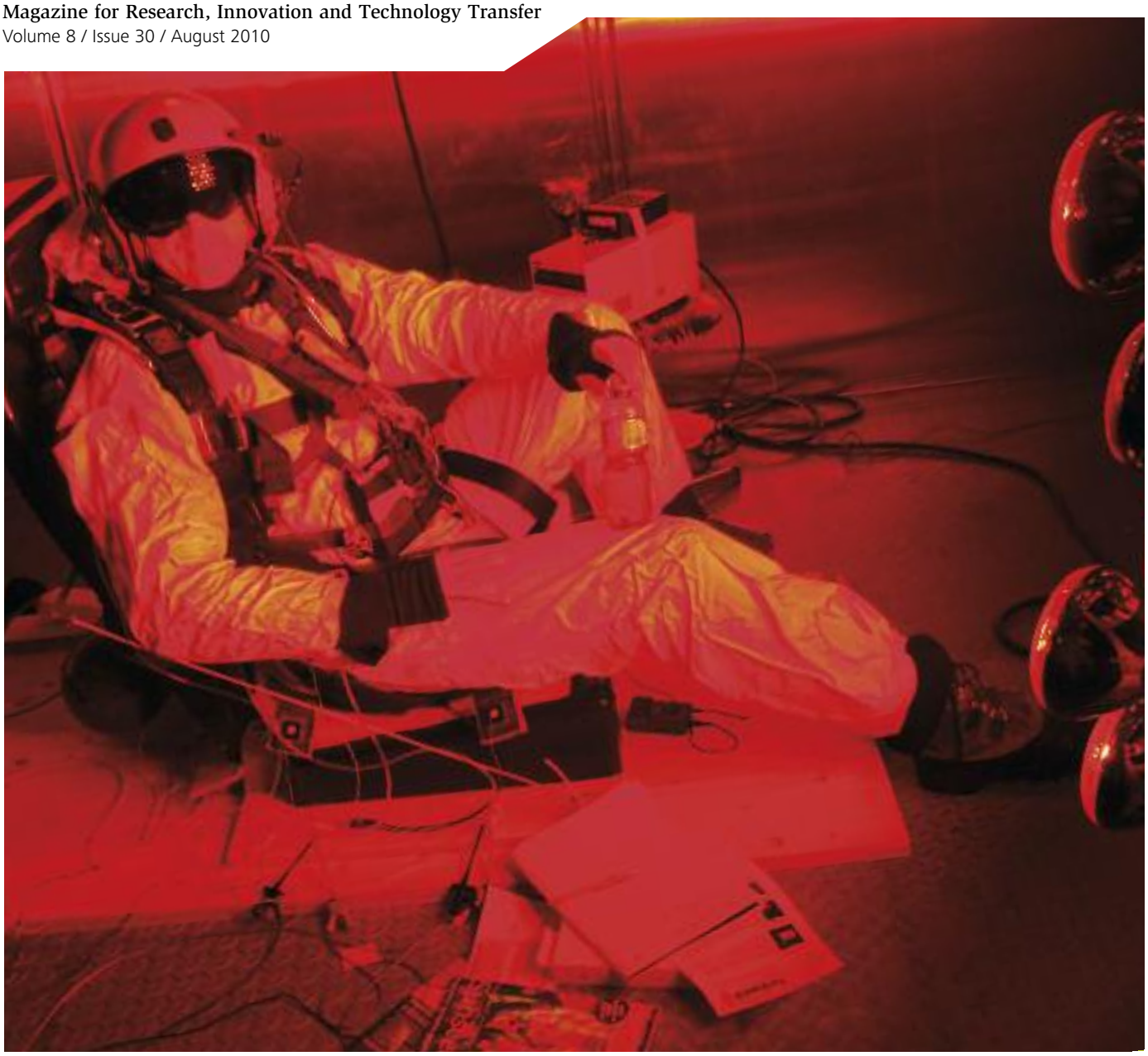
EmpaNews

Magazine for Research, Innovation and Technology Transfer
Volume 8 / Issue 30 / August 2010



Solar Impulse – comfort for pilots under extreme conditions 18

EMPA
Materials Science & Technology

Cleantech: because we have no other choice

Empa has taken off – from 7 to 8 July, the "Solar Impulse" aircraft successfully made its first night flight, and the pilot, André Borschberg, was "wrapped up" almost completely in Empa technology. His suit, designed for both protection and comfort, along with the matching seat, were developed by Empa researchers especially for this showpiece project to protect Borschberg as well as the second pilot and co-initiator Bertrand Piccard from the extreme conditions in the cockpit. This cockpit gear is helping to make it possible for the first time to circumnavigate the globe without any fossil fuels whatsoever, using only solar power.

The Solar Impulse team is pursuing a lofty goal – to put renewable energy in the spotlight and thus get the general public to rethink their ideas so that we preserve some of our natural resources for future generations. Or, as Piccard said during the press conference to mark the first overnight trial in Payerne, "We want to show everyone on this planet that we're not so heavily dependent on fossil fuels as we've always thought."

That's why Piccard and his team fit perfectly into the Focus section of this latest edition of *EmpaNews*. This section is dedicated to Cleantech, in other words the clean technologies of tomorrow which will have the least possible impact on the environment and will help to preserve natural resources. Because one thing is certain – we can't continue to do "business as usual".

Empa has long been heavily involved in the area of environmentally friendly technologies, and that's not just since the recent emergence of the hype around Cleantech. In three of the five Research Focus Areas at Empa – Natural Resources and Pollutants, Materials for Energy Technologies and Sustainable Built Environment – the central focus of our efforts has been on sustainability. In this issue you can find a few specific insights, just a couple of examples being energy-efficient powertrains and renewable energy.

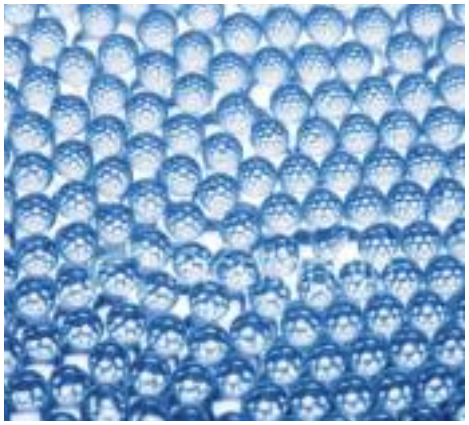
Enjoy your reading!

Michael Hagmann
Head Communications

Non-destructive & automatic
Monitoring system for Europe's roadways 04

Cover

To make sure the pilots of Solar Impulse neither perspire nor freeze during the flight, textile experts at Empa delivered a special clothing system. André Borschberg, CEO and co-founder of Solar Impulse and the pilot of the very first night flight in a solar aircraft, in Empa's climate chamber.



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Imprint

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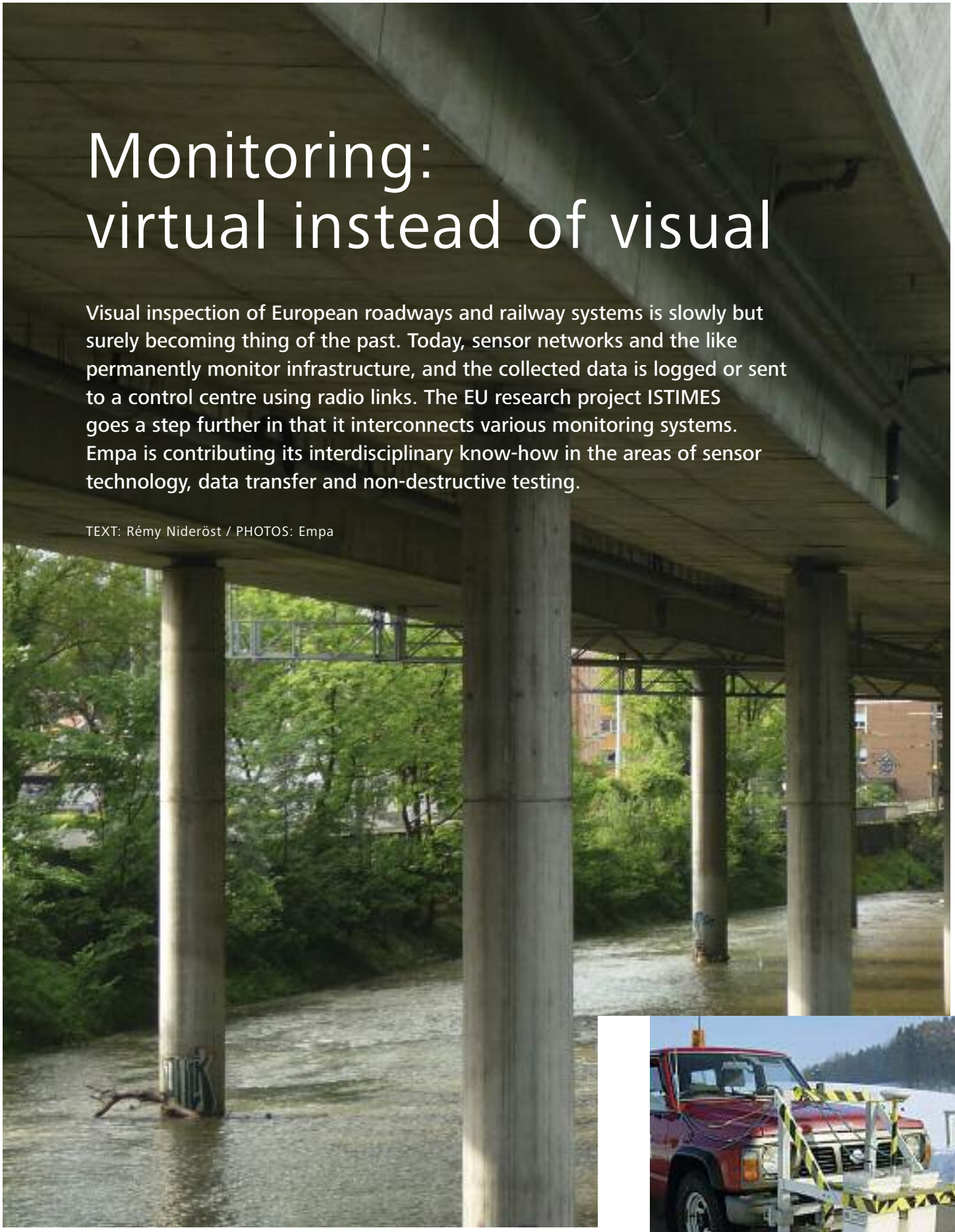
Published quarterly

ISSN 1662-7768

Monitoring: virtual instead of visual

Visual inspection of European roadways and railway systems is slowly but surely becoming thing of the past. Today, sensor networks and the like permanently monitor infrastructure, and the collected data is logged or sent to a control centre using radio links. The EU research project ISTIMES goes a step further in that it interconnects various monitoring systems. Empa is contributing its interdisciplinary know-how in the areas of sensor technology, data transfer and non-destructive testing.

TEXT: Rémy Nideröst / PHOTOS: Empa



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Europe runs a tightly woven and heavily travelled network of roads and railways. On motorways, for instance, heavy traffic regularly leads to congestion and also causes road damage. Moreover, in Alpine regions, bridges and tunnels "suffer" under harsh weather conditions. The same holds for the railway network; ever more trains are travelling faster and putting the infrastructure to the test. Continuously monitoring all these transport routes for damage is a difficult assignment – from the standpoint of finances, personnel and because of the associated impairment of the traffic flow.

Although visual inspections and destructive tests such as bore holes continue to play an important role, today much of the monitoring is fully automated and non-destructive. On heavily travelled stretches as well as on bridges and in tunnels, integrated sensors often continuously measure loads and register possible changes.

For instance, loads on the stay cables supporting Winterthur's "Storchenbrücke" are measured and the data is transferred over a radio link directly to Empa in Dübendorf where it is evaluated. This bridge is being monitored in particular because two of its two dozen stay cables are not made of the usual steel but instead consist of considerably lighter and noncorrosive carbon-fibre reinforced polymers, an Empa development and a world's first when the bridge was erected in 1996.

Automation – taken to the extreme

The EU research project ISTIMES (Integrated System for Transport Infrastructure surveillance and Monitoring by Electromagnetic Sensing), which was launched at the end of 2009, is taking this concept a great deal further. During the next three years, this project, which is being sponsored as part of the Seventh Framework Programme, will develop an integrated monitoring and surveillance system for transport infrastructures. It is based on various electromagnetic sensors which monitor parameters such as temperature, moisture, vibrations or motion, all of which will be integrated into an automated network. Research institutes, public authorities and corporate partners from seven European countries are participating in the project, with Empa being the sole Swiss "representative". The project's goal is to create a reliable monitoring system which will then be built into and tested on two structures, a motorway bridge (the Sihlhochstrasse in Zurich) and a rail tunnel in the southern Italian region of Potenza.

Empa contributes its ground penetrating radar know-how

A first key task consists of determining which data are at all meaningful and therefore should be transmitted and evaluated. Empa is leading this work package, while the entire project is being managed by the Italian consortium TeRN (Earth Observation and Natural Hazard Technologies Consortium), which invited Empa to join ISTIMES. This is not least because of Empa's highly regarded work in the area of non-destructive testing of transport infrastructure by means of ground penetrating radar, a technology that will play an important role in the project.

The process is based on an electromagnetic signal which is radiated from an antenna. The signal's reflections, which arise at a boundary layer such as the underside of the road pavement, are logged and evaluated. The mobile system allows efficient examination of roads and bridges with minimal disruption to the traffic flow. The radar studies indicate, for example, the thickness of the asphalt layer or the condition of reinforcements in the concrete. And in railway lines, ground penetrating radar can be used, for instance, to detect the condition and thickness of the ballast bed. In future, such ground penetrating radar is also expected to be built into buses or trains so that the condition of a section of transport infrastructure can be studied continuously; on the Sihlhochstrasse the ground penetrating radar might, for instance, be mounted on a metropolitan bus.

Warnings – before something happens

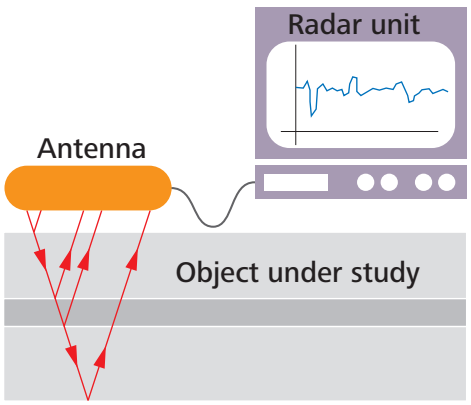
In addition, the other ISTIMES partners are adding their expertise to the project. For example, a Norwegian company is delivering important optical elements for certain sensors. A Romanian company specialises in aerial photographs which, combined with altitude measurements carried out by satellites, provide information about changes in the terrain. With such systems, the ISTIMES monitoring system could, for instance, issue an early warning if a hill and a bridge standing on it are about to slide. //

1
The Sihlhochstrasse, an elevated motorway in Zurich, one of the research targets in the EU project ISTIMES.

2
Mobile ground penetrating radar system from Empa for the monitoring of roads and bridges.

3
How ground penetrating radar works: an electromagnetic signal radiated by an antenna penetrates the object under study and is reflected, for example, at a boundary layer. These reflections are received by the antenna and provide information about the structure of the layers.

4
An approximately 300 m long radar longitudinal profile of a bridge: the red arrow indicates the asphalt-concrete transition, the green arrow the upper reinforcement layer. In this way, the thickness of the asphalt and the depth of the reinforcement layer in the concrete can be determined.



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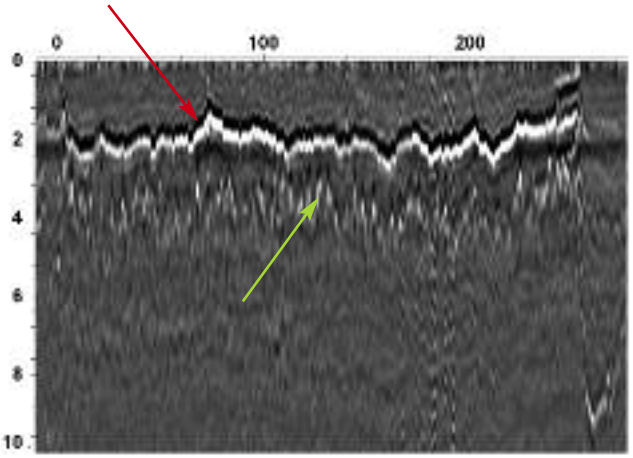

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It's all about the method

All too frequently it is only after new technologies have been developed and deployed that research into their safety is conducted, and obviously this research can only take on a reactive role. In contrast, the emerging area of nanotechnology offers the opportunity to zero in on risks and hazards prior to the widespread application of "nano". Empa is among the world's leading institutions when it comes to establishing standardised – and thus meaningful – methods for evaluating nano-risks.

TEXT: Beatrice Huber / PHOTOS: Empa, iStock

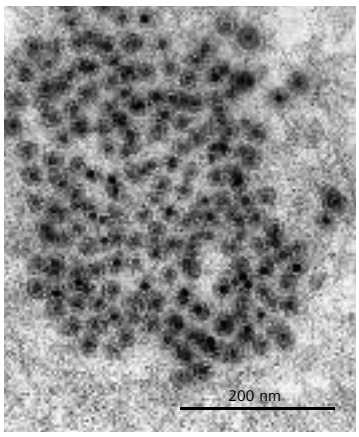
New technologies can be a mixed blessing: they often harbour the potential for both good and harm. Nanotechnology is no exception. But while with other technologies the supposed and actual risks are often determined only after the technology has been put into widespread use, with nanotechnology the aim is to proceed the other way around. Countless projects worldwide are pursuing the goal of evaluating all the possible risks and hazards associated with nanomaterials. The nanotoxicologists at Empa are part of this effort, and in this they're focusing primarily on establishing reliable test procedures.

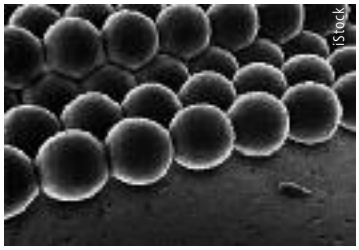
Only standardised tests allow meaningful conclusions

Previous studies on the toxicity of nanomaterials, in other words how poisonous they are, frequently led to contradictory results. Depending on the guinea pig (such as different types of cells or organs) and the procedures used to conduct the testing, nanomaterials have sometimes been found to be dangerous, sometimes harmless. This is not the type of result that could (and should) be expected from meaningful studies. Meanwhile more emphasis is being placed on the realisation that only standardised test methods and procedures can deliver reproducible results. "Only the validation of experiments leads to reliable conclusions," says Harald Krug (see interview below).

In 2008, as part of the International Alliance for Nano Environmental and Health Safety Harmonization, Empa and other research institutes around the world gathered together in order to establish robust meth-

"We want to make reliable statements about risks and hazards."





Nanomaterials in the spotlight: around the world, with the participation of nano-toxicologists from Empa, countless projects are being conducted with the goal of evaluating their every possible risk and hazard.

ods and standard operating procedures (SOPs). In the meantime, these institutes have already carried out various round robin tests; in other words, multiple institutes carried out identical experiments using the same procedures. They showed that only by using SOPs is it possible to arrive at truly reproducible results.

The VIGO project at the ETH Domain's Competence Centre for Materials Science and Technology (CCMX) similarly devotes itself to the standardisation of biological procedures. Researchers at Empa and the Swiss Federal Institute of Technology in Lausanne (EPFL) are participating by closely examining existing procedures so they can eliminate soft spots. MARINA, a similar project, is being set up at the European level. "With VIGO, Switzerland is already a step ahead of anywhere else in Europe," notes Krug. And VIGO isn't the only project dealing with the risk assessment of nanomaterials where Switzerland is playing a pioneering role.

Precautionary matrix – an aid for SMEs

In addition, the Precautionary Matrix for Synthetic Nanomaterials developed with the collaboration of Empa experts on behalf of the Federal Office of Public Health has met with great interest abroad. After a test phase running a full year, in March 2010 the precautionary matrix became available in a revised electronic version. It is intended to make it easier to recognise uncertainties during the production and handling of nanomaterials, for instance at the workplace, and then to introduce appropriate measures. In this way, especially small and medium-sized enterprises (SMEs), which in contrast to large corporations frequently can't afford a department devoted to workplace safety, have a valuable tool at hand with which they can properly address any existing gaps in their knowledge. As a first result they can estimate whether or not a detailed risk assessment is called for.

DaNa ensures transparency and informs

Consumers as well have the right to be informed about the benefits and hazards associated with nanomaterials. This opinion is shared by the DaNa project partners including Empa along with five German institutes. DaNa stands for the acquisition, evaluation and widespread public presentation of Data and findings about Nanomaterials which are relevant to society. The project website is intended to bring clarity to existing knowledge and also to inform about gaps in our knowledge. Under *www.nanopartikel.info* consumers are provided with a serious, understandable source of information about nanomaterials and other aspects of nanotechnology. DaNa is a follow-up to the recently completed NanoCare project which was financed by the German Federal Ministry of Education and Research. //

For 20 years, Empa toxicologist **Harald Krug** has been working with nanotechnology to assess its possible benefits and risks. He talks about the safety research taking place at Empa with *EmpaNews*

Mr Krug, why is Switzerland so committed to safety research?

Well, safety research has long been a part of humankind's history with technology. Even the ancient Romans observed that certain working conditions, for instance in mining, could have negative effects on a person's health. Safety research always has mirrored and continues to mirror a country's culture and its willingness to be open to self-examination. For Switzerland, which can remain competitive only through top-notch innovations, safe products are absolutely essential. That's why it invests in safety research.

What are some recent developments in nano-safety research?

Until now, we were generally a step behind emerging technologies and thus were only able to react. Nanotechnology now offers us a chance to be proactive. So-called parallel safety research runs in tandem with the development of nanoproducts, in other words, before hundreds of tonnes of nanomaterials find their way into the environment.

What is Empa's role in all this?

We are among the world's leading institutions in the area of nanotoxicology. We conduct research not only to address specific questions, such as the effect of nanomaterials on immune cells, but also to develop new strategies, methods and procedures so as to achieve the highest possible level of standardisation. This goes hand in hand with the overall strategy at Empa. Our goal is to make reliable statements about existing and possible future risks and hazards. What's especially gratifying about our work is that it's having an impact; people around the world ask for our opinion. //

1

Killing bacteria gently

What influence do manufacturing conditions exert on the properties of novel plasma polymer coatings containing silver nanoparticles? Empa researchers have looked into this question and can now create tailor-made coatings that leverage the properties of silver ions, which kill bacteria while at the same time are gentle to human tissue.

TEXT: Beatrice Huber

2

1
Silver ions are quite efficient at killing bacteria and thus are very interesting for wound dressings. Too much silver, however, can damage human cells. (Photo: iStock)

2
Empa researchers are developing novel nanostructured polymers with embedded silver nanoparticles. These coatings are intended to use silver ions exactly within a therapeutic range. For their fabrication, radio frequency (RF) plasma reactors are employed. (Photos: Empa)

Silver ions are small miracle weapons in the battle against bacteria. They're very adept at killing these microorganisms and are effective against hundreds of bacterial strains. This makes silver extremely popular as an additive on wound dressings or implants. "The more the better", however, doesn't hold true here because high concentrations of silver ions can damage cells and tissue. Therefore the search is on for surface coatings with integrated silver which deliver a therapeutically useful range of silver ions.

Empa researchers led by Enrico Körner and Dirk Hegemann, working within the scope of the EU project EMBEK1 (development and analysis of polymer-based multifunctional bactericidal materials), have developed novel nanostructured polymer coatings. "We're investigating the impact of manufacturing conditions on the film structure and how this in turn affects the release of silver ions," explains Körner, "because this release is what ultimately determines the coating's antibacterial effectiveness."

Firmly embedded silver nanoparticles

The coatings are fabricated within RF plasma reactors. Inside them, the polymer coatings are deposited on top of a substrate. The gases ethylene (C_2H_4) and carbon dioxide (CO_2) serve as raw materials. The required electrical energy is supplied by electrodes whereby the process remains near room temperature. In order to embed silver nanoparticles firmly in the plasma layer, one of the electrodes is made of pure silver.

The Empa team varied individual process parameters such as the ratio of the two gases and the power supplied to the electrodes. They discovered that increasing the ratio of CO_2 to C_2H_4 leads to smaller silver particles, that more silver gets embedded, and that it gets distributed more homogenously. And while increasing the input power promotes the integration of nanoparticles, doing so allows them to grow larger. Finally, through kinetic experiments the researchers investigated which layers release how many silver ions, and they evaluated the results in the context of antibacterial and cell tests carried out in parallel. "We have determined a range for the silver nanocomposite coatings within which they exhibited antibacterial properties and yet were found to be cytocompatible, that is, gentle on cells," summarises Körner.

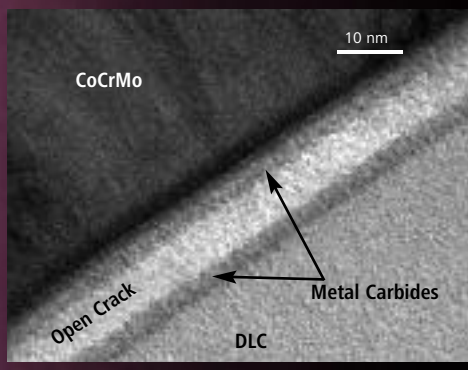
But the work is going even further. The results can now be used to transfer the deposition process from the laboratory scale to Empa's in-house pilot plant, the first step towards industrial production. In addition, the researchers are attempting to create gradients in the coatings to enable a more controlled release of silver ions over time. //

Literature: "Formation and distribution of silver nanoparticles in a functional plasma polymer matrix and related Ag+ release properties", E. Körner, M. Aguirre, A. Ritter, G. Fortunato, J. Rühe and D. Hegemann, Plasma Processes and Polymers, online on 22 June 2010.

Can implants last forever?

Extra-hard coatings made from diamond-like carbon extend the operating lifetime of tools and components. In artificial joints, however, these coatings often fail because they detach. Empa researchers studied the coatings and found out why.

TEXT: Rémy Nideröst / PHOTOS: Empa, iStock



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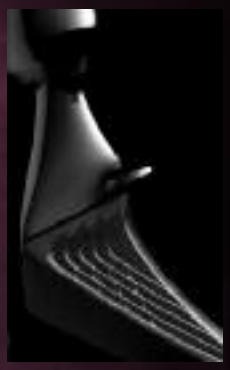


2

1
The failure mechanism has been discovered – coatings made of diamond-like carbon (DLC) can detach from implants if cracks and crevices (the light area) build up in the reaction layer between the implant material and the DLC substrate.

2
Together with several partners from industry, Empa developed a method to predict the expected operating lifetime of a DLC-coated implant in the human body.

Whether on computer hard discs, saw blades, embossing tools, razor blades or fuel-injection nozzles, extremely hard coatings made of diamond-like carbon (DLC) have long proven their value. They reduce wear and thereby give tools and components a longer operating lifetime. What could be more logical than to apply DLC to medical implants such as artificial joints? After all, wear is a problem here, too.

DLC has withstood endless *in vitro* tests in manufacturer's laboratories and has shown itself to be well tolerated by human tissue, extremely hard wearing, and resistant to the relatively aggressive environment in the human body. Despite this, when DLC-coated joints were first implanted into human patients, serious problems arose after a few years. The coatings were not worn away, but rather they detached from the implant material for no apparent reason.

Boundary layers under study

In a project financed by the Swiss Innovation Promotion Agency (CTI) and the medical technology company Synthes GmbH, Empa sought out the cause of this detachment. For this, the researchers conducted detailed studies of the boundary layers between the implant material and the coating. When two materials are placed in contact with each other, the result is a reaction layer at the interface between them which is only several atomic layers thick – and thus a new material is formed. The researchers showed that the so far barely considered reaction layer, which is not corrosion resistant, is responsible for the detachment of the DLC layer.

On the one hand, stress corrosion cracking occurred in the reaction layer. The mechanical load in conjunction with the penetration of body fluids led to slow-growing cracks, which in turn caused the DLC substrate to detach little by little. In other cases, crevice corrosion was responsible for the damage. Over time, an aggressive, acidic medium develops in fine crevices, and it slowly dissolves the reaction layer, likewise leading to detachment.

Procedures to determine operating lifetime

In addition to a corrosion-resistant reaction layer, Empa worked together with Synthes and the coating company Ionbond to develop a process which can determine a crack's growth rate under conditions similar to those experienced in the human body. This then allows scientists to calculate the expected operating lifetime of the coated implant in the human body. For crevice corrosion, too, the test process makes it possible to predict the expected operating lifetime of the implants. //

A clean business

Lately, everyone's talking about "Cleantech". That term refers to clean, ecologically and economically sustainable technologies which use our (limited) resources significantly more sparingly and have the least possible environmental impact. For Empa, Cleantech is a key concern – and not just since the term became trendy.

TEXT: Michael Hagmann / PHOTO: iStock

For once, it probably wasn't the Swiss – though we can't really identify exactly who came up with the term "Cleantech". What's more, the definition of the term is somewhat vague and imprecise. Meanwhile, it's clear that many people make preposterous claims for Cleantech, some going as far as to promise it will save the world – or at least create an economic system which will harmonise environmentally friendly manufacturing technologies with sustainable growth. For quite some time now, Switzerland has also put a strong emphasis on Cleantech as illustrated by the "Cleantech Switzerland Master Plan" announced by President Doris Leuthard in November 2009.

But what's really hidden behind this magic word? Put simply, anything that leads to a reduction in the consumption of natural resources or energy and in turn reduces the impact on the environment. Some examples include technologies aimed at increasing energy efficiency such as in buildings or in the transport sector (see the article on page 12); renewable energy sources as well as innovative approaches to energy utilisation and storage (see the article on page 16); measures to protect air and water, or technologies with which pollution never even arises; plus innovative recycling or re-use systems such as to handle the growing mountain of electronic waste.

With Cleantech, however, the idea is not only to develop new technologies and adapt existing ones for sustainability. Methods must be established so it's even possible to evaluate sustainability, such as life cycle assessments (LCA). The example of biofuels dramatically shows that new products might at first glance appear to be climate friendly through lower CO_2 emissions, but when viewed over their entire life cycle they impact the environment in very serious ways (see the article on page 15).

Any and all examples falling under the heading of Cleantech are topics which Empa has to some extent been researching for many years. This Focus section introduces a few of them. Others were featured in previous issues of *EmpaNews*, at times also as a special Focus section. They include photovoltaics (*EmpaNews* 28), hydrogen as an energy source of the future (*EmpaNews* 26) and LCA as a method of assessing the environmental impact of technologies (*EmpaNews* 23). //

Engine tune-ups take on a new meaning

Cleantech covers, among other things, the improvement of established, widely used technologies to the extent that these measures can significantly reduce environmental pollution and the consumption of natural resources. Along these lines, various Empa projects illustrate that it's entirely possible to have clean internal combustion engines.

TEXT: Beatrice Huber

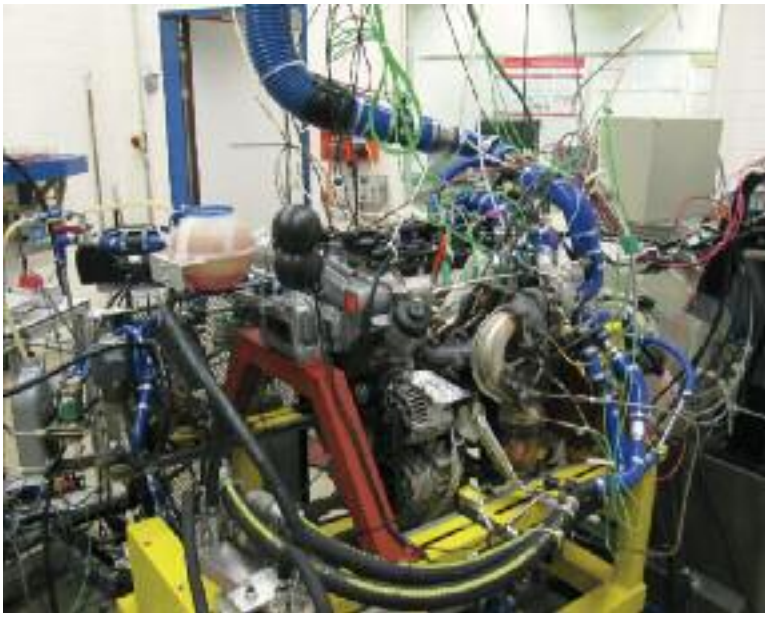
1

Today's mobility continues to be based on "ancient" inventions. The spark-ignition engine was patented in 1876, the diesel engine dates back to 1892, while electric motors are even older. Since then, these engines have benefited from many improvements, but they're far from reaching the limits of how much further they can be developed.

"Twenty per cent measures" for CO_2 reduction

The greenhouse gas carbon dioxide (CO_2) is a central focus in the fight against climate change. In this regard, starting in 2015, automobiles newly placed into service in the EU may emit only 130 grams of CO_2 per kilometre in a normal usage pattern (in Switzerland, a limit of 150 grams per kilometre is being discussed), and by 2020 this value should drop to 95 grams. In 2009, the value in Switzerland was 167 grams. "With the new powertrain concepts in discussion today, CO_2 emissions can be reduced by roughly 20 per cent," comments Christian Bach, head of Empa's Laboratory for Internal Combustion Engines. "Natural gas or hydrogen powertrains, renewable energy sources, hybrid or electric powertrains or even the development potential yet remaining in internal combustion engines – these measures are each individually leading to this reduction. But in order to reduce CO_2 emissions by a significant level, for instance cutting them in half, working piecemeal with any one of these measures isn't sufficient. To reach this goal, a combination of many such individual measures is necessary." That's exactly why Empa, together with ETH Zurich, is working on a new combustion process for natural gas/biogas powertrains and on developing them in conjunction with an electric hybrid concept. Industrial partners in this project are Volkswagen Research and Bosch.

Natural gas and biogas consist primarily of methane. Based on its chemical structure (four hydrogen atoms around one carbon atom), the combustion of methane results in approximately 25 per cent less CO_2 per unit of energy compared to burning petrol or diesel fuel. Methane, however, also has its drawbacks. For one, it's a potent greenhouse gas in its own right, more than 20 times more damaging to the



1
Natural gas filling station in Zurich – driving with natural gas or with an admixture of biogas processed from organic waste represent just two of the many possible "20 per cent measures" to reduce CO_2 emissions. (Photo: Empa)

2
Together with partners from industry and academia, Empa is working on a clean and efficient vehicle within the scope of the CLEVER Project. It should emit only half the CO_2 of a comparable petrol vehicle. (Photo: Empa)

climate than CO_2. When organic waste, especially from agriculture and forestry, is allowed to rot without being utilised, the result is large amounts of methane which escape into the atmosphere and heat up the climate in those areas. Instead, it makes perfect sense to convert this waste into biogas and exploit its energy. Following suitable treatment, the biogas is then ready for storage in tanks. Modifications to natural gas engines or to natural gas filling stations are not necessary. In fact, the gas in Swiss natural gas filling stations today contains roughly 19 per cent biogas.

The CLEVER Project

The CLEVER Project, on which researchers from Empa, ETH Zurich as well as Volkswagen and Bosch are collaborating, intends to combine three "20 per cent measures". For this, they're studying the potential of new combustion processes especially for gas engines and optimising the thermodynamic cycles for natural gas. Empa is responsible for the experimental research and the construction of the prototype, and ETH Zurich for the underlying science. Two hearts are beating within the CLEVER prototype: first, an optimised natural gas engine (25 per cent less CO_2 compared to a standard petrol powertrain) developed just for this purpose, which will be fuelled with an admixture of 20 per cent biogas (resulting in an additional 16 per cent less CO_2); and second, an electric motor to create a hybrid configuration adding fuel savings of another 20 per cent in mixed operation. In total, CO_2 emissions can roughly be cut by half.

Natural gas hybrid vehicles ideal for mid-sized cars

Because the bulky gas tanks in the underfloor take up some amount of space, the natural gas powertrain looks promising in particular for mid-sized cars. These powertrains offer an enhancement to electric motors, which are suitable only for small cars or city/commuter cars because of their limited range and the relatively long time needed to charge the batteries. "In mid-sized cars, when we compare all available powertrain options, natural gas hybrids achieve the largest CO_2 reductions – and this all at low cost," explains Bach.

Considering the current cost structure of natural gas, biogas and petrol, it's possible, through lower fuel costs, to completely amortise the additional expense of purchasing a natural gas hybrid over the total lifetime of the vehicle. Or in other words, with a natural gas/biogas hybrid, it's possible to reduce CO_2 emissions without incurring any extra costs. According to Bach, this isn't possible with any other powertrain concept, not even with petrol hybrid powertrains. What's more, due to its lower environmental impact compared to petrol, natural gas is subject to lower taxes in Switzerland and elsewhere – at least for the time being.

In Switzerland, roughly a quarter of all new cars – more than 65,000 vehicles – are part of a corporate fleet. In this realm, there's enormous potential for natural gas hybrid vehicles because, when making a purchase, fleet managers must not only consider the acquisition cost but also operating expenses and the firm's corporate responsibility and sustainability goals.

>>

Hydrogen for special applications

Natural gas and biogas as fuels are paving the way for another gas, hydrogen. Its combustion results in no CO_2 at all, just water. Moreover, hydrogen fuel cells are very attractive due to their high efficiency also at part load which often occurs in the field. Hydrogen vehicles are already interesting today especially for urban buses or for special vehicles such as street sweepers, which also find use in pedestrian zones or in large indoor spaces such as exhibition halls. Because these vehicles can travel only within a limited radius and always return to a home base, a single central hydrogen filling station is sufficient. "However," adds Bach, "if this is actually to be considered Cleantech, the hydrogen must be produced in a climate-neutral manner, such as directly from solar energy." This is hardly the case today, he adds, but it is the subject of numerous R&D projects.

The "Bucher Schörling CityCat H_2" street sweeper, a joint project of Empa and the Paul Scherrer Institute (PSI) along with various industrial partners, is intended to put the hydrogen powertrain into practical use. Since autumn 2009, this street sweeper has been running in a test phase on the streets of Basel. A look at the results from the first project phase shows that the vehicle consumes on average only half as much fuel as a comparable conventional vehicle. However, there are still a few bumps in the road. Technical malfunctions have interrupted test operations several times. The vehicle's fuel-cell system is currently being completely re-engineered. From late summer of this year, the CityCat H_2, which has had a "heart transplant", will once again keep the streets of Basel clean. //

Technology Days 2010: Where is auto mobility headed?

Tage der Technik 2010
Journées de la Technique 2010

Mobility is an important pillar which supports the Swiss economy – but also a problem child on our way to a sustainable development. How can we ensure continued mobility without having a severely negative impact on people and the environment in the long run?
The opening event of the Technology Days 2010, sponsored by Swiss Engineering STV, SATW (Swiss Academy of Engineering Sciences) and Empa, is operating under the motto "Sustainable Mobility". The event examines the car as a means of transportation from various angles and is targeted at specialists in research, education, politics and economy.

Technology Days 2010:
"Sustainable Mobility – Quo vadis Automobile?"
Wednesday, 27 October 2010, from 1.15 p.m.
Empa Dübendorf, Academy
Places are limited.
Registration possible until 20 October.
www.tage-der-technik.ch

The "Bucher Schörling CityCat H_2" on the streets of Basel – in the first phase of this project, the world's first municipal vehicle with a hydrogen powertrain consumes on average only half as much fuel as a conventional vehicle. (Photo: Juri Weiss)

Driving into the green

Tomorrow's environmentally friendly vehicles for individual mobility need powertrain technologies which create as little pollution as possible. An interdisciplinary research team has investigated the sustainability of 2nd generation biofuels and determined how much petrol and diesel could be saved in Switzerland through the use of biofuels.

TEXT: Martina Peter / PHOTO: iStock

The enthusiasm for what are known as 1st generation biofuels has meanwhile evaporated into thin air. Only a small fraction of the plants is used to produce supposedly environmentally friendly fuels – for example their oil or sugar content. And because these raw materials are used inefficiently, biofuels are significantly less "eco" than originally expected, as shown in an Empa study from 2007.

A beacon of hope in the "2nd generation"

Since then, processes have been developed which allow practically all kinds of biomass to be converted into fuel. This includes green waste, manure (in both solid and liquid form), scrap wood, and plant material with a high cellulose content. However, most of these processes involve an increased expense in both technology and financial investment. As a consequence, except for biomethane, none of these 2nd generation biofuels are commercially viable. Thus government subsidies and promotion programs would be necessary, but they make sense only when these biofuels are proven beyond doubt to be sustainable and environmentally friendly.

Biofuel alone isn't enough

Empa environmental scientist Rainer Zah and his team have been conducting research on behalf of the TA-SWISS Centre for Technology Assessment. Through life cycle analyses, they're taking a close look at 2nd generation biofuels – from their production through their use and to the disposal of any waste products.

The key result of the study, presented last June: the most environmentally friendly biofuels are primarily the ones which are produced using waste products and leftover materials such as green waste, sawmill waste and wood scrap. In contrast, if plants are grown in developing countries solely for the purpose of producing (bio)fuel, the disadvantages dominate the equation. Energy crops directly compete with food crops for agricultural land and also threaten biodiversity. The study further emphasises that in Switzerland biofuels can at best provide no more than eight per cent of the fuel required for individual transport because of the limited amount of waste products that are available.

Does this mean it makes sense to abandon governmental support for biofuel development? "No," says Zah, "that would be a short-sighted reaction." The more important question is how to ensure that the most appropriate powertrain technology is used to meet differing requirements, whether for long-haul traffic, urban mobility or freight transport. Zah has worked out what that means in specific terms for 2030 assuming the most optimistic scenario. "If available biofuels were used for long-haul traffic, not just eight per cent of fossil fuels could be replaced, but thanks to more energy efficient vehicles as much as fifteen per cent. And if at the same time in cities we drove primarily electric cars whose batteries were charged through alternative energy sources such as solar power, then we can add another 25 per cent to that figure. So, in total this would allow us to replace approximately 40 per cent of today's consumption of fossil fuels."

According to Zah, the recommendation to policy makers is clear: it's doing one thing without giving up the other. "Neither electric mobility, nor improved vehicle efficiency nor support for sustainable biofuels should be given priority over the others. Far more importantly, we must find ways to promote all three approaches simultaneously and apply them to where they bring the most benefit." //

Rainer Zah has carried out a study concerning the prospects for 2nd generation biofuels on behalf of TA-SWISS. He was supported by an interdisciplinary team of ecologists from the University of Zurich and experts in the areas of materials flows and resource management from the Wuppertal Institute.

R. Zah, C. Binder, S. Bringezu, J. Reinhard, A. Schmid and H. Schütz. Future Perspectives of 2nd Generation Biofuels, edited by TA-SWISS – the Swiss Centre for Technology Assessment, published by the vdf Hochschulverlag AG of ETH Zurich, 2010. ISBN 978-3-7281-3334-2. Also available as an e-book, www.vdf.ethz.ch

New paths to industrial partnerships

Technology transfer, in other words the transfer of research findings into commercially viable products and services, is at the centre of many Empa activities. With Hexis AG, one of the leading developers of fuel cell-based electricity and heat supply systems, Empa has entered into a strategic partnership which will extend far beyond individual collaborative projects and should help this technology gain a foothold in the marketplace.

TEXT: Beatrice Huber

Fuel cells efficiently convert energy chemically bound in fuels into electricity. This makes them especially interesting for the decentralised generation and supply of electricity. If the resulting thermal waste is also used for heating purposes, the efficiency of fuel cells can be increased to 90 per cent and even higher. Rather impressive, if one considers the mere 60 per cent of energy conversion achieved with central electricity production and separate heat supply as is commonplace today. By using renewable fuels such as biogas the energy supply is not only highly efficient but also CO_2 neutral.

SOFCs, or solid oxide fuel cells, consist of a fuel electrode (anode) connected to an oxygen electrode (cathode) through a solid, gas-tight oxygen ion conductor (electrolyte). At operating temperatures from 600 to 1000 degrees Celsius, the chemical reactions on both electrodes are separated locally; the oxidation of the fuel occurs at the anode, the reduction of atmospheric oxygen at the cathode. In the process, electrons are released; they flow through an external electrical circuit, generating a current that can be used to perform work. Multiple fuel cells are arranged in a stack in order to reach the desired power rating. In contrast to other fuel cell technologies, SOFCs can use not only hydrogen but also methane. That's a key advantage because well-developed natural gas distribution networks already exist.

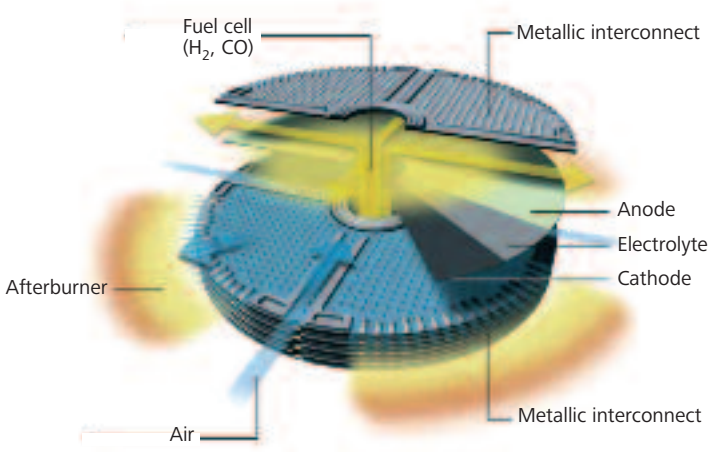
Technology transfer thanks to a strategic partnership

In order to further develop fuel cells and associated systems based on SOFC technology and establish them on the market, Empa and Hexis AG have entered into a strategic R&D agreement. A liaison office ensures the coordination of the corresponding projects, brings experts from various disciplines together and generates new ideas, for instance for EU projects. Together, researchers from Empa and Hexis want to, among other things, improve the operating lifetime of SOFCs by developing materials which better withstand the extreme chemical and thermal conditions. That's because the success of fuel cell technology for decentralised energy supplies depends heavily on the operating lifetime. Users expect that systems will function without problems for years and even decades.

Empa and Hexis complement each other

Empa has been working on the development of materials for fuel cells for quite some time and is active in the manufacture and optimisation of anodes, cathodes and electrolytic materials. In addition, its scientists are conducting research into the thermal-mechanical loads under the extreme conditions in an SOFC. Moreover, Empa has many years of experience in the field of system management for integrating such technology into buildings and evaluating its performance.

Winterthur-based Hexis AG develops fuel cell heaters which are designed to cover the entire heating and electricity requirements of single- and multi-family homes in central Europe. Prototype systems are already in use in many applications. The company has broad expertise in a large number of areas such as process technology, fuel-cell manufacture, technology integration in buildings, as well as servicing of heaters in operation. //



A fuel cell of the SOFC type can be used to generate not only electricity but also heat. For this, any fuel which hasn't been converted is post-combusted upon exiting the fuel cell stack. Such a fuel cell heater provides single- and multi-family houses with all the energy they require. (Pictures: Hexis AG)

"Fuel cells will become a part of our daily lives."

EmpaNews spoke with **Alexander Schuler**, Managing Director of Hexis AG, about the potential of fuel cells and his company's collaboration with Empa.

What do you see as the future of fuel cells?

Fuel cells will in future play a crucial role in various applications and will be available in a number of performance categories. In principle, a fuel cell is the most efficient energy converter when generating current directly from a fuel. The development status has already reached a good level; however, we're just starting to transfer this technology into commercially viable products. I'm absolutely convinced that fuel cells will become a part of our daily lives in many areas.

What are you hoping to gain through the partnership with Empa?

We assume that, together with Empa, we will be in a position to further advance the long-term aspects of SOFC development. For a small company such as Hexis it's important to have access to Swiss and EU funding bodies in order to create the sustainable scientific foundation for our technology. This is a key prerequisite for the creation of new jobs in Switzerland along with the retention of forward-looking technologies.

In your eyes, what does Empa stand for?

Empa is an excellent scientific institution with a broad profile of expertise. That's the special attraction of collaborating with Empa. The development of fuel cell technologies involves a multitude of scientific tasks – from nanotechnology in materials science through to the integration of complete systems in buildings – and Empa can provide extremely valuable contributions in many areas. To fully exploit this potential and collaborate in an interdisciplinary fashion; this is what we aim to achieve together. //

ETH-Empa professor for air pollution control

In May, the ETH Board elected Jing Wang to the position of assistant professor for industrial ecology. Wang's research focus is on, among other things, the development of instruments for the characterisation of the behaviour of nanoparticles in flowing media. Wang is an ETH-Empa professor and works as group leader in Empa's Analytical Chemistry Laboratory. Prior to his appointment to this position he was a research assistant professor at the University of Minnesota in Minneapolis, USA.

newtechClub – Centre for Sustainable Energy and Building Technologies

The newtechClub, located in Schlieren, is an independent and interdisciplinary platform for sustainable energy and building technologies. Mario Jenni, managing director of glaTec, the technology centre at Empa in Dübendorf, is a Board member. The association, founded at the end of 2009 by private companies and the public sector, wants to promote the exchange of knowledge between corporations as well as experts in the field of R&D and management which are committed to the further development and spread of innovative energy and building technologies.

Solar Impulse – comfort for pilots under extreme conditions

Around the world without burning any fuel and using only solar energy – this is the goal of the high-tech aircraft Solar Impulse. So that the pilots neither perspire nor freeze during the flight stages, which will last up to five days and nights, special clothing systems are needed. These are being delivered by the textile experts at Empa.

TEXT: Rémy Nideröst and Beatrice Huber / PHOTOS: Empa

Consider the extreme conditions in the Solar Impulse cockpit: because the aircraft is to remain in the air throughout the night, temperatures will fall to as low as minus 20 degrees Celsius. The aircraft is not insulated in any special way because every gram counts (see the box, "Night flying thanks to the sun"), and so special clothing must take on this task. Although temperatures during the day can be comfortable, solar radiation can make the pilots perspire. Unsuitable clothing would have serious consequences. For instance, one's ability to concentrate suffers in extreme temperatures, while remaining seated for long periods can cause decubitus, better known as pressure ulcers. Further, because the pilot can barely move around in the cockpit – there's simply no room – he can't freely put on or take off layers of clothing.

Thus, off-the-rack clothing was not even a remote option for the Solar Impulse team; they had to find a flexible, adaptable clothing system. That was the perfect assignment for the textile experts at Empa. "Solar Impulse asked if we could develop a suitable clothing system for them," says Markus Weder from Empa's "Protection and Physiology" Laboratory.

Down filling for night time – ventilation during the day

For thermal insulation, the Empa experts reverted to a well-proven material. "Bird down is not only very lightweight, it also provides extremely effective thermal insulation and transports moisture very well," explains Weder. His team furnished the pilot's suit with a total of four down chambers – two each for the arms and legs – which function according to the vAIRis System (see the box, "Birds as the perfect model – the vAIRis System"). The chambers are surrounded on both sides by a breathable foil; depending on the desired level of insulation, air is forced into or out of the chambers. In the case of the suit for the Solar Impulse pilots, a micropump can either fill or empty the chambers in roughly three minutes.

Even when not exerting ourselves physically, we lose roughly a litre of water each day through our skin due to *perspiratio insensibilis*. In high temperatures or though physical activity, this amount can easily more than double. Perspiration must be efficiently transported away so that no unpleasant accumulations of moisture build up, which over time can macerate and damage the skin. For the Solar Im-

André Borschberg, CEO and co-founder of Solar Impulse and the pilot of the very first night flight in a solar aircraft, tested the system in Empa's climate chamber.

Night flying thanks to the sun

Solar Impulse is pursuing the goal of circumnavigating the globe using only solar energy. The primary concern of the team at Solar Impulse isn't about a sporting competition or making it into the Guinness World Records book. Rather, they want the project to demonstrate how much potential there is in renewable energy and technologies.

With a wingspan of roughly 64 metres, the HB-SIA prototype aircraft weighs only 1.6 tonnes. The Airbus A340, which specs a similar wingspan, weighs 170 tonnes, more than 100 times more. This large wingspan is necessary in order to make place for the roughly 12,000 solar cells which supply the energy for propulsion. So that the aircraft can continue to be flown at night, lithium-polymer batteries are on board. Weighing 400 kilograms, they take up a quarter of the total weight. Four electric motors, each rated at 10 horsepower, provide thrust. The maximum flight level is 8500 metres above sea level, and the average speed is approximately 70 km/h.

The men behind Solar Impulse are both Swiss: Bertrand Piccard and André Borschberg. The entire team consists of more than 50 people as well as countless other external specialists such as the textile experts from Empa. The HB-SIA's maiden voyage took place on 7 April 2010 at the Payerne airport in the canton of Vaud; the first night flight from 7 to 8 July – with André Borschberg as pilot wearing the Empa suit. The construction of the second prototype, in which Piccard and Borschberg will lift off to circumnavigate the globe, will start soon.

Picture credits: Solar Impulse

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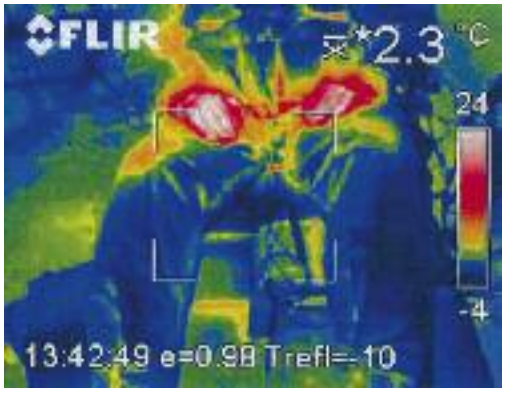


1
Empa researcher Markus Weder discusses final details with André Borschberg of Solar Impulse before starting to run tests on the clothing system in the environmental chamber.

2
It gets cold in the environmental chamber, but the insulation does its job – only the electrically heated gloves radiate any heat. The arms and legs are protected by a layer of down.

3
Even when placed under a heat lamp, the pilot doesn't perspire very heavily.

pulse pilots, accumulations of moisture can become an especially serious problem because the seat in the aircraft covers a third of their body surface. In order to also purge moisture efficiently from the seating regions, Weder and his team incorporated active rear ventilation into the pilot's seat and the areas of the suit covering his back.

Successful tests in an environmental chamber

Together with partners from industry, the Empa researchers constructed a prototype consisting of a seat and a suit – a custom-tailored article of clothing for André Borschberg, CEO and co-founder of Solar Impulse and pilot of the first night flight ever in a solar airplane. After prototype tests in an climate chamber at Empa in St. Gallen, Borschberg was quite enthusiastic. The Empa team was very happy with the results, as well. “The clothing system fulfilled the requirements with flying colours. The tests show that both thermal insulation and the transport of moisture function flawlessly, even under extreme conditions,” comments Weder. As a second pilot, Bertrand Piccard will also get his suit, one tailored exactly to his body. This is important because only with custom tailoring does the thermal insulation reach its optimal level of performance. //

Birds as the perfect model – the vAIRis System

When it gets cold, birds fluff up their coat of feathers; the air pockets between the feathers serve as an insulating layer and protect them from the cold. Conversely, when it gets warm, birds bring their feathers in close to their bodies. Empa researcher Markus Weder and his team copied this behaviour from nature to develop a textile-based innovation, the vAIRis System (short for “variable insulation system”). This patented invention allows the production of down jackets whose insulating properties can be varied. As required, the jacket is filled with air to create effective insulation between the down material. If the ambient temperature rises or if someone performs physical activity, air can be blown out to prevent heavy perspiration. This development also serves as the basis for the pilot's suit for Solar Impulse.

Because the perception of and sensitivity to temperature is very individual, every person needs a bedspread suited to their own preferences. The vAIRis System is well suited for this, as well; Empa recently transferred the corresponding patent to the Swiss company ACT. They sold a licence to a German manufacturer of eco bed feathers and down material, which intends to manufacture year-round duvets which can be optimally adjusted in the summer and winter thanks to the variable insulation system.

Feet without blisters

An endurance test of a special kind conducted at the beginning of May at the Aarau military barracks made headlines in the media. Whenever they set out on a march anytime for an entire week, 60 recruits wore a novel type of sock developed jointly by Empa researchers and experts at armasuisse, the federal competence centre for the procurement of technologically complex systems and materials.

Together with new combat boots, the socks form a part of armasuisse's New Footwear project, whose goal is to help prevent blisters. The prototype socks, made of various textiles, reduce rubbing at the heel and toes, absorb perspiration efficiently and are particularly comfortable to wear.

Following the development of these materials in the laboratory, the socks were tested for their wearing properties at Empa, first on a newly created dummy of a sweating foot, then afterwards by soldiers in battle gear on a treadmill in a climate chamber. René Rossi, head of the project at Empa, expressed great satisfaction: "Thanks to a good, reliable partnership with armasuisse, we could simultaneously validate a product under development with a practical test, that's something quite unique." He adds that the laboratory results have since been confirmed. "We were right on with our laboratory measurements." The Empa-armasuisse socks really do help prevent blisters from forming.

Another person enthusiastic about this cooperation is Andreas Stier, head of the project for armasuisse. "At the end of 2011, following further long-term tests, we will have specified the new footwear system and send it out for bids around the world." Who will end up manufacturing the socks has thus not yet been determined. These socks are also welcome news for athletes. When the new footwear is introduced into the Army in 2013, the socks will certainly also come onto the commercial market.

Endurance test passed successfully – a concept for novel socks, developed by armasuisse and Empa for the Swiss army, showed convincing results not only in the laboratory but also in practice. The comfortable footwear made of a variety of textiles reduces rubbing on the heel and toes and absorbs perspiration efficiently.

The hydrogen coffee maker

Espresso, cappuccino, latte macchiato – today, coffee is no longer simply coffee. This hot beverage, so beloved by all Swiss, goes by many, above all Italian, names. Even in the trains of the Swiss Federal Railways the coffee culture has flourished; the times have passed when coffee was served from giant thermos flasks.

But just as every espresso machine at home or in a restaurant needs electricity, the same is true for the mobile minibars on Swiss trains. Because you can't simply plug them in on a train, other solutions are needed. Together with various partners, Empa is now working to bring a system to market which uses fuel cells and hydrogen to supply electricity for espresso machines. For this, Empa researchers are working on the integration of a special metal hydride storage system which makes optimal use of the waste heat from the fuel cells to release the stored hydrogen. This project is being partially financed by the Swiss Innovation Promotion Agency CTI. Besides Empa, other organisations involved include CEKA Elektrowerkzeuge AG & Co. KG, the Bern University of Applied Sciences (BUAS), Engineering and Information Technology in Biel, the Paul Scherrer Institute (PSI) as well as elvetino AG, SERTO AG, PanGas AG and the Swiss Federal Railways.

Science Apéros

The Empa Science Apéros offer an inquisitive public the opportunity to get informed about current topics first hand and to pepper Empa researchers with questions. The first three events of this year addressed nanoparticles in the human body, earthquake-proof buildings as well as functional clothing especially for footballers.

TEXT: Beatrice Huber / PHOTOS: Empa

At the Empa Science Apéros, interested participants were able to learn more about the placenta as a barrier for ultrafine particles, earthquake-proof buildings as well as functional garments, especially for footballers.

Does the placenta present a barrier to ultrafine particles? This question was the centre of discussion at the first 2010 Science Apéro held at the beginning of May in St. Gallen. This very emotional topic met with great interest and led to some animated discussions. Peter Wick, Co-Head of Empa's Materials-Biology Interactions Laboratory, presented his research findings concerning the barrier capacity of the human placenta when confronted with nanoparticles. When smaller than a given size these ultrafine particles can also find their way into the circulatory system of the unborn child. In addition, external experts explained how nanoparticles can be breathed in through the lungs and how air pollutants, such as fine and ultrafine particles, can affect the development of children's lungs.

Earthquake-proof buildings

The risk of a major earthquake in Switzerland is estimated to be only moderate. History shows, however, that large quakes are also possible here, as evidenced by the one in 1356 in the Basel region. At the Science Apéro at the end of May in Dübendorf, experts provided information about what can be done to protect buildings in the event of such catastrophes. Basically there are two possibilities: strengthening or "softening". With strengthening, a building is anchored, which is done best with reinforced-concrete walls which support the building asymmetrically on all sides, from the foundation to the top floor. In softening, elastic inserts are added to the exterior walls of the basement. They absorb the earthquake's energy so that the building itself remains stable. Empa has developed another very promising method of securing existing buildings – the use of carbon fibre reinforced polymers (CRPs). These come in the form of, for instance, bands which stabilise load-bearing columns or entire walls.

Special football kit

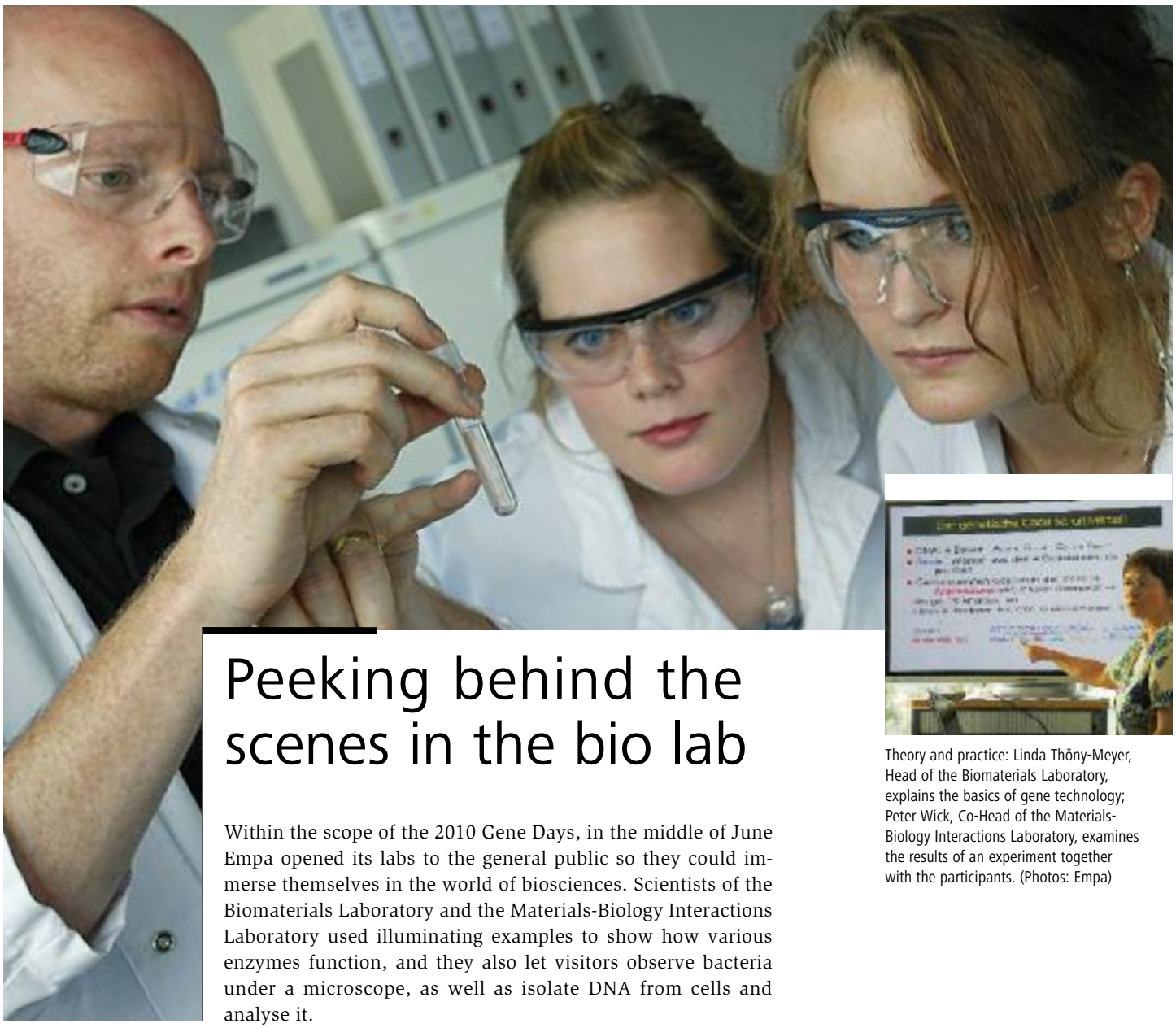
At the beginning of June, that is, just before the start of the FIFA World Cup in South Africa, the Science Apéro in St. Gallen addressed among other things functional garments for athletes. Empa researcher Markus Weder introduced new materials that allow an optimal regulation of body temperature. For footballers such jerseys prevent them from overheating when playing in great heat. On the other hand, an athlete's muscles must not become cold during periods of reduced activity. If this happens and a footballer must then suddenly sprint for a ball, this can lead to injuries such as torn muscles fibres. At Empa, Weder is using "sweating" body parts and robots to investigate which materials are best suited for which conditions. //

During their party's field trip, members of the Social Democratic Party visited Empa in Thun to learn first-hand about Cleantech. (Photos: Empa)

Social Democrats' field trip to Empa

Each year during the summer session of both Federal chambers, the Members of Parliament shift their attention away from politics for an afternoon and depart on their traditional party excursions. A part of the Social Democrat delegation used this opportunity to head to Empa in Thun and gather information about the booming topic of Cleantech. Empa experts showed what they're working on and discussed with these high-ranking public representatives clean technologies and their potential for sustainable economic development.

Cleantech is a central topic not only for Empa but also for the Swiss Social Democratic Party (SP). In fact, the party launched the Cleantech Initiative in the fall of 2009. This petition to modify the Federal Constitution is intended to create up to 100,000 new jobs in Switzerland thanks to renewable energy. The collection of signatures continues until 16 September 2011.



Theory and practice: Linda Thöny-Meyer, Head of the Biomaterials Laboratory, explains the basics of gene technology; Peter Wick, Co-Head of the Materials-Biology Interactions Laboratory, examines the results of an experiment together with the participants. (Photos: Empa)

Peeking behind the scenes in the bio lab

Within the scope of the 2010 Gene Days, in the middle of June Empa opened its labs to the general public so they could immerse themselves in the world of biosciences. Scientists of the Biomaterials Laboratory and the Materials-Biology Interactions Laboratory used illuminating examples to show how various enzymes function, and they also let visitors observe bacteria under a microscope, as well as isolate DNA from cells and analyse it.

Opinion

Alexander Schuler

Alexander Schuler
Managing Director Hexis AG

“The experience we’ve had while collaborating with Empa on individual projects has shown us that Empa has the know-how and interdisciplinary expertise which is vital to us for further developments.”

Events

26 August 2010
Innovation Day 2010: Textiles stretch their limits
For textile and clothing specialists
as well as interested parties from R&D
Empa, Dübendorf

2 and 3 September 2010
Research and Construction in the Context of Energy and the Environment
16th Status Seminar 2010
For experts in construction,
building services and environmental services
as well as interested parties from R&D
ETH Zurich

9 and 10 September 2010
New Trends in Nanomaterial Design and Engineering
3rd WUT-NIMS-Empa workshop
For researchers with an interest in
international collaborations in the area
of nanomaterials and their applications
Empa, Dübendorf

20 October 2010
Mechanical properties of materials
CCMX Technical Apero
For interested parties from science
and industry
Empa, Dübendorf

27 October 2010
“Sustainable Mobility – Quo vadis Automobile?”
Technology Days 2010
For interested experts from research,
education, politics and the world of economics.
Empa, Dübendorf

For details and further events:
www.empa-akademie.ch

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