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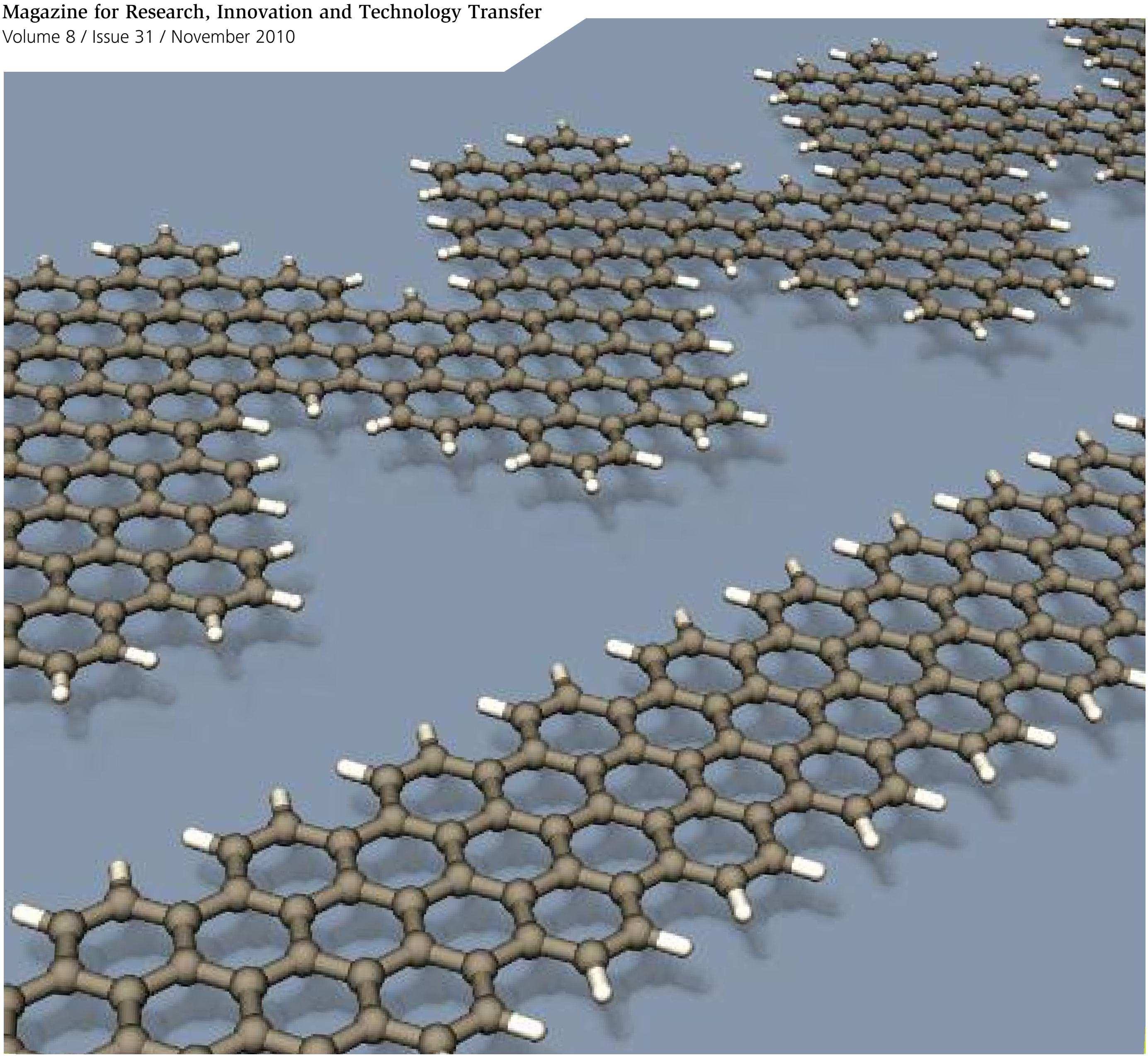


Towards tomorrow's nanoelectronics 04

Good grades from our readers

With this issue, you're holding in your hands the eleventh edition of *EmpaNews* since we relaunched it as a modern research magazine two years ago. It thus seemed like the appropriate time to ask you – our readers – what you like and what you don't care for so much. We did exactly that with the last issue but one. Now we have the results, and they're quite gratifying.

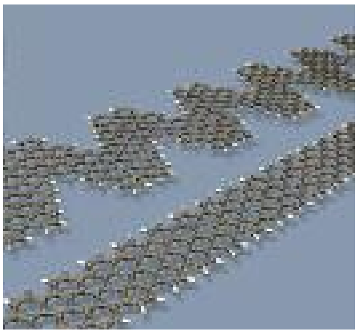
The vast majority of you (96 per cent) rate *EmpaNews* as "good" to "very good", and about 90 per cent read (almost) every issue. In particular, articles about the latest research findings and innovative technologies as well as reportages from the laboratory in the sections "Research and development" as well as "Knowledge and technology transfer" are quite popular. You judge our mix of topics as diverse and varied, and the layout is viewed as being modern but at the same time serious. That's all reason enough for us to follow the suggestion of one reader: "Keep up the good work!" That's exactly what we intend to do, but not without first extending a warm "Thank you" for helping us along.

This current issue takes into account your desire for lab portraits with a visit to Empa's Fire Technology Laboratory (page 8) where, as part of their job, fire experts and engineers put products and components to the test with flames. They're not doing so in a blind destructive frenzy; rather, they're developing new fire-resistant products. Speaking of new products, another promising source is nanoelectronics with examples being nanoribbons made of graphene, a modified (and recently Nobel-honoured) form of carbon with amazing properties (page 4).

And since it is our goal to provide intelligent reading material, for once we've taken that task literally – and thus the current Focus section on "smart" materials. They're also the topic of the National Research Programme NRP 62, which started early this year and in which Empa is quite successfully represented.

We wish you continued pleasant reading with *EmpaNews*, and we look forward to your suggestions and tips, which are always welcome – even without a survey.

Michael Hagmann
Head Communications



Cover

Empa researchers have succeeded in growing graphene ribbons only a few nanometres wide on various surfaces. These ribbons are considered a prime candidate for future applications in electronics because they allow their properties to be tailored – depending on their width and edge shape. (Photo: Empa)

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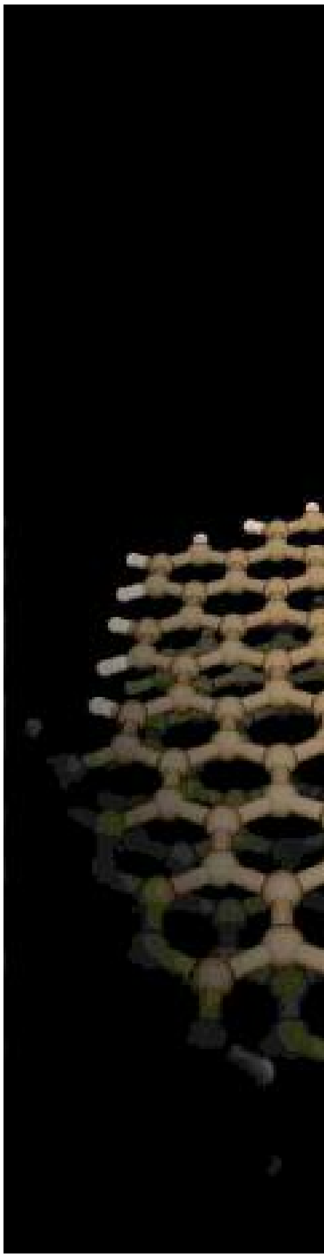
Towards tomorrow's nanoelectronics

To fabricate ever smaller electronic components, new materials are in great demand – for example, ultra-thin layers of carbon known as graphene. As part of an international collaboration, Empa researchers are developing new methods to "grow" these layers in a tailored way on surfaces. To "equip" them with desired properties, the Empa team is also investigating the details of how the structures form – using, among other things, computational modelling.

TEXT: Beatrice Huber / PHOTOS: Empa



Structural model of a graphene ribbon with a zig-zag shape.

Graphene is a very unique material. It consists of a carbon layer only a single atom thick in which the atoms are arranged in hexagons, resembling a honeycomb. Graphene is harder than diamond, extremely tear-resistant and impermeable for gases, and it's also an excellent thermal conductor. When rolled up, this material produces carbon nanotubes; when it's stacked in layers, the result is graphite, which is well known, for instance as pencil lead.

In addition, because of its outstanding electronic properties, graphene is recognised as a possible material to substitute for silicon in semiconductor technology. It's no wonder that graphene and related materials are currently among the hottest research topics. In fact, the Dutch physicist Andre Geim was just awarded the 2010 Nobel Prize in Physics along with the Russo-British physicist Konstantin Novoselov for their groundbreaking work on graphene. Their research team was the first to successfully isolate free-standing graphene layers, something that astounded the scientific community because strictly two-dimensional structures should not actually be stable.

Wanted: a silicon replacement

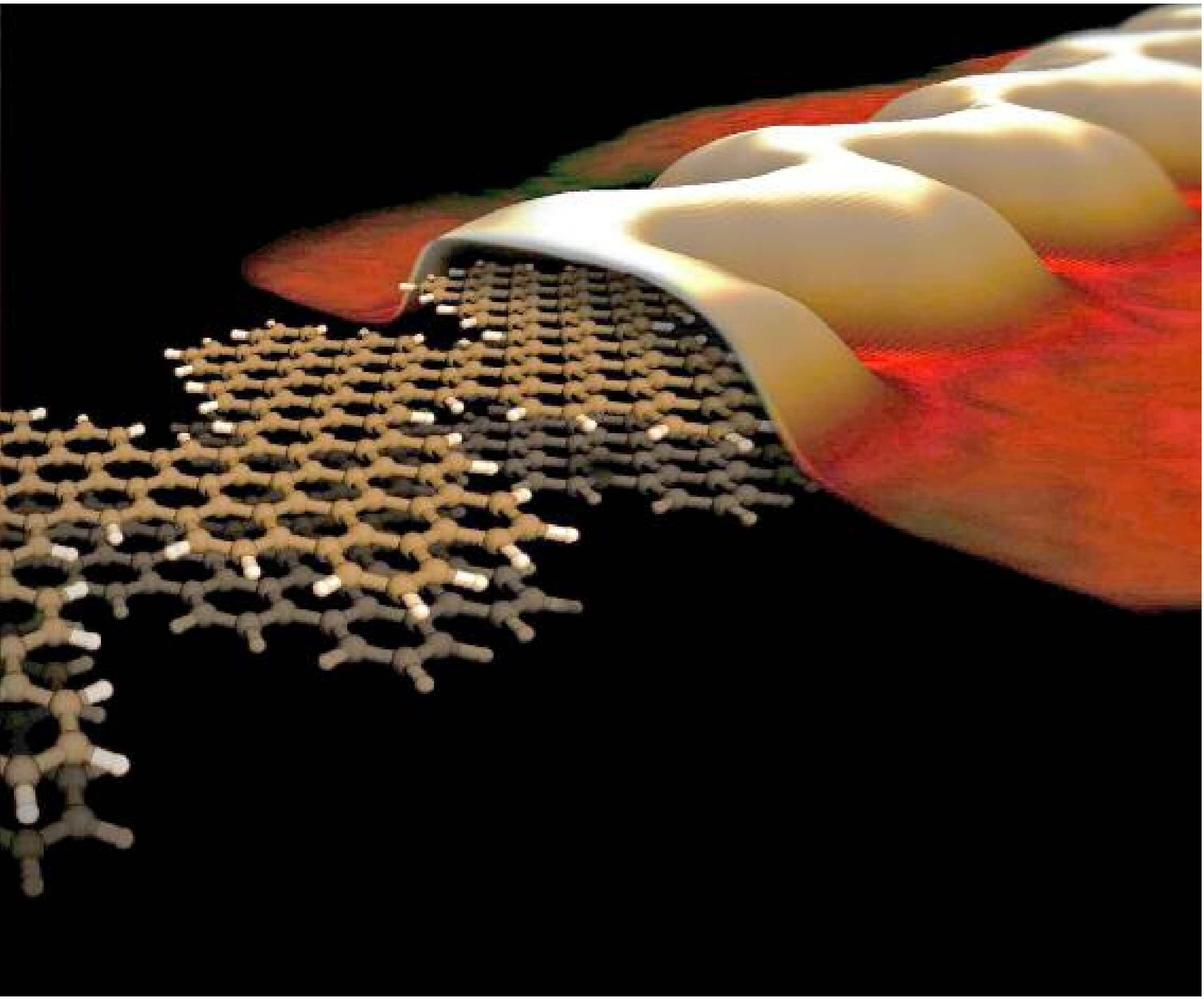
Today, almost nothing happens in semiconductor technology without silicon. One example is the field-effect transistor (FET), the type of transistor most frequently used. Especially for the FET, graphene exhibits properties which could allow a tremendous leap in miniaturisation.

FETs generally have three terminals: the source, gate and drain. The gate controls the transistor by allowing or inhibiting the flow of current from the source to the drain. To do so, the gate either builds up or closes a "channel" between the two other terminals. Graphene now makes it possible to build this channel so it is just a single atomic layer thick, a decisive step towards the further miniaturisation of electronic components and thus towards nanoelectronics. Such thin channels are impossible to produce with silicon, the most common base material in semiconductor technology.

Turning Graphene into a semiconductor

Before graphene and related materials can be used in semiconductor technology, however, several obstacles must be overcome. For one: pure graphene is not a semiconductor. What are known as band gaps, which enable an insulating state, do not exist in graphene. This means that graphene does not allow itself to be "turned off" but instead permanently conducts electricity.

Researchers in Empa's nanotech@surfaces Laboratory are working together with scientists at the Max Planck Institute for Polymer Research in Mainz (Germany) and other institutions on graphene-like materials with band gaps whose size can be set very precisely. One candidate consists of ultra-thin graphene ribbons; another is "porous" graphene, a sheet-like polymer with "holes" of a controlled size and spatial distribution.



Progress towards easy manufacturing

The focus is on methods to produce these graphene-like materials, with their well-defined band gaps, as easily as possible and in ways which are reproducible. “Here we’re employing a ‘bottom-up’ process, specifically molecular self-organisation,” explains Roman Fasel, senior scientist in the nanotech@surfaces Laboratory. “That’s because the conventional methods used until today are not sufficiently precise.” Before components made of these materials can allow custom-engineered optical and electronic properties, the graphene ribbons, for instance, must be extremely narrow, considerably less than ten nanometres wide, and further must have well-defined edges. The “top-down” methods typically used until now cannot achieve these geometries. In those methods, the ribbons are “cut” from graphene layers, or nanotubes are slit open lengthwise and unfurled.

Molecular self-organisation achieves the required precision. In this process, the molecular building blocks join together spontaneously at chemically-defined linking sites and build up a regular structure with the desired electronic properties. The building blocks consist of organic molecules, known as polyphenylenes, which possess halogens (bromine or iodine) at “strategically correct” positions. The geometry of these building blocks and how many halogens are located at which positions then determine what the end product looks like, in other words, whether a ribbon or a sheet-like structure with pores is created.

Ribbons – just a single nanometre wide

Thanks to suitable building blocks, Empa researchers Pascal Ruffieux, Jinming Cai and Marco Bieri together with their colleagues recently manufactured atomically thin graphene ribbons with a width of one nanometre and a length of up to 50 nanometres. “The result is that our graphene ribbons are so narrow that they have electronic band gaps and now exhibit the switching properties of silicon,” says Fasel in discussing the research findings.

But the Empa team didn’t stop there. Depending on which building blocks they used, graphene ribbons develop with various spatial structures: straight, bifurcated or in a zig-zag shape. This work was published last July in the renowned scientific journal *Nature*. With the same methods, it was also possible to successfully manufacture a porous graphene whose pores are only a few atoms in diameter, and whose pattern repeats on a subnanometre scale. This material likewise has the desired band gaps.

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So that the new synthesis methods indeed become a reliable tool with which both graphene ribbons and porous graphene can be manufactured with the desired properties, the reaction pathway must be understood to the last detail. “We want very specific knowledge of the reaction steps,” notes Fasel, listing some questions of interest. Which processes are taking place here? Which intermediate products are produced? What forces are involved? What role does the substrate play?

Reaction pathway elucidated with experiments and simulations

In order to answer questions such as these, the researchers combined empirical observations, in particular from a scanning tunnelling microscope, with computer simulations. Findings just published in the scientific journal *Nature Chemistry* now describe the detailed reaction pathway whereby “model building blocks” couple themselves into a planar nanographene. This reaction runs through six steps with five intermediate products, two of which are stabilised sufficiently on the surface so that they can be identified with a scanning tunnelling microscope. And this was exactly what was predicted by the computer simulations.

So far, so good. But if these novel materials are to be useful in electronic circuits, they must be manufactured on semiconductor surfaces. And until now, scientists have fabricated graphene ribbons and porous graphene only on metal substrates. Besides self-assembly directly on a semiconductor, an alternative is to transfer the materials from metal to semiconductor surfaces. “Right now we’re working at full speed on both approaches,” says Fasel, “and the initial results already look very encouraging.” //

1
Under ultra-high vacuum conditions, the desired building blocks (in this picture 10,10’-dibromo-9,9’-bianthryl monomers) are applied to a gold surface. In the first reaction step, the building blocks are linked to form polyphenylene chains. In the second step involving high temperatures, hydrogen atoms are removed and the result is a planar, aromatic graphene system – graphene nanoribbons.

2
Straight, bifurcated or in a zig-zag shape: by selecting suitable building blocks, graphene ribbons can be synthesised in the desired shape.

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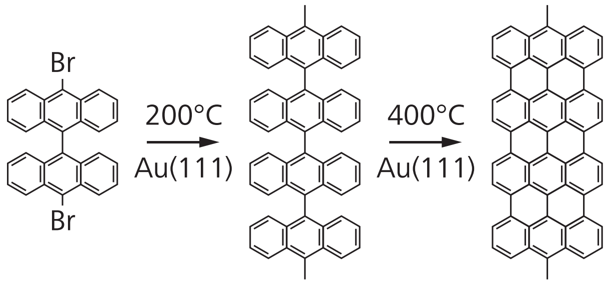

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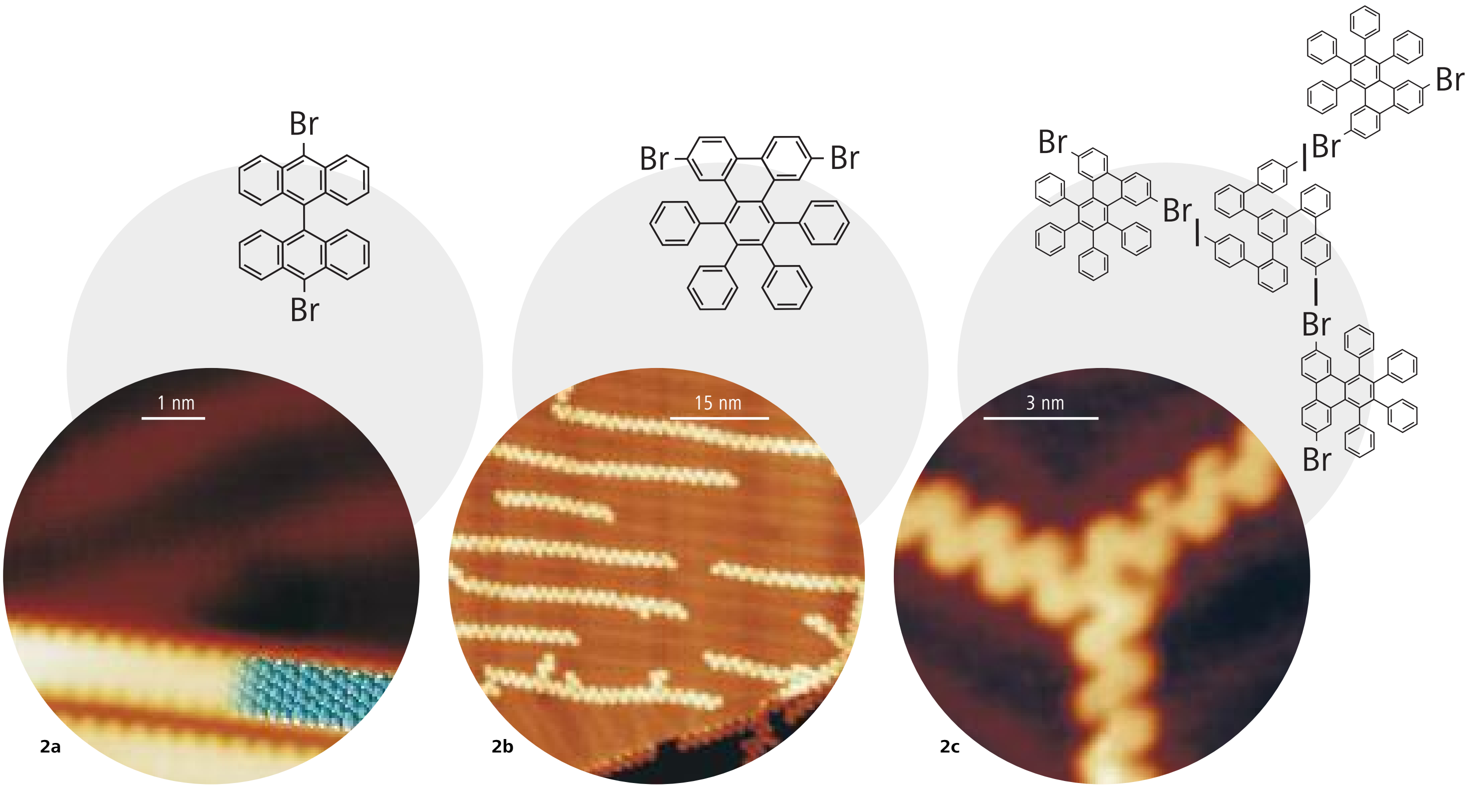

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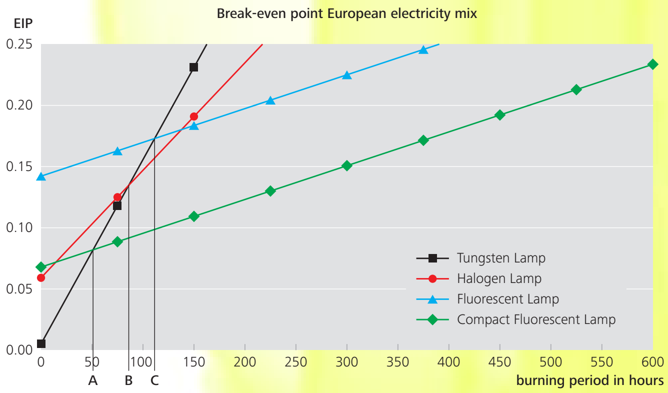
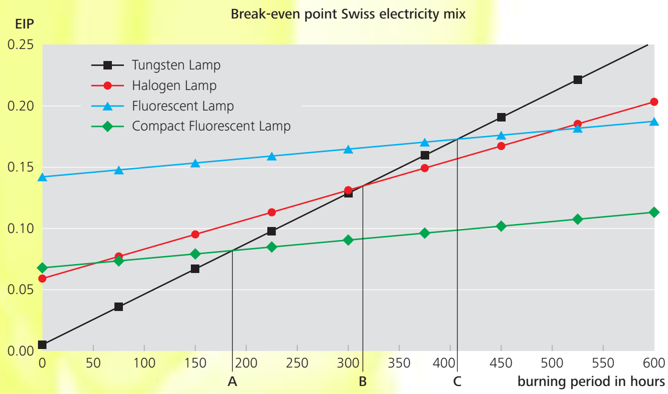
Energy-saving lamp wins

Empa researchers have investigated the eco-balance of various lighting technologies. They considered not only the lamps' own energy consumption using different electricity mixes, but also aspects related to their manufacture and disposal. The clear-cut result: the energy-saving lamp comes out ahead.

TEXT: Peter Merz / PHOTOS: SecretDisc, Wikipedia





In the first 50 operating hours (European electricity mix, left) to the first 180 operating hours (Swiss mix), the tungsten lamp is, ecologically seen, still superior to its competitors. However, as the lamps burn longer, the relationship quickly changes because of the tungsten lamp's high power consumption; then the compact fluorescent lamp produces the best results. (Illustrations: André Niederer)

Intersection **A**: Tungsten/Compact Fluorescent Lamp
Intersection **B**: Tungsten/Halogen Lamp
Intersection **C**: Tungsten/Fluorescent Lamp

Literature reference
"Environmental Impacts of Lighting Technologies – Life Cycle Assessment and Sensitivity Analysis", T. Welz, R. Hischier, L. Hilty, Environmental Impact Assessment Review
www.elsevier.com/locate/eiar

Since 1 September 2009, sales and import of incandescent light bulbs, or more specifically tungsten lamps, have been banned in Switzerland. In addition, on the same day, the EU's prohibition on incandescent bulbs was adopted, a step-wise elimination of this inefficient method of lighting. This legislation, however, has met with resistance in many places. In particular, the compact fluorescent lamp, often referred to as the energy-saving lamp, has been the focus of much criticism. One of the opponents' main concerns is the mercury they contain.

Roland Hischier, Tobias Welz and Lorenz Hilty of Empa's Technology and Society Laboratory have made a detailed investigation of traditional tungsten lamps as well as halogen lamps, conventional fluorescent lamps and compact fluorescent lamps in order to find out which type of lighting is the most ecologically sound.

Many factors to consider

Using a life cycle assessment (LCA), also known as eco-balance, the researchers took into account the material and energy flow throughout the entire lifetimes of these devices, all the way from production, through use and then disposal. One way to express their total ecological burden is in the form of eco indicator points (EIPs). The number of points is a measure for the total damage to our health and environment as well as the consumption of resources necessary for the manufacture of a product.

The analysis showed that mercury is not at all a great burden on the environment. In fact, the power generation by a coal-fired power plant emits the same amount of mercury into the atmosphere in one hour as is contained in 8,400 to 9,000 compact fluorescent lamps.

A more important factor, on the other hand, is the electricity mix used to operate the lamps. A tungsten lamp lit by hydroelectric power has less environmental impact than does a compact fluorescent lamp which is lit up with the electricity mix prevalent in Europe. "By selecting electricity which is generated in an environmentally friendly way, we can achieve more on an ecological basis than by simply switching over to compact fluorescent lamps," according to Hischier.

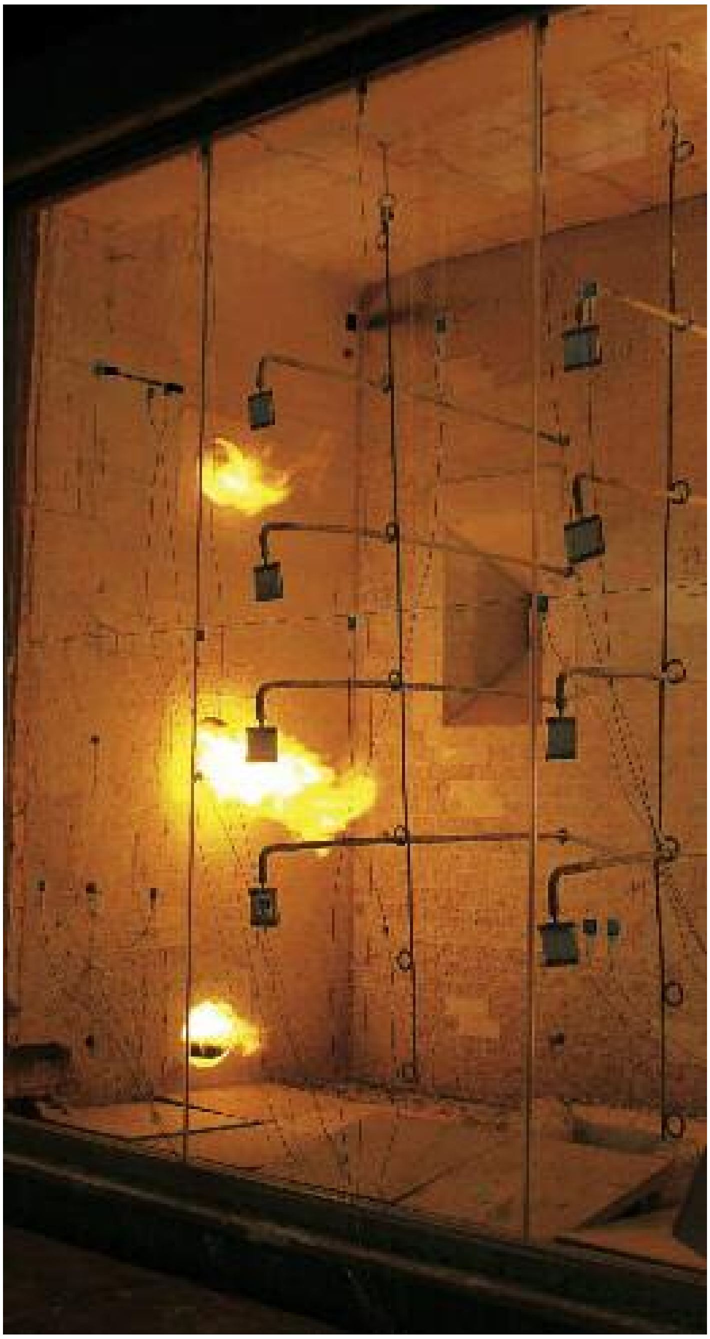
But compact fluorescent lamps do also have an ecological advantage in and by themselves. This is shown when determining the environmental break-even point, which is the time two different lamps must burn while having the same overall environmental impact. With the European electricity mix, which is generated to a large extent with fossil fuels, the tungsten lamp and compact fluorescent lamp reach their environmental break-even point quite quickly, after only about 50 hours. This is because of the tungsten lamp's considerably higher power consumption.

With electricity generated in Switzerland, this point is reached after 187 hours. Given an average operating lifetime for a compact fluorescent lamp of 10,000 hours (compared to 1,000 hours for a tungsten lamp), the purchase of these lamps thus pays off rather quickly from an ecological standpoint. //

Fire in the building!

Empa has been burning for 40 years. In the Fire Technology Laboratory at Dübendorf, the most varied components are turned into ashes. This is done not just to gain knowledge about how materials and components behave when burning, but also to optimise them. In future, even computer models should help predict the materials' behaviour in the event of fire.

TEXT: Daniela Heiniger / PHOTOS: Empa



1

The smell of something burning tells you right away where you are. That's even before you notice the furnace in the hall, where several men are labouring to place a massive 3x3-metre pane of glass in front of it. Empa's fire specialists are placing the last deformation sensors on the glass, which is a component of a new fire-resistant glazing. Then they attach the entire testing unit – the mounting fixture including the glass – to the furnace.

And then everything's ready to go. Giant flames shoot out from the side walls of the furnace. After only a short time there are some snapping, crackling sounds, and the glass takes on a milky discolouration. "This effect comes about because the embedded fire-protection layers foam up. In this way they contain the heat," explains laboratory head Erich Hugi. Even after prolonged exposure to the flames, the panes stand up to the fire; just a few pieces on the side facing the furnace split off.

"Playing with fire" for more than 40 years

During such a fire experiment, at least two team members follow the action from the test station while another does so at a monitor in the control room. They examine how the heat in the flame chamber develops and how the test object reacts. They document every change and noteworthy event and also record everything on video. "The films support us during analysis. With them we can, for example, track where and why the fire-resistant glazing no longer withstands the fire," explains Hugi. On this day, the experiment runs without a hitch. Even at more than 850 degrees Celsius, the glass stands up for more than 30 minutes, enough to be classified according to Euronorm standards.

Empa's Fire Technology Laboratory has been playing with fire for more than 40 years. In this time, a great deal of expertise has been accumulated. That's why Empa is in the position to offer its partners more than just a dedicated analysis of a fire experiment. "A test object always consists of multiple components," notes Hugi. "Often it's only a single element that is responsible for failure in the case of fire. If this weak point is known, then we can perform targeted product optimisation."

This expertise is a major reason for the long waiting list which illustrates why this Empa laboratory, with more than 75 fire experiments per year, is booked up far in advance.

Burning components – to make them better

On the one hand, a successfully completed fire test is the last step for Empa clients before they can put their products to use in applications which have requirements for fire resistance. On the other hand, when viewed on a larger scale, the experiments also deliver insightful data which Empa scientists later apply to a variety of research projects with academic and industrial partners. At this year's Structures in Fire Conference (SiF'10) in the USA, the team presented three papers. SiF addresses the behaviour of structures and materials when exposed to fire, and has established itself as the international platform for researchers, engineers and fire experts.

Consider, for example, one project presented jointly by the Empa Fire Technology Laboratory and the Swiss Federal Institute of Technology in Lausanne (EPFL). It studied fire-induced changes in the load-carrying capacity of a support which is made of fibreglass-reinforced polymers and which also has an embedded water cooling system. Thanks to the findings, it was possible not only to determine how long such wall elements can withstand fire, but the experiment also delivered valuable information about the failure mechanism. This data serves as a key performance input for a numerical model and helps engineers to design construction projects so they're even more fireproof.

From building component manufacturers to the US Navy

As part of a project within the EU's Sixth Framework Programme, Hugi's group worked together with Empa's Structural Engineering Laboratory as well as with Knauf, a German drywall specialist, on a modular, earthquake- and fire-proof building using lightweight construction techniques. "Houses must, of course, first of all offer protection from further quakes," explains Hugi. But because fires frequently break out after earthquakes, the demands on fire protection are likewise very high. During various fire experiments, Hugi and his colleagues investigated the behaviour of a newly developed type of drywall in connection with a lightweight metallic structure when placed under a mechanical load. Depending on modifications, the new drywall was able to carry more load than conventional types and held up as much as half an hour longer.

In addition, the Fire Technology Laboratory is a partner in a new project being organised by the US Office of Naval Research. In order to make ships as light and manoeuvrable as possible, naval engineers prefer to avoid heavy materials such as steel. However, because the first logical candidate as a replacement – aluminium – has in the past not proved to be sufficiently fire resistant, new lightweight construction materials such as fibre-reinforced polymers are being tested. That's anything but a trivial task, even for Hugi and his team. Even just setting up the instrumentation for a test object takes an entire week. In addition, the Empa researchers must adapt the entire infrastructure to the required test conditions such as attaching high-temperature heat-flow sensors and also handling cumbersome structural adaptations with creativity and mechanical finesse. Nonetheless, all the effort was worthwhile, according to Hugi, who adds, "In six fire experiments we gained considerable knowledge on how panels deform. This information then helps us again to refine our numerical models."

Predicting behaviour in a fire

During these projects, it isn't just a matter of determining how long something can withstand a fire. In addition, comprehensive thermo-physical data about the materials in use is continuously gathered. This knowledge contributes to a better understanding of the behaviour of the applied materials in a fire. "As a result, we can develop suitable approaches for performing numeric calculations," explains Hugi. The goal is to use computer models to predict structural behaviour in case of fire. With this, components can be optimised with regard to their behaviour in fires, and the number of expensive fire experiments can be reduced. //

1
Flames shoot up – a highlight after days of work on test objects and setting up experimental rigs in the Fire Technology Laboratory.

2
Fire experts must also be prepared for almost anything: suddenly part of the installation collapses.

3
Meticulous preparations in the Fire Technology Laboratory.

2

3

Materials with brains

Many materials change when exposed to external stimuli. If this reaction is useful, reproducible and controllable, the material is categorised as being "smart". Such materials have a considerable potential for practical applications. In order to exploit this, Switzerland is funding the National Research Programme NRP 62 "Smart Materials". Empa is participating with many projects.

TEXT: Beatrice Huber / PHOTOS: Empa

An example of a smart material: In Empa's Blimp, electroactive polymers (black area) stretch or contract when an applied voltage is turned on and off. The resulting flapping of the tail fin propels the airship forward.

Virtually every material reacts to external stimuli by changing its physical, chemical or biological properties. This can lead to problems. Consider, for instance, train rails which expand and bend out of shape during the extreme heat of summer. These changes, however, can also be a decisive advantage – specifically when materials adapt to their environment and thus can better fulfil their functions, or perhaps start to do so in the first place. If the stimulus is removed, the materials return to their original condition; the reaction to external influences is therefore reversible. If a material also "behaves" controllably and reproducibly, and always exhibits the same reaction to the same stimulus, it's characterised as being "smart". Especially attractive are those materials for which the external stimulus involves little energy. There are many smart systems in nature. For instance, there's the human lens, which is deformed by muscles more, less or not at all depending on where the focus of vision should be.

Materials react to all sorts of stimuli

The stimulus can be mechanical, as in the case with the lens, but also thermal, electrical, magnetic or chemical. What are known as shape memory alloys (see "Ductile materials for mechanical applications") deform or reassume their original shape when exposed to changes in temperature. Hydrogels which release active

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Novel catalysts for natural gas vehicles

The scarcity of oil, climate change and stringent emission regulations, combined with a continuously growing global vehicle fleet, ask for a more efficient and widespread use of alternative fuels. One of these is natural gas, which emits lower levels of nitrogen oxide and CO_2 than petrol or diesel. However, the exhaust from vehicles fuelled with natural gas needs special treatment to remove traces of non-combusted methane, which is a potent greenhouse gas.
Until now, existing catalytic converters from petrol vehicles have generally been adapted to the emission profile of natural gas vehicles. In the project "Palladium-doped perovskite catalysts for natural gas vehicles", the goal of Empa researchers is to develop new types of converters. These should require smaller amounts of precious metals (for example, palladium) and demonstrate increased long-term stability. For this purpose, the researchers are using perovskite metal oxides which react with the chemical composition of their environment. These allow precious metal atoms to enter the crystal lattice in an oxidising atmosphere and exit the surface in a reducing atmosphere.

substances in a controlled fashion due to an external stimulus are interesting for medical applications (see "Nanofibres for intelligent drug delivery"). Piezoelectric materials generate an electric voltage when placed under pressure or tension and therefore are put to use in devices such as deformation sensors. Also included among smart materials are compliant systems. These are flexible enough to allow large deformations but at the same time stable enough that they can withstand large loads (also see the article "You don't win a prize ever day" on page 20).

National research programme with heavy Empa participation
In order to take advantage of the innovative potential attributed to smart materials, the Swiss Federal Council launched the National Research Programme NRP 62 "Smart Materials". Within an NRP, researchers from various disciplines and institutions collaborate on projects which focus on solving urgent problems. The Swiss Federal Council selects the topics; the Swiss National Science Foundation (SNSF) manages the NRPs.

For NRP 62, 21 projects from a total of 79 submitted proposals were approved and are being financed with 6.6 million Swiss francs. With six of the 21 projects being led by Empa researchers, Empa was quite successful. What led to this success? For Andrea Bergamini, who has long been working with smart materials and is heading up one of the projects (see "Ductile materials for mechanical applications"), one reason is the long-term experience Empa has with such materials. He adds, "It's easy to keep track of everything going on at Empa, but even so we have numerous experts from several disciplines who can collaborate on very imaginative projects."

Considerable potential for innovation
Traditional systems such as industrial robots with hydraulic drives or airplane wings with conventional stabilisers actually function quite well. But as the number of individual components increases, so does the complexity of the system. The potential of smart materials lies, among other things, in the fact that a material

Ductile materials for mechanical applications

Structures that can change their shape or stiffness on command are much sought after in technology and engineering. A stiff structure is first converted briefly into a soft state and then stiffened again into a new shape. Such materials, for example nickel-titanium shape memory alloys, already exist; however, they lose their stiffness only when heated, which requires considerable energy. A new approach uses electrostatic forces, which are much less demanding from an energy standpoint. These forces generate a "bonding" between thin layers of dielectric material; when the forces are turned off, the adhesion disappears.
In the project "New approaches to shape and stiffness changing materials", Empa researchers are working together with ETH Zurich to study and optimise dielectric materials to obtain an optimal coupling of the layers with the addition of only small amounts of energy. Possible applications include those in aircraft construction. A wing would no longer need mechanical flaps for steering; instead it would change its own shape, guided by electric pulses. Rotors could also adapt themselves to varying aerodynamic situations.

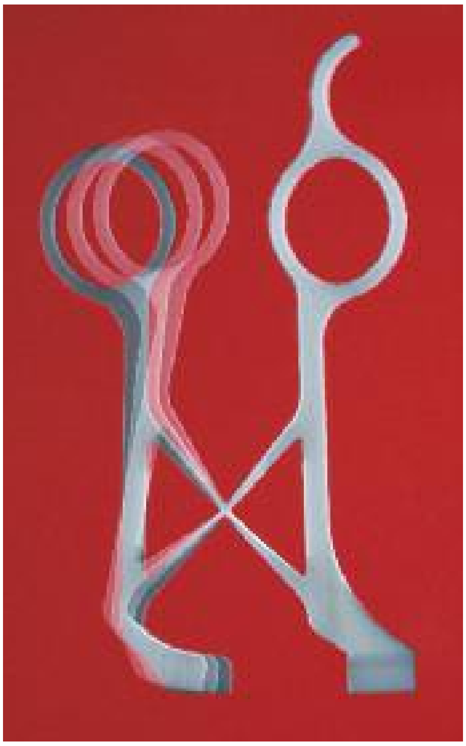
can take on the functions of several individual components. By reducing complexity, the systems become more reliable – there are fewer parts that can fail – and can be better integrated. Fabrication should become easier with maintenance requirements considerably reduced.

It will even be possible to develop systems which were previously pure fiction. An example is airships which fly noiselessly and energy efficiently using "artificial muscles" (also see "New fabrication technology for artificial muscles"). Electroactive polymers, here acting as artificial muscles, stretch or contract when an electric voltage is turned on or off. In the case of Empa's Blimp, a tail fin flaps back and forth to provide propulsion. Such an airship would simply be too heavy if made of conventional materials.

First-time cooperation between SNSF and CTI

What's more, NRP 62 is introducing a completely new element. For the first time, the Swiss Innovation Promotion Agency (CTI) is partnering with the SNSF. That agency promotes knowledge and technology transfer between companies and universities in applied research and development projects. CTI also provides assistance to start-up companies. With NRP 62, the Swiss Federal Council has focussed specifically on Swiss industry because smart materials could in future lead to a crucial competitive advantage. "NRP 62 is clearly focussing on creative scientific work and technical development of new materials and systems which fulfil the criteria "smart" are sustainable and offer an economic potential for the transfer to industry," says Louis Schlapbach, President of the NRP 62 Steering Committee and former Director of Empa, in explaining the goal of this NRP. "I also hope that young scientists and engineers will be educated so they have a wide range of expertise in this area and can then work enthusiastically in an interdisciplinary manner."

No directly marketable products are yet expected from NRP 62. Even so, the direction is clear. "Among the goals is that many projects which are being fully funded in their initial phases by the SNSF are afterwards directed in a second phase towards specific applications," explains Schlapbach. "Then, in a third phase, they can be implemented with a practical focus in conjunction with



"Superelastic" tools for surgery

Compliant systems essentially reproduce the behaviour of conventional mechanical mechanisms. But because these systems exploit elastic deformations within the material, moving parts such as bearings and joints are no longer necessary.
These systems offer major advantages for surgical tools; sterilisation is simpler and more efficient because compliant instruments have no gaps in which bacteria can settle. Accidental lesions are less frequent because the instruments have no hinges which can pinch and injure tissue. And thanks to their inherent monolithic nature – the instruments consist of only one piece – they require almost no manual steps during assembly and hence allow for cost-effective manufacturing.
In the project "Superelastic compliant surgery tools", the goal of Empa researchers is to develop innovative surgical tools based on compliant systems made of superelastic shape memory alloys.

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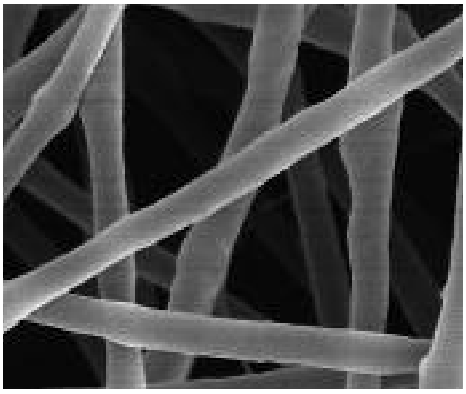
industry partners within a CTI project, leading to the development of prototypes." This is a promising perspective, says Empa's Andrea Bergamini, adding, "For me as an engineer, NRP 62 is quite exciting because this research is very target-oriented, and we must take into consideration real-world conditions." If it is successful, NRP 62 should become a reference model for future cooperation between the SNSF and CTI.

The NRP 62 is divided into four modules: "Smart shape transformers for macroscopic use", "Stimuli-responsive materials for the microscopic range", "Smart drug delivery materials" and "Exploratory research for smart materials". The fourth module concentrates on high risk/high reward exploratory research projects without a fixed field of applicability but which have enormous potential. Empa is heading up projects in all four modules; three in the first and one each in the other three. The projects have a duration of 12 to 36 months. Thus, initial results will probably soon see the light of day. //

Further information: *www.nfp62.ch*



Nanofibres for intelligent drug delivery

Hydrogels can release drugs on demand in a controlled manner and are thus very interesting for medical applications. Those which react to heat or cold are especially attractive because temperature can be changed easily and in a non-invasive manner. The disadvantage of conventional hydrogels is their relatively long response times, which can be from minutes to days.
In the project "Nanofibres for intelligent drug delivery", Empa researchers are working together with the Max Planck Institute for Polymer Research in Mainz (Germany) and ETH Zurich to develop novel types of nanofibres. These consist of two-component nanofibres with a drug-loaded intelligent core. Additionally, they plan to embed magnetic nanoparticles which will allow accurate local heating by magnetic induction. The fabricated nanofibres could be embedded in advanced textiles for therapeutic purposes. They will also open up additional non-medical applications such as clothing which can protect or cool the body.

The photos illustrating the projects do not originate from the projects.

Fluid core fibres as shock absorbers and dampers

Synthetic fibres account for more than 70 per cent of worldwide fibre production. In the project "Synthetic fibre with fluid core for damping applications", Empa researchers, together with ETH Zurich, seek to study the dynamic instabilities of fibres made of polymer blends. As yet, there exists little basic knowledge about them. Better understanding should lead to the manufacture of a synthetic fibre with a fluid core by means of a melt-spinning process. The core's structure and material will allow control of flow velocity, viscosity and friction "from the outside", thus giving the fibre adaptive properties.
Possible applications depend on the fibre's detailed properties. For example, if the core is filled with a fluid which hardens when it reaches a certain flow velocity, such a fibre could be used as an adaptive damping element or energy absorber. Other possible applications include acoustic filters, flow dampers or shock-absorbing clothing. The fibre could also be used as reinforcing fibres in ultralight composite materials or in bulletproof vests.


Photo: iStock

New fabrication technology for artificial muscles

So-called dielectric elastomer (DE) transducers consist of an electroactive polymeric compliant capacitor which undergoes large surface deformations when a voltage is applied. They are attractive as actuators with muscle-like mechanical properties. Such artificial muscles could, for example, be used in robots or in wearable and/or portable orthotics and prosthetics.
In the project "Fabrication technology of smart dielectric elastomer transducers", the goal of Empa researchers is to develop thin, flexible and multilayer films which can produce contraction motion under external tension with relatively low activation voltage and thus can be used as an artificial muscle. The focus is on the development of a process for the fabrication of DE transducers with high robustness and reliability.

"Smart materials give engineers new degrees of freedom"

Great potential is being attributed to smart materials. EmpaNews spoke with Edoardo Mazza, head of Empa's Mechanics for Modelling and Simulation Laboratory and co-initiator of the National Research Programme NRP 62 "Smart Materials", which just recently started up. We discussed these materials but also his research at Empa and ETH Zurich.

INTERVIEW: Beatrice Huber / PHOTO: Ruedi Keller

"Anywhere you have movement, anywhere you have life, mechanics is involved."

Smart materials – how would you describe them?

Smart materials, examples being magnetorheological fluids or electroactive polymers, have the ability to adapt. That means they react to external stimuli by changing their physical and mechanical properties. We want these effects to be reproducible, controllable and ultimately useful. Expressed more directly, we call these materials smart if they do what we want them to do.

What potential do these materials have?

Smart materials give engineers new degrees of freedom. They enable completely new functionality and devices, or known and proven solutions can be optimised or made less expensive. Apart from piezoceramic components and shape memory alloys, at this point there are actually few products on the market which are based on smart materials. Besides basic research, we also need innovative and courageous industrial partners. Not all the material systems we are investigating will live up to their initial promises. On the way to these new products, however, we'll face exciting, far-reaching and interdisciplinary challenges to which students and post-graduates will contribute solutions. This presents us with excellent educational opportunities. This new generation of scientists and engineers will certainly have great potential for the future of our society.

Concerning the National Research Programme NRP 62, which you co-initiated, six of the 21 approved projects are being headed up by Empa researchers. What led to this success?

Empa offers exactly what the NRP request for proposals demanded: comprehensive knowledge in both materials science and engineering. For more than a decade, researchers at Empa have been working with smart materials. In addition, Empa sets its priorities towards making sure that basic research and its transformation into new products go hand-in-hand. This is completely in the spirit of the NRP.

That's also apparent in one special aspect of NRP 62. For the first time, the Swiss Innovation Promotion Agency CTI is involved as a cooperation partner. What does this mean for you as an engineer?

The connection with CTI gives the project a concrete goal because the findings should be implemented in some specific products. For me as an engineer, that's a very positive sign. The Swiss National Science Foundation and CTI represent two cultures which should increasingly enhance each other and not contradict each other.

Your area of research, as the name of your laboratory reveals, is mechanics. What do you find so fascinating about this discipline?

Some people say that mechanics is the mother of physics. And while that's quite an honour, it also makes this discipline sound perhaps somewhat outmoded. The fact is, mechanics is always at the leading edge. It describes the causal connections between forces and motion or deformations. In other words, anywhere you have movement, anywhere you have life, mechanics is involved. Knowledge of mechanics is essential for every modern area of research – whether nanosystems, smart materials, energy technology or biotechnology.

For quite some time you've also been a professor at ETH Zurich. What does it mean for you to work simultaneously at ETH Zurich and Empa?

I'm delighted to have this unusual opportunity. It's very interesting to work for both institutions, although sometimes not that easy. Empa has very knowledgeable and experienced specialists and, in some areas, very good infrastructure. Being there gives me better chances to collaborate with experts from complementary disciplines. As for ETH Zurich, I greatly enjoy my teaching and working together with my students. I greatly value the freedom we have at ETH regarding research and the culture of continuous learning. I see myself as a link which can make the positive aspects of each institution useful for the other, as well.

How do the two institutions enhance each other?

I don't believe in a separation of the missions of the various academic institutions in Switzerland. I see a wide degree of overlap in the objectives concerning basic research, innovation, technology transfer, and the education of our future leaders. Of course, each institution pursues these objectives in a different way depending on its internal organisation, infrastructure and, above all, on the people who work there. Collaboration among the institutions makes it possible for society to benefit optimally from the results they achieve.

You once said that you came to study in Zurich because of its international flair. Have you meanwhile found that flair?

Zurich is a cosmopolitan city. You can sense its international flavour especially in some of the large corporations and research institutions. I find this a valuable source of enrichment for research and in general for society. The institutions of the ETH Domain, and here also Empa, are committed to excellence. Today, excellence must always be evaluated in global terms, and international competition continues to get stronger. This brings to mind initiatives for excellence in Germany or major research programmes in the Far East. In order to retain the highest level of quality in research and education in Switzerland, collaborations such as those between Empa and ETH Zurich are increasingly important. //

Personal background

Since 2006, Edoardo Mazza has been head of Empa's Mechanics for Modelling and Simulation Laboratory and at the same time is Professor of Mechanics at ETH Zurich. He previously studied mechanical engineering there and also earned his doctorate in mechanics. Following completion of his PhD, Mazza switched over to industry and worked at Alstom Power where he was group leader in the steam turbine R&D department. In 2001 he returned to ETH Zurich as an assistant professor, in 2006 he was appointed associate professor, and since 2010 he has been a full professor.

Spark in the dark

Whether on wristwatch dials or for self-illuminated emergency exit signs, luminous substances have long been an integral part of our society. Empa researchers are now developing a new generation of such substances which should light up whiter, more brightly and longer than ever before.

TEXT: Peter Merz / PHOTO: LumiNova

Until the mid 20th century, luminous pigments were blended with radium, which was then replaced by tritium. It is only since 1998, that luminous substances, called "solid state lighting", perform their job without radioactivity; they instead generally contain what are known as afterglow pigments. These continue to operate using the same principle: the crystal lattice of a carrier material such as strontium aluminate is doped with atoms of a second substance.

The design of such pigments is predominantly calculated on a theoretical basis using a computer simulation, as is also done in Empa's Solid State Chemistry and Catalysis Laboratory under the direction of Anke Weidenkaff. "The development of such substances is always a challenge," she explains. "At the early computer modelling stage you must investigate which atoms to embed so that the complicated physical luminescence mechanism functions properly." Only then can the doped atoms move into an energetically excited state when exposed to light. Then, in the dark when no further energy is being added, the atoms return to their original state and in doing so release energy in the form of visible light.

Lighting up longer, more brightly and, above all, whiter

Currently, the best afterglow pigments, patented under the name LumiNova, are created on the basis of strontium aluminate. The patent holder and pioneer in this technology is Nemoto & Co., Ltd. of Japan. That company is now an indirect industry partner of Weidenkaff's project through her work with LumiNova AG (Switzerland), a joint venture formed between Nemoto and the Swiss company RC Tritec Ltd.

In this project, she and her team have been researching a new generation of afterglow pigments since February. The researchers' primary goal is to improve the characteristics of the light's duration and colour. "These illuminants are an exceptionally energy-relevant topic," remarks Weidenkaff, who has a vision that "perhaps in future, thanks to them, there could even be room illumination completely independent of electricity." The Empa team expects to have the first results by the end of the year. //

“First aid” plugs the leak

TEXT: Martina Peter

A hole in an inflatable boat is only a disaster if the air escapes too quickly to reach the safety of land. It’s somewhat less dramatic but nonetheless uncomfortable to spend the night on a leaky air mattress. Even in this case, though, you can get some uninterrupted sleep if only the air leaks out slowly enough. In future, self-repairing layers of porous material should ensure that the membranes of inflatable objects are not only water and airtight but also that they can plug up any holes on their own, at least temporarily.

The idea behind this comes from nature. Bionics experts keep on discovering amazing principles of construction which engineers can adopt for countless technical solutions. This is also the case with self-repairing materials. The self-healing process of the pipevine (*Aristolochia macrophylla*), a liana which grows in the mountain forests of North America, gave the biologists at the University of Freiburg, Germany, a decisive clue. When the lignified cells of the outer supportive tissues which give the plant its bending stiffness are damaged, the plant administers “first aid” to the wound. Parenchymal cells from the underlying base tissue expand suddenly and close the lesion from inside. Only in a later phase does the real healing process kick in and the original tissue grows back.

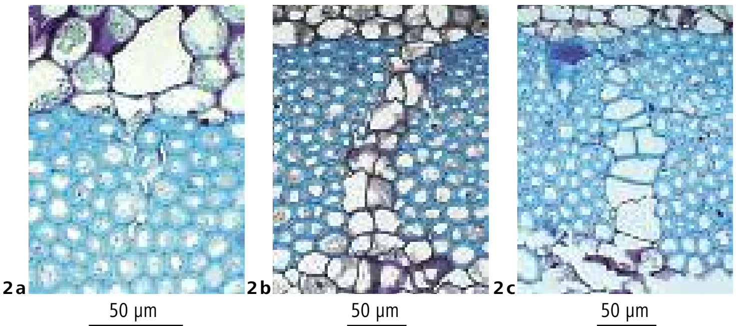
Self-healing inflatable structures

This principle is now being transferred to materials – more specifically, to membranes – in a bionics project sponsored by the German Federal Ministry of Education and Research. An additional layer which foams up whenever a membrane is damaged administers first aid, following the model from nature, and plugs any holes until proper repairs can be made. While researchers from the University of Freiburg under the direction of Olga Speck are busy studying the biological and chemical aspects of the model provided by liana plants, Rolf Luchsinger and Markus Rampf at Empa’s Center for Synergetic Structures are working on technical solutions for polymer membranes. Luchsinger’s impetus, however, concerns neither inflatable boats nor air mattresses but rather load-carrying pneumatic structures for lightweight construction. His tensarity beams serve as elements for quickly erected, lightweight bridges and roofing.

The study’s goal is to understand under which conditions a hole plugs itself up if the foam expands on a membrane following damage. Within the scope of his dissertation, Rampf is studying this process with the help of an experimental setup which places a membrane under pneumatic pressure and then punctures it with a nail. The researchers have already achieved successful interim results. A two-component foam of polyurethane and polyester suddenly expands when exposed to the excessive pressure which arises when air rushes out of a hole.

“It works in the lab,” notes Luchsinger, “and we’re achieving high repair factors.” What does this mean in the real world? Take the case of an air mattress with a volume of 200 litres. Given a certain-sized hole, previously it was necessary to pump it up every five minutes; it now holds for eight hours – enough time to sleep through the night. “We now know enough about the foam that we can enter into discussions with membrane manufacturers about commercialising this technology,” according to Luchsinger, when describing the next steps. //

1
A membrane made of polyvinyl chloride-polyester (yellowish colour) is punctured with a 2.5-millimeter diameter needle, and at that moment the polyurethane foam (brown) uddenly expands. (Photo: Empa)



2
Cell repair in a pipevine (*Aristolochia macrophylla*). Parenchymal cells of the base interior tissue suddenly expand if the lignified cells of the outside supporting tissue are damaged (a and b), and in a later phase (c) they eventually lignify. (Photos: Plant Biomechanics Group, University of Freiburg im Breisgau)

"You don't win a prize everyday"

A new bed imitating the movements of healthy people when sleeping should help protect bedridden patients from decubitus ulcers, better known as bedsores, and at the same time unburden health-care personnel. Behind this project, which recently won several start-up awards, is Michael Sauter, a mechanical engineer and young entrepreneur who in May 2009 founded his own company "compliant concept", supported by Empa's glaTec technology centre.

TEXT: Martina Peter / PHOTO: Ruedi Keller

At first glance, a nursing bed for bedridden patients hardly seems to fit the image of this sporty young man. During his dissertation, Michael Sauter was more interested in hockey sticks. And that's not because of his ambitions in sports, which was actually more in mountain biking. Rather, in his area of research, compliant systems, he saw enormous potential in improving products of all conceivable types.

For example, hockey sticks. In an industry project headed by Paolo Ermanni at the Institute of Mechanical Systems at ETH Zurich, he had the opportunity to incorporate his ideas and develop a new concept of benefit to manufacturers of hockey sticks. And he was successful – since the 2006 Olympic Games in Turin, his hockey sticks have been put to use not only in Switzerland but also in neighbouring countries.

Together with other students, Sauter then developed a new type of automobile seat which can adapt to the driver or passenger and the situation on the road. Then, according to Sauter, something suddenly popped into his head: "There's no good reason why I can't do the same thing with beds..." He couldn't get this idea out of his head even after, following completion of his doctorate in 2009, researcher Flavio Campanile brought him to Empa's Mechanics for Modelling and Simulation Laboratory.

What works for a hockey stick also works for ... beds

But it might have remained a mere idea, had Sauter not taken part in the Venture Challenge course, supported by the Swiss Innovation Promotion Agency (CTI). Here, university graduates learn how to take innovative technologies and convert them into business concepts. At the course, something became clear to him – a bed which can adapt would be an enormous help for bedridden patients and health-care personnel. The problem is that in order to thwart the danger of bedsores or decubitus ulcers, nursing staff must continually change a patient's position. A new type of jointless slatted bed frame made of smart materials and a mattress adapted for the purpose could take over this task. Together they should imitate the movements of a healthy person by gently and firmly changing the patient's position.

The mechanical engineer was convinced that this was technically feasible. However, to gain the necessary medical background and to determine whether there was actually any market for such a new nursing bed, he needed the help of health care experts. The decubitus specialist Walter Seiler initially reacted cautiously to Sauter's enquiry. "That's not at all easy, and many others have already made attempts," he thought. But after a visit with Sauter he became enthusiastic. He was impressed by the fact that an engineer could address and understand the issues dealing with decubitus ulcers in such a comprehensive and systematic way.

Extensive network of partners

With the goal of developing new technologies which make everyday life a easier, "compliant concept" has entered into collaborations with numerous industry partners: OBA AG, Festo AG, Fritz Nauer AG, Bigla Care, wissner-bosserhoff GmbH, Sarna Plastec AG, Produ-Plast AG and Qualicut AG. Also belonging to this network are the Swiss Paraplegic Centre Nottwil, the University Hospital Basel and the HSR Hochschule für Technik Rapperswil.

The scientist-turned-entrepreneur

Sauter had not only discovered his topic but also won over an experienced mentor who then taught him how to better understand medical interrelationships, and this even though Sauter can't stand the sight of blood. He spared no effort in learning to appreciate the needs of those affected, even to the point where he worked as a trainee in a health-care facility.

All this newly gained knowledge finally led in May 2009 to the founding of his own company, "compliant concept". This spin-off from Empa and ETH Zurich set up its offices on the Empa campus in Dübendorf, in the glaTec technology centre. "In Switzerland we have a fantastic set-up where you can get help with every aspect," as he found out, "but you just have to go out and get it."

This also meant that he had to address his weaknesses. For example, he had to learn how to present his ideas in a persuasive manner. For this, Mario Jenni, glaTec's Managing Director, acted as his sparring partner. Sauter was also able to count on Jenni's support in preparing contracts. Jenni praises Sauter as not just being a good listener but adds that he implements suggestions in a professional way and is goal-oriented in doing so. "He's got a good sense for what the market wants, and already at this early stage he's built up a large professional network."

Being open to the inputs of others along with a large willingness to learn and ability to pick up the required knowledge are traits which characterise Sauter. Martin Wyttenbach, a CTI Start-up coach, attests to this young researcher's impressive personal development. He first got to know him when his project was accepted into the CTI Start-up programme. Since then, Wyttenbach has accompanied him as a coach and in helping his development as a young entrepreneur. In this regard, Sauter must address central issues including market positioning, the business model, marketing and financing.

A prize-worthy idea

The progress of this young company has not gone by unnoticed. With his team, Sauter has already won several prizes for young entrepreneurs. Just recently he received the CTI Medtech Award 2010; last January, Sauter was recognised with the Venture Idea 2010 award for having one of the ten most innovative business ideas originating from Swiss universities; and at the end of 2009, "compliant concept" received the Heuberger Winterthur Young Entrepreneurs Prize. However, as Sauter says, "You don't win a prize every day, and many times you simply have to persevere."

While the central focus during the initial stage was on the best product from a technical standpoint, in the second phase it shifted to the construction of a prototype bed. And here Sauter was able to show that the idea worked. A new nursing bed only has a chance of becoming established if it has demonstrable advantages over conventional beds in every respect, so tests were conducted at the Swiss Paraplegic Centre in Nottwil. This is not only a question of how practical the idea of a "self-moving nursing bed" is, any future success also depends on seemingly unimportant details such as how easy it is to clean.

Meanwhile, all efforts at "compliant concept" are focussed on the question of how this bed system can be successfully introduced into the market. Sauter just recently signed a letter of intent with a German company, one of the three largest manufacturers of nursing beds in Europe. In addition, he's continually on the lookout for new partners and investors, especially those with experience in the international marketing of medical equipment. //

Photo: iStock

SMAR 2011

From 8 to 10 February 2011, international experts from science, engineering, infrastructure management and enterprises will gather in Dubai, United Arab Emirates, for SMAR 2011. This is the first ever Middle East Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures. Empa's Structural Engineering Laboratory is organising the conference with support from The American University in Dubai (AUD).

At the centre of attention are testing and monitoring technologies, methods for structural modelling and assessment as well as the application of advanced materials for structural rehabilitation. SMAR 2011 will provide a forum for discussing proven techniques as well as the latest developments. In addition, the conference will provide a platform to explore the potential for international cooperation. One of the keynote speakers will be Ahmad Abdelrazaq, Executive Vice President of Samsung C&T KR, who will review the development of modern monitoring systems for extremely tall buildings. Samsung led the consortium which erected the Burj Khalifa in Dubai, which is currently the tallest building in the world. *http://smar.empa.ch/*

Innovation Day for the textile industry

TEXT & PHOTOS: Urs Bünter

Roughly 250 participants took part in the Swiss Textile Federation's Innovation Day 2010 held in late August at the Empa Academy. The motto was "Textiles stretch their limits". Guest speaker Jeroen van Rooijen, who has worked as fashion editor for many magazines including Annabelle, Bolero and Z – die schönen Seiten, dared to take a first look beyond these limits. For instance, when looking at the megacities where in future most people will live, he saw some wonderful examples for the use of textiles to address changing requirements. Climate change necessitates clothing with improved protective functionality, whereas sustainability requires natural fibres and the recycling of materials. In addition, our increasing digital lifestyles demand interactive fashion. These trends present plenty of challenges for the Swiss textile industry.

At Empa, work is being carried out on a number of projects including some which combine textiles and electronics. Manfred Heuberger, head of the Advanced Fibers Laboratory, introduced his research on textiles with additional functions thanks to metallised fibres. Lukas Scherer from the Protection and Physiology Laboratory discussed light-conducting fibres, for example for luminous textiles in photodynamic therapy, which could be used for, among other things, the treatment of tumours. //

Swiss NanoConvention 2011

The Swiss NanoConvention will bring together leaders from science and industry in the field of "nano", key figures in innovation and technology, entrepreneurs, investors, administrators and politicians. The goal is to enable the efficient development, financing and regulation of innovative technologies. This requires accurate choices based on the most up-to-date information. Supporting decision-makers in that crucial aspect, the Swiss NanoConvention 2011 will be a platform for connecting people, networking, debating and exchanging ideas – or even generating new ones. Key players will be able to gather the best available information on the potential of one of the key emerging technologies of the 21st century, and its opportunities for innovative developments, products and services.

High-level speakers, both national and international, will provide insights into current trends and share with you their views and opinions about future developments in the nano arena. In short: the Swiss NanoConvention is the prime showcase for nanotechnology in Switzerland, supported and jointly organised on a rotating basis by the "who's who" in the Swiss nano scene. Staged annually in different regions of Switzerland, it is the venue for meeting the great minds in nanoscience and -technology.

Key topics include pressing issues such as securing a sustainable energy supply and a clean environment – the area of "Cleantech" –, providing novel nanomedical applications and diagnostics as well as innovative functional materials and their numerous industrial applications. Another focus will be the potential risks associated with free nanoparticles, and how society sees and handles these issues.

The Swiss NanoConvention 2011 will take place on 18 and 19 May in the Congress Center TRAFO in Baden. The event will be organized by Empa, the Paul Scherrer Institute (PSI) and ETH Zürich. A satellite event with emphasis on SMEs will be held by the Swiss Innovation Promotion Agency CTI on the second day, and NanoPubli, an event geared toward the general public, will take place in parallel. *www.empa.ch/swissnanoconvention*

Visitors to the Innovation Day of the Swiss textile industry at the Empa Academy marvelled at all sorts of creative and innovative items.

World Resources Forum 2011

Being held for the second time, the World Resources Forum (WRF) will take place on 19 to 21 September 2011. The event aims to transcend the current political focus on climate change and bring the broader issues of global resource consumption and resource productivity back onto the agenda. Not only politics but also the economy needs a real-world basis for decision-making towards taking the next practical steps to a sustainable economic world order. The basis of WRF 2011 is the Declaration on Resource Governance, which describes a responsible approach to handling resources; this document was drawn up and approved at WRF 2009.

The World Resources Forum is directed towards scientists, politicians, research-oriented practitioners, consultants, sustainability officers and other professionals working in the areas of sustainable development, resource efficiency, eco-innovation and climate change. The conference, organised by Empa, will be held in Davos where each year in January the World Economic Forum takes place. Interested parties can now subscribe to the newsletter; further information is available at *www.worldresourcesforum.org*

World Resources Forum 2011

Opinion

Jean-Daniel Gerber

Jean-Daniel Gerber
Director of the State Secretariat
for Economic Affairs (SECO)

"I'm delighted to see that in Empa, Switzerland has an internationally renowned institution which can build bridges between research and applications, even in collaboration with developing countries."

Events

23 November 2010

Women in science, why so few?
Lecture by Prof. Petra Rudolf,
University of Groningen, The Netherlands
Empa, Dübendorf

25 November 2010

Carbon nanotubes: Unique nanomaterials with a broad field of applications
For interested parties from industry
Empa, Dübendorf

23 to 28 January 2011

5th International Symposium "Hydrogen and Energy"
For interested parties from science and industry
Stoos Seminar Hotel, Switzerland

8 to 10 February 2011

SMAR 2011
First Middle East Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures
American University in Dubai (AUD), United Arab Emirates

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

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