Empa 50 Dübendorf

Empa News

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Gian-Luca Bona sets course

EMPA
Materials Science & Technology

MICHAEL HAGMANN Head of Communications

… and still going strong

Dear Reader,

50 years ago the Empa campus in Dübendorf was literally carved out of a green field on the outskirts of Zurich. A tremendous (and extremely far-sighted) feat of infrastructure investment that would hardly be possible today. Of course, a lot has happened since; and we have resurrected several episodes.

What is much more important, however, is where the journey is going to take us in the future. As a "cradle of innovation" for Swiss industy, Empa's top priority is not to let its innovation pipeline dry up, but to keep developing and churning out new materials and technologies instead. Because as global competition is becoming fiercer all the time Switzerland can only remain competitive through clever ideas, products and concepts. And therefore safeguard its prosperity.

It is thus high time for another "bold move", a Swiss innovation park where research institutes and universities collaborate with Swiss companies and major international enterprises to work out solutions for urgent problems. And heaven knows, there are enough of them. Exactly where this innovation park is going to be built is still wide open. But perhaps the example of Empa has demonstrated that Dübendorf is a perfect place for forward-looking investments …

Enjoy reading!

Imprint
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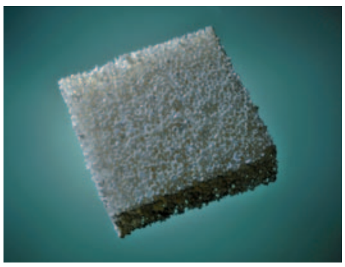
Cover
Empa CEO Gian-Luca Bona has the job of taking Empa forward. What he intends to do and where the challenges lie – see our interview on Page 12. Picture: Daniel Winkler Fotografie, Zurich

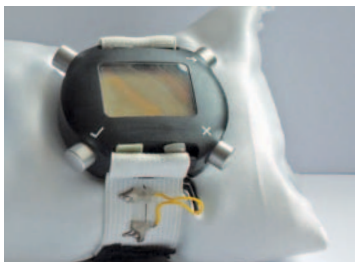
Empa 50 Dübendorf

The Empa campus in Dübendorf was inaugurated 50 years ago. The façades have hardly changed – but the inside of the institute certainly has. 04

Focus: 50 years of Empa Dübendorf



Catalytic converter made from ceramic foam 22



Revolution in blood pressure measurement 25

Re-inventing Empa

The Empa campus in Dübendorf was inaugurated 50 years ago. The exterior of the building has hardly changed. Inside though it's a completely different story.

TEXT: Rainer Klose / PICTURES: Empa Archives

The appearance of the construction lab (left) and the administration building (top) on the Empa campus in Dübendorf has hardly changed in 50 years.

It all began with an enormous leap of faith. In June 1953 Swiss parliament approved 64 million Swiss Francs to move Empa to Dübendorf – and started the most expensive civil construction project since World War II. Empa had previously been distributed over 20 buildings in the city of Zurich – some were converted old residential buildings –, and it had become way too packed. A comparison reveals just how much money 64 million was in those days: The annual budget of Empa in 1955 was about four million Swiss Francs. The new campus was, therefore, worth 16 years of materials research – it would cost 1.5 billion to make the same investment today.

The move was completed in 1962, i.e. Dübendorf was "up and running". The administration and laboratory buildings, the noise/engine/X-ray houses, the construction laboratory and the metals building still exude the modernism that Zurich architect Werner Forrer was striving for with his award-winning design.

The virtually unchanged façades conceal, however, how much Empa has changed behind the scenes. 1962 seems like a different era nowadays: Aviation pioneer Eduard Amstutz was at the helm of Empa, he was also vice-president of the Swissair administration committee. Equipped with limousine and chauffeur in accordance with his status, the Empa director made an imposing figure. It would take until the new century for Empa to experience a tie-less CEO zooming around the campus on his bike.

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Vice-director in 1962 was Ernst Brandenberger, a chemist and at the same time army general and commander of border brigade 6. As the artillery leader of the 4th army corps Amstutz himself was also firmly involved in the network of Swiss military officers. A female member of Empa's Board of Directors, such as Brigitte Buchmann, was not even dreamed of back then.

The crash of the Swissair Caravelle on 4th September 1963 in Dürrenäsch in the canton of Aargau put the analytical capabilities of the "new" Empa to the test for the first time. As former ETH professor for aircraft construction, Amstutz was extremely committed to establishing the cause of the crash. This is how "Empa Dübendorf" first hit the headlines (see text below).

From an outside perspective, Empa was in a position to analyse catastrophes like this in a calm and professional manner; internally, though, upheaval was hard to avoid. Painful changes laid ahead. In 1969 Theodor H. Erismann took up his post of new director – and tackled a structural reform that had long been overdue. Previously, the 20 laboratory heads reported directly to the Empa director, who was extremely busy due to numerous outside appointments. No wonder that the labs were considered "little kingdoms", as a witness from the time recalls. Under loud protest from these "royals", Erismann introduced an additional level of hierarchy and divided Empa into six departments, a structure Empa has been operating with to this day.

At the same time (the beginning of the 1970s), Empa was already playing a pioneering role with regard to protecting the environment and dwindling resources. When the study "Limits of Growth" commissioned by the "Club of Rome" appeared, Empa had long since been busy uncovering and combating damage to the environment. Air contamination and industrial waste water were being examined for damaging components, and the influence of noise at workplaces and residences was being measured. Since 1970 Empa has been observing insecticides such as DDT that contain chlorine,

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1963

Why did the Caravelle crash?

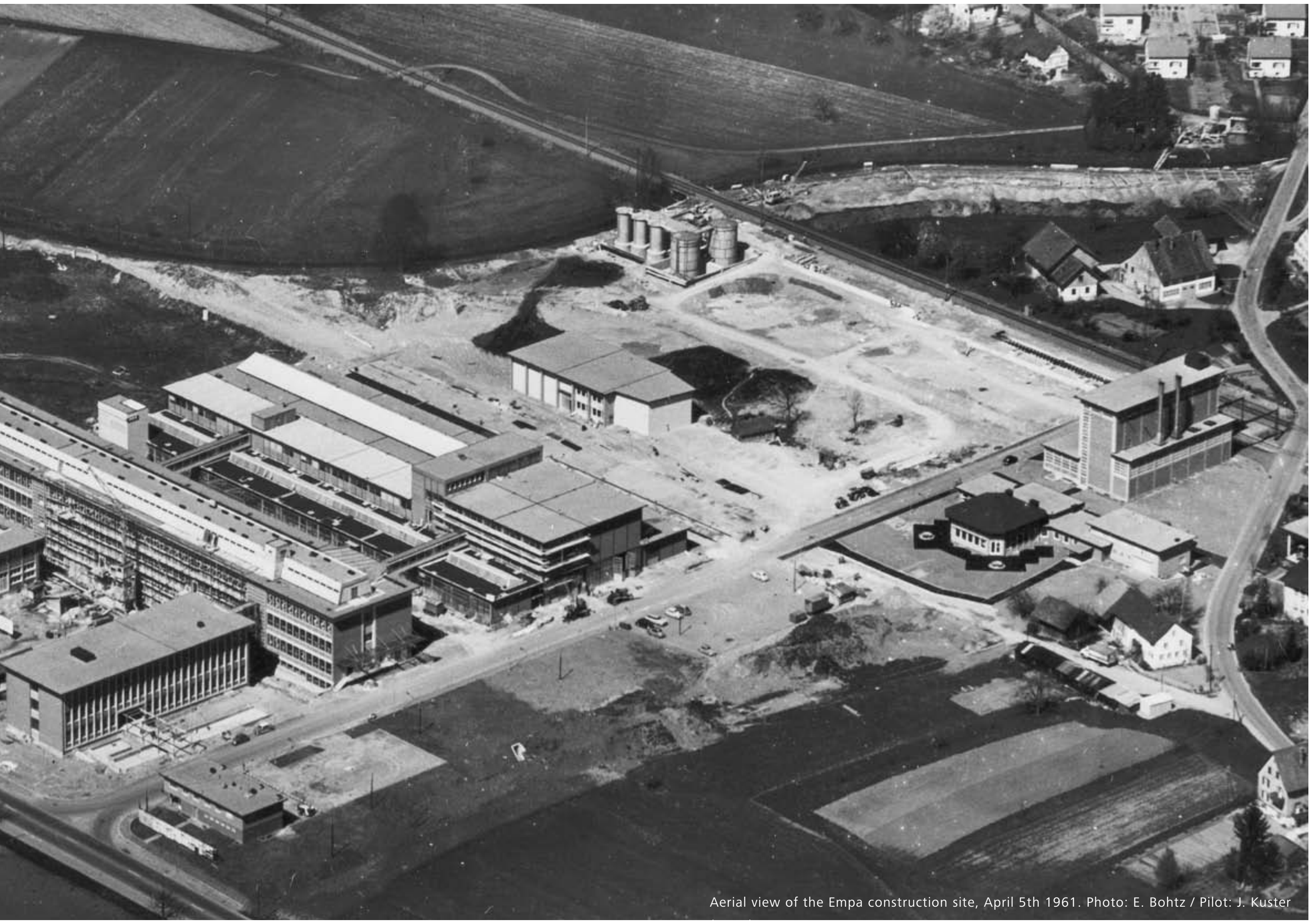
A gaping crater and a scene of devastation are dire reminders of the event that killed 80 people on 4th September 1963. The crash of Swissair flight 306 on the outskirts of Dürrenäsch is Switzerland's second most devastating aviation accident to date. Empa was searching for answers.

There were six cabin crew members and 74 passengers on board the "Sud Aviation Caravelle", which took off from Zurich airport at 7:30 AM, heading for Geneva. However, the flight ended just seven minutes later in a crash with no survivors. According to witnesses, the aircraft was already burning when it took off but no-one knew exactly what had happened.

The investigations took more than a year. The burning Caravelle had lost some parts during the final twelve kilometers of its flight – the rest exploded on impact. Thousands of fragments were collected, categorized and

Flugarchiv Graubünden. Photo W. Friedli

Air Crash at Dürrenäsch



Aerial view of the Empa construction site, April 5th 1961. Photo: E. Bohtz / Pilot: J. Kuster

analyzed. Under the leadership of Carl Högger from the Accident Investigation Bureau (now part of the Swiss Accident Investigation Board SAIB), police, aviation agency, military, the aircraft manufacturer, the airline and several research institutes cooperated in reconstructing the incident. Half a dozen Empa scientists and engineers paid particular attention to the wheels, brakes, fuels and operating materials that might have caused the accident.

Time-consuming testing and analyses followed. “The scope of Empa’s contribution to the accident investigation can best be measured by the number of reports and enclosures that were made available to the head of the investigation, which filled two lever-arch files”, wrote Högger in his final report. The Empa scientists assembled the fragments, carried out chemical and metallographical examinations of the aircraft components, examined X-ray images and analyzed the braking behavior of the aircraft in collaboration with the “Etablissement Aéronautique de Toulouse”.

Eventually, the cause could be established more than one year after the catastrophe. Before taking off, the pilot taxied up and down the runway to check out the visibility – it had been foggy that morning. The parking brake of the Caravelle was on slightly, which generated a considerable amount of heat in the wheels. This made the magnesium alloy brittle, and one of the wheels therefore started to break up as the aircraft turned. One of the fragments must have severed a hydraulic line. The high temperature was sufficient to ignite the leaking oil. When the wheels were retracted into the landing gear shaft after take-off, the fire spread to the tyres until a fuel line finally melted. As the fire spread, the entire hydraulic system failed. The Caravelle thus became uncontrollable, and the crew could no longer stop the nosedive.

The results had far-reaching repercussions on aircraft maintenance and construction. Swissair subjected its aircraft to additional checks before take-off, and pilots were obliged to pay attention to the handling of the aircraft. The fuel lines of the Caravelle were shielded, the hydraulic system was improved, the wheels were equipped with safety fuses, and the hydraulic fluid was replaced with one that was less flammable; brake temperature sensors are now part of the standard equipment of passenger aircraft.

Anna Ettlin

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NEST: The experimental building on the Empa campus will consist of "plug-and-play" modules. This allows to test new designs, construction materials and methods in a scientific manner. Construction is scheduled to begin 2013/14.

and tracking the spread thereof in milk and cheese. The "Internal Combustion Engines" laboratory examined how the lead content in petrol could be reduced. In 1973 the air measuring station on the Jungfraujoch was started up as part of a European measuring network for globally transported air pollutants.

Over the years, Empa has focussed with increasing intensity on applications-oriented research and the development of innovative technologies e.g. in the area of air purity or drive technologies. Today Empa is one of the world's leading laboratories in gas engine research (see below). New research topics were launched – in nanotechnology among other things (see page 11) – and an international research commission as well as an "Industrial Advisory Board" advise Empa. This ensures that Empa research acts at the "leading edge" and, at the same time, does not lose sight of its industrial partners. New laboratories have been set up time and time again, such as for High Performance Ceramics, Nanoscale Materials Science, Biomaterials and various energy technologies (see below).

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1985

The wrong kind of steel

On 9th May 1985 the concrete ceiling of the Uster public pool collapsed, resulting in 12 dead and 19 seriously injured. Empa investigations revealed that the ceiling, built in 1972, was not only 30 % heavier than planned, but was also suspended using unsuitable steel brackets. They developed cracks under heavy strain and corroded in the chlorine-saturated air. In the wake, Empa provided training courses for construction experts.

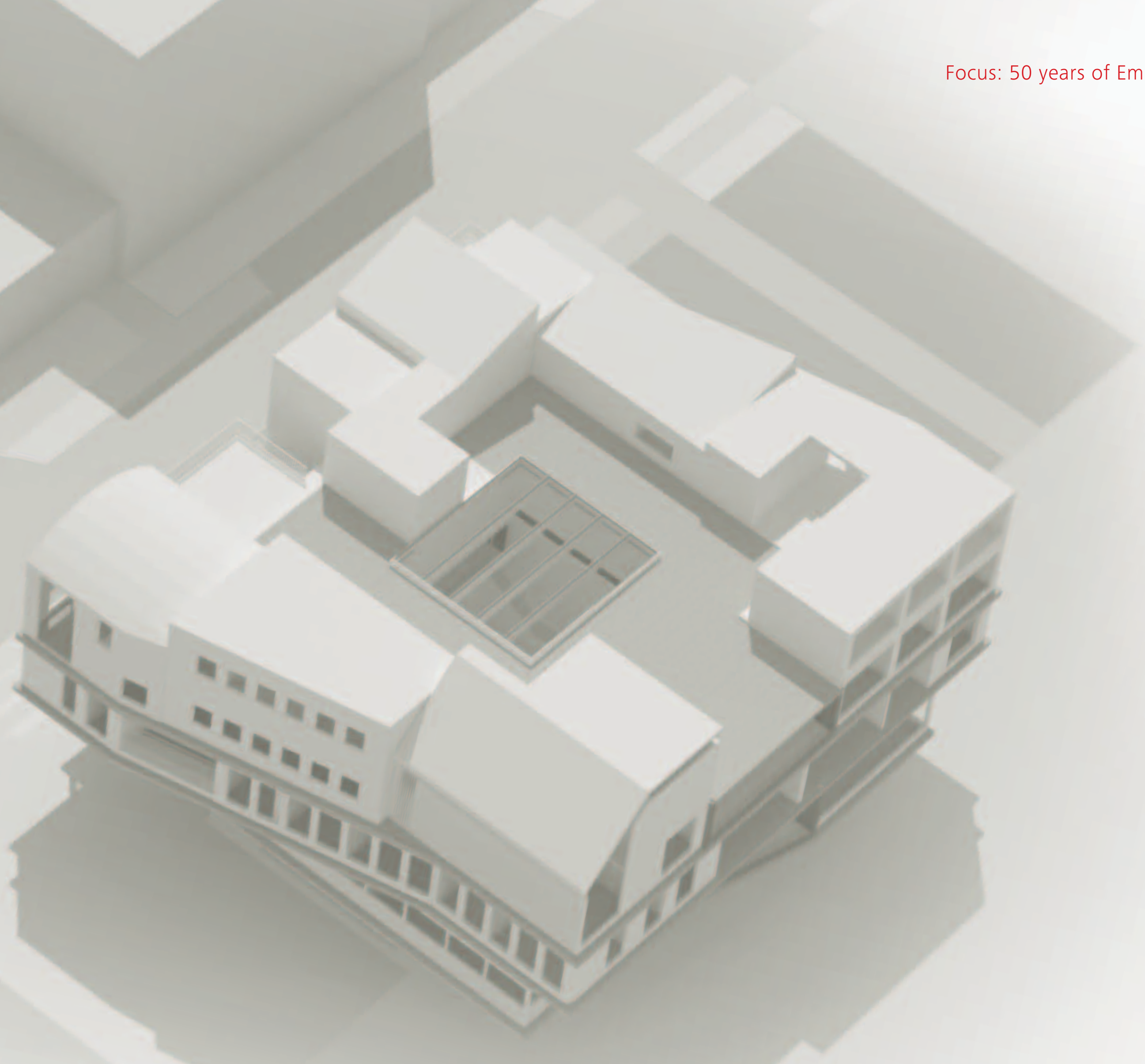
Roof collapse in the Uster indoor swimming pool

1992

"Hot stuff" from the East

On 26th August 1992 a 25-year-old Pole turned up at Empa's reception, asking for an analysis of an Osmium 187 sample, a rare platinum metal he had bought from a Ukranian – and pulled the sample out of his shirt pocket. When Peter Richner, lab head at the time, took the sample to the mass spectrometer, an alarm went off at the instrument's Geiger counter. Radiation protection experts were notified, the Pole and his colleague arrested. The test tube contained highly radioactive Caesium 137! Fortunately no one was exposed to life-threatening amounts of radiation. Since then there is a Geiger counter in the Empa mailing department, to check unknown materials in advance.

Packet checking using a Geiger counter



1994

Testing for space travel

Ariane 5, the European space rocket, can transport a payload of up to 18 tons into orbit. The payload panelling is manufactured by RUAG Space in Switzerland. It is jettisoned at an altitude of 110 kilometers, as soon as the air resistance can no longer damage the rocket. But until then it must stand firm. Empa tested the 14 meter-structure in its hall in Dübendorf. Ariane 5 was successfully launched for its maiden voyage in 1997.

2003

Natural gas turbocharger

Natural gas cars of the 1990s used natural aspiration and had low torque – until Empa came into play: A VW Polo with a 37 kW engine was converted to natural gas. The initial output was 31 kW. Later on, different pistons with greater compression and a turbocharger increased power to 44 kW. CO_2 emissions were also reduced. Today natural gas turbocharged cars are available from VW, Opel and Fiat.

Ariane structure test

Natural gas research car: VW Polo

2005

Cable break after routine job

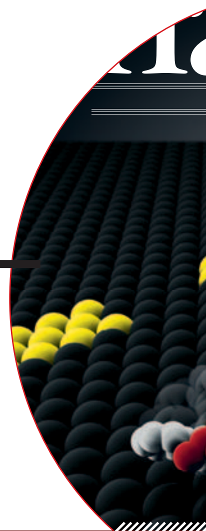
On 29th December 2004 the outer sheath of the cable on the Schilthornbahn snapped with a crack. Passengers were rescued by helicopter, and a section of the cable was brought to Empa. Result: A company had moved the cable a few meters in 1979 and scratched it during this routine work. 25 years later it snapped. 130 cable cars were subsequently checked for similar problems.

Crack in the cable of
the Schilthornbahn cable car

2011

World's smallest four-wheeler

In 2011 Empa made it onto the front page of "Nature". Microscope specialists sublimated a chemical molecule that looked like a Formula 1 car on a copper surface, and carried out a "test drive". The car was "fueled" via the tip of a scanning tunneling microscope (STM). All four wheels rotate at the same time. The joyride was quite short: just six nanometers.



But to get new things started and make them thrive you first have to make room. Empa is no different. Because: In order to "make an impact" and bring about true innovation, the insitute has to focus its activities and not try to be a jack of all trades. Empa continuously reacts to current requirements, e.g. from industry, and adapts its research portfolio accordingly. For Empa scientists and engineers this means staying flexible and periodically starting something new.

The change is most visible in Empa's scientific output: Both the number of scientific publications and the number of PhD students regularly hit new record levels. At the end of 2012 there were 160 PhD students, 44 PhD theses were completed – more than ever before. Empa staff were involved in 120 CTI-funded projects (Commission for Technology and Innovation), 100 SNSF projects (Swiss National Science Foundation) and 70 EU projects. Scientifically, Empa has never been more prolific.

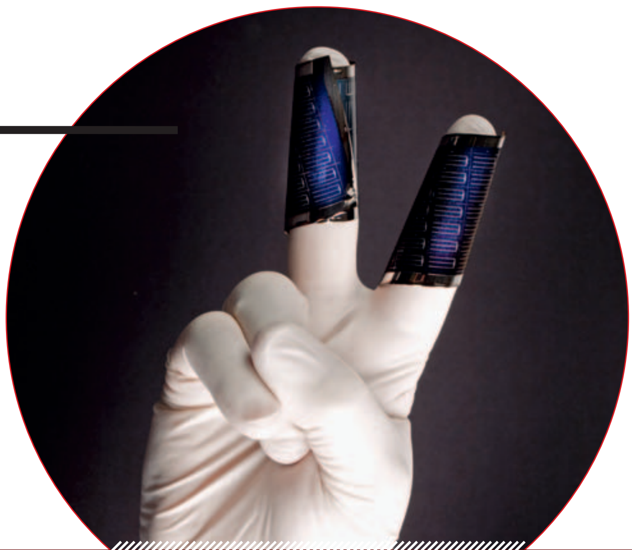
At the same time, Empa researchers filed 18 patents and concluded 33 new licensing agreements with industrial partners as well as 150 research agreements with external partners. Empa's technology centers (glaTec in Dübendorf and tebo in St. Gallen) looked after a total of 15 spin-offs. Yet another record showing that today's Empa is a real "innovation powerhouse" for Switzerland (see also page 12). In spite of the red brick façade from way back when. //

2011

Flexible solar cells at low cost

Empa is a pioneer in the development of highly efficient, low-cost thin-film solar cells: Researchers have succeeded in making flexible cells based on cadmium telluride (CdTe) with a world-record efficiency of 13.8%. A few months beforehand the team also improved the efficiency record for flexible solar cells made from copper indium gallium selenide (CIGS) to 18.7%.

Nano-car



Solar cell efficiency world record

"The place where innovation starts"

After four years at the helm of Empa CEO Gian Luca Bona looks back and takes a peek at the future. Where does Empa come from, and where could it go?

INTERVIEW: Rainer Klose /
PICTURE: Daniel Winkler Fotografie, Zürich

Mr. Bona, you have been leading Empa for four years. The institute has changed quite a bit during this time. Where are we now – and what remains to be done?

I have noticed a significant increase in public awareness and appreciation that there are highly competent and motivated people at Empa, who do not just preside over and develop the scientific basics of their expert areas, but do a lot more: There are people with whom you can collaboratively work on a product or a technology all the way to a successful market entry. And we also transfer the know-how that we develop in-house: 100-plus scientists leave Empa every year, and most of them join industry. We "produce", in a manner of speaking, experts who bring a tremendeous value to our economy and our country.

And things are also changing internally. Our staff has realized that they need to reach out beyond their area of expertise and collaborate with colleagues in adjacent fields. Because this is precisely how great things happen. This process, this cultural evolution is not quite complete yet – perhaps it never will be. Because Empa must grow dynamically with the market, anticipate and shape future developments and change continuously.

"Every year, 100-plus scientists leave Empa to join industry."

When did you first come across Empa?

I remember it quite well, that was 42 years ago, at highschool in St. Gallen. We had a school excursion to the Empa labs. At the first stop a machine was testing the strength of packages by dropping them from a certain height at a certain angle. I found this pretty boring and thought to myself: The packaging manufacturers should do that themselves. I liked the second stop much better: It was testing racing suits on their air permeabilty.

But this goes to show that in those days Empa was nothing more than a testing institute. Unfortunately our past is still clinging to us to a certain extent. We want to change this by showing people time and time again: Today's Empa is a source of innovation. "The place where innovation starts", as our slogan says. Today we are a highly creative research institute. Our partners from industry and academia are well aware of that. But we still have to persuade some more people including certain CEOs. Because in a way this contradicts what Empa used to be: We carried out reliability tests. For some people creativity and reliability are not completely compatible. In science, however, the two complement each other extremely well. You can tackle something new in a reliable and analytical way, and the process that led to this problem-solving approach can be extremely creative, or even chaotic. Good scientists ideally combine both of these traits.

Which research topics does Empa have to deal with in the future?

There is no doubt in my mind that we regularly need to enter new research areas, unfortunately more often than not under financial constraints. Shifts in portfolio will happen time and again at Empa. Which is also a good thing; it is an evolution like the one made by any living organism. A few simple questions will guide us here: How can Switzerland earn money in the future and secure its prosperity? Where does a new need originate from, and how does a sustainable solution look like? Where are new, so far unknown challenges?

For example, 20 years ago I would never have imagined that today almost everyone would carry a Smartphone with instantaneous and permanent access to all information on the web. And in 20 years from now we might possibly have completely different mobility concepts than today.

However, I am convinced that Switzerland's long-term economic survival strongly depends on sustainable and innovative high-tech concepts. Empa has the task of developing and preparing such concepts and technologies. One example for this kind of research is our "Future Mobility" platform, with which we explore how renewable excess energy from wind farms or photovoltaic systems can be converted into synthetic fuels and used in a practical way. Another important area with a great tradition in Switzerland is coatings. The future will bring us coatings that have sensory capability, for instance, or entirely novel functions that we have not even thought of yet.

So what will Empa look like in 20 years?

Of course, I don't know for sure. But it will certainly be a highly networked and flexible organisation. Scientists from various fields will intensely exchange their know-how with each other and jointly elaborate new solutions – the ones that do this in the best possible way will also be the most successful. This means that Empa is and will remain an important pillar of Swiss competitiveness – and hence, for our high standard of living, which can only be kept by ceaseless innovation. Those who stand still will be left behind. //

Carbo-Link AG
CH-8320 Fehraltorf
www.carbo-link.com
Founded in 2000

Designs, develops and produces structural components made from carbon fibres. These parts are used in cranes (Liebherr), formula 1 (Sauber) and in concrete construction.

Ugra
CH-9014 St. Gallen
www.ugra.ch
Outsourced in 2005

Operates the "Swiss competence centre for media and printing shop technology", and promotes scientific investigations in the printing industry.

Empa Testmaterials
CH-9015 St. Gallen
www.empa-testmaterials.ch
Founded in 2001

Makes artificially soiled or dyed textile samples with which detergents and washing machines can be tested.

World Resources Forum
CH-9014 St. Gallen
www.worldresourcesforum.org
Founded in 2012

Promotes the exchange of information about economic, political, social and environment-damaging effects of global raw material use.

Spin-Offs

Empa's s

The most important start-up com

Decentlab GmbH
CH-8600 Dübendorf
www.decentlab.com
Founded in 2008

Designs and markets wireless real-time monitoring systems for bridges, agriculture, forestry and research.

Compliant Concept
CH-8600 Dübendorf
www.compliant-concept.ch
Founded in 2009

Develops intelligent technical solutions for bedridden patients that make care easier and help with health maintenance.

CTSystems
CH-8600 Dübendorf
www.ct-systems.ch
Founded in 2012

Develops actuators (artificial muscles) based on lectro-active polymers for mechatronic systems in the car, multimedia and robot sectors.

Monolitix AG
CH-8600 Dübendorf
www.monolitix.com
Founded in 2010

Designs and manufactures flexible gripping tools for robots and monolithic tools that consist of one injection-moulded part instead of several individual parts.

satellites

panies involving Empa know-how

Humanikin GmbH
CH-9035 Grub
www.humanikin.com
Founded in 2008
Designs and constructs robot manikins that sweat and move, and can be used to test outdoor clothing and protective clothing for the fire brigade.

Swiss Surface Solutionsnano GmbH
CH-3602 Thun
www.sssnano.com
Founded in 2013
Manufactures transparent, anti-reflective and hydrophobic coatings that are kept clean using the "Lotus effect".

QC Expert AG
CH-8600 Dübendorf
www.qc-expert.ch
Founded in 2005
Provides neutral assessments of building damage for property developers, architects and insurance companies, produces refurbishment proposals and carries out building measurements.

ETSS, Gottschalk & Co.
CH-7558 Strada
www.etss.ch
Founded in 2011
Provides corporate advice e.g. in risk analysis, material flow simulation, technology impact estimations, toxicity research, strategy development, game and decision-making theory.

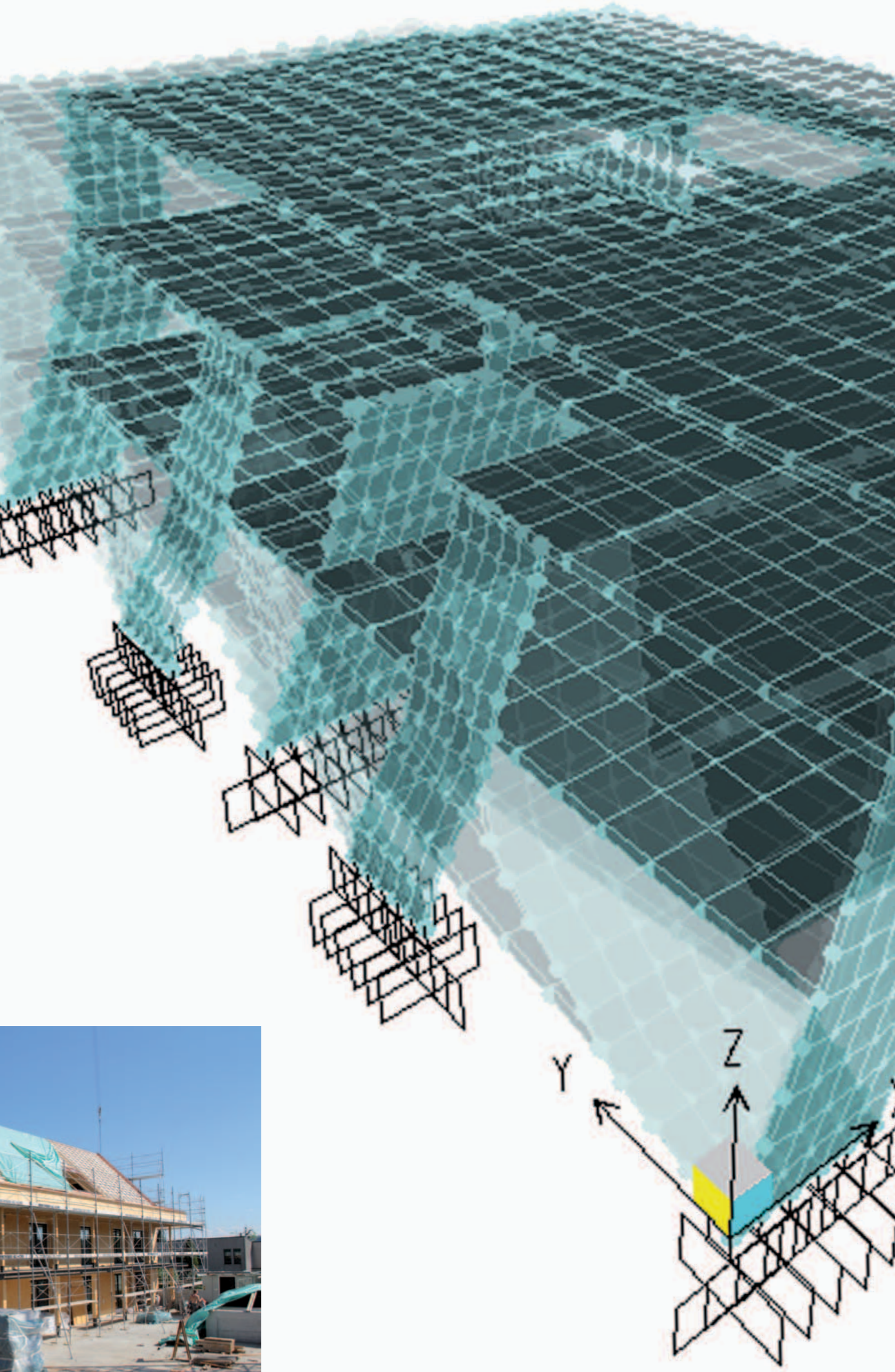
Eleoss Ltd.
CH-3602 Thun
www.eleoss.com
Founded in 2013
Produces stainless steel coatings on a galvanic basis, and precision components made from stainless steel.

Spin-Outs

SVTI
CH-8304 Wallisellen
www.svti.ch
Outsourced in 2009
Services in the area of the integrity of metallic materials and components; routine checks of gas cylinders and pressurised systems.

Quantis
Lausanne, Bellinzona, Dübendorf
www.quantis-intl.com
Outsourced in 2013
Life Cycle Assessments (LCA) in energy, mobility, materials and buildings. The team consists of experts in LCA modelling and inventory data.

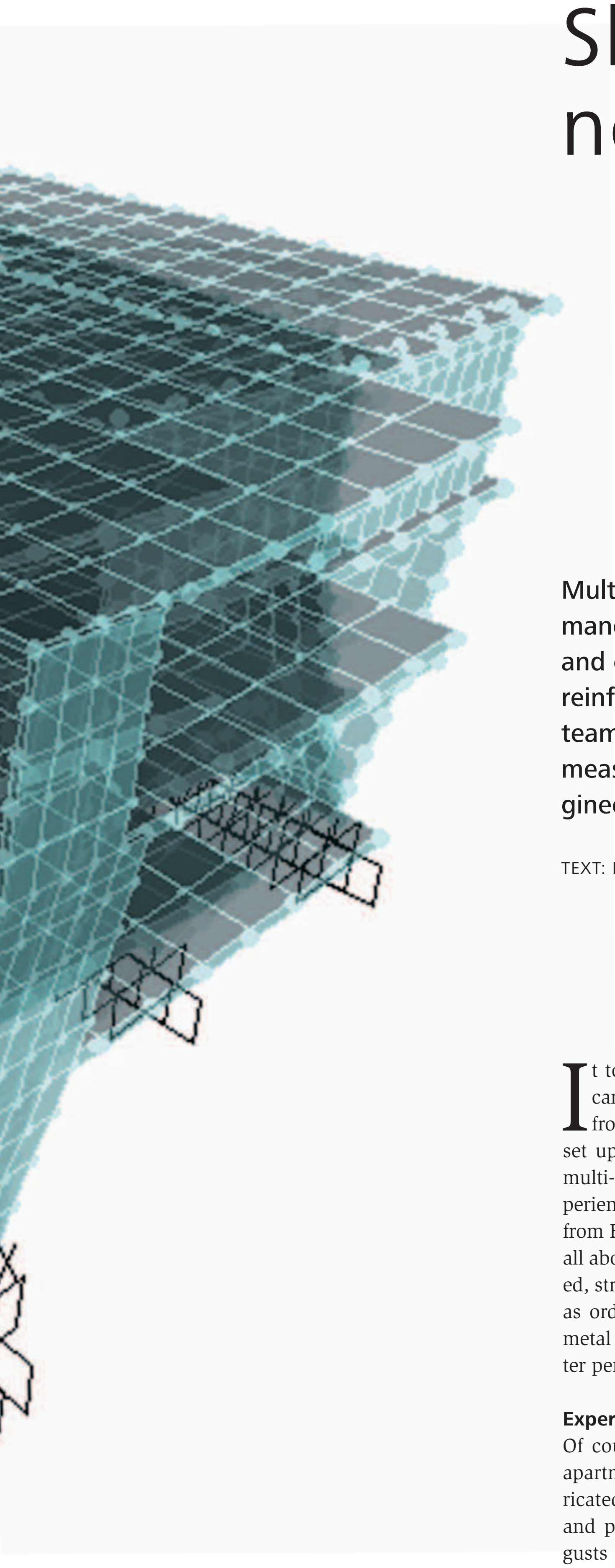
1



1
The results of the vibration tests are compared to calculations made on a 3-D model of the building. The measurement yields a number of parameters to describe the building's behavior: natural frequency, normal mode of oscillation, modal mass and modal damping.

2
Test subject: three-story apartment block with wooden frame in Oberglatt (ZH).

2



Shaken, not stirred

Multi-story wooden buildings are in high demand. But in order to withstand strong winds and earthquakes the support structure requires reinforcement. Using a large shaker an Empa team makes a multi-story house vibrate. The measurements help architects and structural engineers to optimize planning and construction.

TEXT: Martina Peter / PICTURES: Empa

It took three rounds for Empa's large Saurer truck to deposit its cargo at the construction site in Oberglatt: a two-ton shaker. Far from the public gaze, an unusual scientific experiment was being set up. It was aimed at optimizing planning and dimensioning of multi-story wooden houses thanks to better data from practical experience – and finding low-cost solutions. Project leader René Steiger from Empa's "Structural Engineering" laboratory explains what it is all about: "When supporting structures are being planned and erected, structural engineers are confronted with the very same problems as ordinary mortals putting a bookshelf together: Leaving out the metal cross at the back makes the shelf unstable, and it starts to totter perilously even with the gentlest of pushes from the side".

Experimental investigations are (still) lacking

Of course, a mere metal bookshelf cross is not sufficient for the apartment block that was examined. A building made from a prefabricated wooden frame elements and nailed-on oriented strand board and plasterboard panels needs rigidity to withstand strong wind gusts and earthquakes. To ensure this, structural engineers can fall back on various solutions: One either installs additional supporting

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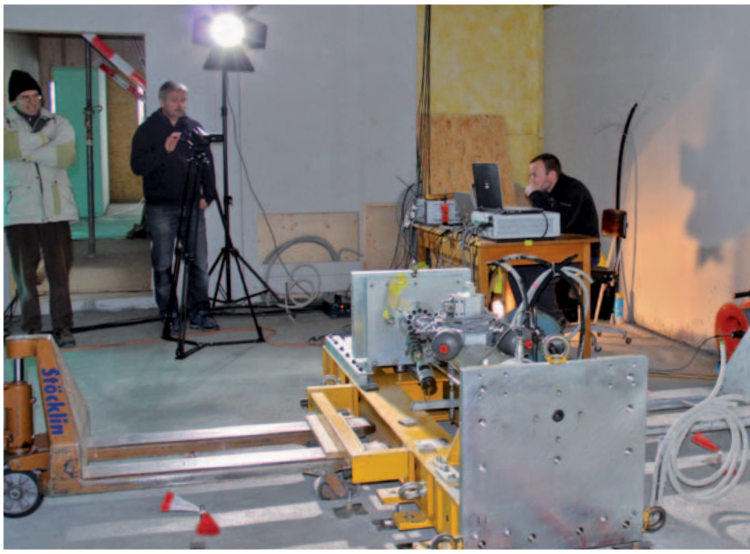
1


2


3

walls or increases the load-bearing capacity of the existing walls by using thicker components, material with better load-bearing capacity or additional connecting materials. "But at the end of the day, this all means more material and additional work. And this this, in turn, brings about higher costs", says Steiger. And to make things even more complicated: Reinforcement is not always the best solution. In order to absorb earthquake tremors, it is sometimes better if the structure is not too rigid, but can react in a flexible way.

The entire wood construction industry as well as architects, engineers and property developers are, therefore, interested in having data available that is as realistic as possible with regard to rigidity, fundamental vibration times and damping in multi-story wooden buildings in order to find the best solution for their specific project. This ensures that one uses exactly the right amount of materials as is really necessary (and in the right places, too).

In the past there were only mathematical approximations, but no data concerning the dynamic properties of a multi-story wooden house that had been collected from an actual building. Vibration table tests have been carried out in Japan and North America. However, they are not completely applicable to the situation in Switzerland, since they simulate strong earthquakes. The Japanese and North American structures also differ considerably from those here. This is because of differing requirements with regard to thermal insulation, sound- and fireproofing. In the current building standards structural engineers only find average values for the rigidity of individual nails, clamps or screw connections, wooden frame components and planking materials. What is missing is information about the rigidity of entire wall elements or even walls that run over several storys. With the vibration tests Empa wanted to close this gap together with the engineering office Pirmin Jung AG and the two companies ZBF Architekten AG and Artho Holz- und Elementbau AG. Another partner was Oberglatt-based building project contractor Ferrario Bau AG, whose willingness to perform the tests on its own building made this unique research project possible.

Measurements during three phases of construction

In April and May, Empa scientists in collaboration with the construction site team from Pedrocchi Bau GmbH hoisted the shaker weighing several tons into the first floor of the building shell by crane, laid countless metres of cable and installed 26 acceleration sensors. 1000 kilograms of weight were set in motion time and time again thanks to precision control of the servo hydraulic cylinder, and made the wooden house vibrate good and proper in exactly the way that would be expected due to wind gusts or small earthquakes in the Zurich lowlands. Meanwhile, the acceleration sensors measured the horizontal movement of the building on three floors and provided values for the rigidity, natural frequency and damping of the support structure. The measurements took place during three different phases of construction. The scientists were, therefore, able to observe how the support structure gained rigidity. Whereas only the supporting walls acted as reinforcement in the first phase, in the second phase the planking of non-supporting walls were clamped and in the third phase the windows were installed.

1
Earthquake expert Thomas Wenk (left) visits René Steiger (right) and his team on the construction site.

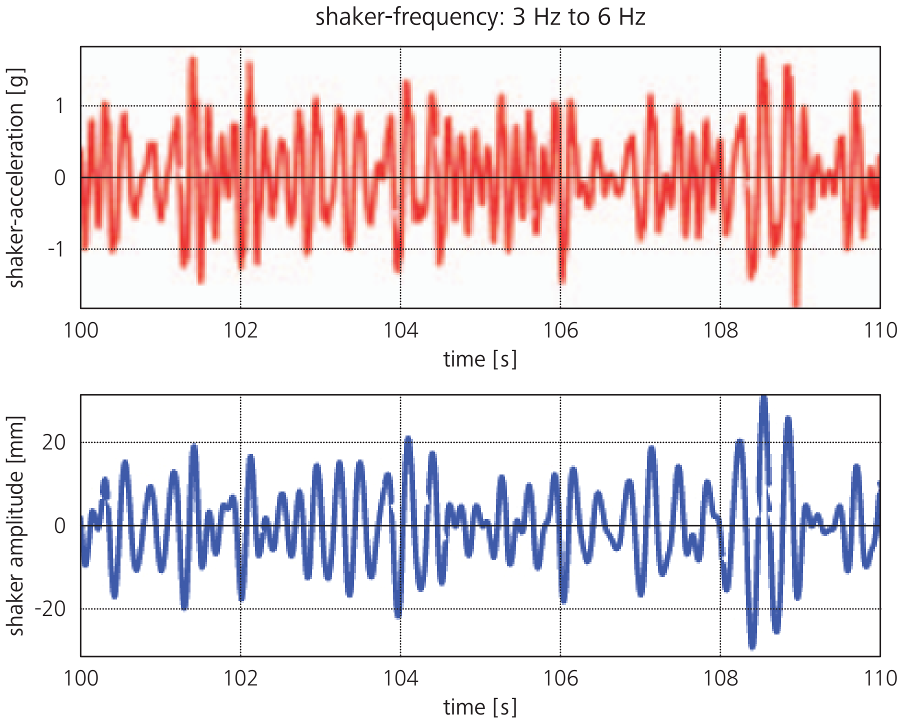
2
The hydraulic horizontal vibrator, which can set a vibrating mass of up to one ton in motion, is moved into position.

3
Quite a few Empa experts were on site so that the vibration tests could be carried out on the emerging building without causing damage.

4
The shaker analyzes the building at varying amplitudes and frequencies.

Video
Shaking a three-story apartment block with wooden frame

http://youtu.be/k8IR1jGGJnI



4

"Wood" research program

In the National Research Program 66 "Resource Wood" (www.nfp66.ch), a team from Empa's "Structural Engineering" laboratory with research partners from the Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud (heig-vd) and the EPF Lausanne, assisted by industrial partner Pirmin Jung – Ingenieure für Holzbau, Thomas Wenk – Erdbebeningenieurwesen und Baudynamik GmbH and Lignum – Holzwirtschaft Schweiz are investigating how connections and wall elements in multi-story wooden buildings behave during earthquakes and in strong winds. The researchers are developing an optimized support system with the aid of a deformation-based measuring method. The results should contribute to making wood more competitive as a construction material, and wooden buildings more reliable, economical and projectable.

The scientists will be busy evaluating the comprehensive amount of data for a while. "The initial results have already shown that the computer calculation did not match the experimental results", says Steiger. The support structure proved to be significantly more rigid than had been calculated based on information in the standards and the models that had been used. The differences in parameters that were determined in the different construction phases were also much less pronounced than expected. In the present case it would, therefore, have been possible to use fewer connecting materials or fewer reinforcing walls, and the building would still have been safe.

The evaluations do not only yield insights about the building in Oberglatt, but also provide information about how the construction materials that are being used affect the rigidity, the normal frequency and the damping of buildings. The scientists' work is used to update standards and models, and helps structural engineers and architects to optimize their planning. And last but not least: The project, which was financially supported by the funds for promoting forest and wood research of the Federal Office for the Environment (FOEN) and the cantons, also highlights the competitiveness of wood as a sustainable construction material for multi-story buildings. //

Dioxin from particle filter

Diesel particle filters are a blessing for the environment – but also a chemical reactor that is difficult to control. Fed with the "right" ingredients, certain filters even produce dioxins, as Empa scientists found out.

TEXT: Rainer Klose / PICTURES: Empa

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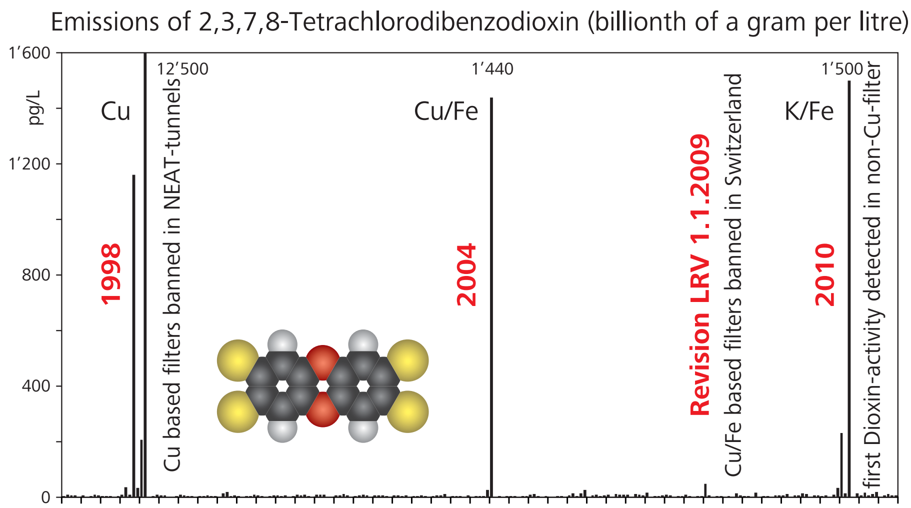


2

1
A construction engine releases unfiltered diesel soot into the blue morning sky near Los Angeles. A retrofit filter would retain large quantities of toxic material. However, these filters reach temperatures of up to 500 degrees C – temperatures, at which highly toxic dioxin can be produced.

2
Norbert Heeb has tested more than 40 different types of filter in the last few years. Only three of these produced dioxin. After Empa made this public they were banned.

I don't want to give particle filters a bad name, but we have to take a close look at what comes out at the rear end", says Norbert Heeb. A while ago, the Empa scientist and his team discovered yet another filter model that takes soot out of the exhaust but also produces highly toxic dioxin, i.e. polychlorinated dibenzodioxin/furan. He made the finding public in the specialist magazine "Environmental Science and Technology" – and not for the first time.

Heeb knows a great deal about diesel particle filters. "The construction of the NEAT basic tunnel gave me 15 years of work" he says. Switzerland actually does play a pioneering role in filter technology because of this tunnel project. A lot of money was at stake: A 57-kilometer long tunnel system was going to be built. It was also a case of protecting the workers from carcinogenic diesel soot from the construction machinery. This is achieved by either blowing in fresh air, which is expensive, or installing particle filters in all of the construction machinery. The VERT test (Verminderung der Emissionen von Real-Dieselmotoren im Tunnelbau – Reduction of emissions from real diesel engines in tunnel construction), which is now internationally recognized and is part of the Swiss air pollution control legislation, was developed in close collaboration between industry, universities and authorities. The people in charge were Andreas Mayer from TTM engineering office, Jan Czerwinski from Biel University, Gerhart Leutert from the Federal Office for the Environment (FOEN) and Andrea Ulrich and Norbert Heeb from Empa. Construction machinery is still being certified in accordance with this standard. And filter expert Heeb is still making surprising discoveries, such as the one concerning dioxin.

Extremely carcinogenic and extremely toxic

The Seveso toxin dioxin (see box) fits like a key into the lock of the human AHR protein that controls cell growth. It is carcinogenic, persistent and builds up in the body. It can be formed at about 300 degrees C from soot particles, non-combusted fuel, oxygen and a little chlorine if traces of copper salts are present. This is where it gets interesting: Precisely this mixture of ingredients (and the right temperature of between 100 and 500 degrees) can be found in certain diesel particle filters.

Many different techniques are available for removing soot from diesel exhaust. Strong or weak oxidizing filters compete against each other; the burning off of the soot particles in the filter is often accelerated using catalytic metals or metal oxides. When Peugeot brought the first diesel car with a soot particle filter onto the market in the year 2000, the engineers mixed in a cerium solution into the fuel. The VW Passat subsequently drove with an iron additive.

A desperate search for feasible processes for construction machinery was also going on at that time. Things did not always go well: In 1998 copper-catalyzed diesel particle filters were found to be dioxin generators. They were immediately banned for use in the NEAT tunnels. In 2007 Heeb and his colleagues discovered another source of dioxin, a filter with an iron and copper mixture as catalytic converter. Shortly thereafter, Swiss government also banned this filtering technique. And since January 2009 copper-containing diesel particle filters have been banned in Switzerland altogether.

Heeb was all the more surprised when he investigated a particle filter last year that was using an iron and potassium solution. Heeb's summary: This filtering technique also produces a considerable amount of dioxin – in spite of the fact that the widespread iron catalytic converter technology had never been linked to this effect before. The researchers still do not know how dioxin is formed in these filters. One hypothesis is that the combination of potassium and iron in the combustion forms magnetite (Fe_3O_4) instead of haematite (Fe_2O_3), which may encourage the formation of dioxin.

A chemical "lucky bag"

A lot of things that happen inside a diesel particle filter can only be assessed on the basis of the result. Too many factors are involved, and there are too many temperature ranges and zones with and without oxygen. Traces of metallic abrasion from the engine come into contact with a wild cocktail of soot particles, non-combusted fuel and hot combustion gas. And also: Idle speed is different from full throttle. And an old filter behaves differently from a new one.

Norbert Heeb and his team must, therefore, painstakingly analyze the exhaust mixture time and time again and track down rogue filters. Fortunately there are only a few: The Empa scientist has tested more than 40 particle filters over the years, and only three of these generated a noticeable quantity of dioxin/furan. There are plenty of alternatives available; a continuously updated list is hosted by the FOEN *(www.bafu.admin.ch/partikelfilterliste)*.

At the end of the conversation we come to the conclusion that exhaust cleaning is no simple matter, but always a compromise that has to be continuously reconsidered. Soot particles are only a part of what a diesel engine emits. Nitrous oxide, polycyclic aromates (PAH), carbon monoxide and various genotoxic materials are also generated. A particle filter in a fork lift truck in a warehouse must be capable of doing something very different than the one used in a bus in the ozone-endangered centers of major cities. However, even though the cleaning power may be different in individual aspects: A filter that has been tested in accordance with the Swiss VERT standard is better than none – a statement upon which Heeb puts a lot of emphasis. Filters that produce dioxin should, however, not be used.

For the Empa scientist it is high time that, just like cars and construction machinery in the past, trucks, tractors and inland waterway vessels were now also equipped with good particle filters. Some of the persuasion work for this process is done by Empa. //

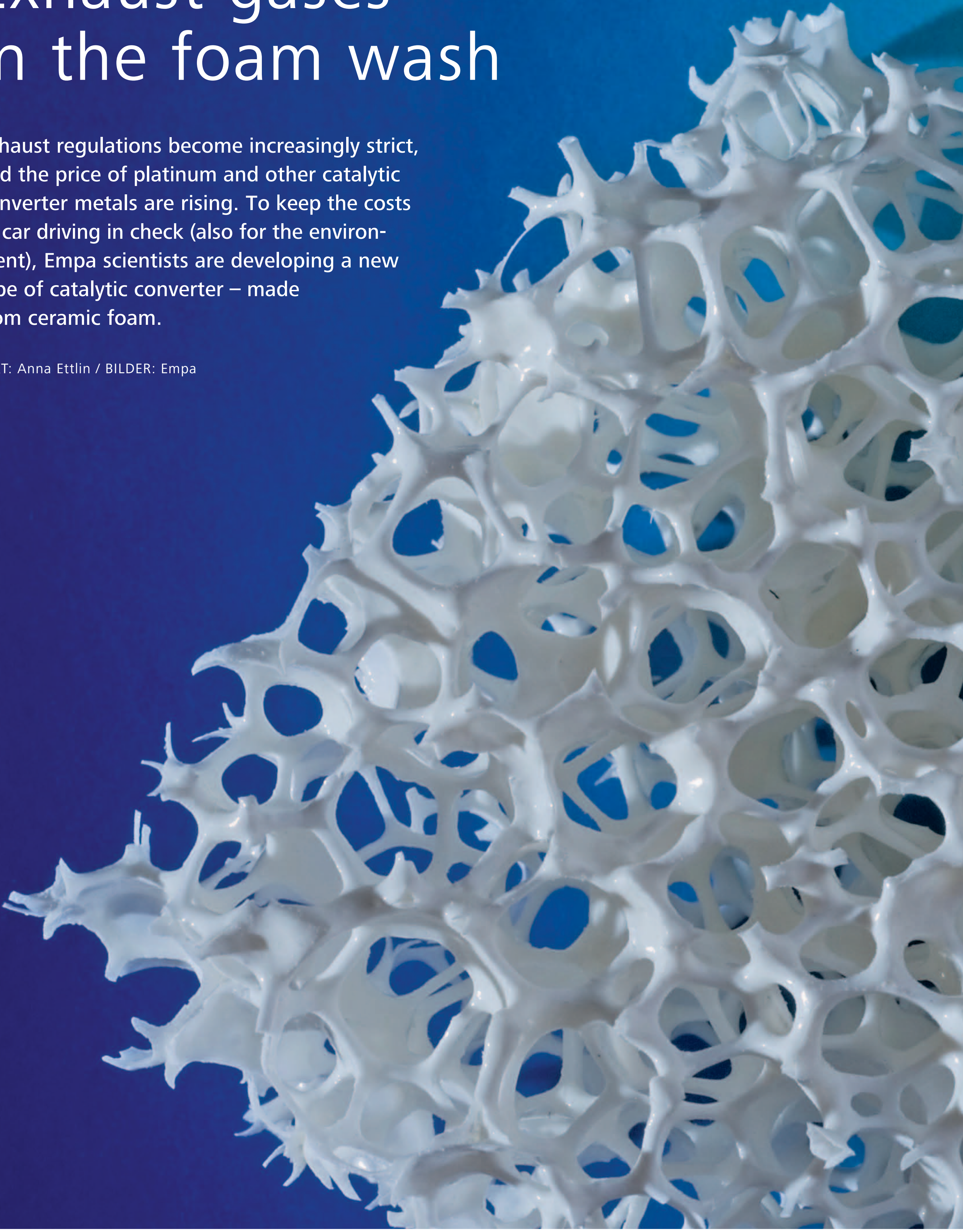
Chlorine on the Jungfraujoch

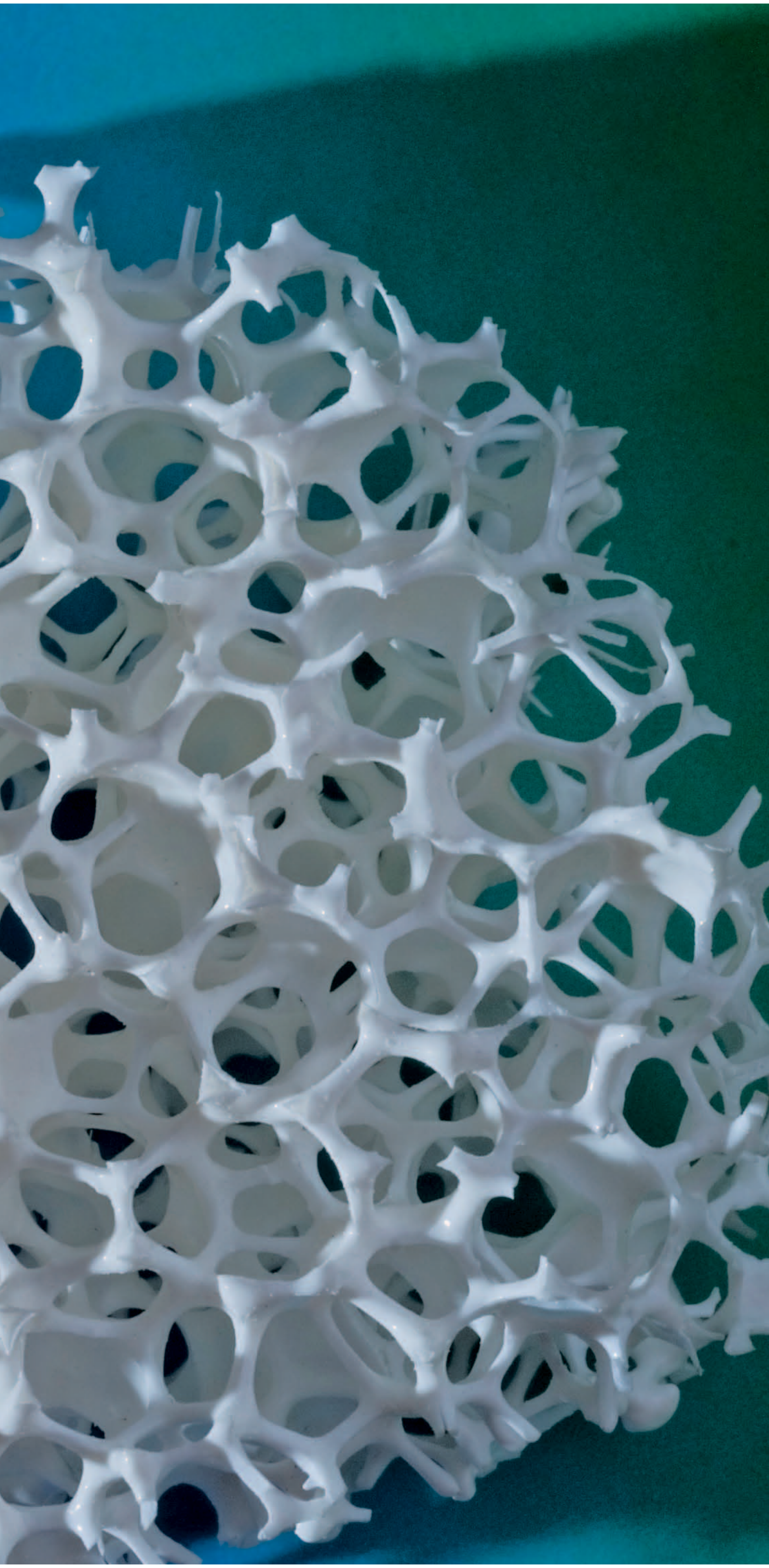
As its systematic name suggests, the Seveso toxin (2,3,7,8-Tetrachlorodibenzodioxin) contains chlorine. However, how does chlorine get into a diesel engine and from there into the particle filter? Can this be prevented, therefore avoiding the formation of dioxin? No, says Norbert Heeb, and makes a simple calculation. Even the clean mountain air around the Empa measuring station on the Jungfraujoch contains 9.5 micrograms of chlorine per cubic meter. A construction machine requires 23 cubic meters of air to burn one liter of diesel – even on the Jungfraujoch it would draw in 220 micrograms of chlorine per liter of burned diesel and send it through the hot exhaust. In coastal areas, in the salty sea air, the proportion of chlorine is significantly higher. Chlorine-free air is thus nowhere to be found. The risk of dioxin can, therefore, not be averted.

Exhaust gases in the foam wash

Exhaust regulations become increasingly strict, and the price of platinum and other catalytic converter metals are rising. To keep the costs of car driving in check (also for the environment), Empa scientists are developing a new type of catalytic converter – made from ceramic foam.

TEXT: Anna Ettlin / BILDER: Empa





Once upon a time ... there was a catalytic converter that “came” to Empa in Dübendorf for analysis in the institute’s engine lab. The cylindrical component belonged to a luxury car and had suffered some unpleasant damage: Parts of the cylinder surface were molten and, therefore, unusable, but otherwise intact. According to Empa’s Potis Dimopoulos Eggenschwiler from the “Internal Combustion Engines” laboratory, this is an indication of uneven distribution of the (hot) exhaust in the catalytic converter, something he sees quite often on the classical monolith catalytic converters with honeycomb structure.

In order to compensate for a reduction in efficiency as the catalytic converters get older, manufacturers are making their exhaust cleaners bigger and bigger, which results in heavier weight and increasing prices. The classical monolith catalytic converter is extremely good for exhaust cleaning, but requires some rare resources (precious metals). In order to solve this problem, Dimopoulos Eggenschwiler and his team developed an alternative, a catalytic converter carrier made from ceramic foam.

Smaller, lighter – and cheaper

In one of the Empa laboratories two test components are lying side by side in the form of identical metal cylinders, a monolithic catalytic converter with a fine, regular honeycomb structure and a coarse-pored ceramic foam, the result of many years of research. The difference does not become clear until you flip the cylinders over. The foam catalytic converter only occupies about half of the cylinder, whereas the monolith completely fills the cylinder. “The two components have the same catalytic effect”, says Dimopoulos Eggenschwiler.

The decisive “feature” of the foam catalytic converter is its irregular structure. Car exhaust flows through a monolith catalytic converter non-homogeneously, and significantly more flows in the middle than at the edges. The flow becomes turbulent in the foam and, therefore, homogenized, and the thermal load is distributed more evenly. Positive side effect: The foam catalytic converter heats up more quickly, resulting in fewer cold start emissions. Thanks to the more intensive turbulence, the exhaust gas is also more likely to come into contact with

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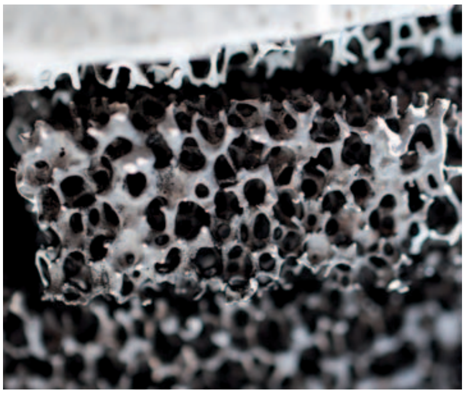

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1
An Iveco delivery truck is used as a guinea pig for the foam catalytic converter at Empa. Another test vehicle is driven for Industrielle Werke Basel (IWB).

2
This happens when hot exhaust gas flows unevenly through a conventional catalytic converter: The material melts in the hot spots. Instead of fine pores, large holes occur – the catalytic converter becomes ineffective.

3
The uneven structure of the ceramic foam catalytic converter creates a turbulent flow. The exhaust is evenly distributed and comes into contact with the sides much faster.

4
Potis Dimopoulos Eggenschwiler developed the foam catalytic converter.

4

How a catalytic converter works

The after-treatment of exhaust gas in a gasoline engine takes place in three stages: The combustion of residual hydrocarbon (i.e. fuel that has not or only partially been burned), the reduction of toxic nitrous oxides into nitrogen and carbon dioxide (CO_2) and the (simultaneous) oxidation of carbon monoxide (CO) to CO_2:

$$C_mH_n + (m+n/4)\ O_2 \longrightarrow m\ CO_2 + n/2\ H_2O$$
$$2\ NO + 2\ CO \longrightarrow N_2 + 2\ CO_2$$
$$2\ CO + O_2 \longrightarrow 2\ CO_2$$

All three processes take place in a catalytic converter, a cylinder with a slightly bigger diameter than the exhaust pipe. The inside of the catalytic converter is covered with an active layer, the "washcoat", which consists of the precious metals platinum, rhodium and palladium. However, all three reactions only take place inside the catalytic converter if the operating temperature and the ratio of air to fuel in the combustion chamber of the engine are correct. Gasoline engines achieve these conditions within a few minutes. However, a diesel engine is operated with excess air, meaning that the carbon monoxide is completely oxidized and nitrous oxide can escape unless an additional catalytic converter is installed.

the catalytic surface. Efficiency increases. Thus, the foam catalytic converter only uses about one third of the expensive precious metals and has the same effect as the monolithic catalytic converter – and is also easy to manufacture.

The project is nearing completion by experimenting with foam materials and structures, flow simulations and measurements. The foam catalytic converter has an excellent efficiency, minimal flow resistance (therefore consuming only slightly more fuel) and is more mechanically robust. It will initially be manufactured in small quantities at Empa. "We want to closely monitor the production process and the composition of the "washcoat", the catalytically active layer," says Dimopoulos Eggenschwiler. But industry is already lining up. Umicore and Fiat Powertrain Technologies are involved in the project. A car at Industrielle Werke Basel (IWB) has already been driving for one and a half years with a foam catalytic converter in an endurance test. There is also a "guinea pig" at Empa, a diesel-powered delivery truck.

The foam catalytic converter could be of interest, particularly for diesel vehicles: The tolerable nitrous oxide emission of diesel cars is going to be reduced by half in the forthcoming "Euro VI" legislation. An additional catalytic converter for nitrous oxides would be needed for this. Together with the diesel particle filter and the oxidization catalytic converter, the exhaust treatment system for diesel would be even bigger, heavier and more expensive. Small, light-weight and low-cost catalytic converters would thus be extremely welcome. //

Blood pressure measurement 'round the clock

The consequences of high blood pressure are one of the most frequent causes of death worldwide. In spite of this, according to the WHO, less than half of those affected measure their blood pressure regularly. The main reason for this is that these measurements are time-consuming. A new wrist sensor should now change all of this.

TEXT: Cornelia Zogg / PICTURE: iStockphoto
ILLUSTRATION: Empa

Blood pressure measurements and monitoring are a troublesome affair for patients. A cuff that is activated every 15 minutes for several hours and compresses the upper arm, a disturbing measuring device on the body, or even invasive monitoring, in which a catheter is inserted into the artery, are the norm. It is no wonder that the persons concerned avoid this procedure if possible.

A new sensor that is no bigger than a wrist watch should soon be providing an easier way of measuring blood pressure. STBL Medical Research AG has developed a device that can be comfortably worn on the wrist and continuously records the blood pressure – without a pressure cuff or an invasive procedure. Contact pressure, pulse and blood flow are measured simultaneously by several sensors on the surface of the skin near the wrist. Michael Tschudin, co-founder of STBL, envisages a considerable amount of potential: "The measuring device can be used for medical purposes such as monitoring risk patients or treating high blood pressure, but also as a blood pressure and pulse rate measuring device for leisure activities and sport, as well as for fitness monitoring in professional sport."

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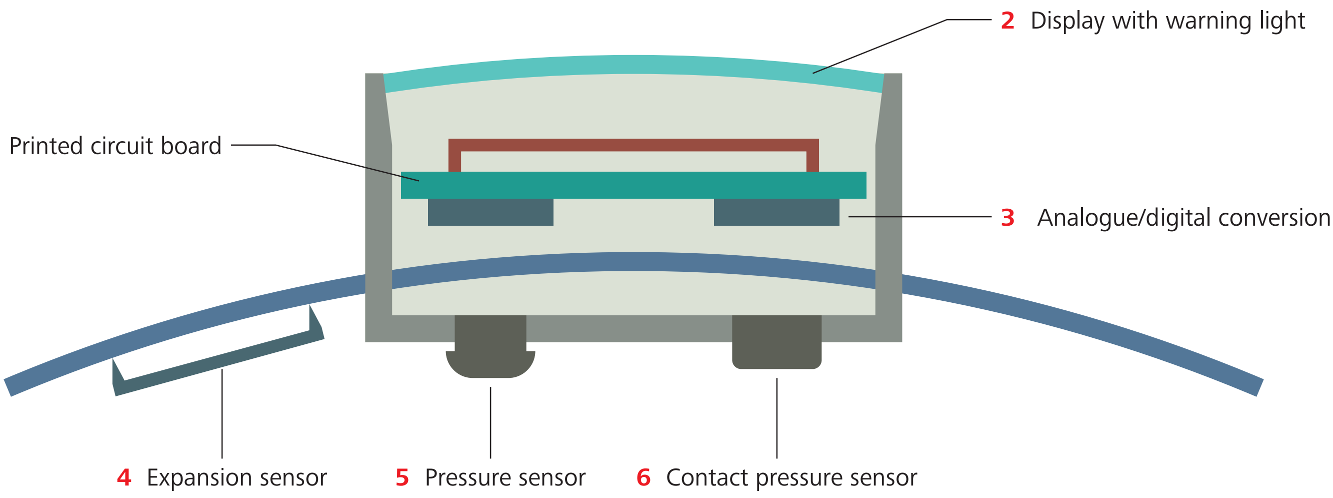


1 Printed circuit board
The heart of the blood pressure sensor is the printed circuit board. It contains the electronic circuit including the processor and the analogue/digital converter, the pressure sensor and the contact pressure sensor.

2 Display with warning light
The blood pressure is shown on the display at regular intervals. The warning light goes off as soon as the blood pressure is in a critical range or if the measuring device detects dangerous changes to the pressure waves that indicate a heart attack or a stroke.

3 Analogue/digital conversion
All sensors are converted into digital signals. This means that all measurements can be analyzed and can be compensated for if need be, if the contact pressure sensor or the expansion of the wristband indicates that the pressure sensors have moved.

4 Expansion sensor
If the wristband expands as a result of swelling of the arm caused by temperature changes or physical activity, this is registered by the expansion sensor. The resulting error can be compensated for in the measurement.

High blood pressure – a risk factor

Together with diabetes, smoking and hypercholesterolemia, high blood pressure is one of the four biggest risk factors for cardiovascular diseases, particularly heart attacks or strokes. High blood pressure cause arteriosclerosis and also heart muscle damage. This leads to potential diastolic heart insufficiency or auricular fibrillation. Not only the heart is affected. The eyes can become damaged and also the kidneys, which leads to restricted renal functionality. From a medical point of view, high blood pressure can be reduced in the majority of cases by a change in lifestyle. Weight loss, additional physical activity, eating more fruit and veggies and eating less salty food reduce the blood pressure. The biggest factor for high blood pressure is smoking. Not only does it encourage high blood pressure, but it also blocks the effect of medication such as beta blockers, which are intended to reduce high blood pressure. Drinking less alcohol also reduces the blood pressure considerably.

Empa sensor increases measuring accuracy

The engineers had to overcome one particular obstacle with the new technology: The pressure the device exerts on the skin changes constantly, which is why extremely sensitive correction measurements are required. The "High Performance Ceramics" laboratory at Empa looked for a solution to this problem within the scope of a CTI-funded project (Commission for Technology and Innovation). A sensor made from piezo-resistive fibers in the bracelet measures the contact pressure of the device on the skin. If the signal strength changes by slipping or increased muscle tension, this could lead to erroneous measurements. Precisely these changes are registered by the Empa sensor – and the measurements can be corrected accordingly. The fiber is electrically conductive, detects a shift or pressure change, converts it into an electrical signal and relays this to the measuring device. This increases the measuring accuracy of the "blood pressure watch" by more than 70 percent. "We manufactured the first prototype four years ago", says Empa's Frank Clemens. In the meantime, appropriate tests have confirmed the functional capability of the sensor. Empa is now working on integrating the piezo sensor in the device in such a way that it is not just visually appealing but can be installed easily without excessive cost. By gluing, laminating or weaving it in, for example.

Emergency assistance on your wrist

The market for such a device is huge. Cardiovascular diseases are the most frequent cause of death worldwide. More than a billion people have to measure their blood pressure daily in order to avoid the potential consequences of their hypertension. About 60 to 70 million measuring devices are, therefore, sold every year, but do not allow continuous measurements. However, permanent measurement could provide additional safety, particularly by generating alarm signals in due time in the event of a potential heart attack or stroke. Because: A heart attack or stroke is preceded by an increased shock wave, which the system detects and analyzes. Emergency measures could thus be taken before something worse occurs. In order to continuously improve accuracy in the case of such events, additional tests on human beings are in the planning.

Permanent measurement also has other advantages, as Thomas Lüscher, director of the cardiology clinic at the university hospital of Zurich and co-founder of STBL explains: "It gives us the opportunity to record the blood pressure in the patient's natural environment. The patient's freedom of movement is not restricted." Also patient nervousness at the doctor's that can potentially falsify measurements, does not apply with the new method.

Cheaper, simpler, more convenient

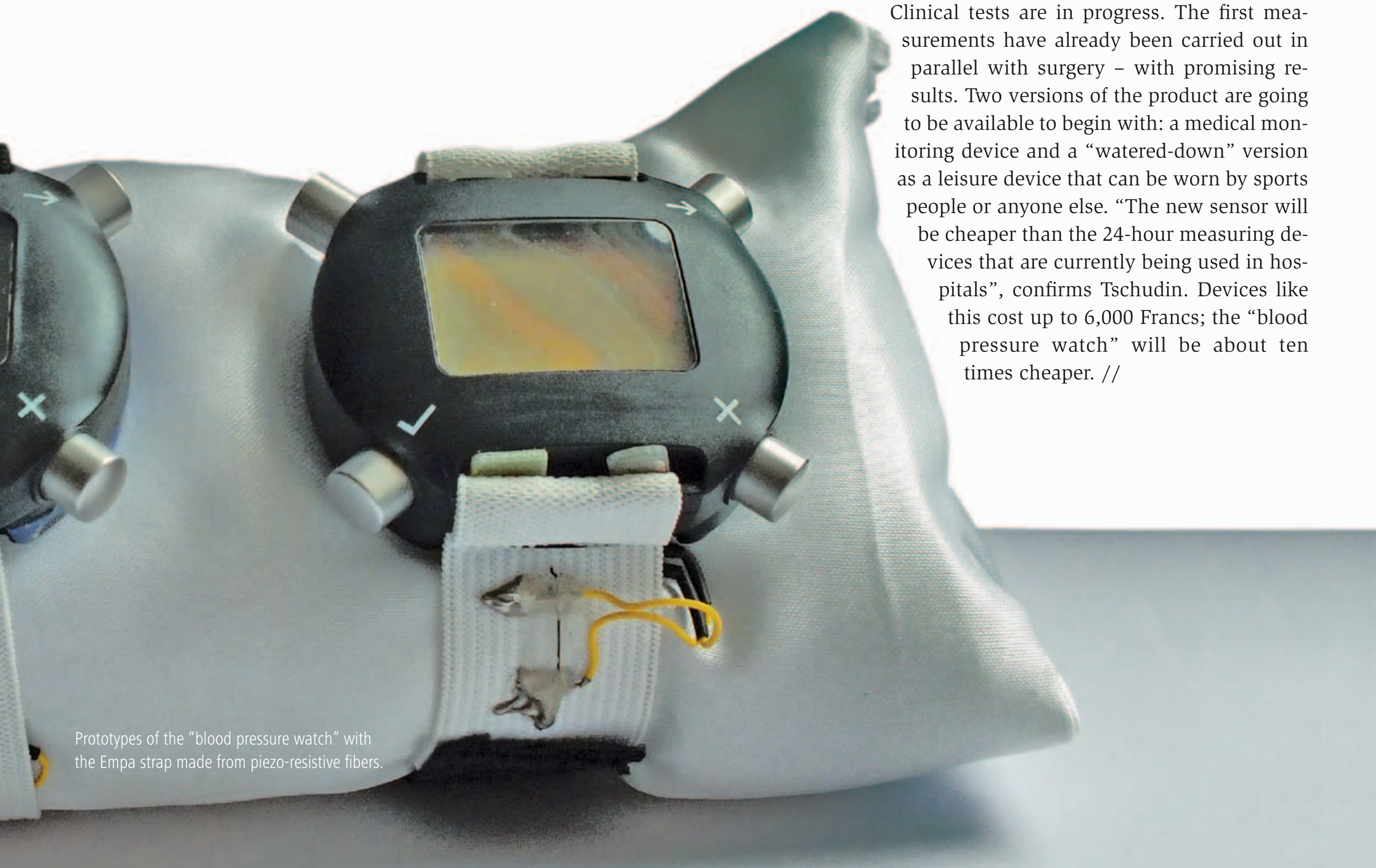
Clinical tests are in progress. The first measurements have already been carried out in parallel with surgery – with promising results. Two versions of the product are going to be available to begin with: a medical monitoring device and a "watered-down" version as a leisure device that can be worn by sports people or anyone else. "The new sensor will be cheaper than the 24-hour measuring devices that are currently being used in hospitals", confirms Tschudin. Devices like this cost up to 6,000 Francs; the "blood pressure watch" will be about ten times cheaper. //

5 Pressure sensor

The pressure sensors measure the blood pressure. They have a sensitivity of 0 to 1.5 bar. Piezo-resistive fibers are currently used that build up an electric voltage as soon as they detect pressure

6 Contact pressure sensor

The contact pressure sensor measures whether the device is still in proper contact with the skin.It works in conjunction with the expansion sensor, which indicates whether the sensors have slipped on the skin. The same sensor type is used as for the pressure sensors.



Prototypes of the "blood pressure watch" with the Empa strap made from piezo-resistive fibers.

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