# EmpaNews

Magazine for Research and Innovation
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## Backache – a matter of mechanics

EMPA
Materials Science & Technology

New artificial hip joints

Portrait: Nano-researcher Oliver Gröning

Smugglers in the crosshairs

**MICHAEL HAGMANN** Head of Communications

# Don’t be afraid of bold ideas

*Dear readers*

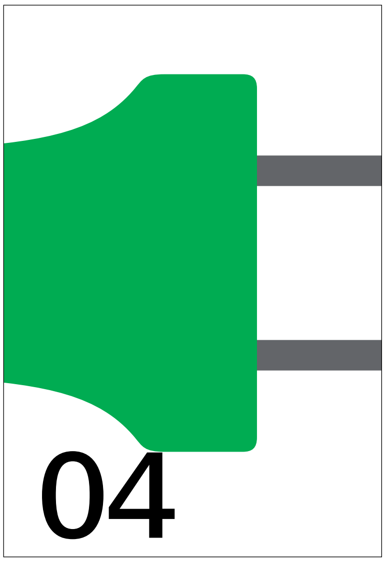
*Switzerland is the world champion in innovation. And has been for a number of years, too. A serial winner in various rankings, as it were. This is great and we can – quite rightly – be proud of it.*

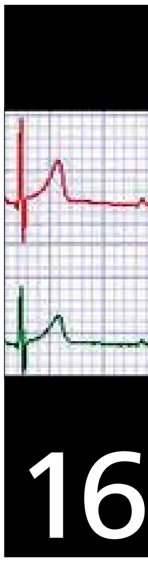
*To presume an everlasting, almost natural superiority of the Swiss research and innovation system, however, would be negligent. Sure, we do plenty right. But we can (and must) keep improving. If you want to remain competitive – and Switzerland unquestionably does – you need to avoid the “ABC of business decay” as US investor Warren Buffet recently put it: arrogance, bureaucracy and complacency. Compared to the rest of the world, Switzerland is (still) relatively well poised. But anyone who looks hard enough will spot the early signs of this kind of development in this country.*

*So what can we do? There is no magic formula, but the course is clear. We should cast off our reluctance to take risks (which is caused to a large extent by our prosperity and success). We have to be bold, mustn’t be afraid of potential failure and should think big, at least every once in a while. Like Switzerland’s National Innovation Park. Whether it will ultimately pay off is still anyone’s guess. However, the (original) vision behind it is quite fitting for Switzerland: ambitious, forward-looking and global.*

*For you won’t stay at the top for very long with a zero-risk mentality and the inability to think beyond the bottom of your own allotment; you’d rather end up where you belong: in the middle of the field. This cannot and must not be an option for Switzerland.*

*Enjoy reading!*

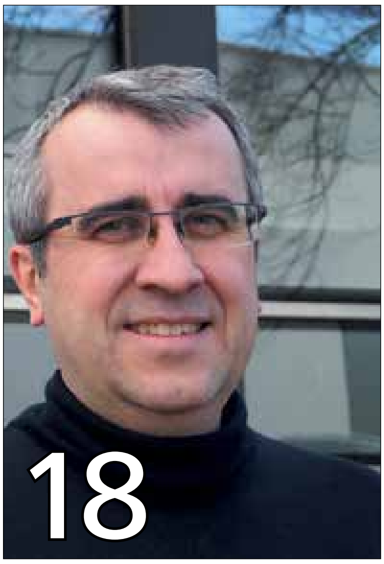




**Cover**
*The medical simulation program Open Sim from Stanford University enables the movements of the human skeleton and musculature to be simulated and the occurring mechanical forces calculated. Empa uses Open Sim to analyze signs of wear on the backbone.* ***Page 08***

Fokus

# Medical engineering





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Charge your car in less than **15** min on a standard house plug

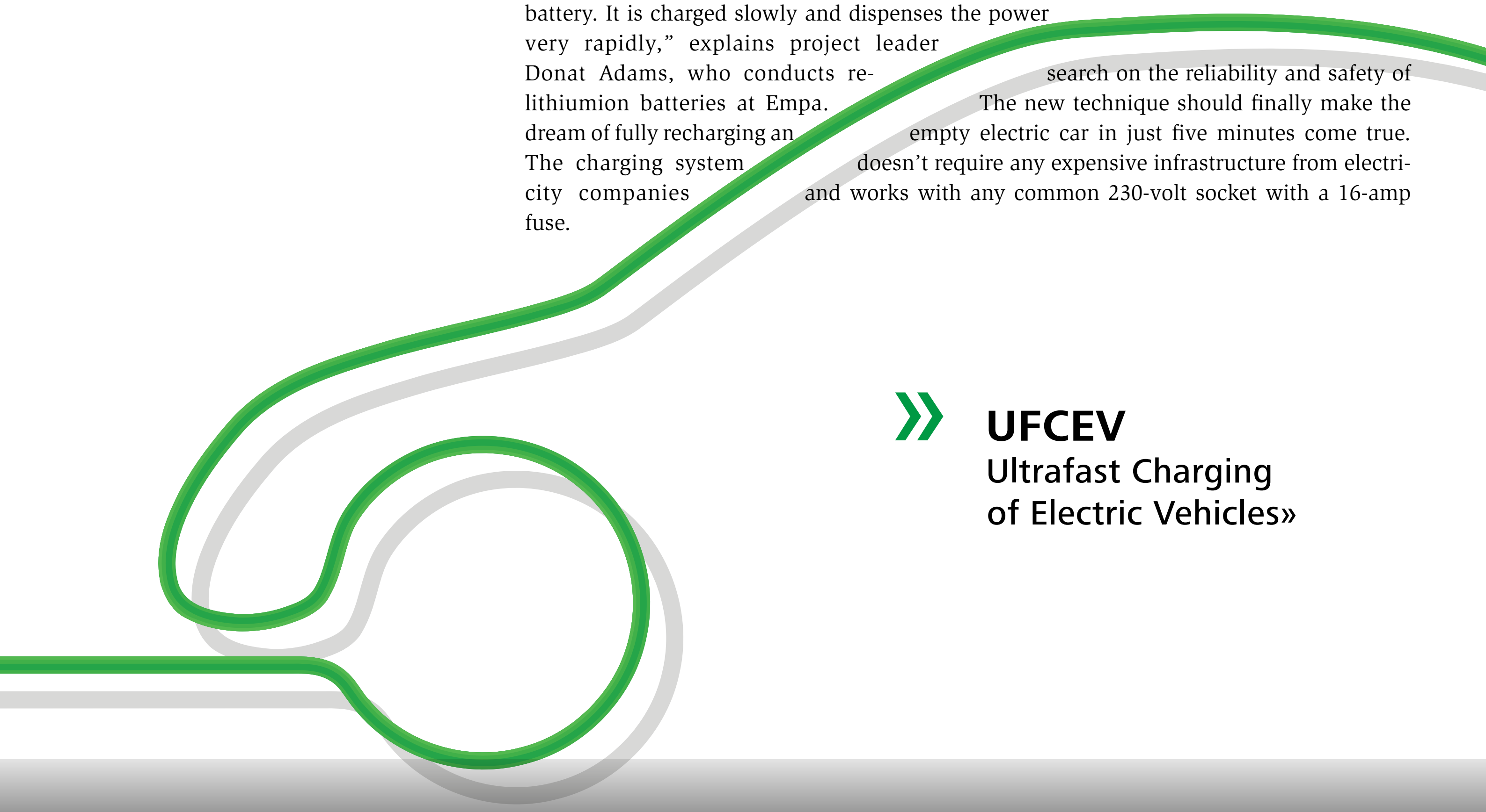
# High voltage for e-cars

**Charging your electric car in only five minutes – a new charging system should make the unimaginable possible. And it still works without any expensive infrastructure, merely with your run-of-the-mill industrial socket**

TEXT: Anemone Seger / PICTURES: Empa / ILLUSTRATION: iStockphoto

On average, an electric car needs to be hooked up to a household socket for seven to eight hours before its battery is fully charged. At a rapid charging station like CHAdeMO or the Tesla Supercharger, it only takes 15 to 30 minutes, depending on the car. Filling up in five minutes, however, – which owners of conventional cars with combustion engines take for granted – has been wishful thinking for drivers of electric cars up to now. But this could be about to change.

Empa teamed up with ETH Zurich, EPF Lausanne and the Bern University of Applied Sciences in a project funded by CCEM (the ETH Domain's Competence Center for Energy and Mobility) and swisselectric research to develop a new charging station termed UFCEV ( for "Ultra-Fast Charging of Electric Vehicles"). "Our charging station is essentially a giant battery. It is charged slowly and dispenses the power very rapidly," explains project leader Donat Adams, who conducts research on the reliability and safety of lithiumion batteries at Empa. The new technique should finally make the dream of fully recharging an empty electric car in just five minutes come true. The charging system doesn't require any expensive infrastructure from electricity companies and works with any common 230-volt socket with a 16-amp fuse.



» **UFCEV**
Ultrafast Charging of Electric Vehicles»

**One step ahead of today's electric cars**

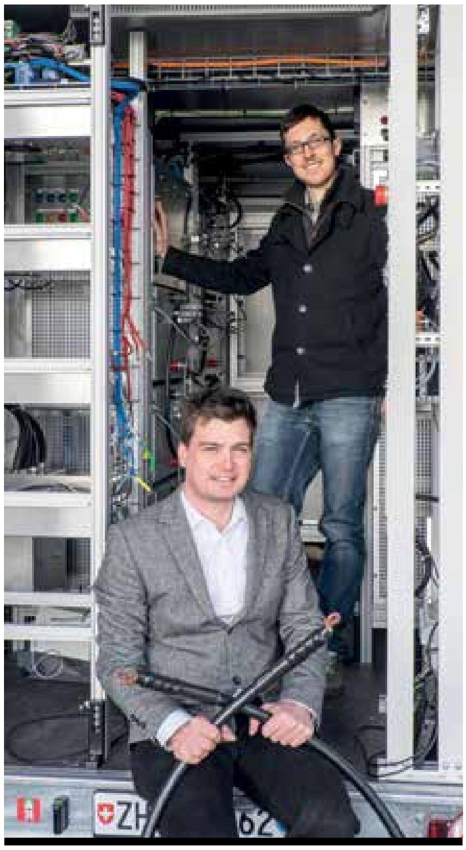
As the UFCEV charging station weighs one and a half tons and is still sup-posed to be mobile, the researchers incorporated it in a car trailer. It takes about an hour to charge on a common industrial socket. Inside the charging station, a converter converts the alternating current into direct current for the 15 battery elements. These consist of several lithium iron phosphate batteries – for two reasons: firstly, they carry no fire hazard; secondly, they are long-lasting. The researchers estimate that the batteries themselves will still be usable in 20 years. An integrated ventilation system uses air to cool the battery elements as they heat up when in operation. During the discharging process, a voltage converter regulates the power output to any electric car that is hooked up to the system.

Although the UFCEV charging station was up and running in late January, this doesn't mean that five-minute charging will be possible as of now. This is because the batteries in today's electric cars are not capable of taking up the power in such a short period of time as the UFCEV charging station releases it. "During the charging process, the roughly 1.5-ton battery elements in the UFCEV charging station heat up by around seven degrees. The batteries in electric cars are a lot smaller. If the car battery were to be charged within five minutes, it would heat up by around 50 degrees or more and go bust," explains Adams. In other words, the UFCEV charging station requires suitable car batteries to exploit its full potential.

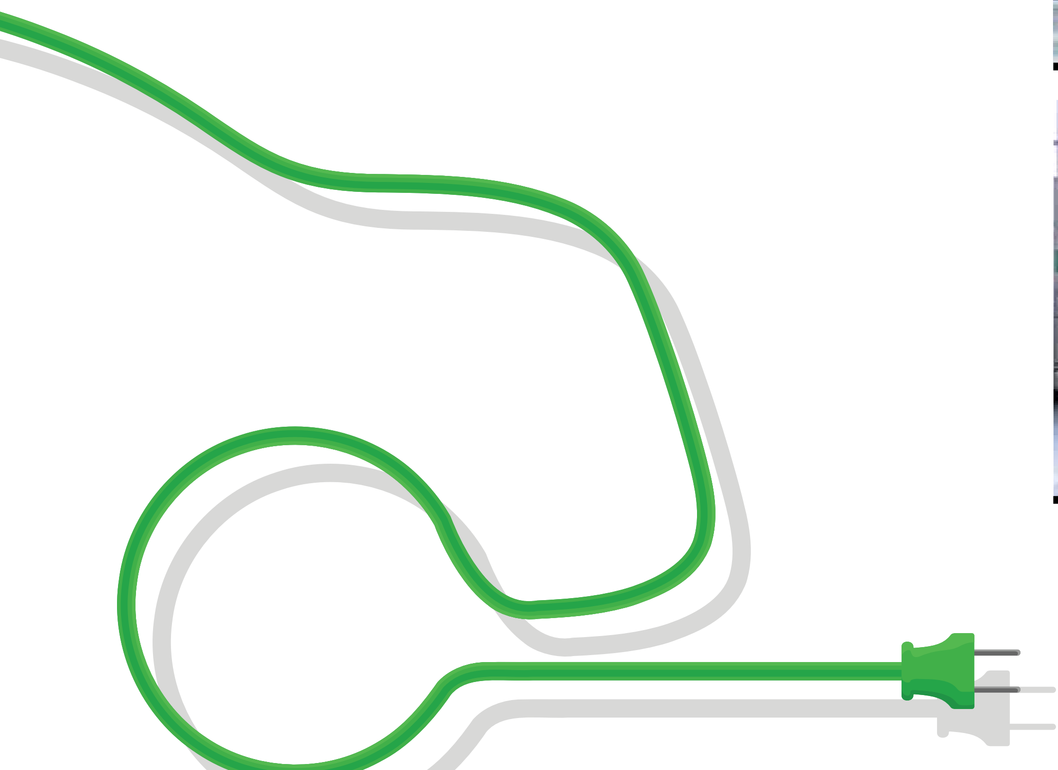
| Charging current connection | Data | Charging time for electric car |
|---|---|---|
| Household socket Switzerland | 230 V and 10 A | 7 – 8 hours |
| Industrial socket Switzerland | 230 V and 16 A | 4 hours |
| Rapid charging stations (e.g. CHAdeMO or Tesla Supercharger) | Up to 500 V and 200 | 15 – 30 minutes |
| UFCEV-charging station | Up to 700 V and 390 A | 5 minutes |

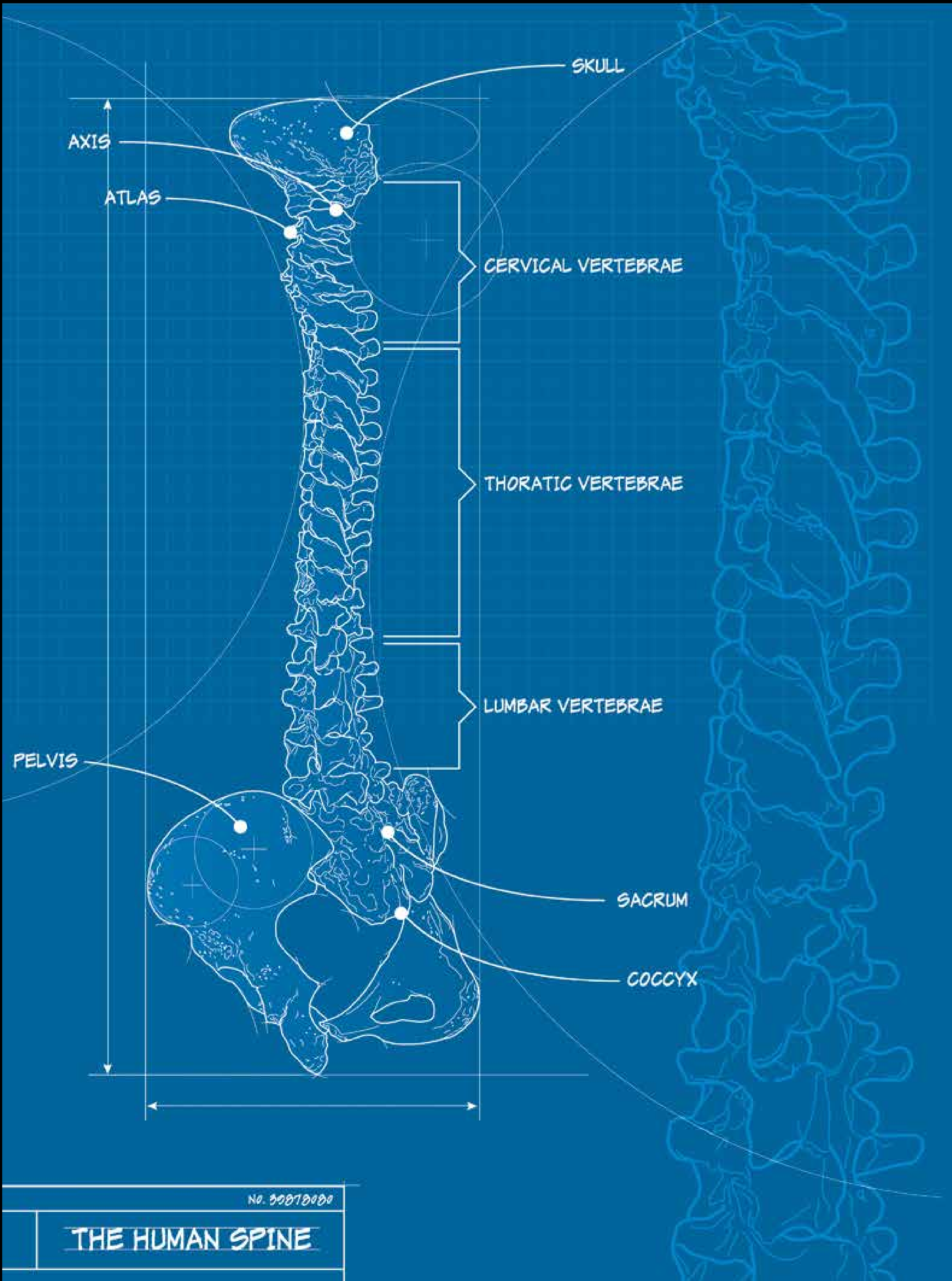
**Charging station and back-up battery**

But until that day comes, the UFCEV charging station won't be standing idle. It can already be used as a "normal" rapid charging station as the researchers can tune it via the voltage converter so that it dispenses its charge in around 20 minutes – the maximum current car batteries can withstand. And as Adams, who also teaches energy storage at EPF Lausanne, adds: "We're also looking into other areas of application. For instance, the UFCEV charging station can also be used as a back-up battery and thus stabilize the power grid." This means that differences between the supply and demand can be compensated by charging the station(s) whenever surplus electricity is available and discharging it again when electricity is required on the grid on short notice. //




Empa scientist Donat Adams (sitting) and Patrick Haldi from Bern University of Applied Sciences mount batteries and power electronics into the UFCEV-trailer.




SKULL
AXIS
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CERVICAL VERTEBRAE
THORATIC VERTEBRAE
LUMBAR VERTEBRAE
PELVIS
SACRUM
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THE HUMAN SPINE

# Our backbone – mystery mechanics

Thanks to a collaboration with the Balgrist University Hospital and University of Pittsburgh, Empa is beginning to decode the mechanics of the lower vertebrae. Researchers would like be able to reveal how wear and tear comes about on vertebral bodies and spinal disks. This would also make choosing the appropriate therapy much easier.

TEXT: Rainer Klose / PICTURES: iStockphoto, Empa, Chalmers University of Technology

Some say that back pain is the price we pay for walking upright: ever since we stood up, the spinal column has carried the entire weight of the head, upper body and arms for many hours a day, which causes increased wear and tear. Others claim that the problem of back pain only really started when humankind sat down to reflect and contemplate: a lack of exercise weakens the muscles, which is compounded with stress in our private lives or the workplace. Humans run through life hunched over with worry and the back muscles cramp up more and more. The upshot of it all: backache.

Regardless of which explanation is true, the problem can usually be remedied by relaxing and strengthening the back muscles. In one in seven cases, however, this doesn't work. Even giving these patients opiates no longer helps. In these instances, a mechanical problem lurks behind the back pain and only an operation can put an end to the suffering. In severe cases, the defective vertebrae or spinal disks are bridged with a metal construction (intervertebral fusion). The fixed segment ossifies and is unable to trigger any more pain. However, this kind of reparatory operation only offers the patients a few years of relief before the problem flares up again in the neighboring vertebrae. The question is why this occurs and how this could be prevented.

>>

**A question suited for mechanical engineers**

Bernhard Weisse and his team at Empa are investigating precisely these mechanical questions. In order to understand why and how quickly a vertebral joint wears out, the researchers need to know the forces that are exerted in this area. This in turn requires an exact understanding of the shape, elasticity and flexibility of the individual "elements". It is a question for mechanical engineers, much like in bridge building, ship construction or the development of chassis components for cars.

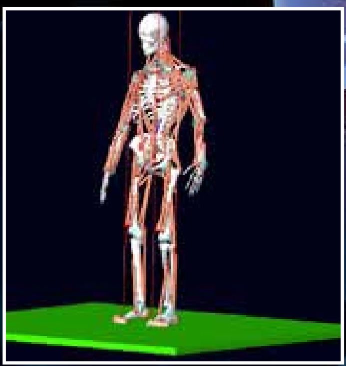
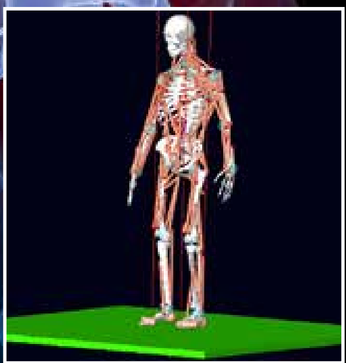
Medical statistics reveal that up to 27 percent of patients who underwent a lumbar arthrodesis (vertebral blocking) suffered a relapse. However, the risk is spread unevenly: if the backbone sits almost vertically above the hip joint, the relapse rate is low. However, if the sagittal misalignment – that is the location of the backbone in relation to the hip joint and the lumbar lordosis angle – exceeds 15 degrees, the relapse rate quadruples.

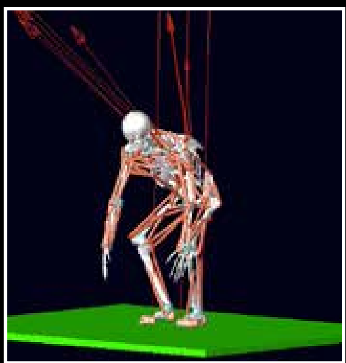
**The skeleton simulator**

The first step for the Empa team was to tweak the theoretical foundation: Marco Senteler fed the computer program "OpenSim", a widely used simulation program for the human musculoskeletal system developed by the "National Center for Simulation in Rehabilitation Research" at Stanford University, with geometric spinal column data from 81 patients. The aim was to illustrate the biomechanics of the spinal column as accurately as possible in this computer simulation: does a spinal disk behave like a ball-and-socket joint? Or more like a rubber bearing? What influence do the muscles have? Does the rubber bearing always remain uniformly rigid or does the rigidity change depending on the angle of the curvature? Empa collaborated with the Laboratory for Orthopedic Biomechanics at Balgrist University Hospital (University of Zurich) and the Institute for Biomechanics at ETH Zurich to find the answers.

With the aid of the computer model, the scientists managed to simulate the mechanics – which is how they came closer to identifying a misalignment of the spinal column as one of the causes of increased risk of a relapse in certain patients. Already in a non-operated state, a spinal column with a relatively large malposition thus has to withstand considerably higher forces. If the person bends forwards to lift a load, the intervertebral joints are strained up to 34 percent more. If a spinal disk breaks and is bridged, the strain on the neighboring vertebrae carries on increasing and can be up to 45 percent higher than in healthy people. No wonder the level of wear and tear rises rapidly.

Studying a health problem using computer analysis alone is insufficient, though. The ultimate goal is to make an individual diagnosis for every patient and then recommend the appropriate therapy. As a result, Weisse's team initiated a follow-up project and received funding from the Swiss National Science Foundation (SNSF). The idea was to produce accurate images of the



patients' spinal columns – in vivo, while they are moving.

**When X-ray images learn to run**

Researchers from the University of Pittsburgh developed a novel 3D X-ray video system called "Digital Stereo-X-Ray Imaging" (DSX). It can display the movement of the spinal column with 250 images per second, while the position of the vertebrae is visible down to an accuracy of 0.2 millimeters. And at a very low X-ray dosage, too. The trick: the blurred X-ray images of the movement are combined with sharp CT images of the patient lying still on the computer.

One of the researchers who worked in Pittsburgh is Ameet Aiyangar. Having already been at Empa as a visiting scientist in 2009, he is now returning to Empa. In the US, he had 12 healthy people lift weights and produced high-resolution films of their spinal column movements. Aiyangar is currently in the process of matching the dynamic X-ray data recorded with the computer models of the individual test subjects.

Once the model for healthy people is consistent, the researchers want to use the method to study the problems associated with arthrodesis. The idea is to film the patient with the DSX system before and after the operation and analyze the motion of their vertebrae. As a result, the forces exerted in the region of the lower spinal column before the operation and the alteration in this distribution of forces due to the arthrodesis can be determined. For the first time in the history of medicine, this will make it possible to compare the in vivo movement and stress distribution and the movement patterns of the individual vertebrae and spinal disks before and after vertebral bridging – and specifically for every patient, too. This study will help to understand the degeneration of vertebral joints much better and identify the source of pain in the lower back more accurately.

In future, this kind of computer analysis could be used for all patients who underwent back surgery. Doctors can decide more easily for which patients a bridging operation is advisable and for whom not. Thanks to the data obtained, spinal column implants with a better design could also be developed (e.g. flexible spinal disk prostheses). //

*Video*
Simulated force distribution in the back while lifting a load (see pictures below).

*http://youtu.be/XYpGCnIJWVk*

*Video*
How Open Sim works – the program that calculates forces and mechanics in the human skeleton.

*https://youtu.be/ME0VHfCtIM0*

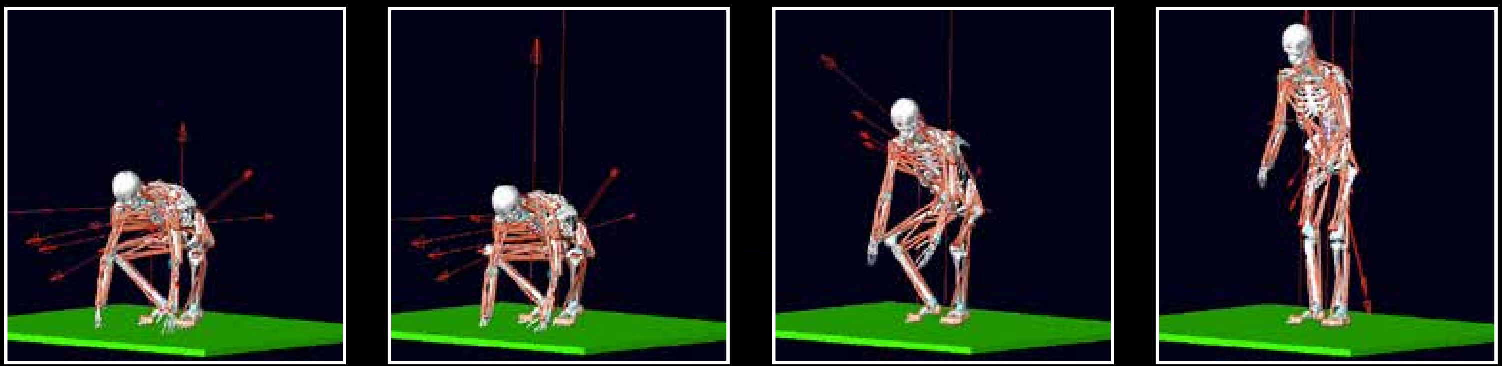
## Empa MedTech Day 8 May 2015

Empa is involved in a variety of materials research projects for the medical sector: For instance, it develops metallic or ceramic implants and examines novel implant surfaces with the aid of special cell culture systems. The MedTech Day at the Empa Academy in Dübendorf on 20 May 2015 provides an overview of medtech research at Empa. In the afternoon, a Science Speed Dating session will offer a perfect opportunity to discuss research topics directly with Empa's experts and explore potential partnerships. Info and registration at www.empa.ch/ibmtd. Admission is free of charge, the closing date for registrations in 8 May 2015.

## Teaming up with Balgrist Hospital

Researchers from Empa are collaborating closely on several projects with doctors from Balgrist University Hospital, a leading international, highly specialized center of excellence for the assessment, treatment and follow-up of all types of musculoskeletal injuries. From the fall of 2015, the collaboration is to be stepped up further, once the Balgrist Campus is ready: A privately funded research center right on the University Hospital's doorstep that is designed to promote musculoskeletal research and yield innovative results. www.balgristcampus.ch

Empa calculates the force distribution in the back with the aid of the program Open Sim developed by Stanford University.



# Ceramics instead of chromium

**Although artificial hip joints last for around 20 years, you can't replace them as often as you like. Together with the Swiss ceramic component manufacturer Metoxit, Empa scientists are looking to postpone joint replacements for as long as possible using a kind of protective cap.**

TEXT: Letizia Krummenacher / PICTURES: Empa



Arthrosis in the hip joint is not just painful; it increasingly restricts the patient's freedom of movement. The last resort is often a prosthetic hip. Today, such a joint replacement lasts for 20 years on average. The most common cause for a replacement's failure is the so-called aseptic loosening of the artificial joint. In other words, it starts to wobble, which means that the joint needs to be replaced with a new one. With the shaft prostheses used in the hip today, however, this procedure cannot be repeated too often. This is because the entire femoral neck bone already needs to be removed for the first shaft prosthesis and the surgeon has to keep drilling further into the bone tissue for every additional prosthesis. Eventually, the "bone wall" becomes too thin.

"Resurfacing prostheses" were developed a number of years ago to preserve the femoral neck bone for as long as possible if the hip joint is damaged. To attach them, only the surface of the bone is milled off and a cap – the hip resurfacing – is placed directly on the femoral head. The corresponding socket (which also needs replacing) is anchored in the hip bone above. The advantage for patients: the thigh's bone substance remains intact.

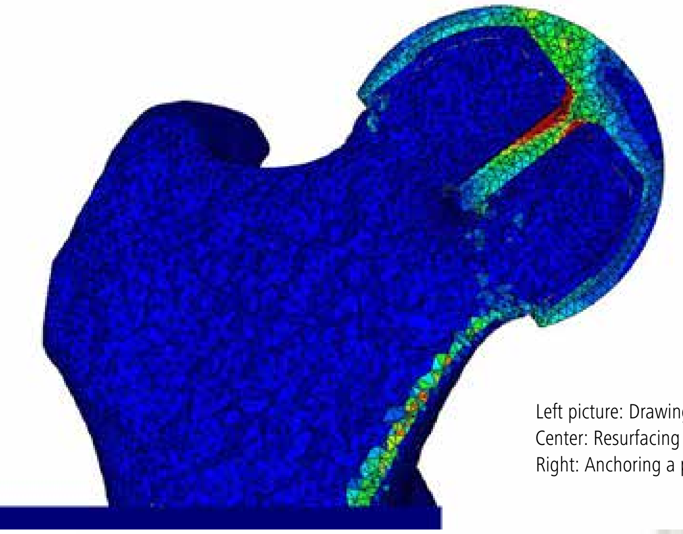
### Metal in the bloodstream

However, resurfacing prostheses consist of a cobalt chromium alloy and often pose problems: when the metal surfaces of the hip resurfacing and the socket slide against each other, metal particles can enter the body, which can cause allergies, inflammations, necrosis or even poisoning.

In order to solve the problem, the Swiss company Metoxit teamed up with Empa to develop a new ceramic prosthesis. But not the ceramics used in flower pots or roof tiles. Unlike such low-tech ceramics, high-strength mixed ceramics made of zirconium oxide and aluminum oxide, also known by the abbreviation ATZ (alumina-toughened zirconia), are used for the new prostheses. Metoxit developed this extremely strong, hard and long-lasting high-performance ceramic material and is already using it successfully in dental implants. Compared to metal alloys, the material is more wear-resistant. Moreover, its good biocompatibility reduces the risk of immunological reactions, even if there were some wear.

### Best possible fixation

Bernhard Weisse and Sebastian Valet developed and optimized the design and macrostructure of the new ceramic prostheses. Unlike the modular systems available today, the hip resurfacing and the cup



Left picture: Drawing of a hip resurfacing prothesis.
Center: Resurfacing prothesis (above) compared to a shaft prothesis.
Right: Anchoring a prototype in artificial bone material.

are produced in a single piece, which makes the prosthesis much easier to insert. But the design also needs to guarantee the best possible fixation. “To do so, several rims with a profile of a fluke are cut and turned into the surface of the cup, which dig into the surrounding pelvic bone after being inserted,” explains Weisse. This guarantees good basic stability from the very beginning. On the opposite side, the surface of the femoral head is milled so that the cap merely needs to be placed on top and immediately holds in place.

**Testing with bone precursor cells**

For the prosthetic to remain stable in the long term, however, bone cells need to be able to adhere and proliferate on the surface. In order to find a suitable surface structure Katharina Maniura and her team at Empa are conducting cell assays on a rough, porous surface where bone precursor cells can multiply. The surface is based on structures, with which dental implants already grew into the jaw bone. Nevertheless, bone cells from different regions of the body differ greatly. The next step will, therefore, be to adapt the implant surface to the special requirements of hip bones. //


Bernhard Weisse using a traction device to check how firmly the prosthesis can be anchored in artificial bone material. The design of the grooves and barbs is crucial.

# Spare parts for the hu


PICTURES: Empa, iStockphoto

# man body

**It's not just competitive athletes that expose their bodies to high levels of wear and tear. Bones, muscles and blood vessels change with age or through illness or accidents. Oftentimes replacement parts offer a solution; these need to be compatible with the human body – and last for a long time. Empa is developing improved replacements and novel diagnostic devices for a long, active life.**


**1 Blood pressure gage on the wrist**
Conventional blood pressure measurements are unpleasant and can only be conducted periodically. A new system that is barely bigger than a wristwatch should make this a lot easier in future. (EmpaNews No. 41)

**2 Blood sugar measurement through the skin**
A novel membrane can determine the blood sugar level through the skin. For now, it only works on newborn babies. In future, however, adults could also use the technology. (page 14)

**3 Bracing the neck vertebrae**
A break in the neck vertebrae is repaired with a tiny cage that supports the broken vertebrae and grows into the bone.

**4 ECG belt**
A chest strap made of conductive textiles facilitates gentle long-term ECGs for elderly patients. In order to record reliable readings, the sensor is able to keep itself moist. (page 16)

**5 Biodegradable stent**
Blocked coronary vessels are widened with a stent. Empa teamed up with the University of Applied Sciences and Arts Western Switzerland to develop a mechanically solid stent with a biodegradable polymer coating. The surface gradually dissolves and dispenses drugs that keep the artery open.

**6 Spinal disk replacement**
Flexible spinal disk implants need to withstand extreme strain. Empa developed coatings that enable such components to last a lifetime. (EmpaNews 45)

**7 Force research on the vertebrae**
Occasionally, defective vertebrae are bridged with metal constructions (inter-vertebral fusion). However, this causes the neighboring vertebrae to wear more quickly. Empa is studying the force ratio in the back and helping to select the appropriate treatment. (page 06)

**8 Artificial hip joints for young patients**
Artificial hip joints last for around 20 years. However, they can't be replaced repeatedly too often. Empa is developing a protective "cap" that postpones the need for a hip implant. (page 10)

**9 Design and color-coding**
Bone screws and plates are special components. Empa is optimizing the design, the material and its surface to provide maximum strength. A biologically neu-tral color-coding for plates and screws makes work easier in the OR and helps avoid mistakes. (EmpaNews 37, page 20)

**A newly developed sensor that measures the blood sugar through skin contact could render blood samples a thing of the past. "Glucolight" is initially to be used on premature babies.**

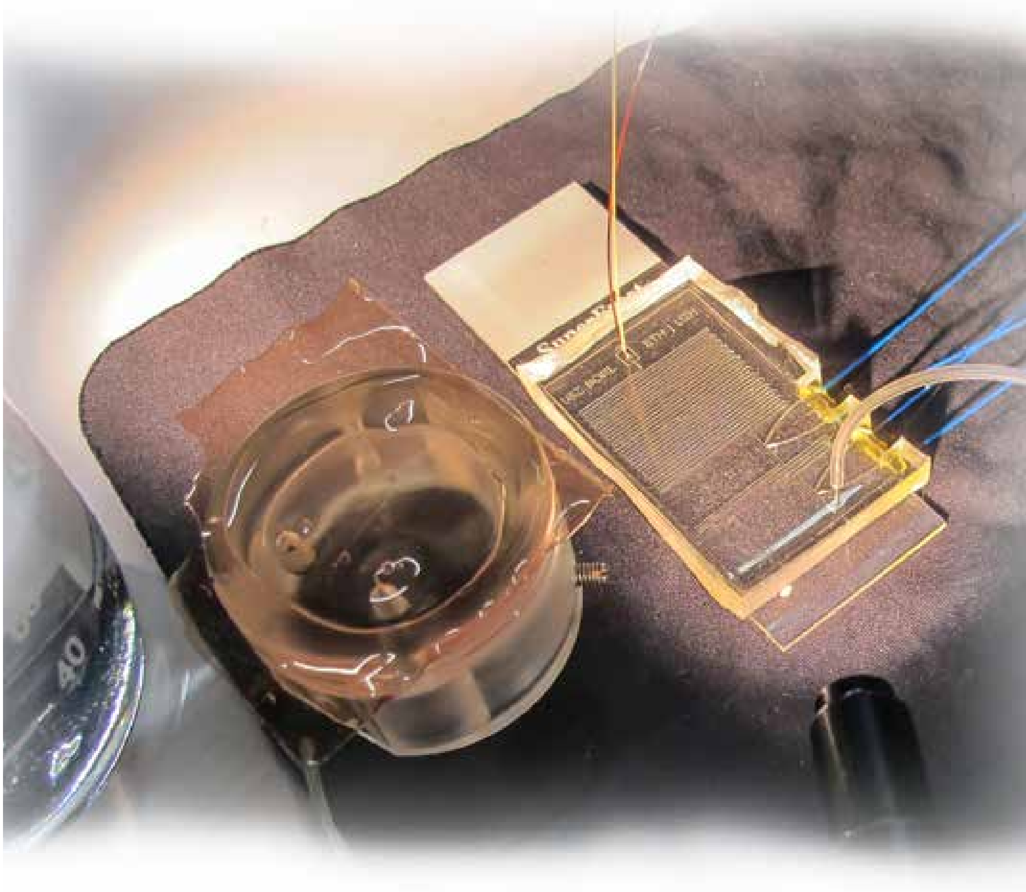
TEXT: Anemone Seger / PICTURES: Empa

One in twelve babies is born prematurely in Switzerland. The blood sugar levels need to be monitored closely in these premature babies, also known as "preemies", as prolonged hypoglycemia can affect brain development. Until now, this monitoring inevitably meant taking blood samples. If the blood sugar is at a critical level, doctors even have to take blood every hour, which causes blood loss, pain and stress. To address this issue, Empa teamed up with the University Hospital Zurich on a five-year project funded by the Swiss National Science Foundation (SNSF) to develop the "Glucolight" sensor, which gages the blood sugar level through the skin, without taking any blood. "As preemies lack the top layer of skin, theirs is permeable for glucose, which is why you can measure the blood sugar level very well via the skin," explains project leader Martin Wolf from the Department of Neonatology at the University of Zurich.

Although skin sensors already exist, they have to be calibrated before use. And this means that the skin's permeability value needs to be known, which depends on the area of the skin, the temperature and the pH value. In order to establish this, the blood sugar level has to be determined via a blood sample and the glucose concentration on the skin measured. Based on these two readings, the permeability can then be calculated and the sensor calibrated.

Doctoral student Damien de Courten, a member of Martin Wolf´s team, presents the measuring head with the "smart" membrane in the lab at the University Hospital

# Light replaces the needle



Initially, glucose molecules diffuse through the membrane from the skin (left) before enzymes are added and the solution is pumped through the microfluidics chip (right).
By means of fluorescence measurement the glucose concentration in the blood can be calculated.

**An intelligent membrane**

Glucolight spares the premature babies blood samples and enables the blood sugar level to be monitored permanently thanks to the sensor's novel measuring technology, which comprises several parts: a microdialysis measuring head, which was developed at the University Hospital Zurich, with a "smart" membrane developed at Empa; light sources; a pump; and a microfluidics chip with a fluorometer, which was also developed at the University Hospital Zurich.

"The smart membrane contains special dye molecules, known as spiropyrans," explains Luciano Boesel from Empa's Laboratory for Protection and Physiology in St. Gallen. If UV light is beamed onto these spiropyran molecules, they alter their chemical structure and become charged (polar). When irradiated with visible light, they revert to their original, neutral structure. As a result, the membrane "opens" when irradiated with UV light and glucose molecules from the skin diffuse relatively easily through the membrane. If irradiated with visible light, considerably fewer glucose molecules pass through the membrane.

The measurement involves sticking the measuring head, which is around three centimeters in size, to the baby's skin and irradiating it with visible light. Some glucose molecules diffuse through the membrane. On the other side of the membrane, the glucose is mixed with a fluid and pumped through the microfluidics chip, while enzymes are added to trigger a chemical reaction. The reaction leads to a fluorescence, which can be measured by a fluorometer; finally, the computer uses the reading to calculate the glucose concentration. The process is then repeated with UV light. The computer then uses the two different readings to calculate the premature baby's blood sugar level.

**Next step: clinical trials**

The researchers filed a patent application for Glucolight in mid-2014. "We hope to be able to test Glucolight for the first time in clinical trials at the University Hospital Zurich in the course of 2015," says Wolf. However, it could be years before the use of Glucolight becomes standard practics. Empa and the University Hospital Zurich are currently in negotiations with partners for the industrial production of the sensor. For the future, the researchers also envisage the use of Glucolight in other fields, such as diabetes.

In the course of the project, the researchers discovered another potential application for the membrane. Its "switchable" permeability can also be used in the opposite direction: in a drug-loaded plaster. Instead of a measuring head, there is a drug depot behind the membrane. If irradiated with UV light, the membrane becomes more permeable and the drug is gently administered through the skin over several hours. In the absence of irradiation, the membrane keeps the drug in the depot. Empa and the University Hospital Zurich developed a caffeine plaster to combat respiratory arrest, which is common in premature babies. (See also Empa News No. 47) //

*Video*
"Intelligent materials take care of premature infants"

*https://youtu.be/GPCws_lHtDM*

# Chest strap for the heart

**An Empa team developed a chest strap for the long-term monitoring of cardiovascular patients. What makes the belt that displays the electrocardiogram (ECG) so special: It keeps itself moist – which is crucial to detect a signal reliably. This makes it just the ticket for the elderly who often perspire a lot less.**

TEXT: Martina Peter / PICTURES: Empa, iStockphoto

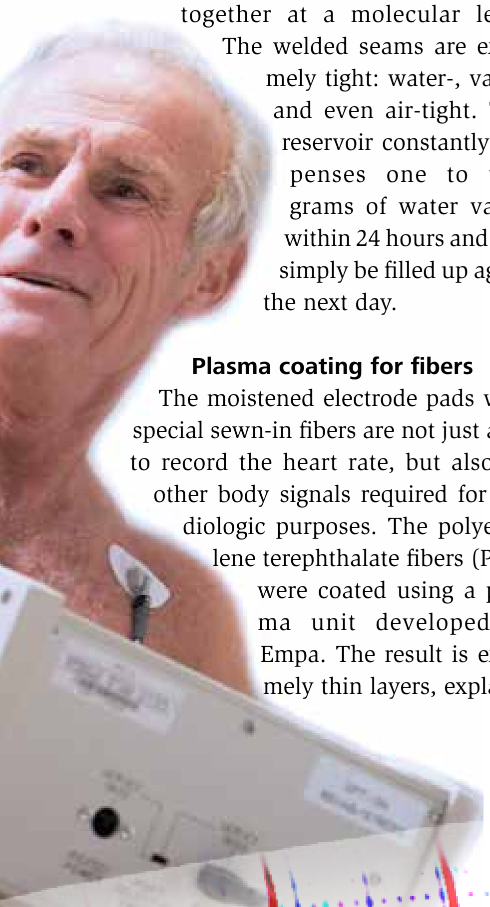
The demand for ECG measuring devices is on the rise: it is not just hospitals and rehabilitation centers that are interested in reliable, skin-friendly devices for the long-term monitoring of cardiovascular patients. The trend towards collecting and monitoring personal health data is booming. The problem: so far, gel electrodes were used for reliable, long-term ECGs. After 24 hours at the latest, however, they dry out and stop emitting reliable signals. This makes them of limited suitability for elderly people who often perspire less and are not as mobile.

The idea of developing an ECG belt for long-term use with wettable electrodes is nothing new, explains Markus Weder from Empa's Laboratory for Protection and Physiology and head of the project funded by the Commission for Technology and Innovation (CTI). "Originally, the idea came from clinical practice where long-term ECGs are customary for monitoring stress in high-risk patients. Nobody wants to stick new gel electrodes on their skin every day." Weder soon realized that such a product only stood a chance if it was easy to use and didn't bother the wearer too much. "The solution as to how we could wet electrodes in a dosed way came from a very different project, where we developed cooling clothing for multiple sclerosis patients using the very same technology," he says.

**Artificial perspiration from a "reservoir"**

The wetting was necessary, Weder explains, to preserve electrodes' electrical conductivity. At the same time, this should reduce artifacts that form when the electrode rubs against the skin ever so slightly. For the metallic sensors to be able to accurately register the body signals and reliably transfer them there needs to be moisture between the electrode and the skin – much like when we sweat. In order to generate a kind of "perspiration", Weder's team developed flexible moistening elements that can be filled with around 30 milliliters of water and ensure that the skin remains permanently moist.

The "reservoir" is a cavity between a watertight membrane and a vapor-permeable textile layer. Instead of sewing the layers together, the scientists welded them together with a laser technique they had perfected recently. A diode laser beam heats up the layers with such precision that they melt point by point and the polymer chains bind together at a molecular level. The welded seams are extremely tight: water-, vapor- and even air-tight. The reservoir constantly dispenses one to two grams of water vapor within 24 hours and can simply be filled up again the next day.



**Plasma coating for fibers**

The moistened electrode pads with special sewn-in fibers are not just able to record the heart rate, but also all other body signals required for cardiologic purposes. The polyethylene terephthalate fibers (PET) were coated using a plasma unit developed at Empa. The result is extremely thin layers, explains Dirk Hegemann, a specialist in functional textile coatings at Empa's Laboratory of Advanced Fibers. This enables the coated fibers to retain their properties – their textile haptics – and gain new ones: the roughly 100-nanometer-thin silver layer ensures that the electric impulses are transmitted and that microorganisms cannot take hold.

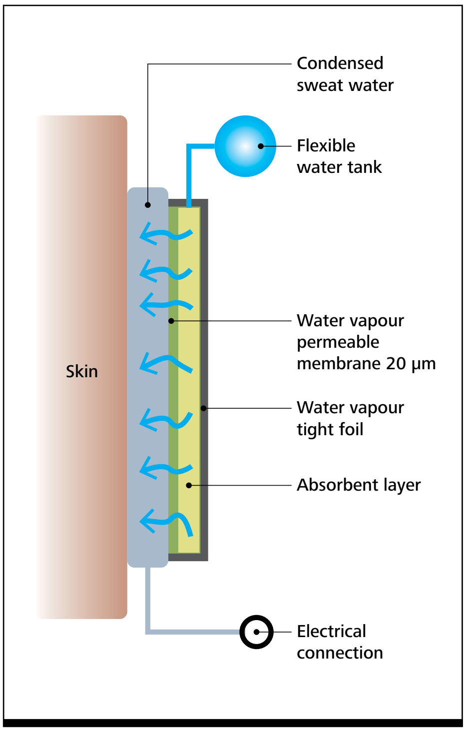
The overlying four to six-nanometer-thin layer made of titanium guarantees stable signals and prevents skin irritations from developing or silver particles from being released. "We already made an attempt with titanium some years ago," says Weder. "But the layer was too thick and the titanium came off." The researchers have now succeeded in applying a considerably thinner layer, which does not peel off when the thread is embroidered.

**Strict requirements**

Two embroidered sensor pads that are directly connected to a data logger are incorporated into each ECG belt. The recorded signals are sent to a database or standard monitoring device. As the data logger is secured with snaps, the wearer can remove and wash it – one of the strict requirements for the system to be cleared for use as a long-term medical ECG device.

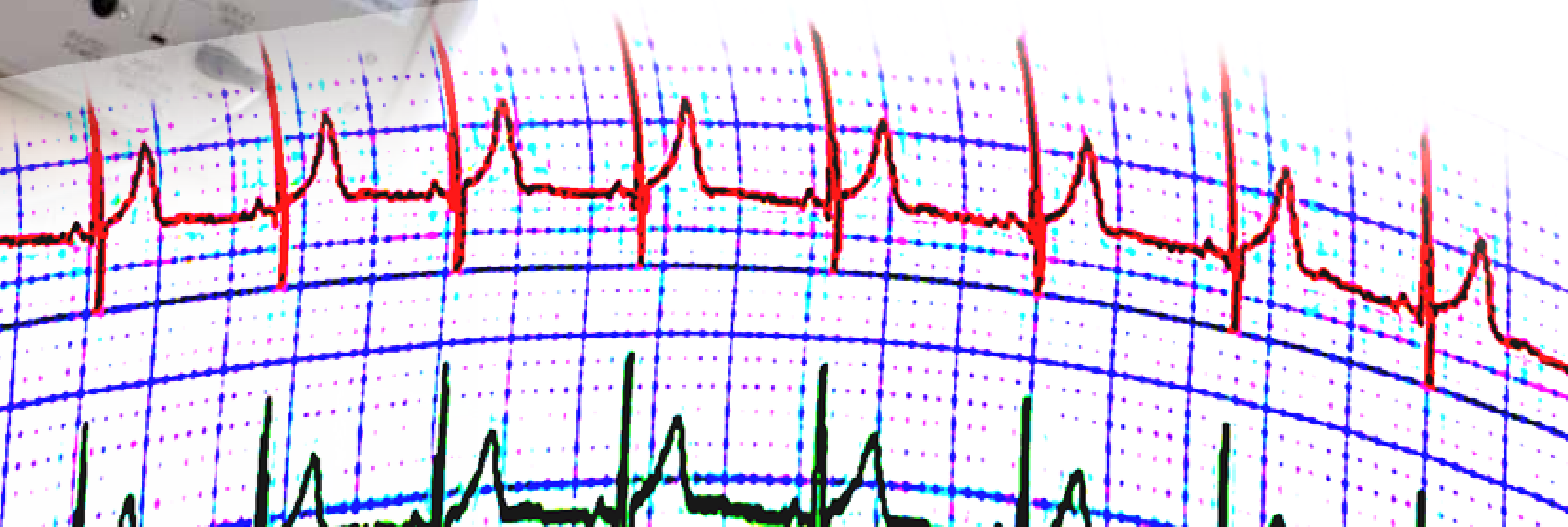
The device has already been tested successfully in well over 100 trials with volunteers. Weder himself as well as his team have also worn the belt extensively. The device could be worn for up to ten days as, compared to reference measurements, the values provided also proved to be extremely accurate after long-term use.

However, it will be some time before the device hits the market. The next step will be clinical trials as part of a CTI follow-up project with the University Hospital Basel and various industrial partners (Unico Swiss Tex GmbH, Forster Rohner, Serge Ferrari SA, xotox and Zietromec). In order to be able to produce the special fibers in large quantities, stable plasma processes that enable layer thicknesses to be set with nanometer precision are also needed. The scientists are currently working on this. Moreover, the researchers are already considering the extent to which the electrodes could be used for other purposes – such as to stimulate muscles in pain therapy or reactivate the colonic function in bedridden patients using interference wave therapy, for instance. //




Function diagram: Thanks to a water reservoir, the electrode always remains moist and yields reliable data.

The prototype of the EKG chest strap was tested on various test subjects in more than 100 experiments.




# Taking the tube

**Oliver Gröning was recently nominated as a Distinguished Senior Researcher – a special award for successful scientists who have enjoyed an excellent reputation at Empa for many years. Gröning "builds" single-variety carbon nanotubes out of precursor molecules – a kind of Lego for nanoscientists – and ponders over his astonishingly linear career.**

TEXT: Martina Peter / PICTURES: Empa

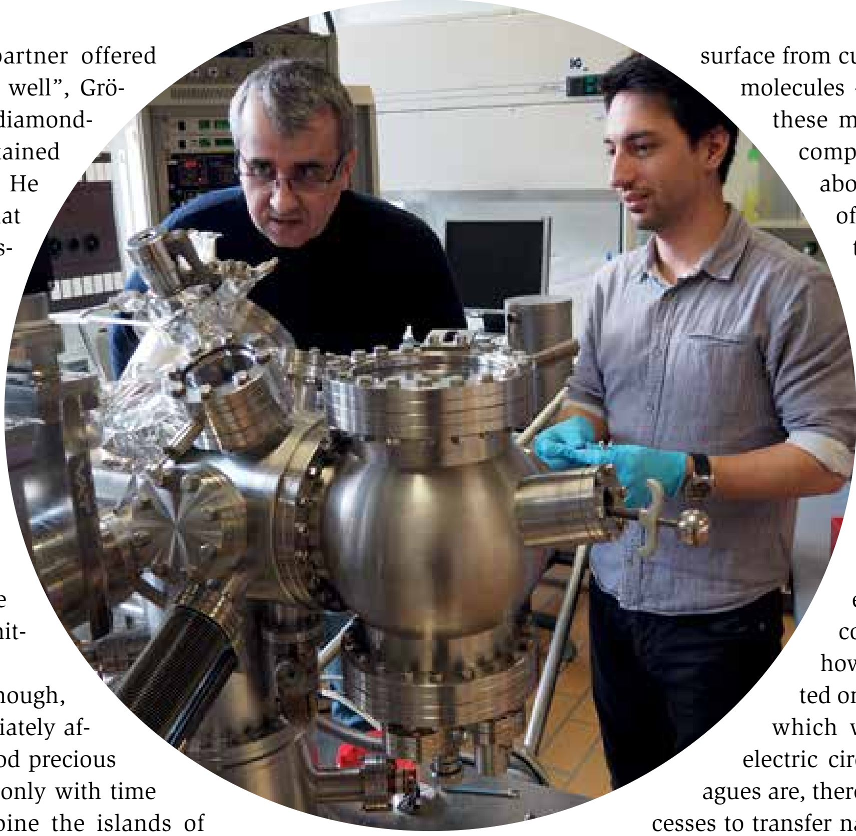
He is interested in fundamental questions. No more – but no less either. Oliver Gröning would like to understand the world around him – recognize "whatever holds the world together in its inmost folds". So the experimental physicist chose just the right job. "Thanks to physics, we can basically understand all the phenomena we encounter in our everyday lives." He points at the table in front of him: "Such as why are the chairs bright orange or my wristwatch shiny." He has always been driven by this curiosity, this desire to know and understand. When it came to choosing a degree, Gröning didn't have to think twice. "I'm not a musical person," he says, describing his talents. "If I ever showed my creative side, it tended to be in mathematics and the natural sciences." His physics degree at the University of Fribourg quickly led him to basic research and into the world of surface science and nanotechnology.

**Research at the limit**

In these fields, researchers work at the limits in terms of size, temperature and purity. "Our machines are comparable to devices on a hospital's intensive care ward. Instead of patients, we examine molecular systems and try to keep them alive under the most extreme conditions for as long as possible," explains Gröning. These extreme conditions – such as very low temperatures and high vacuums – suppress external influences and thus make the world less complex. This makes tracing the observed effects back to fundamental physical theories and models a bit easier.

In order to verify this, the computer calculates simulations that predict certain phenomena. If these can be confirmed experimentally – such as through scanning tunneling electron microscopy – chances are the model is correct. If the experiments produce the "wrong" results, it means revising the model until it works. Gröning: "We have only really understood the phenomena if we modeled the system correctly."

During his dissertation in the late 1990s, he chased a phenomenon, which many scientists suspected might harbor a new physical effect. Back then, everyone was searching for new, unconventional electron sources to replace hot cathodes like those found in light bulbs and electron tubes. One of the materials they had high hopes for as an electron source for novel, high-resolution flat screens was diamond. "The specialist literature raved about how well this emission would work. But my samples told a very different story," recalls Gröning.



When an industrial partner offered him samples that "worked well", Gröning spotted that besides diamond-like carbon they also contained carbon nanotubes (CNTs). He managed to demonstrate that these "impurities" were responsible for the electron emissions – a major breakthrough even before he had completed his thesis. As a consequence, the industrial partner subsequently abandoned his search for novel electron emitters. And Gröning gradually blossomed into one of the leading experts on the characterization of field emitters and CNTs.

Albeit not overnight, though, as he freely admits. Immediately after his degree, he understood precious little about physics. It was only with time that he was able to combine the islands of knowledge and see the big picture, which he also enjoys trying to communicate. Gröning often gives talks at universities of applied sciences or to the general public. He is well versed in explaining complex physical contexts patiently – but still isn't immune to self-doubt. "Sometimes I think: 'You've explained that now quite well.' But then I see nothing but great, big question marks in the eyes of the audience." Soon he'll have the chance to "practice" again; his next public appearance – the first since his nomination as a Distinguished Senior Researcher – takes place on May 9 on a Science Day as part of the 200-year anniversary celebrations of the Swiss Academy of Sciences (SCNAT). Gröning will be answering the question "Nanomaterials: Technical Revolution or Marketing Hype?" at the Cantonal School Schaffhausen (http://www.ngsh.ch > 200 Years SCNAT).

When his PhD supervisor, Louis Schlapbach, offered him a position after his dissertation, he stayed on as a postdoc. And so, when Schlapbach was appointed as the new Empa CEO in 2001, the development of the (then) new Empa laboratory nanotech@surfaces followed on seamlessly. "There was a time in my life when I had problems with the fact that my career path was running so linearly, without any breaks whatsoever." Meanwhile, however, he has come to accept this as "part of his biography".

**His goal: molecular electronics of the future**

Gröning's current projects are geared towards turning molecular electronics – hence, the ultimate miniaturization – into reality. "As important as it is to simplify things, you mustn't lose the relation to technologically relevant problems," says Gröning. Be it in collaboration with industrial partners, be it in the basic research he conducts. "We can't say whether the structures we produce and study in the lab will form the basis of new electronic components one day," he concedes. But as the carbon nanostructures his team produces can't get any smaller, one thing is also clear for him: "If it doesn't work with these structures, it will be very difficult to find alternatives."

In the last few years, Gröning played an instrumental role in "growing" the first ever CNTs with identical 3D structure on a metal surface from customized organic precursor molecules – the prerequisite for using these materials in electronic nanocomponents. The exciting thing about it all: the atomic structure of the CNT – and thus its electronic properties – are determined exclusively by the precursor molecules. The project was featured on the front cover of Nature and made quite a splash in expert circles.

For carbon nanostructures to cut the mustard as electronic switches (diodes), transistors or even merely as nanowires to connect the tiny components, however, they mustn't be located on a conductive metal surface, which would simply shortcut the electric circuit. Gröning and his colleagues are, therefore, on the lookout for processes to transfer nanotubes to non-conductive surfaces – or even cultivate them on an insulator.

One promising candidate is boron nitride. "We assumed that the material would behave very much like a Teflon coating in frying pans, that is to say: no interactions whatsoever between the carbon nanostructures and the surface should come about that could potentially disturb the conductive or insulating functions of our components."

The comparison with the Teflon pan is not far-fetched – as a passionate hobby cook, he is no stranger to kitchen utensils. "No wonder, really, with an Italian mother," he laughs. His pea soup and tomato sauce are certainly not to be sneezed at. "Anyone who simply tips tinned tomatoes into the pan and thinks they make a good sauce hasn't got a clue," he chuckles. His recipe is based on caramelized sugar with roasted carrots and celery.

While Gröning has little to worry about in the kitchen, however, the "non-stick" boron nitride coating did not exactly behave as inertly as expected. Certain iodine-containing molecules that are necessary to trigger the growth of the carbon nanostructures behaved strangely on the boron nitride surface: some iodine atoms broke loose from the molecule, just as expected, while others remained stuck. Again Gröning points at the table: "It would be as if only three chairs could ever be moved away, but not the other three." That is simply impossible: the chairs can't know any more about each other than the iodine atoms.

When the researchers took a closer look, they noticed that not all iodine atoms were sitting in the same position in relation to the boron nitride surface: some were sitting in a "trench" between several boron and nitrogen atoms while others were somewhat higher, directly above a boron atom. Depending on the reaction energy at one place or another, an iodine atom can break away – or not. Therefore, interactions most likely do take place. The model of the boron nitride layer that they initially proposed was simply wrong. In other words, the assumed Teflon layer did not exist. Gröning's conclusion: "Boron nitride can be ruled out as an insulating "breeding ground" for nanocomponents."

**Relaxing on the bike**

Although the job takes a lot out of Gröning, he can switch off easily. On the train trip home from Dübendorf to Gerlafingen in the canton of Solothurn, he also keeps himself busy with the "non-physical", e.g. economic theories. Here, too, he is fascinated by the question of simplicity in complexity. "I have often asked myself while reading articles about economics: would I discover the same thing, even though I'm not an expert?" Once he is at home, he likes to jump on his bike. "The mind focuses on a monotonous activity. For me, that's pure relaxation." He loves nothing better than to ride through the Jura Valley and over the Grenchenberg with his bike club, which is more fun than pedaling alone.

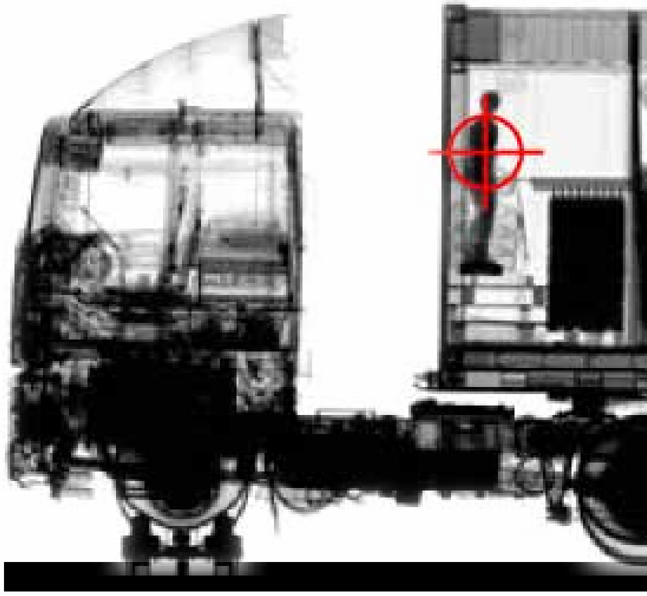
The interview finally draws to a close. Gröning still has something to finish off before he goes on vacation: biking around Tuscany. "I can make up the calories I burn eating all the great food!" //

"Thanks to physics, we can basically understand all the phenomena we encounter in our everyday lives."

*Video*
Promotion Lecture: Materials Science at the Atomic Limit: Status; Prospects and Challenges

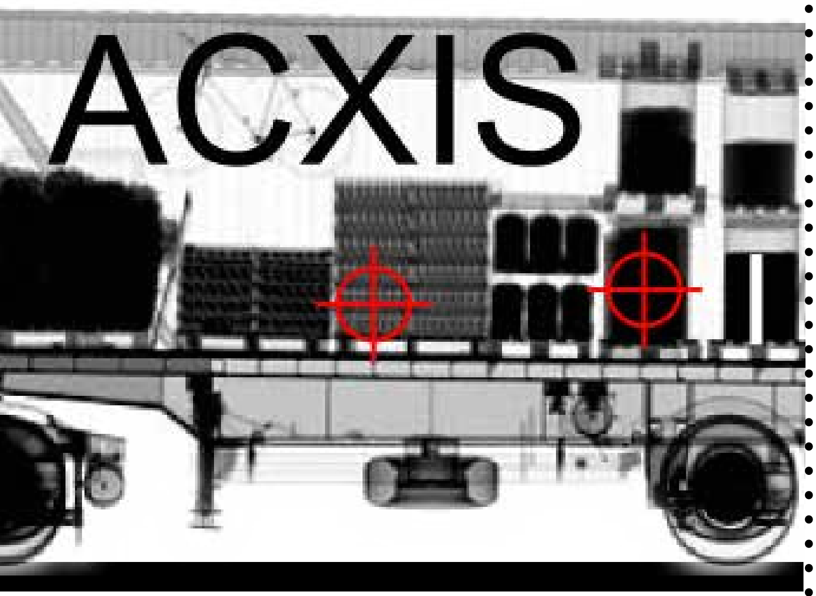
*https://youtu.be/Tx3nOj3TUBM*

# Smugglers in the



Typical contraband in the Empa lab: Thomas Lüthi conceals drugs, weapons and cigarettes behind water canisters. The characteristic x-ray signal of the goods concealed enters a database and should make automatic recognition possible.

# crosshairs




TEXT: Letizia Krummenacher / PICTURES: Empa, ACXIS

As part of the European research project "ACXIS", Empa researchers are developing new X-ray techniques to X-ray shipping and truck containers thoroughly. Many customs authorities have been working with mobile and stationary container scanners for a number of years. Despite the new technology, however, only a fraction of all cargoes can be inspected. Evaluating the X-ray images is simply too much work.

Consequently, Alexander Flisch and Thomas Lüthi from Empa's Center for X-Ray Analytics have teamed up with other partners – a scanner manufacturer and various customs authorities – to develop a sophisti-cated computer system that recognizes "suspicious" patterns of illegal goods on an X-ray scan. The system identifies smuggled goods before alerting the customs officers. By the same token, the system lets through cargo that has been classified as harmless unimpeded. The first prototype of the automated container scanner is expected to be ready for use in around two years' time. //

# *...In demand*

## "Science stories thrive on specific examples. I get these at Empa."

INTERVIEW: Letizia Krummenacher / PICTURE: Empa

Freelance journalist Diana Hornung regularly attends events at the Empa Academy. She keeps her readers abreast of the latest research with reports on renewable energies, nanotechnology, work safety and sustainable resource use.

**Ms. Hornung, you seem to be a real fan of the events at Empa. Why do you attend on a regular basis?**
II find out what's currently being researched and which tasks science faces. Moreover, the events offer a good platform to swap ideas directly with experts from Empa, various universities and industry.

**What do you take back to your everyday working life?**
If something new was discovered that helps the environment, I'd like to report on it. As a journalist, my goal is to communicate new findings to my readers. The specific examples I get at Empa come in very handy in this respect.

**Of all your visits, is there one event that stands out?**
The ground-breaking ceremony for "NEST" last August was a special experience because Empa was laying the foundation for such a pioneering project. Eawag Director Janet Hering, whom I knew from her time as a postdoc, was also present. I'll keep an eye on the research conducted at "NEST" as I find it really interesting how you can reduce the consumption of energy and resources in the building sector.

**What kind of event are you missing?**
I'd love to hear how new findings are transferred from the lab into practice. Representatives from science and industry should explain exactly what happens from the kernel of an idea to the finished product and what needs to be taken into account. This includes questions like: what do companies need from science? What can a research institute do that companies can't do by themselves?

**To whom would you recommend events at Empa?**
Attending an event is worth it for anyone who is interested in science and technology and wants to network with the right people.

In Zusammenarbeit mit der KTI

Förderprogramm Energie
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
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future energy efficient buildings & districts

EMPA AKADEMIE
Zentrum für Wissenstransfer

1. FACHKONGRESS

# Energie + Bauen

Olma Messen, St.Gallen
**Freitag, 22. Mai 2015, 8.30 –18.00 Uhr**

Online-Anmeldung unter www.empa.ch/eub

Energie-Tage St.Gallen
21.–22. Mai 2015

Die Energie-Tage sind eine Wissens- und Community-Plattform rund um die Energiewende.

Weitere Informationen auf:
www.energie-tage.ch

**4. Internationaler Geothermie-Kongress**
Donnerstag, 21. Mai 2015
www.geothermie-bodensee.ch
GEOTHERMIE BODENSEE

**3. Nationaler Energie-konzept-Kongress**
Donnerstag, 21. Mai 2015
www.energiekonzeptkongress.ch
energieagentur st.gallen

**1. Fachkongress Energie + Bauen**
Freitag, 22. Mai 2015
www.empa.ch/eub
EMPA AKADEMIE Zentrum für Wissenstransfer
future energy efficient buildings & districts

**6. St.Galler Forum für Management Erneuerbarer Energien**
Donnerstag/Freitag, 21./22. Mai 2015
www.hsg-energieforum.ch
Center for Energy Innovation, Governance and Investment (EGI-HSG)
University of St.Gallen

Die Energie-Tage St.Gallen werden unterstützt von:

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Kanton St.Gallen
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## Events (in German)

**18./19. Mai 2015**
**Advanced sorption technologies and applications**
Zielpublikum: Industrie und Wissenschaft
Empa, Dübendorf

**22. Mai 2015**
**Fachkongress Energie & Bauen**
Zielpublikum: Fachleute aus den Bereichen Energie und Bauen
St. Gallen, Olma Messen

**20. Mai 2015**
**Medtech Day 2015**
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

**09. Juni 2015**
**FSRM-Kurs Elektrochemische Charakterisierung und Korrosion**
Zielpublikum: Industrie und Wirtschaft
Empa, Dübendorf

Details and further events at
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