Annual Report 2016

Empa

Materials Science and Technology

Our Vision.

Materials and Technologies
for a Sustainable Future.

Cover photo: X-ray diffractometer for materials analysis.
This enables the crystal structures of materials to be determined and phase transformations observed *in situ* using temperature gradients at the Center for X-Ray Analytics. Photo: Adrian Moser

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Materials in a digitalized world

Last year, two talks at Empa in particular got me thinking about societal and technological developments. Firstly, Gerd Folkers, President of the Swiss Science and Innovation Council, pointed out that the number of researchers and their currency, the number of publications, has multiplied in recent years and that, in many areas, research has moved away from purely fundamental questions and towards economically exploitable knowledge. What does this mean for our scientists? They should always focus on the goal of any research: to push the boundaries of knowledge. They will only succeed if they are given enough leeway for creative thinking and analysis, and if they do not allow themselves to be seduced, by the globalized competition, into sprucing up their résumés with "hyped-up" publications.

Then there was Alessandro Curioni, Director of the IBM Research Center in Rüschlikon, who showcased the latest developments in cognitive computing, i.e., computer systems that, like our brains, are capable of gathering, evaluating and learning from unstructured data, and of supplying it in a summarized or even processed form. For instance, it is possible to develop new alloys that can be optimized by combining different classes of materials. However, this also carries the danger of computers rendering humans (and researchers) obsolete for certain tasks as they are simply capable to performing these much more effectively.

It is particularly interesting to combine the messages of both presentations. The human brain is no longer able to process the enormous amount of data generated in today's research (hundreds of thousands of papers are published every year in materials science alone). A computer modelled on human thought patterns can help researchers in this respect and thus give them the freedom to venture into unchartered territory and get creative with their ideas as opposed to merely publishing raw data that will sell well as the research topic is currently "hot".

Cognitive computing, however, is just one part of the rapidly accelerating digitalization that is also in full swing at Empa. We are investing more and more in computer simulations and in the modelling of scientific questions. At the Coating Competence Center (CCC) and the Center for Advanced Manufacturing (CAM), where new materials are produced for additive manufacturing, the future of the manufacturing process is virtually being anticipated – and it is largely digital, whether it be in the planning phase, in product design, quality assurance or in optimizing the distribution channels. Moreover, we are working on linking up our two demonstrators, NEST and move, with a third one, ehub (short for Energy Hub), in terms of energy and in order to control them in a smart way.

All of Empa's research platforms – NEST, move, ehub, CCC and CAM – are open for projects in the field of the Internet of Things (IoT) and Industry 4.0. Together with our partners from industry and research, we would like to create an ecosystem for open innovation. The technological transformation that has been markedly accelerated by digitalization affects us all, which is why we need to shape and steer it together – so Switzerland can benefit from it in the best possible way.

Prof. Dr Gian-Luca Bona, *Director*

01

Fire-proof concrete

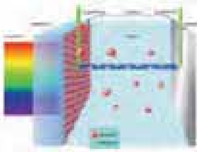
Empa scientists developed a method for manufacturing fire-resistant, self-compacting high-performance concrete which, thanks to polymer fibers, remains stable for a long time, even in fires. In a fire, the fibers melt, leaving a network of channels throughout the concrete, which enables the water vapor to escape. The internal pressure drops and the concrete element remains intact.

Honor for environmental researcher

Thomson Reuters included Empa researcher Bernd Nowack in its list of "Highly Cited Researchers" of 2015. Nowack is one of 132 environment/ecology researchers worldwide to have been honored in this way.

02

Generating electricity from artificial photosynthesis



When it comes to obtaining clean energy from a fuel cell, how water was split into its components, hydrogen and oxygen, is critical. Empa and the University of Basel are co-developing a method where sunlight can be used directly for this purpose.

Page 12

Cleaner jet engines

Empa teamed up with SR Technics and the Federal Office of Civil Aviation (FOCA) to develop a method for measuring fine particulate matter emissions from jet engines – and set international benchmarks. Thanks to this project, the Committee on Aviation Environmental Protection of the International Civil Aviation Organization (ICAO) recently approved a preliminary standard governing the emission of fine particulates by jet engines.

Page 15

03

EU project "TREASORES" completed

A European research team headed by Empa developed flexible luminescent modules that can be printed roll-to-roll, much like a newspaper. The technique paves the way for cost-effective solar cells and LED lighting panels of the future.

Page 18

More space for STARTFELD

The development platform has taken a decisive step forward with the inauguration of an innovation center next door to Empa in St. Gallen. The center is supposed to act as a crystallization nucleus for innovative young companies and SMEs in Eastern Switzerland.

04

Coating Competence Center opens its doors

At Empa's new Coating Competence Center, tailor-made surface technologies find their way from the research labs to marketable industrial applications. The center boasts diverse coating systems

for hard coats, flexible photovoltaics and organic electronics, not to mention 3D printers for metallic and bio-composite materials.

Page 48

Miraculous asphalt cure

A team of researchers from Empa devised a technique that can repair cracked asphalt virtually "by itself". They drew their inspiration from a method used in cancer treatment based on nanoparticles.

05

Building of the future opens its doors

On 23 May 2016 the modular experimental building NEST was inaugurated on the Empa and Eawag campus in the presence of Federal Councilor Schneider-Ammann. Its official goal: to accelerate the innovation process in the building and energy sector by enabling research, industry and the public sector to co-develop sustainable technologies, materials and systems, and test them under real-world conditions.

Page 42

How nanoparticles flow through the environment

Carbon nanotubes remain attached to materials for years while titanium dioxide and nanozinc are rapidly washed out of cosmetics and accumulate in the ground. This is the result of a new model developed by a team of researchers headed by Empa within the scope of the National Research Program "Opportunities and Risks of Nanomaterials" (NRP 64) that tracks the flow of the most important nanomaterials in the environment.

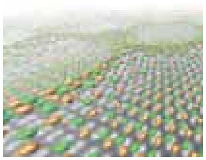
06

Tera incognita

Although terahertz radiation is as harmless as a lukewarm cup of tea, it can penetrate textiles and come into contact with the surface of the skin. Empa researchers aim to use this technique to research, among other things, why babies, sweaty hikers and bedridden senior citizens suffer from chafing.

Water droplets on surfaces

An international team of researchers involving Empa has developed a system that enables them to switch back and forth electrically between the adhesion and stiction (static friction) of a water droplet on a solid surface. The new system is interesting for biological applications, for instance.



07

Collaboration with Korea

The Korea Research Institute of Standards and Science (KRISS) opened an office in St. Gallen, thereby intensifying its collaboration with Empa in the field of nanosafety research.

New nanosafety journal

Empa researcher Bernd Nowack is one of the editors-in-chief of the scientific journal NanoImpact, the first journal to focus solely on nanosafety research, which was launched in May. It aims to cover and bring together the whole gamut of this multidisciplinary research field.
Page 92

08

4,000 visitors at Empa

For 20 years, Empa has been developing materials and technologies for the future at the modern building in Moos, St. Gallen – reason enough to celebrate and open its doors to the public. Nearly 4,000 people accepted the invitation and were shown the research conducted at Empa on three research paths.

Hydrogen-powered road sweeper

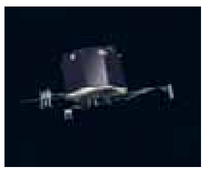
A hydrogen-powered road sweeper has been cleaning the streets of Dübendorf since August. The vehicle developed by Empa in collaboration with the Paul Scherrer Institute and road sweeper manufacturer Bucher Municipal is being tested in practice by the City of Dübendorf for a period of two years. The vehicle is refueled at Empa, where hydrogen is produced from renewable electricity.

09

Single crystal measures radioactivity

A research team at Empa and ETH Zurich has developed single crystals made of lead halide perovskites which are able to gauge radioactive radiation with high precision. The discovery could slash the price of many radio-detectors, which are used in scanners in the security sector, portable dosimeters in power stations and measuring devices in medical diagnostics, for instance.
Page 28

Rosetta mission touches down



After twelve years, Rosetta's mission came to an end. The space probe, which also had analysis equipment developed by Empa on board, reached its final resting place on its target comet Tschuri. The verdict: the mission of Rosetta and its lander Philae, the first probe to touch down on a comet, was a roaring success.

10

700-bar hydrogen station

Empa boasts Switzerland's first hydrogen station for passenger cars. It is part of the mobility demonstrator "move" and used for various Empa project vehicles as well as for privately owned hydrogen cars.
Page 45

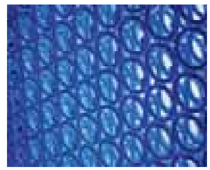
Peptides vs. superbugs

Various peptides have an antibacterial effect – but are broken down much too quickly in the human body. Empa researchers have now succeeded in prolonging their lifespan by encasing them in a kind of protective coat – a major breakthrough as peptides are considered to be a potential solution in the fight against antibiotic-resistant bacteria.
Page 31

11

Switching off vibrations

The structures of a phononic crystal designed on the computer can swallow vibrations with particular frequencies. The revolutionary insulating material can be produced on a 3D printer and may herald a new era of mechanical damping.
Page 34



Innovation Award for flame retardant

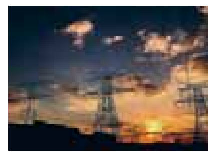
The Empa Innovation Award 2016 went to chemist Sabyasachi Gaan and his team. The researchers were recognized for the development of a new, non-toxic and environmentally friendly fireproofing agent for the production of flame retardant polyurethane foams, which can be used in mattresses, seat upholstery and insulation modules for house façades.

12

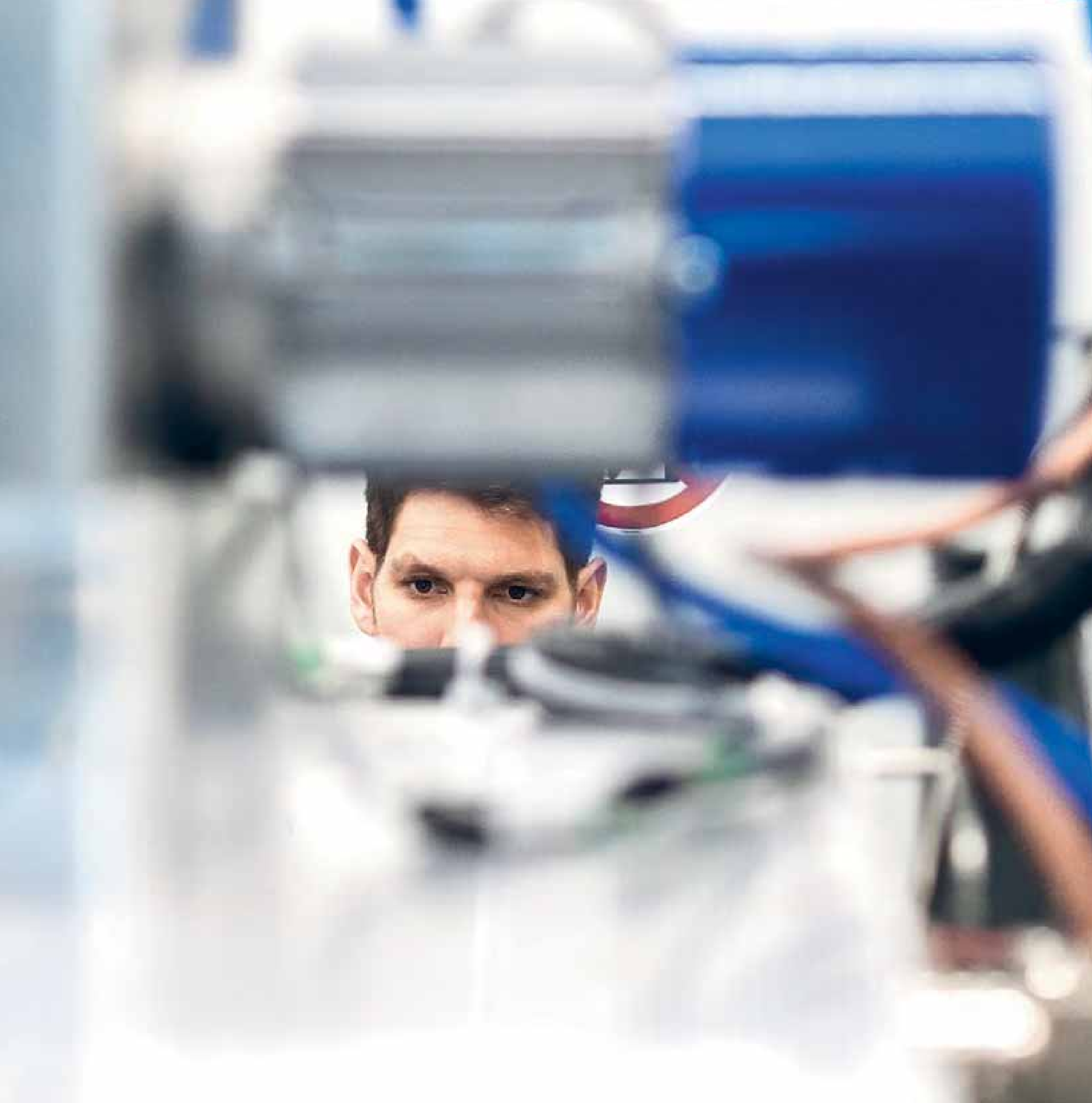
Magnets instead of antibiotics

A new treatment method for blood poisoning: Blood samples taken from patients is mixed with magnetic iron particles, which bind the bacteria to them. These are then removed from the blood using magnets. The initial laboratory tests at Empa in St. Gallen were promising.
Page 32

Fight against creeping cables



Switzerland's overhead power lines are showing signs of old age and can be damaged by power surges. But how long will they actually last? Empa researchers have developed a tool to keep tabs on the aging process. This could help to prevent power outages in future.
Page 70



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.

Clean energy from water and sunlight

Developing clean and renewable energy sources is one of the greatest challenges of our age. Scientists all over the globe are searching for alternatives to obtaining energy from fossil fuels. Artificial photosynthesis is pursued as one of the most promising approaches. It involves separating water (H_2O) into its components, hydrogen (H_2) and oxygen (O_2), with the aid of sunlight and storing it. When the two elements react in a fuel cell later on, electrical energy is generated.

Nature leads the way

Plants have been practicing photosynthesis since the dawn of time, which science uses as a natural role model. Scientists from Empa have also been developing ideas that mimic natural photosynthesis in collaboration with their partners at the universities in Basel, Lausanne, Zurich and abroad. The simplest approach involves using solar power to separate water into hydrogen and oxygen electrolytically. Harvesting sunlight with solar cells and electrolyzing water are processes that, in principle, (can) take place separately. At microscopic level, however, they can also be combined, which is referred to as "direct conversion". If the greenhouse gas CO_2 is included in this direct conversion, hydrocarbons can be produced, which completes the entire photosynthetic cycle. The technical implementation takes place in so-called photo-electrochemical cells (PEC cells), one of which Empa already showcased back in 2011. It can be imagined as a jar of water containing a photoelectrode and a counter electrode. In principle, this integrated system is more cost-effective than combining solar cells with an electrolyzer.

On the path towards their theoretical 40-percent efficiency, PEC cells have just achieved an efficiency level of over seven percent. 15 percent is regarded as a realistic short-term target. Key factors in their optimization are the precise arrangement of the individual components and particularly efficient and stable photoactive materials. Research is especially being conducted on materials for the photoelectrodes that harvest the sunlight, and electrocatalysts. However, all the materials used thus far entail losses in efficiency via various mechanisms and thus reduce the efficacy of photoelectrolysis. A research group from

310

billion cubic meters of hydrogen were generated worldwide from fossil energy sources in 1999. In a sustainable energy industry, hydrogen can be produced from renewable energies such as wind, hydropower and sunlight.

1
Prototype of a photo-electrochemical cell (PEC cell) for the production of solar hydrogen.

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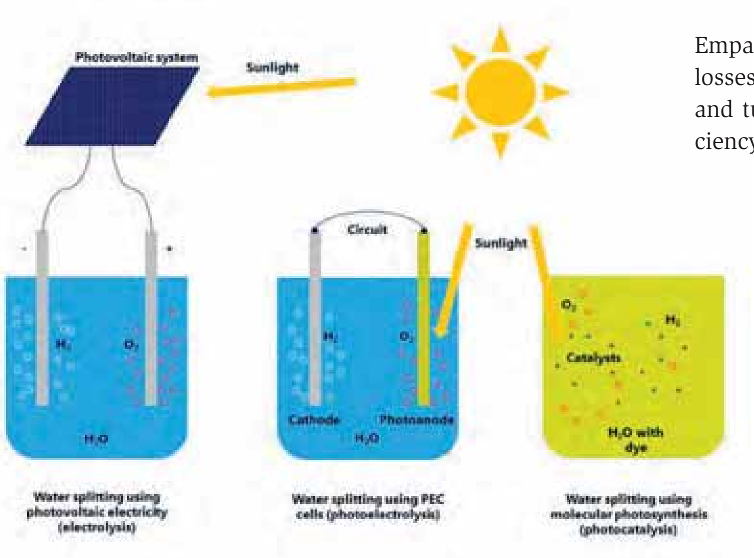

Empa recently presented a strategy to eradicate this source of losses: the scientists structured a photoanode made of gridiron and tungsten oxide like a moth's eye, which doubled the efficiency of the photoanode.

Another method with potential

Researchers recently succeeded in mimicking water separation in a molecular system in aqueous solution – thus rendering the electrodes used in PEC cells superfluous. This technique corresponds to the familiar photocatalysis method, with which the scientists aim to take a step closer to nature's role model. They are concentrating on optimizing individual steps, such as by improving pigments similar to chlorophyll or the catalysts for water separation and CO_2 reduction. Using state-of-the-art techniques, the Empa scientists are studying the molecular reaction mechanisms of the absorber molecules and catalysts to understand their interaction better and thus help prepare energy production based on artificial photosynthesis for the market. //

1
Three different approaches towards artificial photosynthesis: photocatalysis comes closest to natural photosynthesis. Due to efficiency advantages, however, photoelectrolysis is currently primarily used in so-called PEC cells.

Clean jet engines for the aircraft of tomorrow

Since the 1980s, large aircraft engines have had to meet emission limits, which have gradually become more stringent over the years. Today, air traffic contributes relatively little to Switzerland's air pollution levels, and visible smoke trails from jet engines are a thing of the past. However, the emission of invisible ultra-fine particles from jet engines has not been addressed until now. These microscopically small particles can penetrate deeply into our lungs and can have adverse health effects. As a precautionary measure, these air traffic emissions will now also be regulated and reduced.

1/100 000

millimeters: the diameter of the finest soot particles the Empa measuring system can gage.

Cooperation between Research, Industry and Federal Office

From a technical standpoint, measuring ultra-fine combustion particles in the exhaust of a jet engine is extremely complex due to the high temperature, high velocity and high vibrational environment. As part of a collaboration between Empa, SR Technics and the Federal Office of Civil Aviation (FOCA), experts spent years developing a standardized testing method that can be applied to measure ultra-fine particulate matter emissions from aircraft engines. Both the measuring system and the corresponding instruments have been fully developed and tested. The measuring system reports the mass of the particulate matter as well as the number of particles emitted per kilogram of fuel, and even records the smallest particles with diameters of less than a hundred-thousandth of a millimeter, i.e. 10 nanometers.

The development of this new global standard was led by FOCA in partnership with the United States' Federal Aviation Administration (FAA). On 2 February 2016, the ICAO's Committee on Aviation Environmental Protection approved the new standard, which relies heavily on contributions from FOCA, SR Technics and Empa. The standard will be adopted by the ICAO member states this year.

All civil aviation jet engines in production as of 1 January 2020, must be certified in accordance with the new standard. Most engine manufacturers have already begun measuring their engines according to the new standard. In anticipation of even

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more stringent emission limits, measures are already being taken to reduce the emission of ultra-fine particulate matter through the use of more efficient combustion technologies and alternative fuels.

Empa researchers are also assessing the impact that ultra-fine particulate matter has on human health and the environment and whether the engine emissions contain genetically harmful or carcinogenic substances. Compared to on-road mobility, very little is known about aviation emissions and their impact. //

2

1
Together with the Federal Office of Civil Aviation and SR Technics, Empa has contributed significantly to the development of the first worldwide standard for fine particle emissions. Photo: iStockphoto

2
Aircraft engines emit soot. This Boeing 707 leaves a clearly visible cloud as it takes off from the airport in Los Angeles in June 1960. Photo: Charlie Atterbury, Seattle

Flexible lighting panels in mass production

In the project "TREASORES" (Transparent Electrodes for Large Area Large Scale Production of Organic Optoelectronic Devices), European researchers succeeded in getting the lighting technology of the next generation ready for the market. They developed flexible lighting modules that can be produced roll-to-roll, much like a newspaper. This technology paves the way for more affordable solar cells and LED lighting panels of the future.

"TREASORES" was coordinated at Empa and pooled the expertise of nine companies and six research institutions from five European countries. With EUR 9 million in funding from the EU and another EUR 6 million from the project partners, it yielded eight patents and a dozen scientific papers, and laid the foundations for future international standards.

25

lumens per watt: the light output that can be achieved with the novel large-scale luminescent films. Their energy efficiency is comparable to a halogen lamp.

Flexible electrodes and barrier films

Most importantly, the project developed and scaled up production processes for several new transparent electrode and barrier materials for the next generation of flexible optoelectronics. The next generation of light sources and solar cells are to be produced via roll-to-roll manufacturing, for which the new electrodes are ideally suited. Within the scope of the project, the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology in Dresden produced an OLED light source with the project logo using the roll-to-roll technique.

Energy-efficient lighting walls become possible

The flexible, transparent electrodes and new, transparent barrier films – i.e. synthetic films that prevent oxygen or water vapor from entering and destroying the organic components – are crucial for the future mass production and durability of such lighting elements. The electrodes developed within the scope of "TREASORES" are just as effective and transparent as those currently used in OLED technology – and sometimes even better. What's more, they are cheaper to produce and do not require any indium, which is in increasingly short supply.

1

Flexible electrodes made of conductive textiles were manufactured within the scope of the project using a cost-effective roll-to-roll process. The electrodes are highly transparent in the visible and near infrared spectrum, and exhibit low electrical resistance. Photo: Sefar AG

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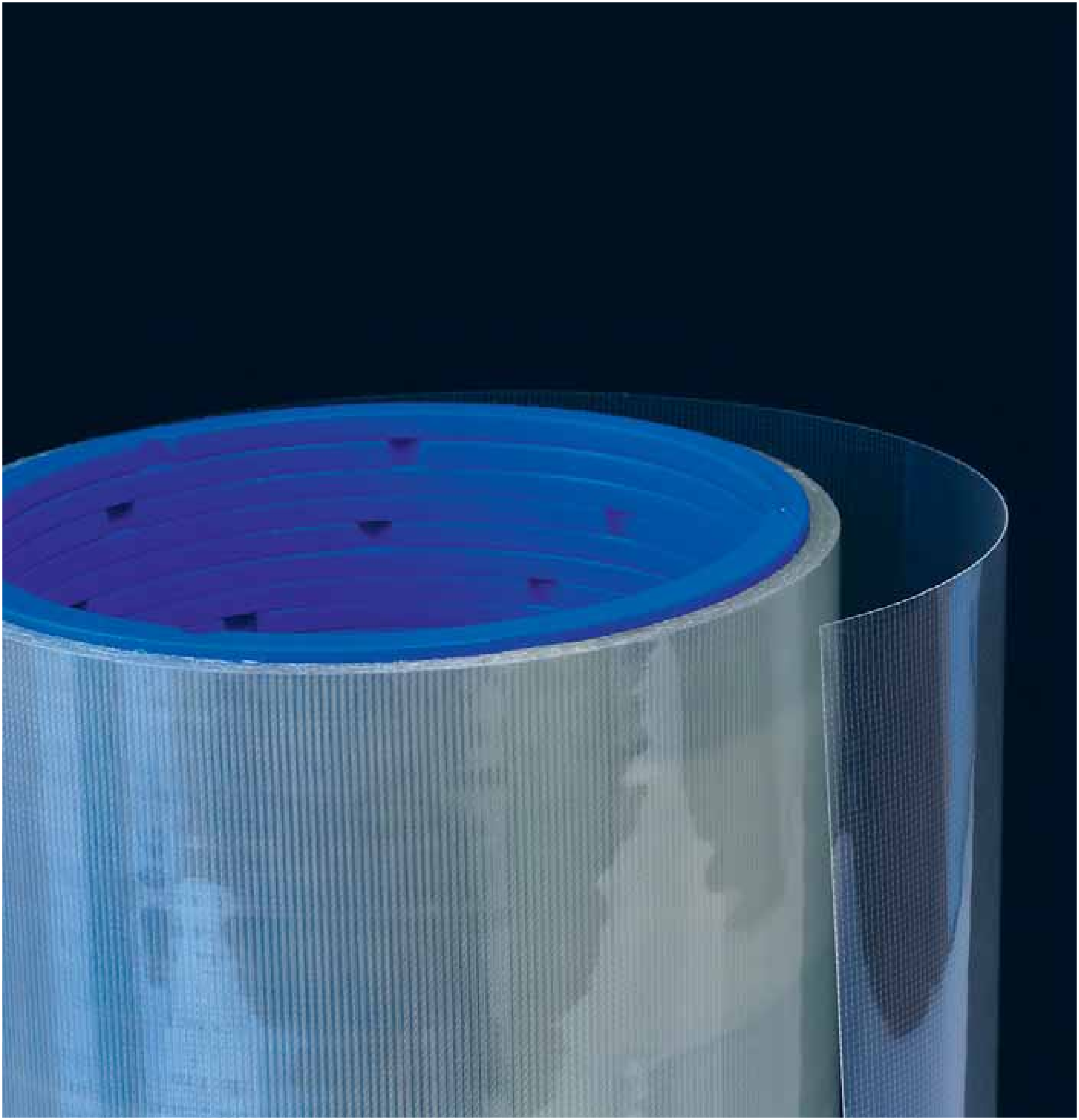

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With the new electrodes, extremely homogenous white light sources can also be achieved on larger areas with an efficiency of 25 lumens per watt – comparable to equivalent components of the existing OLED technology, which are produced on individual sheets using a much slower production process. //

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1
A flexible light source comprising organic LEDs (OLEDs) developed within the scope of the "TREASORES" project. A key area of this technology relates to flexible electrodes and airtight barrier layers. This luminescent film was produced at Fraunhofer FEP in Dresden using a cost-effective roll-to-roll process.
Photo: Fraunhofer FEP

Graphene nanoribbons: it's all about the edges

Researchers from Empa, the Max Planck Institute for Polymer Research in Mainz and the Technical University of Dresden succeeded in producing graphene nanoribbons with perfect zigzag edges from molecules for the first time. The electrons on these edges exhibit different (and coupled) rotational directions ("spin"), which could make graphene nanoribbons the material of choice for the electronics of the future, referred to as "spintronics".

As electronic components are becoming ever smaller, the industry is gradually approaching its limits with silicon, which is traditionally used as a semiconductor material. Graphene, the material with "miraculous" properties, is considered a possible replacement. Only one atom thick, the carbon film is ultra-light, extremely flexible and highly conductive. Before graphene can be used for electronic components such as field effect transistors, however, the material has to be "transformed" into a semiconductor, which the researchers achieved by producing extremely thin ribbons: after all, the narrower the ribbons, the larger their electronic band gap – i.e. the energy range in which no electrons can be located and which is responsible for ensuring that an electronic switch (such as a transistor) can be turned on and off. The Empa researchers were then also able to "dope" the nanoribbons, i.e. furnish the ribbons with impurity atoms such as nitrogen at certain points, in order to influence the electronic properties of the graphene ribbons even further.

4

kilograms: how heavy a cat can be for a one-square-meter graphene hammock to hold its weight. The hammock itself, however, would only weigh as much as one of the cat's whiskers.

"Building" ribbons from precursor molecules

Moreover, thanks to a perfected manufacturing process, the researchers succeeded in synthesizing graphene ribbons with perfectly zigzagged edges from suitable precursor molecules. The zigzags follow a very specific geometry along the longitudinal axis of the ribbon. The geometry of the ribbons and especially the structure of their edges enable the researchers to give the graphene ribbons different properties.

In order to design the best possible synthesis route for the zigzagged ribbons, the scientists kept alternating between computer simulations and experiments. With molecules in a U-shape, which they allowed to grow together to form a snake-like line, and additional methyl groups, which completed the zigzag edges, the researchers were able to finally create a "blueprint" for nanoribbons with perfect zigzag edges. To check that the zigzag edges were exact down to the atom, the researchers investigated the atomic structure using an atomic force microscope (AFM). In addition, they were able to characterize the electronic states of the zigzag edges via scanning tunneling spectroscopy.

Interesting for spintronic applications

And precisely these edge states display a very promising feature. Electrons can spin either to the left or to the right, which is referred to as the internal spin of electrons. The special feature of the zigzag graphene ribbons is that, along each edge, the electrons all spin in the same direction, an effect which is referred to as ferromagnetic coupling. At the same time, so-called antiferromagnetic coupling ensures that the electrons on the other edge all spin in the opposite direction. In other words, the electrons on one edge of the ribbon are all in a "spin-up" state and on the other edge in a "spin-down" state.

Thus, two independent spin-channels with opposite "directions of travel" arise on the ribbon edges, much like a road with separate lanes. By specifically integrating structural defects on the edges or – somewhat more elegantly – providing an electri-

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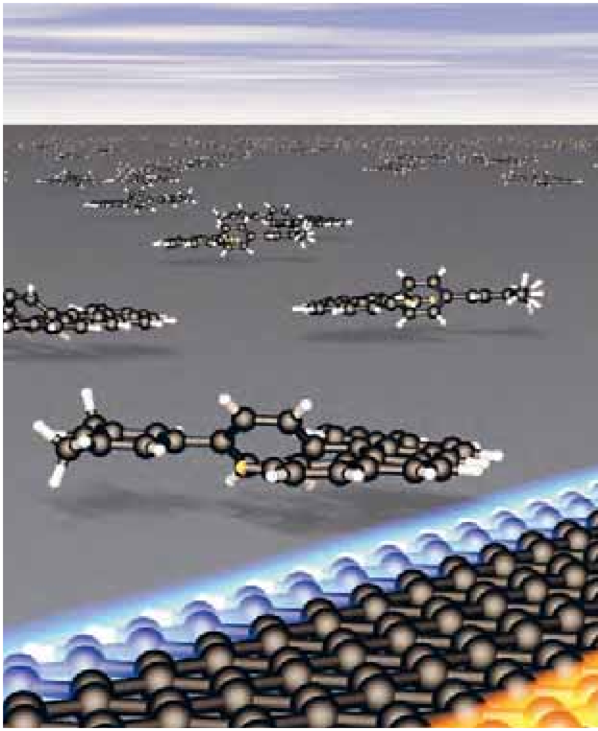

1
Illustration of a graphene nanoribbon with zigzag edges and the precursor molecules used in its manufacture. Electrons on the two zigzag edges display opposite directions of rotation (spin) – "spin-up" on the bottom edge (yellow) or "spin-down" on the top edge (blue).

2
Pattern template for graphene nanoribbons: depending on the direction of the ribbon axis, graphene nanoribbons have an armchair edge (yellow) or a zigzag edge (blue).

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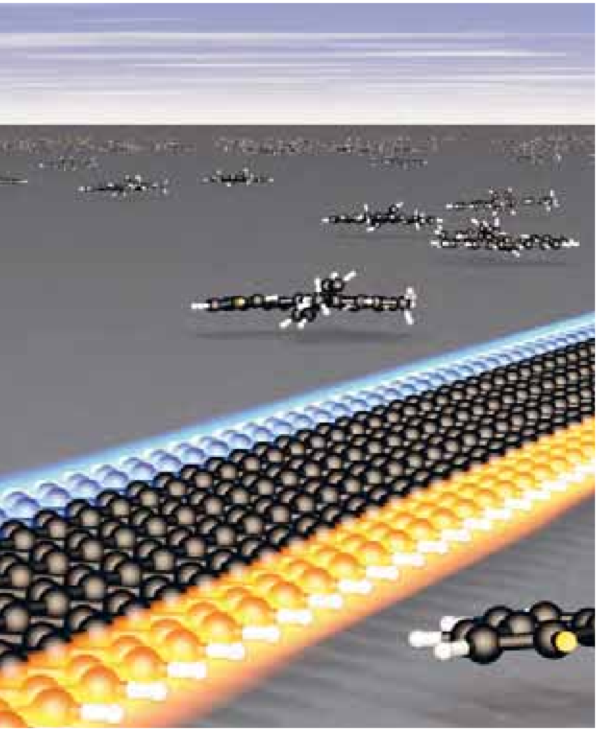

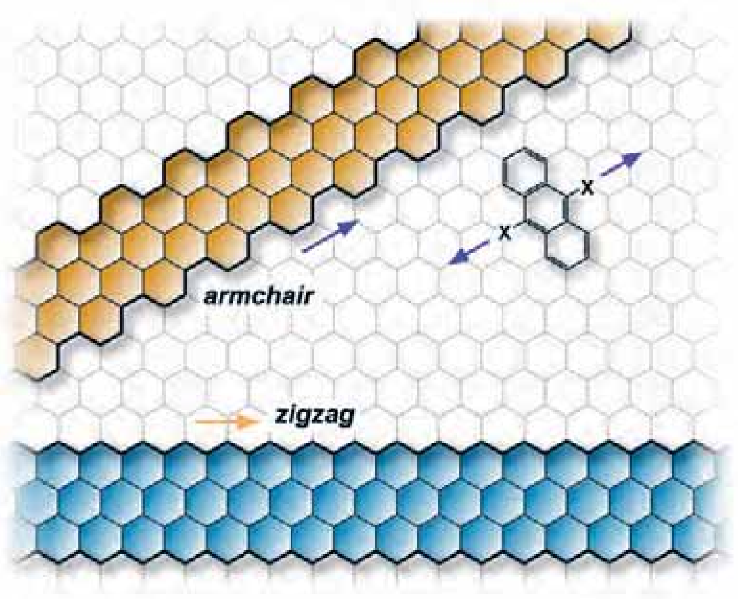

2

cal, magnetic or optical signal from the outside, spin barriers and spin filters can thus be designed that only require energy in order to be switched on and off – the precursor to a nanoscale and extremely energy-efficient transistor.

Possibilities such as this make graphene ribbons extremely interesting for spintronic applications and components, which use both the charge and the spin of the electrons. Thanks to this combination, scientists predict completely new components, e.g. addressable magnetic data storage devices which retain the information that has been fed in even after the power has been turned off.

The graphene flagship

Empa is a partner in the EU flagship project "Graphene". Launched in 2013, the pan-European project is to run for (at least) ten years and pools European research competence on everything to do with this new material. Empa is also studying the electronic properties of the ultrathin carbon material, as well as potential health and environmental hazards. //

Functionalization of wood

Wood is robust and versatile. But even the best of materials has its limits. Consequently, Empa researchers are looking to transform wood into a high-tech material and broaden the range of applications for this natural resource. The trick: to give wood additional, unexpected properties.

There are countless ways of improving the properties of wood, such as by varnishing or coating it. The Empa researchers are now taking it one step further, however, and permanently binding the additives chemically to the natural material. Not only does this alter the properties of the wood on the surface, but also inside the material.

Many of the material developments are tested in the NEST unit Vision Wood, which will reveal how the materials behave under real conditions.

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The total number of cubic meters of wood harvested in Switzerland in 2015. 1.5 million cubic meters were processed further in sawmills. 23 percent was used as raw material for paper, pulp and boards or channeled as a raw material into other applications.

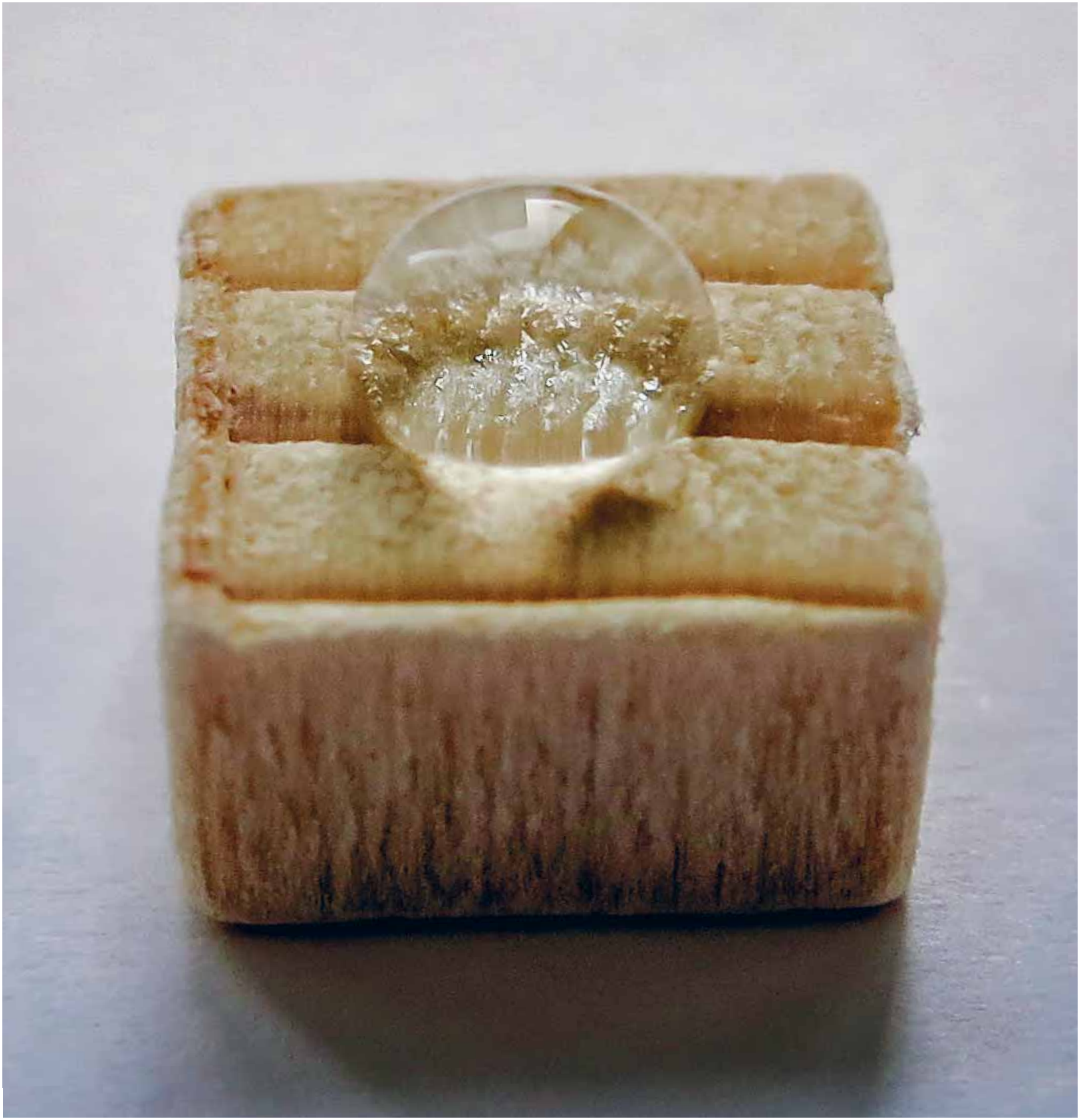
Not so scared of water after all

Water causes wood to weather and, in extreme cases, rot. In order to combat this, a team at Empa inserted styrene – a component of the well-known synthetic material polystyrol – to a depth of a millimeter in the gaps between the cells in wood and bound them chemically, thus turning natural wood into a composite material made of wood and synthetics. In order to render thick pieces of wood waterproof, the researchers cut them into thin layers, integrated the synthetic material and stuck the layers together. Thanks to a special surface treatment using metal oxide, another team created a kind of lotus effect: Now the water rolls off wood like on ceramics. A sink made of this material is to be put to the acid test at NEST, Empa and Eawag's modular research and innovation building (see page 42).

Protection against fungal decay

Wood weathering is also caused by fungi and bacteria as the (organic) building material makes ideal breeding ground for microorganisms. In order to prevent this, the researchers enlisted the help of a substance that comes from fungi themselves: laccase, an enzyme which is supposed to ensure that iodine binds covalently – i.e. chemically "firmly" – to a wooden surface in an "artificial" environment. In an aqueous solution, the laccase oxidizes the iodide (I^-) to form highly re-

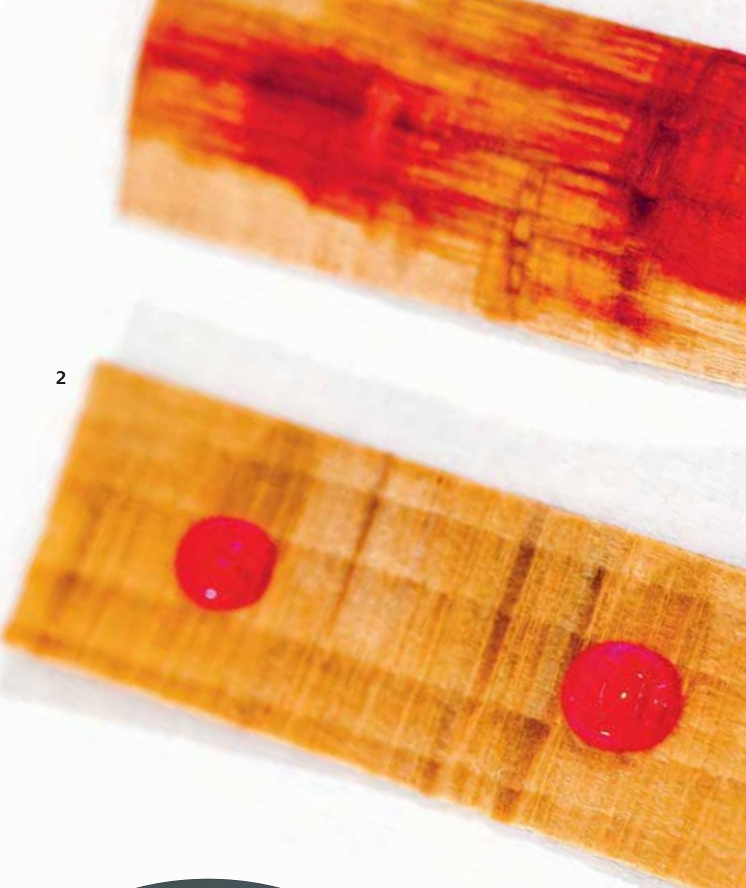
1 The waterproof impregnation works perfectly – the wood keeps the water at bay.

1 

1
Doctoral student Vivian Merk demonstrating that a wooden cube actually sticks to the magnet.

2
As the comparison reveals: in contrast to the treated sample (below), the natural beech immediately soaks up the dyed water.

3
Fire tests yielded promising results. Thanks to the limestone in the cell structure, the researchers succeeded in slashing the wood's flammability level to around a third.



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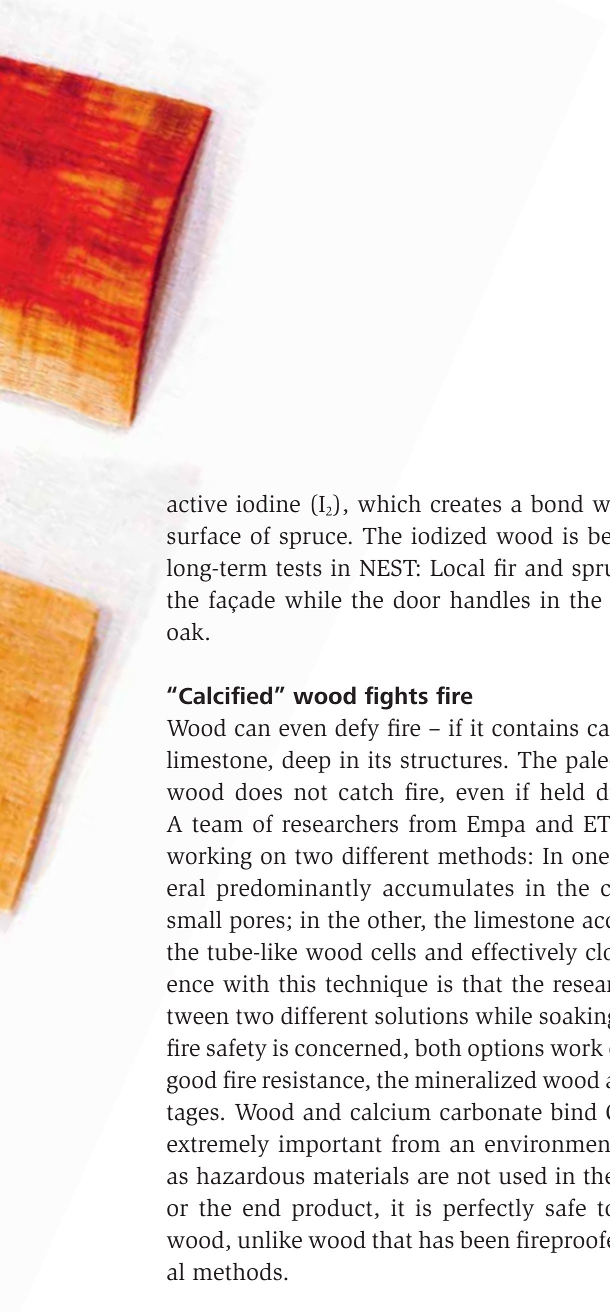

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active iodine (I_2), which creates a bond with the lignin on the surface of spruce. The iodized wood is being deployed in two long-term tests in NEST: Local fir and spruce is being used for the façade while the door handles in the interior are made of oak.

"Calcified" wood fights fire

Wood can even defy fire – if it contains calcium carbonate, i.e. limestone, deep in its structures. The pale-colored mineralized wood does not catch fire, even if held directly in the flame. A team of researchers from Empa and ETH Zurich have been working on two different methods: In one technique, the mineral predominantly accumulates in the cell walls and forms small pores; in the other, the limestone accumulates directly in the tube-like wood cells and effectively clogs them. The difference with this technique is that the researchers alternated between two different solutions while soaking the wood. As far as fire safety is concerned, both options work equally well. Besides good fire resistance, the mineralized wood also has other advantages. Wood and calcium carbonate bind CO_2 within, which is extremely important from an environmental perspective. And as hazardous materials are not used in the production process or the end product, it is perfectly safe to recycle the hybrid wood, unlike wood that has been fireproofed using conventional methods.

Wood attracts

If researchers ultimately channel iron oxide particles into the wood cells, the wood even becomes magnetizable. This involves soaking pieces of wood in a highly acidic solution that contains iron chloride salts. Once the liquid has soaked deep into the wood, it is transferred to a strong alkaline solution, which triggers a precipitation reaction, creating a kind of snowstorm inside every wood cell. As the "snowflakes" are ferrous oxide nanoparticles, however, they are almost black, not white. The particles are enclosed in the wood, where they remain, even if the wood is washed for days on end. The magnetic particles come in two different forms – maghemite and magnetite. The brown-colored maghemite forms from the black magnetite when it oxidizes in in air. As a result, more imperfections develop in the crystal, which affects the color and explains why magnetizable wood is also very dark. So far, it has been used indoors, such as for toys or furniture. And at NEST, it is being tested as magnetizable boards. Use in the automobile industry is also conceivable, however: dark, elegant-looking wooden fittings could also be functionalized magnetically in future, for instance. //

Affordable detectors for gamma radiation

110

minutes: the half-life of ^{18}F-fallypride, a tracer substance for medical diagnostics, which means there is precious little time to test the substance's radioactive purity between its production and application.

Gamma photons almost always form when unstable isotopes degrade. In order to identify radioactive substances, cost-effective and highly sensitive gamma detectors that work at room temperature are thus in great demand. Finding suitable substances, however, is easier said than done. Crystals that recognize gamma rays at room temperature have to be of an outstanding electronic quality, i.e. the carriers in the crystal need to be extremely mobile and exhibit a long lifespan to conduct the signal reliably in the form of electrical impulses. Moreover, the crystal must be composed of heavy elements that can absorb energy-rich gamma radiation. And last but not least, it must be possible to grow large single crystals from this material that are resistant to breakage and temperature fluctuations.

Classical beaker chemistry

Until recently, primarily cadmium telluride (CdTe) and cadmium zinc telluride (CdZnTe) were known for these properties. However, the substance also used to produce thin-film solar cells is not water-soluble and only melts at temperatures above 1,000 °C, which renders the production of detector crystals complicated and expensive. A team of researchers from Empa has now succeeded in manufacturing semiconductors from another class of materials (lead halide perovskites) in a classical beaker experiment that exhibit the same properties as CdTe and CdZnTe – and at a cost of just a few Swiss francs per crystal. One possible application might be a mini Geiger counter which can be connected to smartphones. This might enable people in contaminated areas, for instance, to test their food individually for radioactivity. And the perovskite crystals could even recognize X-rays – another key research field that can be used in medical and safety applications.

Applications in neurodiagnostics

Another potential field of application for the new crystals is diagnosing metabolic problems in the brain. Dopamine receptor disorders can have numerous consequences: Parkinson's, schizophrenia, hyperactivity (ADHD), social anxiety disorders or drug addiction and alcoholism. These disorders are diagnosed by giving patients radioactive tracer substances, which

1
A methylammonium lead iodide crystal – one of the components in the new lead halogen perovskite semiconductors. Photo: iStockphoto


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render the brain activity visible via magnetic resonance imaging (MRI). Administering radioactive substances is not without its hazards, however: if the substance is impure, it can have adverse health effects. However, its purity has to be verified swiftly as the tracer substance has a relatively short half-life, which means it degrades rapidly.

In order to demonstrate the “capabilities” of lead halide perovskites, the Empa team used the new single crystal detector to test the isotope purity of ^{18}F-fallypride, a tracer substance used in clinical trials on dopamine receptors. The researchers teamed up with colleagues from the Institute of Pharmaceutical Sciences at ETH Zurich to compare the efficiency of their new detector material with conventional detectors – with virtually identical results. //

Peptides: new weapons again super germs

Found in numerous organisms, they are natural weapons against pathogenic bacteria in the body: antimicrobial peptides. They offer a possible – and now also urgently needed – alternative to conventional antibiotics, but have not yet been used successfully in a clinical context. The reason for this lies in their molecular structure, which ensures that peptides are broken down relatively quickly inside the human body before they can have an anti-bacterial impact.

In collaboration with the University of Copenhagen, Empa researchers succeeded in developing a kind of shuttle system made of liquid-crystalline nanomaterials (so-called nanocarriers), which protect the peptides and thus ensure they reach their target safely. The nanocarriers developed consist of so-called structure-forming lipids, which can accommodate the antibacterial peptides and hold or release them based on the nature of the structure. Initial tests revealed that the peptides are completely enclosed by the nanocarriers and thus remain stable. As soon as they are released, however, they become active and prove extremely effective in fighting bacteria, at least in lab tests on bacterial cultures.

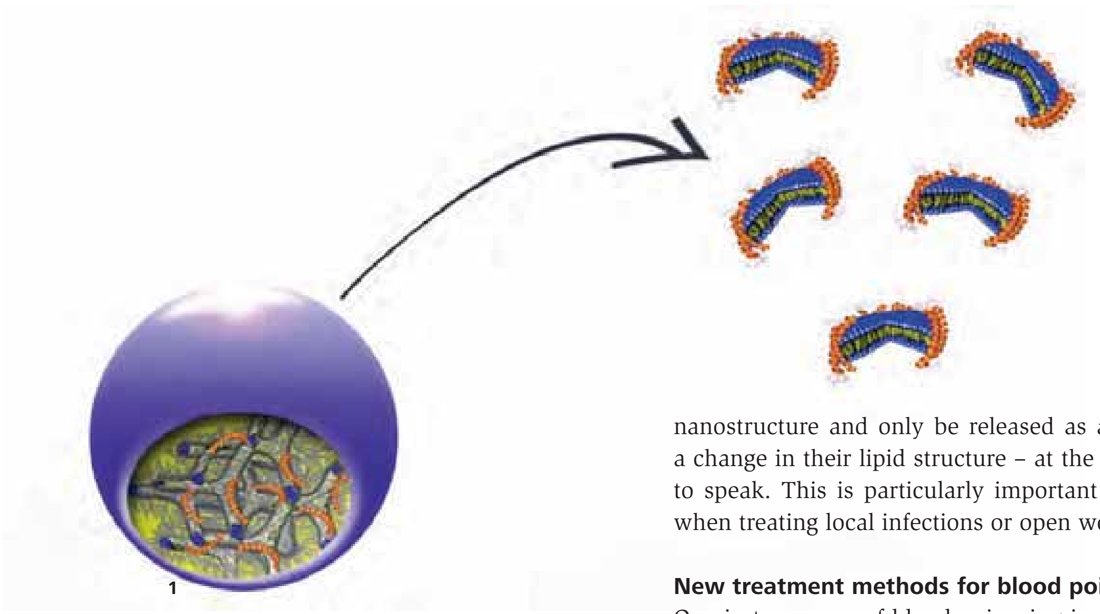
250

The number of people worldwide who die every minute as a consequence of infections that can no longer be treated with antibiotics.

Peptides are good – peptides and nanocarriers better

The researchers also noticed another characteristic of the nanocarriers. Peptides are already effective against bacteria when working "alone" – but in combination with the novel shuttle system they are even stronger. Thus, the protective casings developed from the lipids not only ensure the safe delivery of the peptides to the area where they are needed, but also intensify their impact at the target. The research work could therefore be the first step towards combatting antibiotic-resistant bacteria successfully as peptides use a different mechanism to conventional antibiotics; they destroy the bacteria's membrane, i.e. the casing. Even antibiotic-resistant superbugs are defenseless against this weapon.

As the next step, the researchers now want to structure the nanocarriers in a way that enables them to take effect at a specific time. The peptides would therefore be protected within the



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nanostructure and only be released as and when needed via a change in their lipid structure – at the "flick of a switch", so to speak. This is particularly important in medicine, such as when treating local infections or open wounds.

New treatment methods for blood poisoning

One in two cases of blood poisoning is still fatal today – even though sepsis is absolutely curable if treated at an early stage. The highest priority is therefore to act quickly. For this reason, doctors usually administer antibiotics even if they merely suspect blood poisoning, without first ascertaining whether it is actually a bacterial sepsis, which in turn greatly increases the risk of resistance to antibiotics. It is therefore important to find a fast and effective therapy which ideally can make do without antibiotics.

Empa researcher Inge Herrmann and her team are developing a solution in collaboration with the Adolphe Merkle Institute and doctors from Harvard Medical School. The idea is to purify blood magnetically, a principle which, at least in theory, is fairly straightforward. Iron particles are coated with an antibody that detects and binds the harmful bacteria in the blood. As soon as the iron particles are attached to the bacteria, they can be removed from the blood magnetically via dialysis.

1
The antibacterial peptides are located inside the nanocarrier's protective casing. As soon as its structure changes via external influences, the peptides commence their antimicrobial activity.

2
An X-ray capillary being filled to study the nanostructure of the nanocarrier.

3
Bacteria can be removed via magnetic blood purification. Magnetic iron particles bind to bacteria and can then be removed using a magnet.

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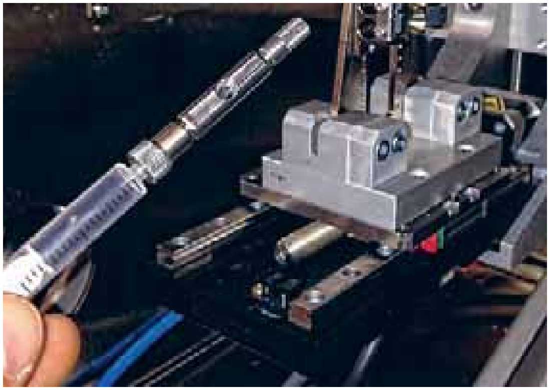
3

However, there is (still) a small catch: So far, it has only been possible to coat the iron particles with antibodies that recognize just one type of bacteria. Depending on the species causing the blood poisoning, however, many different types of bacteria may be involved. Nevertheless, a team at Harvard Medical School has now developed an antibody that is able to bind almost all the bacteria that can trigger blood poisoning – so if sepsis is suspected, the magnetic treatment could be started immediately, regardless of which pathogen is in the blood. Thanks to this "allrounder" antibody, the Empa researchers have now actually succeeded in isolating bacteria.

For the time being, however, the idea is still a vision for the future. Firstly, the method is primarily effective in the initial stage of sepsis, when the damage has not yet spread from the blood to the organs; secondly, the question as to how well this treatment will work in unstable patients or patients with pre-existing conditions needs to be addressed. Nonetheless, the researchers are optimistic – and a step closer towards a new treatment for sepsis. //



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The antivibration crystal

Engineers looking to absorb low-frequency vibrations often opt for a combination of springs and dampers. The soft padding is not without its disadvantages, however – such as in the transmission of power. Empa researchers have now discovered an elegant alternative and demonstrated its practical feasibility: macroscopic crystal structures can absorb unwanted vibrations or filter noise – without any electronics or electricity whatsoever. They are lighter than previous conventional insulating material, have a greater mechanical load-bearing capacity and can even be tailored to their intended purpose.

The novel materials – referred to as phononic crystals – enable a stable foundation to be constructed that is also capable of absorbing low-frequency vibrations. For instance, it could be possible to embed a heavy ship's engine in such a way that its humming is no longer transferred to the hull. Although theoretical physicists had observed such phenomena in nature, only a handful of scientists worldwide had these peculiar synthetic materials in hand and managed to test their properties on the actual object.

After three years of research, a team from Empa applied for a patent for the novel materials in 2016. In September 2016, the researchers produced test structures made of an aluminum alloy on Empa's 3D printer to refine the noise and vibration damping method further.

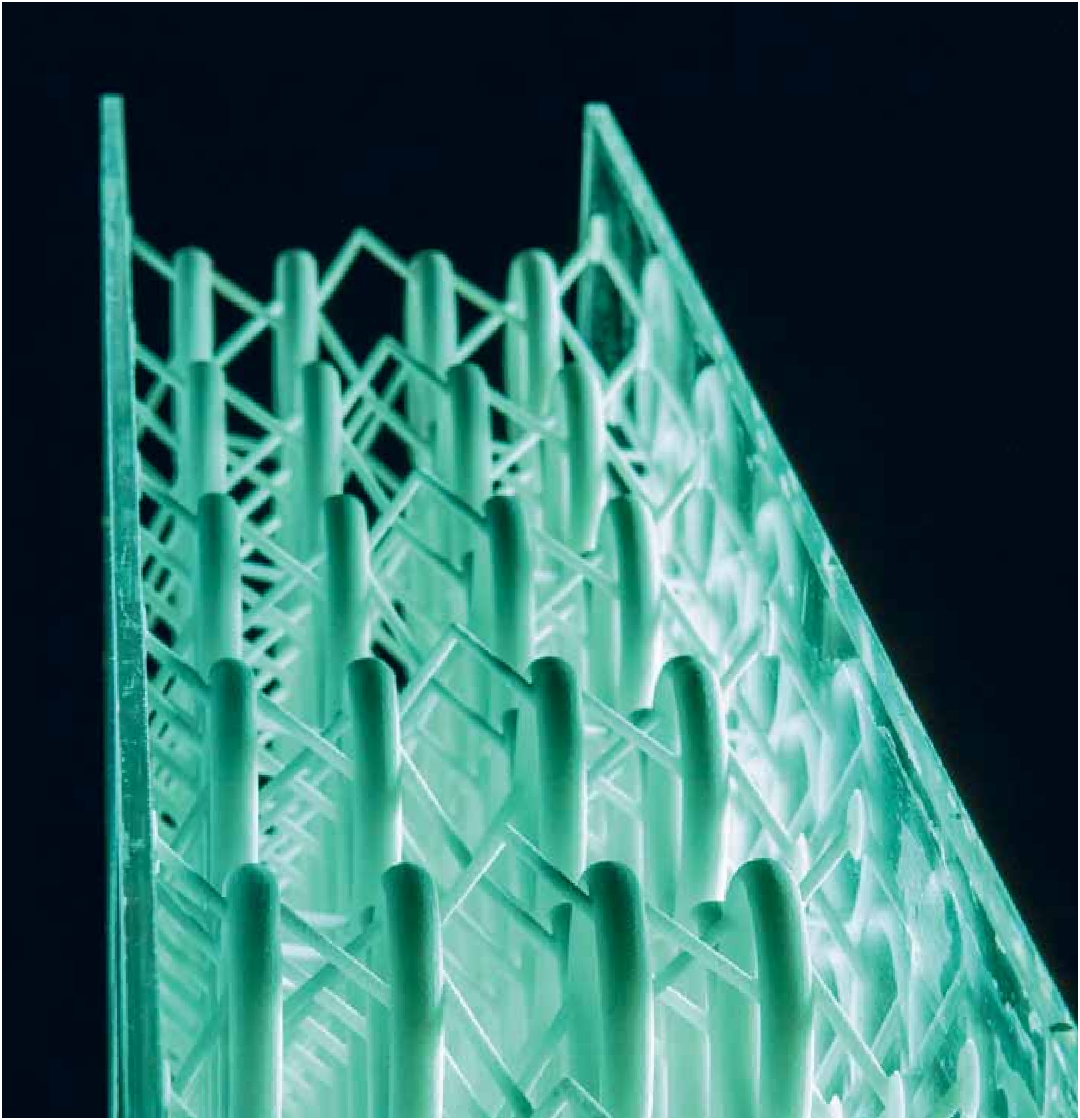
10

million: the number of times larger the phononic crystals are than the original diamond structures. The waves they influence are 10 million times longer: instead of X-rays, sound waves are scattered.

Building on an idea from Caltech

The project got underway in 2013. The Empa researchers studied the wave propagation properties of a synthetic crystal developed at California Institute of Technology (Caltech). First of all, they calculated that the ultra-light, three-dimensional metal grid structures with cells on a millimeter scale as developed at Caltech ought to absorb ultrasound frequencies (100 kHz) extremely well. The logical next question: Are there also structures that absorb sound within an audible range or

1
Model of a phononic crystal. In future, it will be possible to damp low frequencies with lightweight materials.

1 

low-frequency vibrations, which would open up a wealth of possible applications? And can these materials be "tuned" to a specific vibration frequency?

Initial tests were subsequently conducted with the structural model of a diamond. This kind of structure, made of tetrahedron connectors and small tubes, hangs as a demonstration piece in most chemistry labs in schools and universities. The model was embedded between two sheets of aluminum before the researchers excited the lower sheet with diverse frequencies. The result was flabbergasting: the crystal reflected some waves completely. With real diamonds, X-rays are bent and scattered in this way. The diamond model, which was thousands of times larger, had influenced mechanical vibrations with wavelengths that were several times larger in exactly the same way.

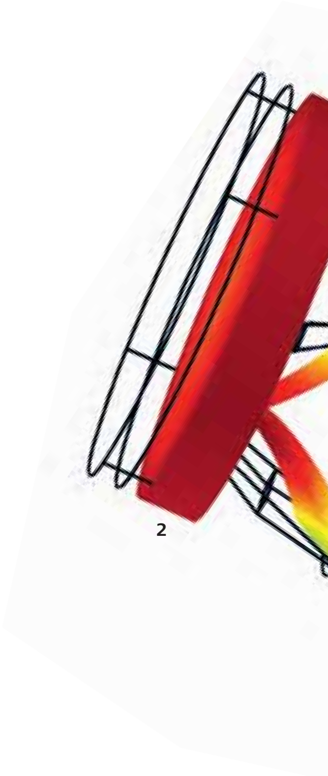
Engineer's rule no longer applies

Until now, the rule for damping vibrations was as follows: while high frequencies and sounds can be damped with lightweight materials, deeper sounds and vibrations require materials with a higher mass. This rule of thumb for engineers is no longer imperative: in future, it will be possible to damp low frequencies with lightweight materials – namely a specially calculated phononic crystal. The crystal is rigid and can bear weight – which means it is not a soft, springy base.

1
Delighted with their success: project head Andrea Bergamini with Ivo Leibacher, Armin Zemp and Stefan Schoenwald (from left).

2
The computer model shows how a single grid cell of the crystal is able to absorb vibrations.

3
Aluminum model from the 3D printer, the vibration properties of which tally well with the calculations.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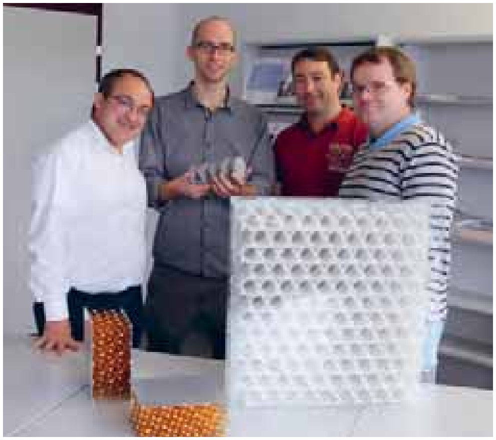
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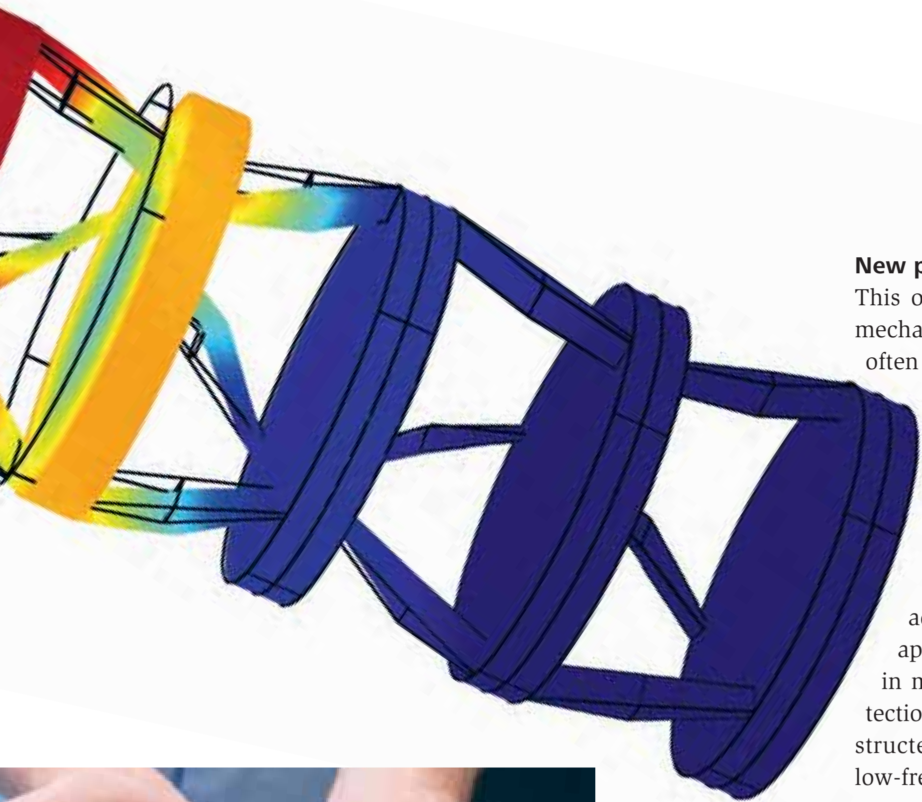

New prospects in mechanical engineering

This opens up completely new prospects for applications in mechanical engineering. Until now, unwanted frequencies were often treated with adaptive systems – i.e. with elaborate measuring and control technology. However, engineers would like to construct something uncomplicated and long-lasting that does not need constant monitoring while in use. Phononic crystals work under their own steam without electricity and monitoring electronics – always as predicted.

A major German company anticipating competitive advantages from the new damping methods has already approached the Empa researchers. Besides soundproofing in mechanical engineering, applications in earthquake protection are also conceivable. Buildings would need to be constructed on special crystal structures that absorb the very low-frequency seismic vibrations. And protecting conference rooms against eavesdropping would also be possible if the phononic crystal were configured for the frequencies of the human voice. //

Geometry leaves nothing to chance: the 3D-printed catalytic converter

Around 95 percent of all pollutants are produced in the first few minutes after a modern gasoline engine cold start. Or to put it another way: the first 500 meters pollute the air just as much as the next 5,000 kilometers driving nonstop.

Catalytic converters for cars which warm up as quickly as possible – or better still already clean the exhaust gas efficiently during the first engine revolution – are therefore vital if we want to improve air quality. One technology that might make this possible is taking shape at Empa. The basis for the next step in catalytic converter mechanics is the so-called Foamcat, which was developed at Empa in 2012. Unlike conventional honeycomb catalysts, the ceramic foam is open-pored, swirls the exhaust gas more effectively and thus can rely on lower quantity of catalytically active precious metals.

The improved turbulence in the catalytic converter compensates for the lower quantity of precious metals, which leads to a comparable pollutant conversion. However, it also triggers a rise in the exhaust gas counter-pressure, which might increase fuel consumption slightly. In order to solve this problem, the researchers conducted detailed simulation calculations to optimize the geometry of the pores.

95

The percentage of all pollutants in the exhaust gas from a modern petrol engine produced in the first few minutes after a cold start.

One drawback of the foam catalytic converter, however, is the random arrangement of the pores. Each foam is based on a polyurethane foam which is dipped in a ceramic suspension and then sintered. The polymer burns in the process, leaving the ceramic structure.

The random structure of the foam catalytic converter hampers its technical realization as the conversion rates, the exhaust gas counter-pressure and the strength behavior vary too heavily.

From computer design to real model

In order to obtain a calculable model system, the engine researchers from Empa produced an X-ray of one of these foams and fed the geometry into a simulation program which can be used to calculate the flow of exhaust gas. The researchers selected a regular, open-pored polyhedron structure as reference geometry. The result of the simulation was astonishing: the

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Model of one of the world's first catalytic exhaust converters with optimized polyhedron structures from the 3D printer.

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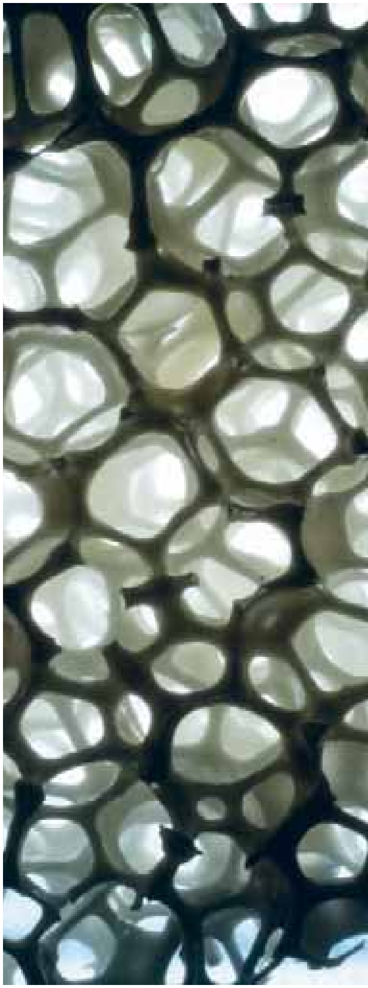

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1
Empa project manager Panayotis Dimopoulos Eggenschwiler (right) with Alberto Ortona, a specialist in 3D printing at the University of Applied Sciences and Arts of Southern Switzerland.

2
The foam catalytic converter developed at Empa: the model for the new catalytic exhaust converter from the 3D printer.

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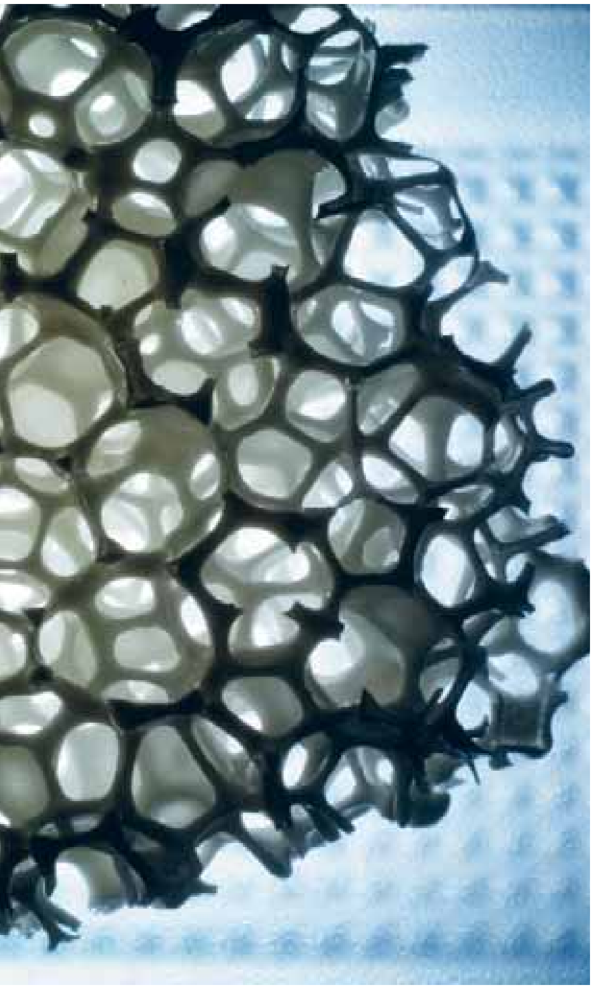

polyhedron structure displayed a better catalytic effect while cleaning the exhaust gas than the ceramic foam – and at a lower exhaust gas counter-pressure, too. Thus, the Empa researchers recreated the lattice model from the simulation in reality: specialists at Scuola universitaria professionale della Svizzera italiana (SUPSI) in Lugano reproduced the optimized polyhedron structure using the additive manufacturing technique. The model was constructed with stereolithography, a kind of 3D print from liquids. Experts from Empa then coated the ceramics with zirconium oxide and aluminum oxide – and the active precious metal layer made of platinum, rhodium and palladium.

Eliminate cold start emissions

To curb the critical cold start emissions in particular, the researchers came up with a rapid heating method for the catalytic converter that is found in any kitchen: the microwave. As silicon carbide can be warmed up effectively using this technique, Empa added it to the catalytic converter coating. Compared to their conventional honeycomb counterparts, polyhedron catalytic converters require a smaller amount of coating with a comparable conversion efficiency, which also means that less energy is required for the heating process. This is crucial if the catalytic converter needs to be brought up to operating temperature in a matter of seconds. The initial studies on microwave-heated catalytic converter models conducted within the scope of SNSF and FOEN projects confirmed the simulation results. The researchers are already contemplating a prototype in a vehicle. //

NEST lives and breathes

6,000

The number of visitors who attended tours and events at NEST between its inauguration at the end of May 2016 and the end of the year.

A residential building, office block and experimental laboratory all rolled into one: NEST is a "living lab" in the truest sense of the word. Those who live in NEST are also test subjects; those who work there are part and parcel of the pilot plant. On 23 May 2016, almost seven years after the initial ideas for NEST began to take shape, the modular research and innovation building was finally inaugurated in the presence of Johann Schneider-Ammann, the President of the Swiss Confederation. Top representatives from industry, research and the public sector joined in the celebrations in honor of this lighthouse project.

With the experimental building NEST, Empa and Eawag are pursuing an ambitious goal: to speed up the innovation and research process in the building and energy sector by enabling research, industry and the public sector to co-develop sustainable technologies, materials and systems, and test them under real conditions. At the same time, NEST serves as a demonstration platform where new things are presented and rendered accessible to decision makers from the construction and energy sector – not to mention the general public. Between the inauguration and the end of 2016, over 6,000 people attended tours and events to see NEST for themselves.

"Living lab" now teeming with life

Apart from the regular tours and events, NEST really started brimming with life in the second half of the year. When the Empa switchboard and reception relocated there in around mid-August, NEST became the central port of call for all visitors to the campus. At the beginning of November, the NEST team moved into offices in the unit Meet2Create, and the novel group rooms have been available to Empa and Eawag staff, as well as all NEST partners, in the "Office Lab" ever since. In Meet2Create, researchers from Lucerne University of Applied Sciences and Arts and their industrial partners are studying the working world of the future.

Life was also breathed into the housing unit Vision Wood. At the beginning of 2017, the first NEST resident moved into one of the three rooms and has been testing the wood innovations installed in the unit by Empa and ETH-Zurich researchers by using them on a daily basis.

1
Attractive architecture, unique modularity, innovative technology and materials: NEST has become a crowd puller for visitors interested in construction and energy.

1
Detailed view of the numerous installations in the basement of NEST.

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A separate research group was formed for the research activities in the Energy Hub (ehub, p. 51). The group was heavily involved in the start-up phase – and even the first expansions of the facilities – until December 2016 before launching the first research projects. Besides energy, water as a resource is also a core research topic at NEST. Eawag is studying water recycling in the Water Hub and developing new concepts to obtain nutrients and energy from wastewater.

Energy-efficient wellness and building with waste

However, Meet2Create, Vision Wood, ehub and Water Hub are just getting started at NEST. The building's three open platforms offer space for around 15 units: the third unit, a solar fitness and wellness facility, is being constructed with the aim of being run entirely on renewable energy.

In another unit, a consortium comprising ETH Zurich, the University of Stuttgart and the Werner Sobek Group will tackle topics related to urban mining and recycling. The unit uses waste as a resource and prototypical products to explore the potential of this source of materials. The same goes for so-called "cultivated building materials" – materials composed of fungal components and organic waste that can grow in any choice of forms – which will be integrated in the unit in the second phase.

Robots on the building site and the façade as an energy source

The National Center of Competence in Research (NCCR) "Digital Fabrication" based at ETH Zurich is working on a further unit. The researchers' goal: to combine digital technologies seamlessly with the physical construction process. Here, NEST serves as a real-world test environment for completely novel on-site digital fabrication and tailored digital prefabrication.

The planning for the unit SolAce is making headway at EPF Lausanne. The unit will contain living and office space for two people. The researchers will focus on the façade and the integration of photovoltaics and photothermals. Besides energy production, however, their research will also center on increasing comfort inside the unit – achieved via optimum daylight control and other active façade elements.

And the research and innovation unit HiLo will demonstrate the possibilities of lightweight construction. For the two-story penthouse, which will serve as living and office space for guests, the researchers and architects from ETH Zurich are combining ultra-lightweight construction in the flooring and roof and adaptive building technology based on the example of a solar façade. //

The key to success: storing renewable energy

500 – 600

kilometers: the range of a typical fuel-cell vehicle with a 700-bar hydrogen tank.

In the fall of 2016, Empa launched Switzerland's first hydrogen station for passenger cars with a filling pressure of 700 bars. The station is part of the mobility demonstrator move and used for various Empa project vehicles and privately owned hydrogen cars.

700-bar hydrogen station

The mobility demonstrator backed by the Federal Office of Energy (SFOE) and various industrial partners has been in operation since November 2015. Besides an electricity filling station, it also offers pumps with natural/biogas (CNG for "compressed natural gas") and a mixture of natural/biogas and hydrogen (HCNG). In the initial phase, pure hydrogen was available with a filling pressure of 350 bars, which is primarily suitable for refueling utility vehicles with large tanks. With the 700-bar hydrogen pump installed in 2016, Empa is looking to study the operation of fuel-cell passenger vehicles more closely, focusing on compact tanks, the longest possible range and rapid refueling. Hydrogen-powered cars can now be refueled in only two to three minutes and have a range of up 500 to 600 kilometers on a full tank, which suddenly gives fuel-cell vehicles a competitive edge over conventional gasoline or diesel vehicles in terms of refueling comfort.

To make rapid refueling possible, the compressed hydrogen is pre-cooled to minus 40 °C, which is necessary to prevent the temperature in the tank from rising too much due to the compression heat generated during the refueling process. The vehicle "communicates" with the pump nozzle via an intelligent infrared interface during refueling and provides data on the temperature and filling status.

Harnessing seasonal surpluses

It will be hard to ignore hydrogen if we want to produce renewable energy on a large scale. As it only accumulates when it can be used on the electricity market, the temporary surpluses need to be converted into an energy source that can be stored and used outside the electricity market. To create a day-night balance, small-scale battery storage devices and large-scale pump storage power stations on the bottom and top power supply levels respectively are available. However, there is an increasing need for technologies that lie somewhere in-between in terms of capacity and performance, and are connected to a middle power supply level. These systems are capable of harnessing seasonal surpluses and include power-to-gas plants, for instance, which can convert renewable electricity into fuel such

move

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as hydrogen or methane whenever it can't be used economically or on the energy market, and therefore replace gasoline, diesel and natural gas.

This especially makes sense for "frequent drivers": around 20 percent of all vehicles in Switzerland clock up more than 20,000 kilometers a year and are responsible for almost half of all the kilometers driven. In order to convert such vehicles from fossil to renewable energy, large ranges and rapid refueling times are therefore necessary, which purely electrically powered vehicles with batteries are unlikely to provide anytime soon. Hydrogen and methane vehicles, however, are also suitable for long trips. Empa is studying various types of use for hydrogen at the recently expanded move filling station: directly for utility vehicles, passenger cars and machines such as road sweepers with fuel cells, and as an admixture with natural/biogas for gas vehicles. //

1
Since the fall of 2016, hydrogen has also been compressed to 900 bars at move in addition to the 440-bar storage. Depicted: the compression and storage unit.

Coating Competence Center: from research to industrial application

At Empa's new Coating Competence Center (CCC), tailor-made surface technologies find their way from the research labs to marketable industrial applications. The center, which opened in April, contains diverse coating systems for hard coats, flexible photovoltaics and organic electronics, not to mention 3D printers for metallic and bio-composite materials. In terms of process technology, the equipment is on an industrial scale, albeit with modifications that enable the researchers to conduct detailed process analyses. This should make the upscaling easier for Swiss industry and guarantee an innovative edge among the international competition.

To survive on the global market, an increasing number of tailored solutions are necessary. This especially goes for coatings, whether they be novel, even more wear-resistant hard layers or intelligent multi-layer systems with specific functions and properties. Flexible solar cells, a promising technology of the future, also consist of a sequence of sub-micrometer-thin layers, which are vapor-deposited in a high vacuum. Even this kind of complex layer structure can be realized on equipment with industrial process engineering at the CCC.

Key interface between research and industry

At the CCC, scientists and engineers work side by side on pilot plants which mirror industrial process technologies. The processes developed and, where necessary, optimized on these plants can then be upscaled to large-scale industrial serial production plants with comparatively little additional development.

Several projects have already begun or are in the pipeline. At the industrial sputter plant Ingenia S3p, for instance, coatings made of amorphous tetrahedral carbon, which enhances components with a diamondlike layer that boasts outstanding tribological properties, are being researched and developed. Applications include engine and transmission components.

10

micrometers: the maximum deviation when the special printer nsm C600 at Empa's Coating Competence Center prints several layers on top of each other.

1
3D printed items show which geometries are possible with Additive Manufacturing.


1

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In 3D alloy printing, one of the things Empa researchers are developing is an acoustic process monitoring system. Seismic analysis should reveal whether material defects arise in the form of a stress crack inside the components during the production of a piece of machinery – an essential step in quality management for the 3D printing process.

The electron beam evaporator BAK 501 Uni and the magnetron sputter system Sputter Cluster CT200 are being used to construct novel, multi-layer, thin-film solar cells. And the precision printer nsm C 600 enables several layers to be printed on top of each other on flexible and rigid substrates with a positioning precision of under 10 micrometers. They should help research and develop novel materials and ink formulations for printable electronics, thin-film batteries and organic lighting elements (OLEDs), for example. //

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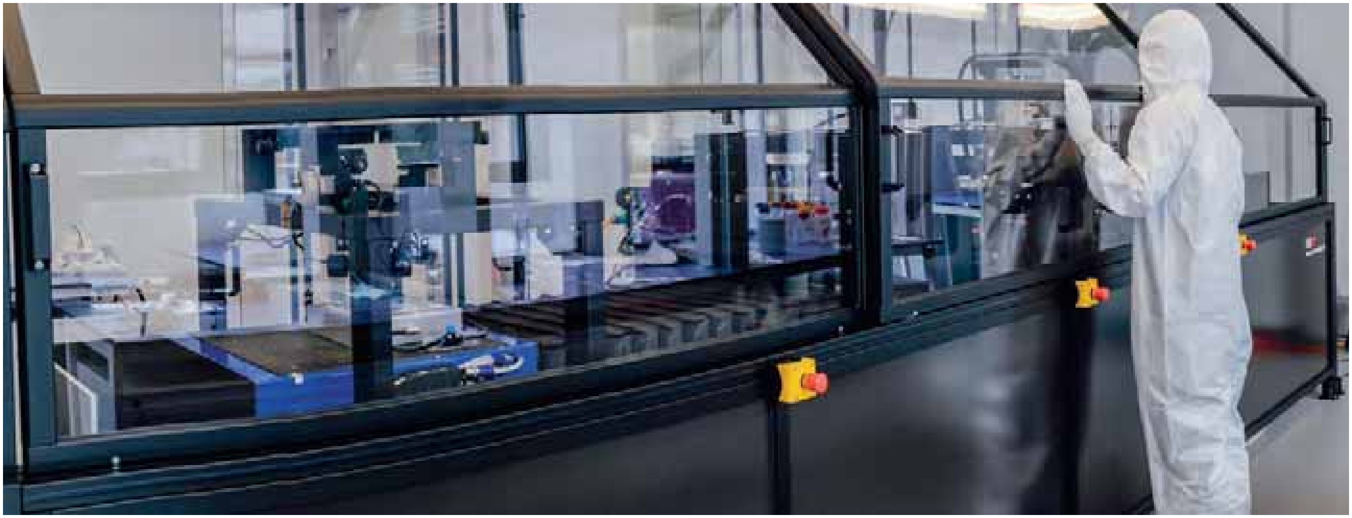
Thanks to its printing mechanisms for flexo, intaglio and screen printing, the globally unique printing and coating system at the Coating Competence Center facilitates high-precision, multi-functional, multi-layer prints on flexible and rigid substrates.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The intelligent energy district

13

The number of different components interconnected in the intelligent energy district on the Empa campus to generate, store and convert energy.

How can we organize the energy supply in the post-fossil era? How can energy be stored efficiently? And how can we organize its distribution as economically and conveniently as possible? The research platform Energy Hub – or “ehub” for short – is seeking the answers. It is a particularly flexible energy network that combines the research units of the building demonstrator NEST (p. 42) with the mobility demonstrator move (p. 45). Together, the Empa demonstrators therefore form a city district of the future and the basis for energy research at district level.

Homes and districts of the future could supply their own energy for extended periods. Although technically feasible, naturally they are not fully autonomous. They repeatedly connect to the public electricity grid, feeding in electricity from solar units, for instance, or collecting additional energy at peak load times or over longer periods, such as in the winter. Not just electricity, either, but also heat and, for mobility, hydrogen or renewable synthetic natural gas is considered.

But what is the best way to regulate this? And whose interests ultimately have the final say? How can this be implemented without causing higher peak loads and having to upgrade grids and power stations? These questions are not only relevant from a social and economic perspective; insufficient research into the technical solution for future feed-in and procurement regulations has been conducted to date. ehub aims to provide answers and demonstrate what is possible. Once NEST has been filled, ehub will supply up to 15 research units containing apartments, offices and leisure facilities. In other words, it will cover the energy needs of 40 residents, as well as 40 people who work in the building during the day. The energy consumption of the individual units will change several times during the day, thus altering the direction of the energy flow. For example, the midday sun will shine on the solar panels on the roofs of the residential modules where no one is using energy, while energy is needed in the office section. In the evenings, the excess heat from the modules with southwest-facing façades can be diverted to heat the sauna in the gym and spa.

Seasonal energy storage

Together with energy management throughout the course of a day, storage media are also being tested that can store energy for a day, week or even an entire season. ehub has an ice storage unit measuring 65 cubic meters, two geothermal probes drilled

260 meters into the earth and one spiral geothermal probe that reaches a depth of 12 meters. In the summertime, excess heat is used to defrost ice, while in the winter a heat pump is used to freeze water again and convert this stored heat for heating purposes. A large share of the energy is stored in the solid-liquid-phase change.

Warm water at a temperature of up to 80 °C is circulated around the three geothermal probes in the summer, and the heat stored in the ground can be recuperated by the homes during the winter months. ehub also has super-condensers for rapid electricity storage, as well as a battery pack with a capacity of 96 kWh (kilowatt-hours). According to plan, the batteries should be able to store enough energy to fuel a fully occupied NEST for approximately one day.

Once the batteries are full, excess electricity can be diverted to move and used to produce hydrogen in an electrolyzer. Hydrogen can be stored for several weeks in pressurized gas containers or used directly in fuel cell cars. NEST itself can also reuse hydrogen as there is a high-temperature fuel cell in the basement that normally converts natural gas into heat and electricity. This system is to be used to test how much internally generated hydrogen can be mixed with natural gas.

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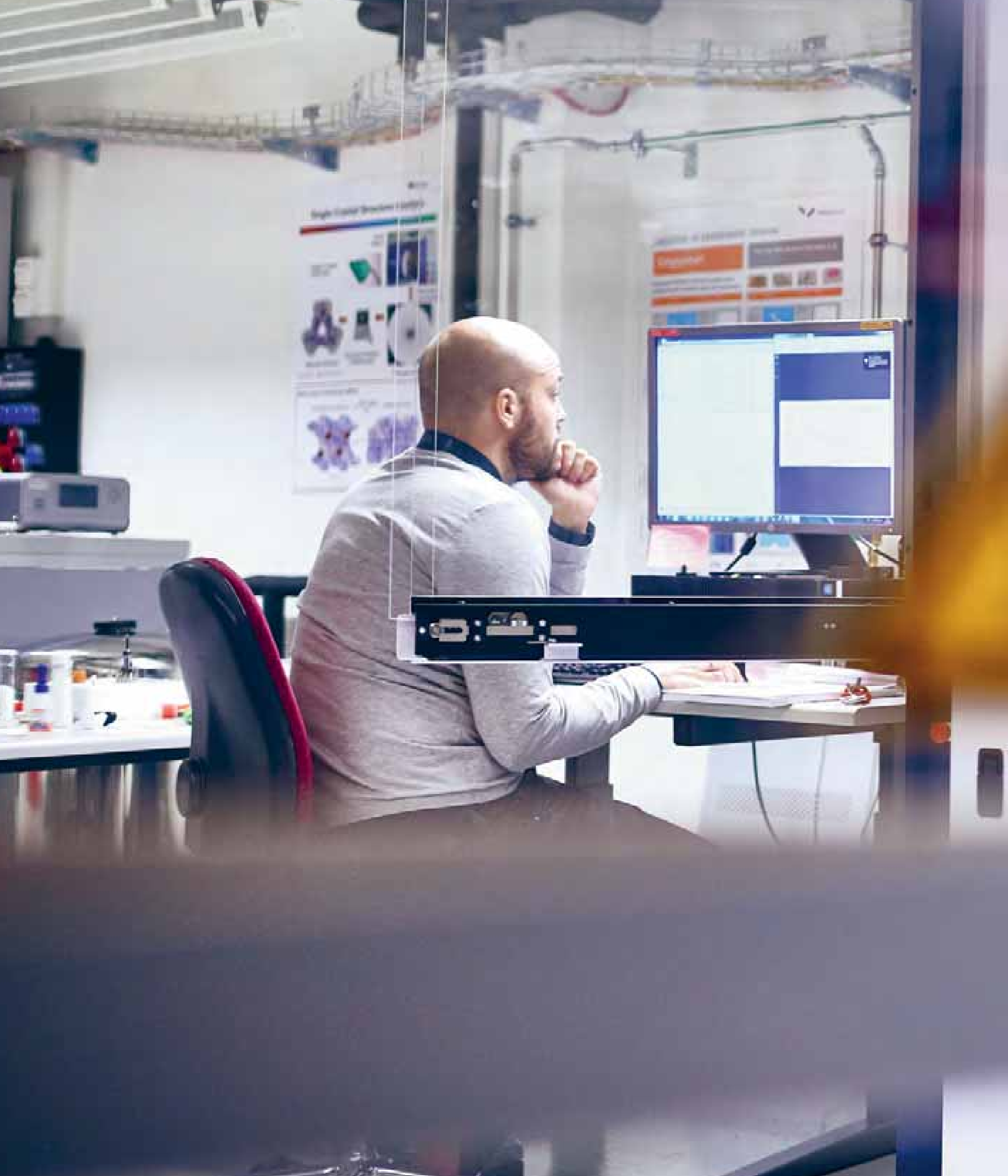
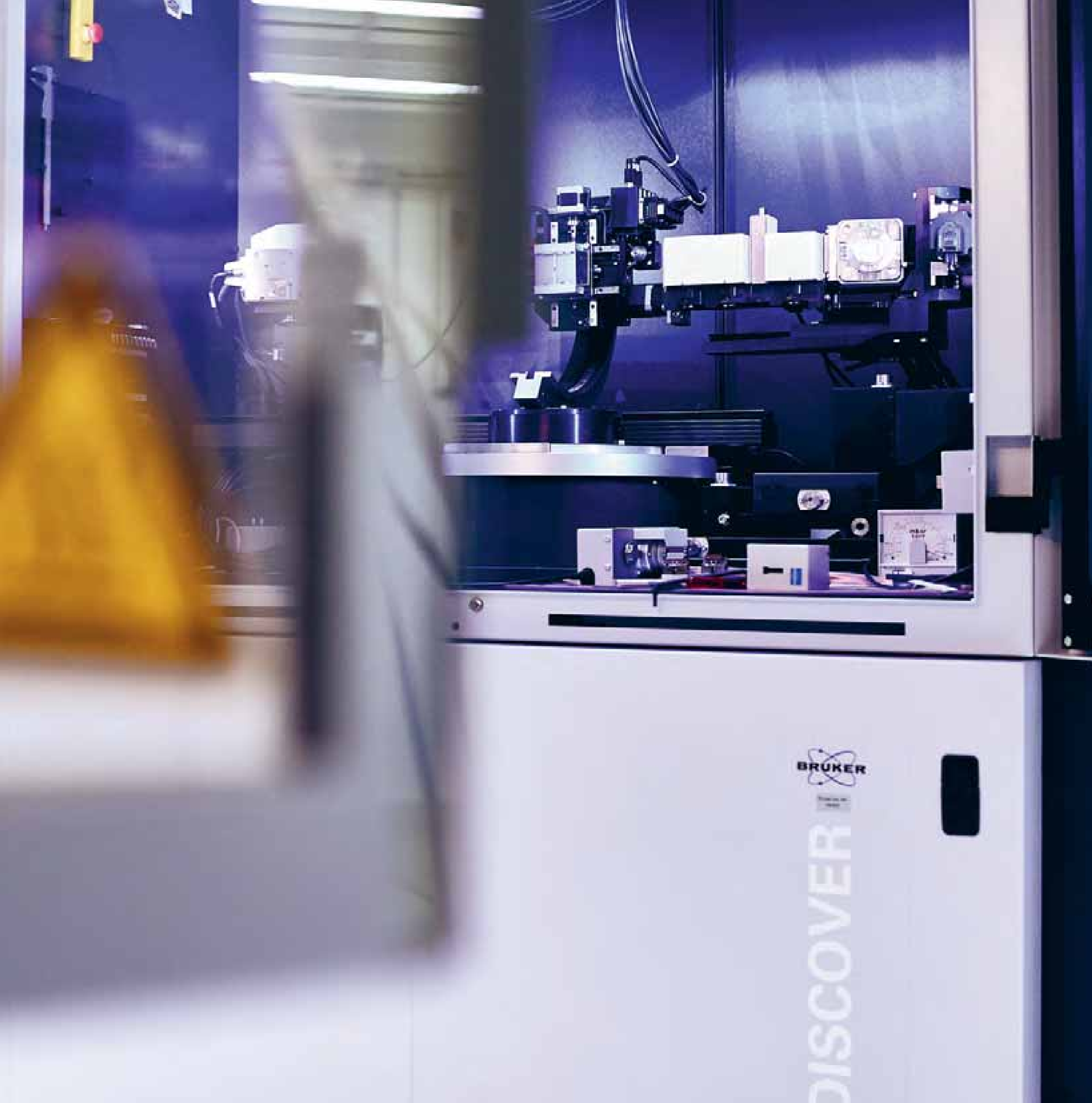
The 13 energy sources and storage media at ehub are attached to three different interconnected energy grids.

Flexibility as a research object

The building technology components integrated in NEST are not prototypes. Instead, they are usually commercially available, state-of-the-art appliances. The trick is in the innovative method used to interconnect the components, which the researchers hope to use to evaluate new energy management scenarios flexibly and analyze their effectiveness. Not only can researchers and partners from industry install and validate new control modules or prototypes there, the regulation itself is also extremely flexible: all the equipment that runs in an automated manner in normal operation can be overridden, given new algorithms and combined to form new consumer groups.

Research commenced at ehub in November 2016. The individual research groups will provide insights into how much energy is needed in residential areas, what the peaks are and how the required energy volume can be minimized with a reasonable amount of effort. It will also provide information on how autonomously residential and office districts can manage their energy supply, and to what extent future legislation and directives can be used to encourage behavior that serves the interests of the grid. In other words, ehub is a political research project as well as a technical and ecological one. //




BRUKER
DISCOVER

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.

Thin films: minimum material – maximum effect

As the famous physicist and Nobel Prize winner Wolfgang Pauli once said: "God created the bulk; surfaces were invented by the devil." What better description of the technical and methodological difficulties involved in developing, optimizing and characterizing surfaces or coatings? Nevertheless, it is the surfaces and their properties that turn a solid object into a functional material. An elegant and efficient approach towards optimizing pieces of machinery and tools, and thus making particular applications possible in the first place, coatings are often micrometers or even just a few nanometers thick.

Not only can thin films be used to refine material surfaces, but also produce complex functional materials by building up the material layer by layer. A classic example of this is thin-film solar cells, which comprise at least three but usually more thin layers, whereby the entire cell is fewer than five micrometers thick.

Skyrmions – magnetic vortices for data storage

Solid state disks (SSD) ousted conventional (i.e. magnetic) hard disks from PCs. However, the latest findings on magnetic vortex structures, known as skyrmions, could help the hard disk stage a comeback in home electronics. Skyrmions are stable magnetic vortices measuring only a few nanometers in diameter. They can be produced specifically using a fine magnetic tip and deleted again, which makes them candidates for the next generation of data storage devices. Skyrmions can develop into extremely thin ferromagnetic films. Their properties are defined by a ferromagnetic layer (e.g. made of cobalt) and particularly by their interfaces with two different, non-magnetic layers (such as platinum or iridium), which they are embedded between. The major technical challenge is to separate the ultrathin layers, which must be homogenous and closed – all at a film thickness of fewer than five atomic layers! As this is virtually impossible with conventional vapor depositing or sputter sources, Empa and an industrial partner are currently developing a novel sputter source that enables the growth of ultrathin films to be monitored and controlled more effectively.

More efficient in tandem – solar cells

The theoretical maximum efficiency for a simple solar cell constructed from an absorber material is 33 percent. There is no material capable of converting more solar energy directly into electrical energy. In order to achieve greater efficiency, at least two absorber materials need to be packed on top of one another. The materials have to be coordinated in such a way that they absorb as much of the spectrum of sunlight as possible and convert it into electrical energy. A suitable material combina-

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Semitransparent perovskite thin-film solar cell: it absorbs the UV and visible light, and is transparent for near infrared light. It serves as the "top cell" in the perovskite/CIGS tandem solar cell.

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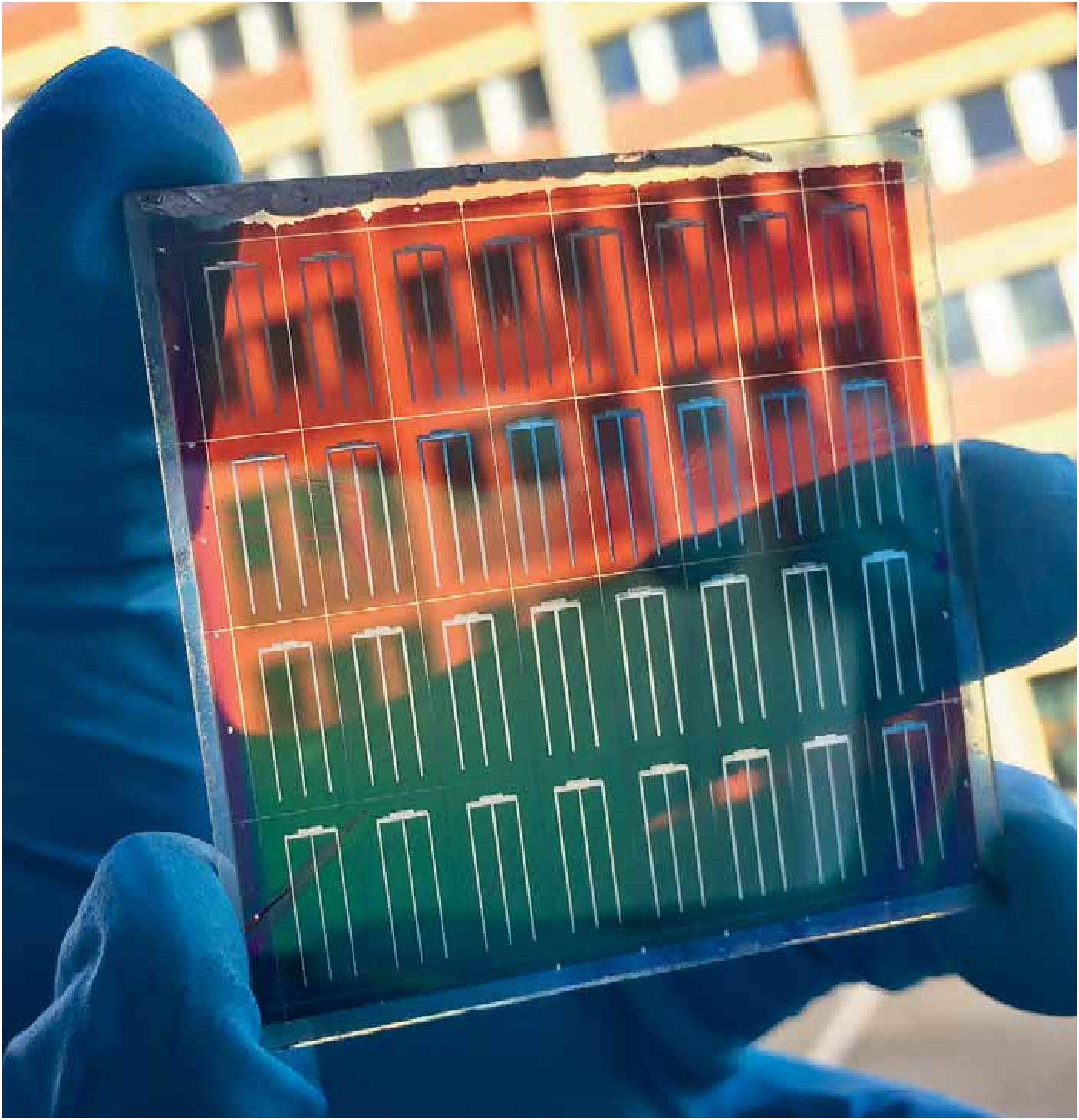
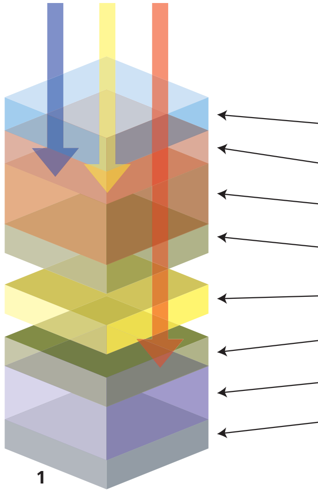


tion: perovskite compounds ($CH_3NH_3PbI_3$) with copper indium gallium diselenide (CIGS). Empa researchers are currently developing a flexible tandem solar cell. Besides optimizing the materials, the research activities focus on process engineering with a view to producing such complex solar cells cost effectively as a mass product. The first prototypes of this tandem solar cell exhibited an efficiency level of over 25 percent. As a realistic goal, the researchers aim to achieve an efficiency level of over 25 percent.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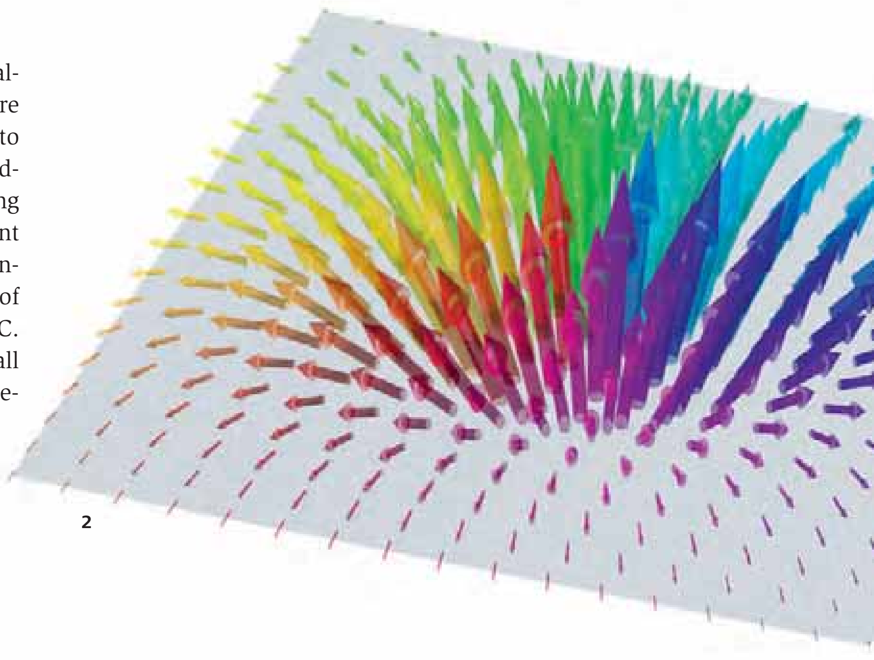
Novel nanosolder: the thinner they are, the lower the melting point

Soldering is a strain for the components to be fused – especially in the production of semiconductors, where structures are becoming increasingly smaller and more sensitive. Efforts to develop solders that melt at ever lower temperatures have yielded a radical new way using nanostructured materials. It has long been known that, with very small dimensions, the melting point of materials depends on size. The melting point of gold, for instance, is 1,064 °C; but the material already melts in the form of particles measuring just three nanometers at around 500 °C. Caused by the increased ratio of the interfaces to the overall volume, this phenomenon can also be observed in nanome-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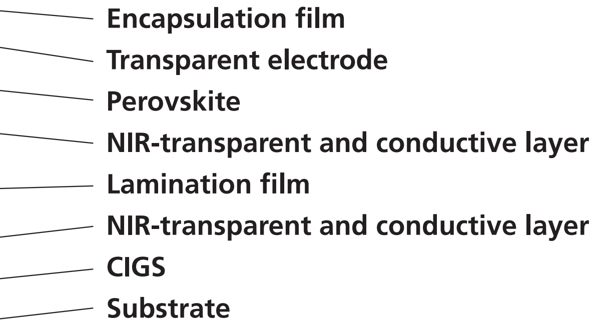
ter-thin layers. Interfaces are energetically unfavorable and thus increase the overall energy of the system. This means that less additional melting energy needs to be applied for systems with many internal interfaces, which reduces the melting point. Researchers from Empa are now looking to use this nano-based effect to develop low-melting solders. One approach is to increase the number of interfaces in the solder material by constructing a layer system from a periodical sequence of nanometer-thin layers of solder material and an inert material. Thanks to the high proportion of interfaces in this nanomultilayer, the solder material melts at a considerably lower temperature, producing a composite made of solder and inert material from the original multilayer system. //



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Schematic structure of a CIGS/perovskite tandem solar cell: the perovskite solar cell absorbs UV and visible sunlight and is transparent for near infrared radiation (NIR). This is absorbed by the CIGS solar cell underneath and converted into electrical energy.

2
Semitransparent perovskite thin-film solar cell: it absorbs the UV and visible light, and is transparent for near infrared light. It serves as the “top cell” in the perovskite/CIGS tandem solar cell.

Maximum efficiency for sustainable buildings

In this Research Focus Area, Empa concentrates on developing new materials, designing complex technical systems and integrating them in buildings and other structures. Moreover, Empa studies entire cities and their interaction with the environment. One central topic on all levels is minimizing the impact on the environment and improving the comfort and safety for users of the built environment.

Urban physics – the urban climate in our sights

In the summertime, cities frequently become "heat islands" with higher air temperatures compared to the surrounding area. Along with climate change, heat islands may in future pose a serious challenge to comfort in cities, to the health of the urban population and the energy used to cool buildings. Empa has embarked on extensive research projects to better understand the physics of the urban climate and to determine measures to address these unwelcome effects. One goal is to understand how local heat islands are generated.

Using models of building complexes, urban canyons or groups of buildings, measurements are taken in Empa's wind and water tunnel. The buildings can be heated or cooled individually, which enables solar-heated roofs or façades, or cooler areas such as roof gardens or bodies of water to be simulated. With the aid of Particle Image Velocimetry (PIV), flow speeds and turbulences can be measured. The surface and air temperature in the wind tunnel is determined with infrared thermography, the water temperature in the water channel via laser-induced fluorescence (LIF).

Bamboo instead of steel as concrete reinforcement

Emerging countries like Thailand, Vietnam, Indonesia, India, Colombia and Brazil have large bamboo resources, which can be used in a wide variety of ways thanks to new technologies. For instance, Empa is currently co-developing innovative materials with the company REHAU and ETH Zurich's Future Cities Laboratory (FCL) in Singapore that could help meet the concrete reinforcement needs in emerging countries. Bamboo is an ecologically sustainable, alternative material from renewable local resources that binds large quantities of CO_2 during the growth phase. Bamboo fibers are cheaper than synthetic materials such as glass and carbon fibers and, compared to steel reinforcements, require considerably less energy to be produced. The first highly promising prototype of a reinforcement element made of bamboo composite materials for concrete beams has already been manufactured. The new composite material achieves lower values than steel when it comes to tensile and bending strength, and modulus of elasticity. However, it only weighs 1.3 tons per cubic meter, which is far less than the density of steel.

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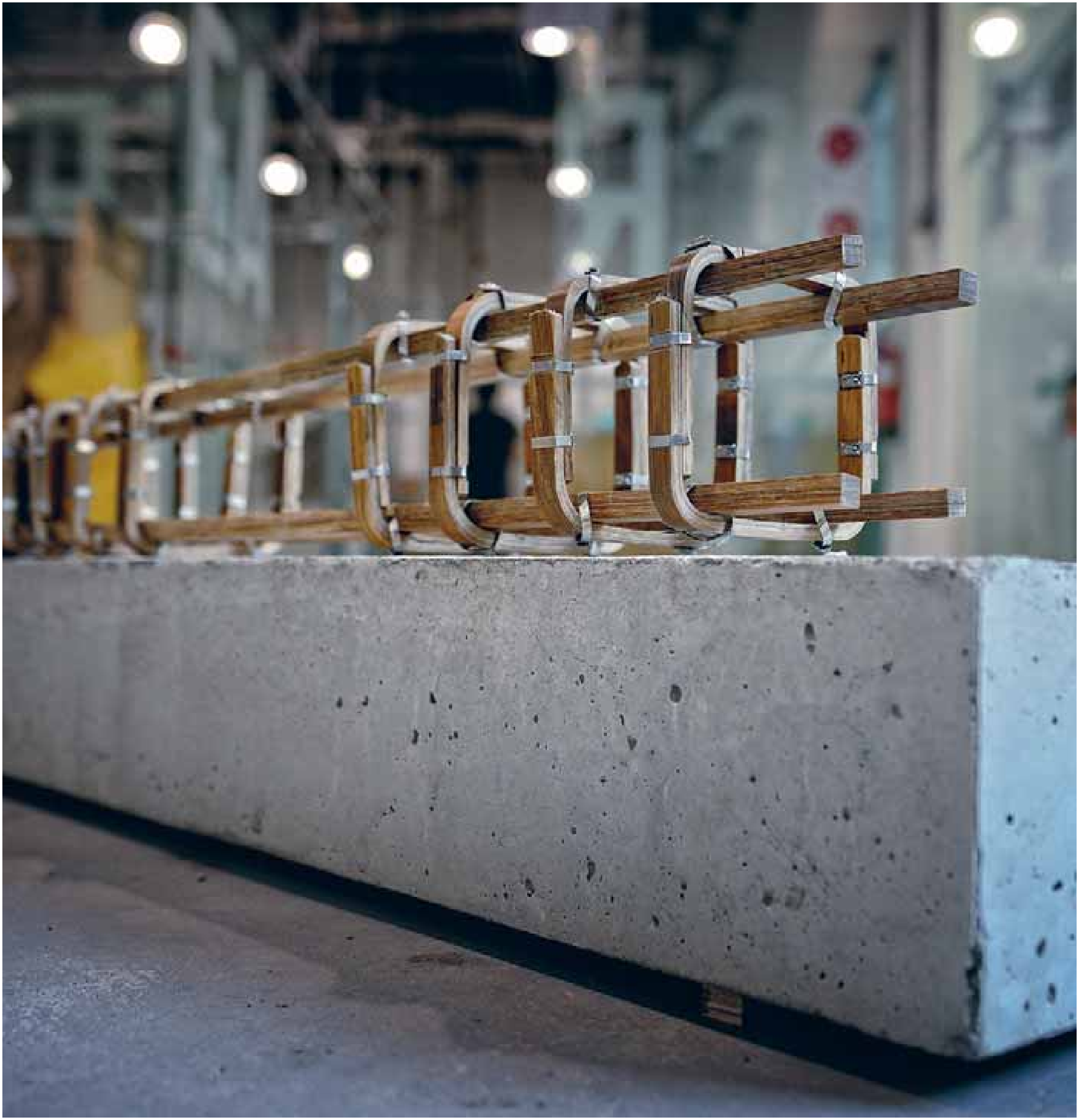
Concrete girders reinforced with bamboo composite material lengthways and crosswise.

1 

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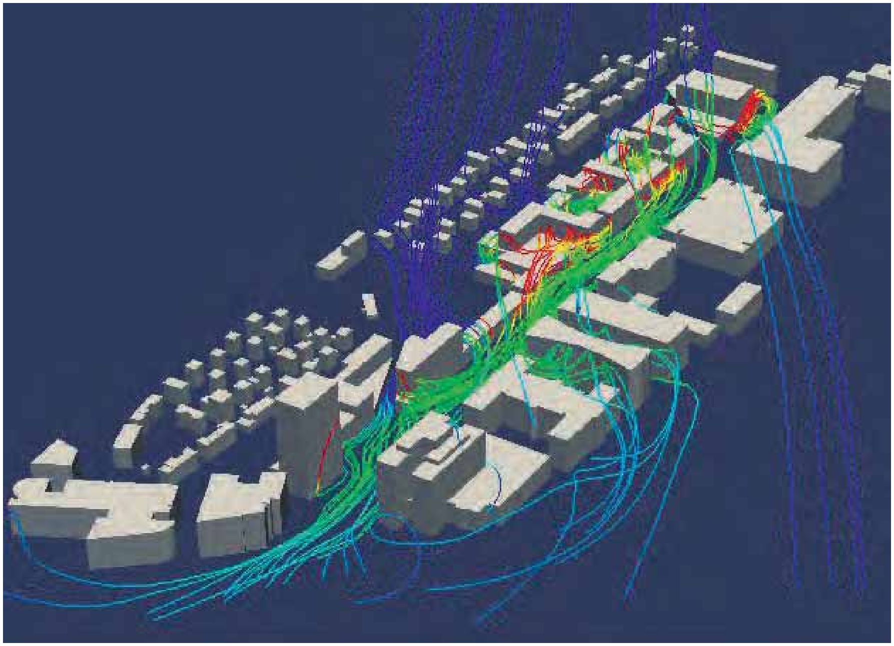

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The wind tunnel (above) and the water channel (below), which Empa and ETH Zurich co-run, are used to study how local "heat islands" in cities can be avoided, for instance.

2
Simulation of the local climate in a Zurich district: colored flow lines indicate temperature increases as evidence of local heat islands. A combination of building energy and fluid dynamics was simulated using computer-based models.

3
Façade of the Falletsche school building in Zurich (2006): high-performance pre-stressed concrete with tendons made of carbon fiber reinforced polymers (CFRP) made the filigree vertical elements possible. Photo: SACAC AG, Lenzburg, Switzerland.

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Carbon-reinforced high-performance concrete that pre-stresses "by itself"

The global trend towards filigree shapes is particularly evident in building façades in the construction industry. However, they can only partially be realized with conventional reinforced and pre-stressed concrete. In a previous CTI project, pre-stressed high-performance concrete elements with tendons made of carbon-fiber-reinforced polymers (CFRP) were developed at Empa. As they are lightweight, strong and elastic, they perform better than steel pre-stressing tendons in many respects. Moreover, they are corrosion-resistant. Thanks to CFRP tendons, considerably more filigree – and yet stable –, concrete elements can be realized. And unlike steel, virtually no pre-stressing is lost because carbon tendons do not relax.

On the other hand, the pre-stressing facilities for CFRP are just as complex as those for conventional pre-stressed concrete. In a project that recently got underway, Empa researchers are, therefore, using concrete that expands after setting and thus adds tensile stress to the CFRP tendon and compression stress to the high-performance concrete. As a result, there is no longer any need for pre-stressing from outside, thus making the production process considerably more straightforward (and cheaper). Using this technique, which is described as chemical or self-prestressing, only low pre-stresses could be produced thus far. Thanks to a new concrete formula and new CFRP tendons with an elasticity modulus of over 460 GPa, however, the Empa team has now achieved considerably higher, permanent pre-stressing.

The pre-stressed concrete girders produced with this new technique are on a par with conventional pre-stressed girders in terms of bending strength and stiffness. Thanks to the self-prestressing, elements can even be pre-stressed in two directions. Even curved pre-stressed elements are feasible. The invention is already patent-pending and Empa is currently looking for industrial partners to refine and market it. //

Reducing emissions – for a sustainable future

Constant population growth inevitably leads to an intensification of activities on both a regional and global level. The resulting emissions, pollutants from industrial processes, and pollution and noise from the increasing mobility compromise both the environment and society. Curbing these emissions is therefore crucial for a sustainable future with an intact environment and a healthy population. One of Empa's main goals is to analyze the origin of the emissions and generate knowledge to introduce technical reduction measures and pave the way for political decisions.

Low-cost sensors with unique possibilities

Novel, affordable and battery-powered sensors can be used in large numbers and harbor the potential to provide information on the environment in an unprecedented spatial and temporal resolution. This opens up new possibilities to determine emissions directly and thus evaluate the health hazard for the population in urban centers.

Empa researchers teamed up with various partners to co-develop a concept to implement this new, as yet little researched approach, in practice. The Empa spin-off Decentlab is involved in the integration of the sensors and data communication; telecommunications specialist Swisscom and the new Swiss Data Science Center are also on board. More than 300 of these sensors have been combined with high-precision measuring stations, and linked up and validated with the aid of statistical algorithms and atmospheric transport modeling. The project ought to be pioneering for the future, where new data transfer concepts such as low-power networks and the Internet of Things will revolutionize this approach even further.

Fighting for nitric oxide abatement

"Selective catalytic reduction" is the most efficient method to reduce the emission of nitric oxides in the exhaust from diesel and lean-burn gas engines. If one of the normally liquid reducing agents, such as urea solution, is added correctly, only the harmless products nitrogen (N_2) and water (H_2O) result. Administering the correct dosage of reducing agent into the hot exhaust gas, however, is extremely complicated as the injection has to be designed in such a way that as few by-products are formed as possible.

Empa researchers studied in detail the transmission of heat and material, and the evaporation and crystallization as the injected reducing agent hits the exhaust gas wall. Laser measuring techniques provide an indication of the size and movement of the droplets, and the heat exchange and local evaporation were analyzed using infrared thermography. The insights gained are a major step towards reducing nitric oxides in combustion engines efficiently.

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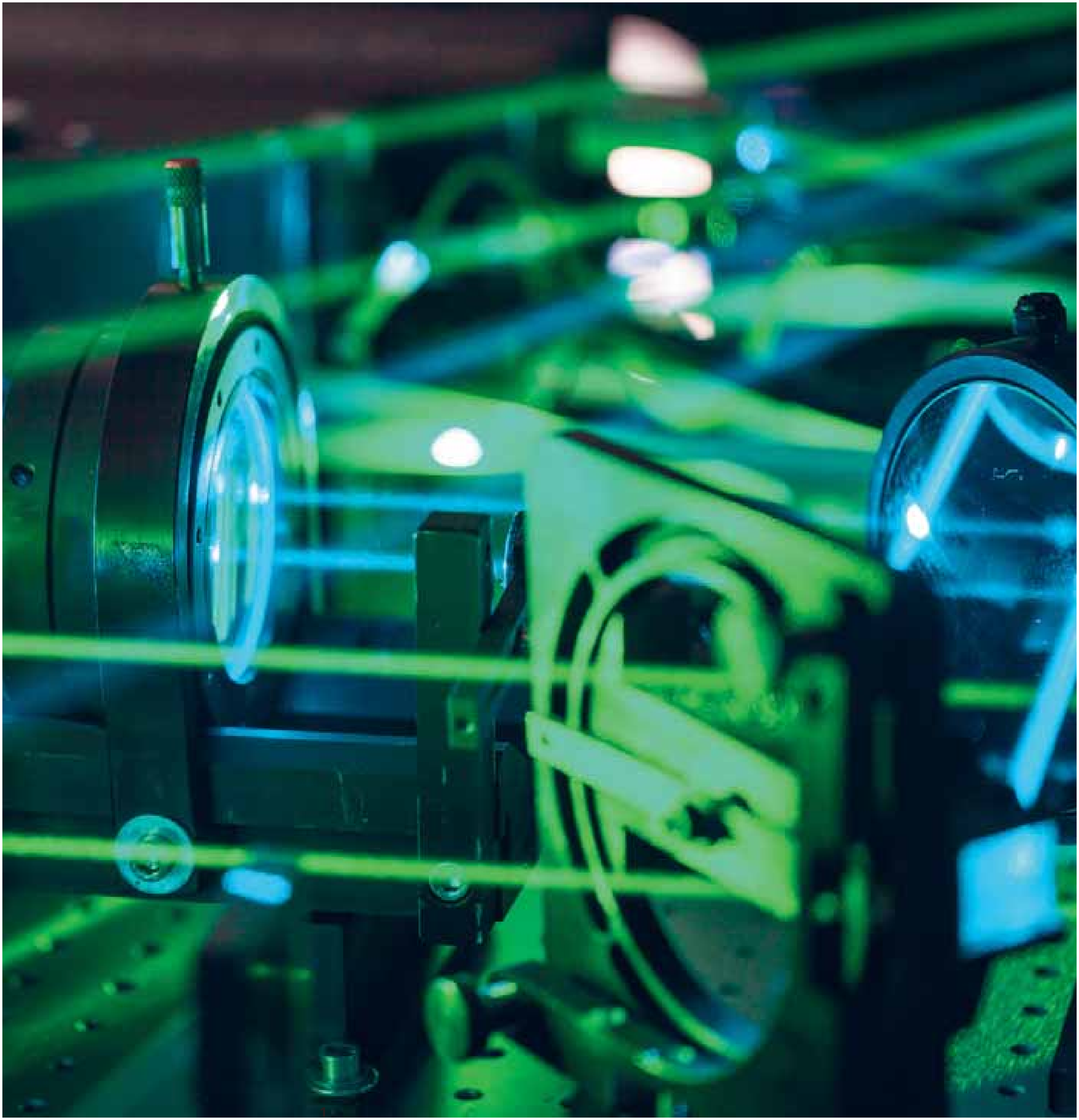
Laser measuring equipment like this phase Doppler anemometer provide an insight into the size and movement of the droplets of reducing agent during catalytic nitric oxide reduction in diesel engines.



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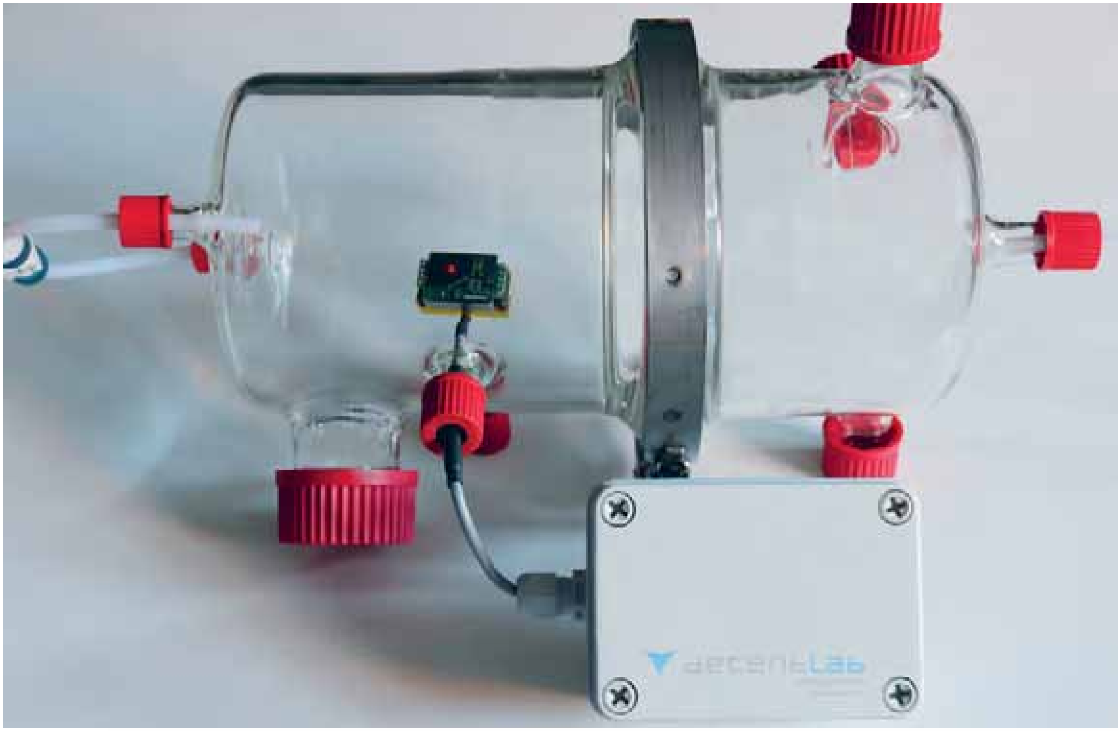

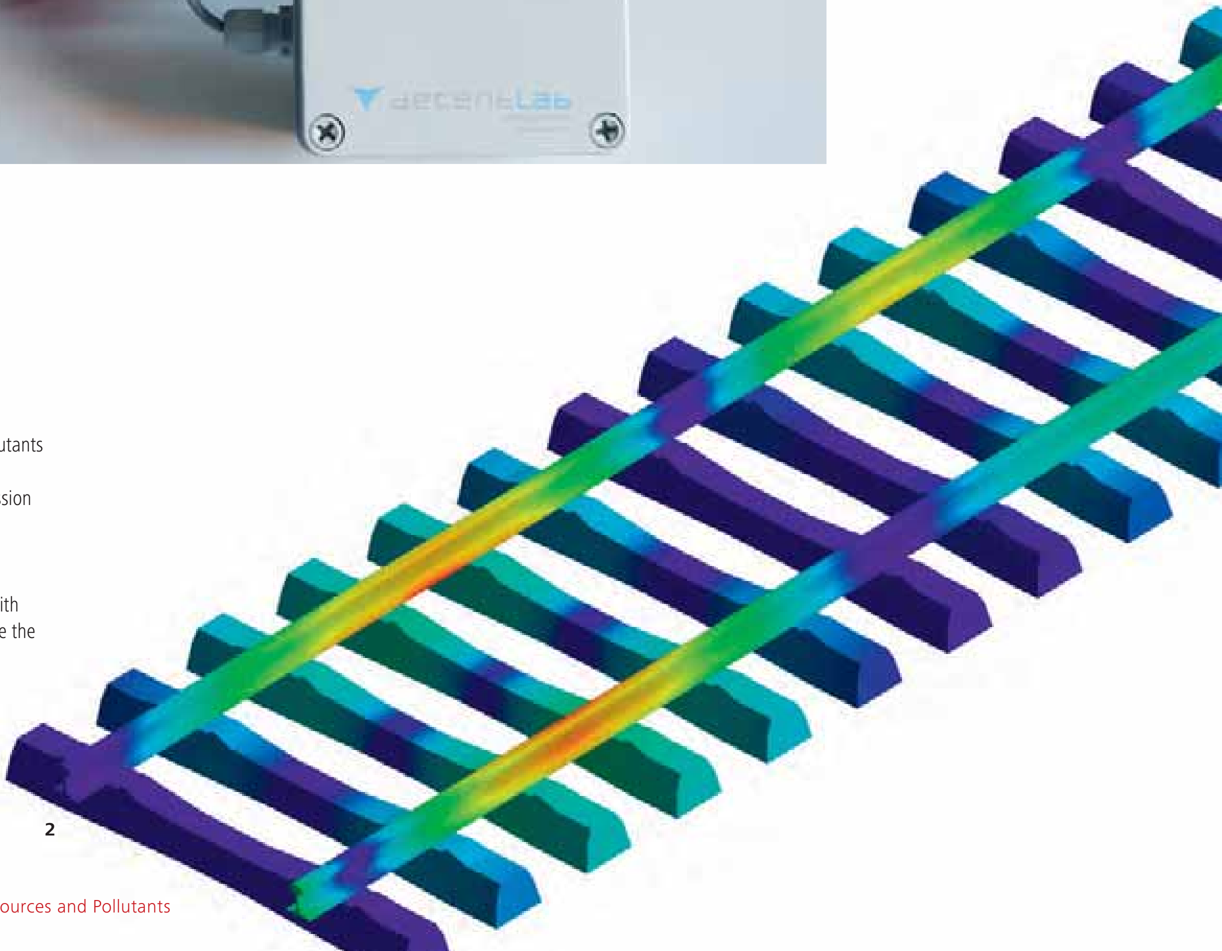
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A low-cost sensor to determine air pollutants being tested in Empa's calibration lab, complete with integrated data transmission for the network.

2
Vibration forms of rails and sleepers (with harmonious stimulus); basis to calculate the noise emissions.

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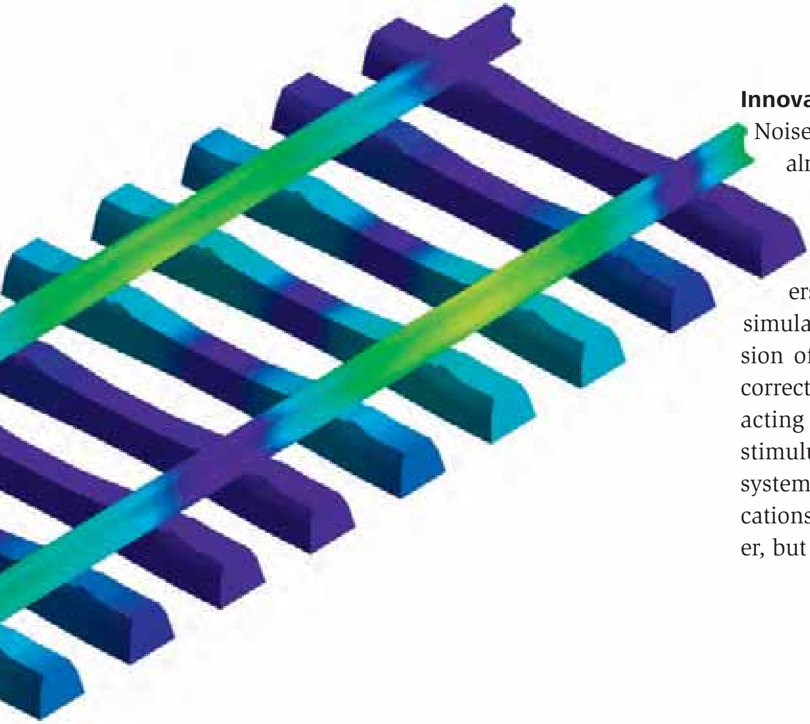

Innovative solutions for noise reduction

Noise has an undesirable impact on our bodies and psyche, and already affects our quality of life at levels way below the legal limits. In light of our increasing mobility, planning and technical measures are crucial to protect the population effectively against traffic noise. Empa researchers teamed up with partners to co-develop an innovative simulation tool that enables the sound generation and the emission of rolling noises of trains to be modeled in a physically correct manner. The driving dynamics model, which simulates acting forces and stresses realistically, enables the vibration stimulus and the associated noise emission of the entire rail system to be calculated. This paves the way for targeted modifications to the railway tracks with a view to making trains quieter, but also safer and longer-lasting with fewer vibrations. //

Energy – utility or futility

From hot chocolate to warm living rooms – nothing works without energy. In recent years, there has been a significant increase in awareness of the pivotal role that energy plays in our lives. Driven in part by the government's energy strategy, many innovative ideas have emerged, and scientists are working feverishly to implement them, including at Empa. Not all of these ideas contribute to the challenges of a sustainable energy future in equal measure, however; some – on the grand scheme of things – are even worse than today's systems in the long run. By the same token, there are technologies that are less energy-efficient but still more sustainable.

Therefore, to distinguish between their utility and futility, Empa is laying the foundations for a sustainable infrastructure for the comprehensive and transdisciplinary consideration of the production, storage, conversion and provision of energy in its Research Focus Area Energy. Last year, the focus was on getting various demonstration and research platforms up and running, establishing the new research group Energy System Impact Analysis (short for "esys") and forging new partnerships with players from the energy industry.

Research and demonstration platforms

Our energy system is changing increasingly dynamically. For instance, new market players offer solutions for the private consumption of solar energy, the costs of battery storage devices are dropping dramatically and there are new concepts for seasonal heat storage systems. Due to digitization, the Internet of Things, electro-mobility and its intelligent combination with buildings, changes to the various networks are being controlled directly by the network operators increasingly less. These bottom-up developments have a direct influence on the energy supply. The research platform ehub (short for Energy Hub) was created to study the impact of these changes (see page 51). Numerous energy technologies were integrated in 2016 – ranging from harvesting, conversion and storage all the way to transportation. The mobility platform move (see page 45) is linked to the building research in NEST (see page 42) via ehub. Switzerland's first 700-bar hydrogen station at move has enabled hydrogen-powered cars to be refueled since October 2016. The facility is used to analyze real-world energy and consumption values, which can then flow into overall models. In conjunction with Empa, the Federal Institute of Metrology (Metas) is devising calibration procedures for hydrogen stations. And the Swiss national accident insurance Suva and the corresponding administrative bodies are compiling guidelines for the approval of hydrogen stations. This unique constellation now enables the interplay between various storage technologies, future forms of mobility and the district of tomorrow, as exemplified at NEST

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Partial view of the numerous technical installations in the cellar of the research platform NEST. Photo: Roman Keller

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with its independent units, to be researched under real-world conditions. With its demonstration and research platforms, and their interconnection, Empa has created optimum conditions for holistic, cross-system observations. Its energy research helps integrate new technologies meaningfully in the overall system. Consequently, Empa supports its partners from industry, society and science with new findings.

Within the scope of the ETH Domain's Energy and Mobility competence center (CCEM) and the Swiss Competence Center for Energy Research (SCCER) Future Energy Efficient Buildings & Districts, models and concepts for decentralized, renewable energy systems were developed and already implemented in "real" areas and districts. In order to be able to store heat seasonally – i.e. for extended periods – the heat and mass exchanger for water vapor absorption in sodium hydroxide solution was refined. These projects are being continued in the SCCER Heat and Energy Storage. Self-learning energy distribution technologies that do not need to be controlled centrally are integrated in ehub. Moreover, the impact of local energy production and the change in local energy demands through new building and mobility technologies are being researched.

Materials research to serve energy

Developing new technologies and improving existing ones are key prerequisites to realize new energy strategies. In the RFA Energy, for instance, researchers are therefore working intensively on highly efficient, flexible thin-film solar cells, particularly alternative materials and processes for tandem solar cells.

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New material syntheses and coating processes for innovative batteries are being researched. In order to render our energy system more sustainable, high-temperature components in power stations, energy transfer systems and combustion engines need to become more reliable and durable. This is also being researched at Empa with the aid of thermomechanical experiments, the microstructural analysis of materials, and computer models. One example is Empa's research on high-voltage cables. Scientists are studying factors such as aging and temperature behavior, expansion (which causes sagging), and the material's creeping behavior in detail, and evaluating viable measuring methods. This increases their conductive capacity and makes them much more efficient to maintain. //

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Facility to test cables for high-voltage overhead powerlines. Researchers are studying the material's aging, temperature and creeping behavior, and evaluate viable measuring methods.

Materials research for the life sciences

The aim of the Research Focus Area Health and Performance: to develop innovative, sustainable technologies and products for the textile, biotech and medical engineering sectors at the cutting edge between materials research and the life sciences. Interdisciplinary know-how in the fields of textiles, materials science, biology and nanotechnology is pooled here. Empa concentrates on materials for medical applications in and on the human body, and conducts research on new materials and systems that protect and help people in their daily lives.

Innovative drug administration and health monitoring systems

One of the things Empa researchers are developing is new encapsulation systems to deliver therapeutic substances to the right place in the human body or protect sensitive molecules such as proteins and peptides so they can be broken down more slowly. For instance, they succeeded in "packing" antibacterial peptides in novel nanocarriers made of lipids so they are effective against bacteria for longer in the body. Besides classic methods from colloidal chemistry, the researchers increasingly use approaches from microfluidics to pack active molecules. Before such nanohybrid systems can be developed, the chemical and physical interactions between the molecules need to be understood. With this in mind, Empa keeps expanding its analytic and modeling possibilities further.

In order to develop sensor systems for health monitoring, expertise from different specialist fields is required. This includes functional surfaces, but also new materials that are able to alter their optic or electrical properties due to their structure or chemistry, for example. Researchers at Empa recently developed a specific hydrogel, for instance, which is capable of displaying two different indicators of the early wound healing phase simultaneously: the pH value and glucose metabolic products. An optic biosensor was able to reveal that a gradient structuring beneath the surface can influence the accumulation of proteins significantly.

Smart implants and models for the human body

In order to test the increasingly more sophisticated material concepts in the medtech sector, such as adaptive release systems or smart surfaces, more effectively and be able to predict how they work in the body, physiological model systems constantly need to be improved. For instance, Empa researchers developed human microtissue or organoids, three-dimensional cell culture systems made of different cell types modeled on particular tissue types. They thus research transport processes for nanomaterials through the human placenta, for example, by studying in detail the reaction of the various cells to nanomaterials and the interactions between the cell types triggered as a result. A better understanding of these processes paves the way for the devel-

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Scanning electron micrograph image of bacteria on a ureteral stent.

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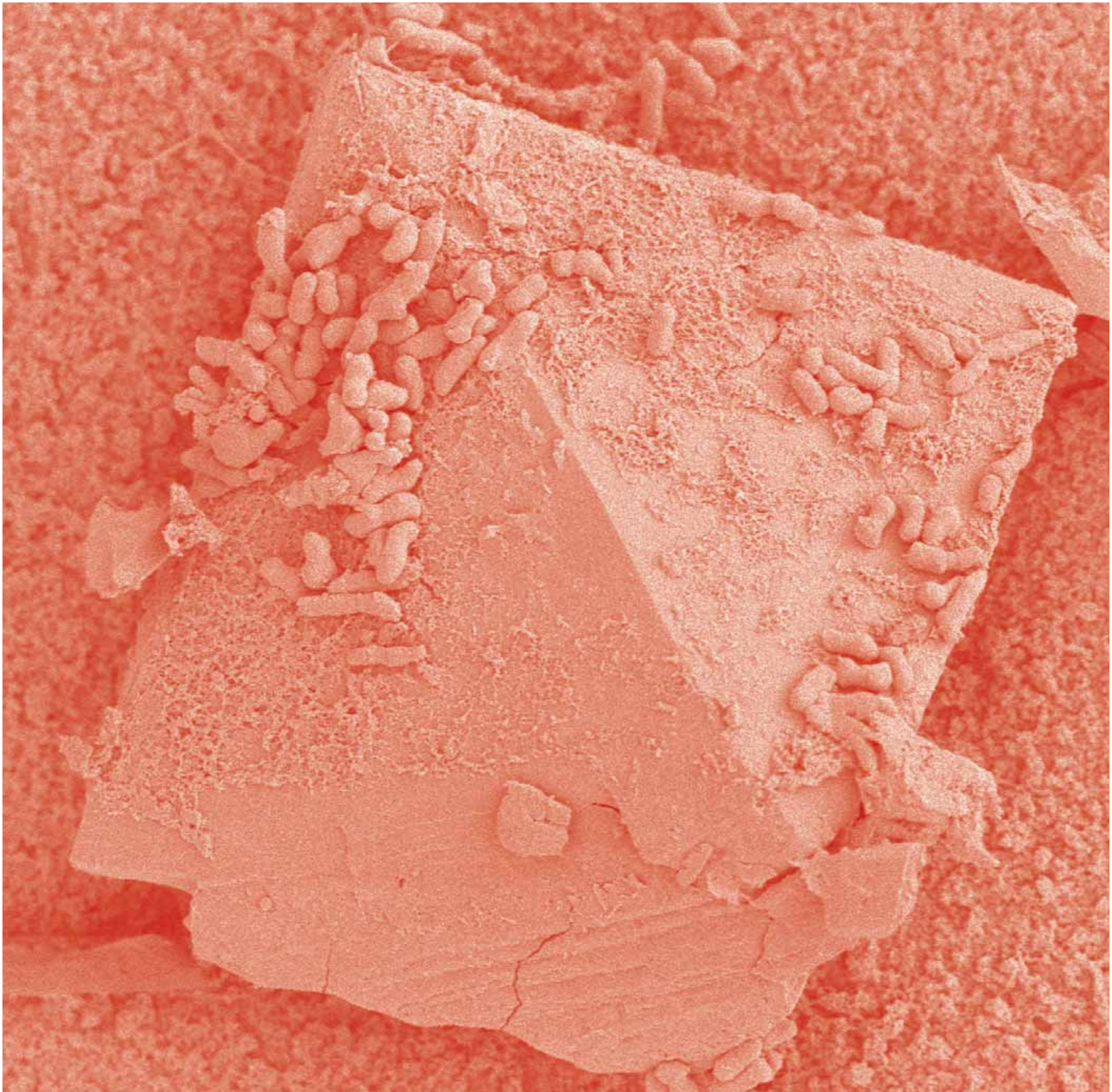

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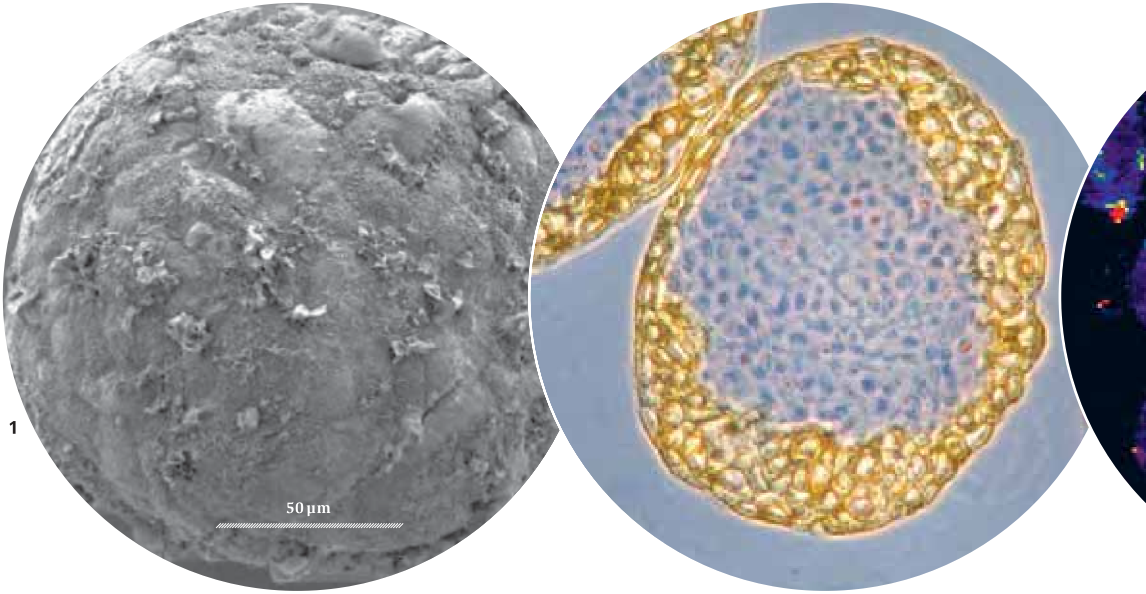

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Empa researchers developed microtissue (left, scanning electron image) with a nucleus made of placental fibroblast cells (blue, center) and a shell made of trophoblast cells (yellow, center). These facilitate mechanistic studies on the absorption and penetration of different nanoparticles at the placenta barrier (right: laser ablation ICP-MS analysis of microtissues which are exposed to gold nanoparticles).

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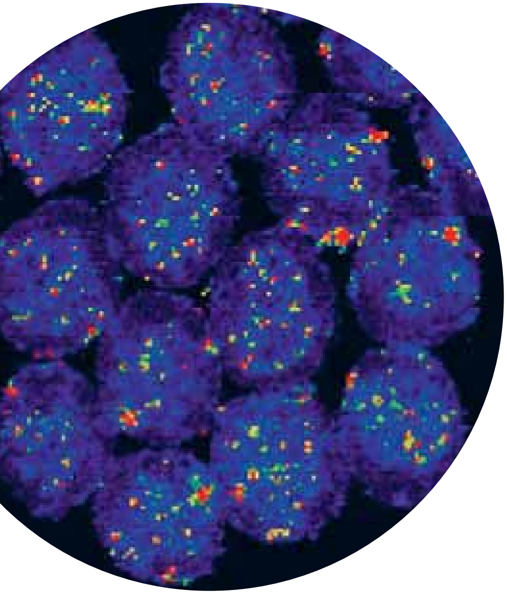

opment of safer nanomaterials, but also new (personalized) drug delivery systems for nanomedicine.

In order to reduce the risk of infection during surgical interventions, there is an urgent need for antimicrobial materials for medical instruments and implants such as catheters, which are used to treat a blocked urethra, for example. After all, microbial biofilms can form on the surface of the catheter and were difficult to combat until now – mainly because there are no effective biofilm models that simulate the situation in the patient's body and thus enable a prediction of the antimicrobial colonization of the implants. A team from Empa and St. Gallen University Hospital recently began studying the correlation between the development of biofilms on implants and symptoms in affected patients. //


ACHTUNG
X-Ray
Strahlung

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 500 highly qualified scientists and top-class infrastructure, Empa is the place to be.

Using collaborations to speed up the innovation process

With increasing cost pressure from globalization and the strong franc, innovation is becoming a key competitive factor for Swiss companies. This is one more reason to step up the collaboration between industry and research institutions in order to bring innovative ideas onto the market sooner.

Once again, in 2016 the number of new research agreements rose by 13 percent to 177 compared to the previous year, the majority of them with partners from industry. Moreover, the sections reported 28 inventions that ultimately resulted in 14 new patent applications. And 13 new license and technology transfer contracts were agreed on with industrial partners.

Red ceramics for the watch industry

For instance, Empa pulled off a masterstroke of ceramics research: a bright red ceramic bezel for a Swiss luxury watch – a stunning feat of top-flight materials research. Within the scope of a CTI project, Empa set about developing a red ceramic material that meets the high demands of the watch industry. The new material had to be non-toxic, which ruled out any compounds containing lead or cadmium for color schemes. A glaze on the ceramics was also unsuitable as it could chip off under high load. The

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On the platinum Omega Speedmaster Moonwatch, the bezel, the moon dial and the data magnifier frame are all made of red Empa ceramics. Photo: Omega

bezel therefore needed to be produced from colored ceramics that would also survive the subsequent engraving of the letters and numerals unscathed. And so the Empa team opted for aluminum oxide as their material of choice – a common, white ceramic material used in artificial hips or as a seal in taps, for instance. Months of experimenting followed, where the researchers specifically mixed tiny amounts of chromium as well as inorganic additives into the ceramics. The multi-stage process to produce red ceramics was co-developed by the Swatch Group and Empa in a CTI project. The extremely complex production path has been protected by a patent application in March 2016. The top-of-the-range model in the Omega Speedmaster Moonphase collection, adorned with the red Empa bezel, is the limited platinum edition with only 57 pieces worldwide.

Removing biofilms from medical instruments and endoscopes

Endoscopes and medical instruments with a small inside diameter are prone to the build-up of biofilms – and thus pose a risk of infection for patients. As aggressive chemicals must not be used to clean them, gentle treatments are called for. Therefore, Empa and Borer Chemie AG set about developing in a CTI project an effective enzymatic cleaner for medical instruments that removes biofilms.

A biofilm consists of extracellular polymer substances (EPS), which contain polysaccharides, proteins and nucleic acids, for instance. The Empa team uses enzymes that are primarily effective against EPS in a biofilm. The scientists also took advantage of the industrial partner's specific knowledge of the composition of cleaning agents for a new formulation that enables top-class cleaning and the effective removal of biofilms from surgical instruments and endoscopic materials. Finally, a disinfection step kills of bacteria and creates a hygienic surface.

Electroforming for complex metallic alloys

The LiGa technique is an additive production method that combines lithography, electroplating and electroforming, which helps to produce extremely high-precision metallic microcomponents. In many branches of industry, there is an urgent need for metals with good mechanical properties that are simultaneously non-magnetic or corrosion-free. Since 2006, an Empa team has been developing several alloys that are suitable for electroforming, including stainless steel.

In the past, it was not possible to electroform stainless steel and complex nickel alloys. Within the scope of a CTI feasibility study, Empa researchers, however, formulated an unique recipe for the bath to also electroform alloys such as stainless steel. The upscaling from the laboratory scale was achieved via

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numerical simulations of the local current density and exact organic additives. Thanks to fundamental insights into electroplating, microstructure and mechanical properties, alloys could finally be produced in a quality that met the demands of the watch industry. Patent applications are pending for all these new material developments for the LiGa technique. //

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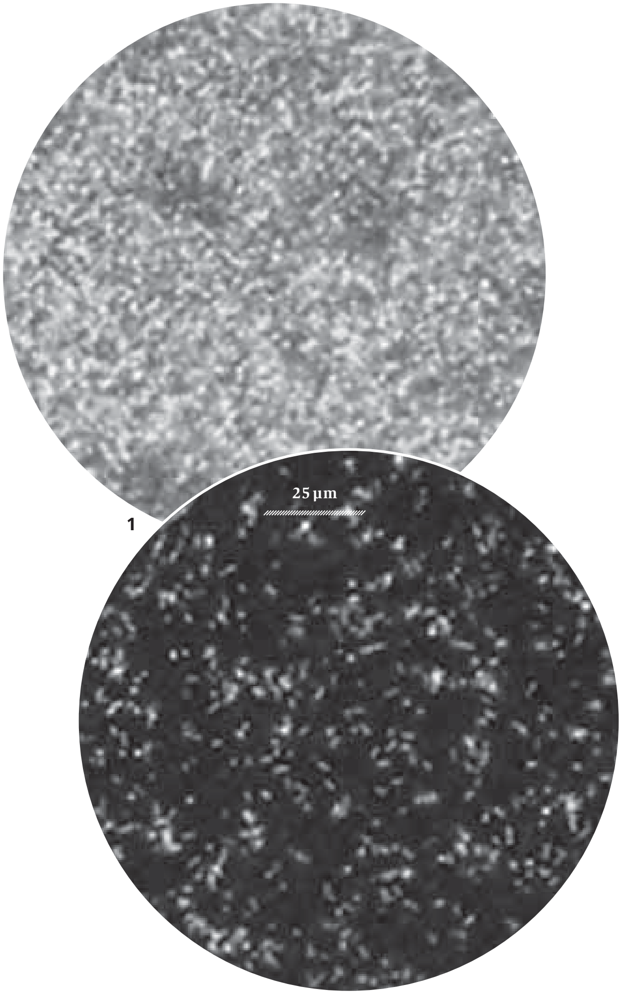

1
Bacteria that remain behind after cleaning the endoscope tube: a) after treatment with water (above), b) with a new formulation developed at Empa (deconex® PROZYME ACTIVE). The white blotches are the bacterial cells.

Called for and encouraged – from the idea to market launch

1
CoWorkingSpace in the new Startfeld Innovation Center.

Last year, 47 start-ups with a total of 290 employees were supported from the kernel of an idea to their launch on the market in Empa's business incubators. Here are two examples.

Fighting fungi with fungi

MycoSolutions, a spin-off from the Empa department Applied Wood Materials, is a technological pioneer throughout Europe when it comes to the efficient use of fungi. Today, fungi are one of the most important groups of organisms in modern biotechnology and used on an industrial scale to produce food, feedstuffs and a vast range of metabolic products such as antibiotics, enzymes and steroids. Fungi play an increasingly important role in "green" biotechnology, where previously unused species of fungus are opening up new methods and fields of application, such as in environmental protection and biological pest control. MycoSolutions uses different fungal structures, such as mycelium and spores, and enzymes and polymers to develop tailored solutions and products for wood and soil treatment. The innovation all began with a CTI project. In 2016, MycoSolutions became a public limited company and could attract investors, including a private investor and Swisscom Ventures. The fledgling company is based right next door to Empa in the new Startfeld Innovation Center in St. Gallen.

1 

A magic tent for the outdoor market

Since December 2016, the all-in-one bivouac system developed by start-up Polarmond has been commercially available. The original vision of the company's founders to protect refugees and the homeless from hypothermia and even freezing to death led to the

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development of the world's first bivouac that warms itself up and can regulate the temperature with an integrated dehumidifying management system. In an initial step, it is now destined for the outdoor market. Thanks to the collaboration with Empa, the University of Applied Sciences Rapperswil and the Schweizerische Textilfachschule (STF), the first products are now ready for the market. While the company was finding its feet, Polarmond was supervised and supported by Empa's two business incubators, glatec and Startfeld. The goal is to make similar shelter systems available to the needy in future.

The patented bivouac system combines the conventional features of a sleeping bag, a vapor barrier liner, a camping mat and a tent in one single product. The spacious sleeping area warms up solely with the body's own heat thanks to a high-tech insulation layer co-developed by Empa and Polarmond which consists of a swellable synthetic filling with reflective layers. Another problem was to ensure that the moisture is transported outside while keeping the insulation layer dry. This was achieved thanks to a novel sleeping area concept, designed with a full vapor barrier. Adventurers and nature lovers enjoy a cozy night's sleep – despite outside temperatures as low as –30 °C. //

1
Empa fungus researcher Francis Schwarze with pellets that can be scattered around trees with a view to biological pest control.

The bridge from research to application

Empa has made bridging the gap "from science to business" its motto. Thanks to individual forms of collaboration and its broad range of services, Empa is able to offer its partners tailored solutions with a view to developing new products, optimizing existing technologies or solving concrete problems. Demonstrators like NEST, move and ehub, and networks such as the research initiative Subitex make a key contribution towards this network and triggered a significant increase in Empa's collaborations with industry in 2016.

1
The Empa Innovation Award was already presented for the eighth time in 2016.

2
Prototype of a full-textile pressure sensor based on light-conducting polymer fibers: the sensor was developed for a bedsore bedsheet in conjunction with the company Schoeller Medical AG, one of the Subitex partners.

1

Shortening the time to market for sustainable medical textiles

In order to exploit the potential of textiles in and on the human body more effectively – and turn them into innovative applications – Empa launched the research initiative Subitex (sustainable biotechnological textiles) in conjunction with partners from the textile industry and other sectors. The development and use of novel materials, fibers, tissues and techniques should secure a long-term competitive edge for Swiss textile companies on the global market. Applications in the field of optic sensors, such as optically conductive fibers, or novel biosensors and even polymer multicomponent fibers such as fluid-core fibers and nanofibers with antioxidative properties or membranes for the con-

2

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trolled dispensation of drugs through the skin are particularly interesting. Meanwhile, 15 partner companies are now on board. Eight of the research projects backed by the Commission for Technology and Innovation (CTI) and one project within the ETH Domain's Competence Centre for Materials Science and Technology (CCMX) are already underway.

A ten-year success story

The Empa Innovation Award, which honors researchers who bridge the gap between science and industry with their applied and market-oriented research, was already presented for the eighth time in 2016. The 2016 award went to chemist Sabyasachi Gaan and his team in recognition of their development of a new, non-toxic and environmentally friendly fireproofing agent for the production of flame-retardant polyurethane foams, which are used in mattresses, seat upholstery and insulation modules for house façades, for instance. The prize was awarded on 8 November against the backdrop of the Empa Technology and Innovation Forum.

When Empa presented its first Innovation Award back in 2006, no one could have imagined what was to follow. Today, the prize is regarded as a landmark accolade on the path towards economic success. Although all the winning projects were technically on point when they won the award, they were yet to realize their full economic potential. However, they all have one thing in common: each and every one of them paved the way for an economically relevant innovation, which served as the basis for economic success. In 2010, for instance, Michael Sauter and Gion Barandun, the founders of the Empa spin-off Compliant Concept, won the Innovation Award for their intelligent hospital bed. The new Sunnegarte dementia ward at Sunnewies nursing home in Tobel (Thurgau) became one of the first centers in the world to be equipped fully with Mobility Monitor beds. The comprehensive sleep monitoring system should improve the patient's quality of sleep and pain monitoring. And in 2012, the prize went to Thomas Stahl, Samuel Brunner, Mark Zimmermann and Matthias Koebel for their special super-insulating aerogel plaster, which they co-developed with the company Fixit. The industrial partner launched the product on the market in 2013 and meanwhile sells it all over Europe together with its affiliates Röfix (Austria) and Hasit (Germany). //

Extensive international network

Nanosafety research is an international concern that links Empa to various globally renowned institutes. After Empa helped set up the new Korean Center for Nanosafety Metrology in 2015, a cooperative agreement was concluded with the new center located at the Korea Research Institute of Standards and Science (KRISS) in Daejeon in 2016. The contract paves the way for a KRISS office at Empa in St. Gallen and close scientific collaboration between various research departments at both institutes.

Nanotechnology is regarded as a key technology, and not just in western countries, either. Thailand, for instance, also regularly attends international forums, such as those organized by the OECD workgroup for processed nanomaterials. The international nanotechnology conference NanoThailand, which already took place for the fifth time in 2016, just goes to show how highly the country rates the importance of nanosafety. Empa researcher Harald Krug, who was a member of the Advisory Board for the conference, gave a plenary speech and chaired events on the topic of nanosafety.

Collaboration initiated with AIST in Japan

During a trip to Japan, Empa Director Gian-Luca Bona visited the National Institute of Advanced Industrial Science and Technology (AIST) and presented the latest results from diverse research activities at Empa. He then signed a Memorandum of Understanding (MoU) with Norimitsu Murayama, General Director of the Department of Materials and Chemistry at AIST, which like Empa is a public research institute with close ties to industry. AIST also concentrates on implementing new technologies and endeavors to transform laboratory results into a successful product together with industrial partners.

1
The international nanotechnology conference NanoThailand was already held for the fifth time in 2016, this year with the active involvement of Empa.

NanoThailand 2016
The 5th Thailand International Nanotechnology Conference
crest

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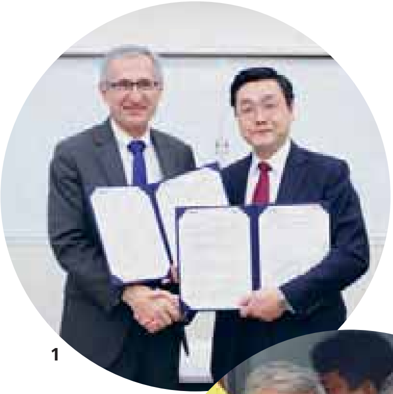

Cross-border innovations for the future

This was the motto of two congresses held at Empa in late September: one on the topic of electromobility, the other on climate protection. It was hosted by the canton of Zurich government, which chaired the International Lake Constance Conference in 2016. Together with Zurich's Economic Director Carmen Walker Späh, Empa Director Gian-Luca Bona was able to welcome more than 50 representatives from municipalities, districts and federal states from Bavaria, Baden-Württemberg, Vorarlberg, Liechtenstein and the cantons of Schaffhausen, Thurgau, St. Gallen and the two Appenzells in Dübendorf for a cross-border exchange of knowledge, the presentation of innovative concepts and the development of joint initiatives.

A new open access journal for construction research

In March 2016, RILEM (the International Union of Laboratories and Experts in Construction Materials, Systems and Structures) launched a new open access journal entitled RILEM Technical Letters. It is freely available online and features the latest advancements in building material research online (letters.rilem.net). RILEM Technical Letters is the first autonomous specialist journal for the RILEM association, which thus aims to explore new avenues in academic publishing – including completing the peer review process for the articles submitted within only a few weeks. Two Empa researchers are actively involved in the new publication: Pietro Lura as Deputy Editor-in-Chief and Mateusz Wyrzykowski as Managing Editor. //

1
Empa Director Gian-Luca Bona and Norimitsu Murayama from the Japanese National Institute of Advanced Industrial Science and Technology (AIST) with the signed Memorandum of Understanding, which paves the way for a closer collaboration between the two institutes.

2
Korea Research Institute of Standards and Science (KRISS) opened an office at Empa in St. Gallen with a view to boosting the close scientific collaboration between departments from both institutes.

Broad range of research on show

At the Empa Academy, the newly opened demonstration platforms NEST and move, and the Coating Competence Center and the Center for X-Ray Analytics, which visitors could see for themselves at numerous special, specialist and public events, were also pivotal in 2016. As every year, there was also a mixture of conferences, congresses, courses and lectures on various other research topics at Empa. Around 9,000 people attended roughly 90 events, including 3,800 at the open day to mark the twentieth anniversary of the Empa campus in Moos, St. Gallen.

Fuel cells in car applications

Just how safe, sustainable and economical are hydrogen-powered vehicles? This was the question that around 300 experts and members of the interested public addressed during a conference held at Empa. While the safety of hydrogen vehicles has been established, one factor plays a crucial role in the sustainability of the new technology: where does the energy needed to produce the hydrogen come from? Invited by Empa, the Paul Scherrer Institute (PSI), ETH Zurich and inspire AG, top guest speakers talked about the production of hydrogen for mobility, its logistics, the market opportunities and the sustainability of using hydrogen as a fuel.

Energy + Building congress

Against the backdrop of the Energy Days St. Gallen, the Empa Academy held the second Energy + Building congress in May in conjunction with the competence center Future Energy Efficient Buildings & Districts, whose vision it is to slash the end energy needs of Switzerland's building stock fivefold in the next few decades through efficient, intelligent and interlinked buildings. Under the motto "From research to practice", the congress revealed how research results are realized based on concrete examples of energy-efficient building and the areas and districts of the future in practice.

25 years of carbon-fiber-reinforced plastic in construction

The building sector has been using carbon-fiber-reinforced plastic (CRP) for 25 years to stabilize supporting structures made of reinforced concrete, such as bridges – all based on an idea from Empa. CRP is much lighter and more resistant to fatigue and corrosion than steel, which was deployed in the past. CRP was first used to renovate the Ibach Bridge in Lucerne in 1991. Numerous successful projects have followed ever since – and there is no end in sight. Reason enough to hold an anniversary symposium dedicated to the topic at the Empa Academy, which 129 participants from Empa attended in August.

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1
The Swiss astrophysicist and astronaut Claude Nicollier at the PhD symposium telling the students about his experiences in space.

2
A packed room at the Empa Academy – in this instance, the inauguration of the Coating Competence Center (CCC).

3
Empa researcher Thomas Geiger (left) explaining to a visitor how a 3D-Bioplotter works.

Fibers and membranes with new properties

Sub-micrometer and nanoscale fiber membranes produced using an electrospinning method are expected to yield novel functions for a wealth of products and applications. Empa held a workshop on the topic in St. Gallen, which examined aspects of electrospinning and fiber and membrane properties for relevant applications in textiles, medical engineering and sensor technology. Technologies that have already been implemented and novel manufacturing facilities and products were presented and discussed.

A space adventure

The annual PhD symposium, which gives young doctoral students a platform and opportunity to gain feedback on their talks and posters from experienced researchers, took place on 14 November. Much like Empa itself, the presentations were extremely diverse: talks on nanomaterials were just as much a feature as ones on solar cells and biochemical processes. One highlight was the plenary speech by Swiss astrophysicist and astronaut Claude Nicollier, who talked about his experiences in space. //

High season at Empa


1

Last year, Empa was a hive of activity. Various big occasions catered for an unprecedented flow of visitors at the two Empa sites in Dübendorf and St. Gallen. And the large-scale research platforms NEST, move and ehub, as well as the Coating Competence Center (CCC), all of which opened their doors in 2016, attracted an even larger crowd – thus already fulfilling their "lighthouse" role for Empa.

A marathon of events

The 2016 series of events kicked off on 7 April in the presence of around 130 guests from industry, research and politics with the inauguration of Empa's new CCC, where tailored surface technologies make their way from the research labs to marketable industrial applications. As a result, the CCC is looking to help the Swiss engineering, electrical and coating industry succeed on the global market through innovations (see page 48). The CCC is merely the first step, though; Empa and its partners are already working on expanding the CCC into a Swiss Competence Center for Advanced Manufacturing with various locations all over Switzerland.

Barely seven weeks later, it was already time for the next drumroll: the official inauguration of NEST, the building lab of the future, on the Dübendorf campus. Speaking in front of around 250 top representatives from industry, research and the


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2

1
Member of Empa's Board of Directors Alex Dommann telling visitors about the latest from his department Materials Meet Life on the Open Lab Day in St. Gallen.

2
Dirk Hegemann (far right) enthralling visitors with a "fire tornado" on the Open Lab Day. By turning the outer mesh, oxygen is added to the flame and a rotating pull twists the flame upwards.

3
A team of VIPs, including Federal Councilor Johann Schneider-Ammann, opening the innovative building laboratory NEST on 26 May 2016.

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public sector, Federal Councilor Johann Schneider-Ammann was evidently impressed by the modular "innovation catalyst" for the building sector: "Switzerland's education, research and innovation sector is strong when it comes to joining forces from both the public and the private sector in order to tackle pressing challenges. NEST has shown this in a paradigmatic way."

And at the end of August, Empa celebrated the 20th anniversary of its St. Gallen campus. Around 4,000 people visited the research institute during a number of events spread over three days and learned about the latest results and innovations from Empa's laboratories on three research paths at the Open Lab Day. Guests included Deputy Prime Minister of Liechtenstein Thomas Zwiefelhofer, State Councilors Karin Keller-Sutter and Andrea Caroni, Member of the St. Gallen Governing Council Bruno Damann and the Mayor of St. Gallen, Thomas Scheitlin.

A new record: an average of 1,000 visitors per month

And it didn't stop there, either: if you add the roughly 3,500 visitors on the regular tours of Empa's labs and around 4,500 people who have visited NEST since it opened, Empa welcomed approximately 12,000 guests to its campuses in Dübendorf and St. Gallen last year – more than ever before.

Once again, these included national and international delegations from industry, science, the administration and politics – such as representatives of the International Lake Constance Conference, which was held at Empa in 2016, the Commission for Education and Research of economiesuisse, the canton of St. Gallen's education department with Member of the Governing Council Stefan Kölliker, and the canton of St. Gallen's SVP party.

Never too young for the lab

In November a budding group of young visitors gathered at the summer camp and at the National Future Day at Empa: a total of 120 primary school children, who ventured their first steps into the lab – making a potato battery or building a compressed air car, for example. "Better than TV", beamed one enthusiastic young researcher-to-be. //

Diversity: Empa is not always the same Empa

Within the scope of a survey for the new action plan Equal Opportunities and Diversity 2017–2020, the proportion of women on the staff, which totaled 27.5 percent throughout Empa in 2015, was recorded in detail for each campus. It revealed that, at 45 percent, the proportion of women on the St. Gallen campus is considerably higher than in Dübendorf (24%) and Thun (16%). However, these results are hardly surprising as Empa's research focuses in St. Gallen – fibers, textiles, biology and biotechnology – tend to attract more women than the Dübendorf and Thun campuses, which concentrate more on physics, chemistry, materials science and engineering. The conclusion of the census: Empa is not the same across the board, and the staff structure can be extremely different depending on the subject. One focal point of the new action plan includes more PR work both internally and externally in the hope of lending more weight to the issue of equal opportunities and diversity.


iStockphoto

Events for women, men and children

2016 saw numerous events on the topics of equal opportunities and diversity. In spring, for example, a networking lunch for women took place. In summer, Empa invited its staff's children to the annual, weeklong summer camp. And in autumn, the event Teilzeitmann ("The Part-time Man") was held to raise awareness of the topic of part-time work among men employed at Empa.

In early November, all eyes were on National Future Day. Around 100 young people visited Empa at its three campuses in Dübendorf, St. Gallen and Thun, where they spent half a day in a technical or scientific workshop. The participants included 30 girls from the national program Mädchen-Technik-los ("Girls-Technology-Go"). And based on the children's feedback, which was virtually all positive, the professions presented were met with great interest.

For the Equal Opportunities workgroup in the ETH Domain, the main focus was the "Fix the leaky pipeline" program, designed to

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support budding female scientists in their research careers. The great news: the program, which is backed by all institutions in the ETH Domain, will continue to run for the next four years, and a new mentoring program will be developed and offered. //

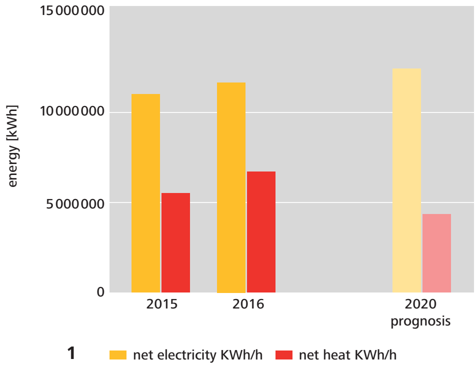
1
A big turnout at NEST on National Future Day, 10 November.

Careful handling of the environment and energy

Not only does Empa currently carry out research on environmental and energy-related topics; it also looks to lead by example. As the energy demand of Empa's research activities cannot be reduced without limit, it is all the more important to substitute fossil energy sources with renewable energy to cushion the environmental impact. Since 2016, for instance, all the electricity that Empa consumes has stemmed from renewable energy sources, the majority of which from hydropower with proof of origin. And thanks to an agreement with Energie 360°, Empa has been able to obtain biogas up to a quantity of one gigawatt-hour (1M/kWh) of energy from the Hagenholz plant in Zurich since 2015, which corresponds to around 20 percent of Empa's entire heat requirement. Detailed studies have revealed that this biogas boasts a far better carbon footprint than fossil natural gas.

Twenty years ago, when the new Empa building in St. Gallen was being constructed, a pioneering solar system was already integrated into the façade. In 2016, a plant upgrade tripled the electricity yield from solar power.

Charging stations recently launched in Dübendorf and St. Gallen facilitate low-CO_2 mobility with electric vehicles and gas-powered production or research cars that were incorporated into the Empa vehicle fleet. With its "multivalent" filling station, the mobility demonstrator move (see page 45) is an actual technology transfer platform that enables realistic studies of potential drive systems.



1

Trend for Empa's energy consumption.

2

Fuel-cell vehicle refueling at move's hydrogen filling station.

3

Edgeless photovoltaic panels on the roof of the Empa building in St. Gallen.

2

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In the modular research and innovation building NEST (see page 42), innovative and pioneering forms of living and working are being studied. The modular nature of the globally unique building coupled with extensive analysis and monitoring possibilities enables new technologies to be tested more rapidly and precisely than would be feasible in everyday construction. Innovations can thus flow onto the market more quickly and have a positive impact on the environment and energy throughout the building sector. //

3

Facts and Figures

Researchers like measuring, including their own performance: in 2016, Empa researchers and engineers published over 580 academic papers and filed patent applications for 14 developments. At the end of the year, 100 projects funded by the Swiss National Science Foundation (SNSF), 85 projects backed by the Commission for Technology and Innovation (CTI) and around 60 EU projects were underway at Empa. Together with other start-ups in Empa's two business incubators, the 22 spin-offs employed a total of 531 people.

Since 1 January 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.*

Empa's risk management

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 handle risks constructively, establish a safety culture that's more aware and thus constantly improve the safety situation at Empa.

Principles of tackling risks

As part of the ETH Domain, Empa geared its risk regulations towards the risk management standards of the ETH Domain and the Swiss 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 at least 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 risk management

Empa's risk management was reorganized in 2016 with a view to making it more streamlined and professional. This led to a higher resource input, increased activities and heightened awareness last year. Thanks to periodical reassessments, risks are now perceived more consciously and can therefore be controlled more effectively.

In order to tackle the risk the many new arrivals pose for work safety, the centrally organized training courses were expanded further on all campuses and a course calendar activated on the intranet. These courses are also open to staff from the neighboring institute Eawag and certain members of the ETH Zurich's Department of Chemistry.

With Eawag's long-term outdoor experiments on the campus and the fact that there are constantly people at NEST, the risk situation has changed, which rendered new measures necessary. In order to get a better handle on these fresh risks, campus patrols was set up for the nighttime, weekends and bank holidays in an initial phase. The job was advertised publicly. The second phase will involve using electronic means to help monitor the complex campus.

Two evacuation drills on the Empa/Eawag campus in Dübendorf and a drill in St. Gallen offered an opportunity to test the concept and technical facilities successfully. The latter are being expanded further; the alarm system is being refined and made more efficient to do justice to the complex Empa/Eawag campus. And the relocation of the Security Center to its new premises in NEST went smoothly.

The tighter mechanical engineering guidelines also raise the safety-related requirements for documenting the risk assessment for in-house developments in machine and plant construction in the vicinity of researchers. Therefore, a customized in-house system in internal construction was implemented in the fall of 2016. //

Human resources development

(previous year's figures in brackets)

At the end of 2016, 936 (942) people, including the trainees, worked at Empa. Due to the wealth of part-time opportunities, this corresponds to a full-time equivalent of 860.9 (868.7) positions.

The number of academic staff was 507 (501) people, 116 (117) of whom were senior scientists. 387 (400) people worked as technical and administrative staff in the reporting year. The 29 (27.5) percent proportion of women reflects the graduate figures from the universities and ETH Zurich in the faculties represented at Empa.

380 (388) people came from abroad, i.e. around 41 (41) percent of the overall staff. 259 (265) people were from EU countries, i.e. 68 (68) percent of all foreign members of staff.

Empa offers a broad range of vocational qualifications and employed 42 (41) trainees. Once again, all the trainees passed the final exams in 2016. //

STAFF (AS OF 31 DECEMBER)

	2015	2016
Scientific staff	**501**	**507**
Technical and administrative staff	**400**	**387**
of which apprentices	41	42
Total	**942**	**936**

Key Figures

SCIENTIFIC OUTPUT

	2015	2016
ISI publications	634	586
Conference contributions	1,121	1,131
Doctoral studies completed	38	31
Doctoral studies in progress	175	168
Teaching activities (in hours)	3,760	3,815
Prizes and awards	35	56

MEDIA EXPOSURE

	2015	2016
Radio and TV	73	93
Print	1,000	1,110
Online	2,853	3,030
Total	**3,920**	**4,233**
Languages	32	29

EMPA ACADEMY

	2015	2016
Empa events	**105**	**86**
Participants	6,100	9,000
Scientific conferences	12	3
Events for industry	44	40

KNOWLEDGE DISSEMINATION AND TECHNOLOGY TRANSFER

	2015	2016
New R&D agreements	157	177
Active exploitation contracts	80	79
New exploitation contracts	20	13
New patent applications	18	14

SPIN-OFFS AND START-UPS (tebo and glaTec)

	2015	2016
Companies total	**45**	**69**
thereof spin-offs	21	22
Employees total	**359**	**531**
thereof employees of spin-offs	105	112

CURRENT PROJECTS

	2015	2016
SNSF	112	100
CTI	89	85
EU	58	57

Bodies of Empa

ETH Board

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

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Christiane Leister Leister AG, Kägiswil
Joël Mesot Prof. Dr, PSI, Villingen
Martin Vetterli Prof. Dr, EPF Lausanne

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

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Andreas Hafner Dr, BASF, Basel
Markus Hofer Dr, Bühler, Uzwil
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Andreas Schreiner Dr, Novartis, Basel
Eugen Voit Dr, Leica Geosystems, Heerbrugg

Research Commissions

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.

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Alexander Wokaun Prof. Dr, PSI, Villigen

Organizational Chart

as of Mai 2017

RESEARCH FOCUS AREAS

(Research priorities)

Nanostructured Materials
Dr Pierangelo Gröning

Sustainable Built Environment
Dr Peter Richner
Prof. Dr Giovanni Terrasi

Health and Performance
Prof. Dr Alex Dommann

Natural Resources and Pollutants
Dr Brigitte Buchmann

Energy
Dr Peter Richner
Urs Elber

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Civil and Mechanical Engineering

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Materials Meet Life

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Center for X-ray Analytics
Dr Antonia Neels

Reliability Network
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Prof. Dr Hans Josef Hug

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Applied Wood Materials
Dr Tanja Zimmermann

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Mechanical Systems Engineering
Prof. Dr Giovanni Terrasi

Multiscale Studies in Building Physics
Prof. Dr Dominique Derome

Mechanical Integrity of Energy Systems
Prof. Dr Edoardo Mazza

Center for Synergetic Structures
Dr Rolf Luchsinger (PPP Empa – Festo)

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Prof. Dr Pietro Lura

Building Energy Materials and Components
Dr Matthias Koebel

Urban Energy Systems
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Dr Peter Wick

Biointerfaces
Dr Katharina Maniura

Transport at Nanoscale Interfaces
PD Dr Michel Calame

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move
Dr Brigitte Buchmann

ehub
Philipp Heer

Coating Competence Center
Dr Lars Sommerhäuser

Empa Academy
Anja Pauling

Business Incubators
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Materials for Energy Conversion
Dr Corsin Battaglia

Advanced Analytical Technologies
Prof. Dr Davide Bleiner

Air Pollution / Environmental Technology
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Automotive Powertrain Technologies
Christian Bach

Materials for Renewable Energy
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Technology and Society
Dr Patrick Wäger

Acoustics / Noise Control
Kurt Eggenschwiler

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Dr Lothar Nunnenmacher

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Stephan Koch

Mechanical Engineering / Workshop
Stefan Hösli

Finances / Controlling / Purchasing
Heidi Leutwyler

Communication
Dr Michael Hagmann

Human Resources
André Schmid

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Gabriele Dobenecker

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