Annual Report 2017

Empa

Materials Science and Technology

Our Vision.
Materials and Technologies
for a Sustainable Future.

Cover Photo: 3-D-printed titanium mesh with variable stiffness.
Implants that have to be elastic in one direction but stiff in others are a possible area of application.

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Shaping the future together

There are numerous social and economic challenges these days that we can only overcome together. With this in mind, the institutions in the ETH Domain develop innovative solutions that help shape our future sustainably and make it worth living in for future generations. The ETH Domain thus launched four strategic research initiatives involving all six institutions; Empa, for instance, brings its expertise in materials science and the development of new technologies to the table.

Firstly, there is energy research. For many years, this has been a core topic at Empa with a special focus on renewable concepts for a decarbonized – i.e. not based on fossil fuels – society and economy, especially in the building and mobility sector. Our goal is to pave the way with our research for the Swiss Energy Strategy 2050 to become a reality. These efforts are in full swing, and I am delighted that our researchers have already been able to present convincing, innovative solutions, such as in electricity storage with the aid of novel battery concepts.

Within the scope of ongoing digitalization, the joint efforts have led to the foundation of the Swiss Data Science Center of ETH Zurich and EPFL. Empa is contributing its expertise in modeling material properties at atomic and molecular levels. Moreover, models on different length scales – from nanometers to hundreds of kilometers – are becoming increasingly important. On the one hand, Empa runs complex measuring networks throughout Switzerland that detect a number of air pollutants with ultra-high precision and in minuscule amounts to determine the atmospheric distribution of the pollutants and their sources using computer simulations. On the other hand, the energy networks are increasingly based on complex algorithms, which regulate the production, distribution and consumption of energy – in other words, topics that Empa is tackling in the large-scale research platforms NEST and Energy Hub.

Via its Research Focus Area "Health and Performance" Empa is also linked to the initiative "Personalized Health and Related Technologies". The in vitro models developed at Empa and our research at the interface between material surfaces and living matter, i.e. human cells and tissues, but also our research on new implants thus lead to new diagnostic and therapeutic approaches in a much more efficient and purposeful way.

Progressive and additive manufacturing technologies are ultimately the topic of the "Advanced Manufacturing" (AM) initiative, which Empa coordinates for the entire ETH Domain and is also instrumental in shaping with new material developments. Understandably, this initiative is particularly important to us as a materials research institute. For instance, the development of new powder materials for 3-D printing offers tremendous opportunities to realize the industrial transformation in this country. Thanks to AM, new oxidic compounds, which are ultra-hard yet at the same time light, enable completely new applications – designed on the computer and produced using additive manufacturing. This would simply not be possible with conventional production methods.

With these initiatives, we at Empa want to help shape the future in close collaboration within the ETH Domain.

Prof. Dr Gian-Luca Bona, *Director*

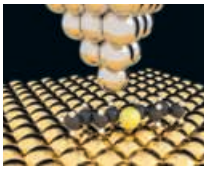
01

Nanostructured surfaces
Empa teamed up with 13 universities, three research institutes and five companies from 13 countries in the EU-funded ELENA network to develop new manufacturing methods for products on a nanometer scale.

Summer heat for the winter season
An EU project involving Empa researchers discovered how summer heat can be stored for the winter: with a cost-effective, reliable method based on soda lye.

02

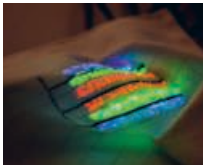
Precious funding for budding researchers
The EU approved Empa's second COFUND application to the tune of over EUR 3.5 billion within the scope of the Marie Skłodowska Curie Program. 50 postdoc positions will be co-funded for five years.



Hot on the trail of entropy
With the aid of a scanning tunneling microscope, Empa researchers gained insights into a somewhat abstract physical property and measured it for the first time based on a single molecule: entropy.

03

Soft sensors for smart textiles
Researchers from Empa have succeeded in producing optic fibers for sensors that are just the ticket for textiles. These could be used in hospitals to monitor whether a patient is developing bedsores, for instance.



Novel fruit spy
A sensor developed at Empa reliably monitors the cooling of fruit in transit from the plantation to the stores. It looks like fruit and behaves like fruit.

Observing chemical reactions in real time
A modern transmission electron microscope opens up new possibilities: it can be used to observe – and film – the growth of nanocrystals in real time, for example.

04

What comes out when you floor the throttle
Exhaust gas aftertreatment in diesel and gasoline vehicles is stretched to its limits in everyday driving. This is what Empa's exhaust gas analyses under real-world conditions revealed.
Page 20

Skin model instead of tests on humans
Empa researchers developed a synthetic skin model based on gelatin that almost perfectly simulates human skin and can thus substitute trials with test subjects.

05

3-D printer ink from the woods
Empa researchers developed an ink made of cellulose nanocrystals that helps produce 3-D-printed microstructures for implants and other biomedical applications.

New components for future batteries
An Empa team demonstrated that sodium and magnesium are suitable for developing new solid state batteries. The aim is to develop alternatives to lithium ion batteries.
Page 24

06

Building with robots and 3-D printers
AAt Empa and Eawag's NEST building, researchers from ETH Zurich are building the three-floor DFAB HOUSE unit in collaboration with industrial partners. It's the world's first house to be largely designed, planned and constructed using digital processes.

New alloys for 3-D printing
Well over 100 guests from industry, research and politics convened at Empa in Thun to experience Empa's know-how in 3-D printing at first hand.

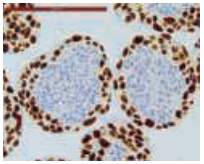
07

Sensor helps wounds to heal

Thanks to sensors, a novel bandage uses light signals to sound the alarm as soon as the wound starts to heal badly – without having to be removed. This means that chronic wounds can be monitored at home.

Medication for unborn children

An Empa team developed a new cell model of the human placental barrier. The "model organ" provides swift and reliable new findings on the uptake of substances such as nanoparticles and possible toxic effects on the unborn child.



08

Algae against arthritis?

A new approach to treat osteoarthritis: in experiments on cell cultures a chemically modified "alginate" suppresses the body's immune response against cartilage cells and thus combats the causes of the disease.

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Solar fitness and wellness

In a world first, a fitness and wellness facility powered entirely by solar energy and the sporting exertions of its users was launched at NEST in August.

09

The largest electric car in the world

Swiss companies are building the largest electric car in the world. The E-Dumper is designed for hard labor in the quarry. Experts from Empa are in charge of operational safety.

Lasers, not stitches

Empa scientists developed a technique to fuse synthetic fiber fabrics – and render the "seam" completely air- and watertight.

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Non-toxic flame retardants

Flame retardants developed at Empa are ideal for mattresses and pillows. Unlike existing chlorinated products, the new substances are non-toxic.

10

Tissue adhesives against bleeding

Wounds inside the body cannot be stitched up or treated with a plaster. A tissue adhesive based on nanoparticles and developed at Empa should help close wounds that are difficult to reach and thus prevent life-threatening bleeds.

Luminous pajamas treat newborns

Babies that suffer from jaundice after birth are treated with short-wave light. Empa researchers have developed luminous pajamas that replace light therapy in incubators.

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Low-cost batteries made of waste graphite

Lithium ion batteries are flammable, and the price of the raw material is rising constantly. Researchers from Empa and ETH Zurich have discovered new approaches as to how batteries might be produced from waste graphite and scrap metal.

Page 24

11

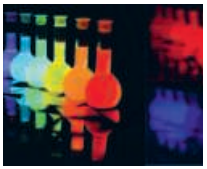
A rubber power station

Researchers from Empa have developed an elastic material that produces electricity when bent. Used as an implant, for instance, it could power pacemakers.

Precise color recognition – maximum resolution

Researchers from Empa and ETH Zurich developed a color sensor that absorbs light almost perfectly and is cheap to produce. The sensors are layered on top of each other instead of being lined up next to each other.

Page 34

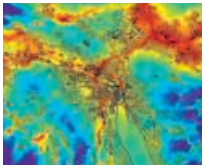


12

Warmed up and raring to go

When a car engine cold-starts, it produces far more fine particles and pollutants than during the trip. Empa researchers, therefore, pre-warm the catalytic converter with microwaves so that it works efficiently right from the start.

CO_2 all over Switzerland



Switzerland is gaining a globally unique CO_2 measuring system: 300 sensors developed by Empa spin-off Decentlab continuously collect measuring data and convey it wirelessly to the Swiss Data Science Center, where it is processed and visualized.

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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.

The road towards nanoelectronics

Prof. Dr Roman Fasel, roman.fasel@empa.ch

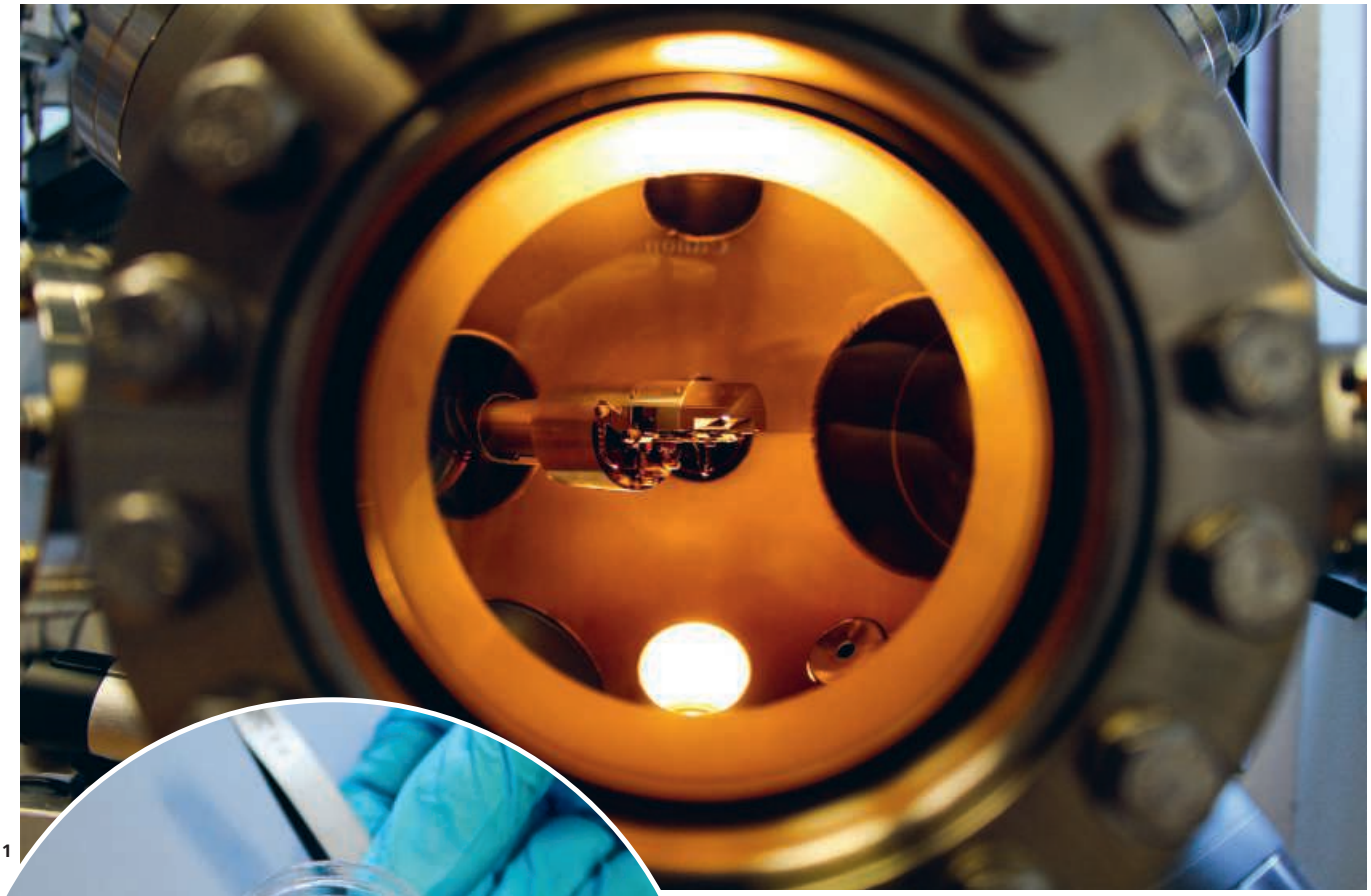
Transistors based on carbon nanostructures: what sounds like a futuristic dream could be reality in just a few years' time. An international research team involving Empa has now succeeded in producing nanotransistors from graphene ribbons that are only a few atoms wide. The stripes, or "graphene nanoribbons", have special electronic properties that make them promising candidates for the nanoelectronics of the future: while graphene – a carbon layer that is only one atom thick – is a conductive material, it can become a semiconductor in the form of nanoribbons. This means that it can switch between a conductive and insulating state, depending on the voltage applied – and thus may become a key component of nanotransistors.

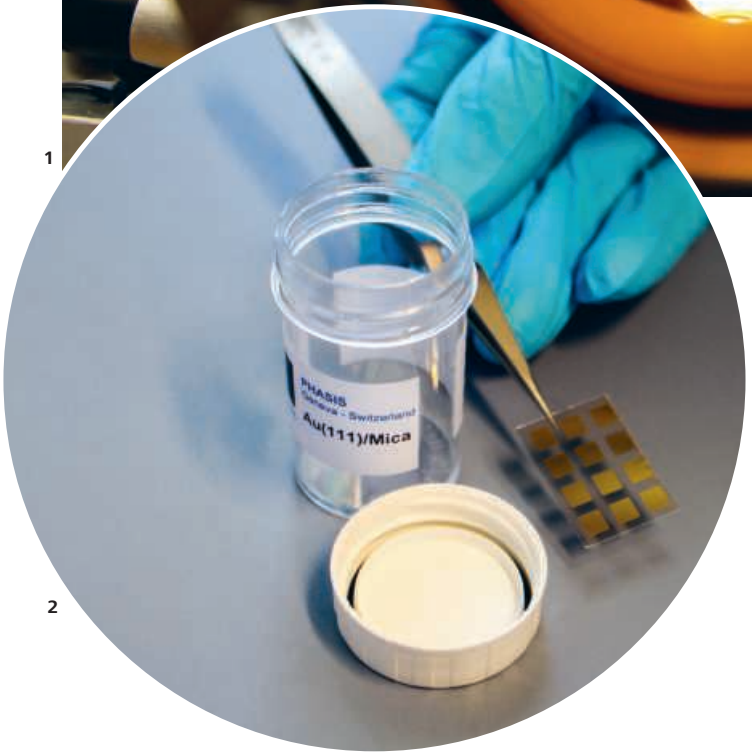
The smallest details in the atomic structure of these graphene ribbons, however, have a massive impact on their electronic properties. These depend on the width of the graphene ribbons on the one hand and the structure of the edges on the other. Since graphene consists of equilateral carbon hexagons, the edges may display a zigzag or what is known as an "armchair" shape, depending on the orientation of the ribbons. While ribbons with a zigzag edge behave like metals, i.e. they are conductive, they become semiconductors with an armchair edge.

Creating a semiconductor with nine atoms

In collaboration with the Max Planck Institute for Polymer Research in Mainz and the University of California in Berkeley, Empa researchers have succeeded in growing ribbons that are exactly nine atoms wide and have a regular armchair edge from precursor molecules. The specially prepared molecules are evaporated in an ultra-high vacuum for this purpose. After several process steps, they are combined like puzzle pieces on a gold substrate to form the desired nanoribbons measuring about one nanometer in width and up to 50 nanometers in length. The researchers transferred these ribbons from the gold substrate to the pre-patterned silicon wafer and completed them into nanotransistors with metal contacts spaced only 20 nanometers apart.

The first attempts, however, were not very successful: measurements showed that the difference in the current flow between the "ON" state (i.e. with applied voltage) and the "OFF" state (without applied voltage) was far too small. The problem was the dielectric layer of silicon oxide, which connects the semiconducting nanoribbon layer to the electrical switch contact ("gate"). In order to achieve the desired properties, it needed to be 50 nanometers thick, which in turn influenced the behavior of the electrons. Nevertheless, the researchers subsequently succeeded in massively reducing the thickness of this layer by using hafnium oxide (HfO_2) as the dielectric material instead of silicon oxide. This layer is now only 1.5 nanometers thin – and the current for a "switched-on" transistor is several orders of magnitudes higher. As a result, the research team has taken a major step on the path towards nanoelectronics. //





1
Graphene nanoribbons are fabricated under high vacuum conditions from specially produced precursor molecules.

2
Graphene ribbons measuring merely one nanometer in width and up to 50 nanometers in length grow on a gold substrate.

New Wood Materials

Prof. Dr Ingo Burgert, ingo.burgert@empa.ch

There is a wealth of possible applications for wood – and they have by no means been exhausted. Researchers from Empa alter and treat this versatile material in such a way that it displays completely new properties – which facilitates quite unexpected applications: from substitutes for precious ebony, which is becoming increasingly scarce, to violins that have been treated with fungi and nanofibrillated cellulose in façade construction.

Tropical wood types are endangered all over the world and, despite strict trade regulations, ebony stocks are plummeting. We need to find a substitute. And this is where Empa spin-off Swiss Wood Solutions comes in. Its product, Swiss Ebony, consists of modified Swiss maple, which possesses almost the same properties as ebony – a sustainable and entirely legal solution. It is used in place of real ebony for tailpieces on stringed instruments, for instance. The fledgling company was founded about a year ago and has already secured its place in the top 100 Swiss start-ups.

Instruments are also at the heart of the Mycowood project. Empa researchers have succeeded in treating violin wood with fungi to give the instrument the same sound as an antique masterpiece. Empa's Laboratory for Acoustics/Noise Control is studying the sound of these biotech violins from the very moment it is produced to the feeling it unleashes in the listeners. In an early experiment, the audience was enthusiastic during a listening test. However, the Empa experts now want to gauge how people perceive the "soul" of the biotech violins – i.e. their sound – scientifically in the AuraLab, Empa's listening test laboratory.

Popular resource

The Swiss National Science Foundation has even dedicated a National Research Program to wood, NRP 66 "Resource Wood", which drew to a close in 2017 and also contained three Empa projects. The focus was on wood as a construction material. For instance, Empa researchers studied how compounds and wall elements behave when exposed to horizontal forces, such as in earthquakes and strong winds. Wood remains an outstanding material for a multitude of applications, however, adverse properties sometimes restrict its usage. Another project was therefore launched with a view to improving wood and wood materials by using polymer chemistry and nanotechnological techniques to alter cell walls and fiber surfaces. A coating made of nanofibrillated cellulose – also developed at Empa – is also expected to play a key role in protecting wooden façades against the elements. //

1
Do violins made of wood treated with fungi sound the same as an antique instrument? Precision structure-borne sound measurements and experiments with test persons should reveal whether a course of fungal treatment can quantifiably enhance an instrument.

2
Violin with a tailpiece made of Swiss Ebony.
Photo: Wilhelm Geigenbau AG, Suhr

Microplastic from the washing machine

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Dr Patrick Wäger, patrick.waeger@empa.ch

Billions of pieces of plastic are floating in the oceans. Even before the UN Ocean Conference we already knew about the disastrous ways in which plastic affects the world's oceans. Marine animals swallow or get tangled up in it, causing them to die in agony. On the other hand, we know less about the consequences of the smallest pieces of plastic, known as microplastics. Empa researchers studied how microplastics are generated and where they actually come from.

The presence of microplastics in our wastewater can be attributed primarily to two factors: firstly, many cosmetic products, such as toothpaste, creams, shower gels and peelings, contain tiny fragments of plastic in order to achieve a mechanical cleaning effect; secondly, microplastics are washed out in the process of washing polymer textile clothing, and thus enter our environment via wastewater.

Many researchers who recently studied nanoparticles have now also begun researching microplastics. They also include researchers from Empa's "Technology and Society" department. The Empa team studied the ways in which detergents, water temperature and the number and length of wash cycles affect the release of microfibers, for instance. They discovered that the quantity of fibers released by five different washing programs was always more or less constant, while washing agents and detergents increased the quantity of microfibers released compared with "normal" water. However, the washing temperature had no effect on the number of microfibers; nor did the duration of the wash cycles have any significant impact – thereby refuting the hypothesis that the longer a textile is washed, the more microfibers it releases.

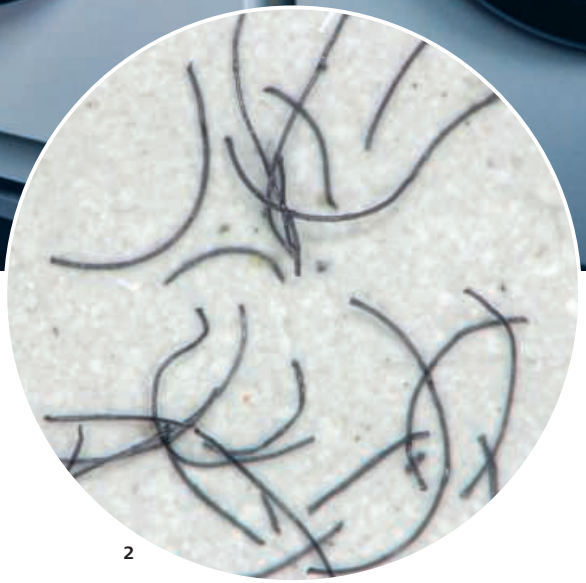
The research continues

Follow-up studies are already underway. In collaboration with Empa's Advanced Fibers department, for instance, a PhD thesis on the generation of microfibers in the wash has already begun. The study systematically analyzes different types of material to shed light on the origin of microfibers in the washing machine.

Recycling plastic in the "KUH Bag"

Every year, around 175,000 tons of plastic that cannot be recycled accumulate in Swiss urban waste. Researchers from Empa were commissioned by the Canton of Thurgau's Office for the Environment to spend two years studying the KUH Bag system (KUH = Kunststoffe aus Haushalten [household plastic]). The idea is to collect plastic waste in a separate bag which you have to buy, before it is sorted and processed. The study recorded and assessed the quantity and quality of the material collected and its processing. The conclusion: the KUH Bag has ecological benefits. Through optimizations such as more disposal points, the ecological and cost aspects can be improved even further. If the high processing quality can also be maintained when the quantities collected increase, Switzerland could become a pioneer in plastics recycling. Due to the high demand and positive results of the study, the KUH Bag initiative is set to continue. //

1



2

1
Bernd Nowack is studying the ways in which detergents, water temperature and the number and length of wash cycles affect the release of microfibers.

2
Microfibers released when polyester textiles are washed as seen under the microscope.

Algae against arthritis

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Dr Markus Rottmar, markus.rottmar@empa.ch

Osteoarthritis is a widespread disease, affecting around 90 percent of all people over the age of 65. However, the degenerative joint disease is also rife among young people. In arthritis, the cartilage in the joint degenerates, causing the bones to lose their protective lubricating layer. This can be extremely painful for sufferers as the process is associated with inflammatory reactions. In the later stages of the disease, the cartilage is eroded to such an extent the bones can even rub against each other directly during every movement.

While all the joints in the body can be afflicted with osteoarthritis, it most commonly affects the knees, hips and fingers. The disease has been considered incurable until now. Current treatment methods, such as anti-inflammatory drugs and painkillers, only target the symptoms. Often, the only remaining option is an operation to replace the affected joint with an artificial one.

Researchers from Empa in collaboration with the Norwegian research institute SINTEF are pursuing a new approach to treating osteoarthritis. The team has identified a substance that has the potential to halt cartilage degradation in joints: a component of brown algae. The cuvie (Laminaria hyperborea) contains the polysaccharide alginate, which resembles molecules in human cartilage.

After the researchers managed to modify the alginate chemically using sulfate groups, they studied how different cell types reacted to the modified polysaccharide. They discovered that alginate sulfate can significantly reduce oxidative stress, which is a common cause of cell damage, and the more sulfate groups attached to the alginate molecule, the greater this reduction.

Slowing the inflammation

But that's not all that alginate is capable of: in cell culture experiments, it was even able to suppress inflammatory reaction, again depending on the number of sulfate groups. It also managed to down-regulate the expression of genes which trigger an inflammatory reaction in both human cartilage cells, known as chondrocytes, and macrophages, the "scavenger cells" of our immune system. The algae molecules could therefore offer a possibility to counteract cartilage degeneration in the joints. The researchers hope the new substance might even stop cartilage loss completely.

So far, the alginate sulfates have only been tested in vitro, i.e. in the laboratory with cell cultures. The encouraging results mean that the research will now continue. The next stage will be to test the efficacy of the substances in clinical trials. However, these tests are laborious and time-consuming. In the best-case scenario, it could still take a number of years for an alginate sulfate treatment to become available. //

1
Alginate sulfate has already demonstrated its healing effects in cell cultures.

2
The new approach to treating arthritis is based on brown algae.
Photo: iStockphoto

1

2

A magic hood for artificial heart pumps

Dr Giuseppino Fortunato, giuseppino.fortunato@empa.ch

People who require a transplant because of cardiac failure have to hope for a suitable donor organ, which is, however, usually short in supply. An artificial heart pump that does not trigger any rejection reactions in the body after implantation would be an elegant alternative. Zurich Heart, a project of the research alliance University Medicine Zurich, of which Empa is a partner, is currently developing such an artificial heart pump.

To ensure that the laboratory-made pump is tolerated by the body, the aim is to coat the inner surface with human cells, much like a cloak of invisibility to shield the foreign material. Thus far, however, culturing multi-layered functional tissues has posed a major challenge in the up-and-coming field of tissue engineering. Empa researchers have now succeeded in integrating cells within a three-dimensional, synthetic fibrous polymer scaffold that mimics the architecture of the natural environment in the body. Importantly, the process does not harm the cells, so they can still develop into bundle like muscle fibers. This approach of cell incorporation can be utilized to engineer artificial blood vessel like structures to prevent thrombosis on the inside of the pump.

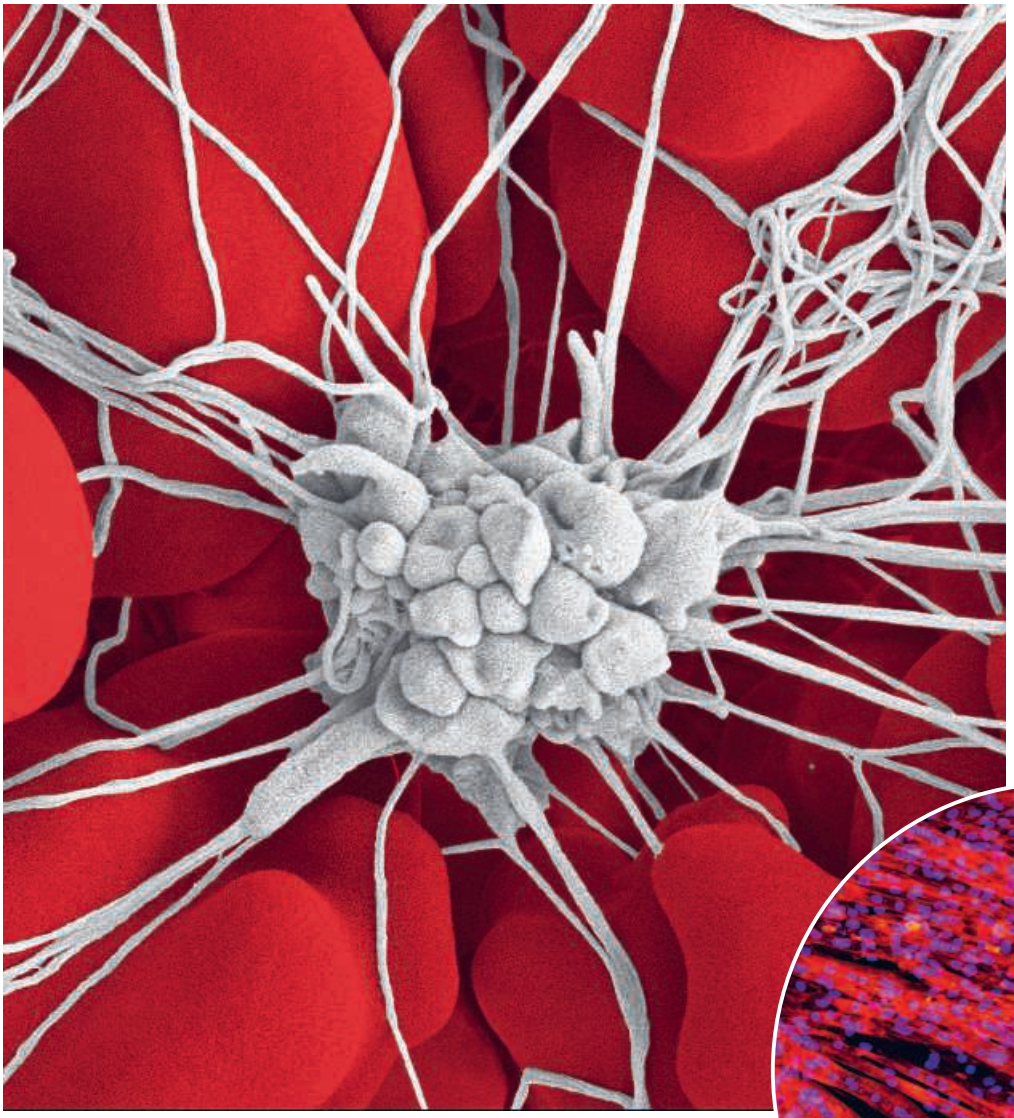
The problem during the fabrication process of such three-dimensional tissues: the cells first have to be embedded in a nanofiber-based scaffold. Cytotoxic solvents are used during the fabrication process – namely electrospinning – of such scaffolds, which can harm the sensitive cells.

Empa researchers, therefore, packed the precious cells in capsules made of gelatin to protect them from the solvents. Subsequently, an electrospraying process enables the positioning of the capsules within the pores of the spun polymeric scaffold. As a result, the protected cells survive the spraying process unscathed. Once the cells are in place, the gelatin capsule dissolves within minutes.

Invisible to the immune system

Microscope images show that the cells feel right at home in their synthetic environment: as soon as the capsules dissolve, the immature precursor cells begin to attach to the nanofibrous scaffold, divide and develop into elongated muscle cells.

The researchers used muscle cells from mice for their series of experiments. These cells enabled the researchers to determine precisely whether the tissue develops in an expected manner, or if the procedure harms the cells. In the future, however, the aim is to introduce cells originating from patients and to implant them at the heart pump surface. Via this approach, the artificial hybrid scaffold inside the pump is expected to be invisible to the patient's immune system. //



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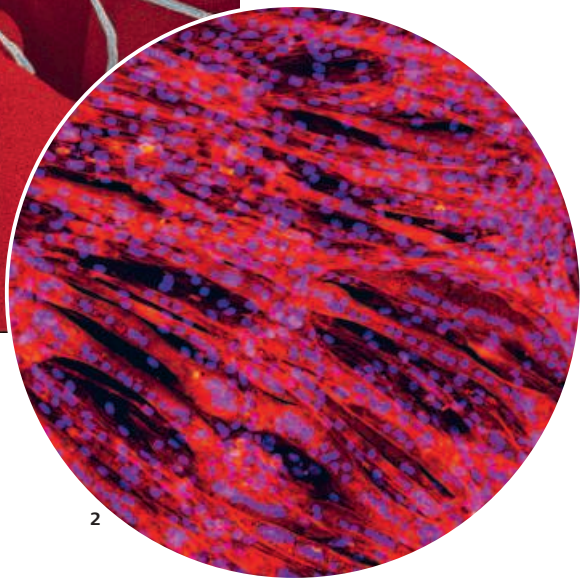

2

1
The body must not recognize the novel polymer scaffold as an intruder. By populating the synthetic tissue with the patient's own cells, it should remain invisible to the immune system. Otherwise, a harmful blood clot consisting of blood cells within a fibrin network (white) could develop.

2
Imitating nature: a network of muscle fibers grows in a polymer scaffold. Under a confocal laser scanning microscope, the muscle cells show up in red, their cell nuclei in blue.

Caught in the act

Christian Bach, christian.bach@empa.ch

Low nitrogen oxide emissions (NO_x) in the laboratory and significantly higher values on the road for Euro 6b diesel passenger cars were also shown in Empa exhaust emission tests. A total of six passenger cars were tested by Empa in the laboratory and on the road. However, the range of nitrogen oxide emissions on the road was considerable. While individual vehicles emitted "only" 3 times higher NO_x emissions on the road than in the laboratory, the figure for the vehicle with the highest emissions was over 10 times higher NO_x emissions. From October 2019, vehicles on the road will be allowed to emit only 2.1 times higher NO_x emissions than in the laboratory.

Unrealistic requirements

How is it possible that modern vehicles have such high emissions on the road? One problem is the existing emissions regulations. These regulations were characterized by unrealistic determination of the curb weight and driving resistances of the vehicles as well as predetermined, high-speed shift points and a driving profile that had nothing to do with real driving. In addition, no road measurements have had to be carried out on passenger cars up to now. Vehicle manufacturers optimized exhaust aftertreatment for laboratory testing and reduced it under real driving conditions or even switched it off completely. Whether such measures are illegal or only undesirable is the subject of ongoing investigations. These technically outdated emissions regulations were replaced in autumn 2017 by a new, in many respects improved laboratory measurement procedure and additional NO_x measurements on the road are mandatory now.

Clean diesel cars are possible

These regulations force much cleaner diesel vehicles. To ensure that exhaust gas purification systems can be used permanently and highly efficiently even at low temperatures and other adverse conditions, they must be understood in detail, properly dimensioned and also operated optimally. The current diesel scandal clearly shows that there is some catching up to do. With its high-temperature flow laboratory, Empa makes valuable contributions by investigating in detail the injection behavior of "AdBlue" – an aqueous urea solution that is injected into the exhaust gas of newer diesel vehicles. The AdBlue spray cone is measured with laser measuring devices down to individual droplets, the formation and evaporation of liquid AdBlue wall films in the exhaust pipe is examined and the decomposition of evaporated AdBlue is measured. The results help to optimize AdBlue-based exhaust aftertreatment.

Interesting: In addition to the Euro 6b passenger cars with diesel engines, Empa also examined six Euro 6b delivery vans with diesel engines. Surprisingly, despite loading the vehicles up to 90 percent of their payload, most of the NO_x emissions of these vehicles were at values that will apply to road measurements from 2019. This shows that "clean diesel" is not a contradiction in terms. //

An Opel Astra 1.6 CDTI in the Empa exhaust laboratory. The pipes connect the exhaust system with a mobile PEMS (portable emission measuring system) in the inside of the car. After calibration of the measurement setup in the exhaust gas laboratory, it then goes onto the road.

Advanced manufacturing – digitally printed workpieces

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Prof. Dr Patrik Hoffmann, patrik.hoffmann@empa.ch

Industry and science are on the lookout for answers to the challenges of digitization. In order to acquire the knowhow that Switzerland needs, the ETH Domain initiated the Strategic Focus Area "Advance Manufacturing" headed by Empa. Its aim is to assist the manufacturing industry in developing advanced manufacturing technologies and thus exploit the full potential of digitization. The opening ceremony took place in Bern on 13 November 2017. Swiss Federal Councilor Johann Schneider-Ammann, the President of the ETH Board Fritz Schiesser, President of ETH Zurich Lino Guzzella, EPFL President Martin Vetterli, Empa Director Gian-Luca Bona and representatives of industry attended the event.

Interest from research and industry

Empa plays a key role in the advanced manufacturing sector; it has been conducting research successfully in this field for years and collaborates closely with industry. On 18 January 2017, over 150 experts from industry and research gathered at the Empa Academy for the technology briefing "Additive Manufacturing – Quo vadis" to swap ideas and experiences on upcoming developments in the field of industrial 3-D printing and novel design approaches.

The technology briefing "Lasers – the perfect tool" held in Thun on 10 May, 2017 then examined the topic of additive manufacturing in great detail: talks highlighted the connection between laser welding and 3-D metal printing. A real-time quality control method for 3-D laser printing was also presented. It is based on monitoring the production process acoustically, a technique recently developed at Empa.

Ideal alloys sought

Empa's Research Prize was also awarded for work on the topic of additive manufacturing in 2017: Empa researcher Christoph Kenel, who currently conducts research at Northwestern University in Chicago, conducted pioneering work on 3-D laser melting processes. Titanium aluminum alloys combine several properties that are coveted in lightweight construction for aerospace. They are light, very strong and, at the same time, oxidation-resistant, even at high temperatures. The aim of the prize-winning dissertation was to provide these alloys with mineral oxide nanoparticles that are evenly distributed in the metal. This enables the alloys' mechanical properties and oxidation resistance to be improved considerably at elevated temperatures. To do so, Kenel used a 3-D laser melting facility, which makes complex components from metal powder with the aid of a laser beam. So far, it has not been possible to produce this kind of alloy using classic casting methods. As soon as the mixture melts, the oxide particles clump together in the alloy or float on the surface as slag. The laser melting technique offers an alternative here. The laser is used to heat the powder mixture only briefly so that the oxide particles remain hidden between the metal parts during melting and hardening and no longer change position. A homogenous, oxide-reinforced alloy is formed.

This research field, which is especially studied at Empa, was first presented to the public at a symposium: Alloys for Additive Manufacturing Symposium 2017 (AAMS 17) took place on 11 and 12 September at the Empa Academy. The Max Planck Institute for Iron Research in Düsseldorf was an event partner. //

A lattice sphere made of an AlSi10Mg alloy, produced using the additive manufacturing method at ProtoShape GmbH, then irradiated and sanded.
Design by George W. Hart.

Five concepts for the battery of the future

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Lithium-ion batteries have taken the world by storm in laptops, smartphones and tablets. The demand is rising constantly. On the one hand, however, these batteries contain flammable components and pose a safety hazard if not used correctly; on the other hand, the majority of lithium-ion batteries are produced in Asia today. There is a risk of supply bottlenecks for lithium-ion cells in Europe, which the European Commission is attempting to combat by initiating the generation of a European Battery Alliance with the goal to establish a cell manufacturing base in Europe. Lithium-ion batteries should be supplemented or replaced with other technologies. Several research teams at Empa are working on different battery concepts.

Stephan Bücheler has been developing thin-film solar cells for years. He is now turning his expertise to the topic of batteries. Bücheler's research concerns electrolytes, which are responsible for conducting ions between the anode and the cathode, the two poles. They need to be stable and not have any holes to prevent short circuits; on the other hand, the ions are supposed to move as quickly as possible during the charging and discharging process, so the shorter the distance, the more efficient the battery. And this is precisely where things start to get challenging for the thin-film specialist. The ultra-thin solid he is currently developing should be mechanically stable, withstand high voltages and transport lithium ions as easily.

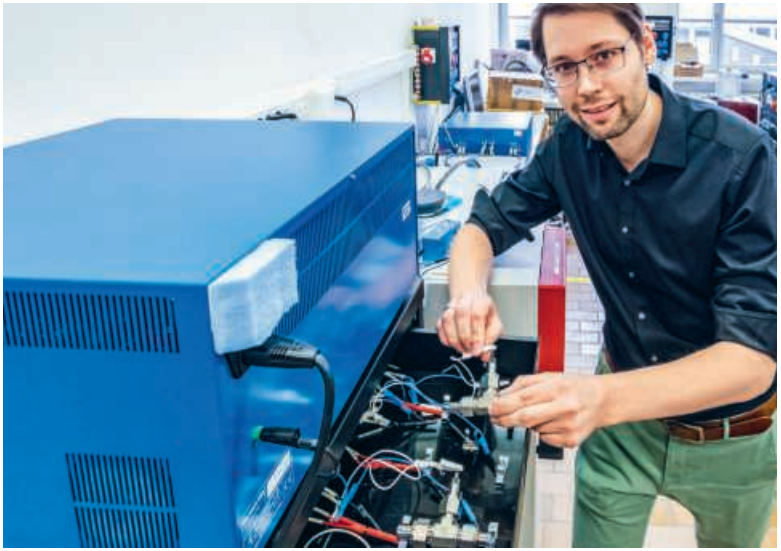
The research group headed by Maksym Kovalenko is working on a battery made of the most common elements. Fitted with an aluminum anode and a graphite cathode, this battery would be just the ticket for the temporary stationary storage of solar and wind power thanks to its potentially low material costs. New concepts for electricity and heat storage are also developed by Empa researchers in the framework of the Swiss Competence Center for Energy Research (SCCER) "Heat and Electricity Storage".

A team headed by Corsin Battaglia is investigating the following question: does water make a suitable electrolyte? Water is cheap, in abundant supply, doesn't burn, and can conduct ions. The major drawback, however: it is only chemically stable up to a voltage difference of 1.23 volts. Consequently, the Empa researchers used a special salt called sodium bis(fluorosulfonyl)imide), which is highly water-soluble. The electrochemical stability of this kind of salt solution is up to 2.6 volts – twice as high as for other aqueous electrolytes. Battaglia's team is also researching solid-state batteries in a project supported by the Swiss Federal Science Foundation. The researchers developed a prototype based on sodium. Sodium batteries have the potential to cover the rising demand while facilitating batteries that can be charged more rapidly. For the electrolyte the researchers used closoborate compounds that give the sodium ions a high degree of mobility. Moreover, closo-borate is an inorganic electrolyte which, compared to the liquid organic electrolytes in lithium-ion batteries, is not flammable.

Empa researchers are also collaborating with the company FZSonick on the development of sodium nickel chloride batteries as part of a CTI project focusing on developing improved ceramic electrolytes. Besides being a very safe technology, sodium nickel chloride batteries use sodium chloride (table salt) and nickel as active materials and do not require any lithium and cobalt that is already classified as critical due to its high economic importance, but high supply risk. //

1

1
Where the prototype of a new battery is born: Marie-Claude Bay and Corsin Battaglia work in a “glove box” as the components need to be handled without air contact.



2

2
Research on the water electrolyte: Ruben-Simon Kühnel connects a test cell to the charger with the concentrated saline solution. The stability of the system is determined in several charging and discharging cycles.

First residents and new units in NEST

Reto Largo, reto.largo@empa.ch

NEST is transforming – and thus fulfils the requirements for a fertile breeding ground for innovation. In the modular research building on the Empa campus in Dübendorf, researchers, companies and the public sector have the opportunity to validate and hone new materials and technologies in a real environment. These innovations from the building and energy sector are used in so-called units, which are integrated in NEST as usable living and office modules.

Following NEST's official inauguration in 2016, the first residents began to move in at the beginning of 2017: in the housing unit Vision Wood, they test various wood innovations developed by Empa and ETH Zurich in practice. Following in Vision Wood and Meet2Create's footsteps, the third unit opened in August 2017: a fitness and wellness center that aims to run on solar power alone. New wellness technologies are expected to slash the energy demand.

Building with robots

Construction work began on two other units in 2017: DFAB HOUSE will be a three-story unit where researchers from ETH Zurich will team up with industrial partners as part of the National Center of Competence in Research (NCCR) Digital Fabrication to put several new digital building technologies from the laboratory into practice – in other words, a house constructed using robots and 3-D printing.

With the cycle in mind

In late 2017 another unit was integrated: Urban Mining & Recycling, which focuses on the resource cycle. The basic idea: all the resources required to construct a building must be completely reusable, recyclable or compostable. The official inauguration took place in February 2018.

Another unit, SolAce, which was developed at EPFL, is also in the starting blocks. It will be focusing on obtaining energy via the façade.

The energy platform ehub, which uses NEST as a vertical district, was launched in 2017 with its first research projects aimed at optimizing energy flows at district level (see page 30). The Water Hub, Eawag's research facility within NEST, was expanded in 2017 and is now capable of processing various wastewater flows on a bigger scale.

Furthermore, initial efforts were made last year to merge the infrastructure of the demonstration platforms NEST, move and ehub at virtual level and bring a fourth demonstrator into being: the Digital Hub, or dhub for short, which was unveiled to an interested specialist audience for the first time at Swissbau in January 2018. Against the backdrop of digitalization, linking the sectors in the Empa campus presents a unique opportunity to develop new, overarching solutions.

Last year, NEST once again enjoyed considerable attention in expert circles and the media. In March NEST received the award "Umsicht – Regards – Sguardi 2017" from the Swiss Society of Engineers and Architects (SIA). Meanwhile, the NEST network has blossomed to over 120 partners and around 12,000 people visited NEST on tours and during events in 2017. //

View of NEST from the east with the new units Solar Fitness & Wellness (3rd floor on the right) and Urban Mining & Recycling (2nd floor). Photo: Zooey Braun, Stuttgart

Getting down to business

Urs Cabalzar, urs.cabalzar@empa.ch

After several years of construction and installation work, everyday research and operations got underway at the mobility demonstrator move in 2017 – albeit briefly. After all, the next development phase is already scheduled to begin this year as move gets its own methanation plant. move has had an electricity charging station, a natural gas/biogas dispenser and a 350-bar hydrogen dispenser since November 2015. Another 700-bar hydrogen refueling dispenser has been in operation since October 2016, and in the summer of 2017 a dispenser was finally installed that enables gas vehicles to be refueled with a mixture of methane and hydrogen – known as HCNG. By admixing with up to 30 vol-% hydrogen, the CO_2 emissions from gas engines can be reduced relatively easily and efficiently.

On the one hand, move therefore provided diverse refueling options for electric, gas and fuel-cell vehicles in 2017. On the other hand, following the successful start-up of the plants, various advantages and disadvantages of the individual mobility paths could already be studied in everyday operation. The focus here was on analyses that provide evidence of the systems' efficiency. Based on measurements at the demonstration plant, well-to-tank tests were conducted for the hydrogen path and revealed that around 57 percent of the original electrical energy reaches the tank while refueling on hydrogen. For smaller-scale industrial plants, this value even increases to 70 percent; the percentages refer to the higher heating value of hydrogen.

The user circle for the 700-bar dispenser climbed from 11 to 13 fuel-cell vehicles in 2017. On average, the vehicles are refueled once or twice a day, resulting in a total consumption of around 1.1 tons of hydrogen (at 700 bar) last year.

HCNG vehicle joins the postal service

In order to analyze HCNG as a fuel, Swiss Post temporarily uses a delivery van that had been fitted with new tanks and fuel lines for its parcel service since summer of 2017. In parallel, the HCNG dispenser, was realized; the highly complex construction and control algorithm had been developed at Empa. The great news: during field trials, no discernible negative effects were detected for the postal vehicle, either when running on pure gas or HCNG, even though the engine and the engine controls had not been modified. And as for operating the HCNG dispenser, nothing at all changed for the filling station users compared to conventional natural gas dispensers.

Digital and analog communication

To communicate the goals of move to the public, an interactive 3-D visualization was also developed in 2017; it is available on a touchscreen on the premises and online at move.empa.ch. And since October 2017, move has been one of several experience stations on the Environmental Bike Path, which stretches from St. Gallen to Zurich. A large picture book in front the entrance to move invites families to stop and find out about mobility without fossil fuels in a child-friendly manner. //

Swiss Post uses Empa's HCNG vehicle – here refueling on a mixture of methane and hydrogen – to deliver parcels since summer of 2017.

ehub: optimizing the energy flows of the future

Philipp Heer, philipp.heer@empa.ch

The energy demonstrator ehub (short for Energy Hub) serves as an energy management research platform in the district of the future. It supplies the research building NEST and the mobility demonstrator move with energy – and enables researchers to test answers to key questions in a real energy network on a district scale: Does it make sense for buildings or districts to supply their own energy independently from the public power grid? How can heavily fluctuating energy production be compensated for? How can seasonal heat be stored efficiently? ehub offers researchers a flexible infrastructure comprising thermal and electrical energy components. These include a photovoltaic plant, heat and cold storage units, a hydrogen cycle, heat pumps, supercondensers and batteries, which are combined with each other in different grids. The various NEST units composed of apartments, offices and recreational facilities act as independent units in a "vertical district".

Balancing out bottlenecks and surpluses

The first research projects in ehub got underway in November 2016, two of which were already concluded in 2017: HeatReserves provide insights into how heat loads can be regulated most effectively to compensate for bottlenecks and surpluses in the electrical transmission network. A building's heating system, for instance, can store heat for a longer period of time – which means it does not constantly need to take in the same amount of energy. If, therefore, too much energy is available in the electricity grid at a given time – such as when the entire photovoltaic system is in the blazing sun – this can be used to power a heat pump and warm up heating water. At peak consumption times, however, the heat pump is switched off without the residents having to feel cold.

The power grid as a marketplace

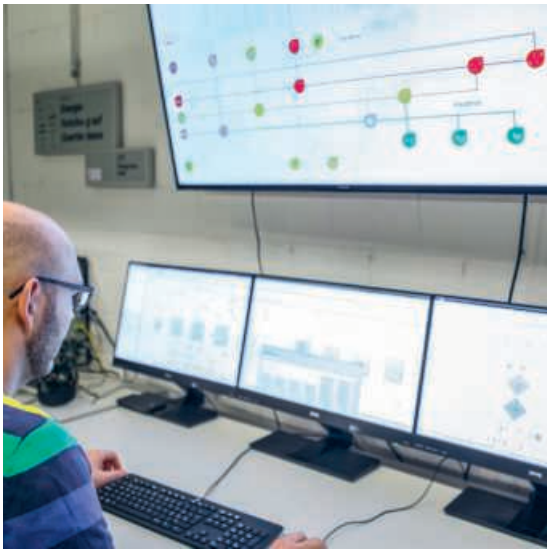
The project ideas4cities goes one step further; it investigates how electrical energy flows in the power grid of the future can best be regulated intelligently and in real time. This is no mean feat: instead of a handful of large-scale energy plants, numerous decentralized renewable energy producers such as solar and wind power plants, short- and long-term energy storage facilities and flexible consumers are constantly coordinated. Researchers from EPFL developed a solution that interprets the power grid as a kind of marketplace: every participant can offer or request energy with their own cost function. An overriding control point manages the energy flows in such a way as to minimize the overall costs of the system. Thanks to its various energy components, ehub offers the ideal conditions to test this framework in practice.

Alongside the research projects, ehub itself also keeps evolving: every new unit in NEST is integrated in the ehub platform. This means that the photovoltaic systems and CO_2 heat pumps in the fitness and wellness unit can now also be used for overarching energy research projects, for instance. //

1
A portion of the energy needed to run the unit Solares Fitness and Wellness (SFW) stems from the photovoltaic elements integrated in the glass façade; these are clearly visible in the photograph.

2
View inside the energy management control center of the energy demonstrator ehub.

1



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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.

New materials – a prerequisite for progress

Pierangelo Gröning, pierangelo.groening@empa.ch

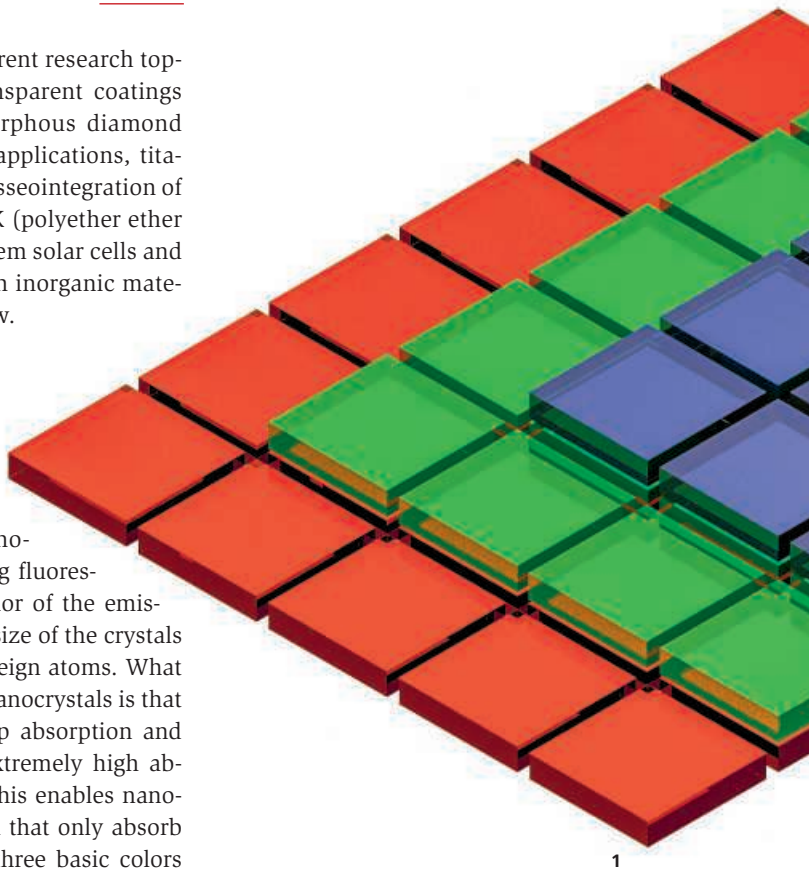
Ever since the word go, new materials have been the prerequisite for qualified technological progress for the benefit of the economy and society. Today, nanostructured materials are the approach that is most likely to succeed in developing materials with improved or even new properties. By probing into the nanocosmos, new approaches are opening up in materials research and development – right up to the boundaries of what is physically feasible.

If a "Werkstoff" is defined as a processed material for specific applications, suitable process and manufacturing technologies need to be in place to produce a valuable "Werkstoff" from the source material. This applies especially to nanomaterials and nanostructured materials, which often display only very limited process windows on account of their complexity and manufacturing tolerances. Therefore, it is essential for the research and development of nanomaterials and nanostructured materials to factor in process engineering aspects.

By launching its Coating Competence Center Empa consistently takes into account these aspects in the field of nanostructured coatings. Here the processes are adapted from laboratory to industry scale. The current research topics are ultra-hard, transparent coatings for smartphones, amorphous diamond layers for tribological applications, titanium coatings for the osseointegration of implants made of PEEK (polyether ether ketone), thin-film tandem solar cells and printed electronics with inorganic materials, to name but a few.

Low-cost thanks to sub-nanometer precision

Like other semi-conductive nanocrystals, halide perovskite nanocrystals display a strong fluorescence, whereby the color of the emission can be set via the size of the crystals and by doping with foreign atoms. What is special about these nanocrystals is that they display very sharp absorption and emission bands and extremely high absorption coefficients. This enables nanocrystals to be produced that only absorb light from one of the three basic colors (red, green or blue) but are totally transparent for the other two. This, in turn, opens up completely new approaches for the production of image sensors, for instance.



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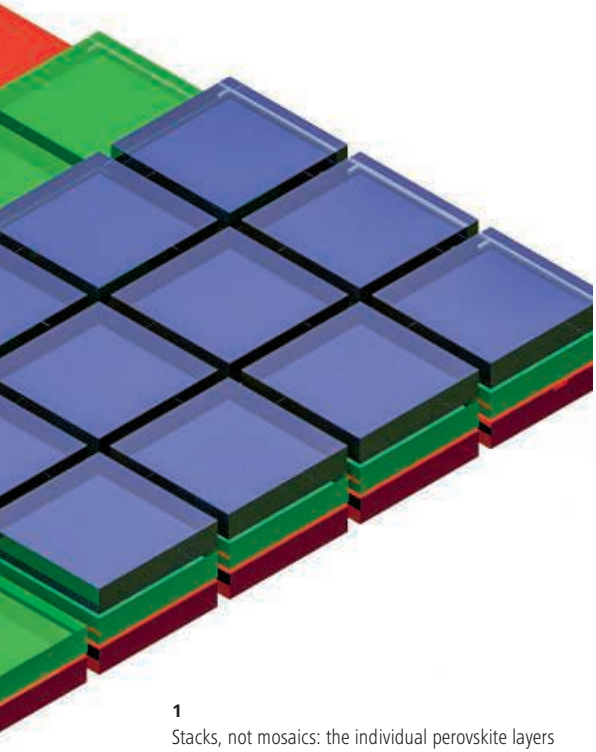
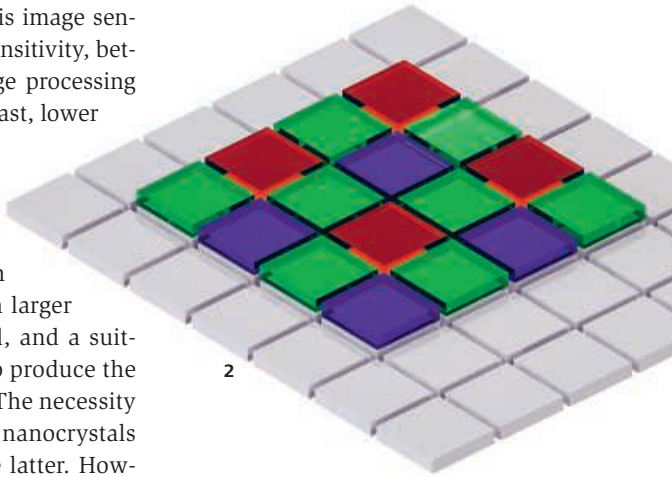


1
Stacks, not mosaics: the individual perovskite layers each absorb only part of the light spectrum and allow the residual light pass through to the next layer. As a result, more color detectors fit on the same area – the chip's image resolution increases.

2
Conventional image sensor: the pixels for the individual colors are arranged next to each other, the chip requires considerably more space than its stacked counterpart and the resolution is lower.

Image sensors similar to those used in today's cameras are structured like mosaics made of red, green and blue color sensors. Intelligent software algorithms calculate a high-resolution color picture from the individual colored pixels. The disadvantage of this architecture is that only a third of the sensor surface is available per base color. It would be better to stack the color sensors on top of each other. This is precisely what the halide perovskite nanocrystals now allow on account of their extremely sharp absorption bands. The advantage of this image sensor architecture is greater sensitivity, better resolution, simpler image processing software and, last but not least, lower manufacturing costs.

The technological challenges consist in the synthesis of monodisperse nanocrystals with sub-nanometer precision in larger quantities on the one hand, and a suitable thin-film technology to produce the image sensor on the other. The necessity for perfectly monodisperse nanocrystals might prove helpful for the latter. However, these exhibit the property of forming perfect micro-crystals in solution. An effect that can be exploited to produce homogenous crystalline color sensor layers – and thus a nanomaterial has been turned into a "Werkstoff". //



Material flow and environmental impact of Switzerland's building stock studied

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Switzerland's building stock, i.e. our building infrastructure, is responsible for the largest flows of material in this country. After all, its expansion and upkeep require large quantities of building materials, especially concrete, gravel and sand, not to mention special materials such as brickwork, plaster, glass, metal and wood.

Moreover, producing and processing these building materials and running the infrastructure swallows up vast quantities of fuels and electricity. In order to assess the resource efficiency in the construction sector and develop scenario-based forecasts, insights into material flows are crucial. Although various partial studies have been conducted in the last ten to 15 years, a comprehensive picture of the material and energy resources required by Switzerland's building infrastructure has been lacking.

The goal of the study MatCH – Bau, which Empa conducted at the behest of the Swiss Federal Office for the Environment (SFOE), was therefore to investigate the material and energy flows and storage quantities of the building infrastructure for the whole of Switzerland. In order to determine the materials currently used in Switzerland's building stock, current studies for structural and civil engineering were consulted. To estimate the change in Switzerland's building stock over time, an approach was adopted that combines horizontal growth (area statistics), vertical growth (compact construction) and changes in building materials. The mass and composition of Switzerland's building stock over time can be extrapolated from the growth rates per material category calculated.

Besides mass flows, the study also reveals the environmental effects caused by material and energy consumption in the building sector. The considerations encompass the entire life of the materials "from the cradle to the grave". This should give the researchers an impression of which materials are environmentally relevant in which section of the life cycle.

In all, around 68 million tons of material and about 7.5 million tons of energy – expressed in oil equivalents – are channeled into Switzerland's building stock. At around 40 million tons a year, concrete is by far the most important construction material. As far as the greenhouse effect caused is concerned, however, it is not concrete or all the other materials put together that dominate, but rather the fuel for the heating needs.

The results reveal that it is worth modernizing Switzerland's building stock for the environment. This is because the environmental impact of the materials this requires can be compensated for thanks to the energy savings for running the modernized infrastructure. //

iStockphoto, Hilda Weges

Digitalization – for a sustainable future

Dr Brigitte Buchmann, brigitte.buchmann@empa.ch

The rapid development of our society inevitably affects the environment and depends on natural resources. The resulting challenges are manifold and significantly influence the sustainable supply of energy and raw materials. Consequently, one of Empa's main goals is to develop new concepts and innovative methods and thus help implement the United Nations' Agenda 2030 with its 17 Sustainable Development Goals in Switzerland. The focuses here are closed cycles and the development of digital innovations for a sustainable future.

Digital information – new concepts for humans and the environment

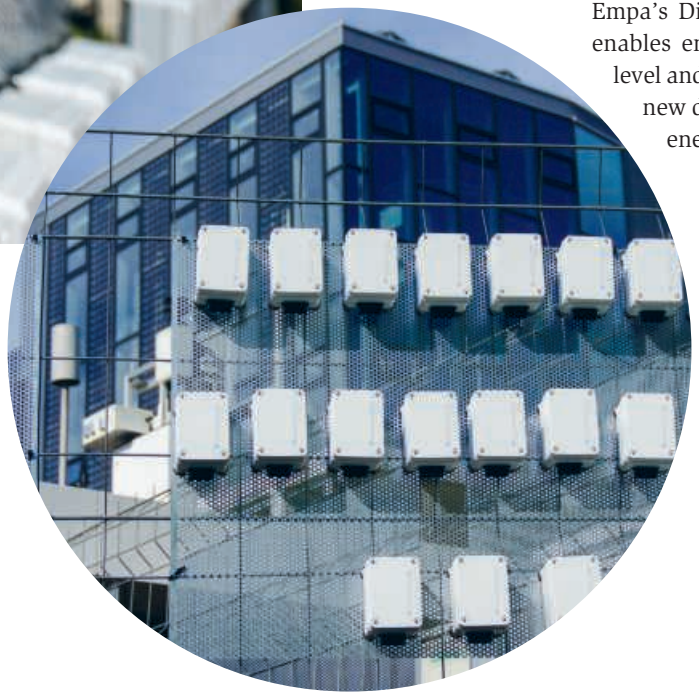
Three hundred simple and low-cost CO_2 sensors scattered all over the country transmit data via the Internet of Things – in this instance, Swisscom's Low Power Network – to a data center in real time. This digital environmental information is complemented with data from a handful of high-precision conventional measuring stations in Switzerland and thus linked and validated using statistical algorithms and atmospheric transport modeling. On the one hand, the project is ground-breaking for new data transfer concepts. However, it also reveals how complex algorithms based on data and models can be used to supply environmental information at an unprecedented spatial and temporal resolution. This opens up new possibilities to determine CO_2 emissions directly and thus evaluate the health hazards for the population in urban centers.

Closed cycles – synthetic fuels for the mobility of the future

Sustainable mobility means slashing the consumption of fossil fuels and CO_2 emissions and closing the carbon cycle completely in the long term. move, Empa's mobility demonstrator, uses temporarily surplus renewable electricity in a different form: on the one hand to charge electric cars, on the other hand to produce hydrogen for fuel cell vehicles or methane for gas vehicles – the latter made from hydrogen and CO_2 that is absorbed from the ambient air. With move, Empa and its partners from research, industry and the public sector demonstrate how mobility of the future can work entirely without any fossil energy.

Numerous sensors and control elements enable operations to be optimized and largely automated with the aid of intelligent algorithms and models. By including weather forecasts, for instance,

load matching for the electrolysis plant for the production of hydrogen can be planned in advance and the necessary fuel for a period of bad weather supplied ahead of time. move thus makes a key contribution towards the fuel supply from renewable electricity and the reduction of fossil fuels, a major goal of the Energy Strategy 2050. Together with the building demonstrator NEST and the energy demonstrator ehub, move is embedded in Empa's Digital Hub (dhub), which also enables energy management at campus level and facilitates the market entry for new digital solutions in the building, energy and mobility sector. //



Low-cost sensors by Empa spin-off Decentlab during a functional check before being installed all over Switzerland.
Source: Decentlab GmbH

Sector-linking – business as usual in Empa research

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Sector-linking – the new buzzword in the energy industry – means combining sectors such as energy and mobility, but also connected energy production and provision, including with different energy sources. By pooling services offered by different companies, the end customers receive all the energy services they need from a single source, known as multi-utility companies. This enables energy strategies and sustainable goals to be implemented more effectively.

What is dubbed sector-linking in the industry is transdisciplinarity in research – something that has long been practiced at Empa. Around 40 percent of Empa's staff deal with energy topics in the various laboratories and centers. They develop new materials for innovative batteries, new, highly efficient insulation materials, novel photovoltaics and much more. However, systemic research in an urban setting, interlinking buildings and mobility in terms of energy, and the integration of various infrastructures in energy hubs are also topics examined at Empa.

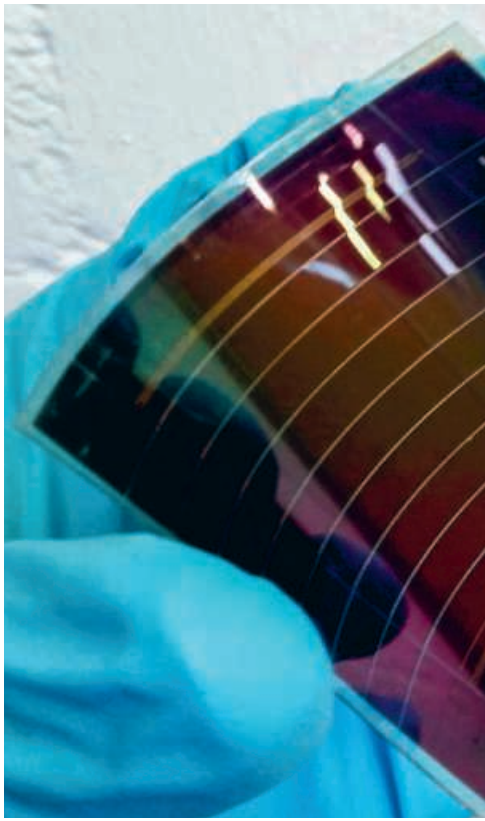
Empa's Research Focus Area "Energy" encourages this by combining and developing research projects from different research areas with other research institutions, especially from the ETH Domain, and numerous industrial partners. "Sector-linking" in energy research has also been practiced successfully at Empa for many years.

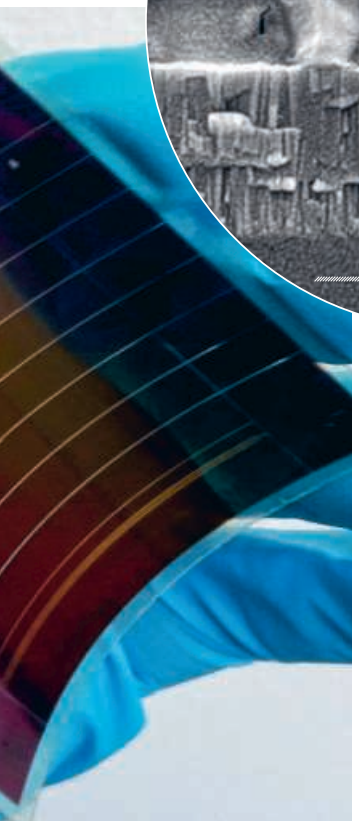
Focus on the Swiss energy market

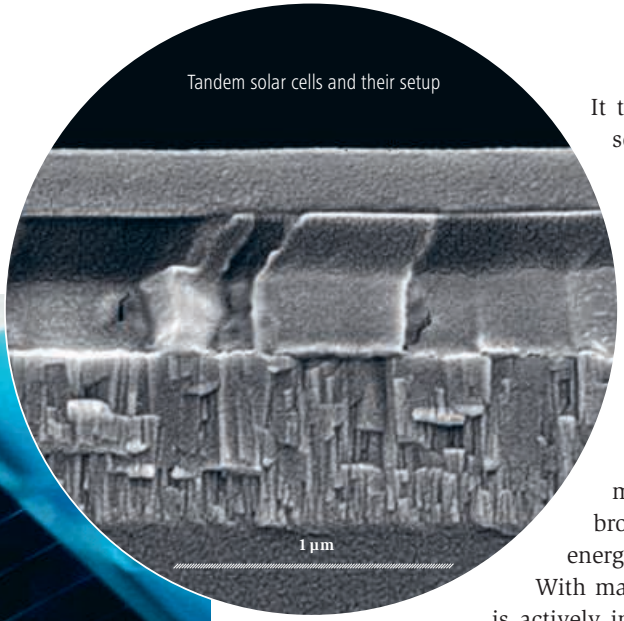
As a prime example of transdisciplinary, "sector-linked" research projects, the CCEM project "Electricity-based Mobility – Impacts on CO_2 and Grids", headed by Empa, was launched in 2017. Partners from ETH Zurich, EPFL and the Paul Scherrer Institute (PSI) are studying how electricity-based mobility might impact on our energy supply and CO_2 emissions.

Two CCEM projects, also managed by Empa, drew to a successful close last year: SECURE and RENERG2, which provided new insights into efficient urban energy systems and revealed options as to how solar energy can be converted into other energy forms in line with the Swiss federal government's Energy Strategy 2050 and introduced onto other markets.

An as yet unpublished study conducted in conjunction with researchers from PSI is examining the potential of power-to-gas (PtG) technology in Switzerland, i.e. the conversion of renewable energy such as solar power into chemical energy sources such as hydrogen and biogenic methane.







Tandem solar cells and their setup

It took into account local resources and sales channels, the dynamic operation of the PtG plants using renewable energy and the economic effects of power-to-gas plants. Accompanying research such as life-cycle analyses in hydrogen mobility, novel battery technologies, building services and much more round off Empa's broad-ranging research in the energy sector.

With many of these projects, Empa is actively involved in the Swiss Competence Centers for Energy Research (SCCER), various National Research Programs (NRP) and international projects. A general collaboration with other research institutions in the ETH Domain and other Swiss universities is the priority here.

Combining materials research and energy leads to new types of battery, for instance (see article on page 24). Or new tandem solar cells with a target of almost 30 percent efficiency which can be produced using cost-effective, scalable coating methods. //

Interdisciplinary research for health and performance

Prof. Dr Alex Dommann, alex.dommann@empa.ch

The rising life expectancy poses an increasing challenge for our society. The Research Focus Area "Health and Performance" aims to find new health solutions. Prevention and monitoring systems, as well as new patient-specific drug-related systems, constitute possible starting points to improve the quality of life and mobility in old age.

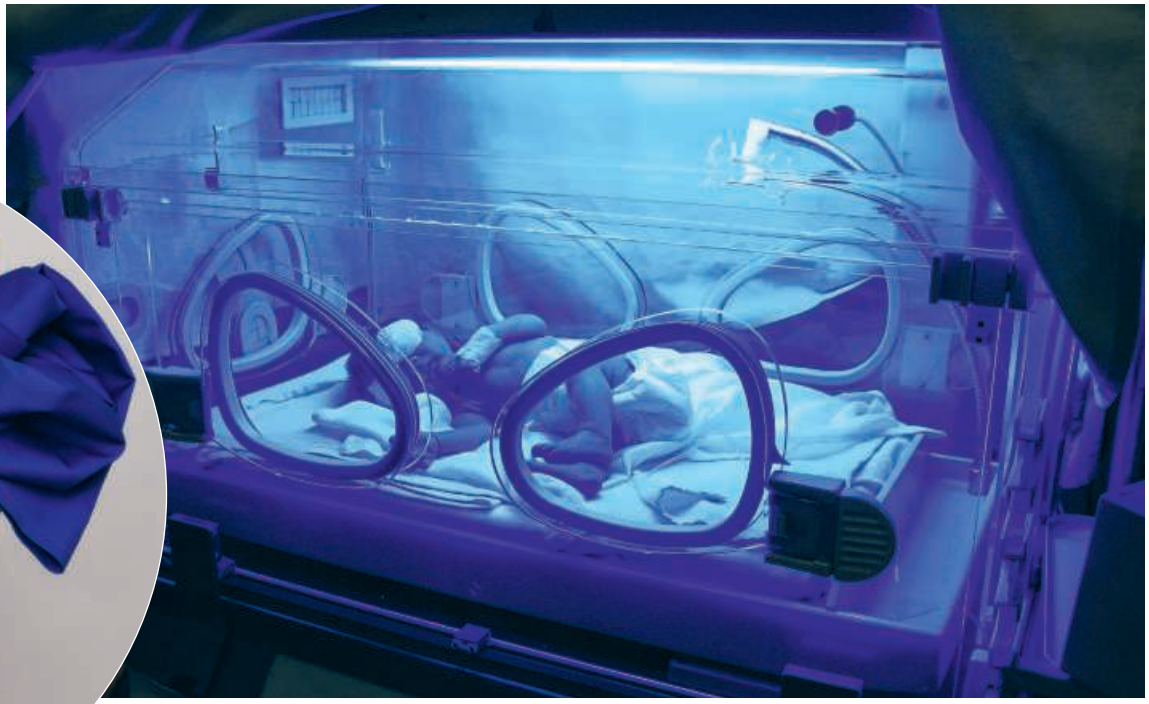
Advancements in the life sciences, information technology and innovative material concepts provide fresh possibilities here to gear medicine towards personalized health care and applied technologies. One example of this is the non-invasive monitoring of vital markers, i.e. vital signs, which means that patients only have to see the doctor if their condition deteriorates. It is also possible to supervise the recovery after a surgical intervention in a personalized manner.

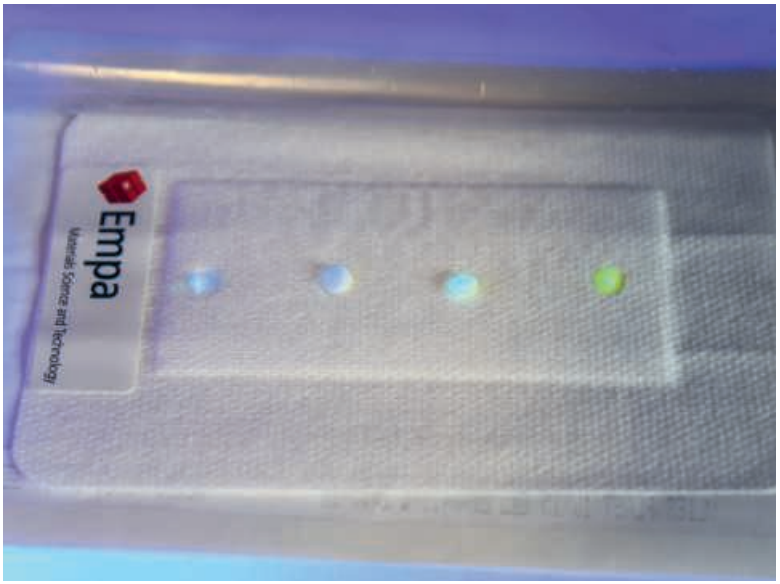
Treatments constantly benefit from new materials: the encapsulation of medication in "smart" carrier systems enables the targeted and patient-specific dosage right where it is needed in the body. Not only does this reduce the drug quantity; it also curbs possible side effects and achieves successful patient-specific treatments.

Like with all new technologies, the careful assessment of possible risks and undesirable side effects is just as important as the function itself. A precise characterization of the materials and their interaction with people paves the way for safe, sustainable health care solutions. In order to achieve this goal, Empa relies on interdisciplinary research above and beyond the materials, life and medical sciences. //

1
Babies with jaundice are treated with short-wave light. Empa researchers have developed luminous pajamas that replace therapy in incubators. For the clinical application, however, the pajamas only emit their blue light inwards, i.e. directly onto the child's skin.

2
A novel wound dressing alerts the nursing staff as soon as a wound starts to heal badly – without the bandage having to be removed. Sensors integrated in the base material alter the intensity of their fluorescence if the wound's pH value changes.





2


SERVICE
X-RAYS ON

From Research to Innovation

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

From research to industry

Marlen Müller, marlen.mueller@empa.ch

Small and medium-sized companies (SMEs) play a key role in Switzerland's economy. Reason enough for Empa to foster its collaboration with SMEs and help them to boost their innovative power. After all, only thus can they hold their own on the market with innovative new products and reinforce Switzerland as an innovation hub.

Last year was no exception: Empa launched over 170 new research projects with more than 200 industrial partners. Moreover, Empa put in patent applications for 14 new inventions, either alone or in conjunction with its research partners, and concluded 13 new licensing and technology agreements with industrial partners.

New flame retardant: non-toxic – even in a fire

Conventional, halogenated flame retardants give off toxic gases in the event of a fire. EDA-DOPO, an environmentally friendly derivative of the familiar flame retardant DOPO (9,10-dihydro-10-oxaphosphaphenantreneoxide) developed at Empa, however, does not. A particularly economical and ecological synthesis method which also simplifies the production of other DOPO derivatives is a crucial part of this success story. The company Metadynea Austria GmbH will manufacture the substance, while the global FoamPartner Group with a production site in Switzerland is planning on using it to produce flame-retardant polyurethane (PU) foams for upholstery and mattresses. The flame retardant is in the process of being certified according to the European chemical regulation REACH. Additional applications, such as in textiles, are currently being evaluated with other partners.

MultipassCell – compact and robust

Measuring trace gases is crucial for a broad range of applications, including industrial process control, measuring breathable air or monitoring the safety of toxic gases. The MultipassCell is a measuring cell for infrared absorption spectroscopy to detect various trace gases, which facilitates a long optical path in a compact, light design. Thanks to its monolithic construction, the MultiPassCell is also particularly impervious to temperature fluctuations and vibrations. There is no need to adjust the mirrors, either.

The fundamentals of the new measuring cell were originally developed at Empa to measure air quality and the isotopic composition of carbon dioxide within the scope of a nano-tera project funded by the Swiss National Science Foundation (SNSF). Following the success of the robust cell, a patent application was filed for details of its setup and it was licensed to IRsweep, a spin-off of Empa and ETH Zurich. Meanwhile, IRsweep sells the cell successfully in Switzerland and abroad.

Glow-in-the-dark pigments – duration and strength improved

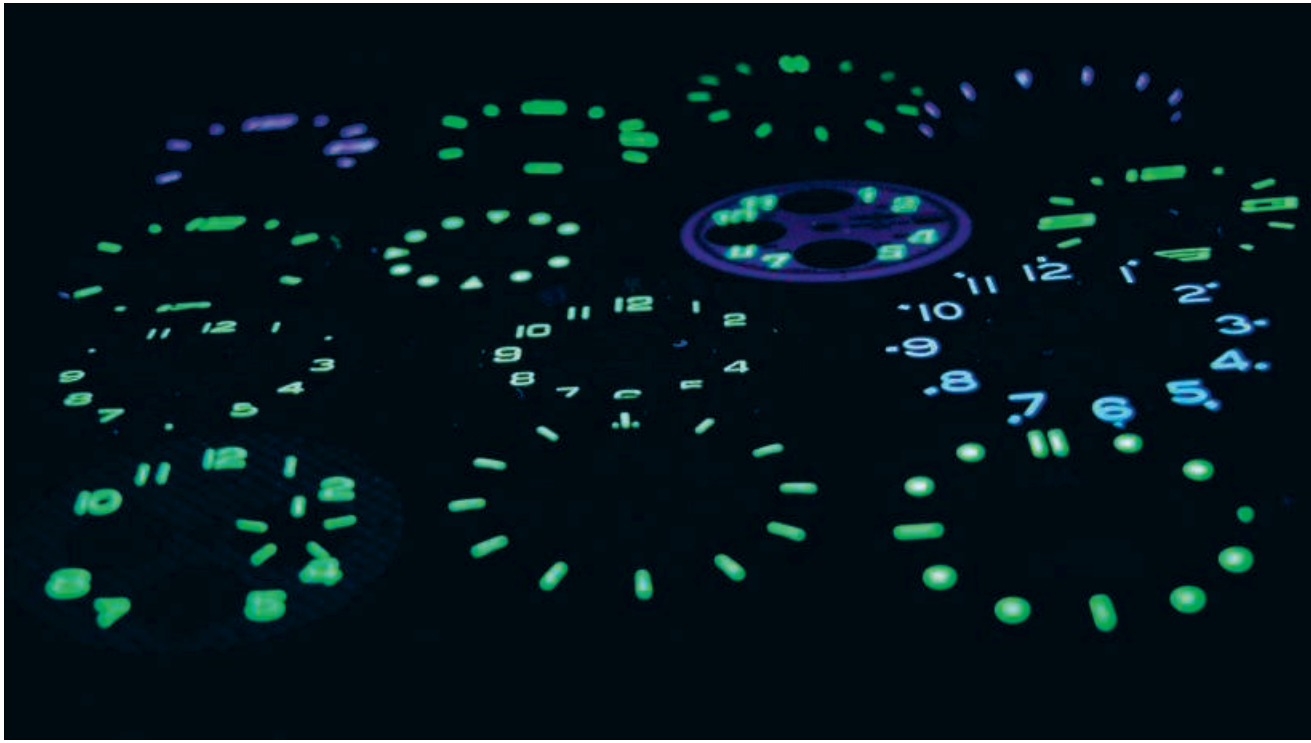
Only by the early 1990s were the widespread, radioactive light sources in watches replaced by safe colors with comparable luminous properties. As the principle supplier of luminescent pigments based on strontium aluminate for the Swiss watch industry, Teufen-based LumiNova Schweiz AG showed great interest in constantly improving the duration of the glow duration and strength.

In two projects funded by the Commission for Technology and Innovation (CTI) in conjunction with LumiNova Schweiz AG and the University of Geneva, Empa researchers managed to increase the glow duration of the best pigments by 60 percent. The technology is licensed exclusively to LumiNova Schweiz AG and selling well on the Swiss and international markets. //

1

1
A long optical path in a compact, light design has been realized to measure trace gases: the MultipassCell.

2
The glow duration and intensity could be improved considerably for luminescent pigments that light up watch faces in the dark.



2

Entrepreneurship as an engine of technology transfer

Mario Jenni, mario.jenni@empa.ch
Peter Frischknecht, peter.frischknecht@empa.ch

In Empa's business incubators, 55 start-ups with a total of over 300 employees were accompanied from the first kernel of a business idea to their market entry last year.

Compact device to aid environmental protection

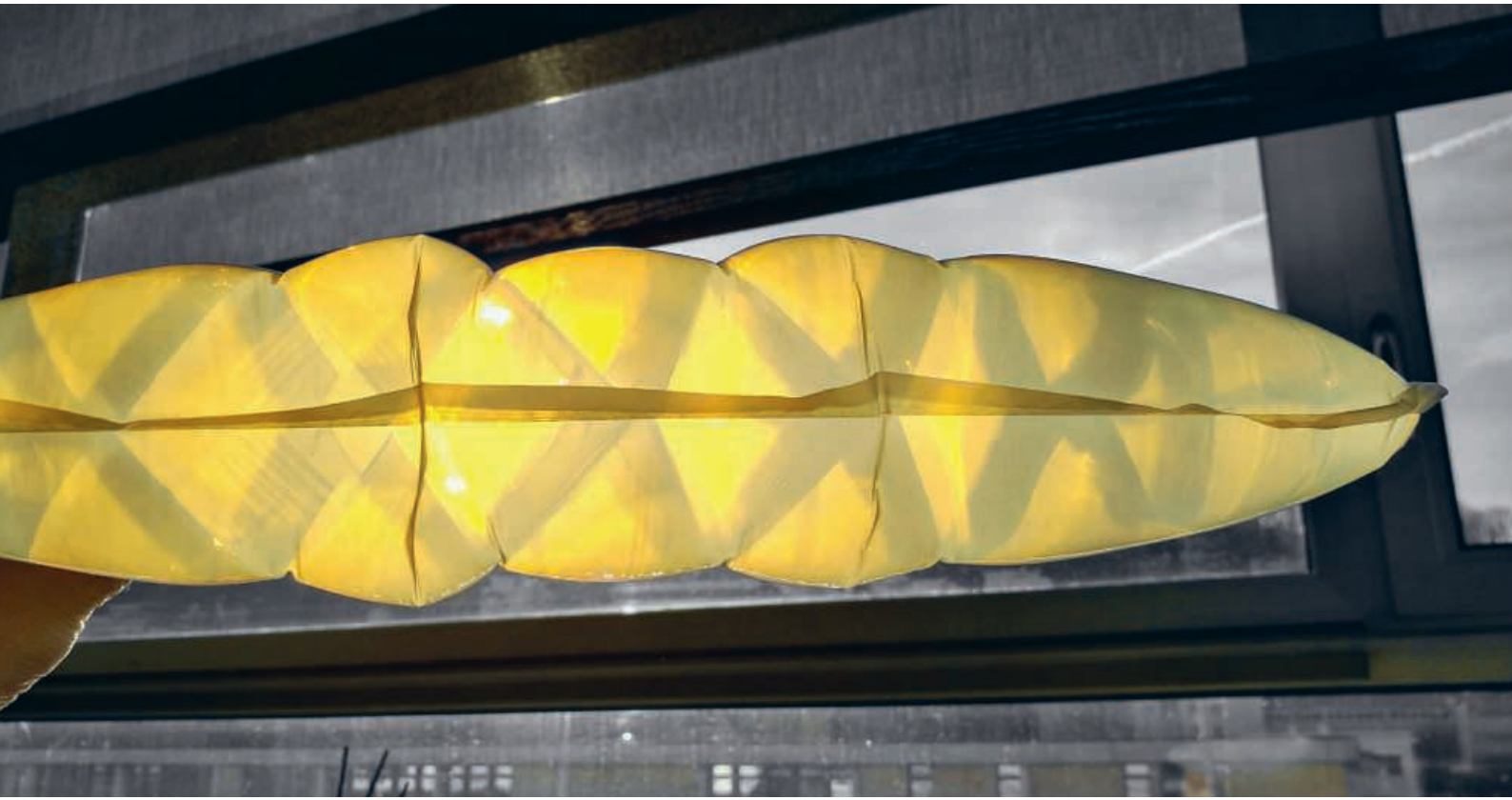
Air pollution and climate change are global problems. Public sensor networks to monitor air quality are supposed to take accurate readings of the air pollution levels and sound the alarm if any limits are exceeded. These networks require complex (and therefore expensive) measuring devices, as different instruments are used for every gas they gage. Moreover, pollutants such as regulated nitrogen dioxide (NO_2) can only be measured indirectly, which can distort the results.

The company MIRO Analytical Technologies was founded as an Empa spin-off to launch the latest gas measuring technology based on quantum cascade lasers (QCL) in the mid-infrared range on the market. This technology enables the development of a compact device which can be used to measure concentrations of the main greenhouse gases and pollutants – including NO_2 – simultaneously and at an unprecedented speed and precision.

Water and air-tight seams thanks to laser technology

Empa scientists have spent several years developing a novel process that fuses synthetic fiber fabrics – making the "seam" airtight and waterproof. In order to exploit the innovative technology commercially, the two Empa researchers Alexander Haag and Michel Schmid founded the spin-off Nahtlos in 2017, a fledgling company based at the Startfeld innovation center in St. Gallen, right next door to Empa.

The new technology creates completely new possibilities in the field of surface structuring and facilitates new functionalities and a new design. Potential application areas might include the clothing industry, vehicle equipment and medical aids. However, interesting prospects are also opening up to the Empa spin-off in the field of interior design, especially the lighting sector. The technology has the potential to replace previous production processes in the industry. //



The fledgling company Nahtlos used a laser to fuse synthetic fiber fabrics and render them water- and air-tight.

The short cut from research to the real world

Gabriele Dobenecker, gabriele.dobenecker@empa.ch

Empa develops solutions for the main challenges that industry and society face, and thus link applications-oriented research to the practical implementation of new ideas. Thanks to an effective technology transfer, Empa converts research results into marketable innovations together with its industrial partners and thus makes a significant contribution towards boosting the innovative power and competitiveness of Swiss industry, true to its motto: Empa – The Place where Innovation Starts.

Further strategic partnerships

Besides more than 170 new research projects which Empa launched in collaboration with over 200 industrial partners last year, strategic partnerships were also formed again 2017. These included BASF (Switzerland), which is looking to team up with Empa and other institutions of the ETH Domain to develop innovations in the fields of recycling management, digital production, novel technologies for surface structuring and materials and systems for the construction sector and set up one of its innovation teams at the glatec technology center on the Empa campus in Dübendorf.

Boosting the Empa site in Thun

Moreover, Empa teamed up with its industrial partners in demonstrators and pilot plants such as NEST, move and ehub to show the feasibility of new technologies and launched pioneering projects in selected research focus areas as public-private partnerships. These include a competence center for additive manufacturing technologies for metallic materials and processes at the Empa site in Thun. In 2017 the Canton of Bern and the City of Thun decided to support the project with a total of 12 million Swiss francs; over the next few years, a new building complex that will also house a start-up center right next door to Empa will be built near Empa's current site. After all, the research results in this field are vital for the industries located in the Canton of Bern (medical engineering, the precision industry and watchmaking). The new competence center will give companies in these sectors the opportunity to step up their collaboration with Empa in 3-D manufacturing processes. Like at other sites, Empa is also a key partner for the regional economy in Thun and represents the ETH Domain in the Canton of Bern. It boasts proven expertise in the field of application-oriented materials research that is also important for additive manufacturing and 3-D printing. Over the next few years, Empa will ramp up its research on processing metallic alloys and ceramic materials for additive manufacturing. //

Empa in Thun – lodged in General Herzog Haus – is a key partner for industry.
It also represents the ETH Domain in the Canton of Bern.

From Japan to Canada – Empa's global network

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

Top-flight research is interdisciplinary and, therefore, has long since become an international endeavor. Representing more than 50 nationalities, Empa's research staff typifies one side of this globalized research world in and by itself. The other one is Empa's broad network of partners, which stretches from Japan and Russia through Europe, all the way to the USA and Canada.

Intensified cooperation with Japan and China

The Memorandum of Understanding (MoU) signed in 2016, which aims at a closer collaboration with the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, was followed by a vivid exchange of ideas last year, including two workshops – one on nanomaterials at Empa in May and a second one on energy research in Osaka in the fall. Like Empa, AIST is a public research institute with close ties to industry. It also focuses on implementing new technologies and endeavors to develop lab findings into a successful product in collaboration with its partners from industry. Empa CEO Gian-Luca Bona also seized the Japan visit as an opportunity to meet up with a number of industrial representatives during an event held at the Swiss embassy in Tokyo. And fruitful exchanges also took place with Empa's "sister institute", the National Institute for Materials Science (NIMS), such as during NIMS President Kzuhito Hashimoto's visit to Dübendorf in late November 2017.

A Chinese delegation headed by Energy Minister Nur Bekri along with representatives from the Swiss Federal Office of Energy (SFOE) paid Empa a visit at the end of January, shortly after the World Economic Forum (WEF) in Davos. They visited NEST and move, the modular experimental building and the future mobility demonstrator, and were visibly impressed by the wealth of innovations at Empa.

Numerous partnerships all over Europe

Empa has been fostering close relations with the Spanish Research Council (CSIC), a national research institute affiliated to the University of Seville, for a number of years now. In the fall of 2017, Empa launched an education program with the University of Seville, which enables around half a dozen students from the University of Seville to do their Master's projects at Empa. The first students are due to start at Empa in mid-2018.

1

2

1
Empa's Deputy CEO, Peter Richner (left), during a panel discussion with representatives of the energy sector from Canada and Switzerland at the "Smart Grid and Energy Storage Road Show".

2
The Canadian Ambassador in Bern, Susan Bincoletto, with Peter Richner, Deputy CEO of Empa.

3
The President of the Federal Institute for Materials Research and Testing (BAM) in Berlin, Ulrich Panne (2nd from right), research management officer Claudia Eggert and the Head of the Materials Engineering Department, Pedro Dolabella Portella (left) during their visit to Empa in July 2017, along with Empa CEO Gian-Luca Bona (center) and his Deputy, Peter Richner (right).

3

In October, Empa also embarked on a research cooperation with the University of Luxembourg in the field of innovative construction technologies. The building sector is responsible for considerable CO_2 emissions, consumes many resources and produces huge mountains of waste. The research cooperation aims to develop novel, sustainable construction methods and design models for buildings, which should become more resource- and energy-efficient as a result.

And in order to explore possibilities of a partnership in the field of nanotechnology, several meetings took place with senior representatives of the National University of Science and Technology (NUST MISIS) in Moscow in 2017.

Canadian delegation at Empa

As one of her first official appearances, the newly appointed Canadian ambassador Susan Bincoletto accepted an invite to Empa. In office in Bern since September 2017, the diplomat met up with representatives from the energy sector from Canada and Switzerland at the Smart Grid and Energy Storage Road Show in Dübendorf in early October. According to the general thrust of the event, the international collaboration on the production and distribution of energy is set to become increasingly important.

20 years in international technology cooperation

The collaboration with Latin American countries, particularly Colombia and Peru, celebrated its 20th anniversary last year. On the one hand, industrial projects for clean production methods and recycling systems for electrical devices were initiated and supervised. On the other hand, studies and research projects could be conducted with several universities such as Lima, Bogotá and Medellín with the aim of curbing industrial environmental pollution and job cuts. //

Empa research the talk of the town

Dr Michael Hagmann, michael.hagmann@empa.ch

Compared to 2016, when Empa launched its large-scale research platforms NEST, move, ehub and the Coating Competence Center (CCC) – each with an official inauguration and crowds of people flocking to the Empa premises – 2017 was a fairly "quiet" year. On paper at least. For even without "big occasions", public interest in Empa research was vast last year. For instance, around 3,200 people took advantage of the guided tours, over 2,200 people attended the roughly 40 specialist events organized by the Empa Academy, and around 10,500 people witnessed the latest construction and energy innovations in NEST. That works out at a whopping total of 16,000 visitors for the year – or more than 300 a week, (once again) a new all-time high. These also included numerous illustrious guests, such as the governments of the cantons of Zurich, St. Gallen and Thurgau, which convened at Empa in St. Gallen in November for their annual meeting.

Novel manufacturing technologies take on central stage

The Advanced/Additive Manufacturing (AM) sector is pivotal for Empa. For instance, the ETH Domain's newly founded Strategic Focus Area "Advanced Manufacturing" (SFA-AM), headed by Empa, was inaugurated in Bern on 13 November. Swiss Federal Councilor Johann Schneider-Ammann, the President of the ETH Board, Fritz Schiesser, the President of ETH Zurich, Lino Guzzella, EPFL President Martin Vetterli and Empa CEO Gian-Luca Bona as well as numerous representatives from industry all attended the event.

In his opening address, Federal Councilor Schneider-Ammann lauded the strong position of Swiss industry on the international stage. At the same time, however, he urged the need to keep a close eye on industrial change in the wake of "Industry 4.0". After all: "Jobs that drift away never come back." This is precisely where the AM research network comes in; it aims to flesh out answers to the challenges of digitization, especially in the field of industrial production, and thus ensure that Swiss industry remains competitive on the international stage thanks to innovations.

He who dares wins

AM was also a talking point at various specialist events, such as two "Technology Briefings" in Dübendorf and – for the first time – in Thun with a total of around 250 participants, primarily from industry. Or at the opening ceremony for last year's "Technology Days" on the topic of "Factories of the Future – a Challenge for Humans and Technology", which enticed around 200 people to Empa at the beginning of October. Riveting talks by speakers such as by Thomas Mayer, the former CEO of the Lotus Formula One team, were interspersed with lab tours, which offered the participants a direct insight into the world of Empa research.

Another aspect of the innovation process – the willingness to take risks – was at the heart of the Empa Technology and Innovation Forum, which was held for the sixth time – in this instance with Swiss Life Asset Managers at event partners. Empa's Board of Directors initiated these exclusive series of annual events to discuss issues of the innovative edge and international competitiveness of Swiss industry with C-level representatives from industry and economy. This time round, Bern-based comedian and slam poet Christoph Simon and winemaker Mathias Bechtel from Eglisau, who was named "Shooting Star of the Year" by the journal Vinum two years ago, demonstrated that innovative ideas and concepts are not just vital in research and industry.

1

2

1
Around 10,500 people were interested in the latest building and energy innovations, such as the adaptive solar panels installed in NEST and a wall constructed solely by robots.

2
More than 2,200 people attended around 40 events organized by the Empa Academy in 2017.

Massive media attention

Besides public interest, Empa's research results also brought the institute a pleasingly large media response. A total of around 6,200 articles in 34 languages reported on Empa's research activities, almost 160 of which were on radio and TV – more than ever before. //

Increasing number of women in senior management positions

Marianne Senn, marianne.senn@empa.ch

Last year, numerous appointments of women in senior management positions sent out a clear signal. On the Board of Directors, Tanja Zimmermann, who previously headed the Applied Wood Materials Laboratory, took over the helm in the Functional Materials department, lifting the proportion of women on the Board to around 30 percent. This trend is also evident in the Engineering Sciences department: "Multiscale Studies in Building Physics" has been run by Dominique Derome since April and Kristina Orehounig will be heading "Urban Energy Systems" as of February 2018. The proportion of women among laboratory heads in this department has ballooned from 0 to 33 percent. Women therefore now hold senior management positions in five of the six departments.

The goal of the ETH Domain's Equal Opportunities committee is to consolidate this trend further. A call for tenders from swissuniversities, the coordinating organ of the Swiss universities, invited all universities and the research institutes in the ETH Domain to submit innovative projects on the topic of promoting women. The ETH Domain compiled a project designed to groom budding scientists for a career outside the world of research following their doctorates or postdocs. After all, there are considerably fewer jobs in the academic world than there are young researchers. The aim of the project is to connect women from a vast range of fields – science, industry, public administration, NGOs – in order to open their eyes to a broader career profile. The recently approved project will be implemented as of 2018.

In parallel, the committee compiled a new strategic document on the topic of gender equality 2017–2020 for the ETH Domain.

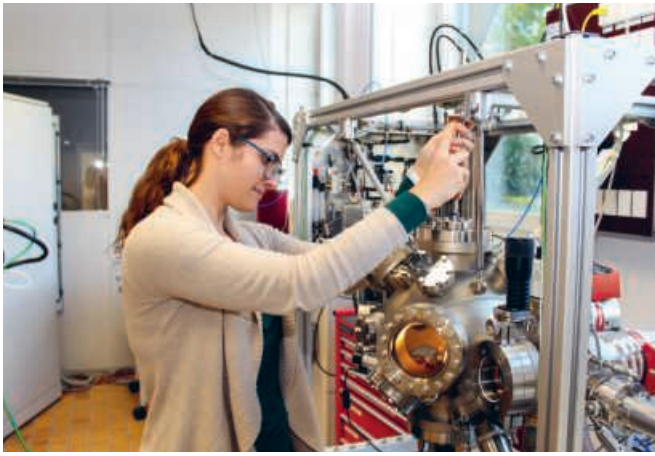
«Women in Science»

Besides networking events for women, the events series Women in Science kicked off last year in conjunction with Empa's sister institute Eawag. At the first event, Simona Isler, the gender equality representative from the Swiss National Science Foundation (SNSF), talked about the SNSF's efforts to achieve equal opportunities for women and men. This includes new funding instruments such as the Flexibility Grant, which can be used to pay for external childcare and reduce the workload; the Gender Equality Grant, which enables mentoring and networking in the workplace; the Mobility Grant, which funds living costs and travel connected with an academic position abroad; and the program PRIMA for women looking to embark on a career at a Swiss university (they receive funding for their own research project for a maximum of five years).

Inspiring young people

Moreover, a wide range of events were held, such as the summer camp for smaller children of Empa employees and the National Future Day for young people facing a career choice.

Once again, more than 100 children took part at all three sites. As a partner on the project Mädchen-Technik-los ("Girls-Technology-Go"), Empa made a point of giving girls and boys an unforgettable experience and offering the researchers of tomorrow an exciting glimpse into the world of research and innovation. //



1
Simona Isler, the gender equality representative of the Swiss National Science Foundation (SNSF), at one of the workshops in the Women in Science series.

2
Unfortunately, there are considerably fewer jobs in the academic world than there are young researchers.

3
A unique opportunity at National Future Day: Driving a hydro-powered road sweeper.

Much more renewable energy in use

Marcel Gauch, marcel.gauch@empa.ch

In keeping with the energy concept for the Empa and Eawag campus in Dübendorf, the energy supply infrastructure is being converted to generate far less CO_2. The main priority is to curb the energy needs by improving building insulation. This is because the majority of the greenhouse gas emissions on the Empa campus stem from the buildings' heating needs. The ongoing optimizations will help slash the current annual greenhouse gas emissions of around 3,500 tons of CO_2 equivalents.

Increased use of waste heat

To cover the lower energy requirements, heat at high temperature levels (supplied by burning natural gas until now) will no longer be necessary in future. The suitability for heating at a reduced temperature level of around 38 °C has the advantage that we can largely do without fossil fuels and use the waste heat from research processes and cooling machines instead. The construction of seasonal heat storage systems is scheduled in the next few years. This means that Empa's energy concept is pioneering and exemplary as regards the energy transition.

Development of photovoltaics

Empa's own production of renewable electricity from photovoltaics was expanded by 90 kWp (kilowatt peaks). Besides systems with classic solar panels, a 30-kWp unit from Empa spin-off Flisom was installed based on state-of-the-art thin-film solar cells. A total area of 5,000 square meters of photovoltaics is in the pipeline and due for completion by around 2020. It should enable approximately 600 MhW of renewable electricity to be generated every year.

Additional categories for mobility and waste now enable the comprehensive monitoring of consumption figures and environmental effects. The proportion of renewable energy could be increased considerably to 59 percent (compared to 21 percent the previous year). As a result, the 75 percent target of the Swiss Federal Office of Energy (SFOE) within the scope of the program "The Confederation: Exemplary in Energy" for 2020 seems perfectly realistic. //

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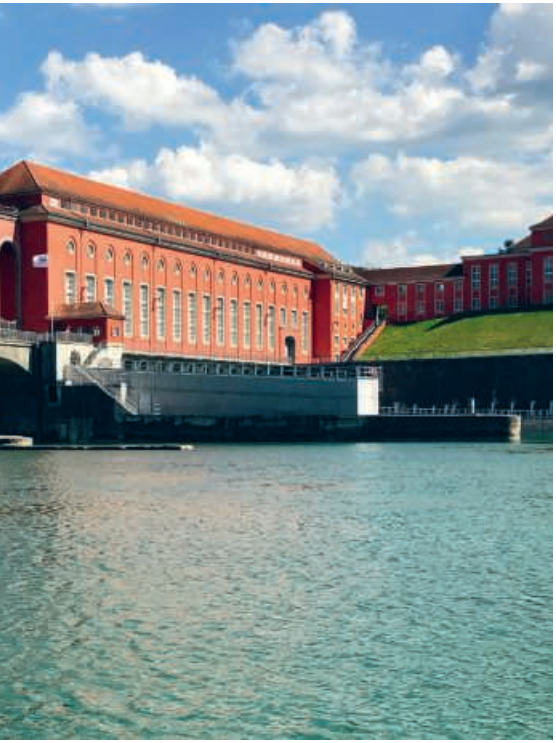
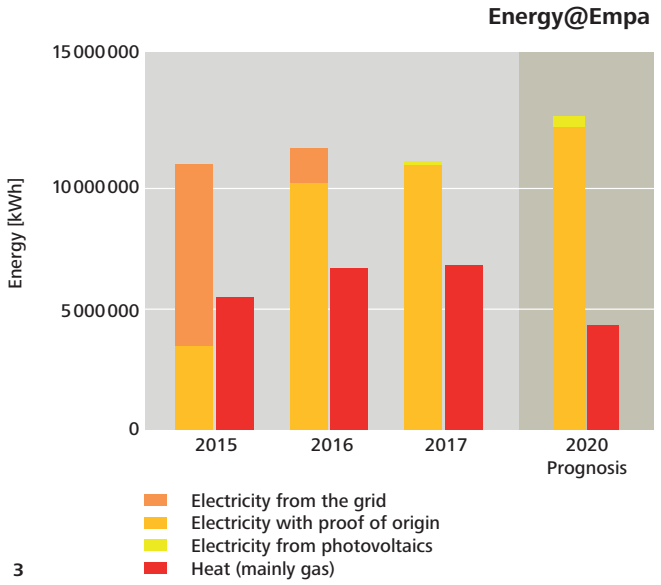


1
The Rheinfelden run-of-the-river hydroelectric power plant supplies Empa with electricity. The proof of origin guarantees that ecological criteria such as residual water quantities and fish friendliness are met.

2
The photovoltaic system from Empa spin-off Flisom was activated in Dübendorf in September 2017.

3
Trend in Empa energy consumption. Electricity with proof of origin (HKN, hydropower) and own production from photovoltaics (PV) cover the entire demand. The heat demand remained more or less constant.



3


Bands
2: 65- band 1
3: 65- band 2
4: 65- band 3

Facts and Figures

Researchers like measuring, including their own performance: in 2017, Empa researchers and engineers published almost 700 academic papers and filed patent applications for 14 developments. At the end of the year, 120 projects funded by the Swiss National Science Foundation (SNSF), 103 projects backed by the Commission for Technology and Innovation (CTI) and almost 70 EU projects were underway at Empa. Together with other start-ups in Empa's two business incubators, the 24 spin-offs employed a total of 580 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.*

Risk management

Stefan Hösli, stefan.hoesli@empa.ch

Empa's risk management is aimed at recognizing and analyzing potential risks to the company and staff at an early stage, 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 regulations towards the risk management standards in 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 evolved in 2017; it was reorganized and new staff were added to help accommodate the increased demands and numerous requests. Security topics were rendered more visible overall to heighten the staff's awareness. This is reflected in the considerable increase in security-related topics and the ballooning amount of time needed to process cases. The topics ranged from operating a glassware washroom in a safe and environmentally friendly manner and advice on operating laser facilities, through setting up and operating a robot, all the way to clarifications for tests on self-driving cars on the Empa campus and working on the demand analysis and the development of a flexible lab concept for a future laboratory building. Moreover, a new process was implemented which improved the protection of expectant mothers and their unborn children. All members off staff were kept informed via the intranet.

The high number of new arrivals poses a particular challenge for work safety. Consequently, the centrally organized training courses were expanded further on all campuses and a course calendar was displayed on the intranet. The collaboration with the sister institute Eawag was also stepped up; members of Eawag are also trained by Empa in chemical and nanosafety and attend its fire extinguishing courses.

The newly organized patrols for the Empa and Eawag campus during the night and on national holidays went extremely well. The complicated site, however, necessitates partial video surveillance. The corresponding project developed with specialists is currently being assessed by the Swiss federal data protection officer and will then be implemented.

Two evacuation drills were conducted successfully on the Dübendorf and St. Gallen campuses. The valuable feedback from both the participants and the organizers was subsequently taken onboard to keep improving the evacuation system. //

Human resources development

(previous year's figures in brackets)

André Schmid, andre.schmid@empa.ch

At the end of 2017, 966 (936) people were employed at Empa (incl. trainees). Due to the large number of part-time options, this corresponds to a full-time equivalent of 895.4 (860.9) positions.

Empa has 530 (507) members of the academic staff, including 116 (116) senior scientists. 392 (387) people were technical and administrative employees in the reporting year. The proportion of women – 28.1 (28.5) percent – reflects the graduate figures of the universities and ETH Zurich in the faculties where Empa is represented.

399 (380) members of staff are from abroad, which corresponds to around 41.3 (41)percent of the total head count. 262 (259) people come from EU countries, i.e. 65.7 (68) percent of all foreign members of staff. Empa offers a wide range of traineeships and employs 44 (42) trainees. Once again, all the trainees passed their final examinations in 2017. //

STAFF (AS OF 31. DEZEMBER 2017)

	2016	2017
Scientific staff	507	530
Technical and administrative staff	387	392
apprentices	42	44
Total	936	966

Key figures

SCIENTIFIC OUTPUT

	2016	2017
ISI publications	586	695
Conference contributions	1,131	1,328
Doctoral studies completed	31	33
Docoral studies in progress	168	177
Teaching activities (in hours)	3,815	3,987
Prizes and awards	56	65

MEDIA EXPOSURE

	2016	2017
Radio and TV	93	155
Print	1,110	1,200
Online	3,030	4,850
Total	**4,233**	**6,205**
Languages	29	34

EMPA ACADEMY

	2016	2017
Empa events	**86**	**55**
Participants	9 000	3 400
Scientific conferences	3	10
Events for industry	40	36

KNOWLEDGE DISSEMINATION AND TECHNOLOGY TRANSFER

	2016	2017
New R&D Agreements	177	175
Active exploitation contracts	79	68
New exploitation contracts	13	13
New patent applications	14	14

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

	2016	2017
Companies total	**69**	**72**
thereof spin-offs	22	24
Employees total	**531**	**580**
thereof employees of spin-offs	112	118

CURRENT PROJECTS

	2016	2017
Swiss National Science Foundation (SNSF)	100	120
Commission for Technology and Innovation (CTI)	85	103
EU projects	57	69

Bodies of Empa

ETH Board

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

CHAIRMAN
Fritz Schiesser Dr iur., Haslen GL

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

MEMBERS
Kristin Becker van Slooten Dr, EPF Lausanne
Marc Bürki Dipl. El.-Ing., Swissquote
Beatrice Fasana Dipl. lng. Lm, Sandro Vanini SA, Rivera
Susan Gasser Prof. Dr, Dr h.c.mult., Universität Basel
Lino Guzzella Prof. Dr, ETH Zurich
Barbara Haering Dr Dr h.c., Econcept AG, Zurich
Christiane Leister Leister AG, Kägiswil
Joël Mesot Prof. Dr, PSI, Villingen
Martin Vetterli Prof. Dr, EPF Lausanne

Industrial Advisory Board

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

CHAIRMAN
Henning Fuhrmann Dr, Siemens, Zug

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

Research Commission

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

MEMBERS
Urs Dürig Dr, IBM, Rüschlikon
Rik Eggen Prof. Dr, Eawag, Dübendorf
Thomas Egli Prof. em. Dr, Feldmeilen
Alexander Wokaun Prof. em. Dr, Endingen

Organizational Chart

as of May 2018

RESEARCH FOCUS AREAS
(Research priorities)

Nanostructured Materials
Dr Pierangelo Gröning

Sustainable Built Environment
Dr Tanja Zimmermann
Prof. Dr Giovanni Terrasi

Health and Performance
Prof. Dr Alex Dommann

Natural Resources and Pollutants
Dr Brigitte Buchmann

Energy
Dr Peter Richner
Urs Elber

GENERAL MANAGEMENT

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

DEPARTMENTS

Advanced Materials and Surfaces
Dr Pierangelo Gröning

Electron Microscopy Center
Dr Rolf Erni

Engineering Sciences
Dr Peter Richner

Materials Meet Life
Prof. Dr Alex Dommann

Center for X-ray Analytics
Prof. Dr Antonia Neels

Electronics & Reliability Center
Prof. Dr Alex Dommann

LABORATORIES

Joining Technologies and Corrosion
Dr Lars Jeurgens

Advanced Materials Processing
Prof. Dr Patrik Hoffmann

nanotech@surfaces
Prof. Dr Roman Fasel

Mechanics of Materials and Nanostructures
Dr Johann Michler

Thin Films and Photovoltaics
Prof. Dr Ayodhya N. Tiwari

Functional Polymers
Prof. Dr Frank Nüesch

Road Engineering / Sealing Components
Prof. Dr Manfred Partl

Structural Engineering
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