Annual Report 2018

Empa
Materials Science and Technology

Our Vision.
Materials and Technologies for a Sustainable Future.

Cover Photo: Textiles with highly sensitive sensors can measure physiological parameters such as heart rate or blood oxygen saturation. The polymer optical fibers of the sensor are produced by melt spinning and can be processed directly as yarn.

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Photo: Nicolas Zonvi

Top-notch research is the basis for a successful technology transfer

In such a highly competitive environment as scientific research, it is a good idea to ask yourself on a regular basis just how well you fare by international comparison. With this in mind, Empa conducted a peer review last October: eleven international experts from all of Empa's areas of activity scrutinized the institute's output in research and innovation and compared it with the rest of the world. Empa's report card was stellar. The experts were unanimous in lauding Empa as an internationally acclaimed materials research institution, which attracts outstanding scientists and engineers. Moreover, they underscored the tremendous impact of the numerous research results and Empa's innovation output for both industry and science, and encouraged Empa's Board of Directors to continue on the chosen path.

For instance, by being at the forefront of using digitalization in materials science and technology development. After all, the topic of digitalization affects all of Empa's research areas. In the field of "Advanced Manufacturing" (AM), the development of new materials requires data-intensive simulations of highly complex production processes and material properties. And modelling novel energy systems with the convergence of different-sized energy grids (single buildings, districts, cities) and the mobility sector is equally complex. As a result, Empa is set to expand its research activities in these areas in future, for example, within the scope of the new Materials and Technology Center of Robotics, through increased collaboration with the Swiss National Supercomputing Center (CSCS) in Lugano and the creation of a new high-performance computing infrastructure at Empa, and by focusing on sensor technologies for autonomous driving.

Empa's outstanding peer review is also reflected in other analyses. Last year the Center for Science and Technology Studies (CWTS) at the University of Leiden conducted a bibliometric analysis of the scientific publications of the last decade. The results: firstly, Empa publications are cited above average internationally; secondly, Empa ranks among the 40 top universities/research institutions in the world in terms of joint publications with industry.

Most of the patent applications Empa researchers file are also world-leading, as an analysis of the ETH Domain's patent portfolio by BAK Economics revealed. The Basel-based economics research institute rated 45 percent of Empa's patents as world-class and a further 20 percent as top patents.

Many of these patents result from cooperative projects. Last year alone, Empa concluded new research contracts with around 330 academic and industrial partners. More than 1,200 active contracts with partners from industry are currently underway, 70 percent of which are from Switzerland – for me, compelling evidence of how basic research spawns innovation. After all, successful knowledge and technology transfer can only thrive if it has a solid scientific foundation. And we will continue to champion this successful combination in future, true to our motto: Empa – The Place where Innovation Starts.

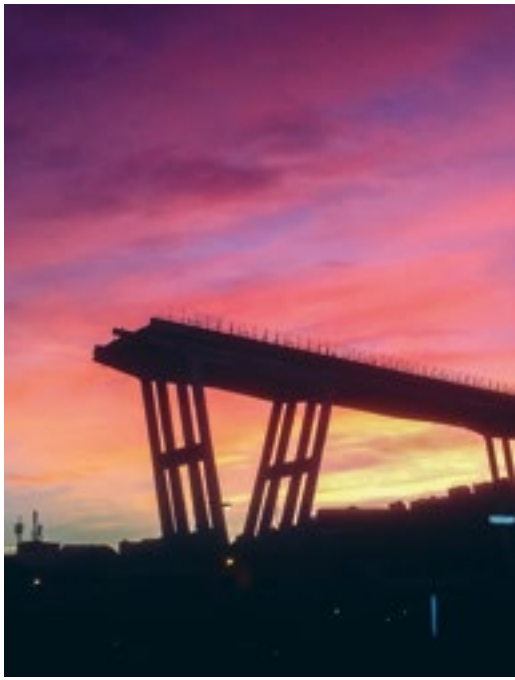
Prof. Dr Gian-Luca Bona, *Director*

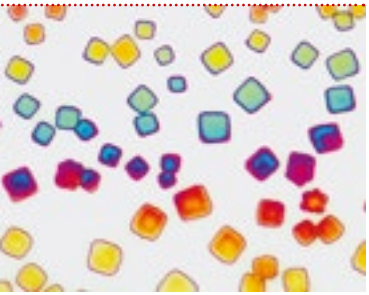
Year at a Glance

Award for Empa researchers
Two Empa researchers, Bernd Nowack and Maksym Kovalenko (below), made it onto this year's "Highly Cited Researchers" list – Nowack for the fifth time in a row. The list is published annually by Clarivate Analytics and reveals which researchers have been cited the most frequently with their publications in various scientific disciplines. Only the top few percent of scientists make the cut – a total of around 3,500 researchers worldwide.

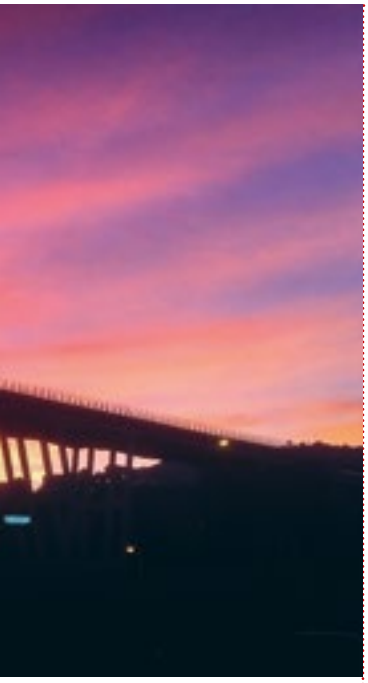
ERC Consolidator Grant for Empa researcher
Maksym Kovalenko is one of around 300 researchers across Europe to receive one of this year's Consolidator Grants from the European Research Council (ERC). Selected from around 2,400 submitted proposals, his project is one of only 13 to be funded in the field of "Synthetic Chemistry and Materials". Kovalenko now has EUR 2 million at his disposal for his project "SCALE-HALO", which aims at developing highly luminescent, molecular and solid-based compounds. The idea is to use them as multifaceted light sources in devices such as displays and lighting, not to mention in future quantum technology.

Living with drones
At Empa's new Materials and Technology Center of Robotics, it's all about autonomous drones. The goal of this new collaboration between Empa and Imperial College London is to integrate functional materials in robot technology, thereby developing and optimizing a new generation of autonomous drones. As permanent residents, the flying robots are supposed to render building maintenance at NEST easier and more efficient. "The city of the future will be a joint ecosystem for people and robots", robotics researcher Mirko Kovac, Scientific Director of the new center, is convinced.





Next generation of watch springs
What happens when something keeps getting smaller and smaller? Empa researchers had been pondering this question. Completely novel balance wheel spiral coils, the beating heart of every mechanical watch, emerged as a by-product. Usually made of milled Nivarox wires, the new Empa coils are made of a cold, aqueous saline solution deposited electrically in the desired form. They are now being fitted in prototype watches in the R&D lab of a major Swiss watch manufacturer. (Photo: A. Lange & Söhne)



Searching for clues in a mountain of rubble
Bridge sections weighing several tons from the Morandi Bridge, which collapsed in Genoa on 14 August 2018, were delivered to Empa in early November to help investigate possible causes of the disaster. In the course of the preservation of evidence proceedings, the three court-appointed experts tasked Empa with conducting laboratory analyses on concrete and steel sections of the bridge. No fewer than five Empa labs were involved in the tests. On 11 December 2018 the 172-page investigation report was delivered to the expert committee on schedule. Two days later, all the rubble and samples were transported back to Genoa. (Photo: iStock)

Top-flight research at 3,450 meters altitude
In the early 1930s, when many countries in Europe were sealing themselves off, Switzerland opened the Jungfraujoch international research station. The center is to receive two awards as a key historical scientific site in 2019: the European Physical Society is honoring the research station's services to physics, the Swiss Academy of Sciences those to chemistry. Empa has been conducting research for close to 50 years now on the Jungfraujoch.

Two new laboratory heads

A focus on technology: already during her architectural studies in Vienna, Kristina Orehounig found herself drawn to the technical aspects of construction, especially structural physics. She has now found her professional home in simulating energy systems: since February 2018 she has been running Empa's Urban Energy Systems lab. Before that, she was a researcher and lecturer at ETH Zurich.

Gustav Nyström, who took over the helm of Empa's Cellulose & Wood Materials lab in April 2018, also sets himself unconventional goals. He is looking to develop batteries made of paper and sensors made of nanocellulose. The Swedish-born researcher's PhD thesis focused on energy-saving cellulose nanofibrils. However, his primary motivation is to help solve fundamental issues of our time.

"Concrete disease" in the crosshairs

When bridges, dam walls and concrete foundations form cracks, AAR is often the culprit: the alkali-aggregate reaction. It causes the concrete to swell and renders renovations or even reconstructions necessary. A project funded by the Swiss National Science Foundation (SNSF) and coordinated by Empa studied the "concrete disease" and discovered that the cracks due to AAR form in tiny crystal fissures and are immediately visible to the naked eye. An alkali calcium silicate hydrate, the structure of which was clarified by Empa scientists, is behind the cracks in concrete.

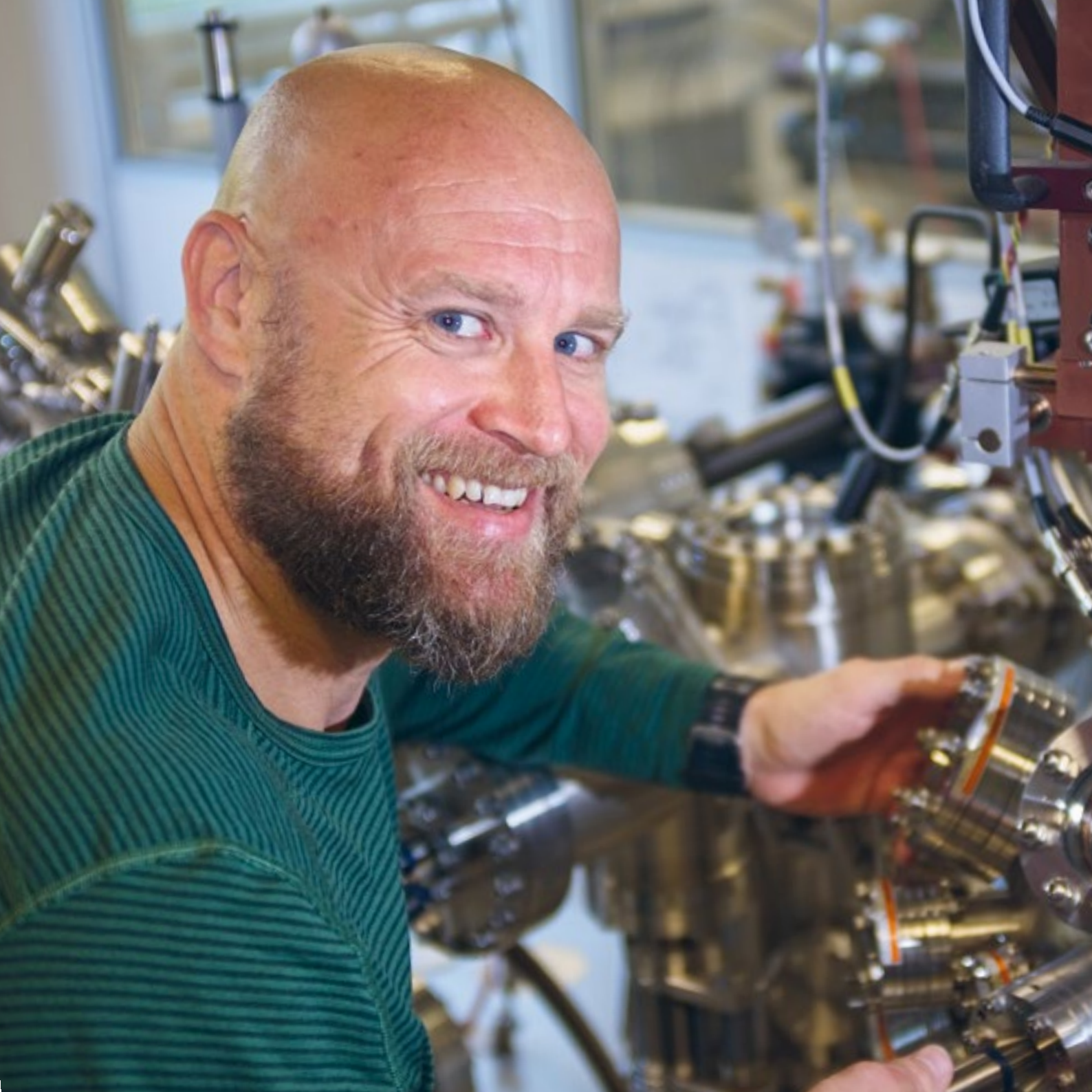
The world's largest electric truck

"eDumper", the largest electric vehicle in the world, has been in action at a quarry in Péry in the Bernese Jura since 2018. The environmentally friendly truck was developed in collaboration with industrial partners and researchers from Bern University of Applied Sciences (BFH), the Interstate University of Applied Science Buchs (NTB) and Empa. Over the next decade, the 58-ton vehicle will transport more than 300,000 tons of materials each year and, according to initial calculations, save up to 1,300 tons of CO_2 and 500,000 liters of diesel in the process. (Photo: eMiningAG)

Insulating with microscopic bubbles
A better heat insulation means lower heating costs – but this shouldn't be at the expense of stunning architecture. Empa researchers, therefore, replaced the perlite usually used in insulating bricks with aerogel, a highly porous solid with very high thermal insulation properties that can withstand temperatures of up to 300 °C. This new kind of brick filled with aerogel will make thin yet highly insulating walls possible in the future – without any additional insulation layer.

What does graphene do in the lungs?
How does graphene, the "material of the future", affect our health if it gets into the human body? A team of researchers from Empa and the Adolphe Merkle Institute (AMI) in Fribourg conducted the first studies on a cellular 3D lung model to examine the behavior of graphene and graphene-like materials once they have been inhaled. The researchers were able to prove that no acute damage is caused in the lungs if the lung epithelial cells come into contact with graphene oxide (GO) or so-called graphene nanoplatelets (GNP). In order to trace chronic changes in the body, too, the SNSF-funded project is set to run for three years. (Photo: iStock)

Lifting the mask
Laughter is beneficial for your health, says medical research. But how are patients supposed to feel like smiling if the faces of the nursing staff and even their loved ones are covered with sterile masks? Researchers from Empa and EPFL are developing a novel face mask, which offers an unobstructed view of the wearer's facial expressions. The researchers have already received the Challenge Debiopharm-Inartis Prize to kick-start the project, which is also funded by the Gebert Rüf Foundation and the Staub Kaiser Foundation and is due to run until 2019. (Photo: iStock)



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.

Rotten to the core

Prof. Dr Francis Schwarze, francis.schwarze@empa.ch

Fungi that normally decompose tree trunks can also conjure up works of art in wood. In nature, however, wood decay fungi not only visually alter the wood of the tree, they also destroy it. Empa researchers are now teaching wood decay fungi how to draw in the lab. The result: marbled wood which can be used to make beautiful furniture or musical instruments.

Even with tree trunks that are deliberately allowed to rot in the forest it takes years before the wood is altered with fungus-induced patterns, let alone capable of being processed. Researchers at Empa have now developed a technology that enables hardwoods such as beech, ash and maple to be treated specifically with wood decay fungi so that the patterns in the wood can be controlled.

The fine black lines running through the wood are battle zones. Fungi that have battled for territory and resources in the wood here clearly demarcate from each other with dark, pigmented lines.

With these demarcation lines, the fine threads of the fungal community not only protect their colony from other fungi; the black boundary also ensures that bacteria and insects stay away and that the habitat retains an ideal amount of moisture.

Black melanin lines

The researchers identified fungi that grow in nature and analyzed them to single out those with the most favorable wood finishing properties. For example, when challenged with each other the brittle cinder fungus and the Turkey-tail leave black lines consisting of the pigment melanin and, at the same time, they bleach the surrounding wood secreting the fungal enzyme laccase. This creates a pattern with a particularly strong color contrast in the wood.

Wood structure remains stable

The gentle bite of the fungi used in the Empa laboratory is particularly favorable: after all, despite their distinct talent for drawing, the candidates selected hardly affect the mechanical properties of wood that retains its stability and shape.

However, the fact that the artistic process can be controlled and geared towards the desired result is not just down to the type of fungus used. The researchers have also developed a process that prepares the wood for processing in a matter of weeks. One of the reasons is that the fungal species selected are able to colonize the wood at considerably lower wood moisture levels. This means that the raw material does not have to be dried in a lengthy, expensive and energy-intensive process before it can be processed for furniture.

Products made of Swiss beech

Together with their industrial partner Koster Holzwelten AG in Arnegg (SG), the researchers are now in the process of implementing an efficient and ecologically sustainable production method.

This also includes the use of regional wood. Beech wood is a hardwood that is common in Switzerland but uninteresting to furniture designers. With marbled wood obtained from local beech trees, however, it is possible to offer sought-after products on the Swiss timber market with an annual volume of around CHF 3 billion. In addition to furniture, parquet floors and kitchen fronts, marbled wood can also be used to make decorative objects and musical instruments. Unique items have been created from marbled or discolored wood i.e, intarsia or inlays ever since antiquity. Thanks to the new technology, these pieces can now be produced faster, sustainable and with the desired marbling. //

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1
Marbled wood from the lab: depending on the kind of wood decay fungi used, the design of the pattern in the wood can be controlled.

2
A fruit bowl made of marbled wood produced in the lab.

2

Structural reinforcement with carbon fibers and memory steel

Prof. Dr Masoud Motavalli, masoud.motavalli@empa.ch

Maintaining, not discarding – not only does this hold for art nouveau villas, rare classic cars or your record collection from the 1960s; 'maintaining, not replacing' is also a good idea for decades-old railway or road bridges, and industrial and residential buildings. These historic structures shape the skylines of European cities and are part of our culture.

Very often, however, historical bridges suffer from today's ballooning traffic volumes – or the interiors of older buildings have become too cramped for present-day uses. The structures need to be upgraded for the future.

Carbon fiber strips for old bridges

A team from Empa is saving old 19th-century iron bridges from collapse. A brace made of CFRP (carbon fiber-reinforced plastic) affixed to the bridge reversibly and in line with monument protection regulations strengthens the resistance of the old structures. CFRP is often the material of choice for reinforcing structures: it's lightweight and corrosion-resistant, and has an outstanding fatigue behavior. Built in 1892, Münchenstein railway bridge near Basel was reinforced with prestressed CFRP plasters in 2015. Several dozen passenger and cargo trains rumble across the historical steel construction on a daily basis. A long-term monitoring system measures the load and movements of the bridge sections and delivers the data to Empa in real time.

Diamond Creek bridge in Melbourne, which was built in 1896 and reinforced in January 2018, also has sensors and will supply Empa with load data for at least 18 months. The CFRP reinforcement system developed at Empa has already been patented.

Memory steel for old industrial buildings

While structures can be strengthened extremely effectively using CFRP strips, memory steel strips are ideal for prestressed reinforcement of older structures. As soon as new windows, doors or lift shafts are installed in the concrete structure of an old building, reinforcing the load-bearing structure is often unavoidable. In industrial buildings, the load-bearing capacity of an old suspended ceiling sometimes has to be increased.

The culmination of around 15 years of research work, experts from Empa and the start-up re-fer AG have now readied a precise method for series production: shape memory alloys based on iron, which contract during heating and thus permanently prestress the concrete structure. Henceforth, the new building material will be marketed under the name "memory steel". To strengthen an old building, a strip of this special steel is fastened under the ceiling using dowels and then heated with electricity or an infrared radiator. Alternatively, the reinforcement can also be set in concrete: first a groove is milled into the concrete slab, then a ribbed reinforcement bar made of memory-steel is inserted into the groove and filled with special mortar. Finally, the profile is heated with the aid of direct current and thus prestressed. Another variant is to embed the reinforcement bar in an additional shotcrete layer.

The new building material memory steel was presented to interested building experts and architects at four specialist conferences in September and October 2018. //

1
Diamond Creek Bridge near Melbourne was reinforced with CFRP strips in 2018 and, once the work was complete, its performance was tested with a 42-ton truck.

2
Reinforcing a suspended ceiling in an old building with memory steel.

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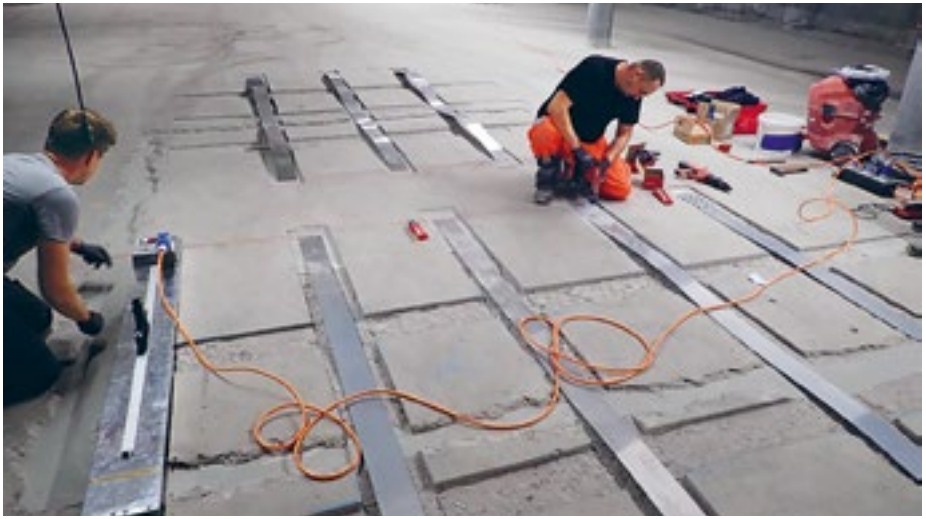

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Circular economy: more than “just” recycling

Dr Patrick Wäger, patrick.waeger@empa.ch

If every human polluted the environment as much as the average Swiss person, we would need more than three earths. In other words, we urgently need to minimize our resource consumption, as many experts stressed at the second Swiss Resource Forum, which took place at Empa in October 2018. Recycle, don’t discard: this goes for worn-out t-shirts, your old smartphone and the insulation or floor tiles in a disused house. Scrap electronics especially harbor a veritable treasure trove – apart from gold, which is already recovered. Although considered rare elements, neodymium and indium are found in many new technologies, often in key ones such as LCD screens. Both metals are at risk of supply gaps – which makes them critical metals for our economy.

Therefore, not only is recovering them sensible, it is becoming increasingly necessary to avoid future bottlenecks. Thus far, however, this course of action has made little financial sense. Nevertheless, a slight increase in the anticipated recycling fee would suffice to render recycling indium economically attractive, for instance, as Empa researchers discovered in a study. According to their research, a pile of used LCD panels contains more indium than a zinc mine containing indium with the same volume. The study shows that the environmental impact of recycling indium from flatscreens is no higher, if not actually lower, than in primary production. As for neodymium, the results come out even more clearly in favor of recycling.

Pan-European stock-take

But which materials are actually in “circulation” and in which quantities? A database for secondary raw materials (www.urbanmineplatform.eu), which Empa was instrumental in developing, sheds light on the matter. Devised within the scope of a project funded by the EU research program Horizon 2020, the database reveals what raw material reserves are contained in cars, batteries and electronic devices purchased, used, stored – and ultimately recycled and discarded – in the 28 EU countries, Norway and Switzerland. Three Empa departments were involved in the project, along with 17 research institutions from 12 countries.

The urban mine harbors far more than the precious metals in used smartphones or computers, however, and it has by no means been exhausted. This is demonstrated by the NEST unit Urban Mining and Recycling, which opened in 2018. Not only do large sections of the module at Empa and Eawag’s innovative research building consist of recycled materials; when it is demolished, it can be broken up into individual components which can be reused and recycled separately. Empa researchers have already proven in a study just how energy-saving and sustainable this urban mining principle is at building level. The results of the models based on the NEST unit suggest that large quantities of raw materials might be saved and environmental damage avoided if this unit’s design were used extensively in future.

Improved recycling, but also concepts such as reuse and a modern product design that factors in the entire lifecycle of the product are therefore pivotal for the careful and economical handling of our resources. After all, only then can natural resources be protected and the future supply guaranteed. //

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1
All the reusable, recyclable or compostable materials used to build the NEST unit Urban Mining and Recycling (UMAR) are documented extensively in the unit's Material Library.
(Photo: Felix Heisel)

2
A partition wall installed in the NEST unit Urban Mining and Recycling (UMAR) can be swiveled 90 degrees. The stones in the revolving wall were made from mineral building rubble.
(Photo: Zooey Braun, Stuttgart)

Quantum chains in graphene nanoribbons

Dr Oliver Gröning, oliver.groening@empa.ch

Empa researchers, together with colleagues from the Max Planck Institute for Polymer Research in Mainz and other partners, have achieved a breakthrough that could one day be used for precise nanotransistors or – in the distant future – even quantum computers.

The graphene nanoribbons, which are only a few carbon atoms wide and exactly one atom thick, have very different electronic properties depending on their shape and width: conductor, semiconductor or insulator. An international research team led by Empa's "nanotech@surfaces" laboratory succeeded in adjusting the properties of the ribbons precisely by specifically varying their shape. What makes this so special: not only can the "usual" electronic properties mentioned above be varied – the technology can also be used to generate specific local quantum states.

Focusing on transitions

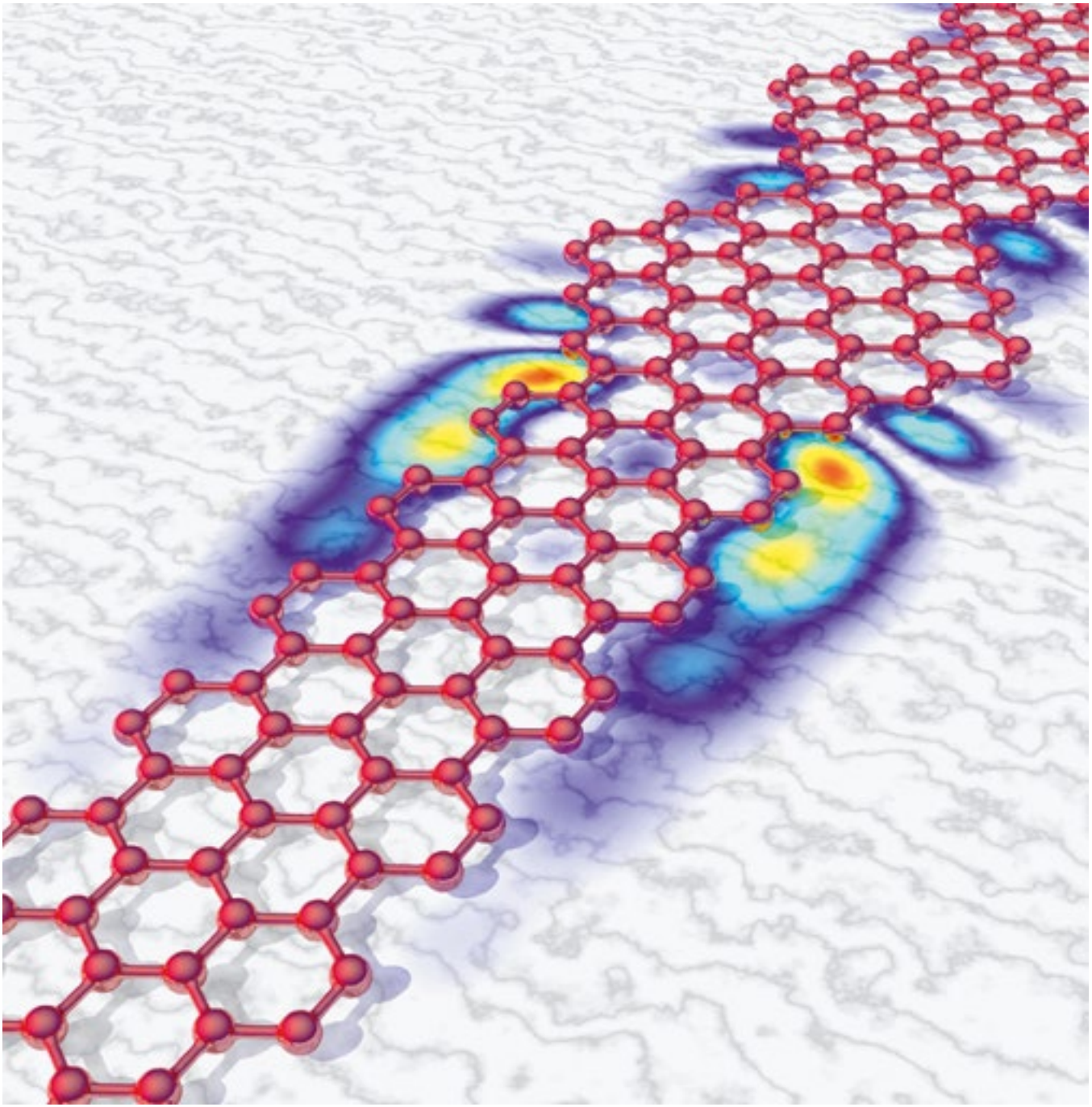
So what's behind it? if the width of a narrow graphene nanoribbon changes, in this case from seven to nine atoms, a special zone is created at the transition: because the electronic properties of the two areas differ in a special "topological" way, a "protected" and thus highly robust new quantum state is created in the transition zone. This local electronic quantum state can now be used as a basic component to produce tailor-made semiconductors, metals or insulators – and possibly even as a component in quantum computers.

The Empa researchers headed by Oliver Gröning were able to show that if these ribbons are built with regularly alternating zones of different widths, a chain of interlinked quantum states with its own electronic structure is created by the numerous transitions. The exciting thing: the electronic properties of the chain change depending on the width of the different segments. This allows them to be finely adjusted – from conductors to semiconductors with different bandgaps. This principle can be applied to many different types of transition zones – for instance, from seven to eleven atoms.

In reality, however, it is not quite that simple: for the chain to have the desired electronic properties, each of the several hundred or even thousands of atoms must be in the right place. "This is based on complex, interdisciplinary research", says Empa researcher Gröning. "Researchers from different disciplines in Dübendorf, Mainz, Dresden and Troy (USA) worked together – from theoretical understanding and specific knowledge of how precursor molecules have to be built and how structures on surfaces can be selectively grown to structural and electronic analysis using a scanning tunneling microscope."

On the road to artificial nanoelectronics

Based on these novel quantum chains, precise nanotransistors could be manufactured in the future – a fundamental step on the way to nanoelectronics. Whether the switching distance between the "1" and the "0" states of the nanotransistor is actually large enough depends on the semiconductor's bandgap. And with the new method this can be set virtually at will. However, further applications are also conceivable, such as in the field of spintronics or even quantum informatics – and thus completely new possibilities for computer-intensive areas like cryptography or in machine learning. //



When graphene nanoribbons contain sections of varying width, highly robust new quantum states can be created in the transition zones.

Innovative drug delivery thanks to therapeutic textiles

Prof. Dr René Rossi, rene.rossi@empa.ch

When it comes to administering drugs, not every substance is suitable for pills you can swallow or liquids you can inject. The skin – our largest organ – on the other hand provides a considerable surface via which substances up to a certain molecular size can be absorbed. Researchers from Empa are working on various projects to exploit the skin's potential for innovative drug delivery.

One possibility are transdermal patches, which apply drugs painlessly and efficiently via the skin. Together with the Adolphe Merkle Institut/University of Fribourg, the Empa team developed a system that can be used to control the dosage of substances with light switches. The molecular light switch was inspired by nature and works similarly to the retina in the human eye. Like the pigments in the eye, the synthetic photochromes are also activated by light. The molecular switches were integrated into polymer nanospheres. When these nanocontainers are exposed to light, their structure changes (they become permeable), enabling the active substances to diffuse out into the surroundings. If the color of the light changes, the chemical reaction stops within seconds and the nanocontainers become impermeable again.

With support from the Swiss National Science Foundation (SNSF) and the National Center of Competence in Research for Bio-Inspired Materials, the team is working to optimize the nanocontainer with light switches. "We will investigate the controlled release of substances that are already approved for application through the skin, such as painkillers", says the researcher.

Fibers recognize need for therapy

Another possibility to feed in therapeutic agents via the skin are textiles which contain and release drugs. For the Self Care Materials project, smart polymer fibers are produced using various techniques. The intended use of the fibers dictates which production method is the right one. Delicate membranes with a large surface are formed during so-called electrospinning. If robust fibers are required, such as for protective clothing, the thermal drawing technology is used.

Thanks to a cunning control mechanism, a precise dosage of antibiotics or painkillers is administered: polymers which are biodegradable in the body release the drugs at a calculated degradation rate. Stimulus that control this process might be the pH level of a skin sore, which indicates that tissue damage needs to be treated. In the form of a garment, for instance, the fibers thus aid the diagnosis and treatment of diseases.

Moreover, external stimuli can also be used to control the release of medication by the fibers. Textiles which release medicine when pressed gently or stimulated by light may help improve the quality of life of patients while taking the pressure of the nursing staff. The system can also be used in prevention in that the fibers act as sensors and record the sugar level in the blood, for instance. As a result, the blood sugar in newborns can be monitored through the skin, without the babies having to endure the needle prick that taking blood samples involves.

For the project with the ETH Domain's Competence Center for Materials Science and Technology (CCMX), the researchers are now honing the smart medical fibers together with colleagues from EPFL. Twenty Swiss companies are already on board as industrial partners, as is the industry association Swiss Textiles with the research initiative Subitex. //

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1
Pipette precision: in the future, smart textiles will be able to administer doses.

2
The nanocontainer with a "light switch" works similarly to the human eye.

2

Out of the lab and into industry

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Creative researchers keep finding ways to produce new products that offer previously impossible functionalities or boast improved properties. A demonstrator manufactured in the lab, however, is by no means the final step on the road to a marketable innovation. It is often merely the springboard for the development of a new technology. Many hurdles need to be overcome and a lot of development work has to be done before a new manufacturing technology is ready for industrial use.

Together with other institutions in the ETH Domain, Empa has set itself the goal of promoting the development and transfer of innovative technologies in the field of Advanced Manufacturing (AM). The strategic focus area AM, which the ETH Board has funded with CHF 20 million for four years in 2017 and which is coordinated by Empa, finances technology development projects. In these, interdisciplinary teams of researchers within the ETH Domain collaborate closely with industrial partners to develop new manufacturing technologies that boost Swiss industry's competitive edge. Currently, the program is funding 11 projects, involving a total of 34 research labs and 41 industrial partners. Further information on the program is available on the initiative's website: *www.sfa-am.ch*

From laboratory to industrial scale

However, providing financial support for projects is not enough by itself. The project teams need appropriate facilities and infrastructures to demonstrate that a new technology not only works in the lab, but that it is scalable and that the new products can be produced using industrial processes. By opening the Coating Competence Center back in 2016, Empa set up pilot production facilities and infrastructures to close the gap between laboratory research and industrial production in the field of coating technologies.

Following this example, Empa has meanwhile succeeded in launching a new initiative together with numerous partners from research and industry. Its aim is to establish a network of technology transfer centers in the field of AM throughout Switzerland – referred to as "Advanced Manufacturing Technology Transfer Centers" (AM-TTC). The initiative is part of the "Digitalization" action plan, which the federal government approved in mid-2017. Consortia from research institutions and industrial companies that plan to set up a joint technology transfer center can apply for public funding. The ETH Board is supporting the initiative with CHF 10 million in the pilot phase, in which the first centers are to be built in 2019 and 2020. For 2021 to 2024, it is planned that the federal government will support these centers with CHF 40 million as research institutions of national importance.

The application process for the centers is currently underway. By the end of 2018, twelve centers had applied for funding. The topics range from 3D-printing patient-specific implants and producing battery cells to using digital manufacturing technologies and robots on building sites. The decision on which centers will receive funding in the pilot phase will be made in mid-2019; the first centers are expected to be operational by the end of 2019. Further information is available on the initiative's website: *www.am-ttc.ch* //

1
A 3D-printed ear: Empa researchers equip nanocellulose obtained from wood with additional capabilities and use a 3D printer, for example, to produce implants for patients with cartilage diseases.

2
Entrance to the Coating Competence Center at Empa in Dübendorf, which was opened in 2016.

NEST: growing and thriving

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At the modular research and innovation building NEST, researchers and companies jointly realize new ideas in real building projects. They incorporate new materials, technologies and systems into units integrated in NEST's typecase-like structure before testing them in practice. The broad network of partners from research, industry and the public sector has meanwhile risen to over 140.

Two new units …

Two more units were added to the existing three in 2018: Urban Mining and Recycling (UMAR) and SolAce. The former has been lived in continuously since May. The idea and concept behind UMAR, the brainchild of German architects and researchers Werner Sobek, Dirk E. Hebel and Felix Heisel, are based on the premise that the structures and all the materials in the residential module can be reused, recycled or composted after demolition.

The unit SolAce combines two other needs under one roof: maximum energy production via the façade and optimum comfort in the interior by using sunlight. EPFL researchers under Jean-Louis Scartezzini came up with the concept of SolAce. The goal is to achieve a positive energy balance all year round – even without a usable roof area – by producing solar power and hot water directly on the façade. Photovoltaic modules and solar thermal collectors with colored glazing will be used for this purpose. Moreover, innovative, microstructured window glass will enable the seasonally dynamic management of the solar heat gains and the daylight.

… and two awards in the bag

There was also good news from the existing units: several products used as prototypes in the office unit Meet2Create are now available on the market. The Solar Fitness & Wellness unit won several accolades for its sustainable concept – including the Norman Foster Solar Award and, in early 2019, the Watt d'Or. The first research projects were completed in NEST's Energy Hub and afforded insights into how to optimize the energy flows in a district – including using artificial intelligence. At the same time, the Water Hub, where researchers from Eawag work on technologies to treat flows of waste water that are collected separately, went through a major expansion. Aurin, a plant fertilizer produced from urine collected at NEST, was approved as a universal fertilizer in 2018 and is marketed by Eawag spin-off Vuna.

One big building site

In 2018 NEST underwent another major makeover. In addition to the two new units, the DFAB HOUSE on the uppermost platform was officially inaugurated at the end of February 2019. DFAB HOUSE is a three-story building which was largely built using robots and 3D printers, and sets new benchmarks in "digital construction" and "digital living". The unit was developed in close collaboration with numerous researchers from ETH Zurich within the scope of the National Center of Competence in Research (NCCR) "Digital Fabrication" and a large number of industrial partners. DFAB HOUSE is yet another shining example of how cooperation between research and industry gives rise to pioneering feats and how all those involved can learn and benefit from each other. //

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1
The double-curved Mesh Mould wall provides a backdrop for the living area. (Photo: Roman Keller)

2
"Spatial Timber Assemblies" enables unique geometries at DFAB HOUSE. (Photo: Roman Keller)

Paving the way for post-fossil mobility

Urs Cabalzar, urs.cabalzar@empa.ch

Around 1.2 tons of hydrogen produced from renewable energy were used to refuel fuel-cell vehicles at move in 2018 – thereby saving around 8,600 liters of gasoline. The demonstration platform for future mobility on the Empa campus offers refueling options for fuel-cell vehicles, charging stations for electric cars and dispensers for gas vehicles. However, move is not just a filling station; first and foremost, it is a demonstration plant where the individual mobility paths can be studied and honed under everyday operating conditions.

A number of milestones were especially laid on the mobility route in 2018, which should facilitate the development of a hydrogen filling station network in Switzerland: together with Suva, the efficacy and reliability of leak tests were studied for hydrogen dispensers – a necessary step to be able to incorporate this kind of dispenser into conventional gas stations. This and other safety measures were channeled into an initial draft of approval guidelines for hydrogen refueling stations in 2018. After consulting all the relevant specialist departments and authorities, these will then serve as a legal and safety-related guide for the construction of hydrogen refueling stations. A calibration process for hydrogen refueling stations is also being developed in conjunction with the Federal Institute of Metrology (METAS) as part of an EU project. The first measurements were conducted in 2018.

Another move project studied the energy required to precool hydrogen during refueling and analyzed the temperature distribution in vehicle tanks during fast filling with the aid of 3D simulations and measurements. The goal is to reduce the complexity and energy consumption of the precooling system.

Salt batteries for temporary storage

A stationary battery storage device was added to move's infrastructure in 2018. The storage device is used as a buffer between move's photovoltaic plant and the electric charging stations, and should compensate for fluctuations on the grid. The salt batteries ($NaNiCl_2$) have a capacity of 67.5 kWh. Like all of move's other components, they are also integrated in the energy demonstrator Energy Hub, and can be controlled and used in a targeted manner.

The third mobility path is due to be implemented in 2019; extensive preparatory work was conducted last year. The phase includes the development of a methanation plant as an example of synthetic fuel-based mobility. In doing so, the waste heat produced by the methanation plant is used to desorb the CO_2 extracted from the atmosphere, thereby improving the overall efficiency by several percentage points. A second sorption-catalytic methanation step that does not require the gas produced to be cleaned any further is also under construction. During the project, 20 tons of methane are due to be produced and used in a gas truck. Detailed economic feasibility studies are also scheduled to gage the market development of gaseous and liquid synthetic fuels.

move at the Geneva Motor Show

As in previous years, move also attracted numerous interested people to Dübendorf in 2018, who learned about the move concept on tours and enjoyed a fruitful exchange with researchers and representatives from industry. One of the highlights in the public eye was move's participation in the Geneva International Motor Show. In conjunction with the Swiss Oil Industry Association, Empa showcased the "gas station of the future", where fuels produced from renewable energy will (hopefully) play the lead. //

1
Patrick Stadelmann conducting measurements on temperature distribution in the vehicle tank while refueling with hydrogen.

2
Federal Councilor Guy Parmelin, who has been Head of the Federal Department of Economic Affairs, Education and Research (EAER) since 2019, practicing refueling a vehicle with hydrogen at the Swiss Oil Industry Association and Empa's "Gas Station of the Future" stand at the Geneva Motor Show.

1

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Energy flows under the microscope

Philipp Heer, philipp.heer@empa.ch

The ehub (short for Energy Hub) serves as a research platform for district energy management. ehub supplies the research building NEST and the mobility demonstrator move with energy – and enables researchers to examine key questions on our future energy supply, such as: how can the various energy forms for buildings and mobility be connected in a meaningful way? Does it make sense to power buildings and districts autonomously? And how can energy be stored in the short and long term?

ehub offers researchers a flexible infrastructure comprising of thermal and electrical energy components. These include photovoltaic plants, heat and cold storage units, heat pumps, batteries and super-capacitors, which are combined with each other in different grids and enable energy to be converted into different forms and stored. 550 sensors and 210 actors with a total of 6,500 data points enable the energy flows to be controlled and all manner of parameters measured.

Are batteries worthwhile?

In 2018 two key components were added to ehub's infrastructure and immediately put to good use in research projects. Firstly, a molten-salt battery: in a project conducted in collaboration with the local Dübendorf energy and heat supplier Glattwerk AG, the researchers studied how batteries with different technologies and sizes can be used in residential buildings and districts in an economically viable way. This is no mean feat: after all, the energy suppliers need to guarantee that the grid remains stable and thus do not want any major fluctuations in the amount of electricity fed in or consumed. The consumers, who at the same time also produce electricity themselves, require a secure, uninterrupted supply on the one hand and would like to obtain as big an economic benefit as possible from the electricity generated on the other, i.e., either feed it into the power grid in a profitable way or only use it when the electricity from the grid is too expensive. The research project revealed that the use of small, decentralized batteries can already be mutually beneficial.

The digital side of energy

The second key new development at ehub is designed to aid networking: thanks to new interfaces, it is now possible to access ehub's infrastructure more flexibly and openly from outside. This facilitates joint research projects with start-ups, companies and other research institutes such as ETH Zurich, PSI and the Lucerne University of Applied Sciences and Arts.

Digitalization is also coming on in leaps and bounds at ehub. The Digital Hub – dhub for short – models, amongst other things, ehub at digital level (see page 30). Digital technologies such as machine learning, for instance, can help control the building services increasingly more effectively. Frequently, control systems for building services such as heating or controlling the blinds ex works are not set optimally for an individual building. While it is possible to optimize them, it is only with a relatively large amount of effort and therefore costs. Empa researchers have now succeeded in improving the settings for the heat pump controls using artificial intelligence. The interplay between ehub, NEST, move and dhub opens the door for further energy research projects – for the energy supply of the future. //

ehub's 550 sensors and 210 actors with a total of 6,500 data points enable the energy flows to be controlled and all manner of parameters measured.

Digital Hub – the hub for digital innovation

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Empa has expanded its demonstrator park – the "Research and Technology Transfer Platforms" (RTTPs): NEST, move and ehub are joined by the Digital Hub, or dhub for short. It represents the digital level of the demonstrator platforms and connects buildings, mobility and energy systems. All data from the three areas is available across sectors and in real time, and paves the way for new products and services for smart cities and smart communities to be developed and validated in practice.

Digital technologies are also changing the competitive landscape in the building, energy and mobility sectors. If companies want to retain or even boost their competitive edge, they need to experiment constantly with new and promising digital technologies, from artificial intelligence (AI) and augmented reality to the processing of big data. Alongside the three established demonstrators in the Empa campus, the Digital Hub can also be regarded as a platform where companies team up with researchers to implement and hone novel digital ideas for the first time in a real environment and without risks.

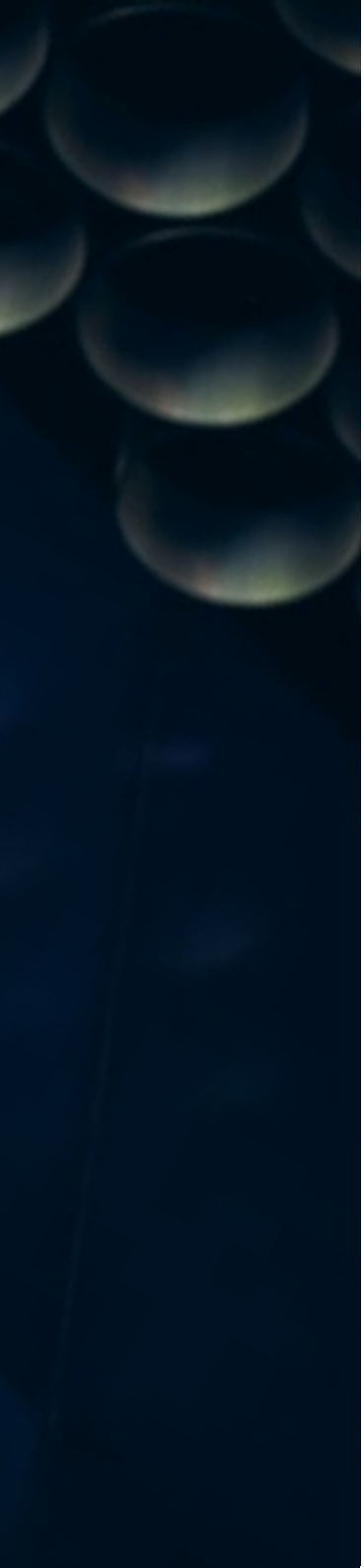
A digital twin for NEST

A series of prestigious companies and research institutions are already on board as dhub partners. The first step was to create a digital twin – i.e., an exact virtual copy – of NEST to form the basis for concrete projects. A 3D model was produced retrospectively. NEST's complete data is now available in a straightforward way via an IoT hub (Internet of Things).

Artificial intelligence replaces conventional control circuits

An initial project involving the ehub infrastructure studied the possibilities of replacing conventional heat pump control circuits with the aid of artificial intelligence. This enables installation and operating costs to be cut for technical installations. Moreover, at the demonstrator hub on the Empa campus it was also possible to show that machine learning can reduce peak loads on the power grid, thereby reducing or even completely avoiding unnecessary investments in the grids. Digital design methods are to be used in the construction of future NEST units within the scope of another project, which might be used to prefabricate all the air-conditioning lines, for instance. //

The Digital Hub (dhub) connects the units of NEST and the three other Empa demonstrators at digital level. (Image: Roman Keller)



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.

Carbon – unique material, outstanding nanomaterial

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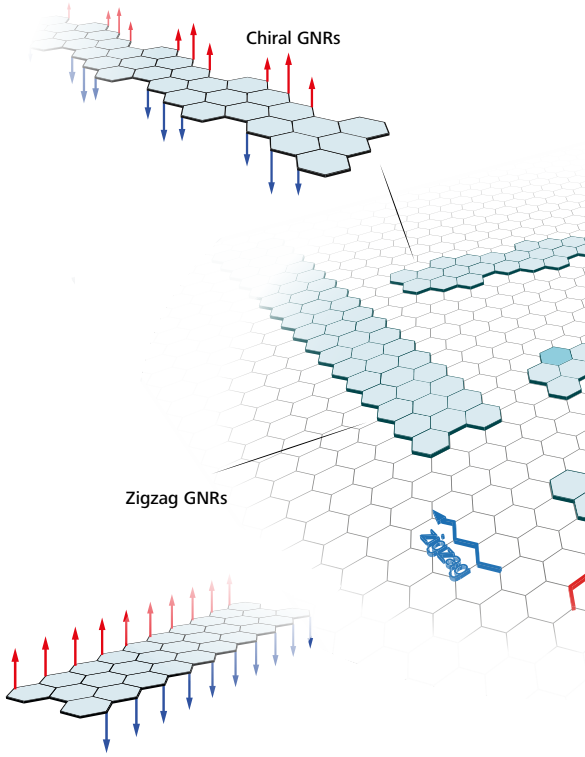
Carbon, the sixth element in the periodic table, trumps every other element with its melting point of 3 727 °C. And, at a density of 2.26 g/cm^3, it is also one of the lightest. These values already hint at how exceptional the mechanical properties of carbon as a material must be. Moreover, of all the elements carbon is able to form the widest variety of chemical bonding states – which is why pure carbon exists in different forms: diamond, graphite, graphene, fullerene or nanotubes. The physical properties of these carbon allotropes are completely different, but always outstanding. Diamond, for instance, is the hardest material, a perfect electrical insulator and transparent. The physical properties of graphite are the exact opposite: black, extremely soft and a perfect electrical conductor. Fullerene C_{60} is the most stable molecule known to man. The extraordinary stability of the carbon allotropes towards oxidation makes them the ideal nanomaterial – after all, they are stable under atmospheric conditions. A crucial factor in realizing technological applications.

For many years, Empa has been researching materials with carbon nanostructures for a vast range of applications – such as organic molecules with C_{60} as an electron acceptor in organic solar cells or carbon nanotubes as a bulking agent in polymers and composite materials to improve electrical conductivity or mechanical strength. For a number of years, graphene has been regarded as the "material of the future", with possible applications for flexible electrodes, super capacitors and– in the form of nanoribbons – nanoelectronics.

Graphene, material platform for the digitalization of the distant future

Spintronics and quantum computers are alternative concepts to classic electronics, where the controls use electrons to conduct logical operations. In spintronics, it is the spin of the electron; in quantum computers it is quantum states. For two decades, researchers all over the world have been looking into suitable materials for spintronics and quantum computers. With their latest spectacular research results, the team headed by Roman Fasel, Oliver Gröning and Pascal Ruffieux revealed that the "simple" material graphene in the form of nanoribbons is just the ticket for nanoelectronics, spintronics and quantum computing in equal measure, the latter eventually even at room temperature, which was unthinkable until now. The only modification that needs to be made to the graphene nanoribbons to get them "in shape" for one



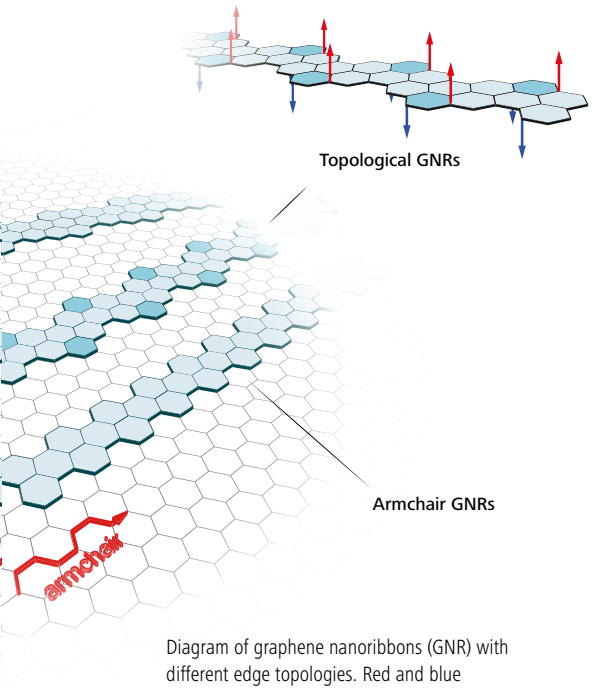


Diagram of graphene nanoribbons (GNR) with different edge topologies. Red and blue arrows indicate the direction of the electron spin. Armchair GNRs are just the ticket for electronics, zig-zag GNRs for spintronics and topological GNRs for quantum computing.

of the three aforementioned applications is the topology of the edges, i.e., a purely geometric modification – that's how aesthetic research can be. Depending on the configuration of the edges – "armchair", "zig-zag" or a hybrid – the graphene nanoribbons are suitable for electronic, spintronic or quantum computing building elements. In collaboration with colleagues at the Max Planck Institute in Mainz (Germany) and Lawrence Berkeley National Laboratory (USA), the Empa researchers have already realized their first building element, a nanotransistor with ultrashort channel lengths of 20 nanometers. This transistor can switch a current density of up to a billion amperes per square centimeters.

Printed supercapacitors

Within the scope of the new Research Focus Area "Printed Electronics", the team headed by Jakob Heier is developing a technology to print a graphene-based supercapacitor, including the electrolyte, using a combination of classic printing techniques (silk-screen, gravure and flexographic printing. Compared to batteries, supercapacitors have a considerably lower energy density, but a power density that is 50 to 100 times higher. Supercapacitors are used wherever high power is needed for a short time (a few seconds). The research is currently focused on developing suitable inks. Within the scope of this development, the researchers have devised a new method to exfoliate graphene from graphite. Compared to today's methods, this centrifuge-based method is considerably gentler, which produces a far better quality of the graphene obtained. The technique is patent pending. The first ink formulations were developed and produced with the new graphene material. The first printing attempts were highly promising. The printing method enables supercapacitors to be manufactured considerably more cheaply. //

In-depth understanding of materials is the key to success

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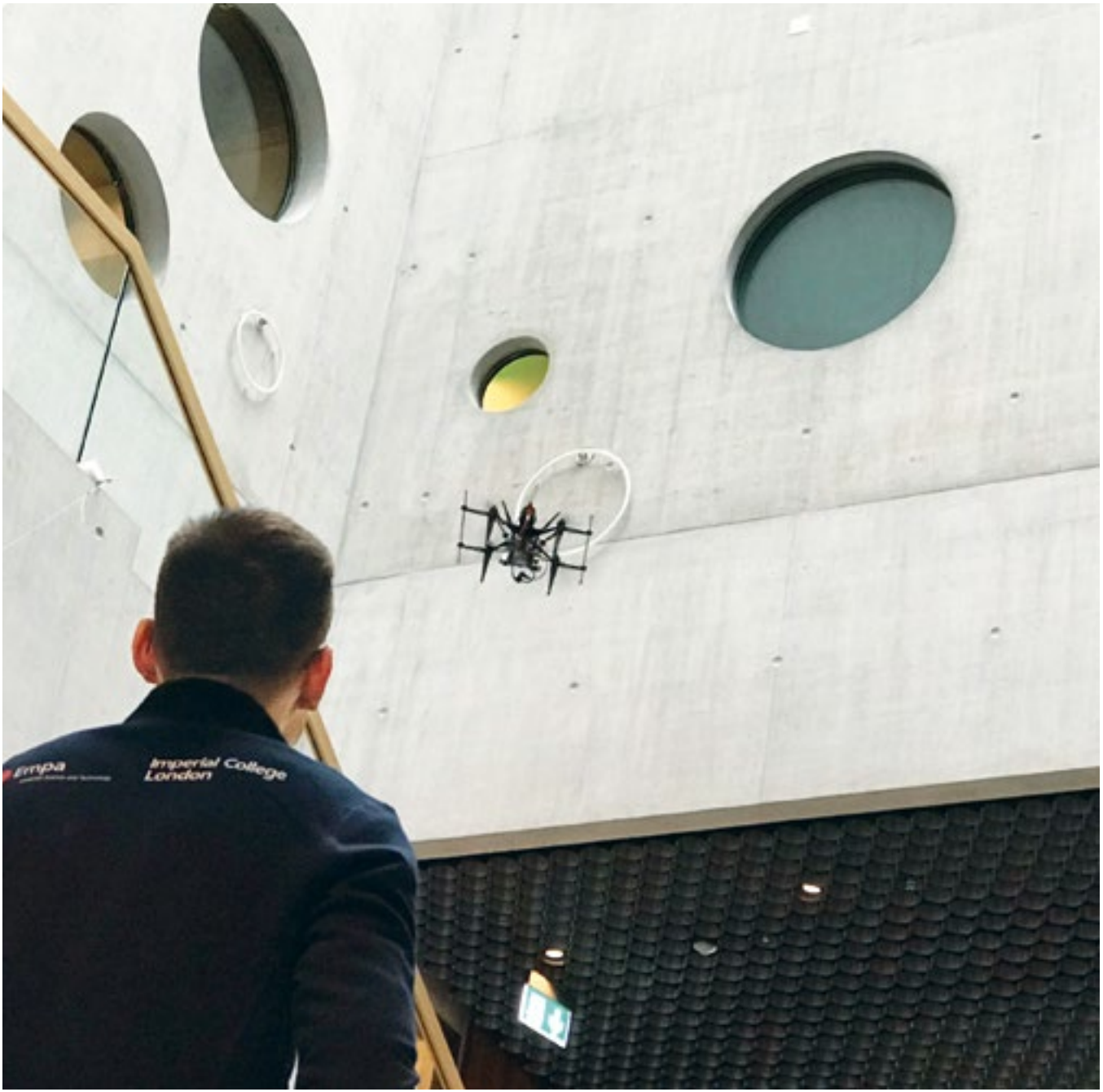
The quality of our built environment is crucial for a truly sustainable society. This includes high-quality and affordable residential and office spaces, transport routes for passengers and cargo, and a reliable distribution of energy, water and information.

Empa's research takes place on different levels, from the development of new functional materials and the design of complex systems all the way to studying the interaction between cities and their environment. Core elements on all levels are minimizing the ecological footprint with the same or even improved comfort and user safety. Looking further into the future, the urban environment might even be monitored, maintained and repaired with the aid of aerial robots. This is the goal of the "Materials and Technology Center of Robotics", which was founded in early 2019 as a joint endeavor by Empa and Imperial College London.

In both the building and the energy sector, it is an enormous challenge these days to launch new ideas and products swiftly on the market. Often, high investment costs in the building sector inhibit the willingness of companies to take risks. With this in mind, the experimental building NEST was built on the Empa and Eawag campus in Dübendorf. For both researchers and companies NEST offers the possibility of validating new technologies in a real-world setting. Innovative materials and systems can thus be implemented and monitored under realistic conditions (see page 24). Excellence in research and cooperation with other research institutions and with industry are the prerequisites for an in-depth understanding of materials and their properties – and thus the basis for success.

Role of water redistribution in creeping concrete

Concrete is by far the most important construction material and one of the most common materials in the world. Therefore, its efficient and sustainable use is vital. Immediate and delayed deformations pose a threat to the stability and durability of concrete structures. Immediate deformations occur due to mechanical load or changes in temperature, for example; delayed deformations such as shrinkage or creep can take decades, even when the mechanical load is constant. Our ignorance of the mechanisms behind delayed deformations may lead to uneconomic structures or even to failure of concrete structures due to excessive deformations. The goal of an Ambizione project funded by the Swiss National Science Foundation (SNSF) was, therefore, to gain insights into how water in concrete contributes towards creep – the time-dependent deformation of concrete under constant stress. To this end, the water redistribution in the microstructure of cement paste was studied by nuclear magnetic resonance. The results revealed that both temperature fluctuations and especially mechanical loads cause the immediate redistribution of the water – from smaller to larger pores. This first direct evidence of water redistribution within the microstructure of concrete under mechanical load provides key findings into the mechanisms of thermal deformation and short-term creep. //



In future, the urban environment might even by monitored, maintained and repaired with the aid of aerial robots. The "Materials and Technology Center of Robotics" co-run by Empa and Imperial College London is working on this.

Reducing emissions – protecting the environment

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The combustion of fossil fuels for today's mobility is one of the main causes of the current increase in the concentration of carbon dioxide (CO_2) in the atmosphere – and therefore jointly responsible for its warming. In order to limit the risk and the impact of climate change, the Paris Climate Conference agreed on the long-term goal of a global average temperature increase of less than 2 °C compared to preindustrial times. In order to achieve this objective, emissions of CO_2 and other greenhouse gases (GHG) need to be slashed in the next few decades. Empa researchers are making a major contribution towards the technical fundamentals for the necessary reductions in emissions.

Fully variable valve drive reduces fuel consumption

For some time, industry and science have been striving to find a flexibly controllable drive which is capable of regulating the fuel consumption for all speed and load ranges efficiently. Today's conventional load controls using a throttle valve are especially inefficient in the extremely common low load range and lead to a higher fuel consumption than necessary. In close collaboration with hydraulics specialist Wolfgang Schneider, Empa researchers have succeeded in developing a novel, fully flexible energy and cost-efficient valve control system which can do without fast-switching magnetic valves, high-resolution sensors and expensive materials. A passenger vehicle's gasoline engine was fitted with one of these systems developed at Empa and run on an engine test rig. The valve drive works as desired on the intake and exhaust side and yielded outstanding results. Thanks to a throttle-free load controls and cylinder deactivation, fuel savings of 15 to 20 percent can be achieved. Empa's goal is to transfer this technology to industry.

New satellite constellations – quantifying CO_2 sources

To support the CO_2 reduction policy, the European Commission is currently developing a global monitoring system to quantify CO_2 emissions. This is based on ambient air measurements combined with atmospheric transport models at national, city and plant level. A key element of this system is a constellation of CO_2 imaging satellites, which are being implemented via the European Earth observation program Copernicus.

Funded by the European Space Agency (ESA) and headed by Empa, the project SMARTCARB analyzed the po-

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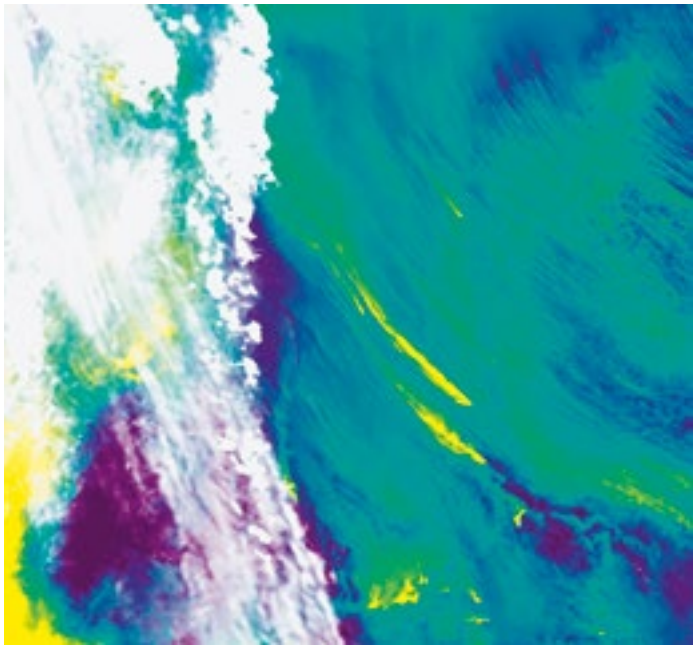
1
Car engine in the lab: the fully variable valve control developed at Empa brought an efficient fuel reduction.

2
CO_2 concentrations in an area of 700 km × 600 km over Eastern Germany. The false-color image produced with the weather forecast model COSMO shows the simulation of the CO_2 emissions from various power stations (yellow streaks) which quickly disperse into the atmosphere.



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tential of future satellite constellations to quantify strong CO_2 sources such as cities and power stations.

To achieve this, realistic simulations of the trace gases CO_2, NO_2 and CO were used to produce synthetic satellite observations with the aid of the atmospheric transport model COSMO-GHG. These were eventually used to evaluate various instrument configurations with differing precision and spatial coverage and propose specific requirements for the new satellite constellation. One key conclusion from the Empa study was that an additional NO_2 measuring instrument would considerably increase the success of the mission. Consequently, the concept of the future CO_2 satellites now also includes one such NO_2 instrument. //

What will the energy system of the future look like?

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Our future energy system must be safe, affordable and environmentally friendly. In its Research Focus Area (RFA) "Energy", Empa develops solutions to facilitate and support this transformation. The biggest challenge of the coming years will be to permanently satisfy our energy demand while phasing out nuclear power. The research conducted at Empa includes the development of new materials and systems for the provision, conversion and storage of energy. To this end, the RFA "Energy" is closely linked to other RFAs at Empa.

One core research topic is novel energy storage technologies. For instance, batteries enable energy to be stored in electric vehicles or in stationary storage systems. Empa develops novel materials, which are especially geared towards these applications: for instance, a cobalt-free sodium ion battery with a non-flammable aqueous electrolyte improves the operational safety and cuts the costs of stationary battery systems. The cell voltage of this novel battery could be increased from 1.5 to 2.6 volts. Moreover, for mobility applications a three-volt solid-state battery was developed that, even after 250 cycles, still exhibits 85 percent of its original capacity and can be operated at temperatures in excess of 100 °C, which speeds up the charging process. For the seasonal – i.e., long-term – storage of electricity in the form of synthetic fuels, Empa developed a catalyst based on copper and tin for the selective electrochemical reduction of carbon dioxide (CO_2) to carbon monoxide (CO), an intermediate product for the production of liquid fuels using the Fischer-Tropsch technique.

Development of seasonal storage systems

Numerous projects have studied how the increasing electrification and the substitution of fossil energy sources will affect the Swiss energy market. Increases in efficiency in building services, the partial substitution of fossil heating systems with heat pumps and a partial electrification of private transport were assumed to be imminent changes. As far as electricity production is concerned, nuclear power stations were omitted and instead, 50 percent of the suitable roof area on buildings was used to generate solar power. A comparison of the resulting supply and demand profile sheds light on the forthcoming challenges: during summer, there will be a significant electricity surplus; in the winter months, however, the exact opposite will be the case.

Maryna Bodnarchuk and her team are studying new materials for energy storage.

In order to solve this dilemma, seasonal storage systems for heating and cooling are needed, which could further reduce the energy consumption in the building sector. Moreover, technologies for the storage or for alternative uses of electricity surpluses – such as through power-to-gas approaches – will help increase the medium- to long-term energy storage capacity. Otherwise, large quantities of electricity would need to be exported in the summer and reimported in the winter – and it is uncertain whether this will even be an option as our neighboring countries will be facing the very same challenges.

The Empa demonstrators NEST, move and ehub are a perfect framework to test and validate various strategies with a view to overcoming these challenges. They enable our researchers to combine numerous technologies in different configurations, and to convert energy easily from one form into another. The first results reveal considerable potential for increases in efficiency, a reduction of peak loads from a demand perspective and a general reduction of our CO_2 emissions. //

New technologies to improve our health

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The steadily growing knowledge in medicine opens up new approaches, and thus the demand for innovative technologies in the health care sector for our growing and aging society is rising. In the Research Focus Area "Health and Performance", Empa develops materials-based innovations that protect and support the human body. A profound understanding of the interactions between material surfaces and biological cells and tissues is crucial for these developments. In order to develop personalized systems with improved properties and performance, Empa researchers pool expertise from various fields such as materials science and processing, computer-aided modeling and the life sciences.

Predicting bone strength

The increasing number of broken bones poses a major challenge for health systems all over the world. Especially hip fractures, which cause restricted mobility, show an increased mortality rate. Bone strength depends on the density of the bone minerals and on tissue quality. In order to identify a change in tissue quality with increasing age and in cases of disease, Empa researchers combine different analysis methods and sources of information. In an interdisciplinary study, Empa teamed up with the Institute for Surgical Technology at the University of Bern, the Orthopedics Department at the University Hospital Bern and ETH Zurich's proteomics platform "Personalized Health and Related Technologies" (PHRT). The aim of the study is to improve the personalized prediction of bone strength and the risk of fracture.

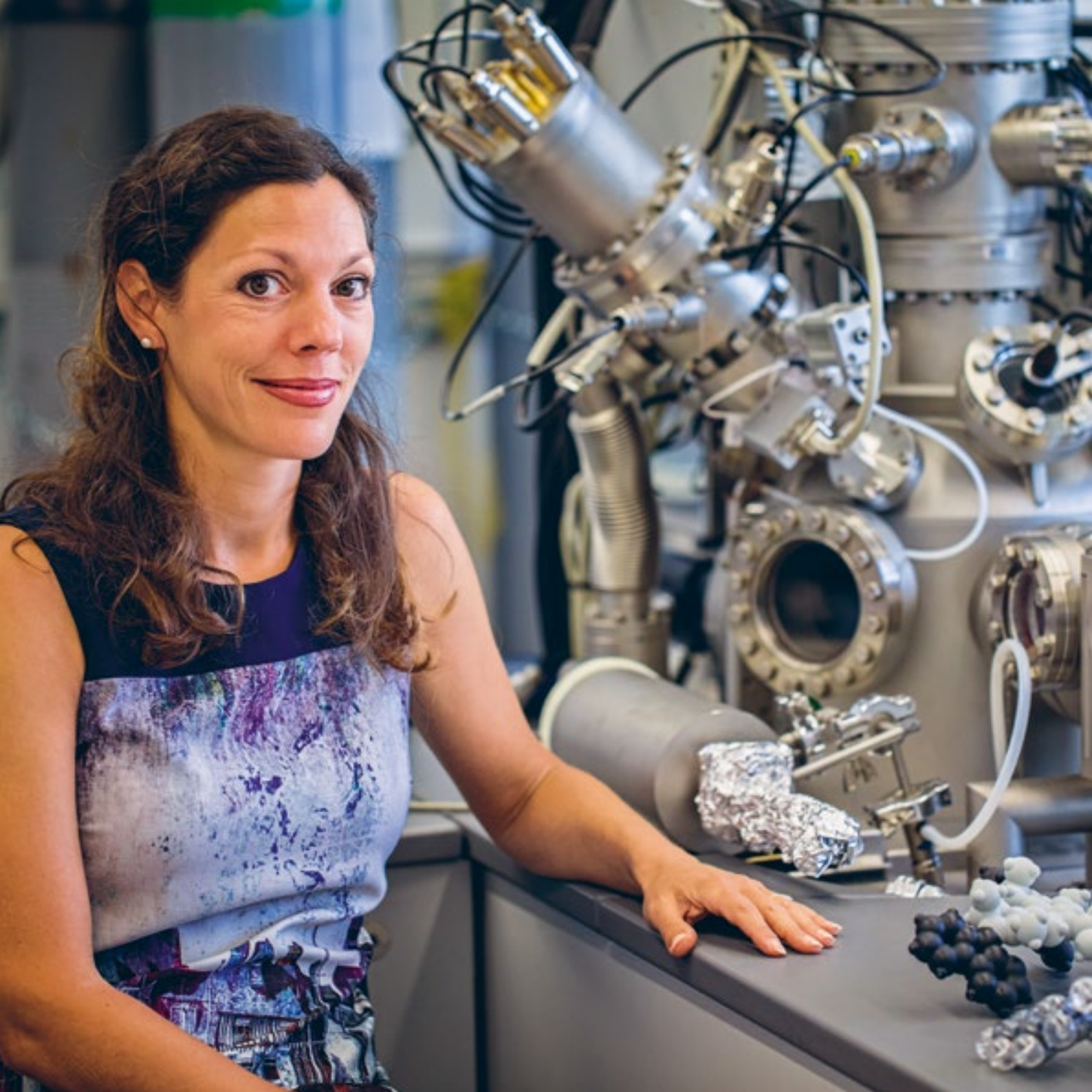
New approach to combat mineral deposits in soft tissue

Soft tissue calcifications, i.e., the formation of inorganic components based on calcium phosphate in fatty, muscle or connective tissue, are widespread and have been identified in a number of different diseases, including atherosclerosis and cancer. Until now, however, little research has been conducted into the composition of the minerals and their ultrastructure. In the project "Mineralomics", Empa is using state-of-the-art techniques to identify and characterize the ensemble of materials in clinical soft tissue samples. Together with partners at University College London and clinicians from the University Hospital Bern and St. Gallen Cantonal Hospital, the mineral deposits in both tumor biopsies and calcified heart valves are studied. This approach facilitates improved diagnoses and new approaches towards preventive and curative measures.

Monitoring wound healing more effectively

Chronic wounds affect 1–2 percent of the population and account for around 2–4 percent of health care costs. At the same time, severe acute injuries are the most common cause of death of industrial countries. Currently, the treatment of such wounds is based on visible signs and symptoms, and heavily depends on the physician's experience. Within the scope of the project WoundSense, Empa researchers are realizing a noninvasive multisensing platform to monitor metabolites in wound secretions with a view to observing the wound healing process more effectively. //

More than 330 researchers at Empa work in the area of medtech.



From Research to Innovation

Top-flight research and a proximity to industry – the two poles between which Empa operates. The institute is able to offer its partners tailored solutions thanks to efficient and individual forms of collaboration and a broad spectrum of services. Whether it be with a view to developing new products and applications, optimizing technologies, solving concrete problems or bringing technical specialists up to the state of the art – with more than 550 highly qualified scientists and top-class infrastructure, Empa is the place to be.

Innovation through cooperation and the transfer of knowledge and technology

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As a small country, it is crucial for Switzerland to preserve and hone its strong innovation culture so that the economic hub can assert its role as a global innovation champion. As one of Switzerland's innovation engine, Empa therefore sets great store by collaborating as closely as possible with partners from industry and academia. Together with its partners, Empa conducts interdisciplinary and competent research on pressing issues geared towards a sustainable future, and promotes and supports the transfer of knowledge and new technologies to industry.

In 2018 Empa launched more than 200 new research projects with partners from industry, a rise of 18 percent on the previous year. Moreover, Empa filed patent applications for 14 new inventions and concluded 16 new licensing and technology transfer agreements with industrial partners.

"Memory steel" for old buildings

Until now, conventional prestressing steel in concrete structures has been prestressed hydraulically. However, the large amount of space required for the necessary apparatus prevented the use of retroactive prestressed reinforcement in old buildings. After many years of research, experts from Empa and the start-up refer readied an alternative method for series production: iron-based shape memory alloys which contract when heated up, thereby permanently prestressing the concrete structure. As it is sufficient to heat the steel briefly using electric current or infrared rays, hydraulic prestressing is no longer necessary. The new building material, which has already been used in several pilot projects, is produced by the company Voestalpine Böhler Edelstahl and sold by refer (see also page 14).

Getting rid of sweat at the push of a button

Winter sports require functional clothing which keeps the body warm and conducts the sweat away. The majority of conventional materials fail to meet both criteria in equal measure. The electro-osmotic membrane developed by the Swiss company Osmotex was the springboard for the development of the hydrobot technology: a membrane comprising billions of pores per square meter surrounded by an electrically conductive fabric. By applying a small electrical voltage, the pores turn into micropumps that conduct moisture away quickly and efficiently. In an Innosuisse-funded project, Empa researchers prepared the technolo-

1
Two functional membranes integrated in the back of the ski jacket actively transport the sweat outside. Hot fun in the cold: during winter sports, the body produces a lot of moisture. Nevertheless, novel functional clothing guarantees a pleasantly warm and dry microclimate. (Photo: Kjus)

2
Reinforcing rods made of an iron-based shape memory alloy called "memory steel" pull together when heated, permanently prestressing the concrete structure as a result. This means that hydraulic prestressing is no longer necessary.

1

gy for the market with the industrial partners Kjus, Schoeller and Oxyphen. The first ski jacket featuring hydro bot technology was presented by Swiss sportswear manufacturer Kjus in November 2018. An integrated control system and smartphone app allows the jacket to be switched on and off. By actively transporting moisture away, this functional clothing creates a dry microclimate for the wearer, and the desired insulating effect is maintained.

Polyamide textiles with flame retardants

Polyamide 6 (PA6) is one of the most used polyamides, such as for industrial, sports or leisure textiles. One major drawback is its high flammability and the fact that large quantities of toxic gases are released when it burns. Existing PA6 products with flame retardants are few and far between because they contain toxic halogens or their mechanical properties (e.g. solidity) are affected by the flame-retardant additive. After a successful preliminary project backed by Innosuisse, Empa researchers teamed up with the company Litrax to ready a new flame-retardant additive called L11 for the market. L11, for which a patent application was filed, is halogen-free, can be processed into granules for fiber production via melt extrusion with PA6, and shows outstanding flame-retardant properties without compromising the good mechanical properties of the fibers. The approval procedure is currently in progress under the EU chemicals regulation REACH and due for completion this or next year. Then nothing else stands in the way of marketing the flame-retardant polyamide fibers. //

Innovative diversity – Empa's business incubators

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Last year, Empa's two business incubators supported 55 start-ups with a total of 286 employees from the initial business idea to market entry.

Innovation award for biological plant and wood protection

MycoSolutions, an Empa spin-off based in St. Gallen, develops fungal solutions for biological plant and wood protection. Trichoderma species are selected in the lab and, depending on the customer requirements, either produced as a tailor-made product or delivered from stock – a totally biological way to keep harmful microorganisms at bay. In various projects in Italy, Switzerland, Germany and Austria, the growth of trees and plants was improved significantly as a result. In September, MycoSolutions won the Empa Innovation Award 2018 for a product that is capable of reducing wood-destroying fungi in the soil and considerably prolonging the service life of chromic or chrome-free, impregnated wooden masts. In collaboration with Swisscom AG, an antagonist was selected and a method was developed for biological control against copper-tolerant fungi. At Deutsche Telekom alone, the annual damage caused by early failures amounts to around 25 to 30 million Euro. The product is already in use at Swisscom, BKW and other electricity utilities.

Software platform for planning sustainable energy systems

Sympheny is an Empa spin-off which focuses on software-based support for the planning of sustainable energy systems for neighborhoods, districts and municipalities. The goal is to help energy system planners to quickly, comprehensively and effectively navigate through the range of available technological options and to identify a set of optimal design solutions tailored to the specific constraints and objectives of a given site and customer. The innovative software platform was developed over the last four years as part of the Urban Energy Systems Laboratory at Empa, the Chair of Building Physics at ETH Zurich and the Swiss Competence Center for Energy Research (SCCER Future Energy Efficient Buildings & Districts). //

In his research so far, Francis Schwarze (third from left), founder of the Empa spin-off MycoSolutions AG, devised new screening methods to evaluate and select helper organisms, which he has already used successfully. He and the company won the Empa Innovation Award for this successful transfer from research to industrial innovation.

Empa Zukunftsfonds – Research for tomorrow's world

Gabriele Dobenecker, gabriele.dobenecker@empa.ch

For almost 140 years, Empa has been one of the most important centers for scientific and technological research in Switzerland. Bridging the gap between research and practice, our scientists, engineers and technicians find solutions to the main challenges that industry and society face – be it the creation of a sustainable energy supply or the provision of innovative and sustainable technologies for the protection of our health. Empa has set itself the task of uncovering and developing paths towards a future that is worth living in for generations to come. To achieve this, our researchers have to push the boundaries of science and technology and constantly venture into new territory. We launched the Empa Zukunftsfonds precisely for this purpose. Thanks to funding from the Zukunftsfonds, we are already able to research tomorrow's world today and play our part in solving the pressing issues of our society.

The Zukunftsfonds supports research projects and promising research talents that do not (yet) receive any funding: pioneering ideas that, once realized, may make a major contribution towards a more sustainable world. The Zukunftsfonds awards funds donated by companies, foundations and private individuals for a good cause. With these and its own funding, Empa has already kick-started a large number of ambitious projects.

Targeted sepsis treatment

Sepsis is a life-threatening infection that has spiraled out of control and affects up to 15,000 people a year in Switzerland; one in every three cases is fatal. Treatment of septic patients is difficult because the microorganism that triggers the infection is often difficult to detect. Therapeutic measures therefore often include broad-spectrum antibiotics, the excessive use of which is one reason for increasingly frequent resistance. Backed by the Novartis Foundation, the project is investigating a new possibility to treat sepsis. It involves using magnetic nanoparticles to directly "fish out" microbes circulating in the blood. This should one day enable pathogenic bacteria to be identified as quickly as possible and a suitable, targeted treatment with antibiotics to be administered.

New materials for new water filters

Every year, hundreds of millions of people fall ill after drinking polluted water; millions even die as a result. Although conventional filters can easily remove bacteria and small organisms from drinking water, these filters do not work for viruses, which are over 50 times smaller than bacteria. The project's goal is to develop new, specially coated materials which serve as a tissue to capture pathogenic viruses in the water filter. The project was made possible by a private donation.

Safe and cost-effective – the salt water battery

Water could form the basis for future, particularly inexpensive, safe batteries. In 2018 Empa researchers succeeded in doubling the electrochemical stability of water with a special saline solution – one step closer to using the technology commercially. The research all began back in 2015 as part of a project funded by the Empa Zukunftsfonds. In 2018 the project was a Swiss finalist at Falling Walls Lab, which takes place in Berlin every year. //

1

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1
Zeroing in on sepsis: bacteria can be removed with magnetic blood purification.

2
Water kiosk with membrane filtration in Uganda. (Photo: Eawag)

3
Research on the water electrolyte.

3

Global partnerships

Prof. Dr Gian-Luca Bona, gian-luca.bona@empa.ch

You can hear it everywhere: research is a global endeavor, also at Empa, of course. A recent analysis of Empa's research projects goes to show that this is not just hot air: according to the study, around 60 percent of all scientific publications by Empa researchers are published in collaboration with international partners. In the last five years, Empa has worked with partners from some 93 countries – virtually the whole world (however, around 60 percent of the partners come from the EU, and countries like USA, Japan, China and South Korea are also strongly overrepresented).

Strategic collaboration with notable partners

Within the scope of the Fraunhofer Society's strategic international cooperation program ICON (International Cooperation and Networking), Empa and the Fraunhofer Silicate Research Institute in Würzburg launched a three-year joint research project in early 2019, which should pave the way for a new generation of batteries for electric vehicles that are suitable for production – with industry on board and all the way to the first prototypes. Unlike today's conventional lithium ion cells, these should only consist of solid matter and no longer contain any flammable electrolyte liquid. With ICON the Fraunhofer Society is looking to expand on the strategic collaboration with international centers of excellence. So far, for instance, projects with the University of Cambridge and the Johns Hopkins University have been initiated; the project with Empa is the first ICON project with a partner from Switzerland.

At the new "Materials and Technology Center of Robotics" co-run by Empa and Imperial College London, everything revolves around autonomous drones. The goal of the new collaboration launched in December is to integrate functional materials in robot technology. The robots use the research building NEST as a flight arena, where they are involved autonomously in the building's upkeep as permanent residents, thus simplifying this process and making it more efficient.

Swiss-Swedish Innovation Initiative

On 25 September around 150 researchers and representatives from industry from Sweden and Switzerland convened at the Empa Academy within the scope of the Swiss-Swedish Innovation Initiative (SWII), the official partnership program to promote market-oriented research and development projects – this time on the topic of "Advanced Manufacturing"

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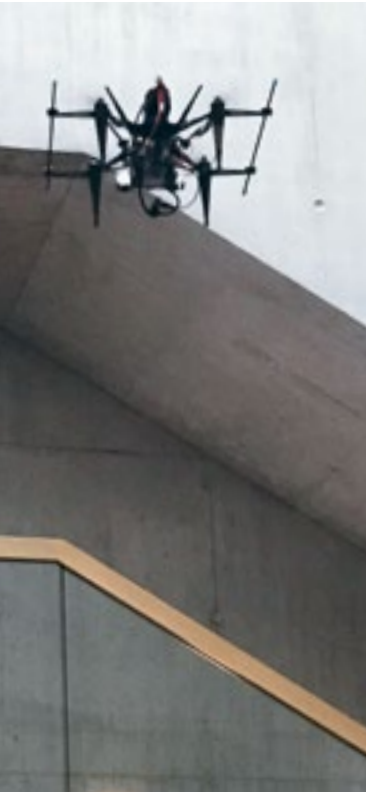

1
Robotics researcher Mirko Kovac is head of the new "Materials and Technology Center of Robotics" co-run by Empa and Imperial College London.

2
Swiss-Swedish Innovation Initiative meeting in the Empa Academy in September. Around 150 researchers and industry representatives from Sweden and Switzerland convened to exchange ideas on AM.

(AM). The goal of these regular networking events – which on this occasion was opened by Swedish Ambassador Magnus Hartog-Holm – is to bring together representatives of the most innovative companies from the two countries with a view to expanding bilateral research collaboration in various strategically important areas. Since October 2012 the SWII has already spawned 34 bilateral research and development projects with a total volume of around EUR 43 million.

Visitors from all over the world

Once again, numerous foreign delegations visited Empa and its research facilities in 2018. These included several groups from various German federal states, such as the Economics Ministers from Rhineland-Palatinate and Saxony, Volker Wissing and Martin Dulig; a delegation from Baden-Württemberg International (bw-i), the State of Baden-Württemberg's competence center for the internationalization of science and industry, with a view to exploring future collaborations with Empa in the field of future mobility; and a group from the Stiftung für Technologie, Innovation und Forschung (STIFT) in Thuringia. Likewise, an Indian delegation led by Ambassador Sibi George, and Peter Dröll, Director of Industrial Technologies in the European Commission's Directorate General for Research and Innovation, also paid a visit to Empa. Peter Dröll attended the Empa Technology and Innovation Forum (ETIF) in late September, the theme of which was "Sicherung des Produktionsstandorts Schweiz – Trumpfkarte Innovation (Securing Switzerland as a production hub – trump card innovation)". //

In dialog with politics and society

Dr Michael Hagmann, michael.hagmann@empa.ch

As a research institute, which is mostly financed with public funds – i.e. tax payers' money –, Empa is interested in a fruitful exchange with representatives from politics and society; after all, they are essentially Empa's "owners". We foster these encounters during the numerous visits Empa receives throughout the year and at events at the Empa Academy. Last year, Empa welcomed around 16,000 visitors – matching our record-breaking year 2017. These included numerous foreign delegations (see page 52) and, once again, no shortage of Swiss companies and industry associations, such as KMU-Frauen from the Canton of Zurich, and representatives of the cantonal and national administration, such as a delegation from the Federal Administrative Court of Switzerland. The countless events held all over Switzerland dedicated to topics such as research, innovation, sustainability and competitiveness presented another opportunity for Empa representatives to cultivate an exchange of ideas.

The Innovation Park in Dübendorf is taking shape

In early March the Innovation Park Zurich celebrated its first major milestone on its site at the Dübendorf airfield: on an open day, the pavilion was inaugurated as a meeting center and first element in the new park in the presence of Federal Councilor Guy Parmelin and Member of Zurich's Governing Council Carmen Walker Späh. Besides the topics of robotics and autonomous driving, other focus areas at the Innovation Park are aerospace, headed by the University of Zurich, and state-of-the-art production technologies ("Advanced Manufacturing"), with Empa at the helm.

Innovation also a topic at WEF

Around 40 representatives from Swiss politics took up the ETH Domain's invitation to the WSL Institute for Snow and Avalanche Research at the World Economic Forum (WEF) in Davos. The interested guests included Federal Councilor Guy Parmelin as the new Head of the Department of Economic Affairs, Education and Research (EAER) and thus the ETH Domain's top boss, and new State Secretary Martina Hirayama from the State Secretariat for Education, Research and Innovation (SERI). Empa's Board of Directors was represented by Gian-Luca Bona and Tanja Zimmermann; they presented to the enthralled audience astonishing innovations made of wood like "Swiss ebony", a sustainable Swiss alternative to endangered tropical timbers such as ebony, fireproof wood, and "marble wood" made of ordinary local wood types, which, following a course of "fungal therapy", can be transformed into beautiful furniture, design objects or musical instruments.

Research also pulls the media

Besides a fruitful direct exchange, Empa also communicates with its "stakeholders" indirectly, i.e. via the media. The large amount of relevant and exciting research results from Empa's labs was met with a major media response again in 2018. All in all, around 5,300 media outlets in 32 languages reported on Empa's research activities, including over 1,250 in print media and 56 TV reports – both new records. //

1

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1
Empa CEO Gian-Luca Bona (left), Member of the Innovation Park Zurich's Foundation Board, together with Member of the Council of States Ruedi Noser and Member of the Zurich Governing Council Carmen Walker Späh, delighted at the opening of the Innovation Park at Dübendorf airfield.

2
Empa CEO Gian-Luca Bona (right) talking to Federal Councilor Guy Parmelin, the new Head of the Department of Economic Affairs, Education and Research, at the World Economic Forum (WEF) in Davos. (Photo: Markus Mallaun)

3
Tanja Zimmermann, member of Empa's Board of Directors, showing off a violin made of Swiss ebony at the WEF. (Photo: Markus Mallaun)

3

Promoting equal opportunities and diversity

Marianne Senn, marianne.senn@empa.ch

In 2018 the ETH Board published its Gender Strategy 2017–2020, aimed at promoting gender balance and equal opportunities for women and men. In particular, the goal is to increase the proportion of women in teaching, research and managerial positions. In March, the Federal Government's "Reporting Human Resources Management" for 2017 was published, which also examined the developments in the ETH Domain over the last five years. For instance, the general proportion of women in the ETH Domain has risen only marginally to 34 percent since 2013, compared to management level, where it increased from 17 to 20 percent. At Empa, the general proportion of women is 28 percent (down 1 percent compared to 2013), whereas at management level it has remained stable at 16 percent.

Promoting (budding) scientists

Empa has continued its involvement in programs which specifically promote young female researchers. For example, Empa supports the Equal Opportunities Group program "Fix the leaky pipeline", which counters the decrease in women in science beyond doctorate and postdoc level. Some PhD students and postdocs at Empa attended the courses and coaching

The fact that Empa is not just a place for top-flight science, but also ranks among one of the top teaching centers in Switzerland was recently confirmed by the consulting company "Great Place to Work". With around 1,000 employees, it offers over 40 apprentices in ten vocations an exceptional and exciting research environment with a modern educational concept. (Photo: Marc Weiler)

groups. In the newly launched mentoring program, however, the cooperation between mentees and mentors bore little fruit. In parallel, the preparation of the Equal Opportunities Group's program CONNECT is well underway. It aims to bring together female scientists and young women in managerial positions from industry and administration to help them find their way into these fields.

The series of "women in science" events organized by Empa and Eawag address all female scientists from both research institutes. Two events took place in 2018: management consultant Silvie Klein-Franke outlined the success factors for women looking to take on these managerial positions. Another event was devoted to the topic of start-ups. Three women in different functions formed the event: Cornelia Gut, Managing Director of the Startfeld Foundation, the network for innovation and start-ups in the St.Gallen-Bodensee region; neo-entrepreneur Kristin Schirmer, who as an Eawag researcher founded the start-up aQuatox Solutions GmbH; and Andrea Kennel, President of SVIN (Schweizerische Vereinigung der Ingenieurinnen) and head of the company Infopunkt Kennel GmbH. They presented a multifaceted and inspiring image of the female start-up community in Switzerland.

Science for young people

Promoting young female researchers and apprenticeships was also one of the focuses at National Future Day. Around half of the girls who attended gained an insight into the various vocations at Empa via the program "Girls-Technology-Go". Leaving the gender issue to one side, once again the Summer Camp was held for our little ones in 2018. Its aim is for some of the parents at Empa to rest assured that their children are doing something constructive for one week during the vacation period. The Summer Camp also gives the children their first insight into their parents' world of work.

Diversity

The diversity at Empa is reflected in the origins of the staff: in 2017 just under 60 percent came from Switzerland and a little over 40 percent from abroad (from more than 50 countries in all). However, it is also reflected in the fact that numerous technical and administrative employees also work here alongside the academic staff. And besides students, Empa also trains more than 40 apprentices in ten vocations. //

Major renovation – major impact

Marcel Gauch, marcel.gauch@empa.ch

The optimization of the building stock on the Dübendorf campus and the progress on the construction of the medium temperature network are going well; soon it will be possible to exchange energy between producers and consumers at different temperature levels. The network connects the entire Empa and Eawag campus in Dübendorf and, combined with the building optimizations, will curb the demand for fossil energy sources significantly. Comprehensive plans for the temporary storage of heat for use in the cold months will reduce the need for natural gas further and help slash CO_2 emissions. The inspiration for the renovation of the entire site was Energy Hub (ehub), which connects the research building NEST with the energy demonstrator move and is able to distribute energy intelligently thanks to a clever line and control concept. In other words, for once Empa research was purely for its own benefit.

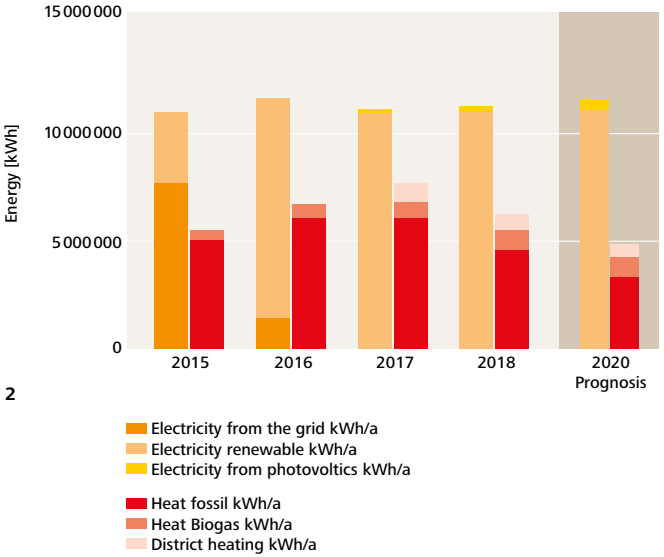
Gaging employee mobility

For the first time, a comprehensive survey on commuter behavior was conducted among Empa staff at all three locations. Thanks to a response rate of 52 percent, it produced representative and interesting results: the average length of the one-way trip to work throughout Empa is around 24 kilometers. Staff at the Thun campus have the longest commute (around 34 kilometers), followed by those in St. Gallen (27.5 kilometers). The average commute among staff at the Dübendorf is around 22 kilometers. In total, Empa's staff notch up around 10 million kilometers per year traveling to and from work, 62 percent of which on public transport, 28 percent using their own motorized vehicles and 10 percent on foot or by bike. The comparison with the number of kilometers traveled for business is interesting: it is only half as high as commuter traffic as the proportion of flights taken by Empa staff amounts to around 4 million kilometers year.

Energy consumption in trend

The total electricity requirement was maintained at the previous year's level, with 100 percent of the electricity coming from renewable sources. The share of self-produced solar power was almost doubled. The ongoing conversion measures are having a positive impact on heating requirements: as a result of the lower energy requirements due to modernization and renovation work, significantly less natural gas had to be purchased; an increased proportion of biogas makes a significant contribution to improving the CO_2 balance. //

1



1
The Energy Hub connects the research building NEST with the energy demonstrator move; comprehensive data acquisition enables research to improve the overall energy efficiency.

2
Trend in Empa's energy consumption: since 2018 the entire electricity supply has come from renewable sources; the yield from Empa's own photovoltaic plants increased.

Facts and Figures

Researchers like measuring, including their own performance: in 2018, Empa researchers and engineers published 700 academic papers and filed patent applications for 14 developments. At the end of the year, 122 projects funded by the Swiss National Science Foundation (SNSF), 95 projects backed by Innosuisse and almost 70 EU projects were underway at Empa. Together with other start-ups in Empa's two business incubators, the 26 spin-offs employed a total of 784 people.

Since 2015, as at all institutions in the ETH Domain, Empa's annual financial statement has been compiled 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

Empa's risk management is aimed at recognizing and analyzing potential risks to the company and its staff, taking measures and testing their benefits. This system helps establish a safety culture that's more aware and thus constantly improve the safety situation at Empa.

Principles of tackling risks

Empa based its rules in this field on the risk management regulations of the ETH Domain and the federal government. Its security and risk policy officially stipulates the homogeneous, systematic and consistent handling of the various risks. All measures prioritize the protection of Empa's staff, visitors and anyone else in the institute's sphere of influence. Other goals include protecting the environment from negative effects, safeguarding intellectual property and the know-how acquired, as well as protecting Empa's reputation. The main focus of these efforts is prevention.

Empa's risk management policy is implemented according to a standardized process, which begins with a periodical risk review. Every risk is assessed according to its potential impact and likelihood of occurrence, and evaluated in the dimensions "financial risk" and "risk to reputation". Finally, measures are defined and implemented to contain the risk. In risk controlling, the risk management process is verified regularly and – if need be – modified.

Refining the safety organization

The reinforcement of the staff in the risk management organization bore its first fruit in 2018. Despite the ongoing increase in numbers, safety-related queries could still be processed within a useful timescale. Diverse projects were concluded and new ones initiated.

The most complex project was to finalize, implement and launch professional video surveillance on the Dübendorf campus. Well-founded legal supervision and the involvement of staff representatives ensure that an acceptable solution for the staff was found and implemented in accordance with the protection of personal rights. The evacuation system was also honed in the course of the year. In addition to the existing system, a relevant software component was evaluated and tested, which considerably increases the reachability of people working on the computer, improves the efficacy of the alarm system and reduces the response time. This will open up the possibility for us to convey information to all PC users simultaneously in an incident from 2019. Moreover, steps were taken to make the fire and chemical emergency team more professional. This will be achieved by holding courses, intensifying drills and investing in equipment and infrastructure.

In 2018 Empa's Risk Management was audited extensively by the ETH Board's Internal Audit team. The areas of Governance, Risk Management, Compliance, Concepts, Processes and Controls were inspected. According to the results, Empa boasts a very well organized and dedicated safety organization and overall a very high safety level.

There were clear improvements in raising the staff's awareness of safety issues. This is evident in the considerable increase in the number of queries on safety-relevant topics such as drone flights on the campus and in buildings, explosion protection, chemical reaction safety or inspections for building a test route for ETH Zurich's award-winning Swissloop project on the Empa campus. In the building sector, risk management is now integrated more effectively in project planning and also included in the assessment of natural hazards or building site safety, for instance. A lot of effort was also necessary to pave the way for a new, flexible lab building project.

Due to social and technical developments, the topic of information security is gaining in importance. The awareness that this goes way beyond the normal work for an ICT department and that every single employee's way of working and handling information is crucial has not yet been anchored sufficiently. This issue is set to become even more topical and extensive, and Risk Management will tackle it intensively in the near future. //

Human resources development

(previous year's figures in brackets)

André Schmid, andre.schmid@empa.ch

At the end of 2018, 994 (966) people were employed at Empa (incl. trainees). Due to the large number of part-time options, this corresponds to a full-time equivalent (FTE) of 928.6 (895.4) positions. New arrivals can primarily be found among doctoral students (+18) and postdocs (+ 8).

There are 558 (530) members of academic staff, including 108 (116) senior scientists. 396 (392) people were technical and administrative employees in the reporting year. The proportion of women of 28.9 (28.1)percent reflects the graduate figures of the universities and ETH Zurich in the faculties where Empa is represented.

436 (399) members of staff are from abroad, which corresponds to around 43.9 (41.3) percent of the total head count. 281 (262) people hail from EU countries, i.e. 64.4 (65.7) percent of all foreign members of staff. Empa offers a wide range of traineeships and employs 40 (44) trainees. Once again, all the trainees passed their final examinations in 2018. //

STAFF END OF 2018

	2017	2018
Scientific staff	**530**	**558**
Technical and administrative staff	**392**	**396**
apprentices	44	40
Total	**966**	**994**

Key figures

SCIENTIFIC OUTPUT

	2017	2018
ISI publications	695	700
Conference contributions	1,328	1,372
Doctoral studies completed	33	45
Doctoral studies in progress	177	191
Teaching activities (in hours)	3,987	4,423
Prizes and awards	65	81

MEDIA EXPOSURE

	2017	2018
Radio	103	72
TV	54	56
Print	1,200	1,250
Online	4,850	3,850
Total	6,205	5,250
Languages	34	32

EMPA ACADEMY

	2017	2018
Empa events	55	96
Participants	3,400	5,931
Scientific conferences	10	17
Events for industry	36	24

KNOWLEDGE DISSEMINATION & TECHNOLOGY TRANSFER

	2017	2018
New R&D Agreements	175	208
Active exploitation contracts	68	68
New exploitation contracs	13	16
New patent applications	14	14

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

	2017	2018
Companies total	**72**	**94**
thereof spin-offs	24	26
Employees total	**580**	**784**
thereof employees of spin-offs	118	131

CURRENT PROJECTS

	2017	2018
Swiss National Science Foundation (SNSF)	120	122
Commission for Technology and Innovation (CTI)/Innosuisse	103	95
EU projects	69	69

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
Fritz Schiesser Dr iur., Haslen GL

VICE-CHAIRWOMAN
Beth Krasna Dipl. Ing. ETH, independent supervisory board member

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Kristin Becker van Slooten Dr, EPF Lausanne
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Barbara Haering Dr Dr h. c., Econcept AG, Zurich
Christiane Leister, Leister AG, Kägiswil
Joël Mesot Prof. Dr, ETH Zurich
Martin Vetterli Prof. Dr, EPF Lausanne

Industrial Advisory Board

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

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Henning Fuhrmann Dr, Siemens, Zug

MEMBERS
Kurt Baltensperger Dr, ETH Board, Zurich
Burkhard Böckem Dr, Hexagon, Heerbrugg
Robert Frigg Prof. Dr mult. h. c., 41 medical, Bettlach
Andreas Hafner Dr, BASF, Basel
Markus Hofer Dr, Bühler, Uzwil
Urs Mäder Dr, SATW, Zurich
Andreas Schreiner Dr, Novartis, Basel

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.

MEMBERS
Urs T. Dürig Dr, SwissLitho AG, Zurich
Rik Eggen Prof. Dr, Eawag, Dübendorf
Thomas Egli Prof. em. Dr, Feldmeilen
Marcus Textor Prof. Dr, ETH Zurich
Alexander Wokaun Prof. em. Dr, Endingen

Organizational chart

as of April 2019

RESEARCH FOCUS AREAS
(Research priorities)

Nanostructured Materials
Dr Pierangelo Gröning

Sustainable Built Environment
Dr Tanja Zimmermann
Prof. Dr Giovanni Terrasi

Health and Performance
Prof. Dr Alex Dommann

Natural Resources and Pollutants
Dr Brigitte Buchmann

Energy
Dr Peter Richner
Urs Elber

BOARD OF DIRECTORS

Director	Deputy	Members of the Board
Prof. Dr Gian-Luca Bona	Dr Peter Richner	Dr Brigitte Buchmann, Prof. Dr Alex Dommann, Dr Pierangelo Gröning, Dr Urs Leemann, Dr Tanja Zimmermann

DEPARTMENTS

Advanced Materials and Surfaces
Dr Pierangelo Gröning

Electron Microscopy Center
Dr Rolf Erni

Engineering Sciences
Dr Peter Richner

Center for Synergetic Structures
Dr Cédric Gallio

Materials Meet Life
Prof. Dr Alex Dommann

Center for X-ray Analytics
Prof. Dr Antonia Neels

Electronics & Reliability Center
Prof. Dr Alex Dommann

LABORATORIES

Joining Technologies and Corrosion
Dr Lars Jeurgens

Advanced Materials Processing
Prof. Dr Patrik Hoffmann

nanotech@surfaces
Prof. Dr Roman Fasel

Mechanics of Materials and Nanostructures
Dr Johann Michler

Thin Films and Photovoltaics
Prof. Dr Ayodhya N. Tiwari

Functional Polymers
Prof. Dr Frank Nüesch

Structural Engineering
Prof. Dr Masoud Motavalli

Mechanical Systems Engineering
Prof. Dr Giovanni Terrasi

Multiscale Studies in Building Physics
Viktor Dorer

Experimental Continuum Mechanics
Prof. Dr Edoardo Mazza

Urban Energy Systems
Dr Kristina Orehounig

Nanoscale Materials Science
Prof. Dr Hans Josef Hug

Biomimetic Membranes and Textiles
Prof. Dr René Rossi

Particles-Biology Interactions
Dr Peter Wick

Biointerfaces
Prof. Dr Katharina Maniura

Transport at Nanoscale Interfaces
Prof. Dr Michel Calame

RESEARCH, KNOWLEDGE AND TECHNOLOGY TRANSFER PLATFORMS

NEST/dhub
Reto Largo

move
Dr Brigitte Buchmann

ehub
Philipp Heer

Coating Competence Center
Dr Lars Sommerhäuser

Empa Academy
Claudia Gonzalez

Business Incubators
glaTec
Mario Jenni
STARTFELD
Peter Frischknecht

International Research Cooperations
Prof. Dr Gian-Luca Bona

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Dr Brigitte Buchmann

Materials for Energy Conversion
Dr Corsin Battaglia

Advanced Analytical Technologies
PD Dr Davide Bleiner

Air Pollution / Environmental Technology
Dr Lukas Emmenegger

Automotive Powertrain Technologies
Christian Bach

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

Technology and Society
Dr Patrick Wäger

Acoustics / Noise Control
Kurt Eggenschwiler

Functional Materials

Dr Tanja Zimmermann

Materials and Technology Center of Robotics
Dr Mirko Kovac

High Performance Ceramics
Prof. Dr Thomas Graule

Road Engineering / Sealing Components
Dr Peter Richner a.i.

Cellulose & Wood Materials
Dr Gustav Nyström

Concrete / Construction Chemistry
Prof. Dr Pietro Lura

Building Energy Materials and Components
Dr Matthias Koebel

Advanced Fibers
Prof. Dr Manfred Heuberger

Corporate Services

Dr Urs Leemann

Library (Lib4RI)
Dr Lothar Nunnenmacher

Fundrising / Entrepreneurship / Industry Relations
Gabriele Dobenecker

ICT-Services
Stephan Koch

Mechanical Engineering / Workshop
Stefan Hösli

Finances / Controlling / Purchasing
Heidi Leutwyler

Communication
Dr Michael Hagmann

Human Resources
André Schmid

Knowledge and Technology Transfer / Legal
Marlen Müller

Real Estate Management
Hannes Pichler

Empa – The Place where Innovation Starts

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