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Nanoparticles – invisible threat?

EMPA
Materials Science & Technology

Fitness regime for run-down bridges

Displays as a source of raw materials

Sailing and research – a success story

MICHAEL HAGMANN Head of Communications

The two faces of new technologies

Dear readers

New technologies are usually developed to solve a specific problem and thus carry a direct benefit. Just think of the light bulb, the telephone, the combustion engine or the steam engine. All these technologies triggered the industrial revolution, from which we still reap the benefits to this day.

However, new technologies often have less desirable consequences, too. Steam and combustion engines need "feeding" with wood or fossil fuels, which in turn affects entire ecosystems and causes global climate change. And this certainly isn't what James Watt and Nikolaus August Otto would have had in mind.

Nanotechnology raises hopes of novel materials for anything from energy technology to functional, "smart" textiles. But it also sparks fears, especially of free, synthetic nanoparticles that spread – in a nightmare scenario – uncontrollably and wreak all kinds of havoc for humans and nature alike.

Unlike in the early days of the new technical age, nowadays scientists contemplate possible "side effects" of new technologies early on and endeavor to investigate them. Such as within the scope of the National Research Program 64, which is fittingly entitled "Opportunities and Risks of Nanomaterials", i.e. it spells out the Janus-faced nature of technological innovation. As Empa scientists played a major role in NFP 64, this issue's Focus section is devoted to the topic (p. 14).

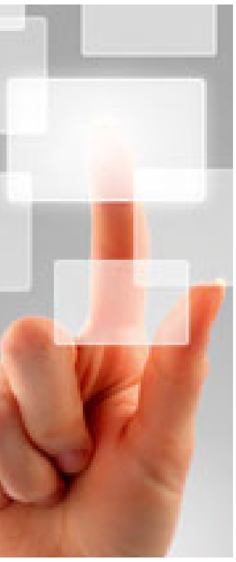
Regardless of how carefully one might assess the risks of something new and unprecedented, however, scientific research will never be able to issue a blank check. After all, there is no such thing as ironclad proof that something doesn't have ANY effects.

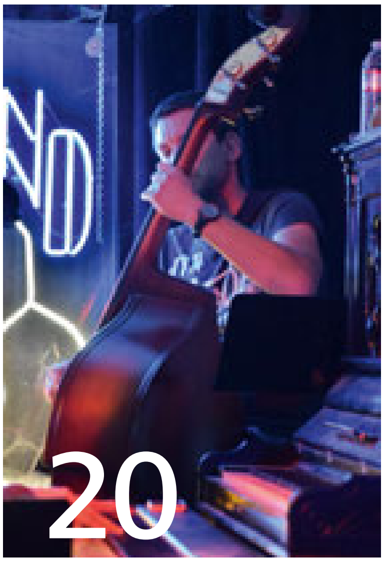
Enjoy reading!

Cover
Nanoparticles are invisible to the human eye. And yet nature – and we humans, too – are increasingly exposed to them. Where do they come from? And where do they go? Photo: iStockphoto. *Focus on page 14*

Focus

Nanoparticles





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50 issues of EmpaNews –

Dear readers,

you are holding the 50th issue of EmpaNews in your hands. At this point, we usually showcase a pioneering research project. For once, however, we're going to do a spot of navel-gazing and look back over the history of EmpaNews, which has echoed the development of Empa over the past decade. When EmpaNews was launched in 2003 – at the time in a rather unusual broadsheet format – Empa was in the middle of a radical transformation process: under the leadership of the then CEO Louis Schlapbach, the former materials testing facility gradually blossomed into an internationally renowned research institute. This called for a new kind of communication: away from engineer test reports and towards science news. EmpaNews talked to Rémy Nideröst from Empa's communications team, who has known the institute's PR work for about 20 years – and still helps shape it to this day.

an opportunity for navel-gazing

Interview: Selina Chistell

Mr. Nideröst, why did Empa decide to launch a customer magazine in 2002?

The Board of Directors wanted to keep our partners and anyone interested in Empa regularly up to date on our research activities. The unequivocal goal was to not just address scientists, but also the general public. Up to that point, there had only been a sporadic information sheet on the St. Gallen and Dübendorf campuses; this was now to be replaced by EmpaNews. We wanted to make it loud and clear that Empa was primarily involved in research and not – as many people still thought back then – in merely testing materials. In the very first editorial of the first issue, Louis Schlapbach, Empa's CEO at the time, asked, "Why does Empa do research?" before answering his

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own question: "Because there would be a gap in Switzerland if it didn't." Schlapbach referred to Empa as a missing link that acquires basic knowledge and implements it in practical applications, oftentimes in close collaboration with industry with a view to developing innovative solutions for technological problems.

Then, in 2008, EmpaNews was re-invented as a glossy magazine.

EmpaNews was originally published as a newspaper in an A2 format, very much like a daily newspaper. Although it stood out from the wealth of other corporate publications, the magazine format eventually caught on. Not only is the size a lot handier; it offers many more layout possibilities, such as for special subjects, rubrics and so on. And glossy photographs come out much better on finer magazine paper than in a newspaper. EmpaNews had taken hold by 2008. Now it was time to pay attention to the look, the appearance, and not just the contents.

So EmpaNews is flexible. What has changed in the last 12 years?

In the early days, EmpaNews was effectively just a compilation of our press releases, which we had our graphics team lay out nicely for the newspaper. In other words, the articles weren't written especially for a magazine or a newspaper. Originally being press releases and therefore geared more towards journalists, the texts were written in a more formal style and generally tended to be a bit on the dry side. When the newspaper was transformed into a magazine, however, we started writing articles especially for EmpaNews, which meant they could – and should – be a bit more relaxed in style. We could also rely a lot more on photos and graphics.

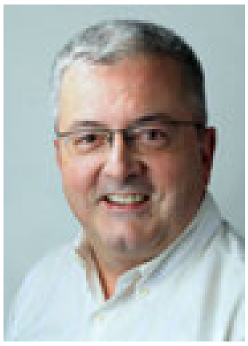
Does EmpaNews still pursue the same goal?

Absolutely. It's just that we do it a lot more professionally nowadays, if I may say so. The approach to the texts is journalistic and not too technical, so everyone should be able understand them. We attach more importance to the quality of the pictures than in the past, both in their content and in a photographic sense. We try to exhaust the possibilities of a modern research magazine to the full.

EmpaNews has become a lot thicker compared to 2003. Is there more to report on research nowadays than 10 years ago?

It seems so at first glance. On the one hand, scientific topics like climate change or genetic engineering have increasingly been in the limelight – and therefore the public eye – in recent years. On the other hand, however, our engineers and scientists are more open these days and don't just want to report on their work in scientific journals with the highest possible impact factor, but also in "popular" science magazines like EmpaNews. They recognize that a well-made institutional research magazine also has its place and that the general public is eager to read up on scientific issues – if dressed up in a generally comprehensible format with attractive pictures. We're thus narrowing the gap between our researchers in the lab and the people on the street. //

Rémy Nideröst works at Empa communications since 1990.



Enter EmpaNews!

In January 2003, the time had finally come: together with Empa CEO Louis Schlapbach the then head of communications, Robert Helmy, had developed the concept for EmpaNews. From that moment on, the sporadic flyers that had previously reported on the research activities in Empa's labs were consigned to the history books. Now there would be research news from Empa four times a year. Schlapbach used the first editorial to sharpen Empa's image and explain to the readers that Empa had ceased to be a pure "materials testing facility" in 1988 and was now a research institute for materials science. The message was loud and clear: testing was yesterday; today, it's all about research – at the interface between basic research and its practical implementation for and with partners from industry, i.e. precisely where innovations are conceived of.

Transformation into a magazine

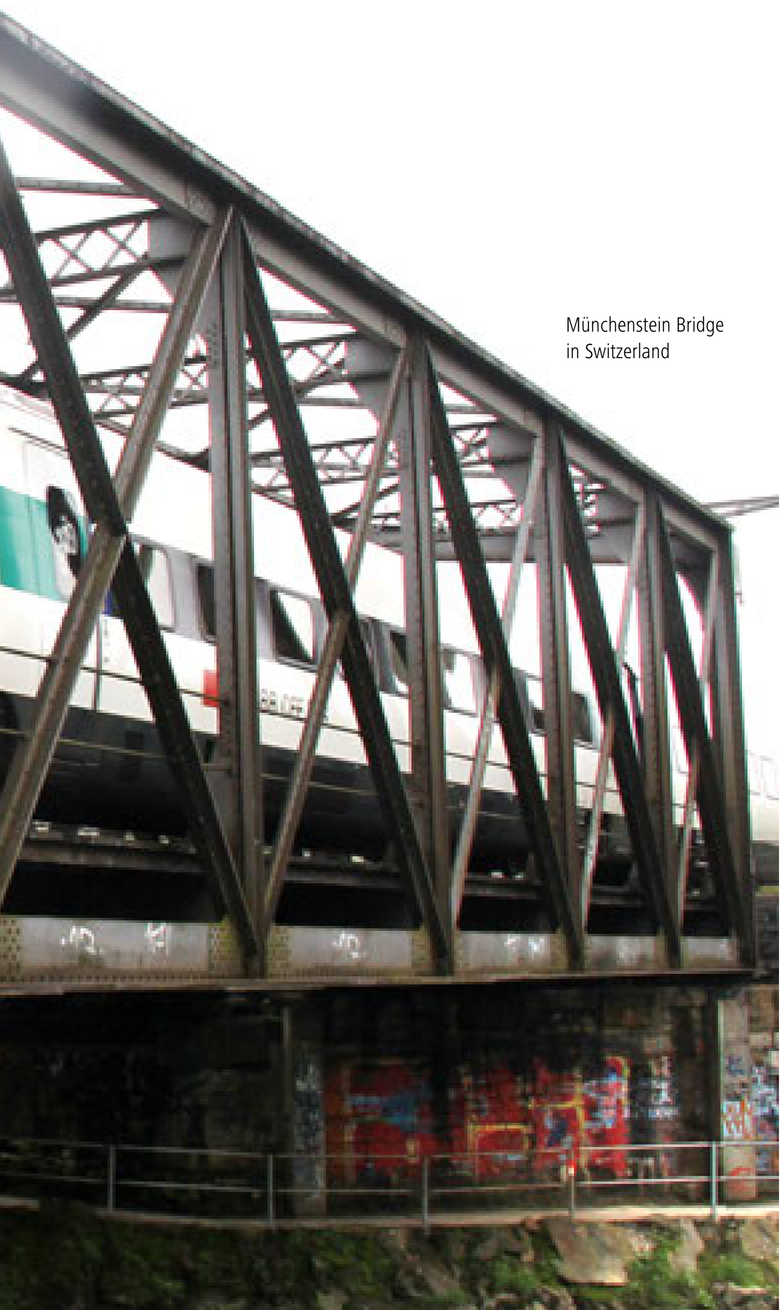
In May 2008 EmpaNews was given a makeover. As of No. 21, the sober newspaper was transformed into a magazine. Head of Communications Michael Hagmann had got another qualified journalist on board in the form of Martin Kilchenmann. Together with Empa photographer Ruedi Keller and the institute's graphics team, the journal we know and treasure today was born. From then on, every issue of EmpaNews was given a "focus" – a special scientific topic. The magazine has been developing quietly ever since: since EmpaNews No.34, the magazine harbors an info graphic centerfold that aims at a somehow bigger perspective for the topic in question: what role does Empa play on the national and international research landscape? How important is the topic globally?

An interactive journal on your tablet

A modern research magazine only on paper? No way! At least that's what the editorial team decided in the summer of 2012. The Apple iPad had caused quite a stir in the industry: videos and animated graphics, internet links and sound bites could now explain a topic far better than a plain text. Empa's editorial team made the most of the features of the iPad and Android tablet and, in January 2013, interactively launched the topic of "noise research". From then on, EmpaNews has been published in two versions: in print and electronically. But in no time IT solutions succumb to the ravages of time. Empa will soon be getting a new-look webpage, which will also display research news on tablets and smartphones in a contemporary format. All digital issues for your tablet can still be downloaded until mid-November at www.empa.ch/app. Then it's over – to make way for Empa's new NewsPortal.

Resilience for aged bridges

An increasing number of steel bridges need to be replaced or repaired due to signs of fatigue. Researchers from Empa fortify the load-bearing elements with pre-stressed, fiber-reinforced plastic plates – a cost-effective alternative to building a new bridge. The recently patented method was now used on the 120-year-old Münchenstein Bridge.



Münchenstein Bridge in Switzerland

TEXT: Martina Peter / PICTURES: Empa, Keystone

Almost 70 percent of Europe's metal bridges are over 50 years old. 30 percent have even been in service for over a century. Many are in dire need of repair. The problem isn't necessarily cracks or visible damage, but rather tired material that no longer bears the load and thus poses a safety hazard. The reason: back in the 19th century, bridge builders assumed that their bridges would only be exposed to a fraction of the stress they are nowadays. Today's vehicles are considerably heavier and cross bridges faster and much more frequently than in the past. The consequence: some bridges have to be reduced to a single lane or closed entirely, which risks grinding the traffic to a complete gridlock.

Bucking the general trend of simply discarding ageing products and replacing them with new ones, an increasing number of bridges are being repaired nowadays. An established solution for concrete bridges is also used to mend metal bridges: extremely light, pre-stressed plates of carbon fiber reinforced plastic (CFRP) are "stuck on" like plasters, which prevents fatigue cracks from growing any wider or even forming in the first place. However, the plasters stick much less effectively to corroded metal surfaces or the uneven layers of several anticorrosion coatings applied over the years than to concrete surfaces. Moreover, rivets often prevent the plates from sticking properly. And the plates mustn't be screwed on, either, as irreversible structural changes are often not permitted on historic buildings.

Reinforcing load-bearing elements

The 120-year-old Münchenstein Bridge in the Canton of Baselland is a prime example. Nevertheless, researchers from Empa's Structural Engineering Research Laboratory came up with a patent solution. Teaming up with the Swiss Federal Railways (SBB) and S&P Clever Reinforcement AG, they developed a novel method in a CTI-funded project to demonstrate how the load-bearing elements of the 45-meter-long steel bridge can be reinforced with pre-stressed CFRP plates. The new, trapezoid "pre-stressed unbonded reinforcements" (PUR) were attached to two of the girders that were most affected by fatigue.

The pre-stressed CFRP plates are clamped to the ends of the transverse bridge girders. Saddles in the middle of the girder ensure that the bands are forced downwards until they are optimally stressed. Two V-shaped plinths are added to these points and the saddle can be removed again. If greater stresses are expected in future, the trapezoid system can be re-stressed by using larger plinths. Moreover, it can easily be dismantled again. After months of recording, a wireless sensor network revealed that the reinforcement of the two girders on the Münchenstein Bridge had worked perfectly fine.

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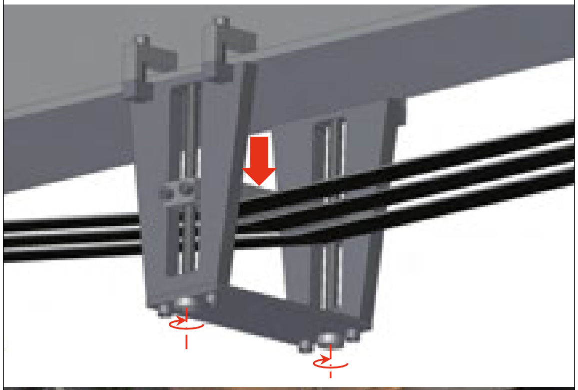
Fortifying old bridges with CFRP plates. How does it work?

First of all, the CFRP plates are clamped to both sides of the bridge with special brackets, then stressed with a special tool. Finally, two V-shaped brackets secure the plates and keep them stressed. If greater stresses are expected for the bridge later on, the system can be re-stressed by reapplying the tool and fitting larger V-wedges.

The system reduces wear and tear on bridges, which can extend their lifespan by 50 years and renders a quick rebuild redundant.



The PUR system now provides bridge operators with a swift, cost-effective alternative to bridge replacements. Wear and tear can be reduced to such an extent that, in theory, fatigue can be deferred indefinitely. While project head Masoud Motavalli is more realistic when it comes to practice, he remains confident: "A bridge reinforced entirely using this method will certainly last for the next 50 years, by which time we're bound to have devised new methods to repair ageing bridges."

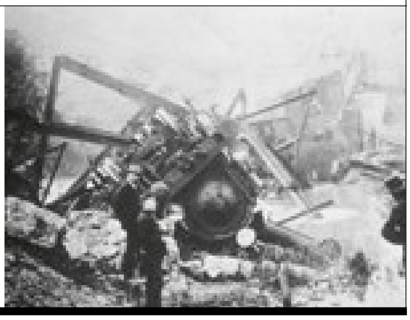
Diagonal cracks and a flat PUR system

There are already two follow-up projects, one of which just got underway in Switzerland. It is backed by the Swiss National Science Foundation (SNSF), with EPF Lausanne as project partner. The aim is to examine diagonal and combined cracks with a view to improving our understanding of how we can prevent them from growing or even forming in the first place.

The second study recently began in Australia: the project headed by Xiao-Ling Zhao from Monash University and funded by the Australian Research Council focuses on the reinforcement of riveted metal bridges. The project partners are Swinbourne University, S&P Clever Reinforcement AG and VicRoads (the transport authority of the Australian State of Victoria). The aim is to develop a flat PUR system that can also be used on girders where there is not enough room for the patented trapezoid PUR system. At the end of the project, in 2017, Melbourne's Chandler Bridge is to be reinforced with the new system developed by Empa. //

The Münchenstein Bridge: Empa's faithful old friend

The cast-iron predecessor to today's Münchenstein Bridge collapsed in 1891 as a steam train was crossing it with ten wagons. 71 people lost their lives. Empa, which had just been founded a few years earlier, conducted the investigation into why the metal bridge constructed by Gustav Eiffel in 1875 came tumbling down after only 16 years. Empa's first CEO, Ludwig von Tetmajer, discovered that Euler's Column Formula, which had been used to calculate such structures thus far, needed correcting for compact girders (as used in Münchenstein).



Displays as a source of raw materials

Indium, one of the rarest metals in the world, could become scarce in future. Every display and flat screen contains the metal in the form of indium tin oxide, where it forms the electrically conductive, transparent layer on the glass plate. In light of the looming supply bottlenecks, is it worth recycling the metal? Swiss researchers decided to find out in the project "e-Recmet" headed by Empa.

TEXT: Rainer Klose / PICTURE: iStockphoto

What is cheaper: obtaining indium from a mine or recycling it from displays? On behalf of the Swiss Federal Office for the Environment, a team of researchers from Empa teamed up with the University of Applied Sciences Rapperswil, Bern University of Applied Sciences and the engineering and consulting firm Basler + Partner AG to investigate this and other questions related to recycling rare metals.

In Switzerland, the industrial association Swico is in charge of recycling electronic devices, which are collected and either partly disassembled by hand or shredded. The actual recycling of the metals takes place in special smelting works abroad. Of the 36 metals present in e-waste, at least half are already recycled today. Two rare and important metals are not yet among them, however: Indium, which is used in flat screens, and Neodymium, which is found in the magnets of computer hard disks.

Mechanical breakdown necessary

As the team headed by Empa researcher Heinz Böni, who coordinated the project, concludes, recycling Indium would be economically viable. However, it depends on the pre-treatment of the e-waste. Although wages are high in Switzerland, many devices are dismantled by hand in order to increase the added value. With manual disassembly, it is possible to separate a mixed glass and plastic fraction with a high Indium content. This kind of recycling would cost around 19 Rappen per TV, around 6 Rappen per computer monitor and around 4 Rappen per laptop. The anticipated recycling fee (i.e. the retail price) would need to be increased by this much.

According to Böni, from an ecological perspective the amount of the recycled Indium is dead-level with that obtained from mineral ores. Indium might be rare, but as it is obtained as a by-product during zinc mining, the cost of producing Indium is still within limits. If the metal really becomes so scarce in future that is needs to be sought and extracted especially, however, the recycling method would be significantly more advantageous than mining primary raw materials.

Neodymium from magnets: recycling pays off

From an ecological perspective recycling is also worth it for Neodymium, the second material examined in the e-Recmet study. According to the researchers, recovering the rare earth metal is far more ecological than mining. And again, dismantling the devices by hand causes 30 percent less environmental pollution. This is because the broken-up magnets stick to the iron components in the scrap during mechanical shredding. In order to prevent this, the computer scrap needs to be heated beforehand to demagnetize the magnets, which means: more energy is consumed and more pollutants are emitted.

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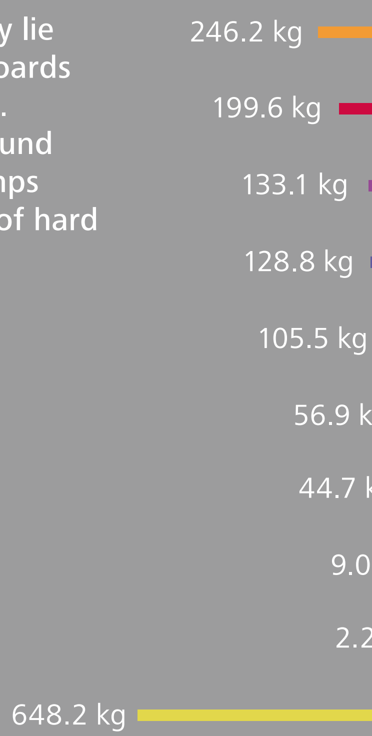
Switzerland has raw materials –

Your old cell phone is gathering dust in the living room cupboard, the flat screen from your last PC but one is in the attic as a backup: there's a goldmine of valuable raw materials in Switzerland, squirreled away in millions of private households. This diagram shows why we should give old devices up for recycling. The rare metals in our used electronics are important for our future.

Rare metals in electronic waste

Some rare metals are not recycled in Switzerland. Enormous quantities are contained in the circuit boards of electronic devices collected in this country every year.

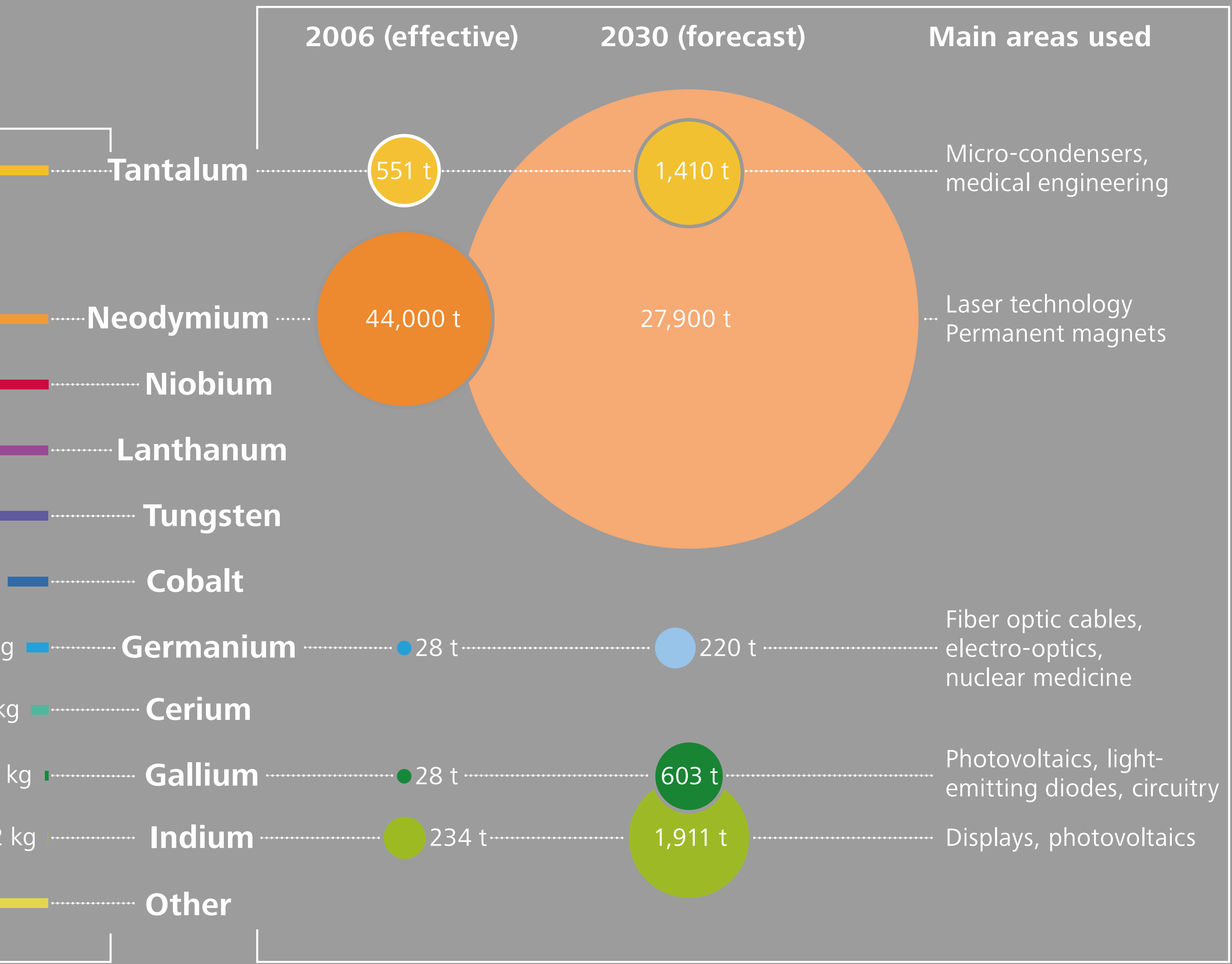
The metals especially lie dormant in circuit boards in electronic devices. And they are also found in monitors, LED lamps and the read heads of hard drives.



– in its drawers

Consumption increases with new technologies

How the demand for rare metals might develop in key application areas all over the world in years to come:



INFOGRAPHIC: BEOBACHTER/AS

Nanoparticles – invisible threat?

TEXT: Rainer Klose and Selina Chistell / PICTURES: Empa, iStockphoto, agefotostock

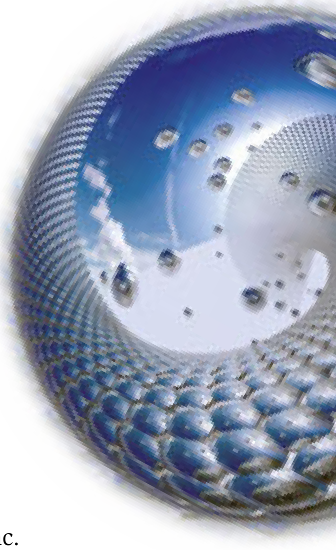
The production of tiny particles and their industrial use is deemed a key technology of the 21st century. Nanoparticles revolutionize many applications – from industrial products such as sunscreens or waterproofing agents for wood all the way to therapeutics. However, their manufacture, usage and disposal can also harbor risks for humans and the environment.

In order to pinpoint and minimize these hazards, but also to seize the opportunities the technology has to offer, the Swiss National Science Foundation (SNSF) launched the National Research Program "Opportunities and Risks of Nanomaterials" (NRP 64) in 2010. The five-year interdisciplinary program is due to finish at the end of 2015. Empa has played an instrumental role in NRP 64 and is in charge of 5 of the 23 projects.

Before the results are published next spring, we'd like to seize this opportunity to take stock. In the following pages, we present the five Empa projects and some of the results achieved so far.

Final destination: sediments

Nanoparticles are already found in numerous consumer products such as cosmetics and textiles, and enter the wastewater when we wash and shower. From there, they gradually spread in nature. What impact do they have on various ecosystems? Where do the particles accumulate? Empa researcher Bernd Nowack and his team set about studying material cycles in Australia.



Tracking nanoparticles in the environment is no mean feat: Currently, there aren't any methods to determine trace concentrations of nanoparticles in environmental samples, so researchers have to trace material flows and perform computer calculations. One interesting model region is South Australia. Firstly, the region is highly developed; secondly, it recycles urban wastewater and uses sewage from municipal treatment plants to fertilize fields. As it rarely rains there, barely any of the sewage is washed into the rivers. Hence, a kind of "closed loop" for nanoparticles exists.

In a study published in the journal Environmental Science: Nano, a team headed by Bernd Nowack calculated the annual mass flow for four different nanoparticles on fields and in sediments from various bodies of water. The model calculation revealed that 54 tons of nano-titanium dioxide, 10 tons of zinc oxide, 2.1 tons of carbon nanotubes, 180 kilograms of nano-silver and 120 kilograms of fullerenes – so called buckyballs – are processed in South Australia each year and eventually end up on the market as components in other products.

The fate of the particles varies greatly: fullerenes and carbon nanotubes are predominantly used for synthetic composites. These particles remain embedded in the synthetic parts and wind up with – or rather in them – on a garbage dump. Nano-zinc oxide, which is used in cosmetics, for instance, is chemically converted into other zinc compounds in sewage treatment plants. As a result, the nano-effect is lost and it can no longer be distinguished from "normal" zinc. It's a similar story with nano-silver, which is turned into silver sulfide – a black metal salt that is not readily soluble and is also formed from "normal" silver.

Nano-titanium dioxide – a popular component in sunscreens – on the other hand likes to go walkabout. Titanium dioxide itself is a non-toxic, white substance used in its conventional form in white wall paint and toothpaste. Titanium dioxide nanoparticles are extremely stable. According to the model study, almost three tons of South Australia's annual consumption (around 5.5 percent) ends up in the ocean. The rest is sprayed on the region's fields in the form of sewage or compost. The model calculation reveals that the concentration in certain soils rose from 9.5 micrograms per kilogram of soil to 450 micrograms per kilogram in just seven years – that's over 40 times more. Whether this permanent "disposal" of nanoparticles in the soil affects health or the environment, however, remains to be seen.

According to the researchers, not only will it in future be necessary to calculate the nanoparticles' path in dry regions like South Australia, but also the transportation of the particles in rivers and marine sediments. This is the only way to assess exactly where and in what amounts these materials eventually accumulate. //

Every sunbathing session spreads nanoparticles in the environment. The long-lived particles, which contain titanium dioxide, eventually end up on agricultural land and in sediments in the sea.

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Gone with the wind

Waterproofing agents that contain copper salts protect wood against rot and wood-destroying fungi. They have been used all over the world for more than a century. Compounds with copper nanoparticles have been on the market in the USA since 2006 and thousands of tons of these sprays are used every year. But what happens when this timber is recycled or does eventually rot?

Children's playgrounds, walkways, fences, poles and wooden pylons along the roadside all need to be protected against wood-destroying fungi. There is only one substance that combats soft rotting fungi from the soil: copper. Back in the early days, toxic solutions such as copper vitriol, chromated copper arsenate and copper chrome boron were used. Meanwhile, wood is waterproofed with copper carbonate or copper citrate (the copper salt of citric acid), which inhibits the metabolism of fungi but is harmless for mammals. Various wood preservatives containing copper carbonate particles that measure between one nanometer and 25 micrometers have been on the market in the USA since 2006. According to the manufacturers, the particles soak deeper into the wood during waterproofing than conventional liquid copper salt solutions, which is why the protection they offer lasts longer. The manufacturers would now like to expand their business on the European market, where refractory types of wood, such as Norway spruce (Picea abies) or Swiss pine (Abies alba), are primarily processed.

The problem: there are also wood-destroying fungi that are copper-resistant. These fungi from the pore sponge family (such as the Antrodia, Postia and Serpula species) store the copper in their cells and shut it away, which begs a question: can the fungi also store copper nanoparticles, multiply and eventually scatter the nanoparticles in the environment in their spores? After all, humans breathe in between 20,000 and 30,000 fungal spores every single day. Empa researcher Chiara Civardi set about investigating this hypothesis with support from Peter Wick, a specialist in nanoparticles, and Francis Schwarze, an expert in wood fungi.

Their first move was to treat spruce and fir wood with the novel waterproofing agents and incubate it with fungi. The researchers then examined questions such as: does the fungus absorb the smallest particles, which are one nanometer in size? Or only the larger microparticles? Do the particles actually penetrate the wood more effectively and, if so, does this increase the wood's durability? The team's next move was to follow the "fate" of the copper particles absorbed by the fungus. How quickly do the particles dissolve in the fungal cells? Do they get into the spores? Do they leave the waterproofed wood and enter the air, soil or even the food chain? //

Wooden telephone poles are still a common sight, especially in the US. As they are meant to last for decades, they are waterproofed with copper nanoparticles, which are supposed to keep rot fungi from the soil at bay. But where do these nanoparticles end up when the wood does eventually rot?

When polymers bare their teeth

Embedded in synthetic polymers, carbon nanotubes convey new properties to the composite material: the part becomes more break-proof and conducts heat and electricity a lot better. But what happens if the part is sawed, sanded or drilled? Are carbon nanotubes released in the process? And if so, is this harmful to our health?

There is a wealth of toxicity studies on free carbon nanotubes (CNTs) and many more on dust formation when CNT-reinforced synthetic polymers are sanded. A number of research teams analyzed this dust in cell and animal experiments, and failed to detect any additional health hazard compared to normal synthetic dust. However, nobody counted exactly how many CNTs are actually released during the sanding and sawing process.

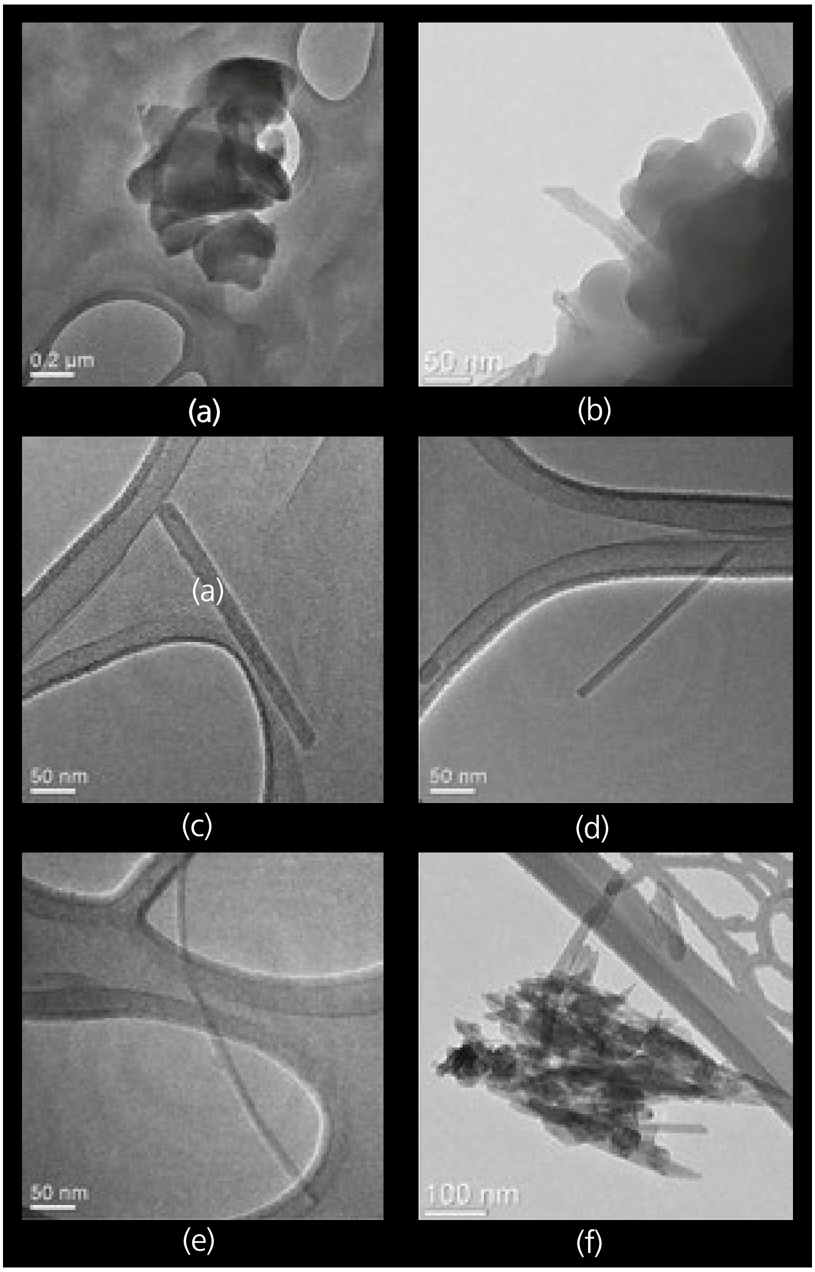
An Empa team headed by Jing Wang and Lukas Schlagenhauf has now succeeded in doing so for the first time. For their tests, the researchers added a certain quantity of lead ions to industrially manufactured CNTs and created a CNT-reinforced synthetic polymer. The test block was then rubbed down using a technique that Schlagenhauf already developed three years ago: he combines a standard scientific sanding device with a special suction system to capture the released dust particles.

Finally, the dust is treated with acid, which releases all the lead ions from the exposed CNTs as only free CNTs come into contact with the acid. Nanotubes that are still completely enclosed by the synthetic material mixture, on the other hand, do not give off any lead ions. Consequently, it is possible to accurately quantify the CNT dust for the first time; the amount of lead ions in solution is proportional to the number of exposed CNTs.

The researchers then used an electron microscope to verify the dust particles and document the free or partially exposed CNTs. Finally, they tested the dust on various cell cultures. The result: CNT dust is not acutely cytotoxic, which the researchers attribute to the fact that only very few free CNTs were detected in the dust particles. The connection between toxicity and the dust's surface properties was, therefore, established for the first time. Possible long-term health effects, however, are yet to be studied and cannot be ruled out.

In the next step, the researchers would like to investigate the mechanisms that release the nanotubes. They want to compare different material mixtures and analyze the dust at higher temperatures. //

Many synthetic materials are reinforced with carbon nanotubes. If the surface is sanded or holes are drilled in the material, parts of the nanotubes are exposed. They are clearly visible under the electron microscope.



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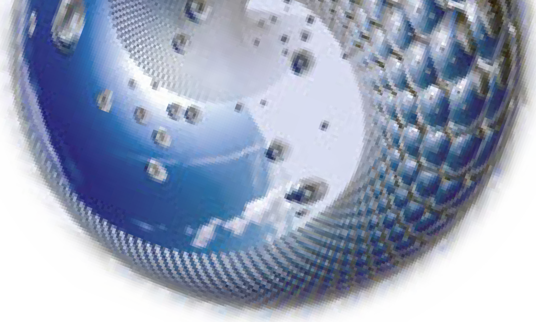


Shuttle service through the placenta

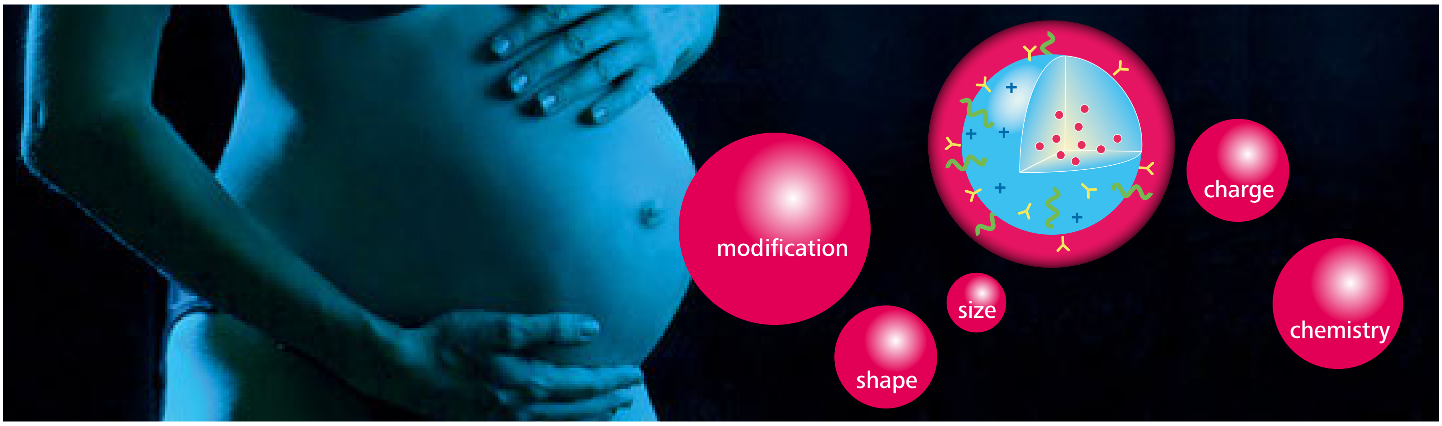
Barely a few decades ago, the placenta was regarded as an impermeable barrier between mother and child. Ever since the sleeping pill Contergan caused deformities, however, we know better. Nicotine, heroin and various environmental toxins also get through to the fetus. Does the same hold true for nanoparticles?

The placenta is a complex organ that is responsible for the exchange of oxygen and carbon dioxide between the mother and child, as well as the transport of nutrients and metabolic products. But it also keeps the mother's bloodstream separate from her unborn child's. Anyone who wants to study how the human placenta works can use data from animal experiments only to a limited extent as the placenta functions very differently from one species of mammal to the next. One alternative is to conduct research on an *ex vivo* model, i.e. on placentas that mothers donate for research purposes after a C-section. Thanks to nutrient solutions, the organs can remain intact for several hours and document the transport of substances through the tissue. This ex vivo study method was first applied in the early 1970s and has been honed continually ever since.

Peter Wick and his team joined forces with MDs from the University Hospital Zurich and Kantonsspital St. Gall to investigate whether tiny polystyrene particles are able to pass through the placenta. The result: particles up to 80 nanometers in diameter passed through the barrier and would have reached the fetus. 500-nanometer particles, however, were stopped in their tracks. What's more, the team also discovered that the nanoparticle shuttling is not passive diffusion. In other words, the particles don't simply seep through the tissue, but are actively transported through the placenta via a mechanism that is yet to be elucidated. A considerable proportion of the particles accumulates in the so-called syncytium, the first cellular barrier layer.

Besides experiments using polystyrene particles, which remain chemically unchanged in the body, the researchers are now looking to study the transport of metal oxide particles or other chemically active substances. The goal is not merely to understand the exchange mechanism of the human placenta, but also to recognize rules with a view to using nanoparticles diagnostically or therapeutically in future. If the mother falls ill, for instance, the drugs could thus be prepared in such a way that the active substances are only administered to the pregnant woman and not to the unborn child. //

The placenta isn't a completely impenetrable wall. Alcohol and drugs can get past the barrier between the mother's and child's bloodstreams and damage the fetus. Nanoparticles of a certain size also pass through the placenta while others are stopped in their tracks. Might this effect be used to encapsulate medication so that only the mother actually receives the drug?



Bone replacement from nanofibers

Bone replacement implants need to be made of biodegradable materials to enable the body to incorporate them into its own bone tissue and eventually replace them during the healing process. Ideally, the replacement material should be as solid and resilient as real bones. Are nanofibers the answer? And how does the immune system react?

Can bones be fashioned from nanofibers? Pieces of bone can be lost through disease or accidents. These need to be replaced with an implant, which dissolves in the body. The problem: as yet, no such material exists.

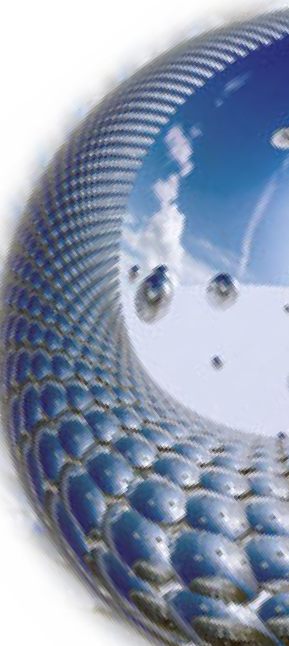
If part of a bone is lost in an accident or due to illness, the missing piece can be replaced with artificial bone material. The bone substance is constantly built up and broken down again in the body, with the result that our entire skeleton is completely renewed within a few years. This is the only way the body can grow and adapt to physical strains as the bones don't become brittle as rapidly and bone fractures generally heal well.

A bone replacement material is supposed to "join in" this physiological construction and breakdown process and, in an ideal scenario, eventually dissolve and be replaced with the body's own bone. In the past, bone was removed from the patient's iliac crest and implanted for minor defects. Larger defects were frequently replaced with bone that had been removed from corpses, sterilized and used as an implant. Research is on the lookout for more ethically acceptable, synthetic materials made of ceramics. So far, however, both the strength and breakdown of the replacement material in the body has posed a problem in larger quantities.

Katharina Maniura's team examines the interfaces between synthetic materials and biological systems. Teaming up with the RMS Foundation and researchers from the University of Bern, the Empa team studies nanofibers made of biodegradable polymers. Such fibers could also give ceramic bone replacement cements the crucial break resistance that such a material needs.

In the first part of the project, thin fibers were produced in collaboration with Empa's textile experts. The fibers are only 200 nanometers in diameter and made of polylactide – a synthetic material that is broken down into harmless lactic acid in the body. The fibers are then mixed with ceramic nanoparticles and cut up in an ultrasonic bath to produce nanofibers that resemble short staples and hold the bone replacement material together more effectively.

The next step is to add these fibers to calcium phosphates and mix them into a cement. Calcium phosphates are also broken down by the body and converted into bone substance. Tests on cell cultures and animals are expected to reveal that these biodegradable composite materials are highly biocompatible. The aim of the research project is to produce molded bodies, supports, and even plates and screws from biodegradable yet solid material. Such an implant wouldn't need to be removed once fitted – which spares the patient a second operation. //



Setting sails for the energy turnaround

Corsin Battaglia converts energy.

Corsin Battaglia joined Empa as head of the new Materials for Energy Conversion lab about a year ago. Topics such as batteries, renewable fuels, photovoltaics and thermoelectrics require a broad knowhow and a healthy dose of experience, which Battaglia not only gathered at various universities the world over, but also through his hobbies, music and sailing. And they have more to do with research than one might think.

TEXT: Cornelia Zogg / PICTURES: private

There is a wealth of – quite literally – hot topics in the energy sector," says Corsin Battaglia. And his lab, Materials for Energy Conversion, deals with the hottest of the lot: the conversion and storage (in a suitable form) of energy. The subject is becoming increasingly important, whether it be in the development of new, more efficient batteries, renewable fuels or issues related to photovoltaics and thermoelectrics.

But why bother to convert energy that is already available into another form in the first place? In a nutshell, not all forms of energy provide power around the clock. Electricity from photovoltaic power plants, for instance, depends on the weather and is difficult to store on a large scale for the long term. As a result, a surplus develops in the summer while there is a threat of shortages in winter months – or we have to fall back on non-renewable energy sources, such as fossil fuels or nuclear power. Battaglia's team is, therefore, working intensely on new batteries that are able to store electrical energy cost-effectively and on technologies that can be used to convert electricity into renewable fuels – which could then be stored forever.

The quest for the Holy Grail

But there is also plenty of potential in the opposite direction. One energy source that is barely used is waste heat, for instance, which accumulates in large quantities in many industrial processes, the increasingly more common computer centers and even car engines. Waste heat can be converted back into electrical energy via "thermoelectric converters". "Electricity is the most valuable form of energy and can be used virtually everywhere," says Battaglia. Converting the less valuable waste heat back into electricity is the Holy Grail of energy research. Initial attempts to find it are already underway.

However, Battaglia is not merely interested in purely academic materials science. Instead, he would like to implement his results in practice to bridge the gap between research and industry. On behalf of the Swiss Federal Office of Energy, Empa researchers are currently studying the potential of thermoelectrics and various competitive processes for the use of waste heat – with a view to launching them on the market as fast as possible. Photovoltaics has already hit the market – a case in point that, according to Battaglia, we can learn a lot from: "How does technology reach the market? How does upscaling work? What does new technology need to do to actually make it on the market? These questions are also extremely important for all our other subject areas."

Starting from scratch

He already acquired a nose for practice at an early stage in his career, such as at the University of California in Berkeley. He brought a great deal from his time in the US back to Switzerland – including a certain willingness to take risks. "In Switzerland, you think twice about whether something will actually work and whether it is all worthwhile a bit more than elsewhere," he explains with a wink. "Plus you're inundated with assessments." On the other hand, Swiss start-ups tend to survive more frequently (and for longer) than in the US.

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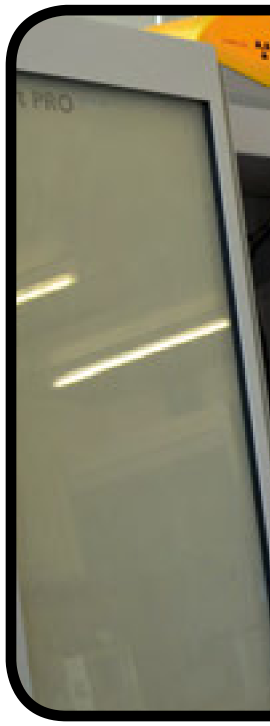
He learnt the knack of improvising and fending for himself on his very first day in Berkeley. Battaglia: “When I arrived at the lab I was greeted by precisely four utensils: microscope lenses, tinfoil, duct tape and razor blades. That was it.” But you can already work wonders with these items, especially if you’re a keen sailor, like Battaglia. Sometimes, out at sea, you haven’t got the right tools, either – such as out on San Francisco Bay when his rudder was torn clean off by a hefty gust of wind. So he knew how to look after himself in the lab, too, and cobbled together the equipment he needed off his own bat. “It’s a different story here in Switzerland,” he says. “As a researcher if you need something, the institute usually hands it to you on a silver plate.”

Then his network in Berkeley gradually began to grow. His expertise in surface physics and photovoltaics went down particularly well at the new Joint Center for Artificial Photosynthesis at the Lawrence Berkeley National Laboratory. “Every week, a pallet full of new equipment was delivered and the Center didn’t have enough staff to set it all up. I offered to help out and thus managed to get my hands on the equipment by the back door.” While Battaglia primarily concentrated on developing novel solar cells in Berkeley, a number of interesting sub-projects also came about. For instance, he used transparent conductive layers that he had originally developed for solar cells to construct transparent electronics. “A bit like the famous scene in Minority Report, the Spielberg film starring Tom Cruise, where Cruise’s character cuts and pastes pics and video sequences on a transparent computer screen with his fingers,” explains Battaglia enthusiastically.



The key to success? Creativity!

However, his path into physics was not exactly clear-cut. After leaving school, he pursued his dream of becoming a musician – and making a living from it. It was in his blood, after all: his father was also a musician and conducted large orchestras. His mother, however, was less keen on his career plans. “One musician in the family is plenty; study something decent,” she urged her son. So Battaglia settled on electricity and eventually physics through his passion for electric guitars.

But he didn’t give up music. Quite the contrary. He often jams with his recently formed jazz band. The secret is the interaction with other musicians. “The bass player begins with a riff, then I come in, followed by the drummer, and that’s how you keep bouncing new ideas off each other until something new, something creative suddenly takes shape.” And that’s exactly how it goes in a decent research environment, too. Brainstorming with colleagues from other disciplines often sparks off astonishing ideas. One person’s input might trigger a creative neuron in someone else and before you know it something new has developed.

But as Battaglia points out, this is only possible if everyone involved has a broad and profound (specialist) knowledge. Good musicians spend years or even decades practicing; it’s no different in research. “Everyone brings his or her rucksack to the table and everyone contributes. It’s such a huge advantage that this kind of multidisciplinary exchange takes place here at Empa.” He also encourages it within his lab. Every Tuesday, the various research groups meet and draw inspiration from their colleagues’ latest findings.

> “Interaction is the key to success in both music and science: you keep bouncing ideas off each other – until something new, something creative takes shape.”

Cue the orchestra

The priority for his lab, however, is to establish a coherent research program that attracts both national and international interest. But – as per usual at Empa – it is also important for him to get industrial partners on board. “I’ve already managed to do that in photovoltaics,” he says, brimming with confidence. “I hope we’ll be able to do so successfully in other subject areas, too.” This bridge between research and industry is promoted more at Empa than virtually anywhere else. “Here at Empa, we have researchers from all walks of science – physicists, chemists, materials scientists, electrical engineers etc. And I think that’s our strength.” Like in music, this helps new approaches and creative ideas to blossom. “The research work is very inspiring,” says Battaglia, “which is what I like most of all.” In other words, not only shine as a soloist, but conduct an entire orchestra of creative minds. //

Work methods inspired by jazz concerts: Corsin Battaglia in the lab.

INTERVIEW: Letizia Krummenacher / PICTURE: Empa

…in demand

“I like Empa’s community spirit. It makes new research results accessible for everyone, not just companies that can afford it.”

As a design engineer with Bruker BioSpin AG, Olivier Zogmal knows the properties of metal, ceramics and steel like the back of his hand. But that doesn’t stop him from attending events at the Empa Academy on a regular basis to keep bettering himself. Last year, for instance, he discovered the solution to a problem that he didn’t even realize was one.

Mr. Zogmal, as a pragmatic you’re primarily interested in Empa’s specialist courses. Are they worth the money?
Empa communicates an enormous amount of knowledge in only one day for a reasonable price. I’d have to fork out four times as much for other courses. I like Empa’s community spirit of making new research results accessible to everyone and not just people or companies who can afford it.

What do you take away from the courses that helps you in your everyday working life?
I always find an expert at the courses who can help me solve specific problems from work. Once, for instance, I even had a Eureka! moment that prompted me to make an immediate change.

What exactly happened?
At the “World of Steel” course last year, I was fascinated by the wide variety of steels that Empa developed. But to my astonishment, I discovered that we’d been using a stainless steel for welding in one of our products that wasn’t exactly ideal for the job. Immediately after the course we swapped it for another more suitable one.

What kind of course are you missing?
None. The course program is just the right mixture. There are courses for pragmatics like me, classes for researchers and industry, and even talks for the general public that provide an overview of the current state of the art.

To whom would you recommend the courses at Empa?
Anyone who has a particular question or technical problem will find the right experts and support at one of the talks, sessions or courses at Empa.

gasmobil

EMPA AKADEMIE

Zentrum für Wissenstransfer

TAGUNG

11. Gasmobil-Symposium

Treibstoffwende mit Erdgas/Biogas

Empa, Dübendorf, Überlandstrasse 129
Mittwoch, 28. Oktober 2015
10.00 – 17.30 Uhr

Online-Anmeldung: *www.empa.ch/gassymp*

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