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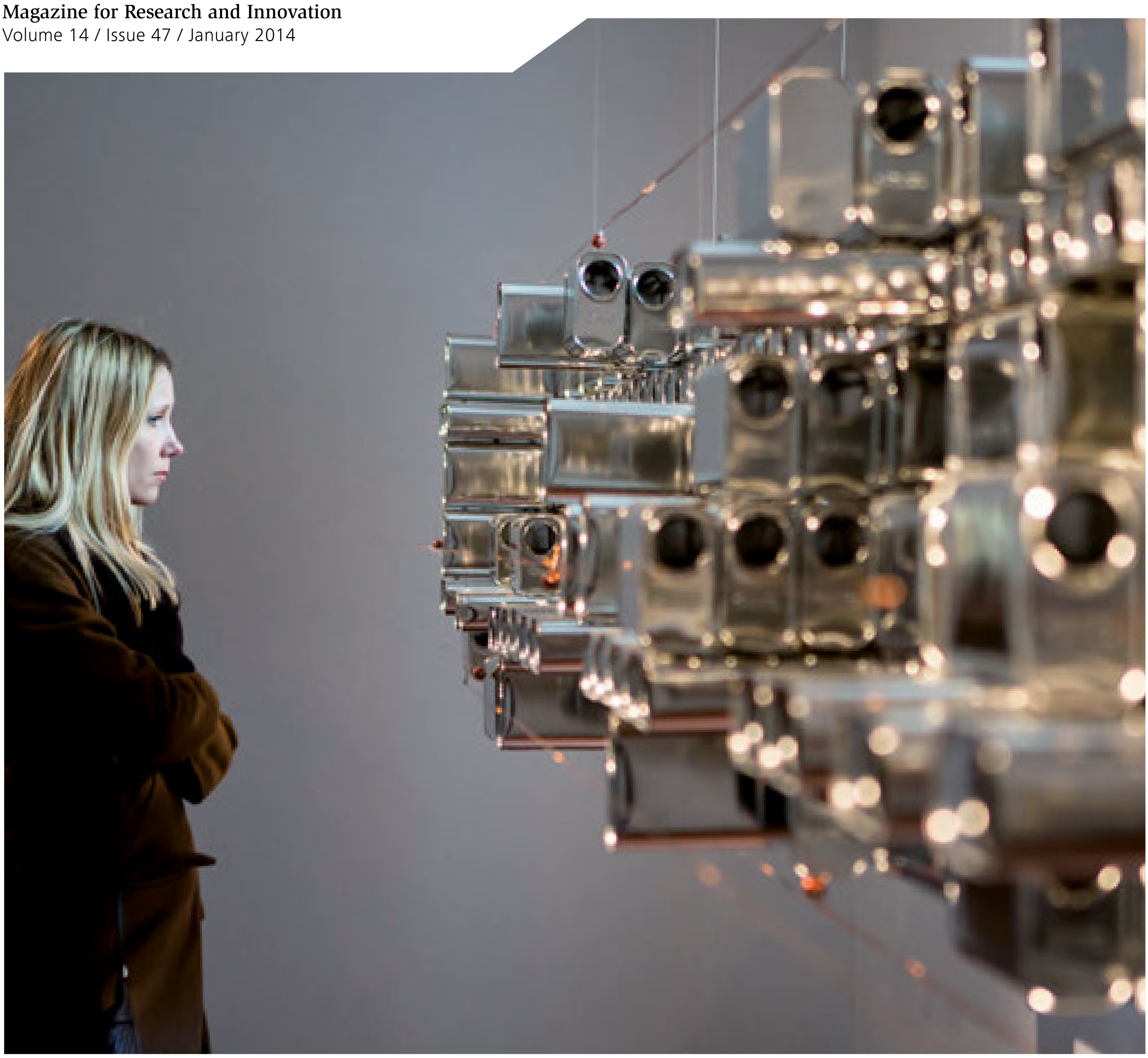


The Sound of Empa

EMPA
Materials Science & Technology

Graphene – the miracle material for the world of tomorrow

Gentle touch for premature babies

Apprenticeships at Empa: eight professions to choose from

MICHAEL HAGMANN Head of Communications

In the eye of the beholder

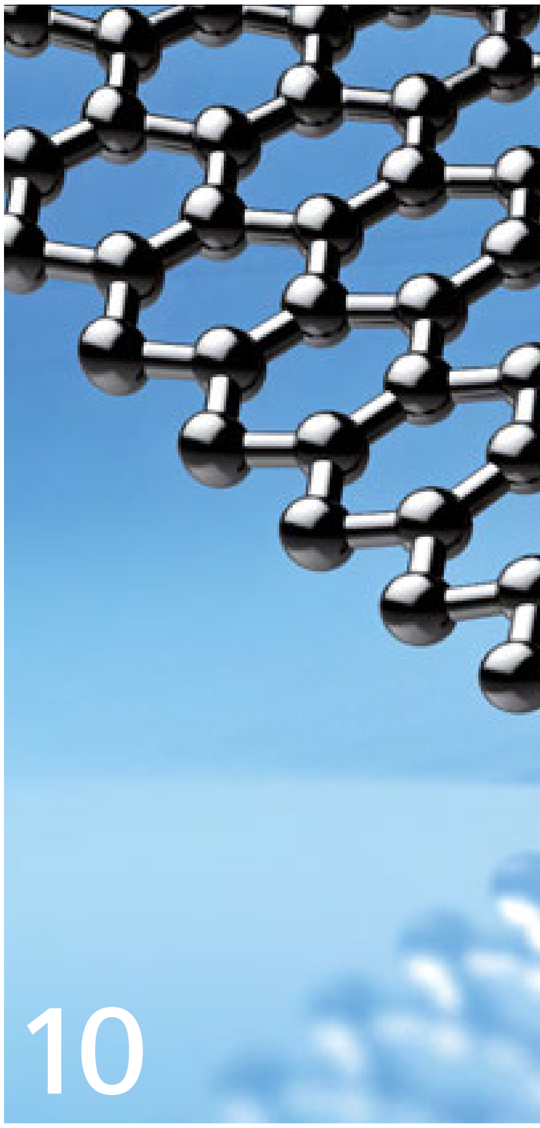
Dear readers

What do the Sistine Chapel and E = mc² have in common? They are both glittering moments in the cultural history of humankind. When people muster the force of their spirit to create something magnificent and generate unique insights – irrespective of the field – they can be sure of our admiration. And often the same elegance is inherent in the boldness of a brushstroke as in the razor-sharp logic of a piece of mathematical proof or the deduction of a new physical law. After all, artists and scientists are both explorers, endeavoring to figure out the world around them (and, ultimately, themselves) and constantly venturing into uncharted territory to push the established boundaries of knowledge.

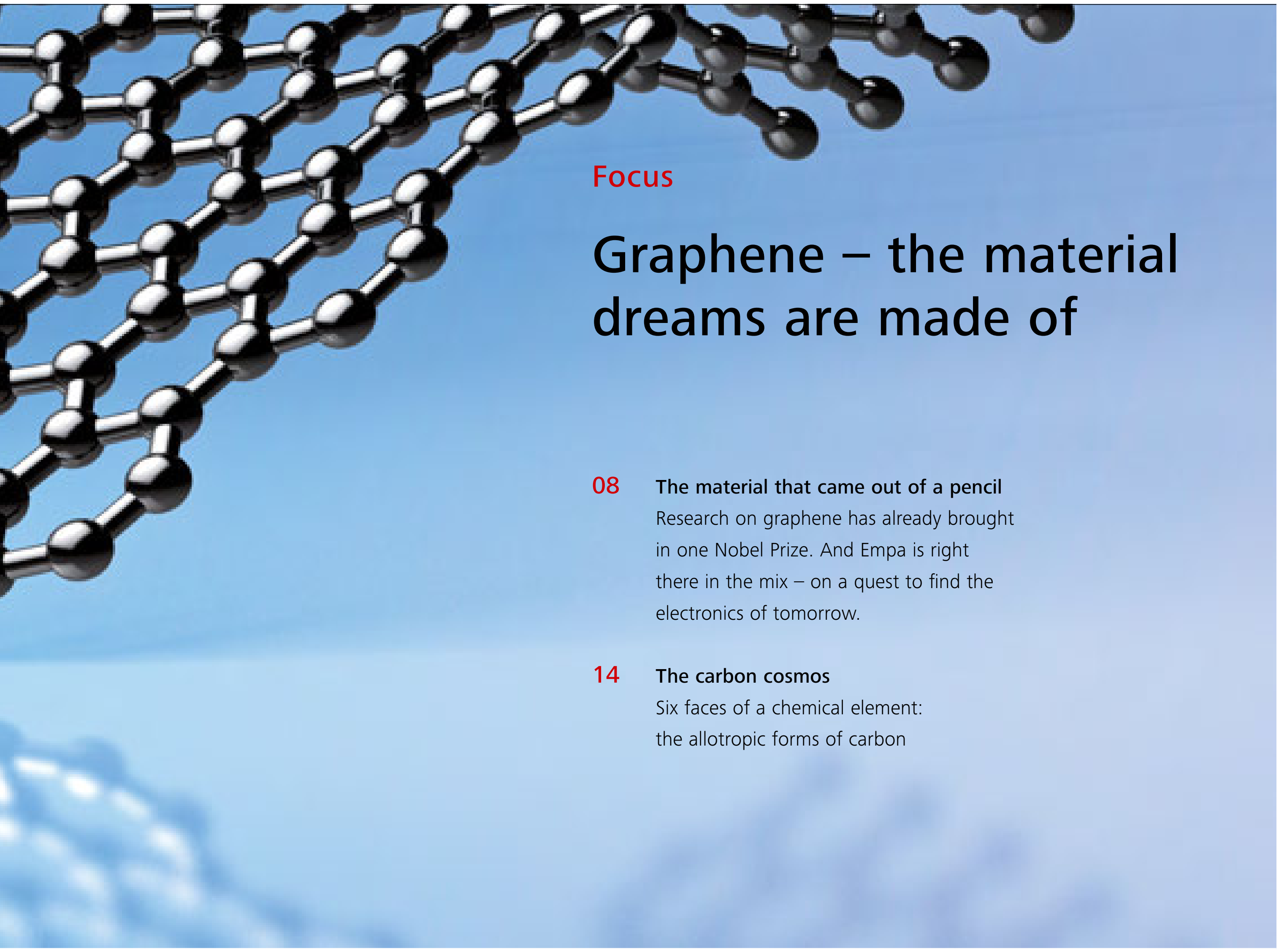
Granted, these different forms of "beauty" are not accessible to all of us in equal measure; for many, it is easier to be seduced by Mona Lisa's smile than by the Schrödinger equation or Fermat's theorem. And yet: when artists like Aernoudt Jacobs are inspired by technological innovations, tremendously exciting, new things can emerge at this interface of arts and science, as you can see on page 22 (and hear on the internet).

Our annual desktop calendar is proof that science is often aesthetic in a purely decorative sense, too. If you hurry up, you might be one of the 25 lucky winners – entry conditions on the last page.

Happy reading and all the best for the New Year!



Cover
A museum-goer listening to the installation "Induction Series #4" by Belgian artist Aernoudt Jacobs. Although his next sound masterpiece is still untitled, it is taking shape with the help of Empa. ***Page 22***.



Focus

Graphene – the material dreams are made of

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Up where we belong

Besides scientists, skilled professionals from all walks of life also ensure that the research at Empa runs smoothly. Of the roughly 1,000 staff members in Dübendorf, St. Gallen and Thun, around a third launched their careers with an apprenticeship. They work in the administrative or technical support. To guarantee a sufficient future "supply" in these vocations, Empa offers apprenticeships in eight different professions in Dübendorf and St. Gallen and currently has over 40 apprentices.

INTERVIEW: Martina Peter / PICTURES: Empa

Apprenticeships at Empa

15 supervisors and 55 tutors are in charge of the apprentices throughout Empa.

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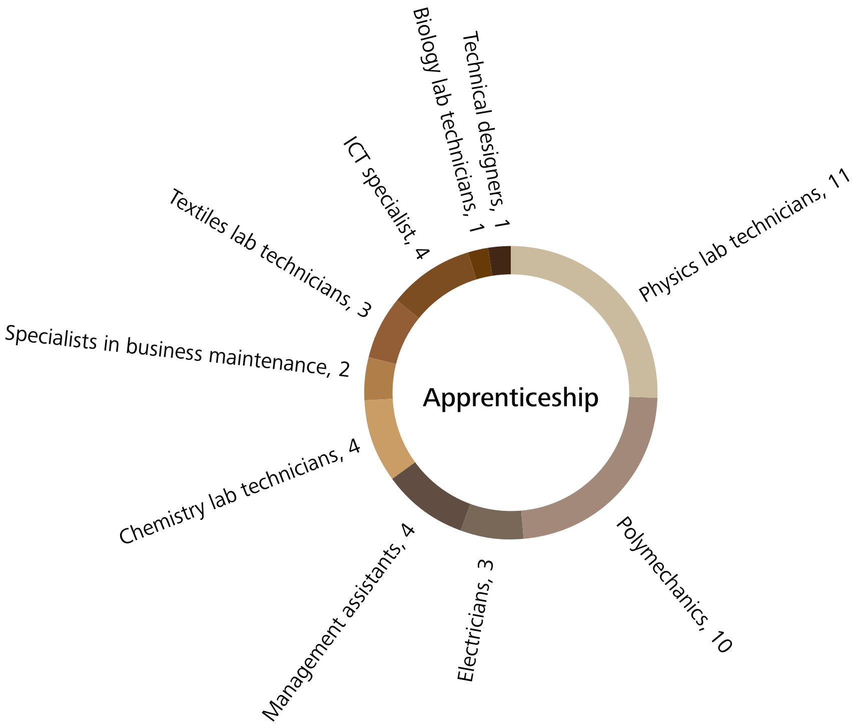

In this interview, Nadja Nenzi, vocational training co-ordinator and apprentice recruitment officer, and Stefan Hösli, head of vocational training (as well as head of Empa's Construction/Workshop), offer a glimpse into the world of Empa's apprentices.

Which apprenticeships are currently in vogue?

Nadja Nenzi: Currently, the absolute favorite is chemistry lab technician. We receive as many as 70 applications for an open position.

Spoilt for choice then. But are there also apprenticeships, for which it is harder to find suitable applicants?

Stefan Hösli: Sure enough, some programs seem to be less appealing than others. Presumably, they suffer from the old preconceived notion: "If school ain't your thing, you do an apprenticeship where you can use your hands." But as a polymechanic, technical designer or electrician you need just as much brains as a lab technician or a management assistant.

What's the situation with vocational training in general? More "in" or petering out?

Nenzi: Well, there is still the stubborn preconception that the world is only your oyster if you've got a high school qualification. Which is why many parents urge their children to go down the grammar school route. It's a pity but many don't know the Swiss vocational training

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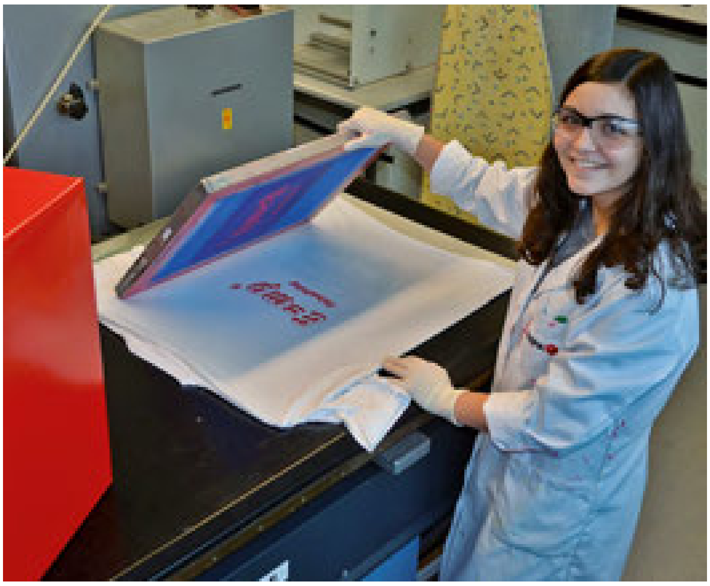


«*I benefit from speaking English in the lab. It'll help me if I want to go abroad later on.*»

Manuel Roth — physics lab technician, 3rd year

«*I like my apprenticeship because we have a good exchange of ideas among the apprentices.*»

Pierrine Zeller — textiles lab technician, 2nd year

system well enough. It's extremely open: here you can eventually become a professor with a vocational qualification. (Note from the editor: Two members – meanwhile with a PhD, though – of Empa's six-strong Board of Directors hold a vocational qualification: Pierangelo Gröning with an apprenticeship in electrical engineering and Urs Leemann with a tool-making apprenticeship.) We absolutely encourage our apprentices to consider aiming for a higher vocational qualification, too. Quite a few people who completed their apprenticeship at Empa have gone on to study at a university.

Hösli: The important thing to remember is that you aren't burning any bridges by opting for a apprenticeship. Quite the contrary. I think it's a bonus to take a step out of school and gain a foothold in the professional world. Once they reach a certain age, many young people might well be fed up with school.

Nenzi: And then it proves to be an advantage to work in a company. A few years down the line, another bifurcation is coming up and young people have to take another decision on how to continue their path – back to school or carry on in the professional world.

What are the advantages for the apprentices if they do their apprenticeship at Empa?

Hösli: One thing is extremely important to us: to give the apprentices useful assignments across the board right from the start. So they aren't gofers. We try to support them in a targeted fashion. It's important to us for them to acquire a decent basic specialist knowledge, which we test regularly. By integrating them in our corporate culture, they also develop their sense of independence, self-discipline or self-initiative. But we're not entirely selfless: if you use the apprentices productively, the company also stands to benefit directly. Every year during the summer vacation, for instance, we really miss our polymechanics apprentices. They are a production factor to be reckoned with and contribute directly towards Empa's output and success. Probably, budding professionals rarely find such varied assignments as here at Empa. They work in a stimulating environment and above all on exciting projects or prototypes.

Nenzi: Sometimes, chemistry and physics lab technicians also work on research projects, which is varied and highly motivating for them. And the researchers also stand to gain from them: unlike many interns from universities and the like, they already bring key expertise to the table from basic interdisciplinary courses and practical work. For instance, with regard to safety issues or operating our facilities.

How does this kind of education go down with the apprentices? Do you get any feedback?

Hösli: One good indication is the fact that we basically have no drop-outs at Empa. The statistics from the Canton of Zurich says it all: 28 percent of young people discontinue their apprenticeship every year. With us, it's been between zero and five per cent for the last eight years!

« *I often don't know what's in store for me the next day. I get called to wherever I'm needed.»*

Nico Bischof — specialist in business maintenance, 3rd year

« *With my enthusiasm for mathematics, physics and geometry, the apprenticeship as a technical designer is just the ticket for me.»*

Cyrill Jaggi — technical designer, 1st year

An extremely low level. Why do you think that is?

Nenzi: We already take a close look during the recruitment phase and want to know whether the candidates are motivated. Incidentally, we have also had good experiences with applicants who have a physical disability. I recently hired an intelligent young man who is hearing-impaired as management assistant. And in the case of a partially paralyzed applicant for a chemistry lab technician vacancy, we organized a two-day trial course. In the end, we discovered together that it wasn't possible for her to perform certain manual tasks easily on account of her disability. For her, that was a painful but important learning with the realization that she would probably be better off looking for another apprenticeship.

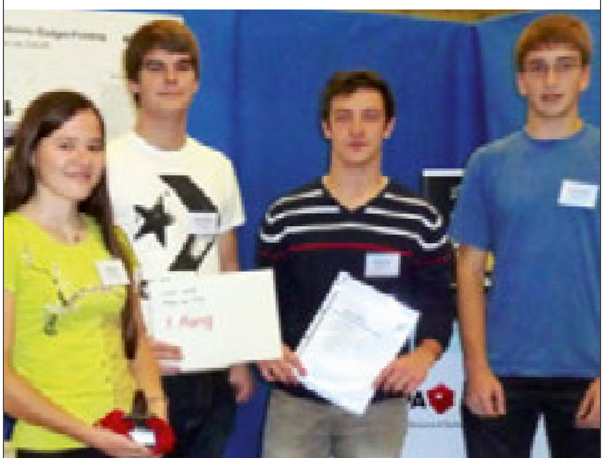
But that must take a lot of effort …

Nenzi: In the long term, I see our commitment towards supervising apprentices as an important contribution to society. We can't look for professionals and complain that we can't find any if we don't train some ourselves. That's how the system works here in Switzerland.

Hösli: As a scientific institute, it bodes well for Empa to offer over 40 apprenticeships a year. After all, we foster many contacts with small and medium-sized companies where trained professionals are at the helm. We send out a signal to them that Empa is doing its bit for the future as a research institute with innovations and science. But this also includes young people who accompany, use and produce the innovations for industry. And we also train them here at Empa.

Distinguished!

Four apprentices from Empa were awarded a prize at the Zurich Oberländer Lehrlingswettbewerb in early 2014. Physics lab technicians Nadja Rutz, Adrian Keller, Simon Holdener and Andreas Freese won first prize for their project "3D Electronic Gadget Printing", under which they had produced a fully functional torch using a 3D printer.

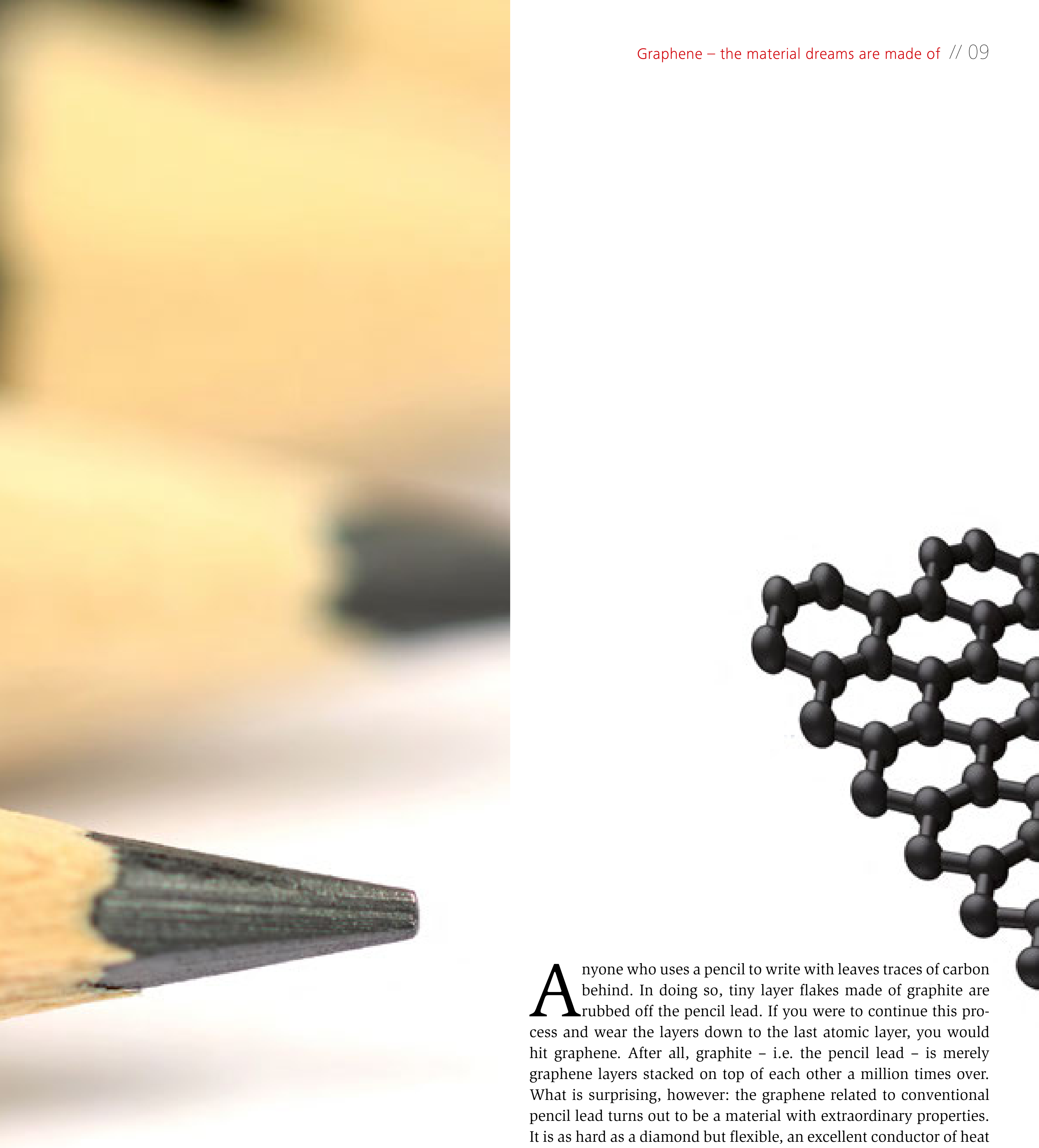


The award-winning apprentice team from Empa (from left to right): Nadja Rutz, Simon Holdener, Adrian Keller and Andreas Freese.

The material that came out of a pencil

Using adhesive tape and graphite as it is found in pencil lead, two physicists proved that graphene, the “miracle material of the future”, actually exists – and won the Nobel Prize in Physics for their work only a few years later. Scientists are also researching the properties of graphene at Empa. For instance, they are investigating how molecules can be used to produce well-defined graphene nanostructures that could one day serve as electronic components.

TEXT: Martina Peter / PICTURES: iStockphoto, Empa, Chalmers University of Technology



Anyone who uses a pencil to write with leaves traces of carbon behind. In doing so, tiny layer flakes made of graphite are rubbed off the pencil lead. If you were to continue this process and wear the layers down to the last atomic layer, you would hit graphene. After all, graphite – i.e. the pencil lead – is merely graphene layers stacked on top of each other a million times over. What is surprising, however: the graphene related to conventional pencil lead turns out to be a material with extraordinary properties. It is as hard as a diamond but flexible, an excellent conductor of heat and electricity, ultra-light, tear-proof and virtually transparent – a material that could one day be used for a vast range of applications in the fields of electronics, communication technology, power generation and storage, vehicle construction and many more. And its research has set its sights on a multi-billion-Euro EU "flagship" project over the next few years.

Graphene actually exists: simple yet ingenious proof

Until 2004, it was inconceivable for science that a monoatomic, two-dimensional layer like graphene could actually exist under normal conditions. The belief was that such an entity would spontaneously disintegrate – until two scientists from the University of Man-

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chester reported an incredible discovery in the journal Science. Konstantin Novoselov and Andre Geim demonstrated how they had produced graphene very easily. Using simple adhesive tape, they had worn away material from a graphite surface until it only consisted of tiny, transparent flakes. In order to render these visible, the researchers stuck the tape to a silicon plate and transferred the flakes onto it. Illuminated with UV light, the flakes reflected onto the plate in a different color to the surroundings. Sure enough, as the examination of the samples with the atomic force microscope (AFM) revealed, it was graphene – monoatomic layers of carbon atoms, arranged in a honeycomb-like, extremely stable structure. In 2010 Novoselov and Geim were awarded the Nobel Prize in Physics for their ground-breaking discovery.

With the publication of their article, Geim and Novoselov sparked great enthusiasm in the scientific community. Numerous research teams began to focus on graphene and industry pricked up its ears. As the adhesive tape method was not suitable for production on an industrial scale, other methods were sought to obtain graphene. Many were based on the so-called top-down approach: individual graphene layers

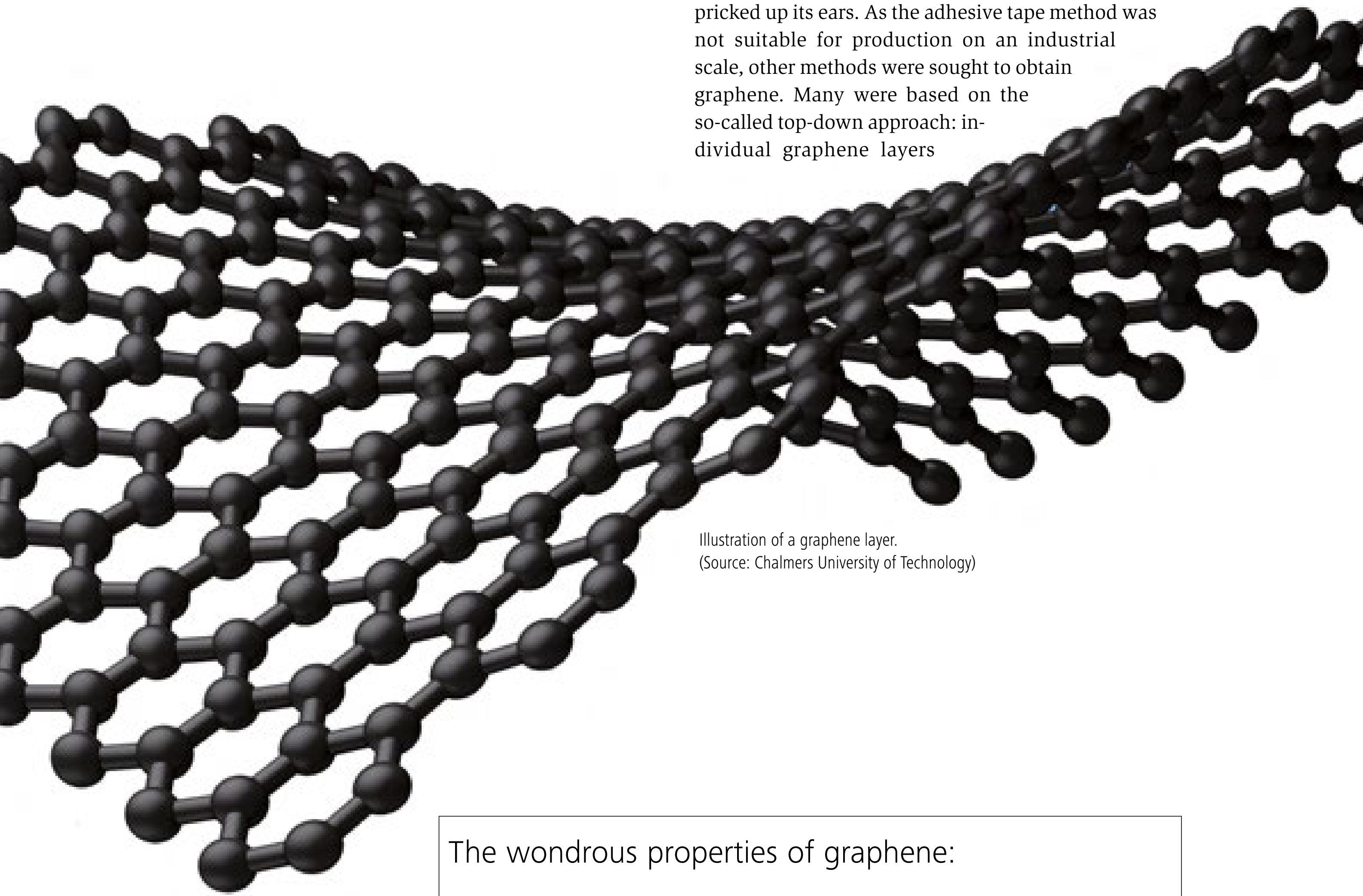


Illustration of a graphene layer.
(Source: Chalmers University of Technology)

The wondrous properties of graphene:

- is 300,000 times thinner than a sheet of paper.
- is ultra-light; 1 square kilometer of graphene only weighs approx. 250 g.
- is the most mechanically robust material ever measured.
- is extremely flexible; it can be stretched up to 20 % without tearing.
- is virtually transparent.
- is impermeable for all gases.
- conducts heat extremely well; the material has more than twice as much thermal conductivity as a thin copper layer.
- also conducts electricity extremely well; electrons move up to 200-times faster in it than in silicon.
- has the largest specific surface measured to date – one gram has a surface of approximately 1.5 soccer fields.

are separated from graphite through chemical exfoliation – much like how Novoselov and Geim had demonstrated with their adhesive tape method. Other groups demonstrated that graphene can be deposited on catalytic copper using the classic chemical vapor deposition technique. Only last year, Sony presented a graphene film that was over 100 meters long and 21 centimeters wide.

Miniscule electronic components

Graphene's extremely high conductivity and subsequent low dissipation power is especially intriguing for researchers who deal with electronic components. As components become increasingly smaller, the traditional use of silicon as a semiconductor material is gradually reaching its physical limits. Reliable components on a nanometer scale are right at the top of the wish list in the electronics world. Would graphene make a good substitute for silicon and Co.? Of course, the scientists from Empa's nanotech@surfaces lab headed by Roman Fasel, an adjunct professor of physical chemistry at the University of Berne, are convinced. However, only if a way can be found to temporarily halt the extremely high electrical conductivity of graphene as well. After all, electronic switches also need to be able to turn off the current, which isn't really possible with graphene because, as a semimetal, it lacks the necessary electronic band gap – the energy range where no electrons can be located.

As scientists were aware from theoretical considerations, unlike large-scale graphene layers, extremely narrow graphene ribbons exhibit the required band gap thanks to quantum mechanical effects. So graphene does make a suitable semiconductor – at least in theory. But how can such narrow graphene ribbons, merely a few nanometers wide, be produced?

Researchers had already conducted experiments using top-down methods: they used lithographic techniques to cut out narrow ribbons from a graphene layer. However, it soon became apparent that the state of the edges was also crucial for the graphene ribbon's properties. Cutting a graphene layer produces frayed, irregular edges. In order to achieve the desired electronic properties predicted in theory, the edges need to be perfectly regular. But how could this be accomplished?

Grow it from molecules then

In 2010 Fasel's team joined forces with chemists under Klaus Müllen from the Max Planck Institute for Polymer Research in Mainz and succeeded in producing graphene ribbons that were only a few nanometers wide and had precisely defined edges. In doing so, they opted for a bottom-up approach: they grew the ribbons specifically from carefully selected precursor molecules on metal surfaces and were able to demonstrate that the narrower the ribbons, the greater the band gap – exactly as the theory predicts. The trick was to find the right molecules to grow into well-defined graphene structures on surfaces. Simulations on Empa's supercomputer "Ipazia" helped the researchers to identify the optimal growth conditions.

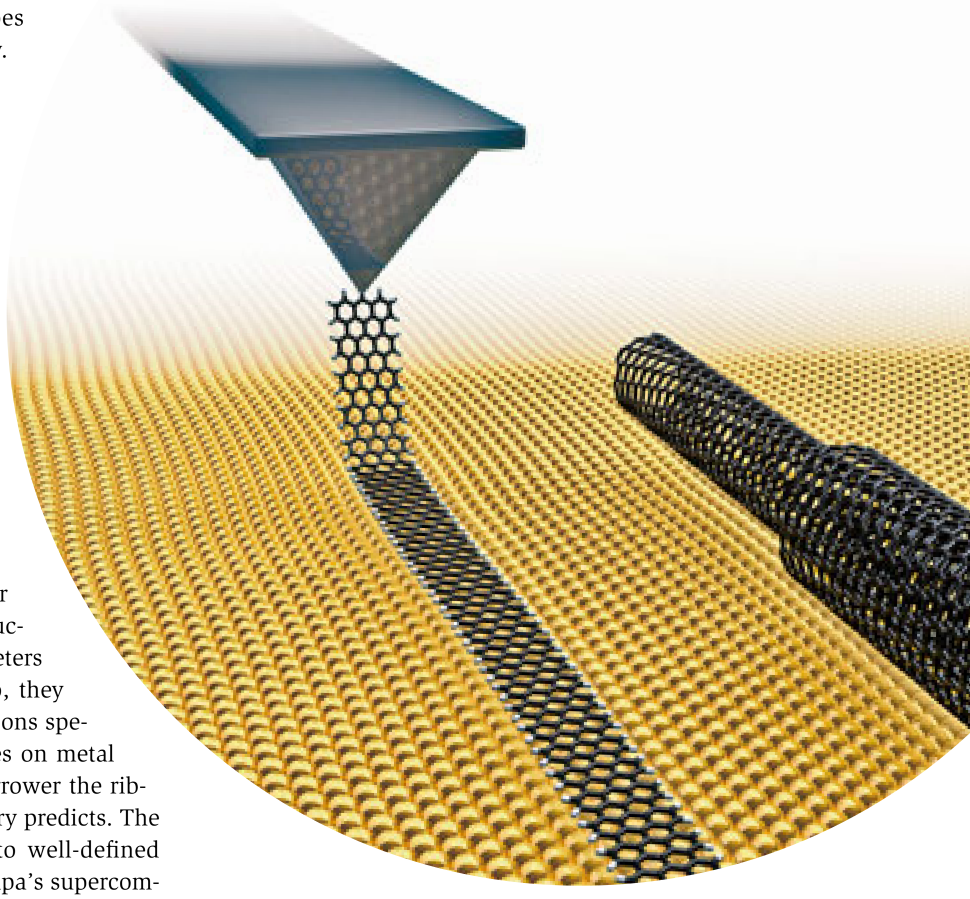
Through repeated rounds of computer simulations and experiments, coupled with measurements of the electronic properties on the scanning tunneling microscope (STM), the Empa researchers eventually managed to perfect the production processes. Using mo-

Transferring graphene to other bases

While they were at it, the Empa scientists also solved another problem: how to integrate graphene-based nanocomponents in the conventional, primarily silicon-based semiconductor industry. Or to put it more specifically: how do you transfer ultrathin graphene ribbons from the gold substrate they "grew" upon to another – non-conductive – surface? After all, graphene components on a metal surface can't be used as electronic switches. Gold, of course, conducts electricity and creates a short circuit, which "sabotages" the interesting semiconducting properties of the graphene ribbon. Roman Fasel's team and colleagues from the Max Planck Institute for Polymer Research in Mainz succeeded in demonstrating that graphene ribbons can be transferred intact to (virtually) any substrate through a relatively simple etching process.

Graphene nanoribbon heterojunctions, J Cai, CA Pignedoli, L Talirz, P Ruffieux, H Söde, L Liang, V Meunier, R Berger, R Li, X Feng, K Müllen, R Fasel, Nature Nanotechnology, 2014, doi.org/10.1038/nnano.2014.184

Conductivity measurement on a graphene ribbon (left) and a carbon nanotube (right): the carbon nanostructures are lifted up with the tip of a scanning tunneling microscope (STM), enabling the current flowing through the structure to be measured.



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lecular "Lego", they constructed graphene ribbons of different widths with different edges: zigzagged or coves lined up next to each other that were reminiscent of armchairs.

But that wasn't all: by incorporating atoms other than carbon such as nitrogen at precisely defined positions within the graphene ribbons, Fasel and Co. were able to influence their electronic properties even further, as they recently described in Nature Nanotechnology. If "normal" and nitrogen-doped segments are lined up on a gold surface, for instance, so-called heterojunctions form between the individual segments. The researchers were able to demonstrate that these exhibited similar properties, like a classic p-n-junction – i.e. a junction from a region of positive charges in a semiconductor crystal to one of negative charges. In other words, the structural basis for numerous components in the semiconductor industry.

Apart from the width of the ribbons, the researchers are now able to set the nitrogen doping specifically, too. This means that there are now two "knobs" that the researchers can turn to influence the electronic properties of graphene nanoribbons. The Empa researchers' work has already created quite a stir among the experts. It offers materials scientists and electrical engineers "tremendous scope to induce properties on demand,"

Carbon nanotubes can also be produced from precursor molecules

The promising experiments using customized graphene nanoribbons have quite a history at Empa. Over ten years ago, a team of researchers headed by Pierangelo Gröning already attempted to use carbon nanostructures, so-called carbon nanotubes (CNTs), for electronic applications. "The problem back then," describes Gröning, "was that there are dozens of types of CNT that all differ more or less electronically. In 2000 we didn't see how it could be possible to produce a well-defined type of CNT in a pure form." Following the successes with the molecular "flat-pack" of graphene nanoribbons, the Empa researchers were convinced that it also had to be fundamentally possible to "grow" CNTs in a controlled manner from suitable precursor molecules. They obtained the necessary molecules – planar polycyclical aromatic hydrocarbons – from Konstantin Amsharov and Martin Jansen from the Max Planck Institute for Solid State Research in Stuttgart, who had already entertained the idea of synthesizing CNTs from precursor molecules for some time.

Together, the researchers succeeded in transforming the planar molecules into a three-dimensional "cap", the germling – much like how a solid entity begins to take shape from a sheet of paper in origami. In a second step, they added additional carbon atoms, like in classic CNT synthesis, which adhered to the open edge between the cap and the surface. As a consequence, the tube gradually grew upwards. The trick: the atomic structure of the CNT and thus its electronic properties are exclusively determined by the original germling, which is how the researchers actually managed to make pure CNTs for the first time. In August 2014 the project even made it onto the cover of the renowned science journal Nature. In expert circles, the results were already hailed as the long overdue breakthrough in the development of structurally pure nanotubes shortly after they were published. As James Tour, a chemist at Rice University in Houston, who hailed it as "a stellar breakthrough", noted in Nature: "To those who have worked in this field for the past two decades, it is humbling to think that the selective growth of these diminutive structures has taken so long. But it is comforting to see it done so definitively."

wrote Hinran Wang, Head of the National Laboratory of Solid State Microstructures at the University of Nanjing, China, in the November issue of Nature Nanotechnology.

Also suitable for sensors or photovoltaics

Apart from electronic components, graphene ribbons could also be just the ticket for building highly sensitive sensors. After all, graphene ribbons respond extremely sensitively to their surroundings – their electronic properties change significantly when foreign molecules adhere to them. And photovoltaic elements could even be based on graphene one day, as Pascal Ruffieux – also from the Empa's nanotech@surfaces lab – and his colleagues recently discovered. They had noticed that especially narrow graphene ribbons absorbed visible light extremely well and thus made ideal absorber layers in organic solar cells. Unlike "normal" graphene, which absorbs light equally well on all wavelengths, the researchers were able to massively increase the light absorption in graphene nanoribbons for certain wavelengths by "setting" the precise width of the graphene ribbons atomically.

The use of graphene ribbons in the electronics world won't happen overnight, however, says Fasel. This is due to problems with upscaling to an industrial scale or replacing established, conventional, silicon-based electronics. Fasel estimates that it might take ten to 15 years for the first electronic switches made of graphene ribbons to be used in a commercial product. Nonetheless, Fasel's collaboration with BASF, which has already lasts a number of years and yielded six patents so far, just goes to show that they don't only conduct basic research.

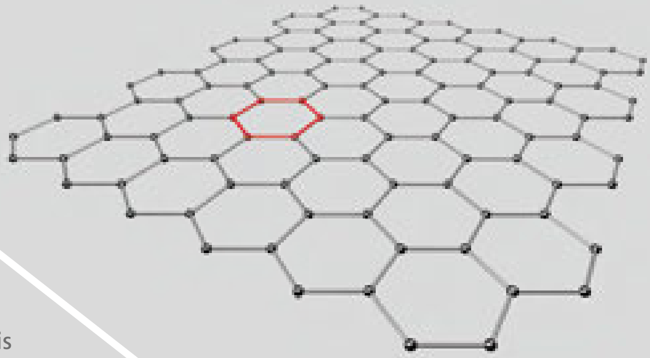
Graphene is also in demand elsewhere. The budgets for industrial research projects were increased all over the world. Moreover, the EU is looking to encourage an industrial breakthrough in the next ten years by investing half a billion Euros in the flagship project "Graphene" to co-fund projects up to 50 percent all over Europe. 142 academic and industrial research groups from 23 countries are involved, including six Swiss institutes – ETH Zurich, ETH Lausanne, the Universities of Zurich, Basel and Geneva, and Empa. Empa's studies on graphene were funded by the Swiss National Science Foundation, the State Secretariat for Education, Research and Innovation (COST action NanoTP), the US Office of Naval Research, the European Science Foundation, and BASF. //

Exciton-dominated optical response of ultra-narrow graphene nanoribbons, R Denk, M Hohage, P Zeppenfeld, J Cai, CA Pignedoli, H Söde, R Fasel, X Feng, K Müllen, S Wang, D Prezzi, A Ferretti, A Ruini, E Molinari, P Ruffieux, Nature Communications, 2014, doi.org/10.1038/ncomms5253

Controlled Synthesis of Single-Chirality Carbon Nanotubes, JR Sanchez-Valencia, T Dienel, O Gröning, I Shorubalko, A Mueller, M Jansen, K Amsharov, P Ruffieux, R Fasel, Nature, 2014, doi.org/10.1038/nature13607

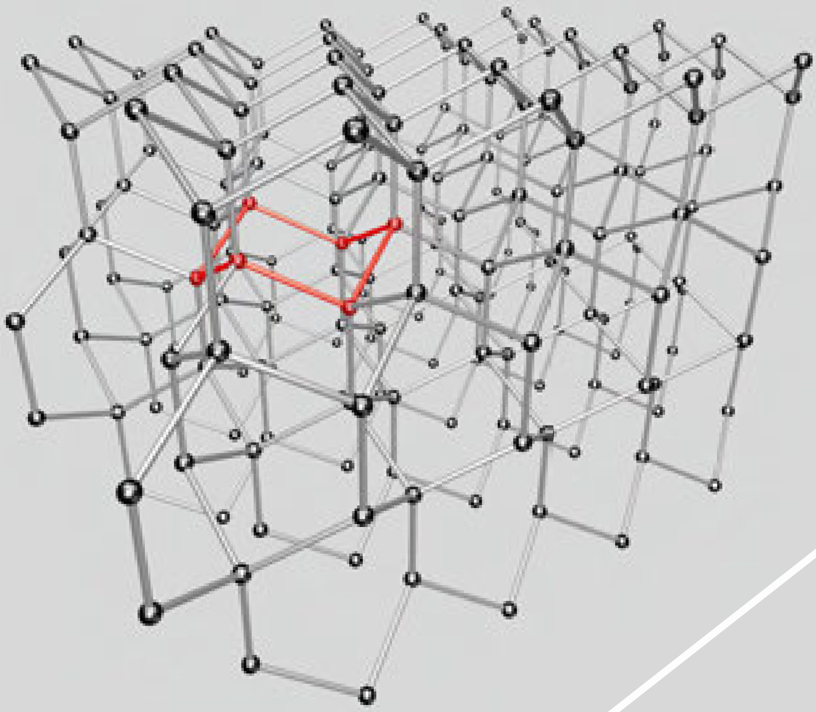
Graphene

A single, isolated graphite layer, only one atomic layer thick (or, better, thin), is referred to as graphene. The carbon is also found in the sp² configuration. Graphene was first produced using the top-down method, which involved separating individual layers of graphite. With the bottom-up approach also developed at Empa, however, graphene ribbons that are merely a few nanometers wide and have precisely structured edges can be synthesized, giving graphene clearly defined electronic properties.



Lonsdaleite

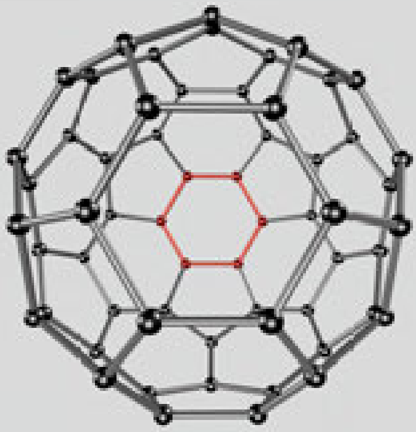
Lonsdaleite is a very rare mineral form of carbon first discovered in 1967. It is formed when graphite is transformed into a diamond-like structure through shock events, i.e. at high pressure and temperature, but the hexagonal crystal lattice of the graphite is preserved. It is therefore also referred to as hexagonal diamond. These conditions are found in meteoritic impacts, for instance.



The carbo

atomic number	6	12,011
density in g/cm³	2,26	2,50
		[He]2s²2p²
		3750 G / 4830
		4, 2, -4
chemical symbol	C	
chemical name	Carbon	

Six faces of a ch
the allotropic f

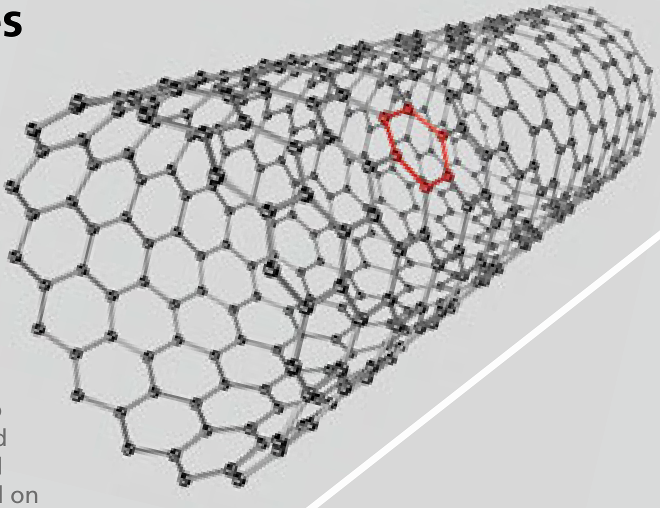


Fullerenes / buckyballs

The "prototypical" fullerene C_{60} resembles a football. The hollow carbon molecules were first produced in 1985 when researchers shone laser light onto a graphite layer. The most stable form of carbon there is, C_{60} is even found in interstellar space. It consists of 12 pentagons (like all fullerenes) and 20 hexagons, and was named buckminsterfullerene (or buckyball for short) after the architect Richard Buckminster Fuller as it looks like the geodetic domes he constructed.

Carbon nanotubes

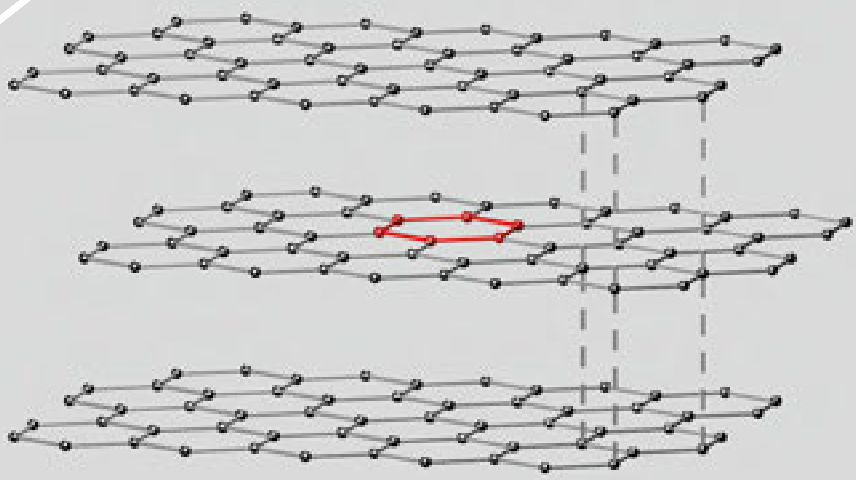
Carbon nanotubes (CNTs) have similar properties to graphene (again: sp^2 configuration) and can be pictured as a graphene layer rolled into a cylinder. They are formed in hydrocarbon combustion processes in the presence of a catalyst – or, as Empa recently managed to demonstrate for the first time, specifically from precursor molecules. Although there are countless forms of CNTs, they are generally divided into two rough categories: single-walled and multi-walled CNTs. Their hexagonal lattice structure can also be twisted on its axis, which is referred to as chirality. Depending on the chirality, CNTs are either semiconducting or metallic.



n cosmos

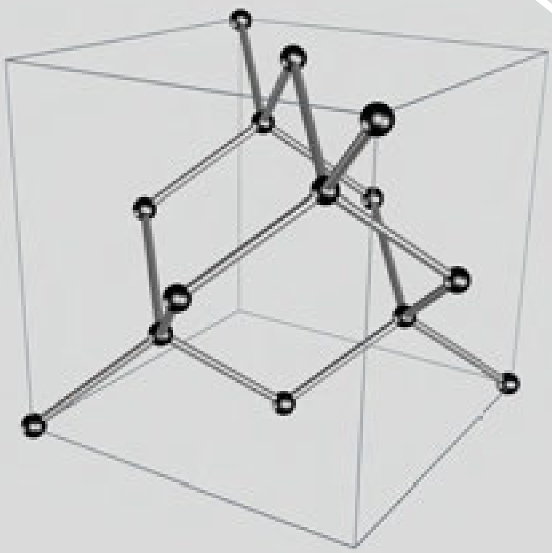
- standard atomic weight
- electronegativity
- electron configuration
- melting point / boiling point in °C
- oxidation states

emical element: orms of carbon



Graphite

Natural graphite consists of countless layers of carbon atoms lying on top of each other, arranged in the form of a hexagonal honeycomb structure. This is referred to as an sp^2 configuration. The bond between the layers is very weak, the material is extremely soft, which is why a graphite pencil leaves a grey trace on the paper when the individual flakes are rubbed away: the layers are worn down.



Diamond

In contrast to many other varieties of carbon, the carbon atoms in diamond are bound to each other tetragonally (i.e. in four spatial directions) and do not have any free electrons. This is referred to as an sp^3 configuration. In many respects, diamond is the "opposite" of graphite: it is an electrical insulator, an excellent heat conductor and the hardest natural material.

Flame protection for the jet set

A new coating protects business jet interiors against fire. Not only is the agent more environmentally friendly than before; it can also be applied more quickly. Empa is thus helping the Swiss company Jet Aviation to leave its competitors in the dust.

TEXT: Rainer Klose / PICTURES: Jet Aviation AG, Bombardier

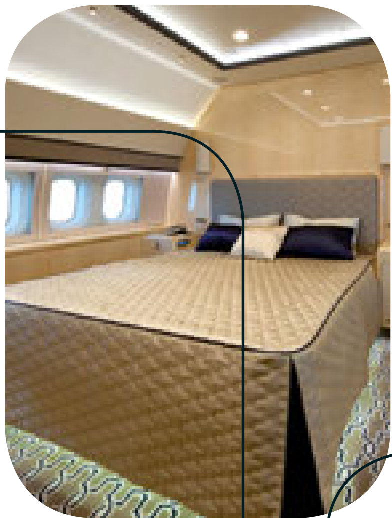
The customers want business jets to be nice inside; the aviation safety authorities want the furnishings to be fireproof. And the jet must never stand around in the hangar for too long while it is being refurbished as that costs money. With these parameters packed in its trunk, the aircraft equipment supplier Jet Aviation touched down at Empa to ask for some support: Since 1977, customers from all walks of life have been leaving their private jets with Jet Aviation to rearrange the furnishings or give the interior a makeover. Until now, it took several steps to fireproof the individual layers of the lightweight furniture while the expensive business jet remained grounded. This begged a major question: Can't this be done more quickly?

Cue Sabyasachi Gaan, who is in charge of developing fireproof textiles in St. Gallen. They carried out numerous lab tests – and eventually found a coating that the customer liked: the new coating is more environmentally friendly than the one used thus far – it can do without chlorinated and brominated chemicals and achieves the flame-retardant effect purely due to its especially heavy molecular weight, which gives it another advantage: the flame-retardant material does not evaporate, so the refurnished jet is not filled with any unpleasant odors.

One layer suffices

The Empa team also managed to guarantee the coveted time-saving aspect when handling the expensive machines: the newly developed flame-retardant material only needs to be applied once – instead of in several layers on top of each other – which saves on labor hours and drying time, and enables the new-look jet to roll onto the runway several days earlier. The project was co-funded by the CTI and launched in 2012 within the scope of the special measures to counter the strong Swiss franc. Meanwhile, the research work has been completed and the method is patent pending.

Project leader Gaan is already thinking one step ahead: if the fireproof equipment saves time while refurbishing private jets, it could also be used lucratively in the production of business aircraft. Talks with business jet manufacturers are already in the pipeline. The production of designer furniture for the flying conference rooms, sitting rooms and bedrooms has thus experienced a small revolution. "We can possibly use the new technology also for coating applications in textiles and wood-based furnishing and architectural systems. That's what we are going to look into next", says Sabyasachi Gaan.



The interior design in business jets doesn't only need to be representative, but also fireproof. Using Empa technology, the approval can be obtained faster and in a more environmentally friendly way than ever before. The method is also suitable for household furniture, where various European countries also demand fireproofing.

“The energy future won’t happen by itself“

Urs Elber, Managing Director of the Research Focus Area "Energy", explains how the energy supply will change in the years to come and how Empa supports this transformation.

INTERVIEW: Rainer Klose / PICTURES: Empa

About Urs Elber

Urs Elber has been Managing Director of Empa's Research Focus Area "Energy" since September 2014. It is his job to launch new research activities in the energy sector. At the same time, he is Empa's prime contact for partners from industry and academia on matters of energy management, research and planning. In over 20 years of experience, Elber has acquired a profound knowledge of the Swiss telecommunications and energy industries: he ran various hydro, wind, solar and biomass power plants, was CEO of the "Holzenergie" group at the electricity supplier Axpo and still manages the ETH Domain's Competence Center for Energy and Mobility (CCEM) at PSI. He is now looking to pool Empa's expertise in the field of energy research and create closer ties with the sister institutes in the ETH Domain. Elber also puts his money where his mouth is: on the roof of his house in Wangen near Olten, a first-generation photovoltaics system has been working for over 20 years.

Mr Elber, why does Empa's energy research need a managing director?

There are various reasons for the new position: around 40% of all Empa research projects are related to the energy sector, mostly with external partners from research and industry. These include the new demonstration platforms "NEST" and "Future Mobility", where system aspects play a crucial role. Energy research is thus becoming increasingly complex. It is obvious that, the longer the more, we need to think, do research and act in a much wider context than we've done so far – i.e. from the harvest and transportation of energy through its storage and conversion all the way to managing its consumption. Helping to focus on the big picture is part of my job here at Empa. This enables us to generate problem-solving approaches for our energy future in collaboration with all those involved in the process – not just from research.

Sounds like a very integrative, networked undertaking.

Precisely. And there's the societal aspect, too. Specific goals are defined in the Swiss government's Energy Strategy 2050. It is now our job to work out options that help us achieve these objectives. That's why additional public funding was set aside for the coordinated energy research action plan. The options aren't at all restricted to materials research: a new battery here or a better solar cell there won't be enough to solve the energy issue alone. Instead, the answer lies in systemic real-world applications that emerge as a result. Which of these options will win through in the end depends on economic and societal decisions. Ultimately, as citizens, not only do we have to decide which kind of energy we want, but above all which paradigm shift we are prepared to put up with in return. After all, every option will also have its drawbacks.

Can you expand on that? If I put a solar system up on the roof and use it to harvest eco-power – where's the disadvantage?

Firstly, solar panels still have an enormous amount of room for improvement: modules that are even more efficient, cheaper and easier to integrate, production methods with a lower carbon footprint etc. And then, especially in the summertime, when a lot of solar power

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is fed into the grid, it is very likely that more solar power is generated than is actually required at that particular point in time. This means that the energy system needs to become a lot more flexible. For instance, we have to develop storage systems, including seasonal ones, to absorb these surpluses. We need to look for new ways.

Such as?

You can never really have "too much" solar energy; you just have to channel the amount that isn't absorbed by the power grid or can't be stored directly into other areas – such as mobility. You can charge electric cars, produce hydrogen for full cell vehicles or, together with the greenhouse gas CO2, make synthetic natural gas from it. We don't need any solar power for heating on during summer – but we can still drive with it and thus substitute more and more imported fossil energy. A second possibility is efficient long-term storage systems. And finally we can manage consumption in such a way that it coincides better with production. So if more and more solar cells are installed on house roofs, it raises these follow-up questions. But not to worry, they can be solved.

Does that mean to say we have already conducted a relatively large amount of research on energy production but neglected the distribution side?

So far, the system was consumption-driven. As much power was produced as necessary. Now we've hit a brick wall with this approach. We have to strike a balance between conventional energies and new ones, such as solar and wind power – which sometimes are available, sometimes not – on the one hand and consumption on the other. This can be achieved by converting it into other forms of energy, centrally or decentrally, or through new sales models, which are geared towards primarily consuming energy when is it available. And the less energy we consume – through efficiency measures, for instance – the smaller the challenge will be.

Electricity and gas networks were invented around 150 years ago. How do these networks need to be renovated to meet the new requirements?

The power grid has a basic problem: it isn't very flexible. Electricity that is fed into it at some point needs to be used somewhere else at the same time. And precisely this kind of network has to make do with more and more non-constant power generators in the future. New technologies will help to expand current transfer networks and to use them more effectively, such as via high-voltage direct current transmission systems and via "Smart Grid". In comparison, the gas grid is very flexible – it can transport far greater amounts of energy in the same space and still store a lot of energy. But we've hardly used these capabilities so far. This begs the question: can I use one network to help solve the problems of the other? We need to find out whether and how we can combine the two worlds.

How can research respond to this challenge? Which research activities should be stepped up? And are there also areas where funding could be reduced?

We certainly shouldn't do any less in basic research. That's where the ideas we seize upon and we can develop further later on are created. But systemic approaches need to be intensified, too. We have to make solutions that work well in the lab – in intensive care, as it were – fit for everyday life. That's not possible in one single step; it takes demonstrators, where lab technologies can be tested on a larger scale and cut their teeth. Only after this step can we put projects into practice together with industry. From the lab "onto the street" in one go is hardly possible in the energy sector.

How do you know what makes sense and what doesn't?

We have to weigh up exactly what the advantages and the drawbacks of a technology are. This is revealed by life-cycle assessments. Often, what might sound good and obvious at first glance actually has negative effects bubbling under the surface. We need to develop computer models that help us estimate the consequences. Models

aren't forecasts, but they give us a certain idea. And the economic reality is just as important as the ecological benefit. We always have to ask ourselves whether and under which conditions a technology or system might actually have a good chance on the market.

Where does Empa come in here?

Several projects are currently on the go at Empa: "Future Mobility", a demonstration platform for sustainable mobility; the test building "NEST"; the "Energy Hub"; and the reconception of the energy supply for the Empa campus. These activities are ideal to combine different research fields in an interdisciplinary, conceptual way. Networked research is hugely important here, both within Empa and with external partners in the ETH Domain, and within the scope of the new Swiss Competence Center for Energy Research (SCCER). My job is to support these activities and interlink them even further.

You mentioned the role of inter-institutional projects. How important is this collaboration?

It's pivotal. In 2006, for instance, with the Competence Center for Energy and Mobility (CCEM), the ETH Domain already recognized that not everyone can do everything in the same depth and that our increasingly complex world calls for more and more systemic considerations. That's why, within the ETH Domain, complementarity is key. Through networking, we minimize – or even exclude – parallel research, which saves both time and money and enables the institutions to focus on their core competencies. There is already a very close collaboration in the energy sector with the Paul Scherrer Institute (PSI) and the other ETH institutions. I see it as my job to push this collaboration further.

Finally, a look to the future: what do the next 35 years hold in terms of energy supply?

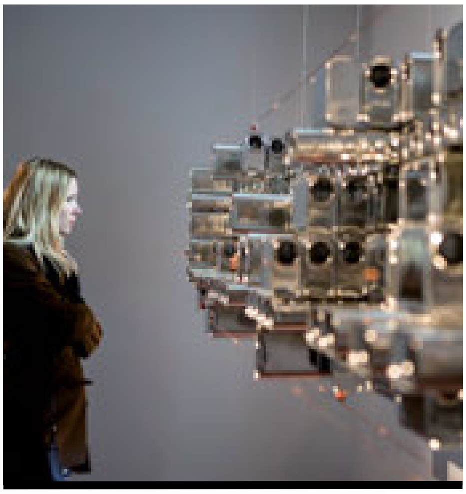
My best guess is that we will experience a drastic transformation, quite similar to the one that took place in telecommunications in the last two decades, with paradigm shifts on the part of both suppliers and customers. Back then, there was a state monopolist who owned all the infrastructure and services and supplied the technology all the way to the customer. And today? We have to be careful transferring this model to the energy sector, though. The transformation will happen much more slowly and in a different way because the energy infrastructure is very much geared towards the long term and its effect on the landscape can't be concealed. Nor can we predict exactly what will happen at what point in time. Technical progress will yield numerous new technologies in the next 35 years, the importance of which we can't even fathom yet. Just think back: hardly anyone could imagine a Smartphone back in 1992. We have some exciting times in store for us – and there will be plenty to do for everyone involved. //

Urs Elber at a small Axpo hydropower plant in Kollbrunn/Tösstal, which he used to run.

Aernoudt Jacobs (l.) and Empa scientist Silvain Michel testing the sound membrane – the beating heart of the installation.

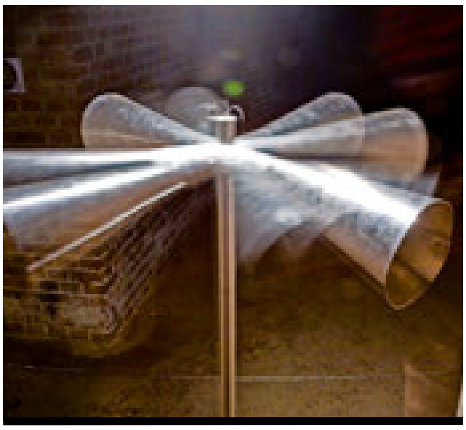
The sound of science

TEXT: Rainer Klose / PICTURES: Empa, www.overtoon.org



Video
Induction Series #4

http://youtu.be/lR0Pg1HvyZU



Video
Phantom Melodies

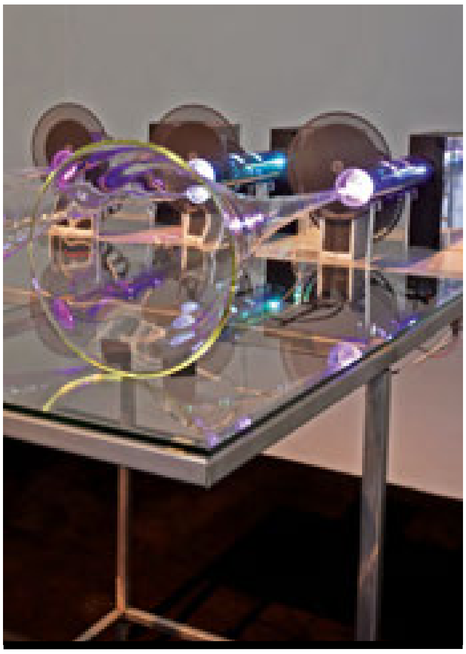
http://vimeo.com/91603030

Belgian sound artist Aernoudt Jacobs is busy with his next work of art – and this time he is relying on Empa technology. Teaming up with Silvain Michel, a specialist in electroactive polymers – which are also known as artificial muscles – Jacobs tested a reflective sound membrane in Empa's labs in early October. Although the developing artwork is still untitled, one thing is for sure: it will be on display in the exhibition Kontinuum at the Vienna gallery "IM ERSTEN" from January 27, 2015 (www.imersten.com). The exhibition was initiated by the art-based research project "LIQUID THINGS" at the University of Applied Arts Vienna (*www.liquidthings.net*).

Born in Brussels in 1968, Jacobs has been concentrating on sound installations for over ten years, which he exhibits all over Europe. The artist is wandering between science and arts by transferring physical phenomena into inspiring artwork. (The QR codes on this page offer a glimpse into his works.) In the installation Permafrost, for instance, he amplifies the crackling sound of frozen water and melting ice. The artwork Photophon #1 is based on the photoacoustic effect discovered by Alexander Graham Bell: Jacobs chops up white laser light and lets his fragile installation "sing" different tones. In the installation series entitled Induction Series #1 – #4, he uses electromagnetic induction to tease out tones that are reminiscent of birds twittering from various objects.

Playing with electroactive polymers from Empa will not be easy for Jacobs: "Presumably, the piece will still be a prototype at the exhibition in Vienna," he says. He isn't entirely sure what it is going to sound like, either. "At the moment, I'm using sounds, which I collect with my recorder – such as during a walk in the forest on a stormy day, for instance. In the end, something like the creaking of wood could emerge. It might also be the sound of religious chants." At any rate, the tones will follow a distinct choreography and combine movement and sound. Visitors will clearly recognize what they are hearing but the tonality will keep changing. "This combination produces a kind of unconventional yet very palpable echo effect," says the artist. //

Have a look in Aernoudt Jacobs's installations on *www.overtoon.org* and *www.tmrx.org*

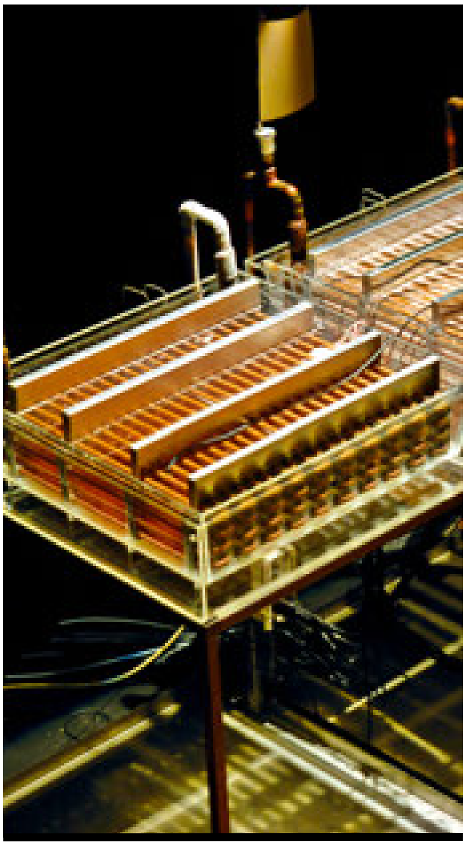


Video
Photophon
(does not run on iPhones)

http://vimeo.com/104899973

Video
Heliofoon
(does not run on iPhones)

http://vimeo.com/112046544



Video
Permafrost

http://vimeo.com/91602237

Gentle caffeine boost for premature babies

Empa researchers have developed a UV-activated membrane which releases a gentle dose of medication to the skin of a patient. In future those who fear injections will be able to sleep soundly, as will premature babies too, since the new dosing technique will spare them additional stress.

TEXT: Remigius Nideröst / PICTURE: iStockphoto

2735 The development of minimally and even non-invasive technologies is increasing in the medical field. It is now possible, for instance, to carry out a range of operative procedures using keyhole surgery with minimal use of the scalpel, leaving only tiny scars as a result. Similar opportunities are now becoming available when providing doses of active agents to patients – instead of using injections or probes to deliver drugs, it will in future be possible to supply them via a plaster which continuously, gently and painlessly delivers the required dosage through the skin.

Drug-loaded plaster to counter the fear of injections

For some years now premature babies – "preemies" – have been given caffeine to prevent respiratory arrest. The dose of caffeine is supplied to the infant in the incubator via a tube or through injection, both of which represent additional stress for the still very sensitive child. On top of this, neither method allows the drug to be dosed in an optimal manner, since at the moment of delivery a peak in concentration occurs followed by a sometimes rapid drop in its value. An ideal dosage technique would be able to maintain a stable concentration over a period of several hours.

In a project carried out in collaboration with the University Hospital, Zurich, and financed by the Swiss National Science Foundation, Empa has now developed a plaster which delivers the active agent via a membrane. This can be simply stuck to the skin of the preemie, after which it will provide the tiny patient with a continuous transdermal dose of, say, caffeine for several hours, without stressing the child as an injection would have done.

Developed in the laboratory, tested at the University Hospital

The membranes developed at Empa change their properties when they are irradiated with UV light. A similar effect is seen in photochromic sunglasses, where silver-doped glass reacts to UV light by darkening. In the new medicinal membranes, however, another light-sensitive functional chemical group is active, so called spiropyrans. When activated, these make the membrane more permeable, so that the active agent is able to pass through it more rapidly, a capability which is retained for several hours. In the absence of UV irradiation, the membrane simply prevents the active agent from permeating through it, as the researchers report in a recently published study in the scientific journal «Advanced Functional Materials».

The ability to precisely control both the quantity of active agent delivered by the membrane and the duration of delivery was of essential importance in the development. The medical staff at the University Hospital of Zurich, who were involved in the project, believe that the new plaster has a good chance of market success, since the delivery rate can be exactly controlled and adjusted to suit individual requirements. It will, however, be some time before the tiny patients can enjoy the new technique as currently Empa is seeking a partner to take on production of the plaster on an industrial scale.

NEST is rising

The construction of the modular research and innovation building "NEST" kicked off with the ceremonial first cut of the spade on August 26. Meanwhile, work has already progressed to the shell of the first floor. The building's base frame, its "backbone", is due for completion in the summer of 2015, after which the first modular research units will be installed.

TEXT: Rainer Klose / PICTURES: Empa

left:
Ground-breaking ceremony August 26, 2014. From left: Walter Steinmann, Director Swiss Federal Office of Energy SFOE; Gian-Luca Bona, Director Empa; Janet Hering, Director Eawag; Lothar Ziörjen, Stadtpräsident Dübendorf; Markus Kägi, Government Councillor of the Canton of Zurich; Fabio Gramazio, Architect NEST.

below:
Progress of construction works by December 2.

The giant pit on Empa's Dübendorf campus has already been filled back in: the cellar ceiling was poured in at the end of November and the construction of the first floor got underway at the beginning of December. The project is being funded by the Swiss government, the Canton of Zurich and the city of Dübendorf. Over the next few years, the one-of-a-kind research building designed by the Zurich-based architecture firm Gramazio & Kohler will be putting future forms of living and working, new construction methods and new, energy-efficient technologies to the test. NEST will be permanently occupied as a guesthouse and the office units are used on a daily basis.

Living and working in the future

The four-story experimental building comprises a core, the so-called "backbone", with three open platforms, upon which several independent research and innovation units can be installed. In these units, apartments, offices and conference rooms of the future are to be investigated, tested and refined under everyday conditions. Unlike with conventional houses, mistakes and wrong turns are not only allowed, they are even welcomed. Never before was it possible to demonstrate and test new technologies and systems in a real working environment. Thanks to the exchangeable units, bigger risks can be taken in NEST than in a conventional building, which speeds up considerably both the acquisition of new knowledge as well as technology transfer.

The construction of the backbone is due for completion in the fall of 2015 and the first research units are scheduled to be installed by the end of the same year. Besides Empa and Eawag, ETH Zurich, EPF Lausanne and Lucerne University of Applied Sciences and Arts are also involved as academic partners. //

Empa researchers among "100 Leading Global Thinkers"

The US journal Foreign Policy has named Empa researchers Artur Braun, Florent Boudoire, Rita Toth and Jakob Heier, and Edwin Constable from the University of Basel in the innovation category on the list of 100 Leading Global Thinkers 2014 in recognition of their research project on moth-eye solar cells for the direct conversion of sunlight into hydrogen. The awards ceremony took place in Washington D.C. on November 17, 2014, in the presence of US Foreign Minister John Kerry.

TEXT: Rainer Klose / PICTURES: www.foreignpolicy.com

Every year, Foreign Policy compiles a list of the top 100 minds in the world – people who have had a major impact on our world and society in the year in question in both a positive and negative respect. Besides the Empa researchers, this year's list of 100 Leading Global Thinkers also includes German Chancellor Angela Merkel, Russian President Vladimir Putin and an Indian research team that sent a space probe to Mars – but also the leader of the IS terrorist militia. The 100 people are divided into ten categories depending on their contribution to global history: "Decision Makers", "Naturals", "Challengers", "Advocates", "Artists", "Innovators", "Healers", "Chroniclers", "Moguls" and "Agitators". The Empa researchers featured in the "Innovators" category. The awards ceremony was held in Washington D.C. on November 17, 2014. The complete list of the 100 Leading Global Thinkers 2014 can be viewed at *http://globalthinkers.foreignpolicy.com.*

Award-winning: Moth-eye solar cells convert sunlight into hydrogen

In June 2014 the research team headed by Artur Braun succeeded in producing a solar cell that imitates photosynthesis in plants and uses sunlight and water to create synthetic fuels such as hydrogen. This photo-electrochemical cell basically works like a moth's eye. The special microstructure of the photoelectrodes literally captures the light and doesn't let it back out again, which enabled the researchers to increase the light yield of the solar cells radically. //

ICT and sustainability – recommended reading

While today's laptops and tablets might be more environmentally friendly during an hour's use than a desktop computer from ten years ago, this doesn't mean that ICT as a whole has become more sustainable. As a study reveals: whereas ten years ago the average household had one computer that was on a few hours per week, these days every home has several laptops and tablets that are on the go in parallel for over ten hours per week.

"The Transition from Desktop Computers to Tablets: A Model for Increasing Resource Efficiency?" is just one of 27 chapters in the new book "ICT Inno-vations for Sustainability" by editors Bernhard Aebischer and Empa scien-tist Lorenz M. Hilty . The book guarantees the reader an exciting, informa-tive glimpse into the research field of sus-tainability in information and communication tech-nology (ICT).

ICT Innovations for Sustainability.
Edited by Lorenz M. Hilty and Bernhard Aebischer.
Springer, Berlin 2014.
(www.springer.com)

Guidelines on nanoparticles

The industrial use of nanoparticles and -structures has aroused high hopes for better product features – and great fears regarding potential health and environ-mental hazards. The legislation in Europe is complex, however, and nanoparticles are available on the market in a wide variety of forms. Empa has thus issued the LICARA guidelines (Life Cycle Assessment and Risk Assessment of Nanoproducts) in collaboration with European partners from both academia and industry. The 44-page information brochure in English describes exactly what nanomaterials are, explains the legal framework, analyzes the benefits of nanotechnology, out-lines the risks for humans and the environment and considers the sustainability of nanoproducts.

A PDF version of the guidelines is available
for download at *www.empa.ch/licara*.

Empa is no stranger to providing safety information for particular industries: Back in 2011, it published the Nano Textiles guidelines on the safe access to and handling of nanotechnology in the textiles and clothing industry in conjunction with the trade association Swiss Textiles.

We're giving away …

Empa's table calendar

2015

You can't buy our popular table calendar in the shops. The calendar, which features our favourite pictures from a year of Empa science, is only to be had as a gift. Feel free to reserve your copy – just send us an email with your mailing address to ***info@newsletter.empa.ch****. And if you are one of the first 25 to do so, the CD-format calendar will drop into your mail box soon.*

Events

(in German)

21. Januar 2015
Additive Manufacturing
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

27. Januar 2015
Kritische Materialien
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

2. Februar 2015
Hightech-Keramiken – Grundlagen und Anwendungen
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

24. Februar 2015
Aerogel – Revolution in der Wärmedämmung
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

25. Februar 2015
Power-to-Gas in der Mobilität
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

26. Februar 2015
Swiss Practice an der Empa-Akademie
Zielpublikum: Führungskräfte der Schweizer Wirtschaft
Empa, Dübendorf

22. Mai 2015
Fachkongress Energie & Bauen
Zielpublikum: Fachleute aus den Bereichen Energie und Bauen
St. Gallen, Olma Messen

Details and further events at
www.empa-akademie.ch

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