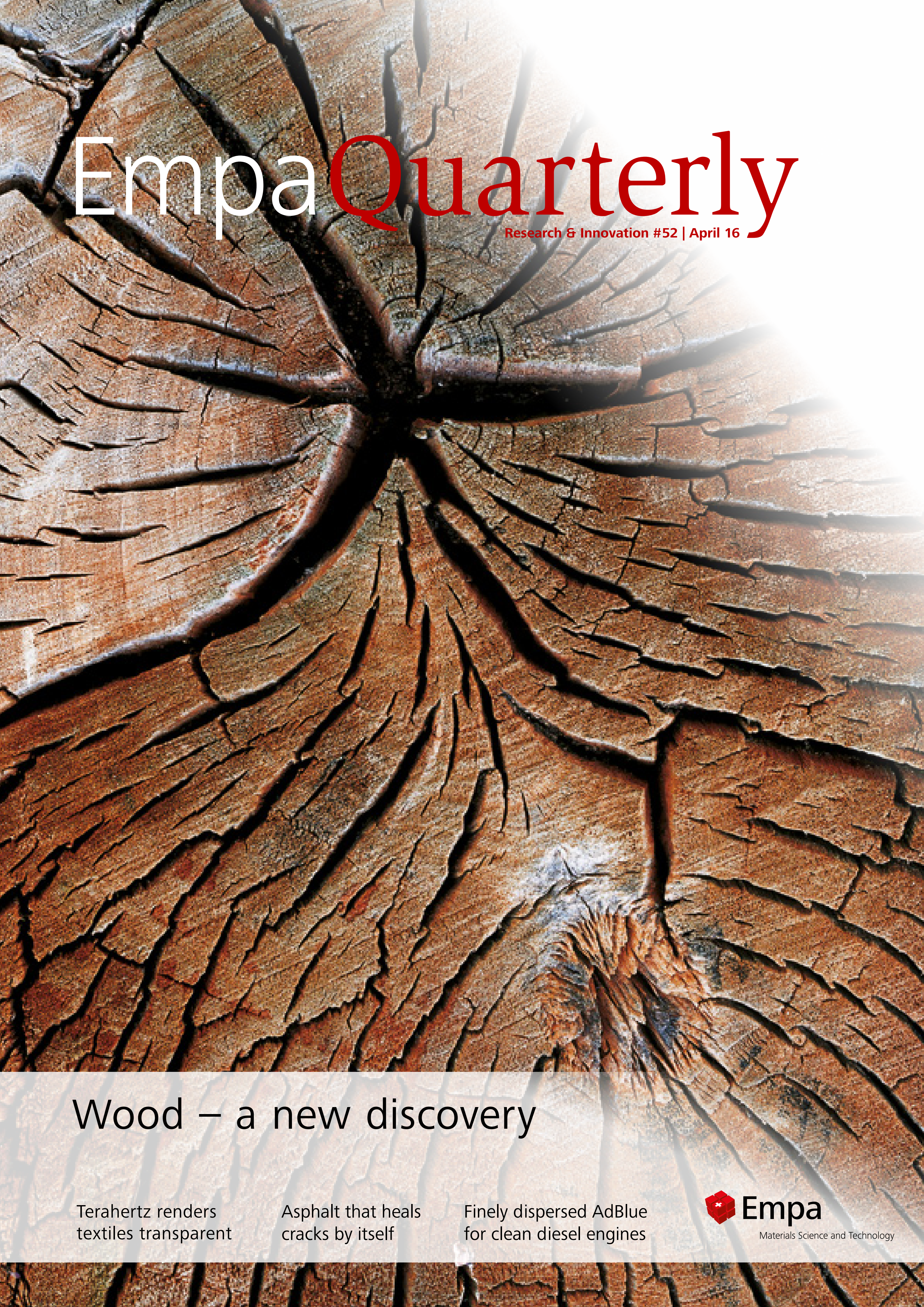


Empa Quarterly

Research & Innovation #52 | April 16

Wood – a new discovery

Terahertz renders textiles transparent

Asphalt that heals cracks by itself

Finely dispersed AdBlue for clean diesel engines

Empa
Materials Science and Technology

MICHAEL HAGMANN Head of Communications

A true all-rounder

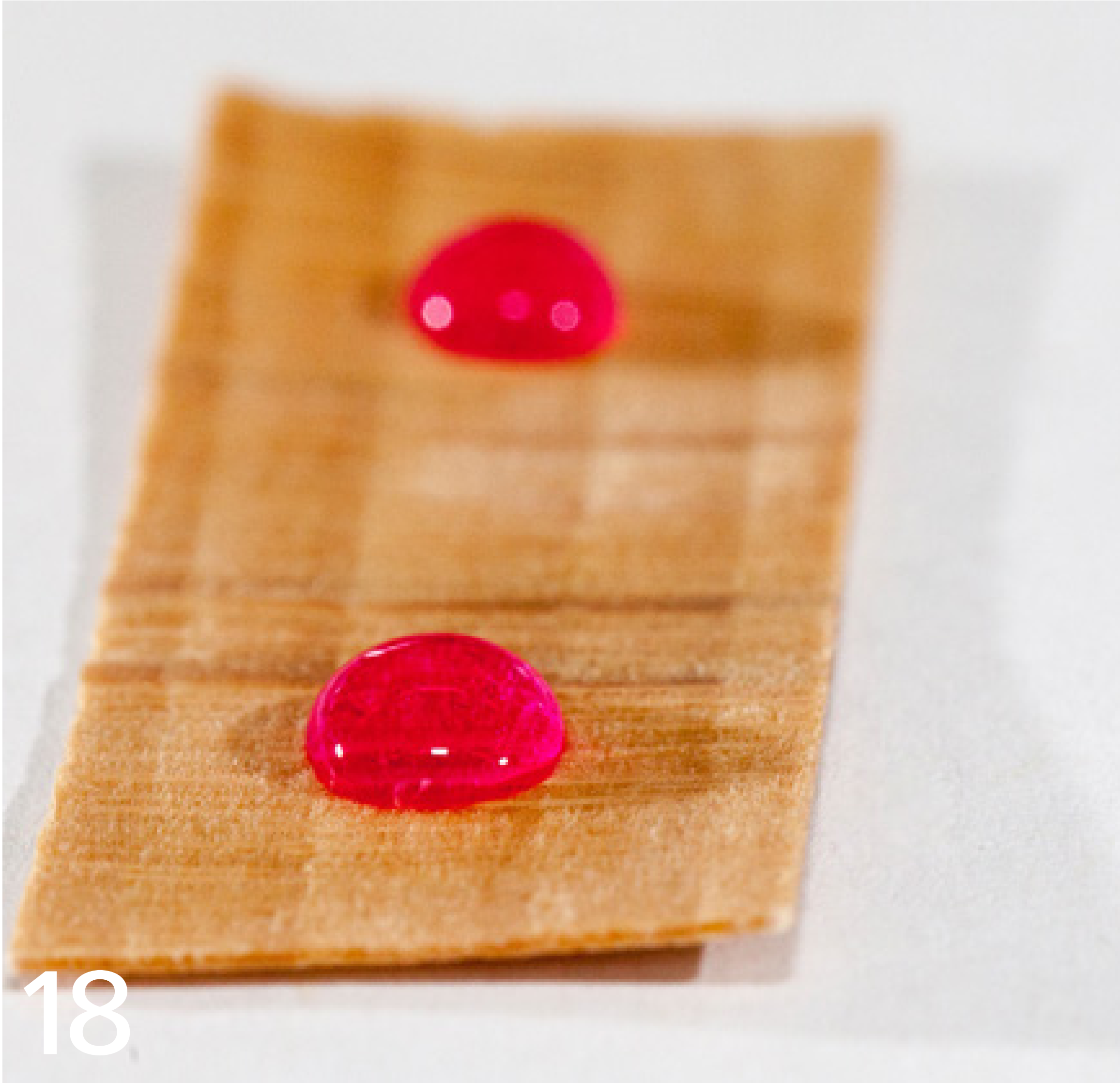
Dear readers

Wood: probably one of humankind's oldest building and handicraft materials. Versatile, aesthetically appealing and renewable, it is one of the few natural raw materials that Switzerland has in spades.

So far, so good. But so tedious. After all, we know virtually everything there is to know about wood, don't we? Far from it, actually – especially when it comes to the wood processed in Empa's labs. The Focus section in the latest issue of EmpaQuarterly (from page 16) reveals what just what these novel high-tech types of wood can do. We already reported on wood that no longer burns in the last EmpaQuarterly. But how about wood with an antimicrobial quality, i.e. it kills germs – which is not just interesting for chopping boards in the kitchen, but also for furnishings in hospitals or care homes. We also demonstrate how wood can be rendered so waterproof that it can even be used to make sinks or bathtubs. A magnetic board made of wood? No problem, either, thanks to embedded iron oxide particles. And so on and so forth… Our imagination seemingly knows no bounds. The timber industry must be over the moon with what Empa's wood researchers dream up.

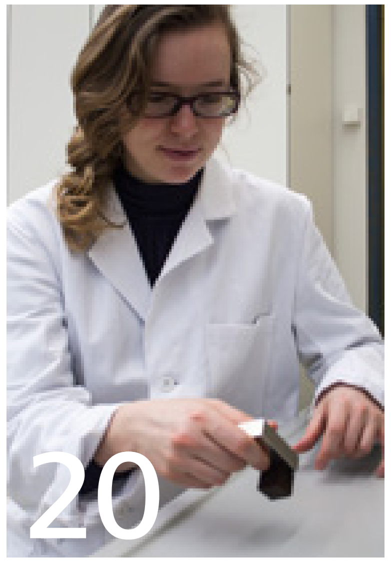
Another key branch of Switzerland's industry, fine Swiss watch-making, recently turned to an Empa innovation for one of its fancy products: The Big Bang Broderie models by luxury watch manufacturer Hublot, which were presented (and limited) last year, are real eye-catchers thanks to plasma-coated, 24-karat gold threads on the faces and straps. The technology for coating fibers with nanometer-thin layers of metal was developed at Empa's textiles lab in St. Gallen (see EmpaNews No. 35, January 2012). You can feast your eyes on the lavish timepieces either at your trusted watch dealer or on p. 31 of our magazine.

Happy reading!



Focus

Wood – a new discovery



Cover
Wood: This age-old material is as popular as ever – and often essential. But you can always turn something good into something better: Empa researchers transform wood into a fireproof, magnetic, water-resistant or antimicrobial material. Photo: istockphoto.com.
Focus topic from page 16

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Smoking ban for jets

Aircraft turbines produce fine particles – much like diesel engines without particle filters. In collaboration with international partners, Empa devised a measuring method, based upon which all jet engines worldwide are to be certified from 2020 onwards. Emission regulations for aviation are now possible and flying is cleaning up its act.

TEXT: Rainer Klose / PICTURES: Charlie Atterbury, Seattle / Empa

How many fine particles come out of an aircraft turbine? Good question. And nobody could answer it until now. After all, at full thrust a customary Boeing 737 engine's emissions fly out of the pipe at speeds of around 1,200 km/h and temperatures of 700 degrees. Anyone who wants to measure something like that had better keep a safe distance.

As part of a collaboration with aircraft servicing firm SR Technics and the Swiss Federal Office of Civil Aviation (FOCA), however, a team of Empa researchers has succeeded in doing so and established an international measurement standard. On February 2, Empa's measuring method was approved by the Environmental Committee of the International Civil Aviation Organization (ICAO) in Montreal. It is expected to be ratified by all member states by 2019. And from 2020 all newly built aircraft engines are to be certified in accordance with Empa's standard. From then on, the exact number and mass of fine particles will be registered. Based on this data, the emission regulations can be adjusted at a later date.

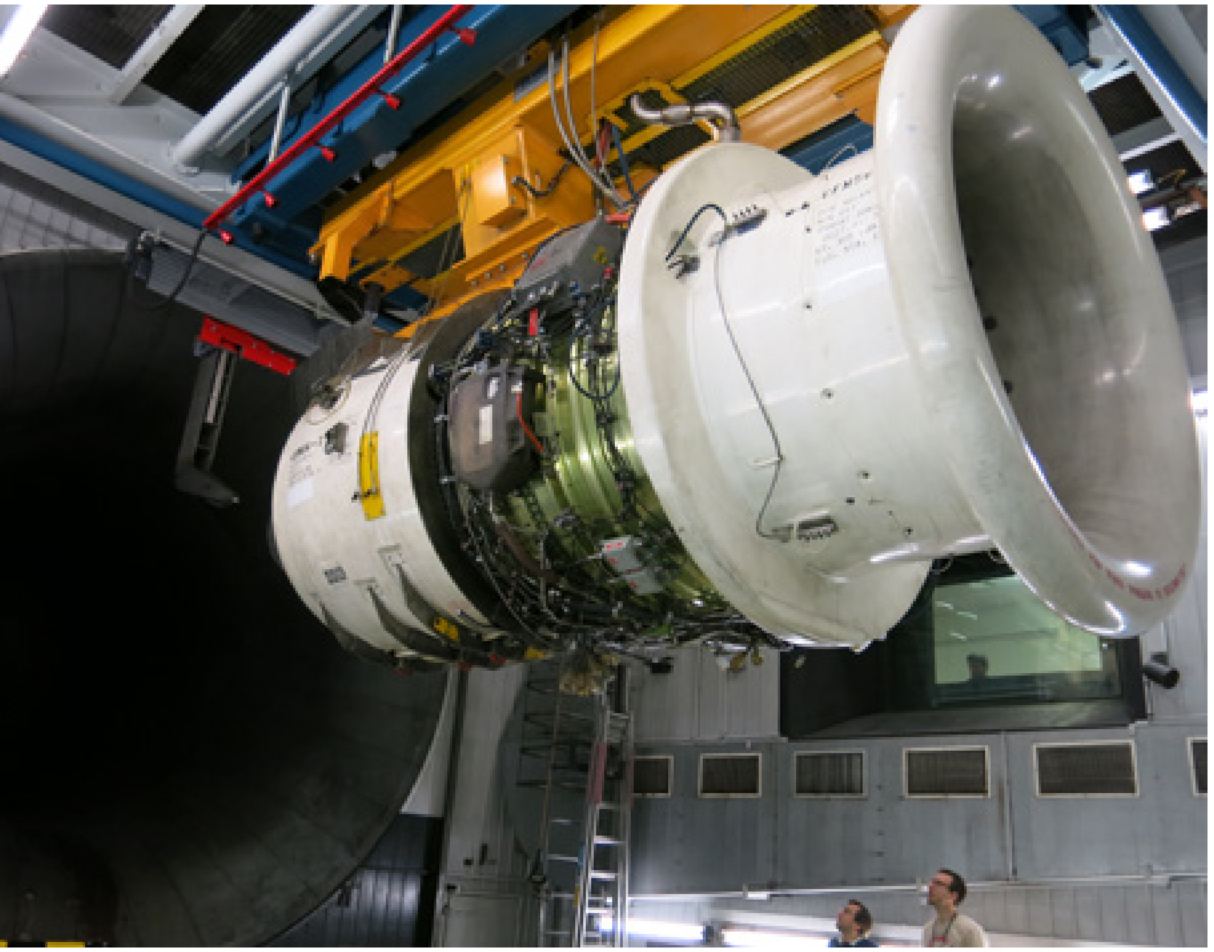
Obsolete measuring method for visible smoke

But first let's rewind to 1960: The front cover of a magazine features a Pacific-bound American Airlines Boeing 707 taking off at Los Angeles International Airport on a muggy morning. A thick cloud of soot is billowing out of all four engines. This kind of take-off doesn't just look unsightly; here, the expensive kerosene is not converted into propulsion, but rather useless soot particles. Consequently, engines soon became quieter and more efficient. By the 1980s, the black clouds of exhaust fumes had all but disappeared.

Full speed ahead: This Boeing 707 leaves a clearly visible soot cloud in its wake during take-off on runway 25L at Los Angeles International back in June 1960. In those days, water was injected into the engines to cool them down. Today's engines are full-throttle-resistant and much more efficient. They produce very fine soot particles, which are no longer visible to the naked eye. Photo: Charlie Atterbury, Seattle

At the same time, the ICAO passed the first emissions regulations for jet engines: Back then, they were still measured based on the so-called soot level – i.e. the visible blackening of a piece of white filter paper. A similar principle was also used to gage emissions from oil heaters and diesel engines at the time.

Nowadays, this measuring technique is regarded as obsolete. As of January 1, 2013, cars with newly approved diesel engines have had to comply with the exhaust fume norm Euro 5b (for trucks and buses: Euro VI), which regulates the number and mass of soot particles. This norm can't be achieved without soot filters. The aviation industry is now lagging behind. And an international group of researchers set about tackling the problem.



Boeing 737 engine on the SR Technics test rig at Zurich Airport. Empa researchers spent 95 hours studying the emissions while taxiing, taking off, climbing and cruising.

Giant metal trunk

The project was launched by Theo Rindlisbacher, an environmental expert at FOCA, in collaboration with SR Technics in 2011. A metal trunk weighing almost 200 kilos was installed on the engine test rig at Zurich Airport. It is strong enough to withstand the flow of exhaust gas from a turbine running at full thrust and can be positioned behind the engine with millimeter precision by remote control. An eight-millimeter hole at the tip of the trunk sucks up the exhaust gas and, at full power, up to 100 liters per minute flow into the measuring system.

This is where Empa's expertise comes in. From 1995 to 2002, Empa had already played an instrumental role in developing filter technology for diesel-powered construction machines at the NEAT building site. The emissions standard Euro 5 is also based on Empa research (see info box "Euro 5"). The researchers were now given the task of adapting the particle measuring method for aircraft engines. From 2011, project leaders Benjamin Brem and Lukas Durdina from Empa's Laboratory for Advanced Analytical Technologies were permanent guests at the SR Technics engine test rig.

The research campaign was called APRIDE (Aviation Particle Regulatory Instrumentation Demonstration Experiments). Apart from Empa, scientists from the German Aerospace Center (DRL), Cardiff University (UK), Missouri University of Science and Tech nology (USA), the National Research Council of Canada and the US Environmental Protection Authority (EPA) were also involved. As the short test runs on revised SR Technics customer engines were insufficient, the researchers rented a Type-CFM56 turbine on the aviation market – one of the most frequently built engines in the world, which hangs under the wings of virtually every Boeing 737. The engine's emissions were studied for 95 operating hours.

The researchers simulated taxiing from the gate to the runway with an engine output of only seven percent, the take-off and climb with an output of 85 to 100 percent, and cruising with an engine output of 40 to 60 percent. In doing so, they had to follow the turbine operating standards to the letter, just like an airline would. 130 tons of kerosene were converted into noise, heat, CO_2, NOx and soot particles on SR Technics' test rig – and scrutinized closely. To a certain extent, this measurement serves as a blueprint for all engine certifications to take place from 2020 onwards. The researchers therefore set a new standard for the jet emissions of the next few years and decades.

Five minutes on the runway equals one year driving a car

The results were mind-boggling: While taxiing from the gate to the runway, the engines run on less than ten percent of their full capacity – i.e. not in the optimum operating range. During this short journey, the two engines of a Boeing 737 emit as many soot particles per second as a modern Euro VI diesel car with a particle filter that has driven 60 kilometers. And five minutes on the runway is equivalent to 18,000 kilometers on a car's clock. The turbines produce a particularly large number of ultra-fine soot particles at rest, during take-off and while climbing. During cruising, however, the engine works more efficiently and emits considerably fewer particles. The particles themselves are around four times smaller than those emitted by a diesel car, measuring one hundred-thousandth of a millimeter in diameter. The electron microscope even reveals that particles exhibit a different structure when the plane is idle compared to at full throttle.

What are the benefits of alternative fuels?

Now that a measuring method has successfully been established to record emissions from jet engines as of 2020, Benjamin Brem, Lukas Durdina, Jing Wang and several emissions specialists from Empa want to turn their attention to analyzing the components that make up the exhaust gas. Back in November 2015, shortly after the conclusion of APRIDE, the follow-up project EMPAIREX was launched at Empa. Once again, the sample trunk will be deployed at the SR Technics engine test rig – this time to study different kerosene compositions. Previous measurements point towards a major discrepancy in the quality of the exhaust fumes depending on whether the plane is refueled in Europe, America or South Africa with the kerosene marketed there. The researchers also want to test the addition of alternative fuels to fossil kerosene. While these climate-neutral fuels obtained from waste fats and oils from the food industry or sugarcane are already available on the market, nobody really knows whether they actually burn more cleanly in the engine than kerosene from fossil sources. Empa's measurements should provide the answer.

Just how toxic are the soot particles?

Even the chemical deposits on the soot particles themselves are to be observed more closely on the gas chromatograph. This is where Empa analytics specialist Norbert Heeb brings his long-standing experience to the table. He has already discovered unpleasant chemical surprises in particle filters on construction machines. "Our work will have an impact on the air our children and grandchildren breathe," says Empa researcher Benjamin Brem. "After all, aircraft turbines are used for 20 to 30 years – as long as the planes themselves." An engine type certified in 2020 will therefore, in all likelihood, still be in use at Zurich Airport, in major European cities and at many holiday destinations in the year 2040. //

Empa researcher Lukas Durdina keeping an eye on the measurements.

From AlpTransit tunnel to emissions standard Euro 5

Empa has more than 20 years of experience analyzing soot particles from combustion engines. It all began in 1993 with the decision to build the AlpTransit base tunnel. It soon became clear that the health and safety regulations in the 60-kilometer tunnel building site could not be satisfied with unfiltered diesel construction machinery. At the time, however, nobody was able to prove the impact of diesel particle filters.

As part of the VERT project (http://vert-certification.eu), Empa was involved in the development of a particle filter certification method from 1997, which was met with great interest in the EU. The international workgroup PMP (Particle Measurement Program) was founded at Empa at the end of 2000 with the aim of anchoring a new, more sensitive particle limit in EU legislation. Barely two years later, Empa organized an elaborate measuring campaign, where all the known and available measuring techniques at the time were compared.

The limit for the number of particles that has been in force in Europe since emissions standard Euro 5b (September 2011) is based on the resulting recommendation to use "the number of non-volatile particles" on a nanoscale as a new measurement parameter. Thanks to this threshold, every new diesel vehicle boasts a particle filter today, which slashes particle emissions by anything from one hundred to a thousandfold.

Ever since the Volkswagen emissions scandal in the fall of last year, the exhaust levels for diesel cars have been hotly debated. It became clear that many questions remain unanswered, especially when it comes to the detoxification of nitric oxides (NOx). An Empa team has spent the last four years investigating this very problem and paving the way for the clean diesel of tomorrow.

Cleansing spray for diesel exhaust

TEXT: Stephan Hauri / PICTURES: Empa

We are on the brink of new diesel exhaust technology," says Panayotis Dimopoulos Eggenschwiler, who has spent around four years working on optimizing the injection of urea into the diesel exhaust flow with a team of Empa researchers and ETH Zurich students. With the introduction of the Euro 6 emissions norm for all new vehicles on September 1, 2015, nitric oxide (NOx) emissions must be slashed to an extremely low 80 mg/km, which requires a complex catalytic converter system. While smaller cars usually make do with the more affordable NOx storage catalytic converter, larger and heavier vehicles are reliant upon a so-called SCR ("selective catalytic reduction") system. In this case, an aqueous urea solution known by the tradename AdBlue is injected into the exhaust line.

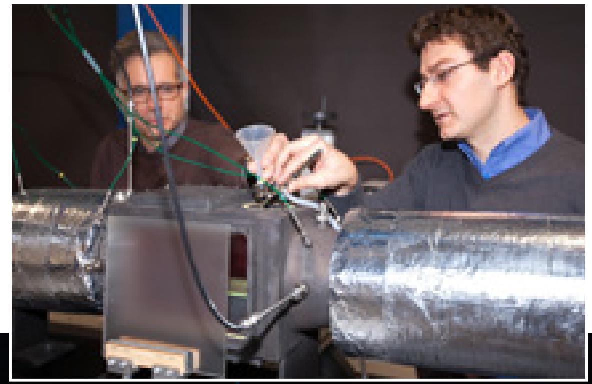
Such SCR systems have already been functioning flawlessly in truck engines for around a decade. However, the AdBlue mixture is trickier in passenger vehicles as the engine loads and revs change quickly and frequently. In order to curb the emission of pollutants in everyday traffic as well as on the test rig, the injection of AdBlue is therefore in need of considerable improvement. Firstly, the injected amount needs to be rigorously coordinated; secondly, other factors, such as the temperatures in the exhaust line, have to be heeded.

How detoxification with AdBlue works

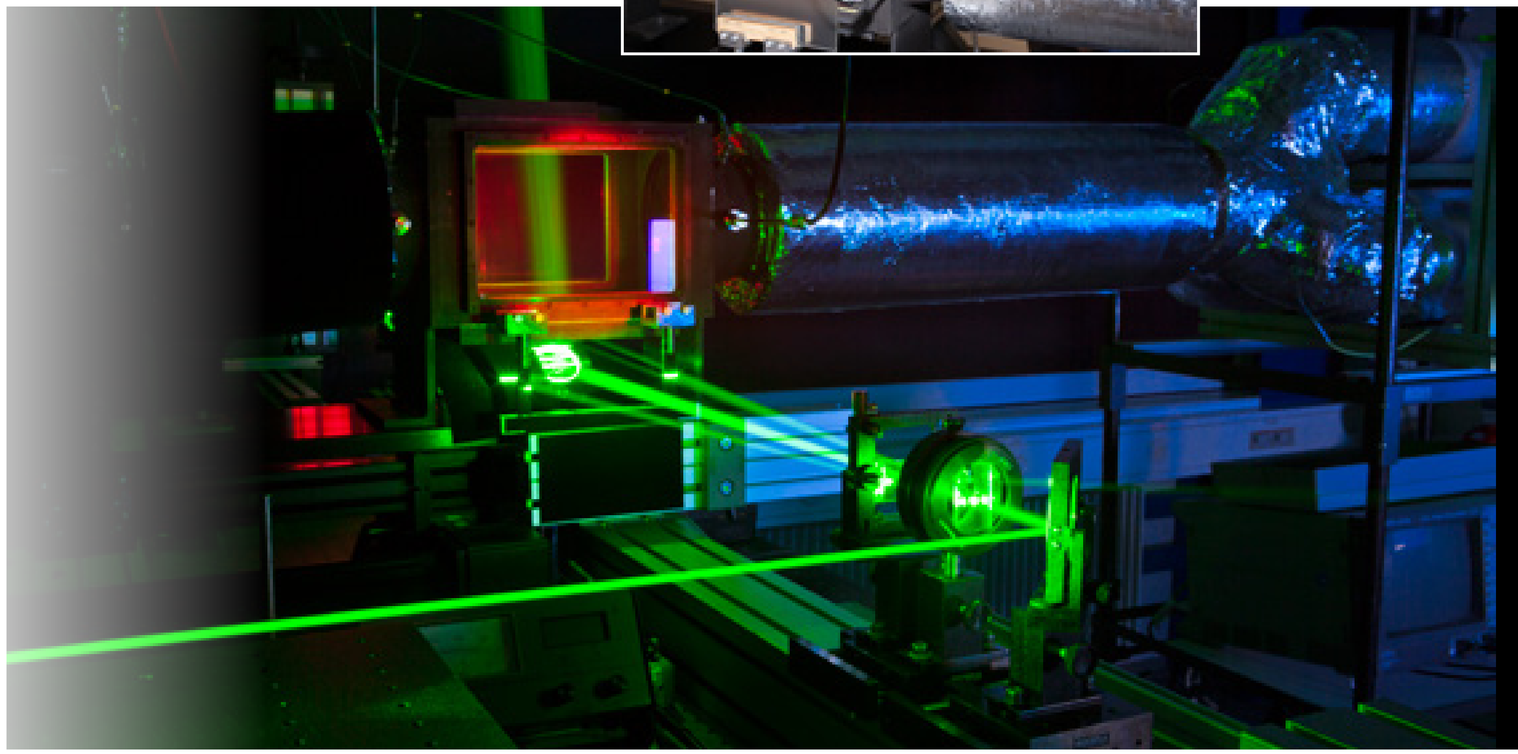
Selective catalytic reduction takes place by injecting AdBlue into the exhaust line behind particle filters and an oxidation catalyst. The urea solution breaks down in the heat to produce ammonia. The nitric oxides contained in the exhaust gas are then reduced by the ammonia formed on site – i.e. converted into the non-toxic components nitrogen and water.

In the passenger vehicle sector, it now transpires that the injection of urea is no trifling matter. Not only does the urea injection's dosage need to be set with high precision; numerous other injection parameters also have to be factored into the equation. If too little urea is injected, the NOx emissions remain too high; if the dosage is too great, the AdBlue consumption is too high and unpleasant ammonia odors develop. Moreover, deposits can form, which, in extreme cases, make the SCR system look like a limestone cave and cause the detoxification system to malfunction.

A high-precision urea injection system is essential for the optimum conversion of all NOx gases. In order to achieve the necessary level of precision, however, the technicians have to understand exactly what takes place in the flow of exhaust gas shortly before the SCR system. And this is where the Empa research team headed by Panayotis Dimopoulos Eggenschwiler are streets ahead.



Empa research duo Potis Dimopoulos Eggenschwiler and Alexander Spitieri in the measuring chamber for spray tests.



Laser optics count the spray droplets and analyze their size and trajectory.

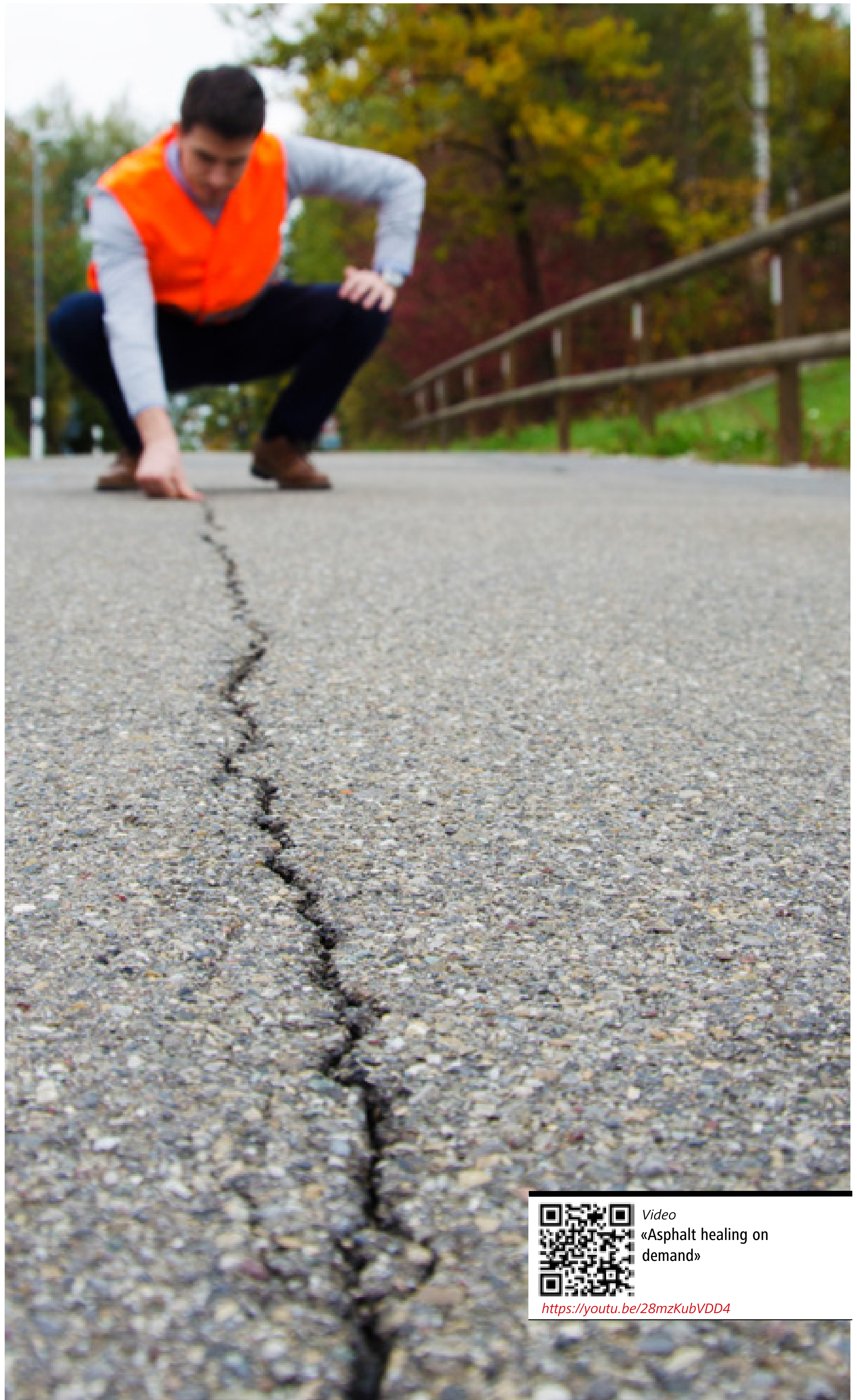
Meanwhile, their findings are so advanced that the Empa researcher expects them to be implemented in a production vehicle in the near future.

Research on individual AdBlue droplets

The team is systematically researching the injection process at a complex testing plant they set up on the Empa campus in Dübendorf. They have discovered that the positioning of the injector, the shape and direction of the nozzle, and above all the size of the individual AdBlue droplets play a key role. The important thing is for the urea to evaporate quickly and fully, mix well with the waste gases and then be converted into the reducing agent ammonia. It was also evident that the evaporation of the sprayed AdBlue liquid is heavily dependent on temperature. If the droplets hit a surface in the exhaust line at a temperature of 150 °C, they evaporate rapidly. If the metallic wall of the exhaust pipe, which the AdBlue spray also hits, is hotter, however, a layer of vapor forms around the liquid droplets, causing them to bounce back off, still in liquid form and with only a slightly smaller volume.

In parallel to their research on the injection process, the Empa specialists teamed up with engineers from the Paul Scherrer Institute (PSI) to develop a small, novel catalytic converter that accelerates the formation of ammonia. This so-called hydrolysis catalyst is integrated in front of the main SCR system in the exhaust pipe.

In summary, Dimopoulos Eggenschwiler notes that the detoxification level of the diesel exhaust gases depends heavily on the quality of the AdBlue injection. And the corresponding knowhow at most car and engine manufacturers is not currently as detailed as in the Empa lab. Dimopoulos Eggenschwiler's team successfully helped truck engine manufacturers develop exhaust gas detoxification systems in the past. Now they need to do the same for passenger vehicles. Empa is paving the way for this to happen. //



From the lab to the streets – Jeoffroy's product is ready to be road-tested.

Video
«Asphalt healing on demand»
https://youtu.be/28mzKubVDD4

Asphalt's miraculous cure

Empa scientists have developed a technique that can repair old, cracked asphalt. They got their inspiration from a method used in cancer treatment.

TEXT: Lorenz Huber / PICTURES: Empa

Etienne Jeoffroy looks through his protective glasses, deep in concentration. With a small spoon, he stirs a copper-colored powder into a test tube. What looks like copper powder are actually iron oxide nanoparticles. When working with these nanoparticles, Jeoffroy has to put his hands in an 'autoclave', a glass chamber filled with inert gases on the inside. Normally, scientists from André Studart's group at ETH Zurich use this laboratory to carry out research into what are referred to as "bio-inspired materials". Today, the workstation is occupied by the PhD student from Empa's Road Engineering / Sealing Components lab: Jeoffroy wants to try to use the iron nanoparticles to revolutionize road construction.

In order to produce asphalt, a material called bitumen is used in road construction that is obtained from processing oil. Bitumen is jet-black, extremely viscous and sticky. It works like a kind of glue in the pavement of the road, holding the small stones and sand together. This glue crumbles due to wear and tear, differences in temperature or chemical substances like oxygen in the air. Cracks form in the asphalt over time. Initially they are microscopic, but they gradually increase under the constant weight of the traffic on the road. This eventually leads to the need for repairs on whole sections of road, which in turn results in high costs, construction sites and traffic jams.

To help avoid this in future, Jeoffroy developed a type of 'healable' bitumen. The idea is to close the cracks in the road surface while they are still small. "If you can see the cracks with the naked eye, it's already too late", he explains. To make the material healable, Jeoffroy mixes iron oxide nanoparticles into the bitumen. When exposed to a magnetic field, they heat up. The heat is transferred to the bitumen, which reduces its viscosity significantly at temperatures of between just 50 and 100 degrees. As a result, it slowly begins to soften again, and closes the small cracks in the road surface. Maintenance for these types of roads would involve driving over them at intervals of about a year using a special vehicle that creates a magnetic field. This would repair the micro-cracks in the asphalt again and again, and the road surface would last considerably longer.

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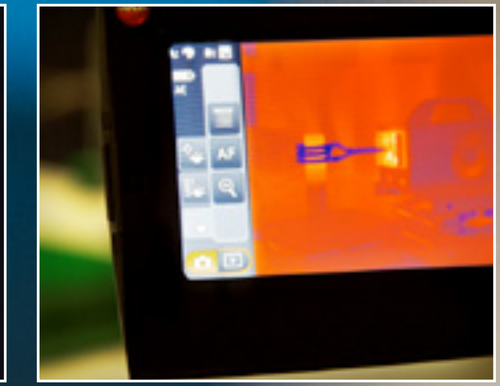
Lab work for road works – Jeoffroy adds nanoparticles to a solution.

A coil generates a magnetic field around the sample.



An infrared camera reveals how the sample heats up.

"Ball of wool" effect

A few years ago, specialists at the lab already pursued a similar approach under the leadership of Manfred Partl. Instead of nanoparticles, the researchers used steel wool fibers at the time. But there were three weaknesses with that method. Firstly, it proved difficult to mix the fibers with the bitumen. Instead of spreading evenly, lumps formed in different places. This is what Jeoffroy calls the "ball of wool" effect. It led to localized overheating when the fibers heated up under the effect of a magnetic field. There was a risk of damage to the road surface. Another problem was corrosion on the fibers. Because they were made from steel wool, after a while rust formed on the surface.

But the main difficulty was that metal fibers of that size needed a long time to heat up in a magnetic field. This meant that it would have taken several minutes for half a meter of road to be repaired. If you extrapolate this figure for a 12-kilometer long section of road (roughly the length of the Northern bypass for Zurich), it could take between one and two months for the healing process to complete. And because a road has to be blocked in order to treat it with the magnetic field vehicle, such a long maintenance period would simply not be realistic.

So Jeoffroy looked at various approaches to resolve the weaknesses associated with the old method. First of all he used millimeter-sized steel particles instead of steel wool. This allowed him to get around the "ball of wool" effect, but it did not solve the problem of rust. And even though the time for heating up was a little shorter, it was still way too long.

Eventually Jeoffroy came across a solution in the field of medicine: magnetic hyperthermia is a procedure that has been used for some years now in treating cancerous tumors. It involves injecting magnetic iron oxide nanoparticles directly into the tumor and, like with the tarmac, exposing them to a magnetic field that heats them up. The aim is to 'burn out' the tumor from the inside and destroy it in this way.

"No more cracks in road surfaces"

Inspired by this method, Jeoffroy reduced the scale of the particles from millimeters to nanometers and replaced the metallic steel particles with magnetic nanoparticles. "The smaller the particles, the faster they heat up", Jeoffroy explains. And he did in fact succeed in reducing the heating-up time to just a few seconds with the help of iron oxide nanoparticles used in cancer treatment. At the same time, the nanoparticles also solved the rust problem. Iron oxide is not a metal, and you can't have rust without a metal.

The tests with the nanoparticle bitumen were all very promising. "With asphalt that uses this kind of bitumen, cracks in the road surfaces will never again be the reason for needing to replace a section of road", he announces. He also explains that the method is not harmful to human health. In any case the iron oxide nanoparticles are biocompatible, but they are so strongly bound in the bitumen that they virtually never escape again.

At present, the only catch with Jeoffroy's method is the price. The nanoparticles he uses are currently much too expensive for practical use. But Jeoffroy thinks he might also have a solution to this problem: he has found similar nanoparticles in a whole different industry that he believes are also suitable for use with his method. They are slightly bigger than the nanoparticles used in the treatment of cancer, but much cheaper. This makes the bitumen marketable.

Jeoffroy has already filed a patent for his development but still has to wait for it to be confirmed. He intends to use that time to try out the new particles and test his method in practice. "Everything worked in the lab. Now it all has to work in practice, too", he says. So Jeoffroy will soon cast his lab coat aside, as it's time for the PhD student to leave the research rooms behind and put his asphalt to the test on the road. //

Black and gooey: nanoparticle-enhanced bitumen.

Tera incognita

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

TEXT: Rainer Klose / PICTURES: Empa

Nowadays, almost the entire range of electromagnetic waves, from X-rays to low-frequency radio waves, is exploited technologically. The entire range? No. A small area between microwaves and thermal infrared radiation defiantly resists technological usage: terahertz radiation. Until now, it has been difficult to produce transmitters and receivers at a reasonable price for this frequency range. And to cap it all, the radiation does not carry very far, either: on a rainy day, it is simply swallowed up by the damp air. Hence, it seems rather useless for wireless data transfer, radio broadcasting, television and the military.

Erwin Hack and Peter Zolliker from Empa's Reliability Science and Technology lab have taken it upon themselves to use terahertz radiation to learn to see things in a new way, screen materials and gain insights that are unprecedented – or were previously only possible with extremely expensive equipment. "Our primary interest isn't spectroscopy," says Hack; "we want images from inside materials and boundary layers that are as precise as possible – and real-time recordings of a change, i.e. ultimately videos." Only a handful of research groups the world over are active in this field, the two Empa researchers stress. So there is uncharted scientific territory to explore.

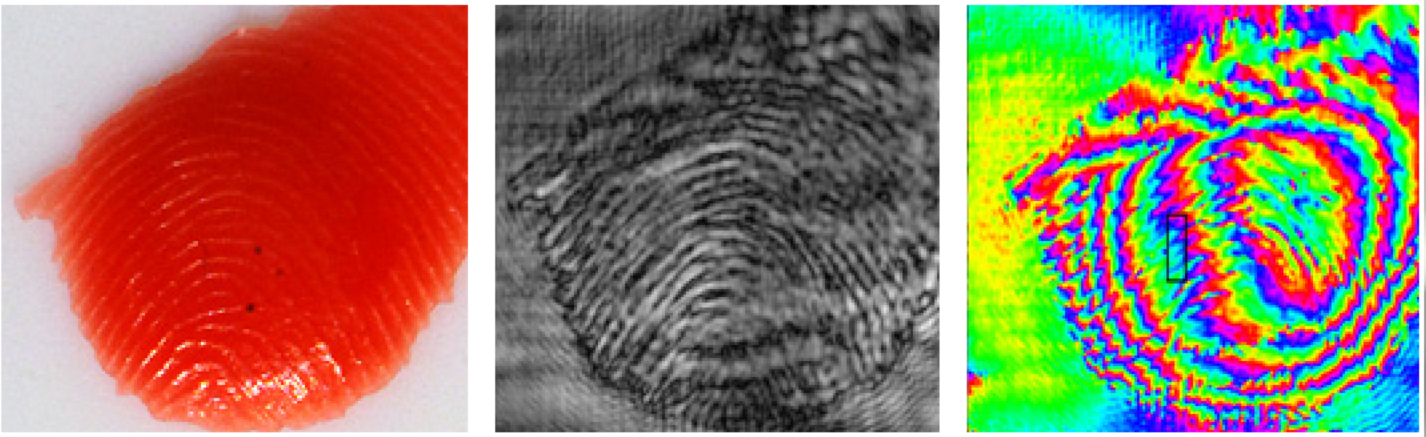
The problem of chafing

One of the questions the scientists hope to answer with the aid of terahertz radiation is an everyday problem for many people: sore patches on the skin. Every hiker is all too familiar with them, and anyone who has ever changed a baby will have their fair share of stories. Generations of inventors have tried to find the solution by inventing the disposable diaper and developing countless powders and creams that are supposed to prevent or help heal the soreness. But as surprising as it might sound, the chafing mechanism remains largely unexplored. This is where terahertz radiation could now come in handy as textiles are "transparent" for these wavelengths while they are reflected on wet skin.

Hack and Zolliker now aim to exhaust the potential of terahertz imaging in collaboration with textile partners from Empa to study the interaction between textiles and skin. Lorenzo Valzania is paving the way in his PhD thesis as part of a project co-funded by the Swiss National Science Foundation (SNSF). A lot of spadework is needed. For instance, the optical properties of the material structures need to be fathomed in a series of preliminary tests. How is the beam refracted on synthetic fibers? And on cotton? The fabric itself is also a problem: it isn't a flat surface, but rather a lattice that bends the beams and distorts the image of the skin's surface – not unlike how glass bricks in the wall of a house create a very blurry view of the garden for anyone peering out. Only complex post-editing with special algorithms on the computer can transform the blurry image into a meaningful one. And that's just one of the challenges.

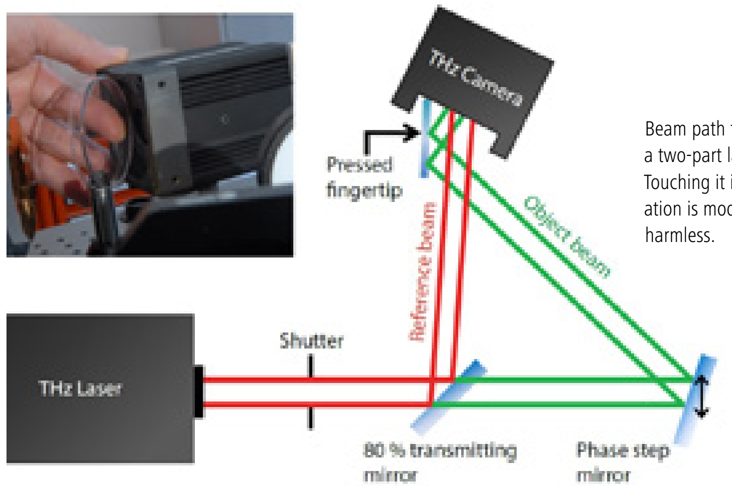
Basic tests on material samples

The equipment the researchers use to trace the waves fits onto a large lab bench: the largest component is the gas laser, which is placed in a case measuring one and a half meters in length. As it exits, a semi-permeable mirror splits the beam into two. Finally, the laser light hits a sample attached to a glass slide and an infrared camera records the reflected beam at an acute angle.

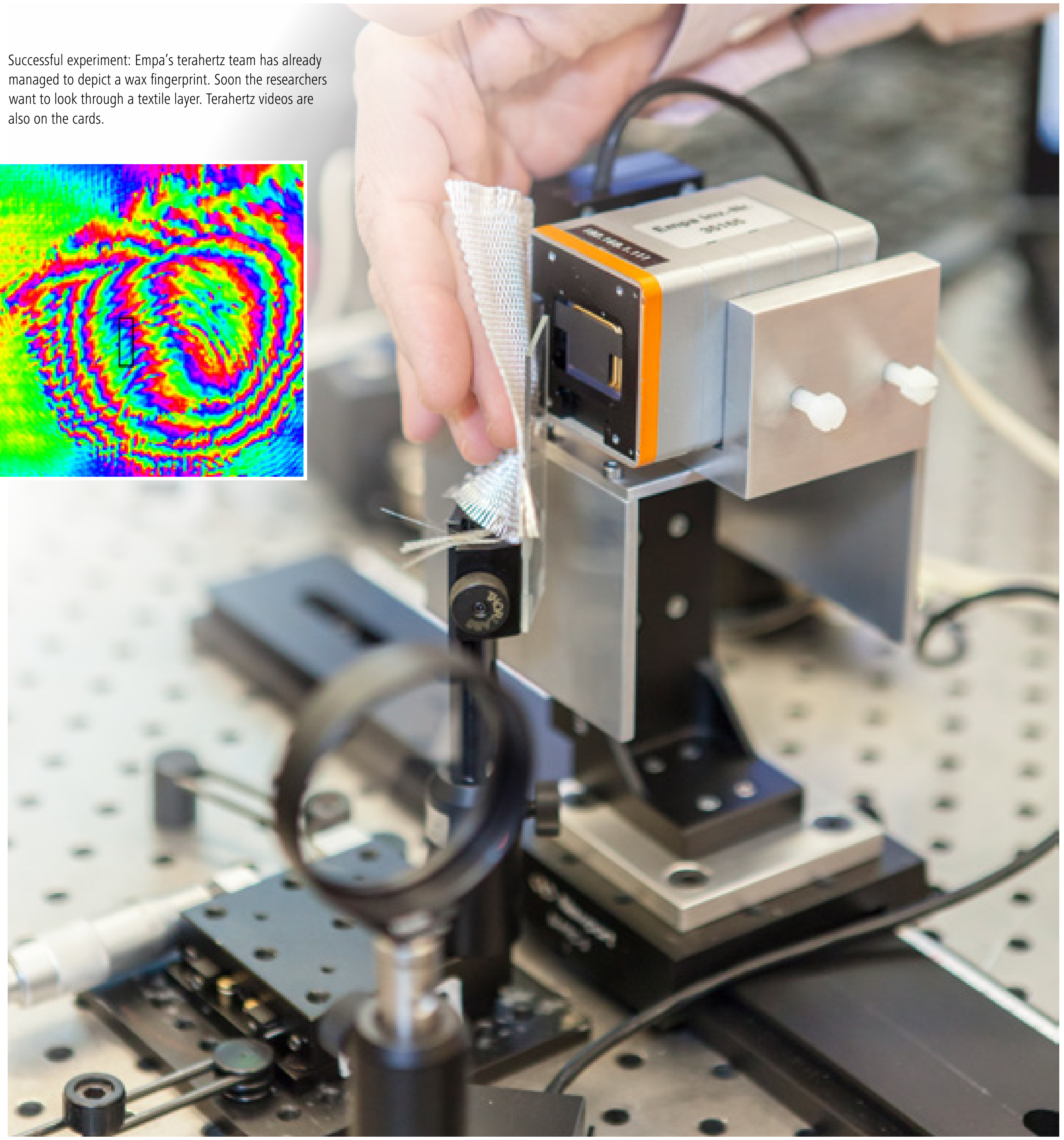


Empa's experimental set-up has already yielded unprecedented images: the research team routinely scans many non-conducting substances such as polyethylene, textiles and wood samples, and has already recorded the soaking of these materials in real-time videos.

Moreover, Hack and Zolliker are well on the way towards overcoming a major drawback of terahertz imaging: the poor resolution of the images. As terahertz radiation has a wavelength of between 0.1 and 1 mm, it has been unable to depict any fine structures – at least thus far. However, this is now possible with the aid of holography. Besides intensity, this can also be used to determine the phase information of the terahertz wave, which enables structures to be depicted that are ten times smaller, and also evaluate 3D information on the sample shot. The optics specialists demonstrated the efficacy of this technical trick with a fingerprint. Its structure with a line spacing on 0.5 mm is clearly visible on the terahertz holograph. At the same time, its contour height is measured – an important step towards imaging for chafed patches of skin. //



Beam path from the terahertz experiment: a two-part laser beam scans the sample. Touching it is no problem as terahertz radiation is moderate in energy and thus harmless.



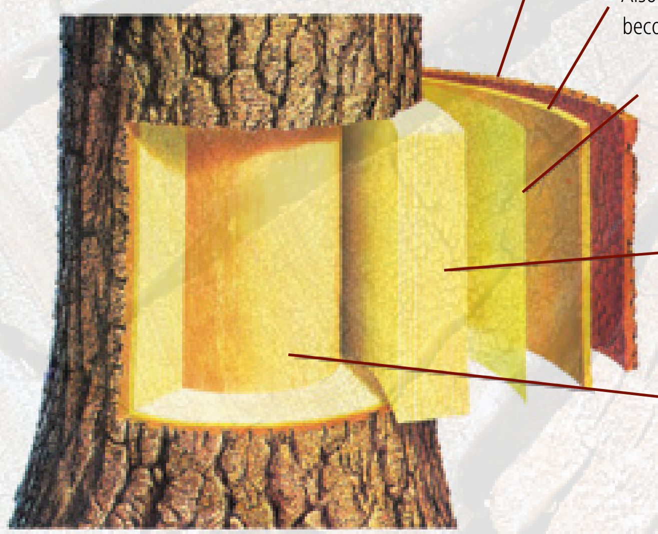
Successful experiment: Empa's terahertz team has already managed to depict a wax fingerprint. Soon the researchers want to look through a textile layer. Terahertz videos are also on the cards.

What is wood?

Wood is robust and versatile. However, even the best material has its limits. Consequently, Empa researchers are looking to transform wood into a high-tech material and thus broaden the range of applications for this natural resource. They tamper with the material's cell structure, where they deposit materials with a vast range of different properties. But before you read on about all the things you can do with wood in the next ten pages of this issue, let's take a closer look at this miracle natural material. How does a tree grow, for instance? What do tree rings tell us? And what does the structure of wood look like at microscopic level?

From bark to heartwood

The structure of a tree trunk



The outer bark
Protects the tree from heat, fungi and insects, and regulates evaporation.

The inner bark
Also called liber, is the tree's supply line. It soon dies, transforms into cork and eventually becomes part of the outer bark.

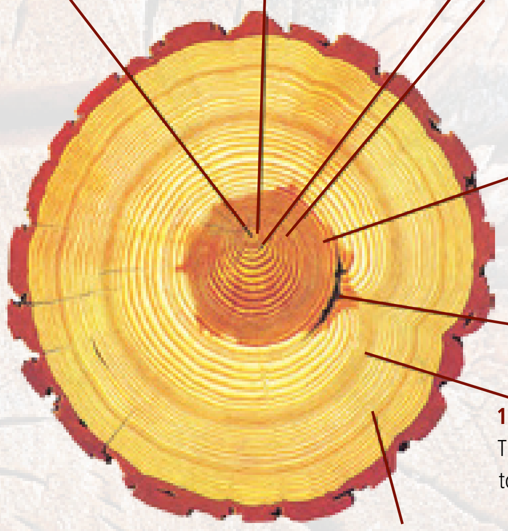
The cambium
The tree's growth tissue. This is where new bark and wood forms every year.

The sapwood
The tree's water supply line to the crown. On the outside, new wood forms; on the inside, the cells lose their vitality and transform into heartwood.

The heartwood
The tree's central supporting column. Although it is actually dead, instead of decomposing it retains its supportive strength as long as the outer layers are alive.

What tree rings can tell us

62 growth cycles using the example of a pine tree



1913
The tree is "born", the seed germinates.

1918
Undisturbed, the pine grows fairly quickly. The rings are wide and uniform.

1923
Once the tree is ten years old, something presses against it. It leans to one side and forms "reaction wood", which helps to withstand the pressure.

1933
The tree is growing straight again, but a neighboring tree is hogging the sunlight and water.

1936
Other trees nearby are felled. More nourishment and sunlight enable our tree to grow more quickly again.

1939
A ground fire rips through the forest. The tree survives, but has the scars to show for it.
Every year, the damage is covered with new wood and it bulges.

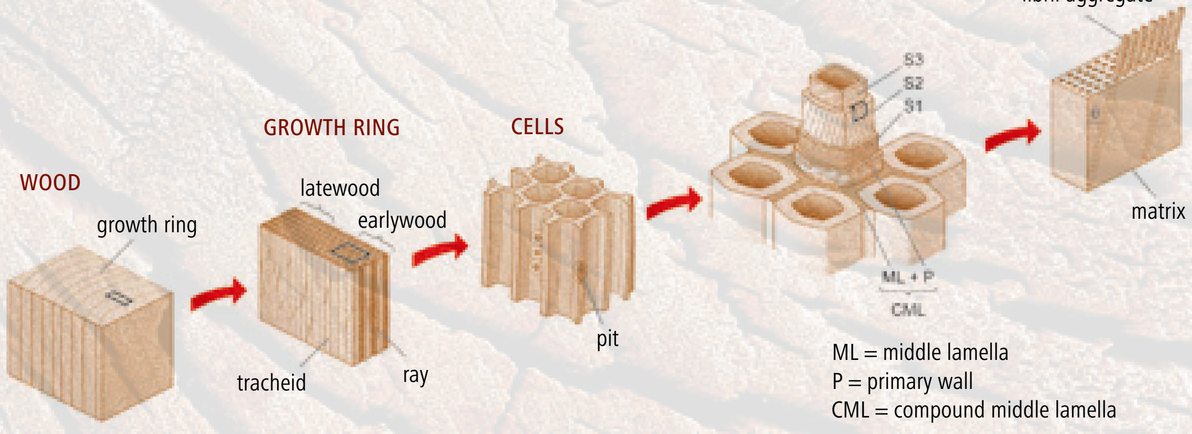
1951
The region is hit by a lengthy dry spell. The rings are close together and the growth rate falls.

1966
Another cluster of narrow tree rings might have been caused by an insect infestation. Insect larvae eat the tree's needles and buds.

1975
The pine is felled at the age of 62 due to disease.

From tree rings to cell walls

The microstructure of a well-known material



ML = middle lamella
P = primary wall
CML = compound middle lamella

Graphic: Schutzgemeinschaft Deutscher Wald, www.sdw.de / Empa

Video (German language)
«Wunderwerkstoff Holz – belastbar, vielseitig und nachwachsend»
https://youtu.be/i_SoteRa1fM

Waterproof through and through

Water causes wood to rot and weather, which looks unsightly and gradually destroys the material. Empa researchers have now developed a strategy to combat this.

1

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3

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1
It is not obvious from the spruce specimens that there is synthetic material in the gaps between the cells.

2
The waterproof impregnation works perfectly – the wood resists water.

3
Etienne Cabane testing the freshly modified slats. They are destined to make a sink.

4
The comparison: unlike treated wood, natural beech immediately sucks up the dyed water.

TEXT: Amanda Arroyo / PICTURES: Empa

Tropical wood like teak is readily used outdoors because it is extremely weatherproof. It is somewhat resistant to water because the wood cells deposit substances called flavonoids and terpenes in the tight spaces between the cells. As there is hardly any room left for rainwater to get into the gaps between the cells, the teak escapes weathering. “This gave us the idea for our first experiment,” says Empa researcher Etienne Cabane. He and his team began by trying to add even more flavonoids to the wood. When he placed the enriched sample in water for a few hours, however, the substances leaked out again. This occurs because the substances are not chemically bound to the wood. In other words, teak also weathers, albeit a lot more slowly.

Integrating synthetic materials in wood

As flavonoids can’t be bound chemically, the researchers sought other substances. And they didn’t have to look very far: combining individual molecules is the principle of polymers. Placing these molecules in the gaps between cells, however, is easier said than done. It requires a carrier fluid. Water would be ideal as it is readily absorbed by the wood. But unfortunately, the water causes the fibers to swell and trigger microcracks in the cell wall. “Which is precisely what we’re trying to prevent,” says Cabane. Chemical solvents such as DMSO or pyridine make good carrier fluids that don’t cause swelling. And although they are neither healthy nor environmentally friendly, at least they enabled the researchers to demonstrate in the lab that the idea actually works.

For instance, they placed molecules called styrene, a component of the well-known synthetic material polystyrene, in the gaps between the cells, chemically bound them to the wood and interlinked them. This transforms natural wood into a composite material made of wood and polymers. “The wood even remains waterproof when I scratch it,” says Cabane. “This is because the synthetic material has penetrated deep inside the wood.” He is talking about millimeters, not centimeters. So if he wants to make a thick piece of wood waterproof, another technique is needed. “We’re currently building a sink,” says the researcher. This involves cutting the wood into thin layers, integrating the synthetic material and sticking the layers back together again – which is referred to as veneering.

The team’s research is not quite there yet, however. They plan is to move away from harmful carrier fluids and use water or supercritical carbon dioxide (CO_2) instead of solvents in future. After all, these substances aren’t just safe; they are also available in abundance – another pivotal factor in the mass production of waterproof wood and its acceptance among consumers. //

The bio-magnet

Wood can be magnetized. And an Empa team has figured out exactly how. Even if magnetic wood only lends itself to smaller applications, the first industrial partners have already expressed their interest.

TEXT: Amanda Arroyo / PICTURES: Empa

Empa and ETH Zurich researcher Vivian Merk sits in her lab playing with a magnet. Not to while away the time; it's her job. Nor is the magnet in her hand just any old magnet; it is made of wood and Merk magnetized it herself. "It's a piece of cake," says the researcher.

To magnetize a piece of wood, Merk soaks it in a highly acidic solution containing iron chloride salts. Once the liquid has penetrated deep into the wood, Merk places the sample in a strong alkaline solution. What happens next is referred to as a precipitation reaction. It suddenly starts "snowing" in the test tube – and this is precisely what takes place inside every wood cell, the lumen. The snowstorm begins on the cell's interior wall. As the flakes are ferrous oxide nanoparticles, however, the snowflakes are almost black, not white. The magnetization is strongest along the grain because the wood cells are arranged lengthways and the most ferrous oxide particles are stored in this direction. The particles are enclosed in the wood, where they remain, even if the wood is washed for days on end.

The magnetic particles come in two different forms – maghemite and magnetite. The brown-colored maghemite forms from the black-colored magnetite when it oxidizes in air. As a result, more imperfections develop in the crystal, which affects the color and explains why magnetizable wood is also very dark.

"Realistically, we'll never treat an entire beam in a house," says the researcher; "magnetic wood is more suited to smaller applications." These might be toys or furniture, such as the magnetic board Merk is currently producing. Use in the automobile industry would also be conceivable to functionalize wood fittings in future. Not only would this have an interesting additional function; thanks to the dark color, it would also look very elegant. //

Vivan Merk demonstrates that the wooden cubes actually stick to the magnet.

Video (German language)
«Holz in Hochform: Optimierter Schutz für Oberflächen»

https://youtu.be/QdEAWpVzCtM

Germs don't stand a chance

Enzymes from fungi, bacteria and plants render wood resistant to decomposing and pathogenic microorganisms. Possible applications might be germ-resistant wood surfaces for hospitals and nursing homes, but also fungus-resistant façades that last longer even without a protective coating.

TEXT: Martina Peter / PICTURES: Empa, iStockphoto.com

An exterior façade made of wood needs protection against fungal infestations. Thanks to Empa's method, no toxic substances are required.

Weather-beaten wooden façades on exteriors are often a sorry sight: gray with fungi, eaten away by bacteria, the handsome material loses much of its original splendor, which discourages many home-owners and building contractors from using wood as a construction material. And wood is also regarded as an absolute no-no in kitchens or nursing homes, where hygiene is paramount. This is because, as a natural material, wood is an ideal breeding ground for many pathogenic microorganisms.

Although wood varnishes or glazes can prevent an infestation, they frequently cause new problems as they often contain toxic substances. These pose a health risk during production and application, and can be washed out of the wood by rain or through wear and tear. Copper can get into the soil, for instance, where it pollutes the environment.

Biochemical processes

Finding a method that protects wood from fungi and bacteria without any toxic additives would therefore be ideal. And a team of Empa researchers from the Laboratory for Applied Wood Materials has now hit the jackpot. The trick: the scientists used a biochemical method that involves a substance taken from fungi themselves. Forest and environmental scientist Mark Schubert is a specialist in wood fungi. For him, fungi are more than just "pests" that damage wooden façades; some species of fungus also contain enzymes that can give the material useful properties. For instance, the many-colored polypore, a wood-dwelling species of fungus found all over the world, has enzymes that "arm" the wood with antimicrobial iodine protection.

These enzymes – known as laccases – act as catalysts in their natural environment and ensure the oxidation of phenolic substances. In woody plants, for example, laccases are involved in the synthesis and breakdown of lignin, one of the main components in woody cell walls.

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The researchers' idea: in an "artificial" environment, the laccase obtained from white rot fungi is supposed to ensure that iodine is joined covalently – i.e. chemically "bound". In an aqueous solution, the laccase oxidizes the iodide (I^-) to form highly reactive iodine (I^-), which creates a bond with the lignin on the surface of spruce. "The advantage," explains Schubert, "is that the chemically bound iodine can't be washed out and is therefore permanent."

The researchers have already patented the eco-friendly, simple and affordable application that doesn't alter the wood's haptic properties. They are now in talks with various partners from the furniture, construction and paper industry, who want to use the technique for their own purposes – whether it be to produce furniture with antiseptic surfaces for hospitals, provide wooden façades that are immune to bacterial and fungal infestations, or replace toxic binding agents for fibers in the production of paper.

Mark Schubert uses an enzyme to alter the chemical structure of the lignin in the wood. This enables auxiliary substances to be "installed" in the wood in a waterproof manner.

The many-colored polypore, a wood fungus, has enzymes that alter the structure of wood. This property was the inspiration behind the research project.

Use at NEST

Two long-term tests with iodized wood are just getting underway at NEST, Empa and Eawag's modular research and innovation building. Local fir and spruce is being used for the façade, while the door handles in the interior are made of oak. The wood is initially iodized with the aid of laccase from the fungus Trametes versicolor. The treated timber will then be exposed to everyday conditions for several years to give the researchers an idea of how bacterial and fungal infestations might be curbed or even prevented in practice.

But it doesn't stop there: not only are laccase-catalyzed techniques just the ticket for iodizing surfaces; damping plates are also used at NEST, which were improved by Empa within the scope of a CTI project in collaboration with industrial partner Pavatex. They succeeded in reducing the synthetic binding agent before eventually replacing it completely with sustainable, environmentally friendly biopolymers thanks to laccase-catalyzed reactions.

Various areas of application

Laccases are already deployed in numerous branches of industry: in the food sector, the enzyme is used to remove toxic polyphenol from orange juice or beer mash, for instance. The textile industry uses laccases to dye jeans or create smoother textile surfaces. And in cosmetics, laccases are used to produce aromas and fragrances. The biocatalysts are interesting for industry because they are robust, don't need any special additives and can be obtained in large amounts and at affordable prices. Moreover, enzymes work under mild conditions, i.e. in aqueous solutions, at room temperature and under normal pressure. //

Finding the right laccase

Until now, pinpointing which laccase is best suited for a particular reaction was a guessing game. However, Empa researchers have now come to the rescue: theoretically, hundreds of thousands of combinations are possible, all of which need to be determined experimentally to find the ideal laccase for the desired field of application. So the researchers turned to artificial intelligence – or, to be more precise, so-called artificial neural networks.
Artificial neural networks are modeled on the human brain in the way they work. They are capable of learning and, thanks to skillful training and design, can recognize complicated relationships and hidden dependencies based on fuzzy data, and use this information to make a prognosis. This enables the number of potential candidates for certain uses to be narrowed down considerably. In the next step, only the most suitable laccases are then used for experiments in the lab. Thanks to an artificial neural network, Mark Schubert has now succeeded in predicting the suitability of various laccases for particular reactions before verifying this later on in an experiment.

Reaching for the sun

Wood has one particular property that tends to cause problems: it swells when it gets wet. As this occurs according to strict rules, however, a team of Empa researchers is looking to produce wooden building components that move automatically.


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TEXT: Amanda Arroyo / PICTURES: Empa

Even as a child, I'd hold fir cones in my hand and wonder how they opened and closed by themselves," says Empa researcher Markus Rüggeberg. The answer: humidity. Water vapor seeps deep inside the plant fibers and causes them to swell. But wood doesn't expand uniformly in all directions; this primarily takes place across the grain. Strictly speaking, this is one of wood's unwelcome properties. "However, we want to use what others fight against," says the researcher.

Crooked like a croissant

"The principle is pretty straightforward," says Rüggeberg: "You simply stick two pieces of wood together." The important thing is the direction of the grain. If they lie at a 90-degree angle to each other and the moisture level in the wood changes, one layer swells or shrinks and the other remains rigid. As both layers are firmly attached to each other, the wood bends like a croissant. Another bending effect is achieved via a 45-degree alignment as the wood twists like a screw.

Rüggeberg is able to predict exactly how much the wood will warp by using a formula that was developed about a century ago to calculate the expansion of metals but also works for wood. However, the thickness of the wood layers needs to be accurate to within a tenth of a millimeter. And the type of wood is also important. Beech, for instance, has very high top swelling coefficients, which makes it just the ticket for particularly pronounced curves.

Always towards the sun

It is easy to see why, of all materials, Rüggeberg chose wood for his research: apart from its swelling properties, the material is strong and sturdy, can be processed easily and is used to build in large dimensions, which makes a range of possible applications possible. For instance, the researcher has already constructed an autonomous device that points solar panels towards the sun. After all, the humidity levels differ depending on the weather and time of day. When the sun rises, it dries out the night-time moisture, which bends the wood attached to the photovoltaic unit and points it at the sun.

"This autonomous tracking already works very well," says Rüggeberg. His autonomous panels have the advantage of requiring far less maintenance than their electronic counterparts. As a next step, the researcher would like to make the wood movements even more precise so that they can capture even more solar energy in future. //

1
The wood bends to a varying extent depending on the humidity level.

2
The wood can twist like a screw.

3
Markus Rüggeberg examining the uniform curvature of a board.

4
Beams that bend autonomously control the solar cells depending on the humidity level.

Skyscrapers made of bamboo concrete

Bamboo is a feat of nature. After all, this member of the grass family contains fibers that are as strong as steel. With a bit of help from the lab, it has the potential to become the building material of the future.

TEXT: Amanda Arroyo / PICTURES: Empa, iStockphoto.com

In developing and emerging countries like Malaysia and Indonesia, cities are growing at breakneck speed. Every year, vast quantities of steel are required to satisfy the mounting demand for new buildings. As steel isn't produced domestically, however, it needs to be imported, which is neither particularly ecological nor economical. Consequently, Dirk Hebel's group from ETH Zurich teamed up with Empa researchers Mateusz Wielopolski and Sébastien Josset to search for an alternative – and struck gold: bamboo, a member of the grass family with the tensile strength of steel. What's more, it is six times lighter and, as it grows in tropical regions, is particularly hardy.

The fact that this grass can withstand incredible forces is nothing new. Until now, however, it has not been possible to use it as a construction material. Back in the 1960s, researchers attempted to replace iron reinforcements with bamboo but the rods tended to soak up so much water that they cracked the concrete as they swelled.

In order to prevent this, the Swiss researchers devised a cunning technique. They don't merely use bamboo straight out of the ground. "We cut up the bamboo and stick it back together again," explains Wielopolski. The glue they use is a specially developed resin that renders the wood waterproof. As a result, Wielopolski managed to achieve the best material values ever for bamboo composite materials.

Using bamboo as reinforcement opens up completely new possibilities in architecture. "As the material is six times lighter than steel, you can build much higher buildings with it," says Wielopolski. Not only might it replace steel, it can also be used in lieu of carbon, glass or other wood fibers in composite materials.

A material that lasts

In actual fact, there was no need for Wielopolski to develop a new glue. After all, there are already perfectly good resins on the market, which are used in the automobile and aviation industries, for instance. Airplane components, such as wings, are increasingly being glued – and have to withstand high levels of stress. "But we didn't want to use these high-performance glues," says Wielopolski. "They are so expensive that no developing country can afford them." In other words, it's the resin that drives up the cost, not the bamboo. Consequently, he minimized the proportion of resin and also gained in sustainability. Moreover, the new glue comes from a renewable raw material: vegetable oil. "Not extra virgin olive oil, of course," says Wielopolski with a grin; "we use plant waste." He extracts the oil and, via a chemical conversion, the resin, which makes the wood both waterproof and malleable – just the ticket for a broad range of applications.

"Now that we've developed something, we want to use it," says Wielopolski. However, he realizes how difficult it is to test innovative materials on new buildings in practice. "Which is why I'm over the moon about Empa's research building NEST," says Wielopolski. This gives him the opportunity to try out his material for the first time. But we won't be seeing any skyscrapers made of bamboo just yet. To start with, Wielopolski is concentrating on smaller applications – decking or garden furniture – to test just how weatherproof the material is under real conditions. As soon as it has cleared this hurdle, the use of bamboo for reinforcement purposes will soon be on the cards. "But we're still a far cry from replacing established materials from the building industry," says Wielopolski. //

Mateusz Wielopolski is delighted with the fruits of his labor: the bamboo composite material can be used wherever a strong, lightweight and weatherproof material is required..

The beaming Italian

About 18 months ago, Davide Bleiner took over the helm at Empa's Laboratory for Advanced Analytical Technologies. And he has big plans – for small things. Right at the top of his wish list is the development of a plasma-based X-ray laser – albeit on a foosball scale. His curiosity and thirst for knowledge have not only taken him around the globe, but also into a vast range of different fields.

TEXT: Cornelia Zogg / PICTURES: Empa

"Most labs at Empa conduct research into new materials. My lab, on the other hand, develops new measuring methods to observe chemical processes during the application of these materials." Davide Bleiner has ambitious plans, including for his laboratory, which he renamed "Advanced Analytical Technologies" (from "Analytical Chemistry"). While laser beams were regarded as playthings for atomic physicists half a century ago, they have become an integral part of everyday life. Bleiner's laboratory works with analytics, which enables even the minutest of parts and concentrations – such as trace levels on a nanoscale – to be quantified. While "normal" X-ray sources, such as in the medical sector, act like a lamp and beams of "white light" radiate in all directions, "colorful" lasers are able to concentrate the beams, focus them on one point energy-selectively and thus illuminate tiny things. The latest developments in laser spectroscopy enable ultrarapid processes to be observed in real time ("femtochemistry"). Researchers from Bleiner's laboratory establish these advanced technologies at Empa with a view to specific issues of materials science – such as analyzing combustion processes in engines or the catalytic conversion of hydrogen with CO_2 into hydrocarbons..

A foosball-sized particle accelerator

However, the native Italian's plans go way beyond "mere" routine analytics: his goal is the laboratory application of a so-called "free electron laser" (FEL). This kind of laser has already existed for a few years, albeit only in the form of giant electron accelerators – such as SwissFEL, which is currently under construction at the Paul Scherrer Institute (PSI). Consequently, there are only a handful of them worldwide. "There aren't many scientists who can plonk a 300-million-ton synchrotron in their lab as soon as they have a brainwave," says Bleiner. Using one of these synchrotrons takes a lot of preparation and expensive trips, let alone time: for one project, Bleiner's team usually has to wait anything from six months to one and a half years before they can carry out their measurements – in California, Japan or Italy, for instance. "It would be a huge advantage if everyone could conduct their own experiments in their own lab." With this in mind, Bleiner and his team are working on a tabletop version of a plasma laser. He first examined the topic as an SNSF-funded professor at the University of Bern's Institute of Applied Physics and worked on and with a table-top X-ray laser called Beagle. "We don't just want to develop new lab tools, but also optimize the corresponding 24/7 applicability," says Bleiner, summing up his laboratory's work.

From the Stone Age to the 21st century

Bleiner owes the fact that he now deals with lasers to a stroke of fortune. The Empa scientist has a geology degree under his belt. Originally, he also wanted to do a doctorate in geochemistry at ETH Zurich but before he could get started, his advisor was given an assistant professorship in analytical chemistry. "He told me that if I wanted to join him in chemistry, there wouldn't be any field trips, which suited me right down to the ground." So Bleiner agreed. As his PhD thesis was about the micro-analysis of ore streaks based on laser ablation and the derivation of a mathematical description of the measuring signals, his geochemical knowhow really stood him in good stead.

After his doctorate at ETH Zurich, a position as a project leader at Empa and a two-year stint as a postdoc at the University of Antwerp, where he studied the fundamentals of laser plasma and computer simulations, he returned to Switzerland to take up a post at ETH Zurich – but in mechanical engineering, not chemistry. "An unusual move," concedes Bleiner, "but then laser expertise is called for in virtually every field." He teamed up with engineers to develop a laser-powered source of extreme ultraviolet radiation for use in next-generation lithography. "The engineers were grateful for my laser expertise and it was rewarding for me as I was working in an environment – namely fluid mechanics – where I still had plenty

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Left: Davide Bleiner holding the book Short Wavelength Laboratory Sources. He is one of the editors of this standard work.

Right: Bleiner is a passionate bassist and plays in jazz bands and classic orchestras.

to learn." According to Bleiner, that's the advantage of switching fields every now and again: "I frequently felt like Forrest Gump in life and found myself in situations without really understanding how I'd got there, but something good always came out of it in the end."

At ETH Zurich, this included topics such as fluid mechanics and turbines – knowledge that he can now put to good use on a current project at Empa. In conjunction with SR Technics and the Federal Office of Civil Aviation (FOCA), his team developed a measuring technique that is able to gage the fine particle emissions of airline turbines directly, recording even the minutest of particles that are less than a hundred thousandth of a millimeter in size – i.e. less than ten nanometers. (Read more about this project on page 4.)

"When someone tells me that something is too hard, those are the projects I find the most exciting."

The book smuggler

Bleiner is no stranger to airports, either. Once, his love of travel and physics books even landed him in the soup at Zurich Airport. The customs officials mistook him for a book smuggler when he tried to stroll through customs with a suitcase crammed full of books. He ended up getting slapped with a fine – after all, how could he prove that he was bringing all these books on quantum mechanics across the border for personal use as opposed to trafficking them? He has another passion, too: calcio (football to non-Italians). Although he has hung up his boots as a player, he remains a fan of AS Roma – one of the clubs in his hometown. That said, he now calls Switzerland his new home. He likes it here and people don't immediately cotton on that he isn't actually Swiss. "Most assume I'm from Ticino." And Bleiner has another fitting anecdote at the ready. Back when he was a PhD student at Empa, someone recommended "going abroad for a few years" because it looks great on your résumé. To which he replied: "But I already am abroad!" Nonetheless, he heeded the advice and worked, among other places, in Belgium, the USA and Italy before eventually returning to Switzerland.

Switzerland: an ideal place for research

Nonetheless, Bleiner is not just looking to bring the subject-specific experience he has gained on his travels through foreign countries and various research fields to the table. Now that he runs five research groups, team spirit is particularly important to him. Apparently, there is no shortage of Lionel Messis in research. "But one Messi doesn't make a team – you're missing ten other good people who work together." That's why it's crucial to respond to individual members of the team and create a lab spirit; otherwise, you stop enjoying your work and become dissatisfied. That's the essence of his reshuffle. For him, exchange programs are therefore extremely beneficial.

He is a prime example of this himself. When he joined Empa after his doctorate more than a decade ago, he underestimated the research environment at Empa. During his stints abroad, however, one thing in particular dawned on him: in Switzerland and especially at Empa, researchers have it cushy, but most of them – like him back in the day – don't even realize it. He still recalls from his time at the renowned Lawrence Berkeley National Laboratory in the US how five researchers would share an office that was half the size of his present one at Empa – without any windows and just a clapped-out old fan in California's summer heat; conditions that would be unthinkable in Switzerland.

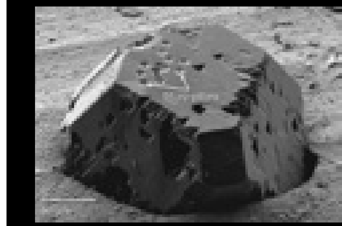
If at first you don't succeed…

As a laboratory head, Bleiner no longer works on the analysis equipment or in the lab as often as he used to – not that this is a problem for him. "Eventually, every football player has to trade in his boots for the dugout," he says. These days, he is more interested in helping budding young scientists. Soon he will be following in the footsteps of his great role model Erwin Schrödinger when he takes up a professorship at the University of Zurich. At Empa, he supervises his PhD students' projects and, in doing so, keeps seeing new challenges – especially in complicated cases. "When someone says it's too hard, those are the projects that inspire me the most."

Of course, he doesn't advocate that his PhD students should only produce one string of failures after the other for three years. But they stand a far greater chance of stumbling across exciting new findings if things do go wrong every now and then. "If you carry out an experiment and the result is exactly as you'd expected, that isn't research; that's an internship. If the results are surprising, however, things start to get interesting!" Bleiner's own career has been littered with unexpected twists and turns – but that's a good thing, he insists. "Life is like the movies, not a book. When you read, you can skip to the end and sneak a peek. You can't do that at the cinema. But somehow it always works out." //

Exactly how hard is diamond?

Testing the hardness of diamonds is a tricky business as almost every material that might be used to press onto it is softer. Due to its inner crystal structure, a diamond has "softer" and "harder" sides. Empa researcher Johann Michler and his team took it upon themselves to tackle the direction with the most hardness – namely vertical to the 111 surface. They milled small columns – measuring just 300 nanometers in diameter – out of a diamond with the aid of ion beams and stressed them with diamond counter bodies. These columns were then stressed to breaking point. The result: Just as the theory predicts, the hardest material in the world displays the highest degree of hardness ever measured in an experiment. Michler's confirmation takes the theoretical model for the super-hard substances of this world an important step further.



Nanoparticle database in English, German and French

The online database on risks and environmental hazards from nanoparticles has now been translated into French as well. The Dana 2.0 Knowledge Base located under the link http://www.nanora.eu/tools is available in English, German and French. The database is just the ticket for industrial companies, politicians and journalists who would like to find out about the properties of particular kinds of nanoparticles at a glance. Thanks to the translation, the database is now even more suitable for international collaborations and multilingual companies. For Empa's part, nanoparticle specialist Harald Krug played an instrumental role in setting up the database.

Swiss luxury lady's watch featuring gold thread by Empa

Lovers of fine embroidery and luxury gold watches can now enjoy the best of both worlds in the Big Bang Broderie Gold line in lady's watches produced by the manufacturer Hublot. The watch face features embroidery by the traditional Swiss brand Bischoff. And the shiny golden thread is produced by Tersuisse Multifils SA in Emmenbrücke using a technique patented by Empa. It involves cold-vaporizing a piece of gold in a plasma process. The metallic vapor settles on the thread and sticks.

For the Big Band Broderie line, the gold thread is stitched onto carbon fibers, dipped in synthetic resin and pressed. After all, the watch's hands mustn't catch on the embroidery.

In Zusammenarbeit mit der KTI

Förderprogramm Energie
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Empa Akademie

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Energie + Bauen

Olma Messen, St. Gallen
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www.energie-tage.ch

5. Internationaler Geothermie-Kongress
Donnerstag, 26. Mai 2016
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2. Fachkongress Energie + Bauen
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4. Nationaler Energie-konzept-Kongress
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7. St.Galler Forum für Management Erneuerbarer Energien
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Veranstalter und Organisator

Olma Messen St.Gallen
Empa Materials Science and Technology
Stadt St.Gallen
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Events (in German)

11. Mai 2016
FSRM-Kurs Polymerwerkstoffe für technische Anwendungen
Zielpublikum: Industrie und Wirtschaft
www.empa.ch/polymerwerkstoffe
Empa, Dübendorf

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07. Juni 2016
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16. Juni 2016
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