# Empa News

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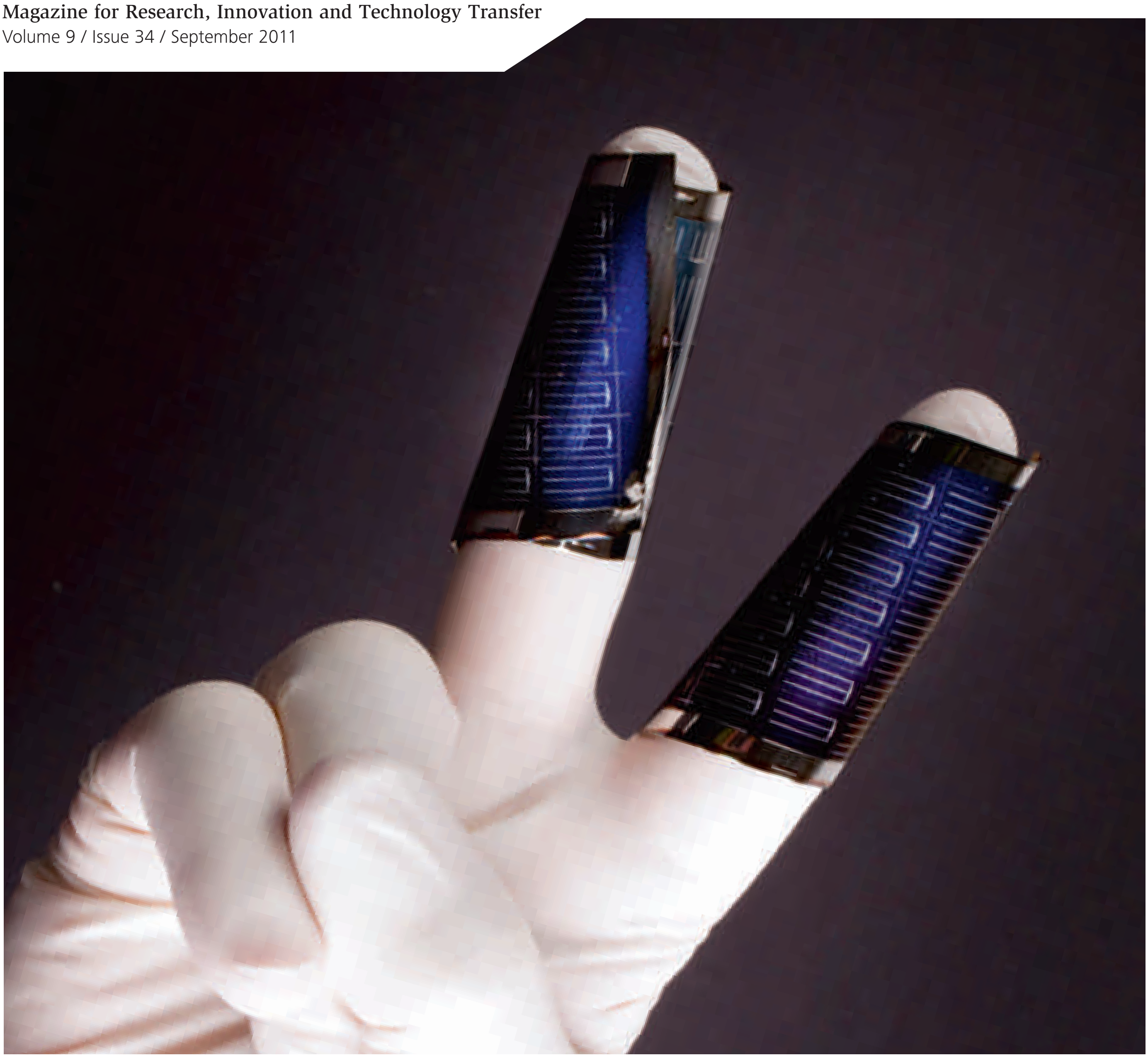

## How to use resources efficiently

EMPA
Materials Science & Technology

# Closing the loops

How does our free-spending, shopaholic society work? We purchase a product, of course as inexpensively as possible, use it and then "dispose" of it as soon as we no longer fancy it. Along these lines, it's astounding what today is considered a disposable product, at least in industrialised countries.

This linear flow of goods, with its beginning and end, has one flaw – the raw materials needed to manufacture these goods and products, including our fossil energy carriers, are all gradually running out. That's why energy-efficient technologies that preserve our natural resources are more in demand than ever.

The ultimate would certainly be closed material cycles. In the case of carbon, this would mean using hydrogen obtained from solar energy to convert the atmospheric "waste product" $CO_2$ into methane (or even possibly into liquid hydrocarbons), which then in turn could be burned as fuel. As the various stories in this issue of the EmpaNews go to show, Empa has been working with its partners on this and other resource-preserving technologies.

In order to firmly anchor ideas and concepts such as sustainability in the minds of young people, Empa has also been active in the development and education of the next generation of scientists. Our summer camp was, just as every year, a resounding success, and the first (but by no means last) "guest performance" of the "Kinderlabor" at Empa was quickly booked up. The fact that this technology transfer is by no means a one-way street is illustrated by the article about the winners of this year's "Schweizer Jugend forscht" special award, who developed a LED-based sun simulator (which is meanwhile being used regularly by our scientists).

Enjoy your reading!

**Michael Hagmann**
Head Communications



**Cover**

Sustainable use of energy and raw materials is a central research topic at Empa. Here two highly efficient CdTe solar cells are wrapped around two fingers. The victory sign is no accident – the cells convert 13.8 per cent of the sunlight into electricity, and thus Empa now holds (another) world record in conversion efficiency. (Photo: Empa)
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# Jatropha's second chance

Jatropha was once considered Africa's great hope. The plant yields combustible oil, grows without fertiliser even in inhospitable locations, and its fruit is inedible. Sounds like a sure thing for bio-energy, but so far the "wonder nut" hasn't been able to deliver. Empa is investigating to find out why.

TEXT: Rainer Klose / PHOTOS: Empa

Jatropha plant in Eastern Africa.

Despite this promising background, Simon Gmünder, a researcher in Empa's Technology and Society Laboratory, is now investigating its initial failure and trying to find out whether it still represents a viable energy solution for developing countries. That's because during the introduction of the plant, many things went wrong. "People sold many small farmers on jatropha as 'green gold'", relates Gmünder. Large investors also jumped on the idea, started plantations and promised the local village inhabitants rapid wealth. Even relief organisations were enthusiastic. They recommended that people plant jatropha in block plantation, in other words, planting a mix of jatropha and domestic crops on the same plot.

**Dubious sustainability**

This initial euphoria was soon followed by disenchantment because in many locations, harvest yields were below expectations, and the same held true in the demand for jatropha nuts. The market didn't cooperate, prices remained low and thereby further reduced the chances that the costs of production could be covered. To achieve higher yields, many growers moved to fertile land or intensified cultivation. Hence, jatropha started to compete directly or indirectly with the production of food crops, which diminished its ecological balance along with acceptance by society.

For this reason, jatropha has got a bad reputation in Eastern Africa over the last few years. Many small farmers but also large investors have abandoned the idea. This false start could have been avoided,

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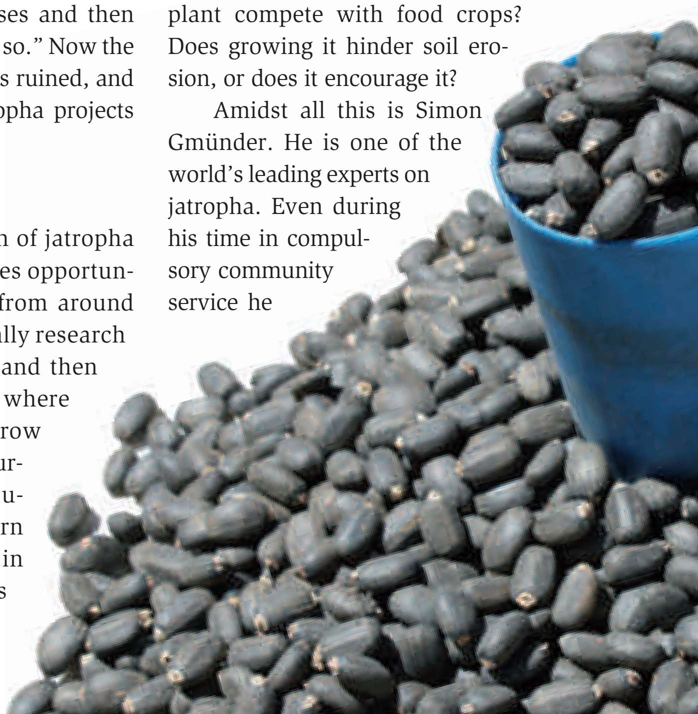
The jatropha nut has already become a part of the everyday culture in Eastern Africa. From its oil, local craftsmen produce soap (photo at left), and jatropha is also planted to prevent soil erosion in gullies (photo above). However, commercial uses of this oil fruit are yet lacking. This is the objective of the current research project.

according to Empa researcher Gmünder, who believes we should have researched suitable cultivation practices and investigated the local ecological and socio-economic implications in advance. “The step from vision to effective cultivation simply came way too fast. This is especially true for small farmers, who believed the unrealistic promises and then had to pay a high price for doing so.” Now the plant’s reputation is more or less ruined, and as a consequence, serious jatropha projects are also being affected.

**A second chance for jatropha**

Clearly, the initial introduction of jatropha failed. Nonetheless, science sees opportunities. A union of researchers from around the world wants to systematically research the jatropha nut and its uses and then make recommendations as to where (and how) it makes sense to grow the plant. Six institutions in Europe (including the ETH Lausanne (EPFL), University of Bern and Empa), five universities in Africa and three institutions from Central America are working together on a three-year project that started in June 2009. They are working on the optimal cultivation of the plant, a suitable technology for processing the nuts and, last but not least, on environmental aspects. What is the eco-balance of jatropha oil? Does the plant compete with food crops? Does growing it hinder soil erosion, or does it encourage it?

Amidst all this is Simon Gmünder. He is one of the world’s leading experts on jatropha. Even during his time in compulsory community service he



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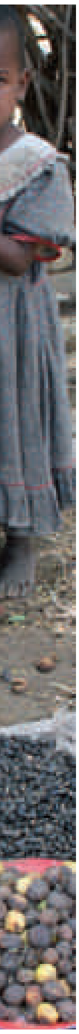
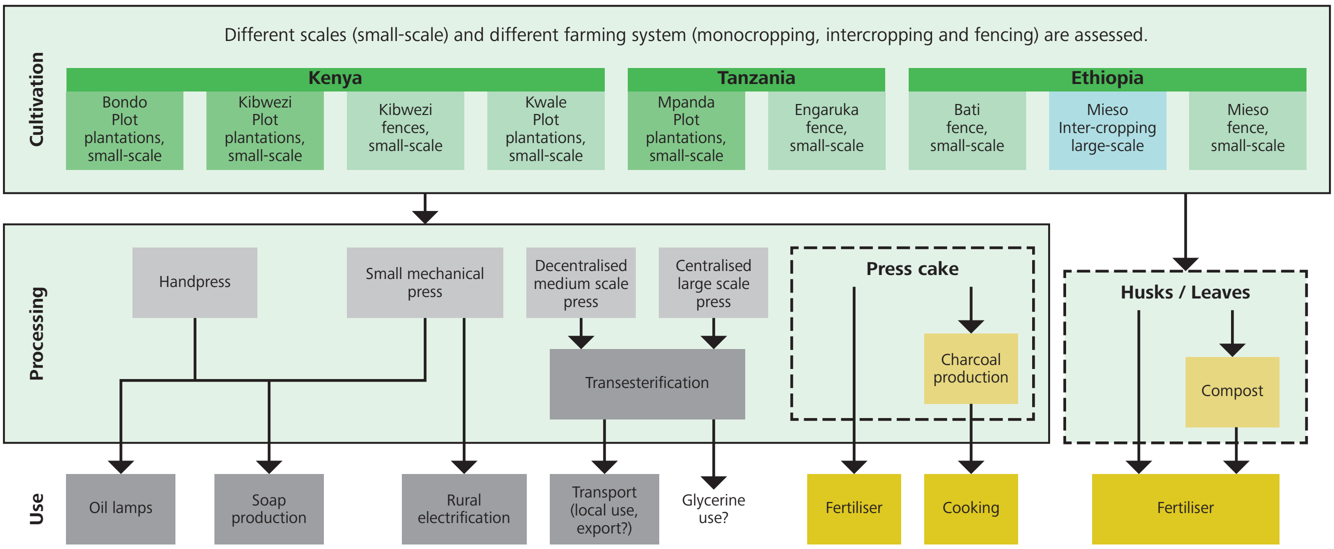





Different options of farming and processing are investigated in several projects, small-scale as well as large-scale.

was busy with a jatropha project in India which, by the way, is still running successfully. True, the project isn't yet complete, but the first results are in. Gmünder considers large jatropha plantations as being counterproductive. That's because in large plantations, jatropha competes especially hard with the growing of food crops, and that strategy is more than questionable given the current catastrophe of hunger and starvation in Eastern Africa.

## New strategies to provide a fix

A far better idea would be to plant jatropha bushes as windbreaks on the edges of fields. This reduces soil erosion and protects the cultivated area from wild animals. If jatropha were planted instead of commonly used thorn bushes, the plant windbreak would serve a further purpose: at harvest time it would supply energy-rich oil as a "waste product". It can not only be converted into fuel – such as for electric generators or motor-driven water pumps – but it can also be processed into soap or used for lighting in hand-crafted oil lamps.

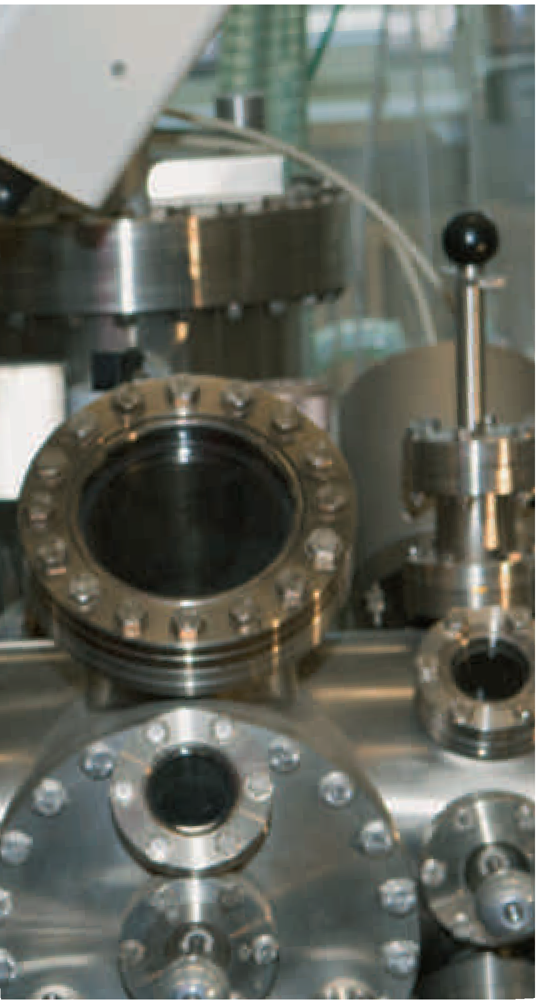
Gmünder's conclusion is that when it comes to jatropha, the hopes of green gold aren't dashed quite yet. However, this last opportunity must be seized. For this, the mistakes of the past along with the needs and aims of everyone involved must be analysed very closely. If this can result in the formulation of a common strategy which can be rapidly implemented in pilot projects, jatropha cultivation could still become successful and parts of Africa could supply themselves with home-grown bioenergy. Because the oil can also be used as fuel for vehicles and aircraft, it could ultimately even result in export opportunities for many countries, which in turn would stabilise prices for the product.

"Our task is to create a sound scientific basis and then spread the knowledge we have gathered so far", elaborates Gmünder. "Ultimately we want to arrest the non-sustainable growing of jatropha, which is done mostly at the expense of the rural population, and instead promote sustainable cultivation methods and uses." Beneficiaries could be development aid organisations, agriculture in general plus local policy-makers in Africa, who with the help of science can take better decisions. //

# The octane vision

Why dispose of something if it can still be put to use? Empa researcher Andreas Züttel, together with colleagues from ETH Lausanne (EPFL) and the Paul Scherrer Institute (PSI), wants to turn an ambitious vision into reality. Starting with hydrogen and the unwanted greenhouse gas carbon dioxide, the idea is to produce a liquid hydrocarbon that can be used to fuel engines. The concept is already working in the lab.

TEXT: Rainer Klose / PHOTOS: Empa



Empa researcher Andreas Züttel is "producing" $CO_2$. The physicist uses the vacuum analysis equipment in the background to investigate how $CO_2$ and $H_2$ can bond together on metal hydride surfaces to form olefins, the basis for synthetic fuels. His vision: to create fuel from the greenhouse gas $CO_2$.

## $CO_2$ extraction from air

While the efficient production of hydrogen is still being researched, Swiss startup company Climeworks has already patented a "machine" for extracting $CO_2$ from air. The company came into being as a spin-off from a research project at ETH Zurich, also supported by Empa. The process is based on repeated cycles of absorption and desorption. The $CO_2$ collects on a special filter material and there is again eluted at regular intervals and stored as a pure substance in gas bottles. The advantage of this process is that only moderate temperatures are required. The necessary heat can either be generated with solar collectors or it can come from the inexpensive exhaust heat from power plants and industrial facilities. Thus, the Climeworks technology is not only a nose ahead in ecological and economical terms, it can also be put to use everywhere. The process could possibly serve as the basis for Andreas Züttel's visionary project – and help produce fuel out of thin air.

This trip into our energy future starts with a look back into the past. "Since the steam age, mankind has been dealing with energy in very much the same way", observes Andreas Züttel, "We dig energy carriers out of the ground, burn them – and emit $CO_2$ into the atmosphere." That has to change, believes the head of Empa's Hydrogen and Energy Laboratory. "If our society wants to find ways to sustainable sources of energy, we will need a closed cycle for energy carriers." For instance, a $CO_2$-neutral carbon cycle which on the one hand could reduce dependence on oil and on the other hand could stabilise a country's $CO_2$ emissions.

**Hydrogen storage as the central issue**

For 15 years, Züttel has been working with hydrogen as an energy carrier and the possibilities for storing it, in particular storage in metal hydrides. He is president of Hydropole, the Swiss Hydrogen Association, and he has been head of Empa's Hydrogen Laboratory since 2006. Despite his many years of experience, Züttel had to recognise that it's at best very tedious to get metal hydrides to serve as an everyday hydrogen storage mechanism. Hydrides are often highly sensitive to air and must therefore be encased in metal containers for safety reasons, making them even heavier and thus less competitive. Electricity from solar and wind power is expensive to generate, and storing it is still difficult, leaving a key problem to using them as sustainable energy sources still largely unsolved.

To solve it, many energy researchers have long been tinkering with an idea that would have made the alchemists of the Middle Ages proud – take a cheap, unwanted gas and with it "transform" hydrogen into a much more manageable energy store. Züttel is convinced that such a process could be feasible with the "waste product" $CO_2$. In the end, an unwanted greenhouse gas could be turned into valuable synthetic fuel, today called synfuel. The old alchemists' dream – to turn lead into gold – would thus be translated into 21st-century terms.

**Chemistry with a peace mission**

The idea also has political implications. "Today, most global conflicts arise in places where there's oil", notes Züttel. "If everyone were in a position to make fuel literally out of air instead of oil, this greedy appetite would vanish. The $CO_2$ we need doesn't stop at national borders. It's available everywhere in the atmosphere for anyone to extract it."

Naturally, there's also a chemical concept behind this vision. A catalyst developed at Empa is intended to bond $H_2$ and $CO_2$ into short-chain olefins, such as octane. This hydrocarbon, which is a liquid at room temperature, is best known among car drivers as a constituent of petrol; the "octane rating" is considered a quality characteristic of knock-free petrol. Synthetically produced octane can be used in cars with conventional engines. With it, hydrogen generated with solar or wind power could finally be turned into an easy-to-handle form, and at the same time, the method would bind $CO_2$. An ETH Zurich spinoff, in collaboration with Empa, has even developed a suitable technology for $CO_2$ extraction (see box).

Naturally, Züttel didn't simply pull this idea out of thin air. For years, his laboratory has been investigating metal hydrides and complex hydrides, originally for hydrogen storage. The advantage is that hydrogen is bound in these hydrides in atomic

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**1**
Top: Andreas Züttel checks the air tube at his reactor. When the gas-analyser reports a "smell of petrol", he has been successful. Below: the sought-after reactions are expected to take place in this heatable metal cylinder in Züttel's lab. It worked once already: a small amount of methane was produced from $CO_2$ and $H_2$ – a promising start.

**2**
The vision of an energy supply for the future: artificial fuels will be synthesised from "green" electricity and $CO_2$ – these so-called synfuels can be used to fuel cars, lorries and airplanes just like we do today. The greenhouse gases from the exhaust pipes are "collected" and reused, so the cycle is closed.

1

form, in other words, in a clearly more reactive form than in the hydrogen gas $H_2$. According to Züttel, there had to be some way to make this useful for the reactions he had in mind.

**Energy cycle of the future**

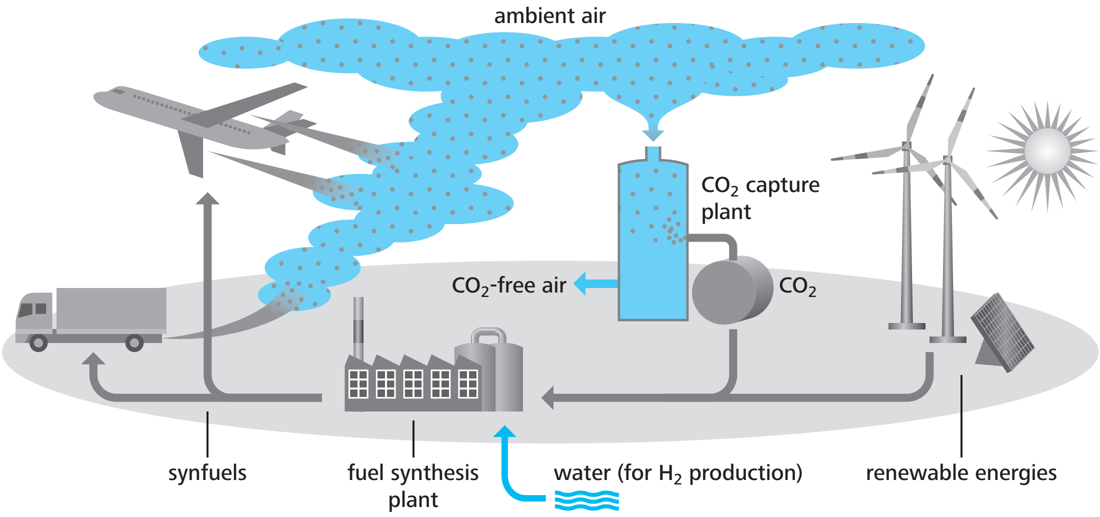
The necessary equipment is now ready for use in his lab at Empa. It's an unimposing, heated metal cylinder about the size of a keg of beer. Here is where what might one day change the world – the energy cycle of the future – is planned to become reality. Mixed with a carrier gas, $CO_2$ and $H_2$ flow into the cylinder, where the gaseous mixture comes into contact with a metal hydride, at the moment $Mg_2NiH_4$. In order to observe what is happening in the reactor, a mass spectrometer and an infrared spectrometer are each connected to their own outlet tubes. The analysis equipment shows exactly when the desired reaction has taken place, specifically when the so far "useless" greenhouse gas $CO_2$ has been converted into methane ($CH_4$), the main constituent of natural gas.

In a laboratory next door, a similar experiment is being conducted under greatly reduced pressure. Using spectroscopy the researchers want to understand at the atomic level which reactions are taking place on the hydride surface.

**From methane to octane?**

Although this small reactor has only been in operation since earlier this year, first results are already available. At temperatures between 150 and 350 degrees Celsius, the Empa team was able to produce methane from $CO_2$ and $H_2$. They are already postulating about a mechanism. The metal hydride $Mg_2NiH_4$ gradually decays into magnesium oxide (MgO) and finely dispersed nickel during the cyclic sorption and desorption of hydrogen. $CO_2$ molecules then accumulate on the nickel particles and, as is desired, are hydrogenated to form $CH_4$. These results will soon be published in the magazine Energy & Environmental Science.

But the generation of (gaseous) methane is only the first step on the path to liquid synfuel. "We must understand better the mechanisms on the surface of the hydrides. Then we can look for structures on which eight $CO_2$ molecules can group together next to each other and be hydrogenated all at the same time", explains Züttel, "and then we would have octane."

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**The race of the modern-day alchemists**

With his efforts, Empa researcher Züttel is under considerable competitive pressure because other projects are likewise working on "$CO_2$ alchemy". For example, early this year Aldo Steinfeld, professor for renewable energy carriers at ETH Zurich, presented his vision for solar fuel production in the journal Science. Steinfeld's team selected a high-temperature process. Cerium oxide is heated to 1500 degrees C in a solar reactor, whereupon it decays into cerium and oxygen. That material is then "activated" and, at a temperature of 900 degrees C, is able to convert a mixture of water and $CO_2$ into a mixture of $H_2$ und CO. This mixture is known as syngas, from which petrol can be synthesised.

However, Steinfeld's reactor converts only 0.8 per cent of the solar energy into fuel. Using his method, Züttel would like to improve upon that level of efficiency. The race among the solar alchemists has begun. //

**Link**

Direct link to laboratories, to original publications and podcasts: *www.empa.ch/empanews*

## International scientific collaboration

The hydrogenation of $CO_2$ on metal hydrides is part of a research project being conducted across Switzerland and coordinated by Andreas Züttel; it also involves, among others, Thomas J. Schmidt with his team from PSI, Gabor Laurenczy from EPFL and Jens Norskov, an expert in surface catalysis at Stanford University, USA. The research team is looking for new, more efficient methods of manufacturing a synthetic fuel from renewable energies and $CO_2$, a fuel which is suitable for use in conventional as well as aircraft engines. The researchers are investigating the production of synthetic fuel (synfuel) in two stages:

Stage 1 addresses the efficient production of hydrogen. Three different processes are being investigated:

- **a)** hydrolysis systems which are based on polymer electrolyte membranes (PEMs) – PSI, Empa, EPFL
- **b)** electrocatalysts for the reduction of $CO_2$ and $H_2O$ into an aqueous solution – PSI, EPFL, Stanford
- **c)** the reduction of $CO_2$ and $H_2O$ at higher temperatures; here the search is on for new ceramic materials which can easily conduct the $O_2$ – oxygen ions – Empa

In Stage 2, the hydrogen is further processed. Two methods are being investigated:

- **a)** the reduction of $CO_2$ onto metal hydrides in order to create long-chain hydrocarbons such as octane – Empa (see main text)
- **b)** the reduction of $CO_2$ and hydrogen into a homogeneous catalyst (the Fischer-Tropsch process) – EPFL, Stanford.

In the end, it might be possible to find a way to efficiently convert solar electricity into liquid fuels. This would be a major step not only for the industrialised world but equally for emerging countries – it would bring the world a bit further away from its dependence on oil.

World Resources Forum 2011


# Towards a greener economy

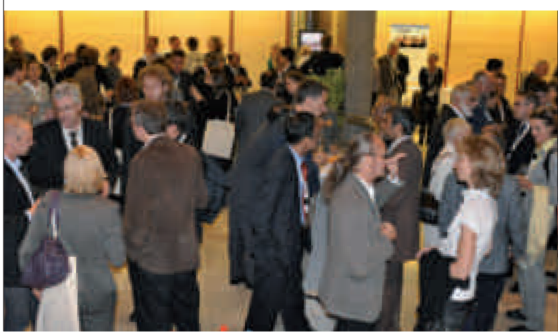
The World Resources Forum 2011 (WRF), which takes place from 19 to 21 September in the Davos Congress Centre, is putting the spotlight on a serious problem: our current economic system consumes too many resources.

How can the use of resources and economic growth be reconciled? Can we find a way to deal with our resources in a sustainable way? How can we reduce the depletion of resources and at the same time increase productivity? How can we distribute resources globally and between the generations in a fair way? Which lifestyles, which production patterns and consumer habits can we still afford? How can we simultaneously conserve the ecosystem which sustains our lives? What would a "green economy" look like? The aim of the WRF organisers is to establish the event as a platform to elaborate and disseminate answers to these vital questions.

**Shaping the future of natural resources**

Among the speakers at the WRF 2011 are Swiss Federal Council Doris Leuthard, Switzerland's Minister for the Environment; Achim Steiner, Executive Director of the United Nations Environment Programme (UNEP); Janez Potočnik, European Commissioner for the Environment; Jacqueline McGlade, Executive Director of the European Environment Agency (EEA); and Ashok Koshla, Co-President of the Club of Rome.

The WRF is an initiative of Empa; among its partners are the UNEP "Resource Panel", the Swiss Federal Office for the Environment (FOEN), the the German Federal Environment Agency (UBA), the Swiss Agency for Development and Cooperation (SDC), the Swiss State Secretariat for Economic Affairs (SECO) and the Swiss Academy of Engineering Sciences (SATW). The biannual precursor event to the WRF was known as R'93 to R'07. In 2009, the event was relaunched as the World Resources Forum.



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Further information and registration at *www.worldresourcesforum.org*.

# Adding the spark to hydrogen

**Empa's engine experts had already promoted and even co-developed the natural-gas turbo engine. As an "encore" of sorts they next want to mix in solar-generated hydrogen, which will save energy and improve engine operation.**

TEXT: Rainer Klose / PHOTO: Empa

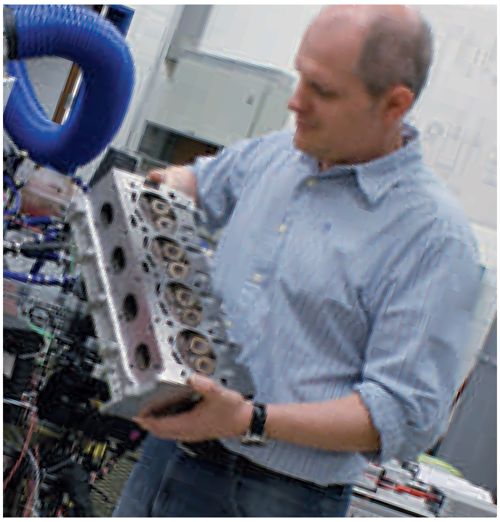
The soundproof test facility in Empa's engine building is a type of torture chamber for internal combustion engines. An engine is bolted down to a yellow steel frame; from it hang hundreds of cables in all colours along with instruments, exhaust hoses and small boxes full of electronic circuits. This is where new engine concepts are being conceived and tested.

### The Empa/ETH natural gas engine

Torturing the engines is done methodologically as part of an ongoing research project. Empa wants to investigate in great detail the interaction of natural gas and hydrogen inside the engine. Research on natural gas engines has a tradition in Dübendorf. Starting in 1999 and going through 2004, the Internal Combustion Engine Laboratory, working in collaboration with ETH Zurich and the automobile industry as part of the Clean Engine Vehicle (CEV) project, converted a VW Polo to operate on natural gas and compensated for the loss of performance with a turbocharger. They were able to show that natural gas and biogas are very well suited as fuels for modern engines, emitting extremely low levels of pollutants. In fact, in 2006 the project team was awarded the Innovation Prize of the German Technical and Scientific Association for Gas and Water. In the meantime, natural gas motors have entered the market, an example being the VW Passat Ecofuel with a supercharged 110 kilowatt (150 hp) 1.4-litre natural gas engine. In 2009, this model was the first car to receive the very strict five-star rating from the ADAC (German Automobile Club) EcoTest.

### How much hydrogen would you like?

Now comes the next step, the hydrogen-natural gas mixture. Initial tests were run in 2005, first on a CEV engine, then on a larger series-manufactured engine. The results to date show that mixing in hydrogen considerably improves ignition performance. This means that mixtures which are difficult to ignite can quickly and reliably be ignited if a small amount of hydrogen is mixed in, whereby there is also a gain in efficiency and a reduction in pollutants. In addition, it's possible to feed more exhaust back into the engine and in this way control engine power. In this case, the throttle can be opened even further so the motor runs with less throttling, in other words more economically.



Project manager Patrik Soltic inspects a cylinder head which is to be used for the hydrogen-natural gas experiment. In the background you can see the Empa test stand for 4-cylinder engines.

The experiments are moving ahead fast. Two series-manufactured vehicles with the latest natural gas drives are placed on Empa chassis dynamometers and are fuelled up with various amounts of hydrogen blended with natural gas. As a first step, the researchers investigate what effect the gas mixtures have when no adjustments are made. In a second step, the vehicle's engine control system is modified to get the most out of existing systems.

At the same time, the basic principles are being further investigated. What are the effects of directly injecting natural gas into a cylinder and hydrogen into the intake manifold? What happens in the reverse case? What changes take place in terms of combustion, exhaust gases and fuel consumption?

### Collaboration with the Competence Centre Energy and Mobility

These fundamental questions about a natural gas/hydrogen engine, however, are not being clarified with something similar to a series-manufactured car engine but in a 250-cc single-cylinder engine mounted on an additional test bench. This engine is provided by the Swiss company Swissauto Wenko AG. Two such engines are set up at the ETH Zurich where the use of alcohol is being studied and rules for their use in hybrid vehicles are being researched. These coordinated research efforts are taking place under the auspices of the Competence Centre Energy and Mobility, a platform in which various institutions of the ETH Domain are working together. "At a later stage, we plan to equip the engine with optical access points so that, based on optical diagnostics, we can study how the formation of the gas mixture and its combustion are influenced by hydrogen", explains Patrik Soltic, head of the Drive Technologies group.

Besides enabling stable, balanced combustion, adding hydrogen has a second big advantage: the opportunity to make use of regenerative energy in an internal combustion engine. "Excess" electricity from solar and wind-driven power plants could be turned into hydrogen through electrolysis and be added to the natural gas or biogas supply, explains project leader Soltic. "In this way we would actually have 'sun in our tank'."

**Link**

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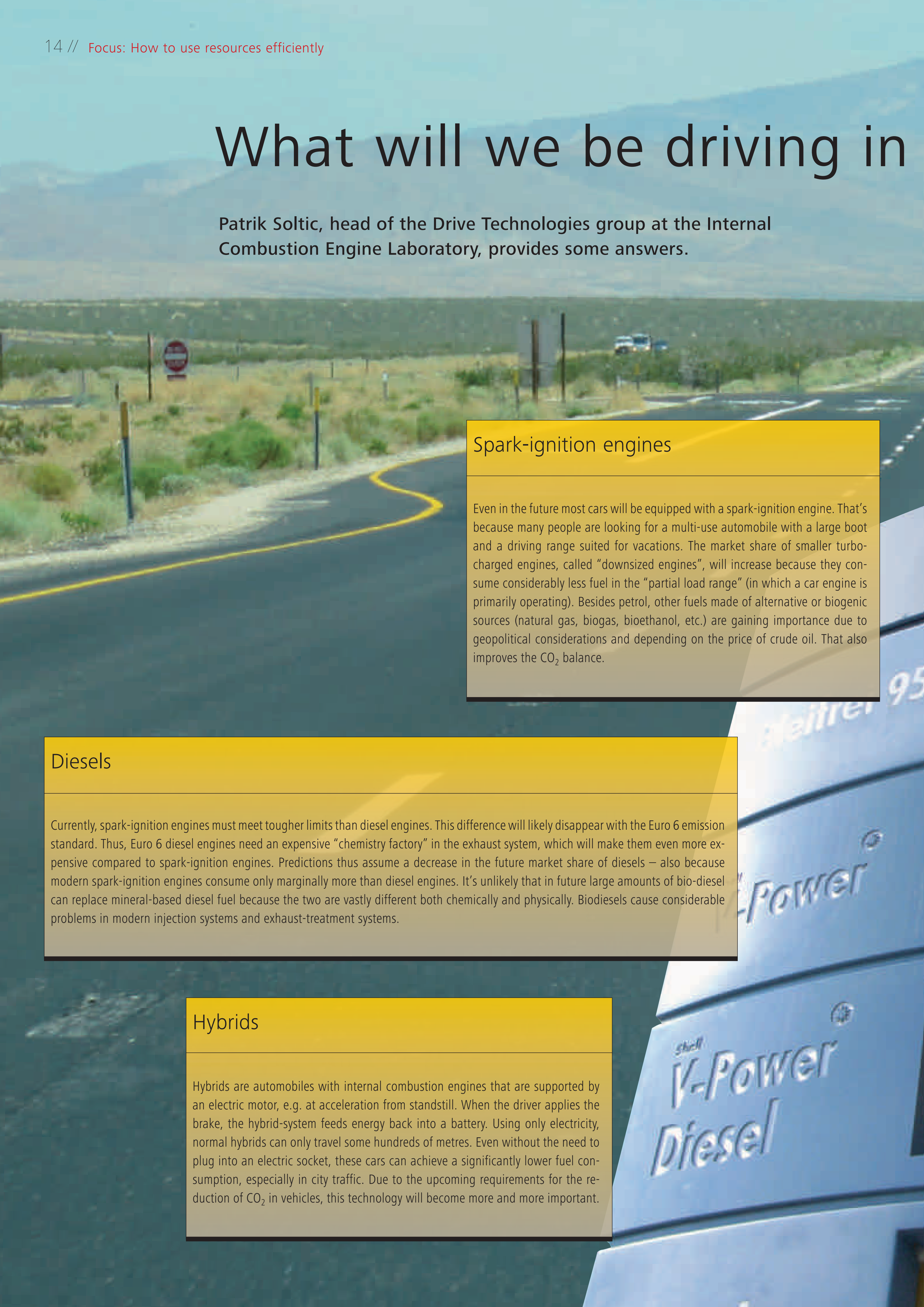
# What will we be driving in

**Patrik Soltic, head of the Drive Technologies group at the Internal Combustion Engine Laboratory, provides some answers.**




## Spark-ignition engines

Even in the future most cars will be equipped with a spark-ignition engine. That's because many people are looking for a multi-use automobile with a large boot and a driving range suited for vacations. The market share of smaller turbo-charged engines, called "downsized engines", will increase because they consume considerably less fuel in the "partial load range" (in which a car engine is primarily operating). Besides petrol, other fuels made of alternative or biogenic sources (natural gas, biogas, bioethanol, etc.) are gaining importance due to geopolitical considerations and depending on the price of crude oil. That also improves the $CO_2$ balance.

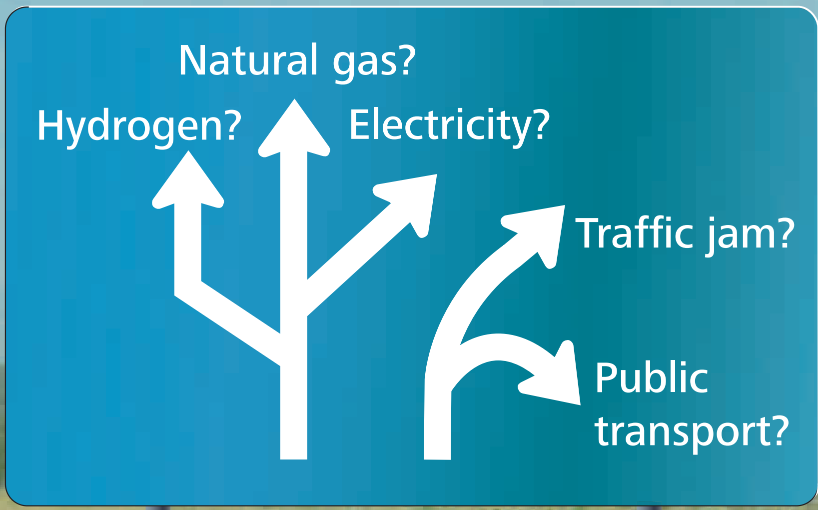
## Diesels

Currently, spark-ignition engines must meet tougher limits than diesel engines. This difference will likely disappear with the Euro 6 emission standard. Thus, Euro 6 diesel engines need an expensive "chemistry factory" in the exhaust system, which will make them even more expensive compared to spark-ignition engines. Predictions thus assume a decrease in the future market share of diesels – also because modern spark-ignition engines consume only marginally more than diesel engines. It's unlikely that in future large amounts of bio-diesel can replace mineral-based diesel fuel because the two are vastly different both chemically and physically. Biodiesels cause considerable problems in modern injection systems and exhaust-treatment systems.

## Hybrids

Hybrids are automobiles with internal combustion engines that are supported by an electric motor, e.g. at acceleration from standstill. When the driver applies the brake, the hybrid-system feeds energy back into a battery. Using only electricity, normal hybrids can only travel some hundreds of metres. Even without the need to plug into an electric socket, these cars can achieve a significantly lower fuel consumption, especially in city traffic. Due to the upcoming requirements for the reduction of $CO_2$ in vehicles, this technology will become more and more important.

# 20 years?




## Electric cars

These make sense for certain applications, such as municipal vehicles and regional delivery services (such as parcel services) as well as commuter cars that only drive short distances and regularly return to their base station. Electric cars, though, are not always more eco-friendly. In the EU, on average approximately 570 grams of $CO_2$ are generated per kilowatt-hour of electricity, and global predictions tend towards an increase rather than a decrease of $CO_2$ emissions for electricity production. Thus, in the foreseeable future, mass motorization using electric vehicles would not lead to a reduction in $CO_2$ compared to modern vehicles with internal combustion engines.

## Plug-in hybrids

Plug-in hybrids can draw energy from an electric socket and typically have an electric driving range of a few tens of kilometres. At this time, however, they are favoured in the calculation of $CO_2$ emissions because of a legal loophole: electricity from a socket is considered $CO_2$-free – even if it is produced by a coal-fired power plant. As soon as the actual $CO_2$ emissions are taken into account, plug-in hybrids lose much of their $CO_2$ advantage, except when they are operated purely in an urban environment.

## Fuel cell cars

Drivetrains based on fuel cells are also a sort of hybrid because in addition to the fuel-cell itself a battery is needed for intermediate storage and the distribution of the load. Fuel cells are currently only useful for municipal vehicles and regional delivery services because a public network of hydrogen stations does not yet exist. In addition, hydrogen is nowadays not generated in a sustainable way (i.e., from solar or wind power). Almost all hydrogen produced today is synthesised chemically, mainly from natural gas, heavy oil and coal. When considering $CO_2$ emissions, this has no advantage unless the fuel cell is replacing a very inefficient conventional drivetrain.

# "Switzerland has a joint responsibility"

**Patrick Wäger has been analysing problems associated with dwindling raw materials. With the growing industrialisation of emerging countries plus increasing global demand for ICT-equipment these problems are bound to become more serious. EmpaNews asked the expert how he rates the situation.**

INTERVIEW: Rainer Klose / PHOTO: Empa

***You've been involved with questions about the supply of rare metals for quite some time. What has since changed?***

Awareness of the possible shortage of rare metals has increased significantly in scientific circles as well as in the popular press. This is not least of all because of the significant increase in prices, such as for the "rare earth metals" cerium, lanthanum and neodymium, which have been caused by China's drastically sharpened export limits. At the same time, this topic is now being addressed, for example, by the EU 7th Framework Programme, and it has also manifested itself in political initiatives such as the EU's new raw materials strategy.

***Which of these raw materials are causing particular problems?***

According to an ad hoc working group of the European Commission, of the 41 non-energetic mineral raw materials under examination, 14 are especially "critical". These include, beyond the rare earth elements the platinum group metals plus antimony, gallium, germanium, indium, cobalt and tantalum.

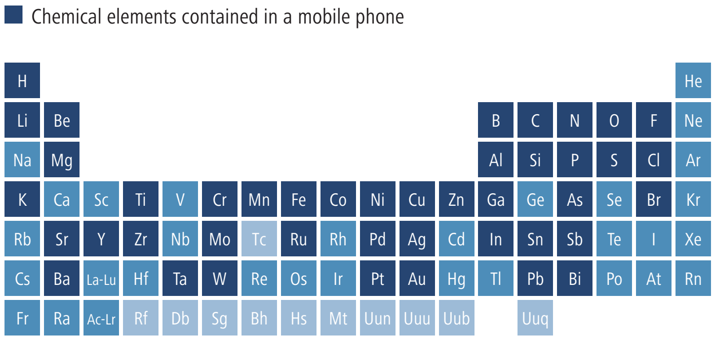
***Will this situation become even more severe in the future?***

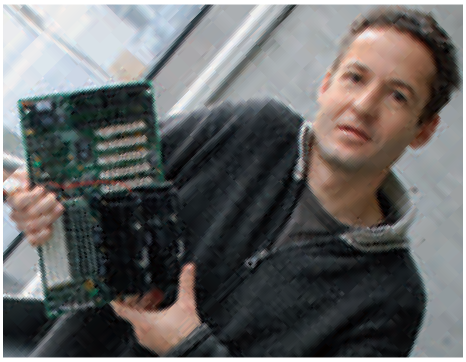
That depends above all on the demand for these raw materials. Because they play an important role in future technologies such as electrical drive systems, microelectronics, photovoltaics and speciality alloys, the demand for elements such as gallium, germanium, indium, scandium and neodymium will likely increase in the coming years. The growing awareness of the possible consequences of this development could, however, also lead to us spending more time searching for less critical substitute materials.

***What can Switzerland contribute to solve this problem?***

The supply of raw materials is a global challenge. Switzerland manufactures and consumes high-tech products which are highly dependent on these raw materials, it shares responsibility for the ecological and social repercussions which go along with their extraction, even when this takes place in completely different parts of the world. One possibility is, for example, support for programmes such as the Extractive Industries Transparency Initiative (EITI). Moreover, we should do everything possible to use these valuable raw materials as efficiently as possible and to recover as much as we can from waste products.

"We have to try to use these valuable raw materials as efficiently as possible"



Patrick Wäger holds a computer motherboard. Complex electronics have long since become mass-market products, but can they also be recycled?

Chart above: almost half the periodic table of elements is contained in a mobile phone.

***What is Empa's role in all this?***

As an institution for applied materials research and technology development, Empa can make a valuable contribution with regard to substitution, improved efficiency and recovery of raw materials. One team, for example, is investigating how rare earth metals in catalytic converters and thermoelectric generators – in this case tellurium – can be replaced with perovskites. With the help of substance flow analyses, Empa researchers are investigating, for instance, the potential for the recovery of critical raw materials from new types of products or future technologies. Then they develop suitable instruments and systems to reintegrate critical raw materials into the value-added chain – such as the certification of metals which are recovered from e-waste, a project which is being addressed within the scope of a new programme of the Swiss State Secretariat for Economic Affairs (SECO). //

# R.I.P., LCD

**Each year, 1.4 million flat screens are sold in Switzerland. The LCD panels harbour valuable indium as well as poisonous mercury in the background lighting. How can this electronic waste be recycled?**

TEXT: Rainer Klose / DRAWING: André Niederer

Where are we going to put our old flat-screen monitors and TVs? For the consumer, the answer is clear: hand them over to the dealer or importer. Those companies simply pass the units on to SWICO (Swiss Association for Information, Communication and Organisation Technology), the recycling organisation of manufacturers and importers of IT equipment.

In 2009, the Swiss disposed of approximately 300,000 flat-screen monitors, 60,000 flat-screen TVs and 240,000 laptop computers. In 2010, these numbers were certainly even higher, and this year they'll increase further. In the search for ecological recycling methods, SWICO turned to Empa, which for a number of years has gained significant experiences in the exploitation of electronic waste (e-waste).

In their study "Disposal of flat screens in Switzerland", the Empa experts Heinz Böni and Rolf Widmer from the Technology and Society Laboratory came to the following conclusions.

- A difficult aspect arises from the backlighting of LCD screens because these circuits contain mercury. However, in the latest models, the fluorescent tubes have been replaced with LED lighting, so this problem will eventually disappear. The largest number of mercury-containing flat screens should make their way into recycling by 2014, and across Switzerland that should amount to 36 kilograms of mercury. Compared to the total amount of 1380 kilograms of mercury, which is separated each year in Swiss waste incineration plants, this amount is, however, small.
- The screens also contain the valuable (rare) metal indium, from which conductive layers on sheets of glass can be manufactured. In 2017, 115 kilograms of indium will accrue in Switzerland through recycling, with a market value of US$ 66,000. Even so, it won't be worth recovering the indium.
- In the past, flat screens were disposed of in incineration plants, mainly because there were no alternatives. Böni and Widmer discourage this practice because the caloric value of the screens is low and precious materials are for the most part lost.
- In mechanical processing (shredding), the mercury contained in the LCDs is emitted in gaseous form at various locations in the system. Thus, flat screens should only be shredded in enclosed systems.
- Precious materials can best be recovered through manual disassembly. Even if the LCD lamps which contain mercury are broken, there are no health risks for the workers because measurements show emission levels beneath the TLV (threshold limit value).

Based on its study, Empa recommends that the technical regulations for SWICO recycling be adopted and improved in the specified points. //

## Tracing mercury

In early 2011, the world's first method for analysing mercury (Hg) in the lamps used for flat-screen displays was developed at Empa. Such lamps generate a rainbow of UV radiation. A fluorescent layer on the glass converts this radiation into visible, white light. Over time, the mercury vapour combines with the fluorescent material, and the lamp goes out. During recycling, it is necessary to deal with both the vaporous and chemically bound mercury. Lamps containing more than 5 mg of mercury are not permitted to be sold commercially in Switzerland and the EU. Information: *renato.figi@empa.ch*.

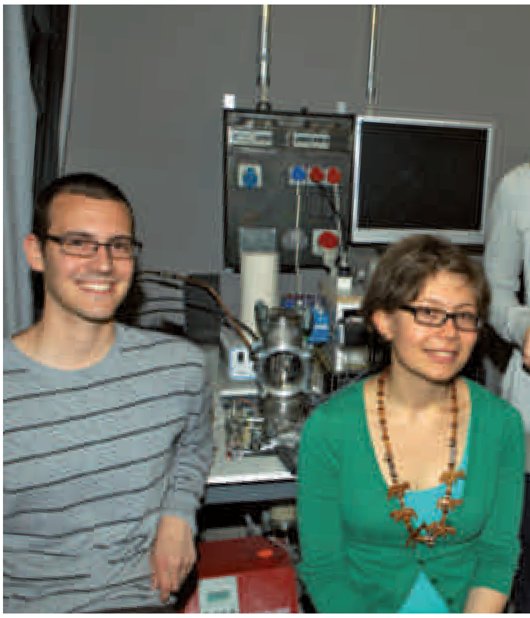
## Link

Direct link to laboratories, to original publications and podcasts: *www.empa.ch/empanews*

# The midget sun

It all started with a high-school graduation project dealing with solar energy. What actually resulted was a sunlight simulator developed and built by three graduating students from Aargau together with Empa scientists – and which today is being used to measure the efficiency of solar cells.

TEXT: Martina Peter / PHOTOS: Kevin Schmid; Empa



**1**
The sunlight simulator generates the spectrum of the sun. With this device you can determine how efficiently a solar panel converts sunlight into electricity.

**2**
Fabian Pianezzi, Kathrin Ernst, Debora Bachmann and Miriam Marti (left to right) built a portable sunlight simulator.

Kathrin Ernst has long been interested in how solar energy can be used. When she was just 15, she got involved in the Greenpeace “Solar Generation” campaign and volunteered to help build systems which allow solar energy to be converted into other forms of energy. Later on, in the summer of 2009 the high-school student suggested to two of her classmates in Zofingen that they get involved with solar cells for their graduation project. Because her central area of study was “Physics and Applications of Mathematics”, Miriam Marti wanted to write a technical paper and was on board in an instant, and it didn’t take long to get Debora Bachmann interested either.

But how to get started? It was soon clear to them that in order to move ahead, they would need a mentor from the university environment. On the homepage of the Swiss Academy of Sciences they ran across Empa and Fabian Pianezzi, who has been working as a PhD student since 2009 in the Thin Films and Photovoltaics Laboratory. At the start, though, he wasn’t overly enthusiastic. “Way too complicated”, thought Pianezzi after a first meeting, during which the students suggested they wanted to develop an organic solar cell.

While they were talking, though, the four of them came across another idea. During the development of solar cells, it’s important to determine how efficient a cell is in converting solar energy into electricity. When conducting these tests in the lab, Empa uses a sunlight simulator. Pianezzi, however, was interested in a new system which ideally would be mobile, could be set up quickly and was inexpensive. Commercial systems are not only expensive, they also need as long as half an hour to warm up. “The very idea of developing a product for Empa which the researchers could then actually use motivated us even more”, recalls Kathrin.

**The search for a low-cost material**

To simulate sunlight inexpensively, the students decided to work with a low-cost raw material: light-emitting diodes (LEDs). In order to cover the entire solar spectrum in the wavelengths from 350 to 1100 nanometres, they needed a large number of lamps of various colours. But which were the right ones? Using calculations alone they would have never found the optimal combination of LEDs according to Miriam, the maths specialist in the team. “Instead, we tried various combinations by varying the number and the type of LEDs.” After numerous tests they found a selection of LEDs, which matched sunlight in terms of colour spectrum and brightness.

For technical drawings and fabricating the aluminium dome that would hold the LEDs, the school technician came to their aid. “We were mounting the LEDs in the dome largely by ourselves, as well as doing the soldering and connecting up the controls”, relates Miriam. Her classmate Kathrin took on the task of programming the controls which supply the LEDs with the necessary voltage and which can turn each individual lamp on and off, and to do so she had to learn a new programming language.

**Useful test results**

“In contrast to many of our classmates, we never got bored”, says Kathrin. “For months, we were in constant contact with the experts and were even able to carry out tests ourselves in the laboratory at Empa.” They received a continual stream of new tips on how to further improve their self-built simulator. That was necessary because although the first design did work, it had too little output power. To increase that, Kathrin and her group built in additional white power LEDs along with a lens that would bundle their light, in other words, concentrate it. The easiest solution would have been to simply opt for LEDs with a higher light intensity. The problem, according to the students, is that such devices are not yet available on the market or – if so – are very expensive. They are convinced, though, that in a few years it will be possible to build an affordable sunlight simulator with the desired output power using commercially available LEDs.

“Although in the end, the sunlight simulator built with standard LEDs didn’t achieve the desired output power, we can still make very good use of it at Empa”, says their Empa mentor Pianezzi. “We already use it to measure the quantum efficiency of solar cells.” Because it’s possible to turn each of the 64 LEDs on and off individually, researchers can calculate the percentage of light of a certain wavelength a solar cell can convert into electric current.

**Success with “Swiss Youth in Science”**

At this point the story could come to a close, but it doesn’t. Even before submitting their graduation project, the young women had sent a preliminary version to the Swiss Youth in Science competition. “To our surprise, the jury immediately waved us into the final, without us having to make even the smallest change”, recalls Kathrin with pride. Even so, they took the optional recommendations of the jury to heart and worked them into the final version.

Then, on 30 April at ETH Zurich, their work was awarded the rating “excellent” along with a cash prize of 800 Swiss francs by the Swiss Youth in Science Foundation. On top of that, the three of them received a special award – they were invited to attend the International Summer Science Camp in Aalborg, Denmark. What's more, they also had the opportunity to show a short film describing their project at the annual meeting of the Swissmem trade association. And finally, their graduation project also impressed their high school, which praised it as one of the 24 best in the canton of Aargau.

So what conclusions do the young women draw? “In doing this work, we got a pretty good impression of how research in the lab is done”, comments Debora. “At the lunch table, we sometimes sat together with scientists from around the world and learned a lot about what they are involved in.” Even before entering university they had the chance to experience the daily life of a researcher. After their summer holidays, all three plan to enrol at university. Kathrin would like to study microtechnology, Miriam is beginning her physics courses, and Debora is starting to study educational science so that she perhaps one day could teach natural science to high school students.

**Link**

Direct link to laboratories, to original publications and podcasts:
*www.empa.ch/empanews*


1

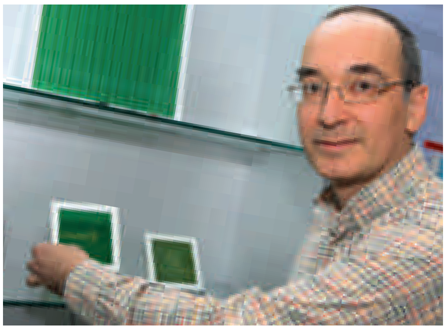
1
Neo-entrepreneur Bin Fan wrote his PhD thesis at Empa and then took his findings home to the company Weihua Solar in China.

2
Delighted with the successful implementation of his research project: Frank Nüesch, head of the Laboratory for Functional Polymers and Bin Fan's supervisor.

# Empa technology for a Chinese startup

**Flexible thin-film solar cells have good prospects to replace today's rigid silicon-based solar cells, among other reasons because their production requires significantly fewer raw materials. Empa recently filed a patent for a novel type of organic solar cell. And former Empa researcher Bin Fan will shortly start manufacturing and marketing the new cells with his Chinese startup company.**

TEXT: Rémy Nideröst / PHOTOS: Bin Fan; Empa



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The Empa patent concerns a novel thin-film solar cell in a "sandwich" construction. The real advance here is that the so-called active layer does not consist of rare and thus expensive elements but rather of synthetic organic dyes which have long been used in analogue photography for the emulsion of colour film. These absorb light extremely well, and they're also efficient at converting it into electricity. Thanks to an Empa development, more specifically: ultra-thin salt layers which form a kind of interface between the two active layers. In this way, the flow of charge – the electric current – generated by incident sunlight is dramatically increased between the two layers, and thus the efficiency of the organic solar cell, as laboratory experiments have impressively shown.

**From the lab to industrial scale – a giant leap**

However, what works flawlessly in the lab can't always be implemented in a practical setting, in other words, in industrial production. That's because the scale up from the lab to industrial production frequently proves complicated and expensive – common knowledge for investors and corporate decision-makers, whose support for this technology transfer is indispensable.

And a lesson to be learned by Bin Fan, a young Chinese researcher who was involved in the development of the new Empa solar cell as part of his PhD thesis. After he successfully earned his PhD, he wanted to pursue this development in his own company. When putting together his business plan, he found the necessary support at "glaTec", Empa's business incubator in Dübendorf, which promotes the founding of companies and innovative processes in the areas of materials and environmental science and technology. But even the best business plan isn't worth much unless you get funding. And exactly this money needed to get his start-up off the ground couldn't be found in Switzerland.

**License issued even before the patent was granted**

The young Chinese had more success in his homeland where sustainable energy technologies have been promoted by the government since 2008 as part of the China Greentech Initiative (see box). Bin Fan won a business competition and received a grant of 12 million yuan (roughly CHF 1.4 million) with which he founded the company, Weihua Solar, in his home town of Xiamen. Besides the founder's technical expertise, the young entrepreneur's most critical "asset" is a licence for the further development of the solar cell which Bin Fan had already acquired – before the pending patent was even issued to Empa.

Meanwhile, he has ten employees, and on the side he sells various consumables which are necessary for solar-cell research. Frank Nüesch, head of Empa's Functional Polymers Laboratory and Bin Fan's thesis advisor, is pleased that the developments started at Empa are now making their way into practice. "For a researcher, this is a confirmation of his work." Nüesch estimates that another five to ten years of development effort are necessary before the first solar cells designed around this new principle can be put on the market. Even so, he greatly admires the step taken by his former student. "That requires, among other things, a certain willingness to take on economic risks. We could never have done that in our laboratory." //

## China Greentech Initiative

The China Greentech Initiative (*www.china-greentech.com*) was established in 2008 with government support to make China a technology leader in the area of environmental technology. At this time, more than 100 organisations are collected under the auspices of this initiative, and they are networked with more than 300 partners from industry – among them international corporations such as PricewaterhouseCoopers (PWC), Alstom, General Electric, IBM, Panasonic, BP, Bayer and the bank HSBC.

The initiative's activities are divided into six branches: clean conventional energy, renewable energy, electric infrastructure, efficient building design and construction, clean means of transportation and clean water. Upon submission of an application, the organisation awards support grants for environmental technologies, in this case organic solar cells.

# The flying pixels

**Ten years of research on polymer "explosives" have led to brightly glowing results and an intermediate victory on the way to colour screens via laser processes.**

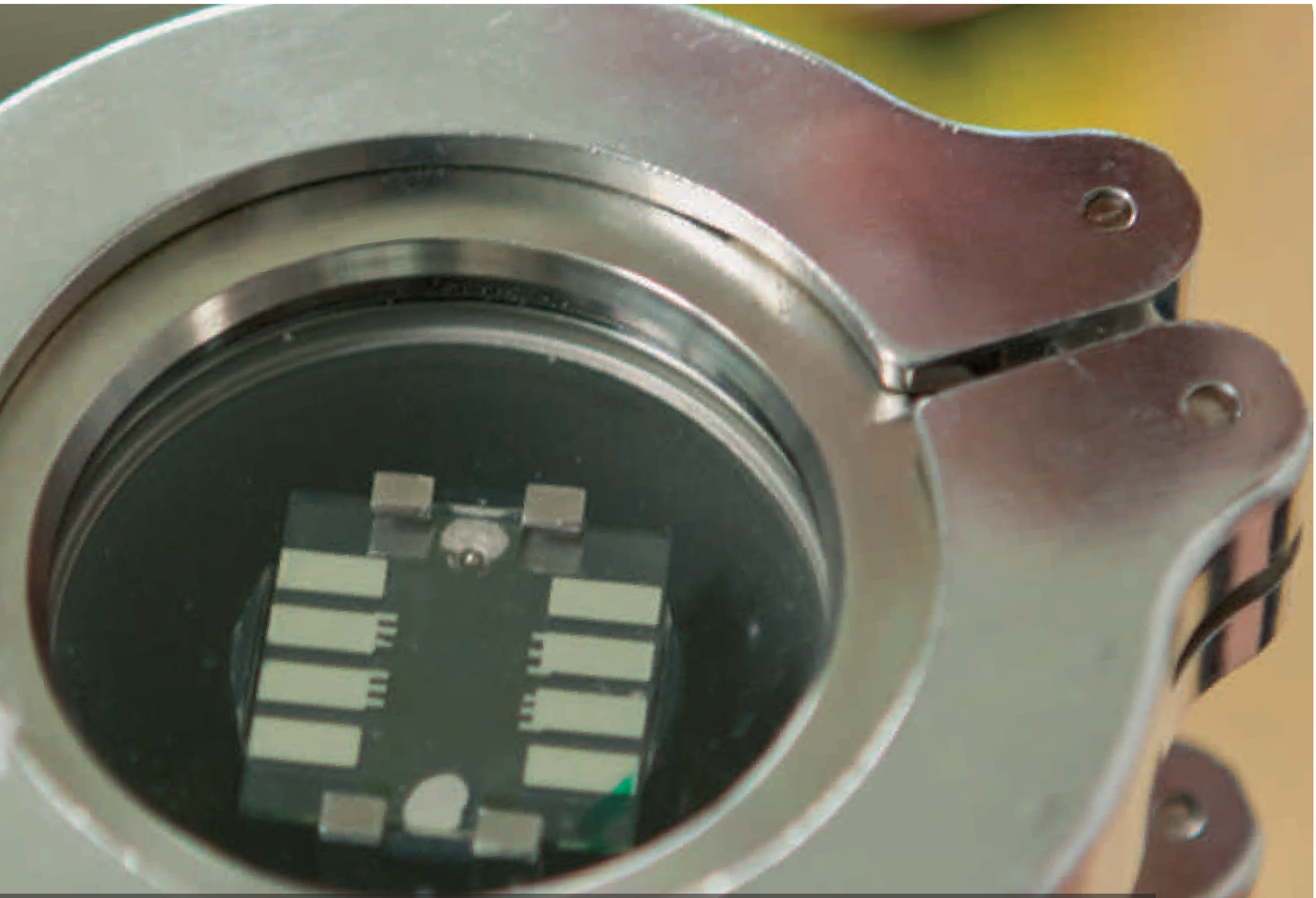
TEXT: Rainer Klose / PHOTOS: Empa

PhD student James Shaw-Stewart (left) and project manager Matthias Nagel examine the completed chip. On the plate, which is enclosed in a protective atmosphere, pixels should start glowing in three colours. If they do, the experiment was a success.

In a chemistry lab at Empa, two men in white lab coats lean over a tightly bolted metal cylinder with a viewing glass in its lid. "Looks useful", observes one of them. "Let's see if it worked", mumbles the other one somewhat sceptically. Shortly thereafter, the metal cylinder including its contents is mounted onto a support. The younger of the two, PhD student James Shaw-Stewart, examines the results through a spectrometer, and a smile comes across his face. Project leader Matthias Nagel is equally thrilled, gleaming with pride about what they have achieved.

**The triazene polymer – an explosive plastic**

What made the Empa researchers so pleased were three small spots inside the cylinder which are glowing red, green and blue. These are not conventional light-emitting diodes (LEDs) but rather the first samples of a luminous plastic, a light-emitting polymer (LEP). The special thing is the three coloured pixels were "shot" onto a carrier chip using a special method being developed at Empa in collaboration with the Paul Scherrer Institute (PSI). An explosive plastic – a triazene polymer – makes it possible. The polymer is exposed to a laser pulse, then decays within a fraction of a second and in the process generates a large amount of nitrogen. In this way, everything sitting on top of it is locally "blown away" and is propelled towards a target with high speed. And, if everything is set up properly, the layers atop remain undamaged and continue to function.



This type of "propellant" made of triazene polymers, along with all the other ballistic parameters (such as the optimum distance to the target, amount of propellant, strength of the laser pulse and air pressure in the environment), are being painstakingly investigated and optimised at Empa and at PSI. Only when everything works together perfectly do the luminous pixels arrive at the desired location undamaged. This technology is known by the acronym LIFT, which stands for laser-induced forward transfer.

But what's the use of teaching luminous colour pixels how to fly? Well, for example, to construct a colour display with the three primary colours red, green and blue. The individual screen pixels can be applied to a surface in an elegant way using the Empa-PSI method based on a laser process, and do so with pinpoint accuracy, without any solvents and at low cost. "At this point we've demonstrated that the system works", notes Nagel. "Now industry has to take over, further develop the process and bring it to the market."

What Nagel is describing is the preliminary conclusion of a research project, which started about ten years ago and which at the same time represents a typical case of the basic research with industrial applications being conducted at Empa. Shortly after the turn of the millennium, Nagel ran across the triazene polymer, which had already been developed in the 1990s and since then has been used primarily in lithography: a laser is shot on the triazene layer, the exposed spots are exploded away locally resulting in a highly precise relief, similar to a printing plate.

**Buffers and titrates for a crystal-clear, extremely thin film**

The project partners Empa and PSI wanted to go a step further. What happens if the triazene layer is exposed from behind? Will this also cause the useful "micro explosions"? Success can only be achieved with hard work, in this case, a laborious, carefully conducted chemical synthesis. Although there was already a "recipe" for triazene polymers which a doctoral student at the Technical University of Munich had developed, the results were less than satisfactory. "When we duplicated the recipe, we ended up with a lumpy brown soup", recalls Nagel. "And while that works adequately for lithography, for our experiment we needed to manufacture very defined, thin layers. This material was clearly unusable for that."

Nagel analysed the synthesis process step by step and finally found the weak point. In the Munich recipe, at a certain point the acid was neutralised too quickly. Everything tipped over to an alkaline solution whereby an unwanted side reaction took place and led to the "lumps". The answer was clear: buffer and titrate, which every first-year chemistry student learns and practices over and over again. If the pH value is reduced

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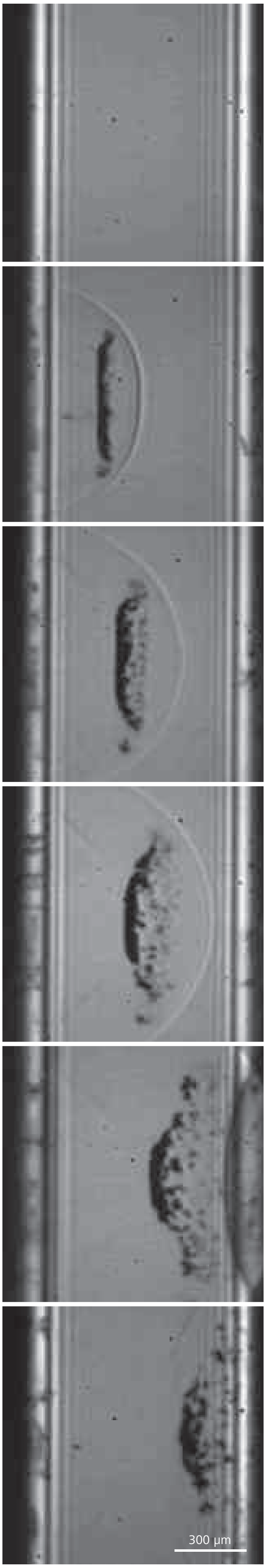


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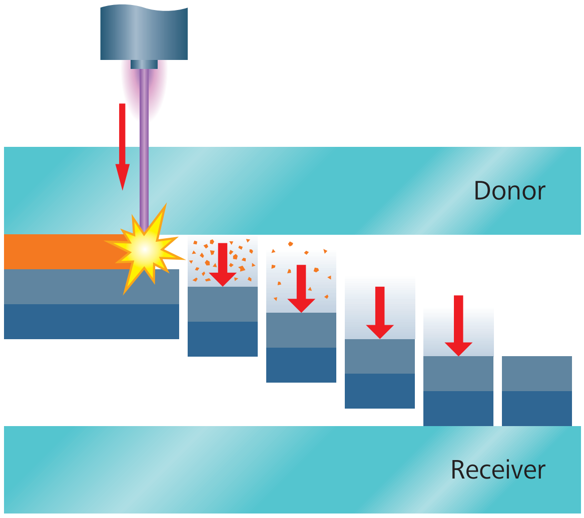


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in a controlled manner, the result is a clean triazene polymer. Now there was nothing standing in the way of an extremely thin film as clear as glass.

With material fabricated in this way, all sorts of experiments could be conducted. As early as 2006, biologists and physicists were able to catapult nerve cells onto a microscope slide for the first time using Nagel's film samples. Once the cells arrived at their target, they continued to live and even multiplied. In this way, a very gentle method for the transfer of the tiniest amounts of material was discovered.

1
A pixel as it flies by: there is a flight path of only 1 mm from the "launch ramp" on the left to the "target" on the right. On pictures 2, 3 and 4 note the pressure wave speeding ahead of the pixel pigment at the speed of sound. If you use too much triazene propellant, the pixel flies faster than sound and would be destroyed as it "passed" the pressure wave. The researchers were able to photo-document this case as well.

2
A diagram illustrating what is known as the "LIFT" process. The triazene layer (orange) is caused to explode by an UV laser pulse. Large amounts of nitrogen gas develop; the layers above break free and are pushed into the target. This method is so gentle that sensitive colour pigments and even living cells can be transported in this way.

**The pixelated Easter rabbit as proof**

Science, though, is far more than the art of engineering. Scientists just don't want to know that something works, they also want an explanation as to why. And so in 2007 silver layers had their turn. "Using low levels of energy of only 65 millijoules per square centimetre, we shot holes into a triazene layer upon which we had applied a layer of silver. Such weak laser light would never had been enough to vaporise the silver layer", adds Nagel. Even so, the silver on the illuminated spots disappeared. This served to prove that the triazene layer had precisely exploded away the layer of silver which sat on top of it. Nagel still carefully keeps the sample from back then in his desk; it has the image of a laughing Easter bunny made of individual, tiny pixels eluted from the reflective silver layer.

**Failed shots actually prove useful**

The next step was "target shooting". With Nagel's support, the PhD students Romain Fardel and James Shaw-Stewart examined the flight characteristics of the material being "shot". Again and again, they fabricated samples at Empa, made the trip to PSI where they fired laser pulses on them, then returned to Empa to characterise the results.

Even failed shots helped the researchers towards their goal. Why didn't these pixels fly completely to the target? Why doesn't a thicker triazene layer produce better results? Why does overly intense laser light harm the results? Among other things, the researchers discovered that during a shot, a shock wave is created which creates problems. A laser pulse that's too intense accel-

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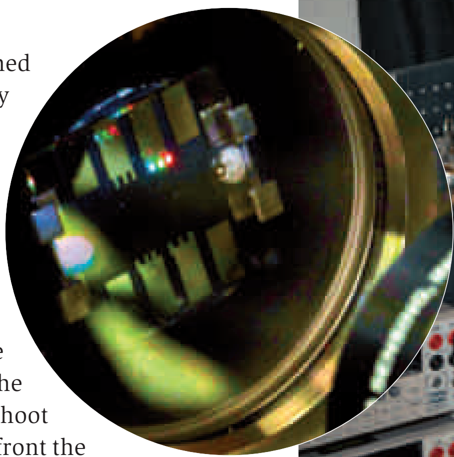
erates the shot material to supersonic speed. As soon as it flies through the leading shock wave, it gets pulverised and nothing reaches the target.

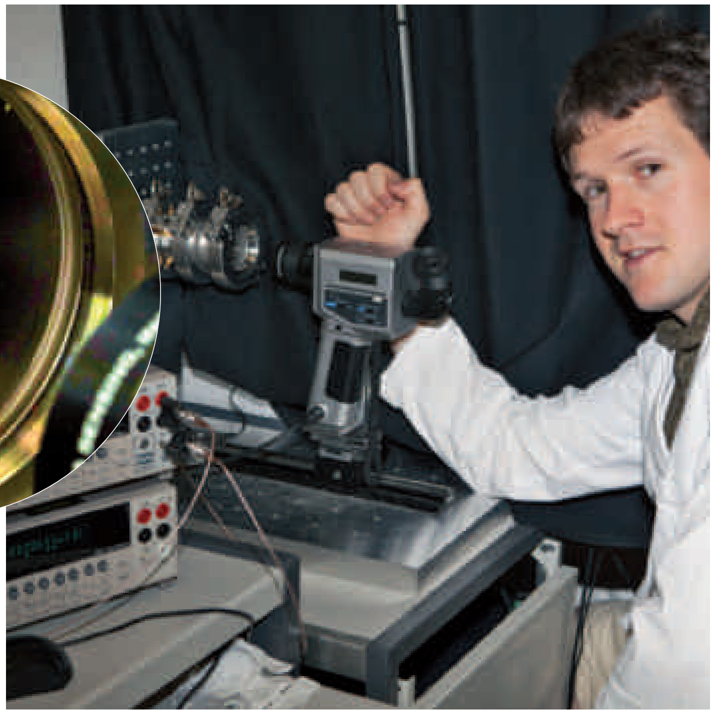
**Now it's industry's turn**



Dozens of scientific papers were published during this time, appearing in scholarly journals such as Applied Surface Science, Journal of Physical Chemistry and even as the cover story in Macromolecular Chemistry and Physics. Now their colleagues at universities and industry should know how they will have to proceed, specifically, to properly specify the gap between the shooting position and the target so that the material doesn't stick to both sides; to shoot with reduced air pressure in order to confront the destructive shock wave; to properly gauge the laser's intensity so that the sensitive pigments continue to light up nicely even when they reach the target.

However, the proud moment that accompanies a successful experiment is also the time to say goodbye. The three glowing coloured points represented one of the last experiments for the time being in the area of flying pixels at Empa. That's because the system is now characterised and well understood. The further path to commercial applications is something industry must tackle. That's something a national research institute cannot afford – and should not have to. From these results, Shaw-Stewart will write his PhD thesis, which should be finished in the spring, and then he'll move on.

With the end of the LIFT project, project leader Nagel will also turn to new topics. He already has ideas for the next one, and he isn't worried about finding tough nuts to crack. "There are plenty of fundamental problems in the area of functional polymers", he says with a grin. Photovoltaics with organic materials are being intensively studied at Empa. "There are questions dealing with interfaces and morphologies which are not yet answered." Nagel will look for something that is not – or not yet – working, and then his research activities will start all over again. //



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**3**
James Shaw-Stewart prepares a sample within a protective atmosphere.

**4**
Bingo! The pixels have reached their target in good shape and glow brightly. The Empa researcher examines the results with a spectrum analyser.

**Link**

Direct link to laboratories, to original publications and podcasts:
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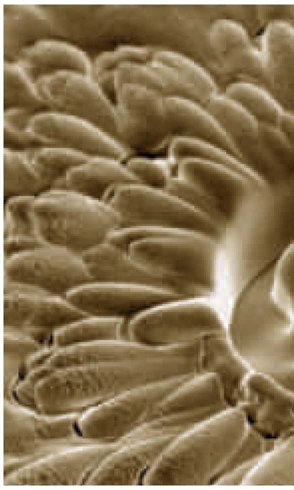


# Innovations emerge thanks to "nano"

Nanotechnology is opening new markets and enabling solutions to address countless challenges in a wide range of industrial sectors – this was the consensus of the 1st Swiss NanoConvention, which was held on 18 and 19 May in Baden. Organised by Empa, the Paul Scherrer Institute (PSI) and ETH Zurich, the conference offered the almost 300 attendees a platform to get and exchange first-hand information about productive developments in the nano sector for the benefit of society, but also to discuss potential risks.

More than two dozen speakers from Switzerland and abroad illustrated why our lives will soon be unimaginable without "nano": smart windows which adjust their transparency to solar radiation thanks to a nano coating and thereby help save energy; new diagnostic methods and customised medication against HIV and arteriosclerosis; nanofibres which on the one hand pave the way for effective dust filters and on the other hand protect vineyards from pest infestations thanks to the dosed release of pheromones; new, nanostructured materials for efficient batteries; and innovative storage media holding unimaginable volumes of data. These are only a few of the developments on which nano-researchers are currently working and about which there were lively discussions in Baden.

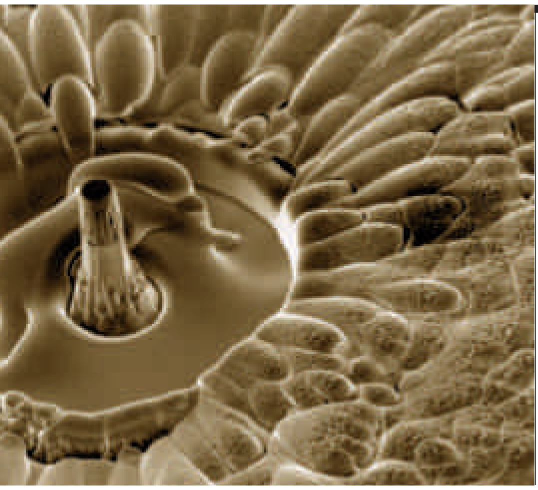
It was noted that in Switzerland there is presently a love/hate relationship with nanotechnology. Even critics don't dispute that nanotechnology could one day be able to solve problems in medicine and environmental protection. However, according to the unanimous opinion, our fears should also be taken seriously. For instance, several initiatives are currently under way in Switzerland and in Europe where representatives from science and industry are gathering with consumer and environmental associations to establish safety guidelines for applications of various synthetic nano-materials. This is creating the basis for sound decision-making for any risk-reducing measures by industry and public officials.

Next year the Swiss NanoConvention will be organised by the Swiss Federal Institute of Technology in Lausanne (EPFL). It will take place on 23/24 May 2012 at the Rolex Learning Centre in Lausanne.

Scenes from the Swiss NanoConvention in May 2011. Empa Director Gian-Luca Bona conversing with participants (middle).
The convention organisers were pleased to have Nobel laureate Heinrich Rohrer as a speaker (right).

## Video-Podcast

Podcasts on EmpaTV with coverage of the Swiss NanoConvention 2011:
impressions, encounters, conversations as well as presentations
from Thomas Borer, John E. Kelly, Aymeric Sallin and many others:
*www.swiss-nanoconvention.ch* and *www.empa.ch/empatv*



### The beauty of the nano-world

With a focused ion beam or FIB, Siddharta Pathak (from the Mechanics of Materials and Nanostructures Laboratory as well as the Advanced Materials Processing Laboratory) built tiny towers with a diameter of 500 nanometres from an extremely dense carpet of carbon nanotubes. Using micro tools, he wanted to find out how much pressure these towers could withstand before they collapsed. His results were that the towers can handle a very large load and are suitable as candidates for energy-absorbing applications in micro-mechanical systems.

Even so, this wasn't the end of the story. In documenting his experiment, he created a series of fascinating images generated with a scanning electron microscope. These have not only appeared on the covers of renowned scientific journals, Pathak and his colleagues also won prizes for artistic merit. A prime example is the international online competition NanoArt21 (*www.nanoart21.org*), where Pathak won first place with the image depicted here.

### Setting records at Empa

Empa's Thin Films and Photovoltaics Laboratory specialises in the development of highly efficient (and less expensive) thin-film solar cells. The researchers working in the team of Ayodhya N. Tiwari have been able to develop and optimise processes at low deposition temperatures (in other words, below 450 degrees C) for high-efficiency cadmium telluride (CdTe) solar cells. Using glass as a carrier substrate, Tiwari's team has achieved an efficiency of 15.6 per cent, and on flexible polymer films a record value of 13.8 per cent. Just recently, the team also improved upon the efficiency record with flexible cells made of copper indium gallium selenide (CIGS, for short), achieving 18.7 per cent.

Flurina (age 9) tests the suspension bridge – and her courage.

### The joy of research – and building a bridge

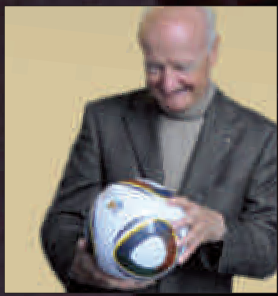
During a week-long summer camp in the middle of July, 21 children of Empa employees became enthusiastic researchers in various laboratories. There they discovered strange worlds, from the cosmos of nanotechnology to environmental science, and combined their everyday experiences with new knowledge. The most challenging task for these researchers-to-be was constructing a load-bearing suspension bridge across the narrow river Chriesbach in Dübendorf.

Working with the young designers, the bridge expert and former Empa director Urs Meier studied various concepts, which the children themselves had developed. Ceila (age 12) had this to say about the preparatory work: “At the end we knew exactly what was important.” The implementation was even more challenging. Together they erected the pylons – the bridge piers – and carefully connected ropes with rungs to a walkway. After concentrated work, the bridge was standing. But would it hold them? The small bridge-builders weren't too worried. “We worked on it ourselves”, was their enlightening rationale.

At the end, the summer camp was a resounding success for the young researchers. “It was really cool, and I'd really like to come again”, is how Jessica (age 9) summarised her impressions.

# Opinion

## Heinrich Steinmann



Heinrich Steinmann
former President of "Hasler Stiftung"

"Empa went out of their way to make their industry-related R&D accessible to us. It was amazing to see how up-to-date and competitive these projects are."

# Events

26 September 2011
**Catalytic methane oxidation**
Empa, Dübendorf

27 September 2011
**Bioplastik: Verpackung der Zukunft?**
Empa, St. Gallen

30 September 2011
**Smart textiles – applications and potential in optical and electrical measurement**
Empa, Dübendorf

6 October 2011
**Metallische Gläser: Eigenschaften, Technologien, Anwendungen**
Empa, Dübendorf

24 October 2011
**Scattered Light and Electrical Mobility – Eyes and Hands of an Aerosol Scientist**
Empa, Dübendorf

9/10 November 2011
**Titan-Anwenderseminar 2011**
Empa, Dübendorf

11 November 2011
**Cytoprotective signalling pathways in the skin**
Empa, St.Gallen

22 to 27 January 2012
**6th International Symposium Hydrogen and Energy**
Seminar- und Wellnesshotel Stoos, Switzerland

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

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