU research initiative ever launched at the time, with a total budget of around 1 billion euros. Participation in such large-scale projects is of enormous importance, emphasize the researchers involved. Not only thanks to the direct funding they received and its additional "pull effect" – the total of around 3 million Swiss francs in direct funding was more than matched by almost 6 million Swiss francs in follow-up projects, almost tripling the original funding – but above all thanks to the enormous international network that had developed over the years. A direct association with the EU research programs therefore pays off for researchers in Switzerland in several ways. //

1

1
Empa Director Tanja Zimmermann meets the mascot of EXPO 2025 in Osaka, Myaku-Myaku, during her visit to Japan. She is joined by Martina Hirayama, State Secretary for Education, Research and Innovation, and Felix Moesner, CEO of swissnex Japan.

2
A delegation from Innovate UK, the counterpart to Innosuisse, during their visit to Empa.

3
Chemists from almost 90 countries as guests at Empa: The 55th International Chemistry Olympiad IChO took place in Switzerland for the first time in 2023. Image: ETH Zurich / Luca Ferrari



2

3

Open, transparent and proactive – Empa-style stakeholder dialogue

Dr Michael Hagmann, michael.hagmann@empa.ch

The fact that the exchange with its core stakeholder groups is of great importance to Empa can be seen from the figures alone: In 2023, almost 11,500 interested people took the opportunity to experience research up close on one of the almost 500 guided tours through NEST or through Empa's laboratories. In addition, there were almost 6,500 participants in the 85 Empa Academy events and more than 5,000 visitors who explored the virtual NEST online. In general, however, the trend of the last two years shows that the return to live and analog appears to offer advantages over purely digital formats – the proportion of online participants in Empa events fell from 34 percent in 2022 to 15 percent last year.

The most important "subgroup" for direct exchange and dialogue, and not just in terms of numbers, is the general public, for whom Empa has launched several new platforms in recent years. The two wissen2go events, compact, 90-minute evening events on current technology topics – last year on new materials for medicine in May and on Mining the Atmosphere (see p. 28) in October – were attended by more than 400 participants. The newly launched livestream format Bright Minds, in which Empa researchers present their smart ideas for a sustainable future in a clear and practical way and answer questions from viewers via chat, was also very well received; the first three editions on the topics of drone technology, printed electronics and new types of batteries lured a total of close to 9,000 viewers to their laptops and smartphones. Empa researchers were also present at the open day of the sister institution EPFL in Lausanne to present the innovative solutions to the challenges of our time from the Empa laboratories to the Swiss population across the language border. As with the annual international science festival Pint of Science, this can also take place in unusual places, such as in pubs.

Together with ETH Zurich, EPFL and PSI, Empa is also involved in the ETH Domain's Joint Initiative Energy Science for Tomorrow, which, in partnership with the Swiss Museum of Transport in Lucerne, aims to promote dialogue with the public on the energy transition in order to jointly develop a climate-neutral energy system.

Empa also maintains a close and lively exchange with representatives from politics and administration. In this way, the research institute aims to make a contribution to facts-based policy-making in Switzerland. An impressive success story in this respect: In July, the European Commission proposed new measures to strengthen recycling and the circular economy in the automotive sector in Europe; Empa researchers played a key role in developing the scientific basis as part of a science-for-policy study. These measures were also incorporated into the recently revised Swiss Ordinance on the Return, Take-Back and Disposal of Electrical and Electronic Equipment (VREG) from end-of-life vehicles which was led by the Federal Office for the Environment (FOEN) and is to be removed and recycled separately in future. This makes Switzerland a pioneer in adapting legislation to promote e-waste recycling.

Empa's senior management also exchanged ideas with the FOEN Directorate in March during a joint visit to the Jungfraujoch research station. Here, Empa researchers and its Director Tanja Zimmermann were able to demonstrate Empa's activities in the field of environmental and greenhouse gas monitoring, among other things. Climate change and a sustainable economic and energy system also took center stage at the Swiss Green Economy Symposium in Winterthur in September, where several Empa researchers led innovation forums, gave keynote speeches or took part in panel discussions, as well as during Federal Councillor Guy Parmelin's visit to Empa and Eawag in November.

The energy transition – and how we can master it thanks to innovation – was also THE topic at regional and municipal level last year. In May, the city council of Zurich and the mayors of Hamburg and Vienna were guests at Empa, and in November, around 60 representatives of Swiss municipalities, cantons and industry from the Innosuisse-funded MUNICIPAL network discussed new ideas for technology transfer in the energy sector at Empa. In April, Empa Director Tanja Zimmermann presented Empa's various cooperation models and innovation partnerships, particularly in the SME sector, at the Innovation Zurich event organized by the Canton of Zurich's innovation promotion agency at the Innovation Park in Dübendorf.

How to communicate knowledge and new findings and make them widely accessible was also the topic of an event organized by SRG (the parent organization of the Swiss TV and broadcasting networks) at the Empa Academy on the state of science journalism in Switzerland and the (rather rhetorical) question of whether it is merely "nice to have" or, on the contrary, fulfils a very important role in and for society. Namely, precisely as a mediator in the dialogue between research and society mentioned at the beginning. //

1

2

3

1
Pint of science: Fancy a glass of science? Experiments in the pub.

2
Peter Richner, Deputy Director of Empa, with the Head of the Federal Department of Economic Affairs, Education and Science, Federal Councillor Guy Parmelin (right).

3
The team from SRF's science program Einstein made Empa's battery research the focus of one of its programs. Gustav Nyström (center) shows TV host Tobias Müller his biodegradable paper battery.

Continuity and progress for excellence

Melina Spycher, melina.spycher@empa.ch

The year 2023 once again reflects the diversity of employees, with their unique skills, tasks and backgrounds, thanks to which Empa's top performance is created. One of Empa's strengths is its continuous efforts to create an inclusive and respectful working environment. In addition to constant innovation and new projects, the tried and tested measures also retain their firm place. In 2023, numerous female employees once again took part in equal opportunities programs, such as "CONNECT", which bridges the gap between academia and industry for participants through company visits and networking, and "Fix-the-leaky-Pipeline", which offers coaching, workshops and peer mentoring, among other things. In addition, Empa's ombudspersons were able to take part in two supervision sessions, exchange ideas with other ombudspersons and develop their consulting skills.

Networks are key

The membership of Advance, a business association for gender equality in Switzerland, remains a key aspect of Empa's DEI efforts. Advance promotes the increase in the proportion of women in management positions with skill-building courses and networking events and much more. In addition, Empa has been a member of the new and constantly growing Women in Power network since this year, which offers additional opportunities for exchange.

Promoting young talent through 1:1 mentoring

Last year also saw the launch of "of feMLEAD (female Mentoring: Leadership for Equity and Diversity). Nine mentees from Empa are taking part in the first round, together with mentees from PSI and WSL. The participants benefit from valuable 1:1 mentoring with experienced leaders, workshops, pitching sessions and networking. Empa is also part of an inter-institutional think tank with the aim of submitting a project to get more girls interested in STEM professions and courses of study.

Changing sides and fun for the little ones

Over 80 enthusiastic children visited Empa at its sites in Dübendorf and St. Gallen on National Future Day. Beaming faces could be seen in workshops such as "Fire extinguishing", "Liquid air", "Hands-on mechanics", "Concrete" or "Insight into conducting and recording interviews". The summer camp, in which 21 children took part in a varied program, was also very popular. Workshops on topics such as programming, multimedia journalism, X-rays and microscopy provided educational and entertaining hours.

Empa's female talents in science were recognized on "Women and Girls in Science Day. Participation in the first National Sexual Harassment Awareness Day enabled a day of dialogue about respect and tolerance.

1

2

1
Together against sexual harassment at universities and research institutions: In a video to mark Sexual Harassment Awareness Day on 23 March, the heads of various institutions took a stand.

2
The summer camp and National Future Day amazed the young researchers and gave them the opportunity to immerse themselves in the world of research and development and to play with materials.

An exciting online webinar also on the topic of tolerance and open dialogue was held during Pride Month with guests from Switzerland and abroad. An event on the topic of mental health encouraged a shared awareness of self-care. These events and contributions were not only an opportunity to raise awareness, but also the start of an open and respectful dialogue.

"Homes of Empa" – a diverse playlist

One highlight was the "Homes of Empa" inclusion project. This involves collecting not only employees' favorite recipes and songs, but also thoughts that connect them with their home country and the international collaboration at Empa. The resulting Spotify playlist is an expression of the cultural diversity at Empa. The project also offers a platform for exchange and understanding. //

Sustainability as both an obligation and an opportunity

Marcel Gauch, marcel.gauch@empa.ch

The ETH Domain as a role model for the whole of Switzerland in terms of sustainability – this is a commitment that Empa fulfills with conviction. As part of the Climate Package of the Federal Administration, Empa's CO_2 emissions are to be reduced by 50 percent by 2030 compared to 2006. The remaining emissions are to be offset by financial compensations. Empa has already achieved the 50 percent reduction target and is now aiming at achieving net zero. To this end, projects and activities have been launched to reduce greenhouse gas emissions in buildings, research processes and procurement as quickly as possible at the source. If greenhouse gas emissions remain unavoidable in future, Empa is involved in research into measures to neutralize them.

Flight emissions – a tiresome topic

Discussions about the extent and necessity of flights are difficult. Attending conferences and establishing and maintaining worldwide contacts are intrinsic to the work of researchers. Younger scientists in particular should be able to gain such experience. Unfortunately, this contrasts with the targets for reducing emissions: Compared to the previous year, flight activity in 2023 has increased significantly and is almost back to pre-pandemic levels. The largest share of CO_2 emissions now, for the first time, comes from mobility.

Implementing our energy future

In contrast, the picture in the electricity and heating sector is encouraging. Thanks to efficiency measures and the purchase of guarantees of origin for electricity and (bio-)gas, energy-related emissions were reduced by more than 15 percent compared to the previous year. According to Empa's reduction strategy, these measures should continue to pay off in the coming years; emissions in the energy sector can therefore be expected to continue to fall.

The importance of plants and trees not only as carbon sinks, oxygen producers and climate regulators, but also for the well-being of animals and humans, is part of Empa's research. For this reason, Empa is currently creating green zones as part of the redesign of the new campus in Dübendorf, which will connect the entire Empa-Eawag site and underline its claim to be a role model not only with regard to climate issues.

Positive visions for and with the next generation

Inter-generational exchange is important for scientists. After all, we stand on the shoulders of our predecessors, and the next generation of scientists will likewise stand on our shoulders. Somewhat in the background is the idea that even today, we could be inspired by the next generation – and vice versa. The Swiss National Science Foundation (SNSF) has been inspired by this idea and is funding the project "Co-Creating Circular Futures" of Empa and the University of Teacher Education St. Gallen. It is inspiring for everyone involved to see how many creative ideas are thought up by the children. Under the professional guidance of educators and Empa's technical guidelines, these ideas are collected and combined into a children's book on the topic of circular economy. It should also be interesting for adults to see how children imagine a sustainable future … //

1
The children's enthusiasm is infectious for everyone involved in the SNSF project "Co-Creating Circular Futures".

2
A green corridor – here still being planted – through the Empa-Eawag campus in Dübendorf is a sign of Empa's commitment as a role model in sustainability issues.

3
Despite significant improvements in heat and power supply, Empa's total emissions have risen due to the increase in business travel. This makes it more difficult to achieve the net zero target by 2030. If the mobility sector is excluded, however, it is clear that the measures are showing an effect.

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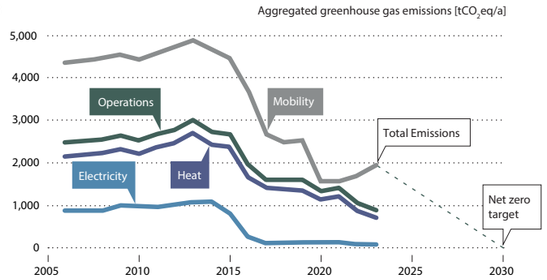

Facts and Figures

Researchers like measuring, including their own performance: In 2023, Empa researchers and engineers published 746 academic papers and filed patent applications for 10 developments. At the end of the year, 100 projects funded by the Swiss National Science Foundation (SNSF), 84 projects backed by Innosuisse and 90 EU projects were underway at Empa. Together with other start-ups in Empa's two business incubators, the 37 spin-offs employed a total of 1,188 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

Stefan Hösli, stefan.hoesli@empa.ch

The aim of risk management at Empa is to identify potential risks for the institute and its employees at an early stage and to take appropriate measures. This system contributes to a lively safety culture, sensitized employees and a constantly improving safety situation at Empa.

Principles for dealing with risks

Empa has aligned its regulations in this area with the specifications for risk management in the ETH Domain and at the federal level. Its safety and risk policy defines the systematic handling of the various risks as well as the willingness to take risks on a topic-specific basis, the acceptance of these risks and how they are to be dealt with. All measures are primarily aimed at protecting the lives of and preventing harm to the 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 preservation of the know-how acquired and the protection of Empa's intellectual property and reputation. The aim of Empa's risk management is prevention.

Potential energy shortage and other challenges

The Empa team responsible for the topic of energy shortages analyzed the situation in summer and autumn 2023 and came to the conclusion that there is currently no need to take additional measures to those taken. Improving the energy efficiency of the Empa and Eawag campus has been a focus for years, as illustrated by the construction of the large high-temperature ground probe field to reduce energy requirements by between 20 and 30 percent, which was completed in 2023. The focus therefore shifted more towards consolidating measures already taken as part of the preparations for an energy shortage in 2022, such as replacing an energy-intensive hot water system with a more efficient solution. A project has been developed to secure the electricity supply in the event of an energy shortage or increased instability of the Swiss electricity grid. This is ready to be called upon should the corresponding funding be available or the priority be placed on a secure power supply for the campus in future.

Construction work on the Dübendorf campus will be completed in 2024 with the official handover of the buildings to Empa on 1 February. Preparations for the smooth handover of the three new buildings – the laboratory and multifunctional building and the parking garage – have been underway for some time. Extensive acceptance tests and the integration of the buildings and new facilities into Empa's security system with the corresponding tests were complex and time-consuming. The next step is to increase the building knowledge of Empa's intervention teams and the municipality's emergency services with regard to the new buidlings. The Risk Management team also supported the project for the construction of a temporary secondary school for around 650 pupils next to the Empa site. Various topics such as traffic routing for motorized and non-motorized traffic, communication between the fire alarm and other systems, the exchange of information and possible cooperation between the intervention teams were discussed.

Further development of the security organization

A central point of Empa's prevention efforts is the training of employees – a major challenge with more than 600 new employees and academic guests joining and leaving the company every year. Therefore, the Risk Management team offers a wide range of training in areas such as chemical, nano or laser safety for various user levels.

The company rescue service and the fire and chemical safety team maintained their training regime last year. The level of training was further improved with additional, specific tuition. Internal, integral exercises provided important input for further improvements to processes. Following joint exercises with blue light organizations, further optimizations were implemented on both sides; this cooperation will be expanded and further exercises are already in preparation.

The topic of information and IT security has become even more relevant in view of the general threat situation and the increase in cyber attacks. A team of experts has implemented an information security concept, various directives on information security and further corresponding measures. There is currently a new emergency concept being developed, covering various scenarios such as cyber attacks or other "normal" BCM scenarios. The first steps towards its implementation have already been taken. //

Human resources development

(previous year's figures in brackets)

André Schmid, andre.schmid@empa.ch

At the end of 2023, 1,058 (1,021) people, including trainees, were working at Empa. This corresponds to a full-time equivalent (FTE) of 994.50 (959.5) positions, due to numerous part-time employments.

Scientific staff, including PhD and postdoctoral students, comprises 610 (577) individuals. Of these, 99 (102) are Senior Scientists. Technical and administrative staff comprised 403 (401) persons in the year under review. The proportion of women, at 31.6 percent (29.5 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 494 (467), or 46.7 percent (45.7 percent) of total staff. The EU accounts for 279 (179) persons, or 56.5 percent (59.7 percent) of all foreign employees. Empa offers vocational training for a number of professions and currently employs 45 (43) apprentices. As in previous years, all Empa apprentices successfully passed their final exams in 2023. //

STAFF END OF 2023

	2022	2023
Scientific staff	577	610
Technical and administrative staff	401	403
Apprentices	43	45
Total	1,021	1,058

Key figures

SCIENTIFIC OUTPUT

	2022	2023
ISI publications	**869**	**746**
Conference contributions	**1,103**	**1,400**
Doctoral studies completed	**54**	**49**
Doctoral studies in progress	**226**	**231**
Teaching activities (in hours)	**5,390**	**6,732**
Prizes and awards	**52**	**81**

MEDIA EXPOSURE

	2022	2023
Radio	150	105
TV	45	45
Print	1,200	1,250
Online	7,700	7,550
Total	**9,100**	**8,950**
Languages	39	41

KNOWLEDGE DISSEMINATION & TECHNOLOGY TRANSFER

	2022	2023
New R&D agreements	**196**	**238**
Active exploitation contracts	**45**	**45**
New exploitation contracts	**9**	**12**
New patent applications	**18**	**10**

EMPA-ACADEMY

	2022	2023
Empa events	**64**	**85**
Scientific conferences	19	29
Events for industry	20	17
Conferences for science and business (New category from 2023)	–	19
Events for the public	9	13
Participants	4,038	6,408
On site visits / online	3,011 / 1,027	5,385 / 1,023

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

	2022	2023
Companies total	**112**	**147**
thereof spin-offs	34	37
Employees total	**1,082**	**1,188**
thereof employees of spin-offs	196	221

CURRENT PROJECTS

	2022	2023
Swiss National Science Foundation (SNSF)	**104**	**100**
Innosuisse	**86**	**84**
EU projects	**76**	**90**

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).

CHAIRMAN

Michael O. Hengartner Prof. Dr

VICE-CHAIRWOMAN

Pascale Bruderer Entrepreneur and independent board member

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Marc Bürki Dipl. El.-Ing., Swissquote
Beatrice Fasana Dipl. Ing. Lm, Sandro Vanini SA
Susan Gasser Prof. Dr, Dr. h.c. mult., Universität Basel
Christiane Leister Leister AG
Joël Mesot Prof. Dr, ETH Zürich
Cornelia Ritz Bossicard Business economist, graduate auditor and independent board member
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.

CHAIRMAN

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Beat Flühmann Dr, Vifor Pharma Group
Robert Frigg Prof. Dr mult. h.c., 41 medical
Markus Hofer Dr, Bühler AG
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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Urs T. Dürig Dr, SwissLitho AG
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Thomas Geiger Dr, Empa
Erwin Hack Dr, Empa
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Georg Spescha Dr, Empa
Marcus Textor Prof. em. Dr

Organizational chart

as of May 2024

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Dr Lorenz Herrmann	Dr Peter Richner

LABORATORIES

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CENTERS

Electron Microscopy Center
Prof. Dr Rolf Erni

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

RESEARCH FOCUS AREAS (Research priorities)

Nanoscale Materials and Technologies	Built Environment	Health and Performance	Energy, Resources and Emissions
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RESEARCH, KNOWLEDGE AND TECHNOLOGY TRANSFER PLATFORMS

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Center for X-ray Analytics
Prof. Dr Antonia Neels

Library (Lib4RI)
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Fundraising
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Scientific IT
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