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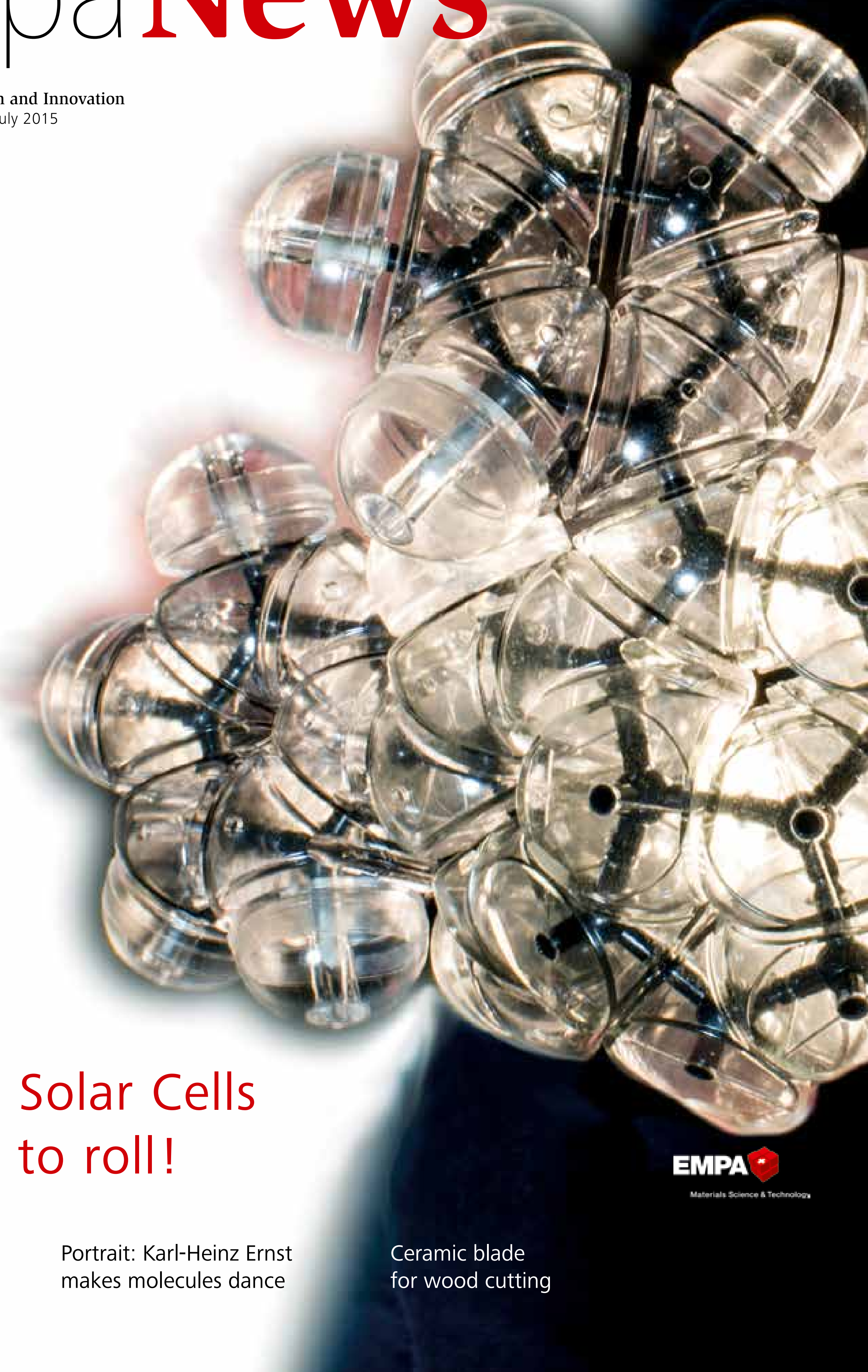


Flexible Solar Cells – ready to roll!

Anesthetics in Antarctica

Portrait: Karl-Heinz Ernst makes molecules dance

Ceramic blade for wood cutting

EMPA Materials Science & Technology

MICHAEL HAGMANN Head of Communications

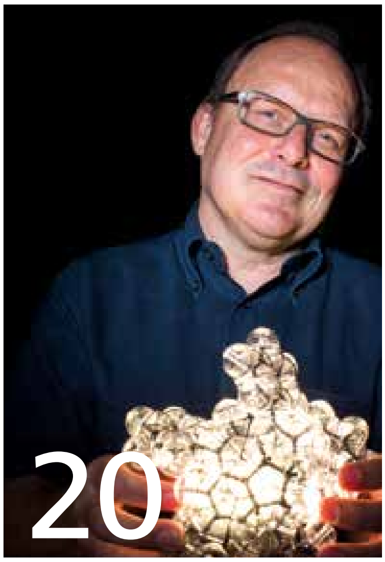
Out and about

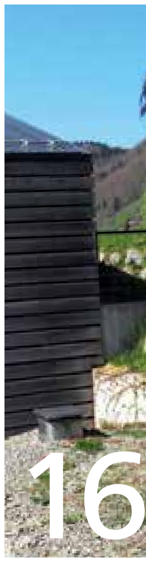
Almost all research labs the world over have one thing in common: they give rise to new, unprecedented innovations. The novel ideas, concepts, technologies and materials that Empa researchers and engineers conceive and develop need to hold their own in the real world, too, i.e. pass the practical test. After all, Empa researchers want to make a difference and help find solutions to pressing questions, whether it be in the energy or healthcare sectors or in the quest for a clean environment.

Therefore, the true litmus test for innovations does not take place in the lab, but rather "on the street". Empa scientists are, therefore, frequently out in the field – at the Korean King Sejong research station in Antarctica or on the Jungfraujoch to analyze air samples and trace climate gases and other man-made air pollutants, for instance (p. 8 ff.). Or at the inauguration of a pilot production plant for flexible thin-film solar cells, with which Empa/ETH Zurich spin-off Flisom is hoping to shake up the solar industry (p. 4). Or near Rütli mountain meadow, where a home-owner has had the first prototype of a novel Empa "concrete heating system" installed in his garage (p. 16).

The latter example also goes to show how the transfer of technology from the lab to practice sometimes takes place in peculiar ways – and that a healthy dose of courage is always necessary: a few years ago, home-owner (and construction physicist) Mark Zumoberhaus read an article in a commuter newspaper about the concrete heat storage system that was being developed at Empa and immediately got in touch with the researchers. This coming winter, the visionary will be heating his vacation home in Seelisberg with solar power from Empa's ettringite concrete for the first time – without any guarantees or double flooring whatsoever. Hats off!

Enjoy reading!





Cover
Molecular model of Karl-Heinz Ernst's "waddling duck": the researcher specializes in chiral structures and specifically constructed molecules, which can move when «tickled» by the scanning tunneling microscope (STM). In February 2015, Empa awarded him the title of «Distinguished Senior Researcher». ***Portrait on page 20.***

Focus

Atmosphere

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Ready to roll

Flexible solar cells featuring Empa tech near Zurich. The pilot plant of the spin This is the culmination of eighteen yea

TEXT: Rainer Klose / PICTURES: Heidi Hostettler

Protective clothing was the order of the day at the inauguration of the Flisom pilot production plant on 11 June. Not to protect the visitors, but rather the sensitive machinery, which will manufacture the first flexible solar cells on a large scale by the end of the year. No dust particles are allowed to get into the equipment. The young company's production plant is a world first: rolls of flexible solar cells measuring up to one meter in width and based on the CIGS technology developed at Empa are to be produced in large vacuum evaporation machines.

The acronym CIGS stands for "copper indium gallium selenide", the semiconductor mixture used to convert sunlight into electricity. Unlike in conventional solar cells made of crystalline silicon, the CIGS absorber layer is merely a thousandth of a millimeter thick – and therefore supple, which enables flexible solar cells to be produced for the first time. Instead of a large-scale "window factory", a space-saving "film factory" is sufficient to produce solar modules in series. As a result, a major step towards the mass distribution of solar technology has been achieved: the low-cost modules can inexpensively be mounted on roofs or incorporated into the sheet metal body of cars, busses and trucks.

Much like potato chip bags

"What we do here has a lot to do with packaging for potato chips," says Ayodhya N. Tiwari. The company founder is both its current Chairman and Head of Empa's Laboratory for Thin Films and Photovoltaics. "The metallized foil bags that potato chips come in are also produced in vacuum machines using similar roll-to-roll methods," he explains. While the structure of the CIGS layers is considerably more complicated than the simple aluminum layer needed to protect food, the vision is the same: produced in large quantities, low-price films stand a chance of worldwide distribution.

K.R.S. Jamwal, Executive Director of the Indian multi-industry group Tata Industries, hopes to conquer the global market with the technology developed in Niederhasli.

Production hall at the Flisom pilot plant in Niederhasli. Flexible solar modules are mass-produced on the roll machines. Every year, solar cells with an output of 15 megawatts can be built.

nology will soon be rolling off the production line at a brand new factory in Niederhasli -off Flisom is the first step towards serial production and could slash the costs for solar modules. rs of research and development, the majority of which took place in Empa's labs.

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Jamwal is also responsible for the promotion of start-ups at Tata. The global giant already invested several million Swiss francs in the Swiss company in recent years. "We're involved in high-tech companies in Silicon Valley, Boston, Great Britain – and now here in Greater Zurich, where the start-up conditions are at least as good as in the US," said Jamwal at the opening. "I'm glad I came across top-class scientists here, with whom you can talk about revenues as well as about research. That's a great combination."

However, there is still a long way to go before the first sales revenue from solar cell production comes rolling in. Production is to be launched and increased in the next nine to twelve months. Even then, however, the first CIGS cells from Flisom still won't be freely available; instead, they will be reserved for research purposes, durability tests and experimental buildings such as NEST on the Empa campus in Dübendorf. Once the production process is fully up and running, the factory in Niederhasli will churn out solar cells with a total output of 15 megawatts (MW) every year. The pilot plant serves as a kind of blueprint for commercial factories with a total annual output of 100 MW. This is equivalent to the output from the new hydroelectric power plant in Rheinfelden, which opened in 2010.

Good things come to those who wait…

While the plant in Niederhasli produces solar cells that are one meter wide, Flisom's somewhat older facility on the Empa campus will also carry on working. Innovative production methods for the solar cells of the next generation are already under development at this smaller plant. In parallel, Tiwari's group at Empa is conducting further research into the basics of thin-film technology, such as increasing their efficiency in energy transformation – a field where his lab has already broken world records (see box at p 07).

It is not always possible, though, to transfer what works well in the lab to industrial production. It took the supple CIGS technology almost two decades to be ready for mass production. "A long way, which wouldn't have been possible without the support and expertise of Empa," Tiwari is convinced. As important as private investors are for the development of market-ready products and technologies, this is clearly too long for them. "This example illustrates the key role that Empa plays as a bridge between research and practical application," says Empa CEO Gian-Luca Bona. "All the years of hard work we put into researching renewable energy have now finally paid off."

In the meantime, Flisom's experts are already working on their business model for marketing the CIGS cells. "We're competing against Asian manufacturers, who also produce inexpensive solar cells – albeit on glass plates at present," says Stephan Stutterheim, who is responsible for business development. "We offer pioneering prospects and new business models for solar module production and integration. The advantage we've got is that we can provide customized and inexpensive solutions for our international customers."

One of the first results from this close interaction with customers was already evident at the inauguration: Roland Kern, who is responsible for product development at Flisom, showcased ready-to-mount rooftop modules, complete with solar cells and electrical wiring. "We're able to integrate our flexible cells directly in sheet aluminum or steel. The sheet metal can subsequently be bent into a metal roof tile or façade element," says Kern. "This makes our light and semi-flexible solar modules just as easy to install as a normal tin roof, which saves time – and therefore money – as the roof and solar technology come in one piece." However, not only are particularly inexpensive solar roofs feasible; special aesthetic solutions can also be discussed at Flisom. "Many architects like the uniform black color of the Flisom modules," says Kern. //

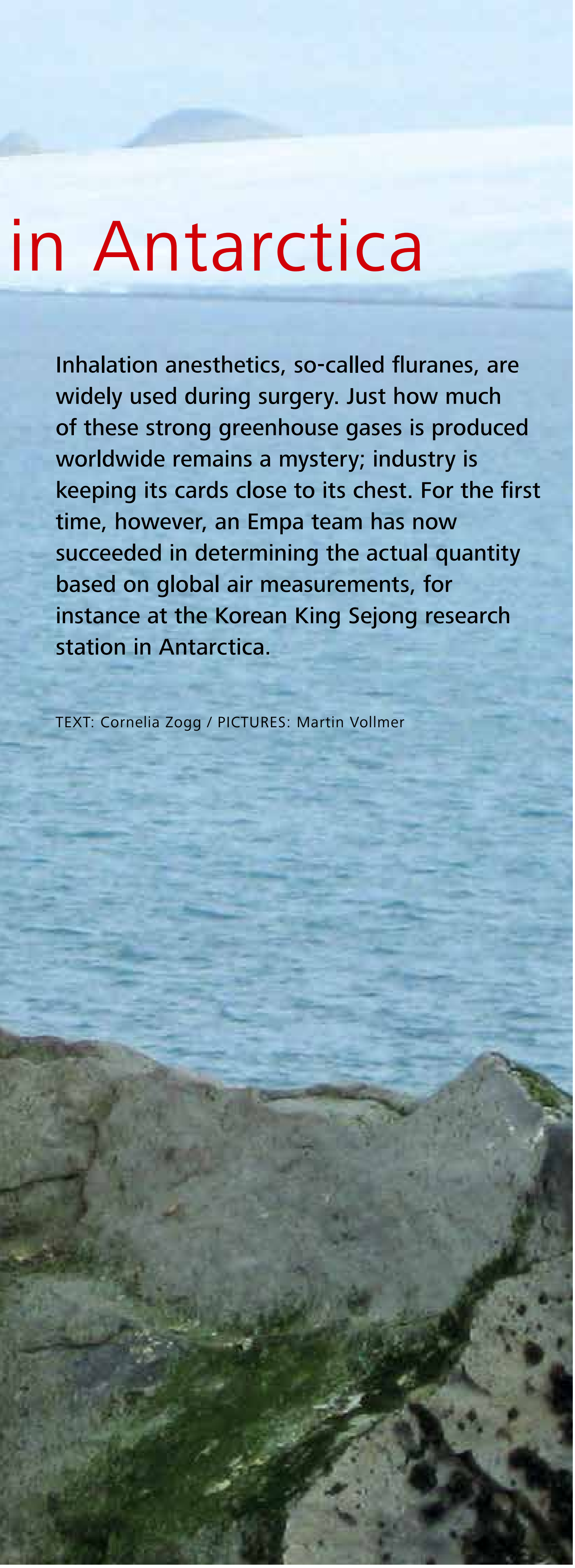
Researchers neck and neck

While production gets underway at the Flisom pilot production plant, research in the lab mustn't grind to a halt. For a reasonably priced, competitive solar cell, efficiency is key – i.e. the proportion of light that is converted into electricity. Over the years, Empa researchers have managed to keep increasing the efficiency for flexible CIGS solar cells: from 12.8% in 1999 to 14.1% (2005), 17.6% (2010) and 18.7% (2011). And in 2013 a team headed by Ayodhya N. Tiwari succeeded in achieving a world record value of 20.4%. The secret to this success was a new production method for CIGS solar cells, where tiny amounts of sodium and potassium are incorporated into the CIGS layer. This special treatment alters the chemical composition of the complicated sandwich structure changes – and thus its electronic properties, as detailed electron-microscopic studies revealed.

With an efficiency level of 20.4%, the CIGS cells can (finally) keep up with the best polycrystalline silicon solar cells. This makes Empa CIGS cells some of the most efficient in the world. The research projects are funded by the Swiss National Science Foundation (SNSF), the Commission for Technology and Innovation (CTI), the Swiss Federal Office of Energy (SFOE) and the EU Framework Programs.

Top: Inauguration of the Flisom pilot plant in Niederhasli (ZH) on 11 June 2015. Seated: K.R.S. Jamwal from Tata Industries; behind him, Empa scientist and company founder Ayodhya N. Tiwari.
Bottom right: Flisom product developer Roland Kern demonstrates how the flexible Flisom solar modules can be turned into ready-to-fit roof tiles.

Anesthetics



in Antarctica

Inhalation anesthetics, so-called fluranes, are widely used during surgery. Just how much of these strong greenhouse gases is produced worldwide remains a mystery; industry is keeping its cards close to its chest. For the first time, however, an Empa team has now succeeded in determining the actual quantity based on global air measurements, for instance at the Korean King Sejong research station in Antarctica.

TEXT: Cornelia Zogg / PICTURES: Martin Vollmer

They are called desflurane, isoflurane and sevoflurane and put patients in a deep sleep while surgeons patch them back up again on the operating table. But fluranes also have a dark side: they considerably heat up the Earth's climate. As a greenhouse gas, desflurane is 2'500 times more potent than carbon dioxide, or CO_2, for instance. A global inventory would, therefore, be very much in the spirit of the Kyoto Protocol. However, this is proving more difficult than anticipated as industry is remaining tight-lipped. To date, only estimates are available, which were obtained using a bottom-up approach by projecting the consumption in hospitals the world over and deducing an approximate production quantity.

A team of Empa researchers headed by Martin Vollmer has now taken the opposite approach: top-down. They analyzed air samples from various stations in the global AGAGE measuring network (Advanced Global Atmospheric Gases Experiment, see map on p.14 – 15) for traces of inhalation anesthetics and used the results to calculate the global production quantity – which turned out to be equivalent to around three million tons of CO_2. While that might sound like a lot, says Vollmer, Switzerland's public transport system alone produces around three times as much every year. So a comparatively low amount of greenhouse gas actually gets into our atmosphere via operating theaters. Nonetheless, especially desflurane is thought to have an impact on the climate and, with a half-life of around 14 years, is extremely long-lived. By comparison, sevoflurane and isoflurane break down in only one to three years.

After two years gases show up at the south pole

Measurements in Antarctica also revealed that these substances reach the remotest regions of our planet. It takes the greenhouse gases around one to two years to make the journey to the poles. Atmospheric scientist Vollmer traveled to the Korean King Sejong research station in Antarctica already twice to carry out measurements, take probes and analyze the samples. As this is too time-consuming for long-term monitoring, however, Korean colleagues at the station regularly fill flasks with air and send them to Dübendorf.

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And Vollmer's team can also fall back on samples from an air archive for their analyses: Australian researchers have regularly been collecting air from the atmosphere and storing it for later studies since 1978.

But what is the next step now that effective statistics are available and we know that these substances are not just found in urban centers – i.e. where they are predominantly used – but travel to the ends of the Earth? Nobody can really agree, says Vollmer. Fluranes have already been produced since the 1980s, and even back then had their opponents and supporters. Although they are extremely strong greenhouse gases, their absolute amounts are so low that it hardly makes any difference in the big scheme of things. In contrast, they have no end of advantages for human and veterinary medicine. Vets use fluranes to anaesthetize livestock quickly and easily before castrating piglets, for instance, which is considerably more cost-effective than drugging one animal after another with injections. While cost plays a lesser role in human medicine, inhalation anesthetics is certainly more pleasant for the patients.

As for the threat of climate warming, however, the question remains as to whether more atmosphere-friendly alternatives can be developed. //

Prestigious EU grant for Swiss scientist

Climate physicist Hubertus Fischer from the University of Berne received one of the prestigious ERC Advanced Grants for his research on polar ice cores. Within the scope of the project "deepSLice" (Deciphering the greenhouse gas record in deepest ice using continuous sublimation extraction / laser spectrometry), his team is looking to develop a novel method to extract air from ice cores and a special analytical method to measure both greenhouse gas concentrations and carbon dioxide (CO_2) isotopes. During the project, Fischer will be supported by Lukas Emmenegger's team from Empa, which leads the way in the development and application of laser-spectroscopic methods for gas analytics in atmospheric research.

Laser-based gas analysis is extremely accurate and only requires very small quantities of gas – both of which will play a crucial role in the measurement of samples from an international ice core drilling project in the Antarctic that is scheduled for 2019/20. This should expand the history of greenhouse gases over the last 1.5 million years. To date, science has only been able to look 800'000 years into the past with the aid of ice cores. The European Research Council (ERC) has granted almost EUR 2.3 million for deepSLice over the next five years.

The atmosphere doesn't forget

Fourth-generation, halogenated coolants and foaming agents have only been in circulation for a few years. They replaced long-lived greenhouse gases such as R134a, which were used in (car) AC systems, refrigerators and various foams. The latest generation of these substances is a major step forward as they break down in the atmosphere considerably faster than their predecessors. Meanwhile, substances such as HFC-1234yf, HFC-1234ze(E) and HCFC-1233zd(E) are also increasingly being used, as initial results from the Empa measuring stations on the Jungfraujoch and in Dübendorf reveal. Since the first measurements were taken in 2011, these three coolants are being detected in the air with increasing frequency, which suggests that more and more manufacturers are switching to the new generation. The results were recently published in the journal "Environmental Science & Technology".

Measuring the older generation

The latest generation's predecessors are also still being analyzed. In another study recently published in PNAS ("Proceedings of the National Academy of Sciences of the United States of America"), an international research team – including Stefan Reimann and Martin Vollmer from Empa – analyzed the amount of HFC emissions and compared them with the official declarations submitted by various manufacturing companies, which are required to estimate their emissions and report them annually to the UNFCCC ("United Nations Framework Convention on Climate Change"). Not only do the emissions stem from the production process; they primarily enter the atmosphere when the substances are used: leakages in cooling devices or the gradual seepage of foaming agents from cold insulations are the most common culprits. The researchers compared the data evaluated by the UNFCCC with the measured concentrations. Sometimes, there were considerable discrepancies – in both directions. Some of the readings were higher than reported values (e.g. for HFC–125 and HFC–143a) and lower for other substances (HFC–134a). According to the study authors, this discrepancy can be attributed to the fact that not all countries provide data on the consumption of coolants. On the other hand, there is still a lack of measuring stations for more detailed studies. The Empa station on the Jungfraujoch, for instance, is already involved in two international networks: AGAGE ("Advanced Global Atmospheric Gases Experiment") and GAW ("Global Atmosphere Watch"; see infographics p. 14 –15).

Video
Atmosphere and Climate Research at Jungfraujoch

https://youtu.be/c0uoRynYOmw

Coolants for AC systems, foaming agents and solvents are harmful greenhouse gases and often remain in our atmosphere for a very long time before they degrade. After the latest generation of coolants was launched a few years ago, the first data on their global atmospheric distribution is now at hand.

TEXT: Cornelia Zogg / PICTURE: jungfrau.ch

Resea

SOURCES: iStockphoto.com, GAW / AGAGE

rch without boundaries

Empa is part of a global atmospheric research network. All participating researchers enjoy access to all data collected at stations around the world.

AGAGE stations *Advanced Global Atmospheric Gases Experiment*

The ALE/GAGE/AGAGE stations are coastal or mountain sites around the world chosen primarily to provide accurate measurements of trace gases with lifetimes that are long compared to global atmospheric circulation times.

GAW stations *Global Atmospheric Watch*

The programme of WMO is a partnership involving the Members of WMO, contributing networks and collaborating organizations and bodies which provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere.

Concrete heating

A unique experiment is currently underway in Seelisberg: a construction physicist from Lucerne had Empa researchers install six cubic meters of special concrete in the garage of his vacation home. The concrete stores heat during the summer and releases it in the winter as and when needed, which enables the house to be heated for weeks – sustainably and ecologically.

TEXT: Martina Peter / PICTURES: Empa

The house of construction physicist Mark Zumoberhaus is not far from Lake Lucerne. The building expert describes his little house as an "experimental hut". He now has a customized prototype in the cellar: the world's first concrete heat storage system.

Bottom left: Empa scientist Josef Kaufmann who developed and built the storage system.

Right: Storage module after casting.

We have enough energy in Switzerland to keep us warm during winter," says Mark Zumoberhaus, a construction engineer and owner of a detached, wooden-clad house in Seelisberg in the Canton of Uri. He is currently preparing an exciting real-world experiment in his garage together with Empa researcher Josef Kaufmann and his team. After all, Zumoberhaus is convinced that it must be possible to get by without oil or natural gas the whole year round, even in a village 850 meters above sea level. Instead, his (sole) heat source is the sun. The burning question, however, is how to conserve sufficient summer heat for the winter months.

Back in 2007, Zumoberhaus fitted the cladding on his house in Seelisberg with modern but fairly thin heat insulation based on a nine-cubic-meter water tank, which can store heat on a large scale. It is connected to the solar collector unit next to the house and a wood stove, which enables the water in the storage tank to be heated to 85 degrees Celsius in the summer. It ensures that the boiler supplies hot water and that the floor heating works in the winter. The temperature in the living quarters on the third floor is a pleasant 20 degrees, while 16 degrees is sufficient for the bedrooms on the second floor.

Usually, however, the stored energy only lasts until Christmas. And it isn't until February that the output from the solar system is sufficient to heat the boiler and living quarters again. "Until mid-February, I have to fire up the stove every time I enter the house," he says. The temperatures in the upper rooms drop to around 15 degrees. While he could always switch on the off-peak electricity if need be, he would rather do without it. But how?

Attractive solutions for energy problems

"That's my experimental hut," says Zumoberhaus, who advises architects on construction physics for a living. His customers usually want field-tested, reliable solutions. In order to save energy, as most construction physicists in this country agree, the heat insulation on a building's cladding needs to be as thick as possible. However, Zumoberhaus banks on other solutions in his private life: new, as yet untested solutions are more appealing, he explains.

Like many buildings in the region, his house boasts a wooden façade. However, he dispensed with conventional constructive protection from the elements – i.e. a projecting roof and overhangs – in the horizontal Swiss pine formwork. Instead, a good rear ventilation system ensures that any moisture that gets in can dry out again harmlessly. Consequently, the wooden façade is evenly exposed to wind and rain and can actually weather the elements without leaving any marks.

Another experiment was the unventilated tin roof construction with a variable vapor retarder. Thanks to its increased diffusion resistance, this foil, which was novel at the time, prevents too much

Video
Wunderbeton als Wärmespeicher (SRF)
(German language)

http://goo.gl/6kAHZX

Above: Concrete formwork for the small batch production of the storage elements, spring 2015. The concrete storage system comprises 24 separate blocks, which were cast at Empa using a special concrete. Every block weighs around 400 kg and is streaked with copper piping. The blocks are placed in an insulated, watertight metal casing. The local plumber connects it up to the central heating.

moisture from getting into the roof construction in the winter and causing the wood to rot. Thanks to the variable retarder, the moisture stored in the wood is "forced back" into the living quarters via reverse diffusion in the summer: the wooden construction completely dries out again. Zumoberhaus had heard about the foil developed by Hartwig Künzel from the Fraunhofer Institute for Building Physics and the corresponding analysis software WUFI, which promised excellent results. "The idea of finding out whether it would prove successful in practice appealed to me," says Zumoberhaus. So he not only obtained the foil; he also installed diverse sensors and a small weather station to compare the practical results with the theoretical calculations. His results, which corroborated the Fraunhofer Institute's theory, also led to a long-term collaboration with wood construction physics researchers in Germany and Austria.

Concrete heat storage in a modular system

When Zumoberhaus read about Empa's concrete heat storage system in the media in 2012, he was immediately taken by the idea. Researchers from Empa's Concrete/Construction Chemistry lab had reported that concrete building components produced with calcium sulfoaluminate cement (CSA) might make ideal seasonal heat storage systems. If the concrete blocks are heated to 80 degrees via heating coils with the aid of solar panels in the summer, the mineral ettringite contained in the CSA cement emits water vapor. This leaves behind the dehydrated concrete block, which "stores" the heat virtually loss-free. In winter, the process is reversed: water is channeled into the dry concrete, absorbed by the ettringite and heat is released, which can be conducted away via the heating coils.

"Could this be the solution to plug the gap between Christmas and February?" wondered Zumoberhaus. After a discussion with Empa research Kaufmann, he was convinced to attempt the project together. "Other men at my age park a convertible in the garage," chuckles Zumoberhaus. Instead, he decided to place a six-cubic-meter concrete block in his.

Empa scientists Josef Kaufmann and Frank Winnefeld are delighted: "The collaboration is a unique opportunity for us to hone a system that proved itself in the lab for practical use." They received support from the Swiss Federal Office of Energy.

In the spring, against a breath-taking backdrop with a bright blue sky and framed by the Central Swiss mountains towering up to 3'000 meters into the air, a heavy truck finally rolled up. The Empa team unloaded 24 concrete blocks, which had been cast at Empa, and installed them against the rear wall of the garage. The concrete storage system's first drying tests went well, even if it was not heated up to the intended 80°C. Zumoberhaus is adamant about the advantages of the energy storage system: apart from CO_2 emissions during production and transport, it is ecologically sound. And cost-effective: one ton of CSA concrete costs less than 400 Swiss francs.

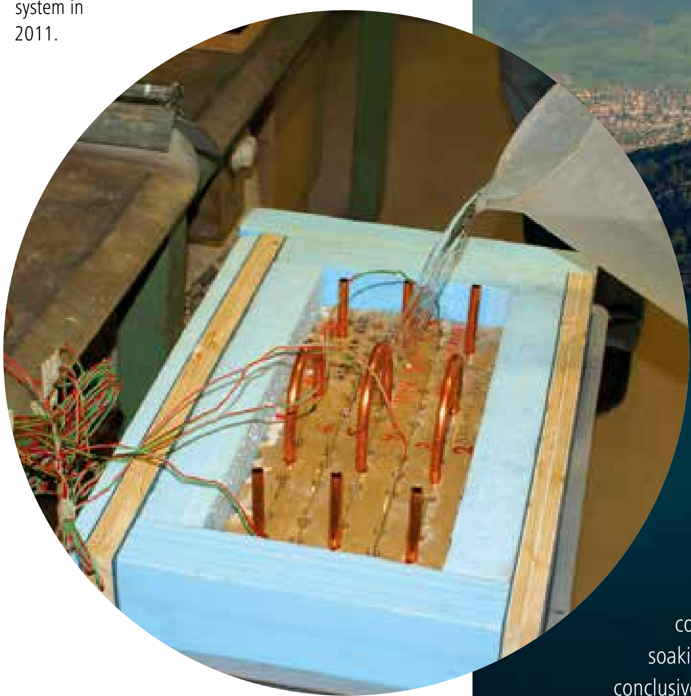
Is the concrete storage system already a solution that is suitable for daily use by other home owners in its present form? "No," stresses Zumoberhaus. But then that is not his intention. "For me, it's simply another experiment that I got involved in." If it doesn't work, he can easily dismantle the heat storage system again after the three-year test phase thanks to its modular structure. "But it's bound to yield results that will be useful for research on energy storage systems and help find the solution to our energy problems," Zumoberhaus is convinced. And thus it comes as no surprise that the two Empa researchers, Kaufmann and Winnefeld, are already pondering simple, more practical solutions. //

The crystals that store heat

"The heat storage system actually arose out of pure curiosity," says Josef Kaufmann, one of the two inventors. While searching for materials, he stumbled across the interesting properties of the mineral ettringite, which binds a lot of heat when dehydrated. This, he pondered, should be a perfect material for seasonal heat storage. Meanwhile, his colleague Frank Winnefeld was involved in a CTI project aimed at developing a cement that sets particularly rapidly. The candidates included a Chinese CSA (calcium sulfoaluminate) cement, which is still quite unusual in Europe. This cement forms very high proportions of ettringite during the binding process (hydratation), making it an almost perfect concrete mixture for a heat storage system.

Ettringite, a mineral with the chemical formula $3\ CaO \cdot Al_2O_3 \cdot 3\ CaSO_4 \cdot 32\ H_2O$, binds 32 molecules of water in its crystal structure. At temperatures above 80 degrees Celsius, however, the crystal rereleases the majority of the water to create so-called meta-ettringite – the "dry" form of the mineral. The majority of the material keeps its shape and can be stored indefinitely in the absence of moisture. When water is added, meta-ettringite is converted back into ettringite, thereby releasing around 600 kilojoules of heat per kilogram.

Lab prototype of the concrete heat storage system in 2011.



From the lab bench to the garage

As a first step, Winnefeld used phase diagrams to develop a special concrete made of CSA cement, Portland cement and gypsum, which contains a maximum concentration of ettringite. The two researchers then cast small sample cylinders, dried them, moistened them again and analyzed the amount of heat emitted in a calorimeter.

Following some promising results, the first lab prototype was developed in 2011: a small concrete block measuring 18 x 40 x 50 cm in size. It already had drill holes to speed up the soaking process and integrated copper pipes to heat the block from within. The experiments were conclusive: if you pour water at room temperature over the block, it heats up to 80 degrees Celsius within an hour. The method passed the practical test and is now patent-pending. In January 2012, Empa-News, Swiss journals, internet portals and daily newspapers all reported on the project.

"We were over the moon when Mark Zumoberhaus got in touch with us and requested a heat storage prototype for his house in Seelisberg," says Kaufmann. "This gave us the unique opportunity to demonstrate this kind of storage system on a 1:1 scale." Kaufmann and his team designed the modular structure of the prototype: 24 individual concrete elements, equipped with drill holes and water channels to wet the concrete, and slots for forklift trucks to enable the storage system to be installed and removed. Every block contains copper pipes embedded in concrete, which are interconnected and transport solar-heated water in the summer to dry the concrete. In the winter, cold water flows through the pipes and carries the hydratation energy generated by the ettringite into the house.

Some things still remain to be seen: the repeated conversion of ettringite into meta-ettringite and back again may cause cracks in the concrete blocks. Do they improve the storage performance or will they have the opposite effect? Do the quantities of heat released in practice match the values from the lab? Where can the construction still be optimized? In May and June 2015, solar heat was already channeled into the concrete storage system. By next March, we will know more.

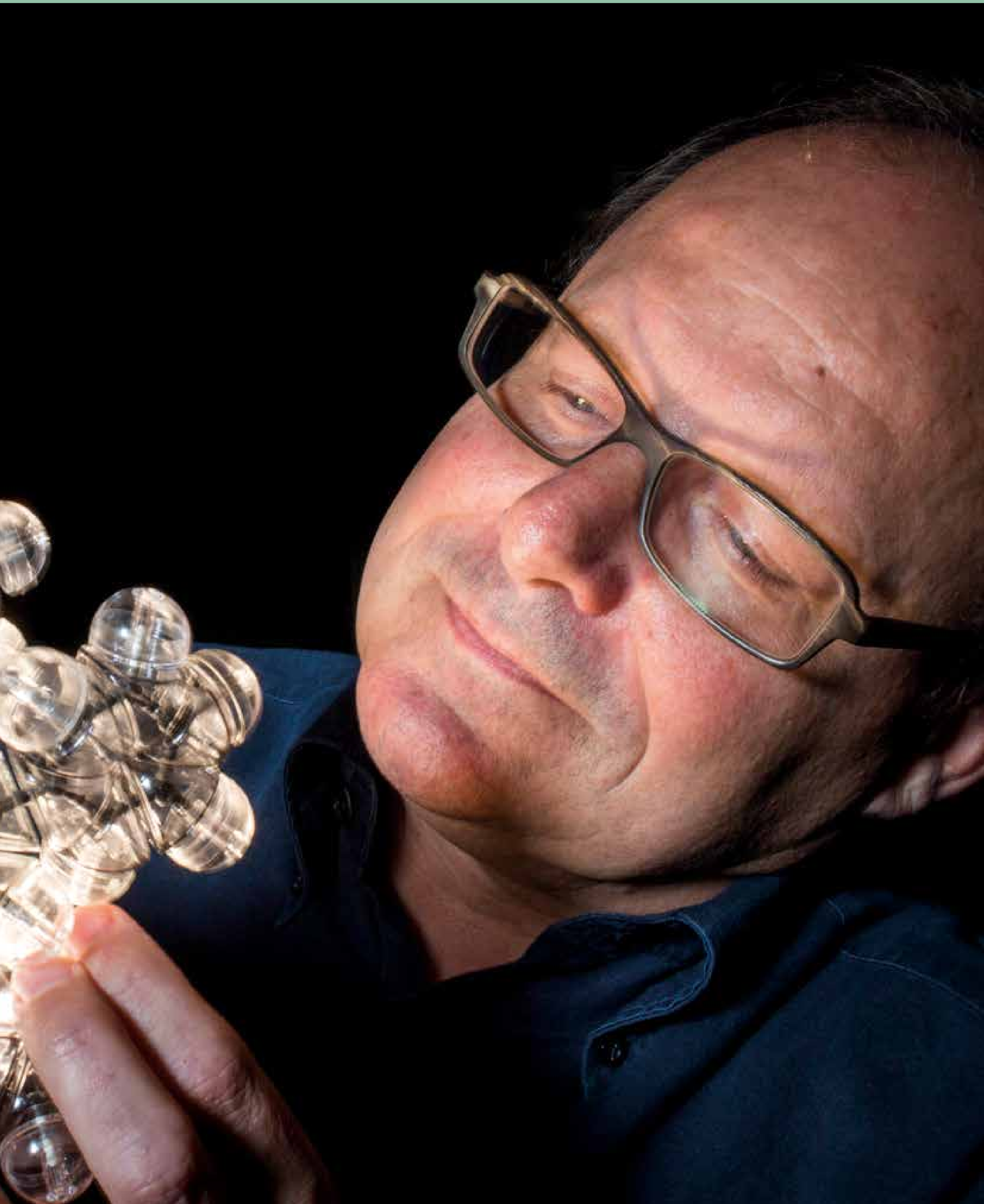
An unexpected journey

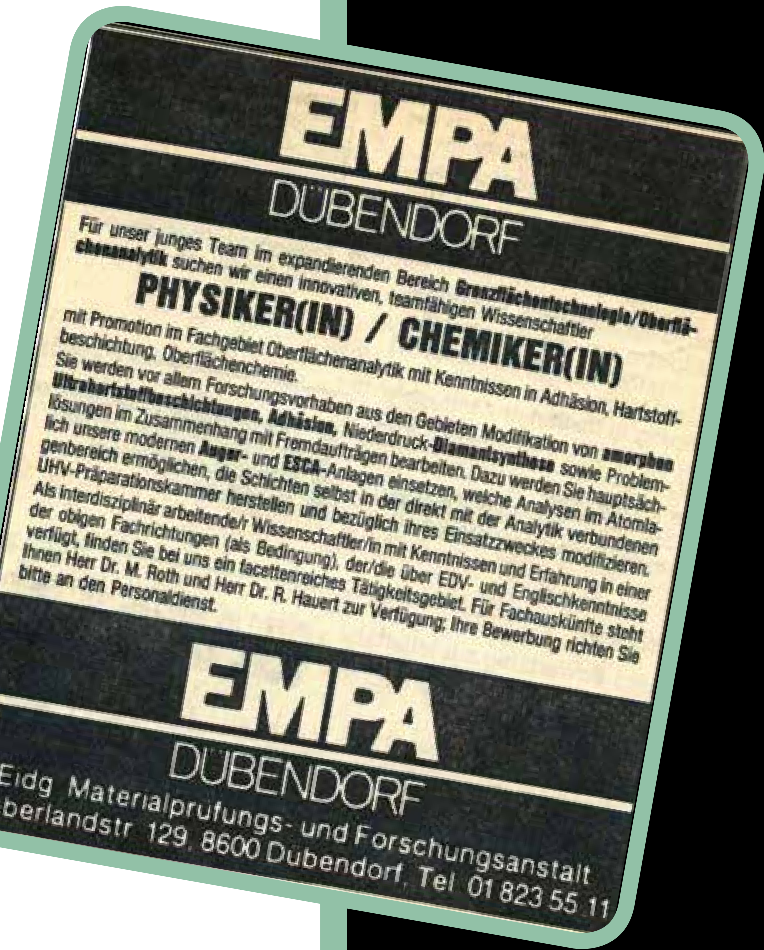
Karl-Heinz Ernst was recently awarded the title of "Distinguished Senior Researcher" by Empa's Board of Directors. His career took many twists and turns before he eventually ended up at Empa. And his research field also has a lot to do with changes of direction. For more than twenty years, he has been investigating the chirality of molecules.

TEXT: Cornelia Zogg / PICTURES: Gian Vaitl, private

Karl-Heinz Ernst could be described as a behavioral scientist for molecules. Since the beginning of his career, the chemist has been fascinated by the question of how molecules react to external influences and why they only behave in certain ways. He researches left- and right-handed, so-called chiral molecules and their behavior on different surfaces. Indeed, numerous chemically identical compounds, such as proteins or sugar molecules, can occur in two different configurations. In other words, the molecules only differ in the spatial arrangement of their atoms and behave like an object and its mirror image. These are referred to as enantiomers (mirror-image isomers), the properties of which can differ greatly from one another.

One particularly drastic example is the sedative Contergan, which was commonly prescribed in the 1960s. While the right-handed form of the substance thalidomide ensured a good night's sleep, the left-handed molecule caused severe fetal deformities in pregnant women. As both enantiomers usually form together in the chemical synthesis of these kinds of substances, the problem can only be solved by painstakingly separating one form from the other. This is often achieved through crystallization, where only one of the two enantiomers is precipitated – a process which, although in use for more than a century, is still not understood at a molecular level and usually only succeeds through plain trial and error. Ernst and his team have been researching how chiral molecules recognize and interact with each other for almost 20 years.





One step at a time

Initially, an academic career was not exactly on the cards for Ernst. By the age of 15, he had already had enough of school, dropped out and opted for a apprenticeship as a chemical-technical assistant. “I never liked school. Except chemistry, that is,” says Ernst. But he did finish high school later on and eventually studied chemical engineering at the Technische Fachhochschule Berlin (University of Applied Sciences Berlin). His plan was to get a decent job in industry. Before long, however, he had a change of heart. During a summer job at the tire manufacturer Continental, suddenly a light-bulb went on in his head. “I realized that chemists with a PhD always told the chemical engineers what to do. So it dawned on me that I had to keep going.” This meant a chemistry degree at the Freie Universität (FU) Berlin and ultimately a dissertation, in 1990, on the topic of hydrogen adsorption on monocrystalline metal surfaces at the FU Berlin and the Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung m.b.H. (BESSY).

With these qualifications under his belt, Ernst (finally) looked to return to his original plan and join the chemical industry. Once again, it didn’t work out, more due to the general economic situation than to ambitious plans. The crisis in the 1990s prevented him from entering industry – and then he stumbled across an Empa job ad in the FAZ. “Analytical methods such as ESCA and Auger, which were mentioned explicitly in the ad, are surface techniques that only insiders understand. That’s what caught my eye,” Ernst recalls.

Spurred on by boredom

Once he had been selected from around 130 applicants and offered the position, he focused on these methods. “I was involved in setting up the former Surfaces and Joining Technology lab,” explains Ernst. “We were on the lookout for material flaws.” When a metal broke somewhere – whether it be in plane crashes or cable car accidents – it was their job to find the cause and analyze the material surfaces at the breakpoints as closely as possible. “Most of the assignments came from industry and we were primarily a service-provider operating in the background.” There were some truly spectacular cases to study, including a jumbo jet that had crashed into a house in Amsterdam, which Ernst helped to explain using his highly sensitive analysis methods.

Nowhere near challenging enough for the new member of Empa in the long run, however; Ernst simply got bored. His ambitions went way beyond merely looking for flaws. He was still fascinated by basic research, such as the behavior of certain molecules under different external influences and on different surfaces, which had already intrigued him during his diploma thesis – in particular, why on one surface, enantiomers like to gather with their own kind or left- and right-handed isomers prefer to mix on another surface. “We’re looking for answers to detailed questions like this – small pieces of the puzzle, but which might give rise to fresh knowledge somewhere down the line.”

His interest in these basics made him react immediately to a suggestion from his former supervisor, Roland Hauert: “We can now also submit our own research proposals,” as he once mentioned to Ernst in passing – and thus triggered the next phase of his career. Ernst submitted a project to the Swiss National Science Foundation (SNSF) with the aim of applying chiral molecules with a spiral structure to a surface and subsequently vapor-depositing metal, which was supposed to take on the

specific properties of the molecules. His project idea went down extremely well with the management committee of the former National Research Program 36 "Nanosciences" and even though he was a no-name in Switzerland, his application was approved and actively supported. Ernst endeavored to vapor-deposit copper and palladium on the molecular structure, but it didn't go as planned. Vapor-depositing the metal at around 100K (-173°C) destroyed the spiral structure. However, the project still took him forward. "Back then, the thinking was too simple," he admits. "But we observed interesting effects on the way to this new material and carried on our research in this direction." Perhaps Ernst was simply ahead of his time. "Today, there are gentler methods. Maybe I'll give it another try soon," says Ernst with a telling grin.

Worth all the blood, sweat and tears

He didn't always feel like smiling in the early days at Empa, however. "At the beginning of the early 1990s, Empa already carried 'research' in its name, but it hadn't reached the labs or people's minds yet." He had to fight hard for every instrument and every project, and it wasn't until the leadership changed and Empa focused entirely on research under Louis Schlapbach that things started to go uphill for Ernst. "Give this man a lab," came the cry and overnight the ball started rolling. The Nanoscale Materials Science lab was launched and Ernst joined it right away. Publications in prestigious journals soon followed.

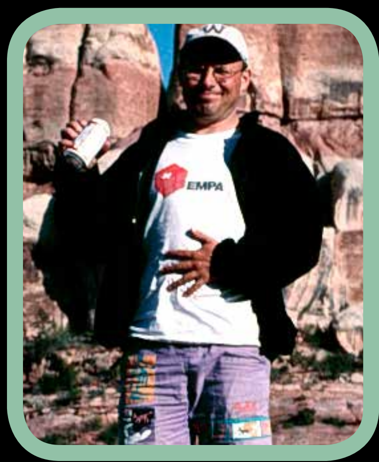
Among other things, his team succeeded in using an electron beam to make molecules oscillate with high precision in the scanning tunneling microscope (STM), which enables individual atoms and molecules to be manipulated. The molecules begin to hop, twist or even change into their mirror-image configuration. With the aid of the STM, Ernst and his team were able to demonstrate this behavior visually, which caused a sensation and made a name for them in the research world. One example of this was a molecular car, where Ernst's team made the wheels of the vehicle rotate. As they only turned in one direction when stimulated by an electron beam, it was possible to "drive" the molecule across a surface. In 2011, media all over the world reported on the project and the Chinese Academy of Sciences even hailed it as one of the ten most important discoveries of the year.

Now the researchers want to follow up this project. They are currently studying engine molecules – which Ernst affectionately calls "waddling ducks" – and trying to find our why these molecules only ever wander in one direction and not the other. "This is very fundamental research. How molecules behave and work is not all that easy to understand and we want to do our bit to help. Sometimes you have to do crazy things. And we do. We make molecules hop."

It is not only Ernst who benefited from the institute's change of direction. Empa also stood to gain. "Nobody abroad had heard of Empa before. Nowadays, I often get approving glances," says Ernst, whom the Board of Directors made a Distinguished Senior Researcher in early February in recognition of his achievements – an honor that so far Ernst shares with just one other fellow researcher, Oliver Gröning.

Freedom and desistence

However, it is not possible to keep on doing "crazy" things all the time. Sticking to guidelines and rules is especially important in the supervision and education of budding young researchers. Oftentimes, though, university regulations are too strict and don't give the young researchers enough leeway, Ernst complains. Project plans, milestones and predictability are called for. Ultimately, the PhD thesis needs to be completed within three years. Major (or even just surprising) discoveries are hardly possibly anymore under these conditions, says Ernst. It takes freedom and desistence – within the scope of sabbaticals, for instance. He regularly took time off to do things that deviated from his everyday routine. "Disconnecting" is key for him; removing yourself from existing processes to gain a fresh perspective or generate new ideas. But he also had to fight for this freedom. "Nobody comes up to you and says: Why don't you go away for a couple of months and have a think."



Ernst has also been a professor of chemistry at the University of Zurich since 2010. "That doesn't exactly make taking time out any easier," says Ernst. The chair fell into his lap. He didn't apply; the position was offered to him by the current President of the University of Zurich, Michael Hengartner. "At 47, I was already a bit long in the tooth for the post and just thought: now, really?" Nowadays, becoming a professor in your early thirties is commonplace. Nonetheless (or perhaps because of this), he accepted his "late" appointment and meanwhile even regards his career path as a kind of experiment: "You simply have to give many things a go," he says, shrugging.

He approaches research with the same openness: success in small steps. But here – unlike with his molecules – it makes no difference whether they go left, right or straight on. After all, in research you often have to take a detour to pass the finishing line in the end. //

Wood cutting made easy

Ceramic kitchen knives are ten a penny. What has become the norm in Swiss kitchens, however, could soon work to industry's advantage, too. Empa scientists have developed a ceramic blade for industrial wood cutting that is lighter than its existing carbide counterparts. The new knife recently made its debut at a joinery in Embrach.

TEXT: Cornelia Zogg / PICTURES: Empa

The milling machine whirs into action, saws through the wood and transforms the thick plank into a ready-made, clean-cut profile for window and door frames. Like at the joinery in Embrach, timber is cut into shape all over the world. Conventional machines work with blades made of tungsten carbide, a hard metal developed around 80 years ago. As the base material, tungsten, primarily comes from China and has now been classified as critical (see box); supply bottlenecks, therefore, threaten Swiss SMEs.

A number of years ago, Empa had teamed up with Oertli Werkzeuge AG and started developing ceramic materials for super-sharp wood cutting blades. The aluminum-oxide-based ceramic composites developed in the first step are extremely hard. However, they have a major drawback for wood processing: ceramic materials are not very good at dissipating heat. Without cooling, the blade would overheat, which would, in turn, leave unattractive burn marks on the wood. This is hardly surprising as temperatures of up to 800 degrees Celsius build up during the cutting process. Nevertheless, the Empa team headed by Jakob Kübler from the Laboratory for High-Performance Ceramics found a solution for this problem: an ultrathin coating that reduces friction and at the same time dissipates heat more effectively.

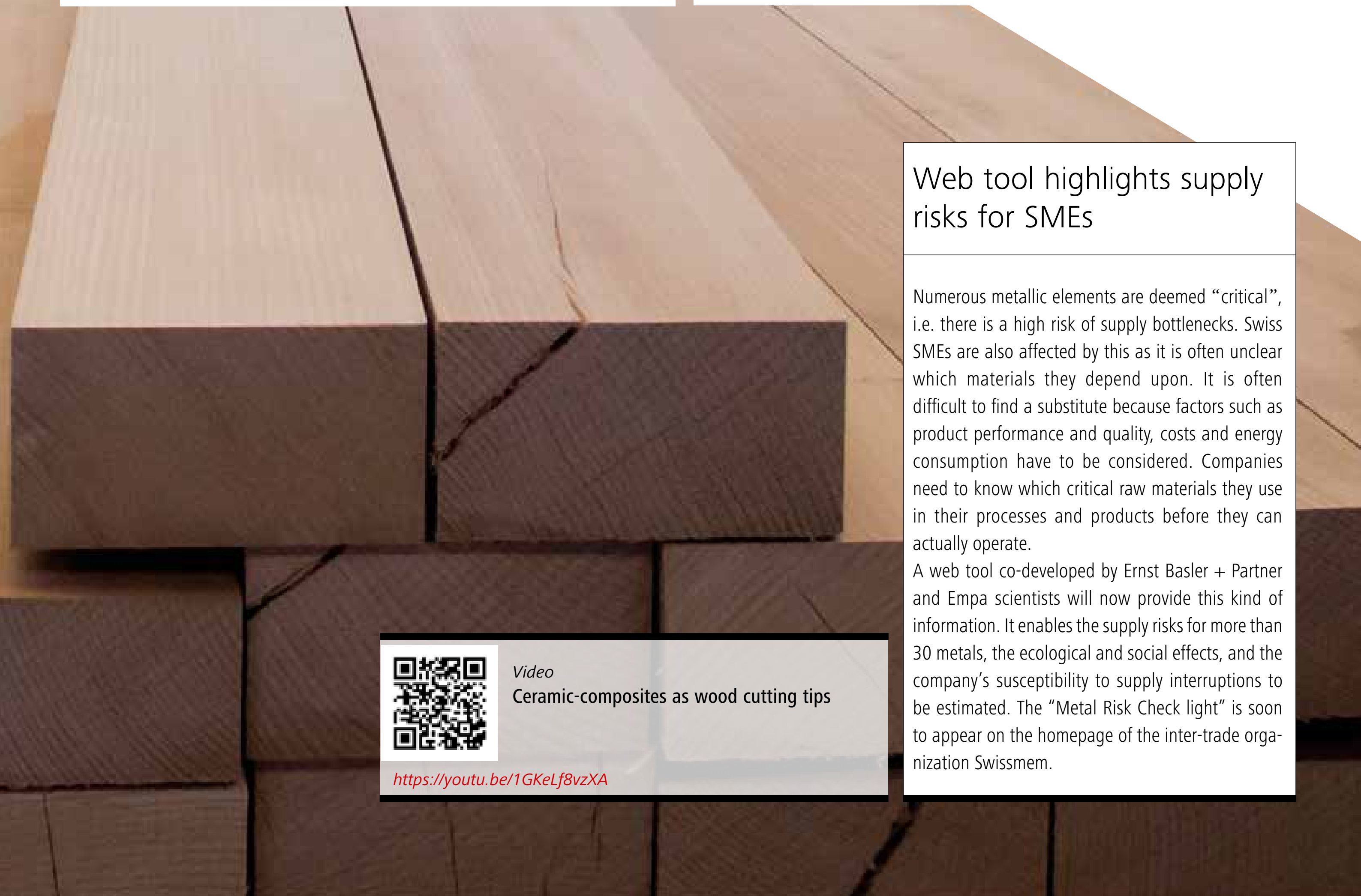
Reaching the target in several project steps

Last March, Oertli Werkzeuge AG and Kübler's team launched the first practical cutting tests. In particular, they examined the durability of various blades. The blade that turns out to be – literally – a cut above the rest will then go into mass production. At the beginning of the project, production costs were the burning issue, says Kübler: "While the cutter we initially developed was up to five times more efficient than conventional blades, it was simply too expensive for mass production." So the project's goal was readjusted to develop an innovative product at a marketable price. The results of the "field trial", which has now been completed: the new ceramic blades cut just as well as those made of carbide metal, but are a lot lighter and thus faster that they are streets ahead of their predecessors. Instead of 75 to 95 meters per second, the ceramic blades are able to cut through wood at a speed of 120 to 150 meters per second. Moreover, they also more than match up to carbide metal cutters in price.

How research spawns innovation

"For us, cutting tools are clearly an economic factor," confirms Bruno Ehrle, Director of Technology at Oertli Werkzeuge AG. "During this project, we were able to fall back on Empa's expertise and thus launch a marketable innovation as the result of a good collaboration." Empa's Kübler couldn't agree more: "We reached our goal." Now it is the company's job to take over the commercial side of things and work towards launching the product on the market. The support from the Commission for Technology and Innovation (CTI) was also instrumental in the project's success. The collaboration just goes to show how marketable innovations can be realized efficiently if research and industry work closely together. "It was a huge challenge for us to develop new materials and combinations whilst bearing the production costs in mind," says Kübler. And as the price of tungsten has ballooned in recent years, the timing couldn't be better. Many small production companies are no longer able to compete under these conditions. Therefore, it is all the more important to help Swiss SMEs maintain their competitive edge internationally via marketable innovations and alternatives. //

Test run of the newly developed ceramic blades on a milling machine at a joinery in Embrach, ZH. Bottom right: Bruno Ehrle, project manager at Oertli Werkzeuge AG, tests the stability of the new blades with a colleague. Thanks to the cutting technology developed at Empa, wood can be processed three times faster than with conventional carbide blades.



Web tool highlights supply risks for SMEs

Numerous metallic elements are deemed “critical”, i.e. there is a high risk of supply bottlenecks. Swiss SMEs are also affected by this as it is often unclear which materials they depend upon. It is often difficult to find a substitute because factors such as product performance and quality, costs and energy consumption have to be considered. Companies need to know which critical raw materials they use in their processes and products before they can actually operate.

A web tool co-developed by Ernst Basler + Partner and Empa scientists will now provide this kind of information. It enables the supply risks for more than 30 metals, the ecological and social effects, and the company’s susceptibility to supply interruptions to be estimated. The “Metal Risk Check light” is soon to appear on the homepage of the inter-trade organization Swissmem.

Video
Ceramic-composites as wood cutting tips

https://youtu.be/1GKeLf8vzXA

High-tech components made of microfibrillated cellulose

During a visit to the new fiber technology lab of Wicor Weidmann in Rapperswil on 12 June, Federal Councilor Johann Schneider-Ammann (in the yellow waistcoat) seemed impressed by microfibrillated cellulose as an environmentally friendly, high-tech building material. Empa researcher Tanja Zimmermann (right) explains how an oil-absorbing cellulose sponge works: floating MFC absorbers that suck up as much as 50 times their own weight in oil but are totally hydrophobic are in the pipeline, for instance. This Empa development could be an invaluable asset in oil-related accidents and help to contain environmental disasters in future. Empa played an instrumental role in adapting the production method from the lab to an industrial scale.

Weidmann Fiber Technology is part of the Wicor Group, which has 2'900 employees worldwide and produces components for transformers and the car industry. Under a development project funded by the CTI, microfibrillated cellulose (MFC) is now to be produced on an industrial scale. The environmentally friendly and recyclable material is planned for use in new products for the paper and card industry, vehicle construction, the building sector, cosmetics, filter construction and special environmental products.

Video
Mikrozellulose-Schwämme gegen ausgelaufenes Öl (German language)

https://youtu.be/TKPZgAfZF7Y

Empa chairs US materials science conference

5,500 materials researchers convened in San Francisco in early April for the spring meeting of the Materials Research Society (MRS). Every year, five Meeting Chairs share the chairmanship for the meeting, which is the largest in the world in its field. This year, the organizational committee included Empa researcher Artur Braun from the Laboratory for High-Performance Ceramics.

INTERVIEW: EmpaNews / PICTURE: Empa

EmpaNews: Mr. Braun, what do you have to do to become an MRS Meeting Chair?

Artur Braun: I asked my colleague Sam Mao the very same question when he became an MRS Meeting Chair in 2011. I know him from our time together in Berkeley. His reply: "Organize a symposium with over 250 abstracts."

And did you do that?

No. And I'm glad, too. Otherwise, you'd have to reject more than half of the abstracts. It would be an utter waste. But I organized several MRS symposiums after former Empa CEO Louis Schlappbach gave us a bit of a pep talk. I remember his annual lab visit to the ceramics lab in 2008 like it was yesterday. He wrote in our guestbook: "As materials researchers, you need to organize symposiums, especially at the MRS."

EmpaNews did a report in 2009: "The Power of the Sun".

That's right. At the time, I was just learning how you can do chemistry with the sun – especially for clean drinking water and energy applications. So with Empa's support I held a symposium on photocatalysis and photoelectrochemistry. That gave me a taste for it, so I went on to organize other MRS symposiums on whatever I was working on at the time. Word got around

and two years ago the MRS President from the Boeing Company asked me if I fancied becoming a Meeting Chair.

Will you continue to organize MRS symposiums? After all, San Francisco is a lovely place to work!

Award for Empa textile researchers

The chest strap developed at Empa for the long-term monitoring of cardiovascular patients won the Techtextil Innovation Award 2015. The prize was presented at Techtextil in Frankfurt am Main on 4 May. The picture features the Empa research team: Michel Schmid, Alexander Haag, René Rossi and Rudolf Hufenus (from left to right).

The flexible wetting elements in the ECG measuring strap can be filled with around 30 milliliters of water and ensure that the skin remains permanently moist so that the metallized sensors are able to register the physiological signals and transfer them stably. The water reservoir consists of a watertight membrane and a vapor-permeable textile layer, which are fused using a laser-based method perfected at Empa.

The new electrodes solve a well-known problem associated with long-term ECGs: the gel electrodes used until now dry out within a day and stop emitting suitable signals. To date, it was especially difficult to take long-term ECGs in elderly people as they move and perspire less. The project was funded by the Commission for Technology and Innovation (CTI). The prototype of the ECG strap was already tested successfully in more than 100 experiments. The next step will be clinical trials conducted at the University Hospital in Basel.

San Francisco is a great city and my American home. I worked there after my PhD thesis. Yes, I will still be involved in the MRS as a volunteer. It's so invaluable that the MRS opens its doors for anyone who is interested to get involved. I can only recommend it to anyone who has anything to do with materials as a forum for an exchange of ideas.

As delighted as I am that I had the honor of being an MRS Meeting Chair, however, it is also a pity that the MRS Spring Meeting was held in San Francisco for the last time. From 2016, the MRS Spring Meetings will take place in Phoenix, Arizona. In the end, San Francisco had unfortunately grown too cramped for an organization like the MRS with its 16'000 members from 80 countries.

I already went to Phoenix to check how it will be there and took some photos in the desert. A great place! I am looking forward to the next MRS meetings. //

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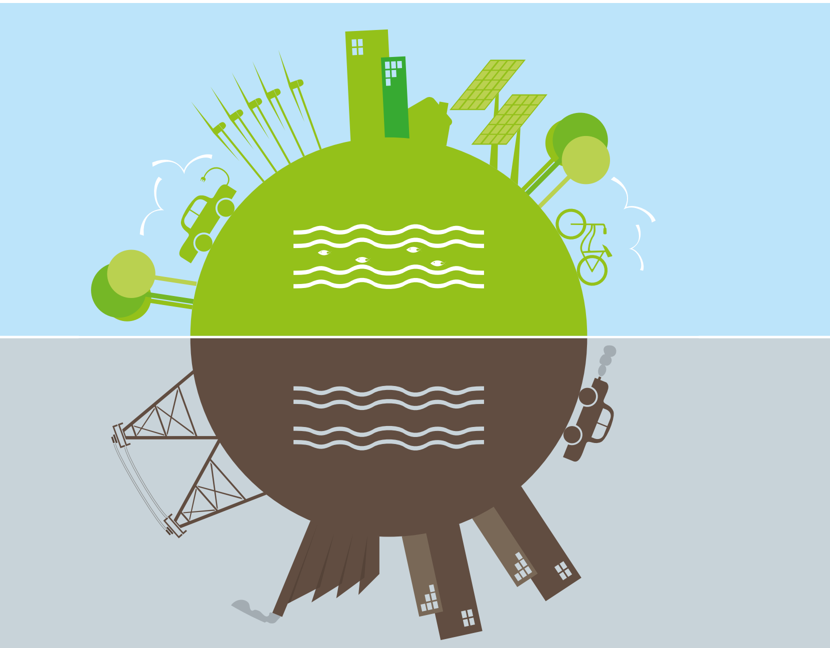

Empa, Dübendorf, Überlandstrasse 129
Dienstag, 27. Oktober 2015, 13.30 – 19.30 Uhr

Online-Anmeldung unter *www.tage-der-technik.ch*

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Events (in German)

13. August in Dübendorf / 23. August in St. Gallen
Holz – überraschend anders («Forschung live»)
Zielpublikum: Öffentlichkeit
Auskunft: anja.pauling@empa.ch
Empa, Dübendorf / St. Gallen

27. August 2015
Innovation Day
Zielpublikum: Textil- und Bekleidungsindustrie
www.swisstexnet.ch
Empa, Dübendorf

02. September 2015
FSRM-Kurs: Materialbearbeitung mit Laser
Zielpublikum: Industrie und Wirtschaft
www.empa.ch/laser
Empa, Dübendorf

16. September 2015
FSRM-Kurs: Die Welt der Stähle
Zielpublikum: Industrie und Wirtschaft
www.empa.ch/staehle
Empa, Dübendorf

29. September 2015
FSRM-Kurs: Die Wärmebehandlung – «Werkzeug» zur gezielten Einstellung von Eigenschaften
Zielpublikum: Industrie und Wirtschaft
www.empa.ch/waerme
Empa, Dübendorf

11. – 14. Oktober 2015
World Resources Forum 2015
Zielpublikum: Industrie und Wirtschaft
www.wrforum.org
Kongresszentrum, Davos

Details and further events at
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