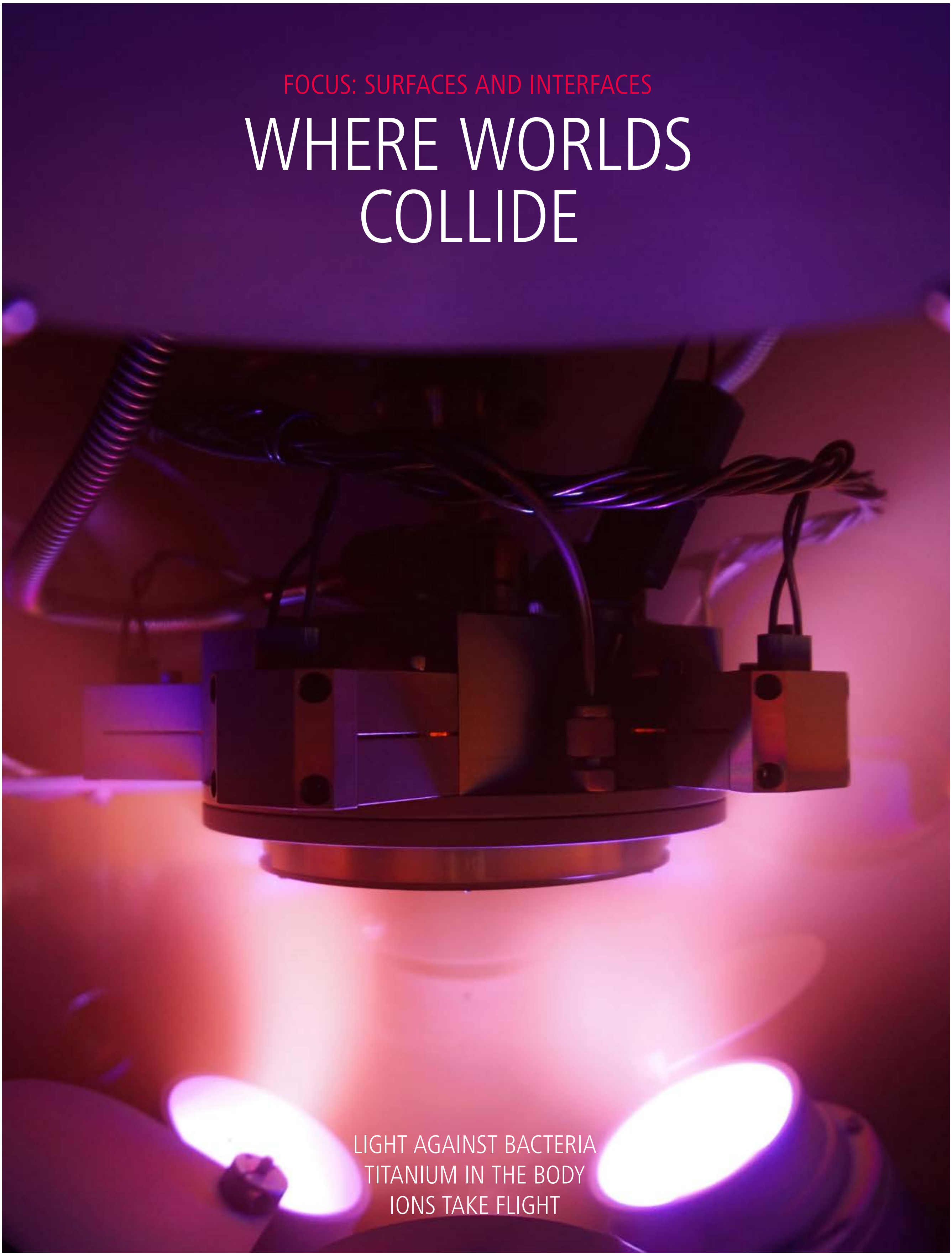
Empa Quarterly

RESEARCH & INNOVATION II #88 II JULY 2025



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Photos: Empa

[COVER]

This mysterious glow is not mood lighting but argon plasma, which is used to produce functional thin films by means of magnetron sputtering. Empa researchers have taken this well-known technology to new heights with clever timing (p. 12).

Photo: Empa

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[IMPRINT]

PUBLISHER Empa
Überlandstrasse 129
8600 Dübendorf, Schweiz
www.empa.ch
EDITORIAL Empa Kommunikation
LAYOUT PAUL AND CAT.
www.paul-and-cat.com
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ISSN 2297-7414
Empa Quarterly (English edition)

TOTALLY SUPERFICIAL

Dear Reader,

What we consider to be a negative character trait has a thoroughly positive connotation for materials scientists. Because, chemically speaking, it's what happens on the surface that counts. Whether it's biological compatibility in implants, antibacterial coatings in hospitals, or catalytic processes in the production of, say, synthetic fuels – surfaces are crucial to all of these.

And it is often the surfaces that are responsible for very specific properties of the material. This is the basis for various high-tech coating technologies that can be used to produce piezoelectric thin films, for instance, which are widely used in microelectronics and are also likely to play a decisive role in future quantum technologies and photonics applications (p. 12).

Sometimes coatings are "only" there for protection. Certain oxide layers are just as important in high-strength steels, where they prevent "hydrogen embrittlement" and thus ensure stability (p. 20), as they are in titanium implants, which are protected from biocorrosion in the very same way. This is because our bodily fluids are a surprisingly aggressive environment, even for materials as robust as titanium (p. 15).

Of course, it is always worthwhile to look beyond the surface and get to the bottom of things. For the current issue, however, we are actually only scratching the surface – because even that holds enough secrets ...

Enjoy reading!
Your MICHAEL HAGMANN

ATOMIC COLORS

These almost psychedelic colors are not the product of an artist's brush, but of a high-tech coating process called atomic layer deposition (ALD). Researchers at Empa's Laboratory for Mechanics of Materials & Nanostructures use the process to manufacture multilayer thin films of ceramics, such as aluminum oxide, and metals, including copper. The oxide layers, just a few nanometers thin, are deposited not only on the sample but also on the walls of the vacuum chamber, which doctoral student Samuel Bojarski photographed for this image. The rainbows you see are created by interference effects: thicker oxide layers appear in different colors in comparison to thinner ones. The multilayer structures result in films which are both stronger and more ductile than their individual components, and could be used for robust electronics, optical applications, or other advanced coating technologies.

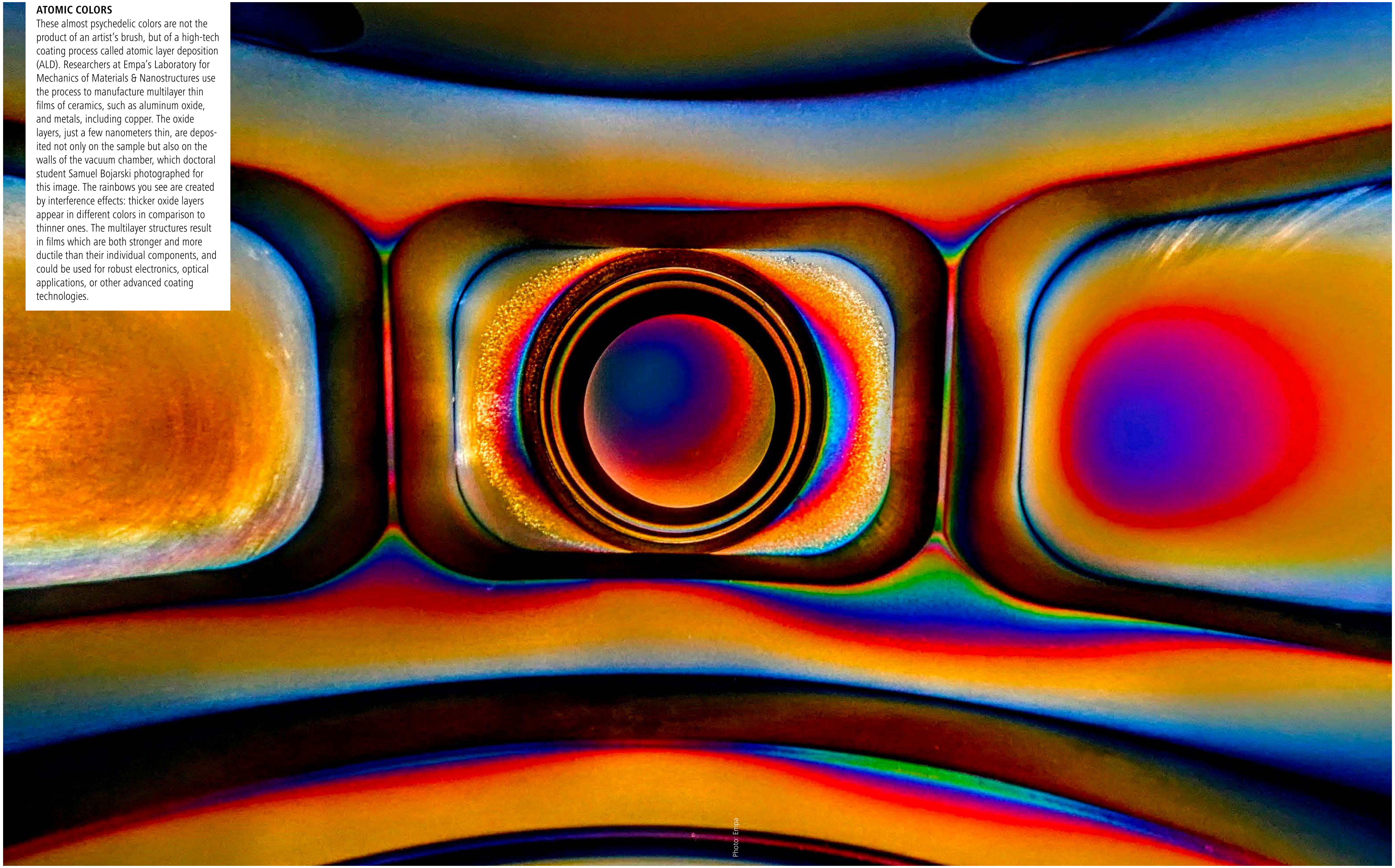


Photo: Empa

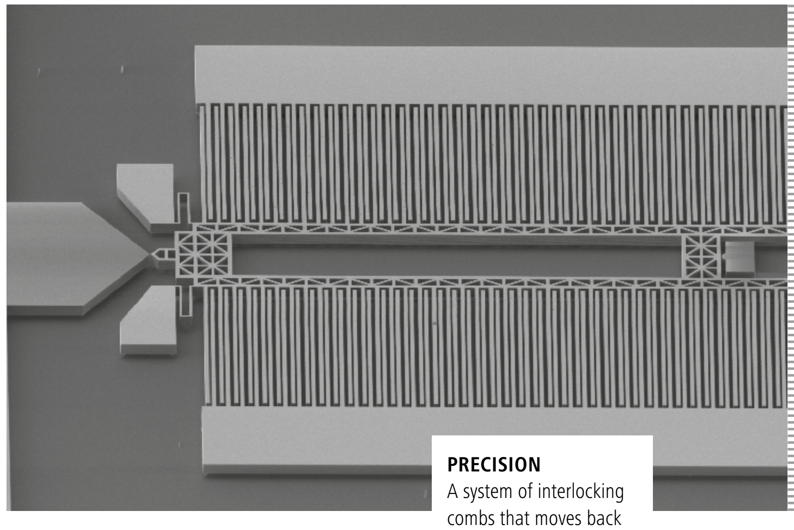
URS LEEMANN NEW DEPUTY DIRECTOR OF EMPA

NEW ROLE
Urs Leemann, new Deputy Director of Empa and Head of the Corporate Services department.

Urs Leemann was appointed Deputy Director of Empa at the beginning of April 2025. The Head of the Corporate Services department succeeds Peter Richner, who is retiring from the directorate. Leemann brings a wealth of experience in research, business, and start-ups and is also involved in the Cleantech Hub Dietikon Limmattal. Together with Director Tanja Zimmermann and Lorenz Herrmann, he will help shape Empa's strategic development.

NANOMATERIALS UNDER TENSION

Researchers at Empa and ETH Zurich have developed an electromechanical system that selectively strains nanomaterials. This makes it possible to produce electronic components with novel properties, which hold promise for quantum computing, communication, sensor technology, and energy conversion. A video of the moving system by Empa researcher Peter Lendway was awarded first place in the SNSF competition for scientific images in the category Videos.



PRECISION
A system of interlocking combs that moves back and forth when electrical voltage is applied.

Photos: Empa

Photos: Empa

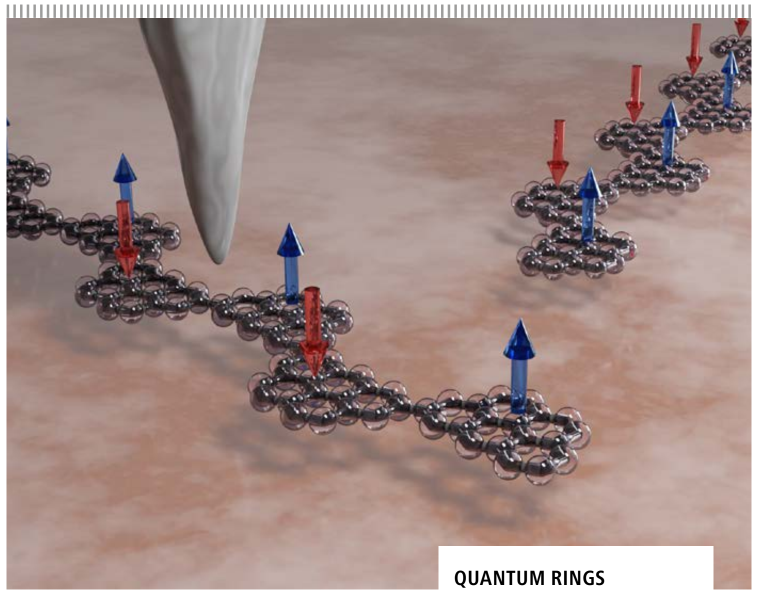
CO_2 AS A RESOURCE: EMPA FELLOWSHIP FOR CARLOTA BOZAL-GINESTA

EXCELLENCE
Carlota Bozal-Ginesta at the experimental facility for CO_2 electrolysis.

Empa researcher Carlota Bozal-Ginesta wants to make CO_2 more efficient to use. Using machine learning and high-throughput experiments, she is developing better electrodes for CO_2 electrolysis, a key technology for the production of synthetic fuels. The aim is to produce as few specific products as possible instead of complex mixtures. She was awarded a two-year Empa Young Scientist Fellowship for her innovative project.

SECOND QUANTUM SPIN MODEL FROM NANOGRAPHENE MOLECULES

For the second time, Empa researchers from the nanotech@surfaces laboratory have experimentally recreated a fundamental theoretical model of quantum physics that goes back to Nobel laureate Werner Heisenberg. The basis for the successful experiment is a kind of "quantum Lego" made of tiny carbon molecules, so-called nanographenes. The second success makes it clear that this method enables versatile experimental research into quantum technologies, which could one day help them break into the mainstream.



QUANTUM RINGS
The nanographene molecule Olympicene, which consists of five carbon rings, was used for the Heisenberg chain.

ENGINEERING THE FUTURE

Photo: Marion Nitsch

RESEARCH AND APPLICATION
Matthias Sulzer heads the Department of Engineering Sciences.

In January 2025, Matthias Sulzer was appointed Head of Empa's Engineering Sciences Department, where he deals with the full range of materials and technologies for the built environment. The engineer is convinced that research and industry mutually benefit each other – a principle that he has lived by throughout his career in both "worlds". The real key to success for him, however, is people.

Text: Anna Ettlin

Organized, neat, tasteful: Matthias Sulzer's office reveals a visual thinker. A hand-drawn poster shows the steps of strategy development: A road winds its way up a mountain, with signposts marking the crucial milestones. "I like to sketch out problems, also as a basis for discussion," says the researcher and engineer. Discussions and meetings are an everyday occurrence in his new role: Sulzer has been head of Empa's Department of Engineering Sciences since January 1, 2025.

His path to this position was just as winding as the metaphorical road on the poster in his office. Sulzer first came into contact with Empa exactly 30 years earlier, while working on his Bachelor's thesis. "It was about the thermal modeling of heat storage systems," he recalls. Research into energy systems would accompany Sulzer throughout his rather atypical career – although for a long time his main focus was not on the academic world.

APPLICATION MEETS RESEARCH

Even as a boy, Sulzer was the hands-on type. His father, also an engineer, instilled in his son a love of mathematics and technology. Sulzer completed an apprenticeship as a ventilation planner and then enrolled at a university of applied sciences to study engineering, encouraged by his vocational trainer. The joy of learning, combined with his entrepreneurial streak, subsequently led him to the University of New South Wales in Australia for a Master's degree in Business Administration (MBA) with a specialization in Energy Economics.

"At the time, Australia was at the forefront of the renewable energy sector and the university was very international," Sulzer recalls. These experiences shaped him when, shortly afterwards, he founded a company with two partners. What began as a traditional ▸

building technology business quickly developed into a pioneering company in the field of energy systems under his leadership. His formula for success: research. At the same time as founding the company, Sulzer was awarded a research contract at the Lucerne School of Engineering and Architecture.

Thanks to this dual role, he was able to bridge the gap in both directions: Innovative solutions and applied research went hand in hand. Novel district heating networks, hydraulic systems for hydroelectric power plants, facilities for the chemical industry – as CEO, Sulzer was happy to take on a wide variety of challenges. Prominent projects followed, including the anergy network at the ETH Hönggerberg campus and the development, planning and construction of the building technology for the high-altitude Monte Rosa hut.

In 2017, his career path took its next turn: Together with his partners, Sulzer took the company public and decided to focus entirely on research – at Empa. He joined Empa's Urban Energy Systems Lab as a senior researcher and took over the management of the cross-institutional Swiss Competence Center for Energy Research: Future Energy Efficient Buildings and Districts (SCCER FEEB&D).

The industry veteran quickly felt at home in the academic environment. "Empa combines excellent research with knowledge transfer to industry," he says – a bridge after his own heart, which beats for both research and engineering.

RESEARCH AND CONSTRUCTION FOR THE CLIMATE

The built environment has an enormous impact on the climate and the planet. "95 percent of all man-made materials used in urban areas flow into the construction sector," says Sulzer. His research department at Empa is tackling climate change in three ways: through the decarbonization of energy systems, closed material cycles and the Mining the Atmosphere research initiative, which aims to reuse and recycle atmospheric carbon as a raw material.

The potential for innovation is accordingly high. Sulzer finds it particularly interesting that his department covers the entire range of Empa's vision: materials and technologies for a sustainable future. Research at the department goes beyond the development of sustainable building materials and technologies.

"We are also researching innovative solutions in robotics, experimental continuum mechanics and mechanical engineering, with applications in various fields. In the Laboratory for Sustainable Robotics, for example, we are developing drones for autonomous repairs to infrastructure and environmental monitoring. Experimental continuum mechanics provides fundamental findings for the development and use of new materials with improved properties, for example in medical technology. The Mechanical Systems Engineering laboratory focuses on the optimization of metallic materials, plastics and composites for a wide range of applications," explains Sulzer. "And we do this on very different scales, from molecules and chemical interactions to national and international analyses of infrastructures and entire energy systems."

1 + 1 = 3

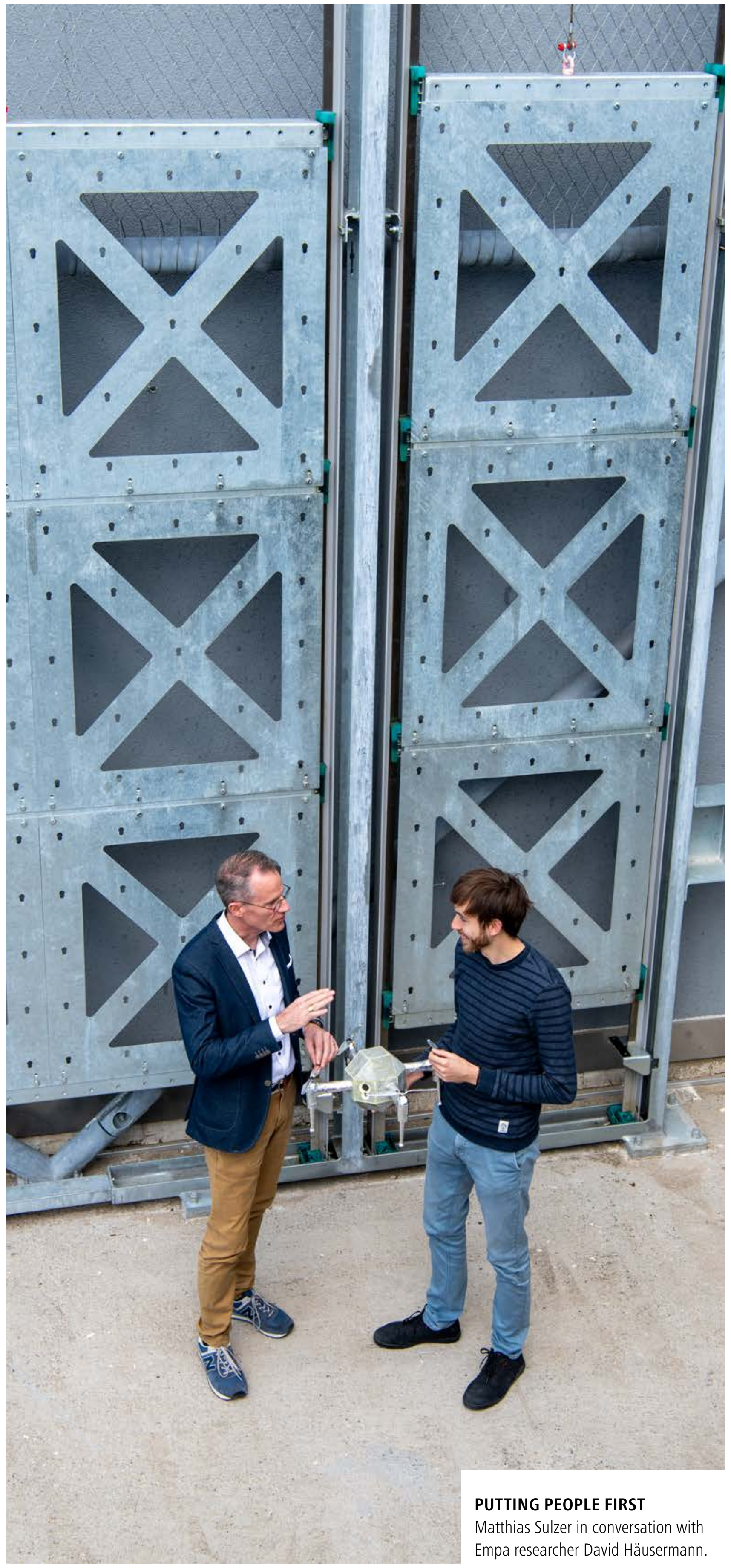
To prepare his department, Empa, and the Swiss research landscape as a whole for the future, Matthias Sulzer believes one thing is needed above all: people. "Our most important task is to train the next generation of researchers," he says. He sees his role as an enabler of scientific excellence: "I want to create spaces that offer researchers optimal conditions for their work," he says. For him, this also includes interdisciplinary and transdisciplinary collaboration, known as team science. "The traditional academic career path trains researchers to achieve individual excellence," says Sulzer. "That is important and the right thing to do. My aim is to then integrate these excellent researchers into a team in such a way that 1 + 1 doesn't just equal 2, but 3 – a real added value. This is particularly true in interdisciplinary projects, such as the development of biocompatible materials for medical implants, where collaboration between engineers, materials scientists and medtech experts leads to innovative solutions."

MATTHIAS SULZER

CAREER: Matthias Sulzer studied building technology at Lucerne School of Engineering and Architecture, followed by a Master's degree in Business Administration (MBA) with a specialization in Energy Economics at the University of New South Wales in Sydney, Australia. On his return to Switzerland, he and two partners founded a group of companies in the energy and building technology sector, which they successfully took public. He worked part-time at the Lucerne University of Applied Sciences and Arts, where he was involved in various research projects and obtained the title of professor. In 2017, Sulzer joined Empa's Urban Energy System Laboratory as a senior scientist. He has headed Empa's Department of Engineering Sciences since January 2025.

He sees putting together and leading effective teams as the greatest challenge and the common thread running through his own career. For him, leadership is not just a matter of talent: Even more important are the

Photo: Marion Nitsch



PUTTING PEOPLE FIRST
Matthias Sulzer in conversation with Empa researcher David Häusermann.

right skillset and experience, which Sulzer symbolizes as a kind of leadership keyboard that, over time, acquires more and more playable keys.

> "Our most important task is to train the next generation of researchers."

However, the department head does not spend his free time playing the piano, but rather climbing – preferably in the great outdoors – and sailing on the Mediterranean. Since his grown-up children have moved out, the family man also enjoys spending time with his wife. To balance out his demanding job as Head of Department, Sulzer has also reserved a small space for research: at the Lawrence Berkeley National Laboratory in the US, which he visits once a year as a visiting scientist. Here, too, the engineer cannot help but build bridges: "The Energy Technology Area at the Berkeley Lab has a similar focus as the Engineering Sciences department at Empa – this leads to a very fruitful exchange," he says. ■

TIMING IS EVERYTHING

When fractions of a second make all the difference: Empa researchers developed a process for manufacturing advanced thin films in which sophisticated timing enables high-quality functional layers at low process temperatures. The new method has applications in the semiconductor industry as well as in future quantum and photonics technologies.

Text: Anna Ettlin

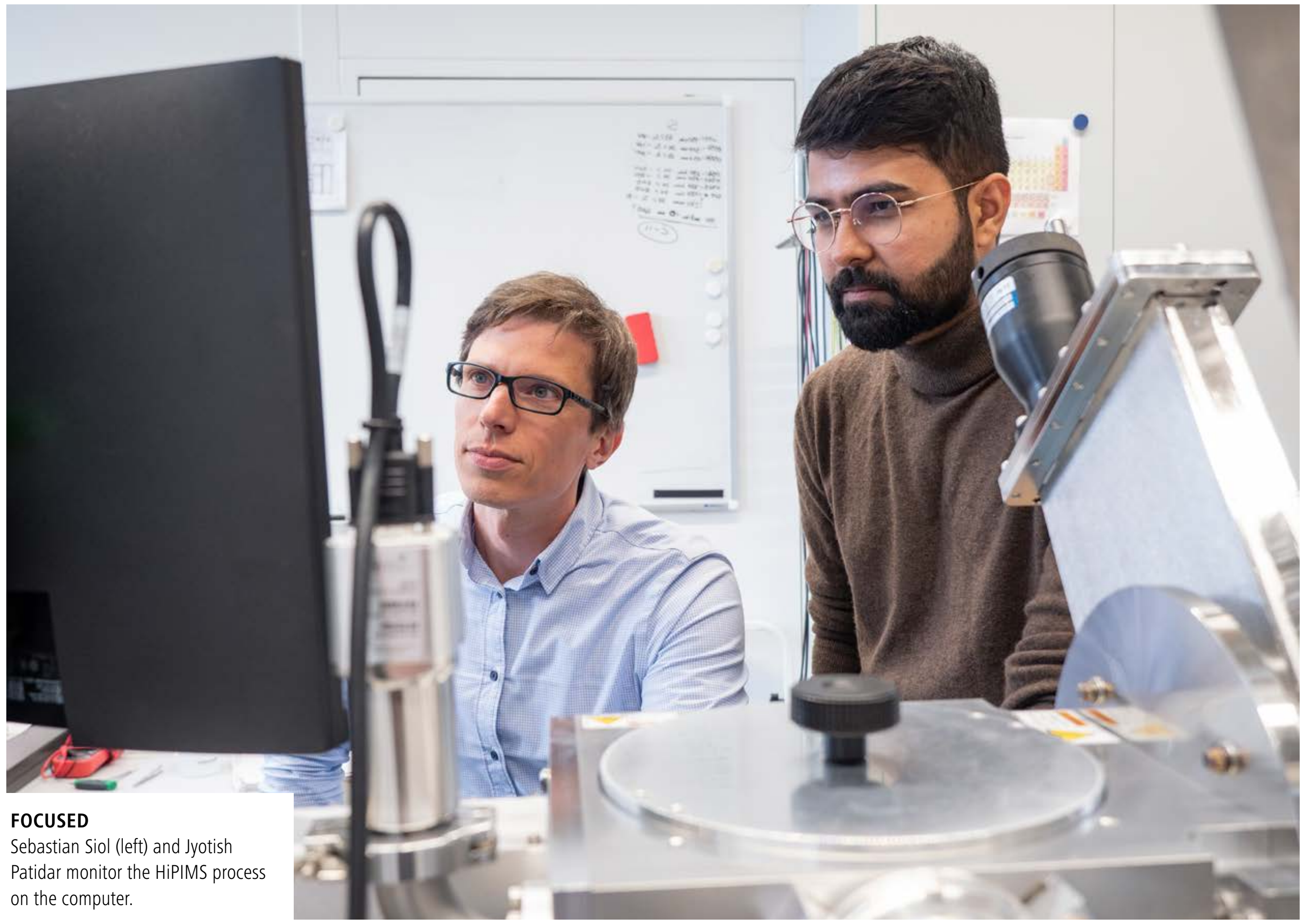
Our everyday lives are so riddled with electronics that we hardly notice them anymore. When we casually reach for our smartphone, we rarely think about how complex this device is. Hundreds of tiny components work together within it – each of them a high-precision masterpiece of engineering. These rarely noticed components include radio frequency (RF) filters. They ensure that a device only receives the correct signals, whether via Wi-Fi or mobile networks. Every device that communicates wirelessly contains such filters. They are often based on piezoelectric thin films. Piezoelectric materials have a special feature: They generate electric charges when they are deformed and change shape in return when an electrical voltage is applied. In addition to RF filters, piezoelectric thin films are used for many other components in microelectronics, whether as sensors, actuators or tiny energy converters. Additional applications, such as quantum technologies, are the subject of ongoing research. However, one thing is clear: For such thin films to do their job, they need to be of a very high quality. Depending on the composition and function of the thin film, this calls for different manufacturing processes.

Empa researchers from the Surface Science & Coating Technologies laboratory have developed a new deposition process for piezoelectric thin films. The novelty: Their method allows the high-tech layers to be produced in very high quality on insulating substrates and at relatively low temperature – a first in the field. The researchers have published their results in the journal Nature Communications and applied for a patent for the process.

NEW STRENGTHS FOR AN OLD PROCESS

The researchers used a common technique called HiPIMS – short for high power impulse magnetron sputtering – as their starting point. Magnetron sputtering is a coating process in which material is deposited from a solid precursor material – the target – onto the component to be coated – the substrate. To achieve this, a process-gas plasma is ignited at the target. The process-gas ions – usually argon – are then shot at the target, knocking out atoms that subsequently land on the substrate to form the desired thin film. Many materials can be used as targets. For piezoelectric applications, metals are commonly used, often with the addition of nitrogen to produce nitrides such as aluminum nitride.

HiPIMS works in almost the same way – except that the process does not take place continuously, but in short, high-energy pulses. This not only means that the ejected target atoms travel faster – many of them are also ionized on their way through the plasma. This makes the process interesting for research. In contrast to neutral atoms, ions can be accelerated, for example by applying a negative voltage to the substrate. Over the past 20 years or so, this approach has been used to produce hard coatings, with the high energies resulting in especially dense and durable layers.



FOCUSED
Sebastian Siol (left) and Jyotish Patidar monitor the HiPIMS process on the computer.

Photo: Empa

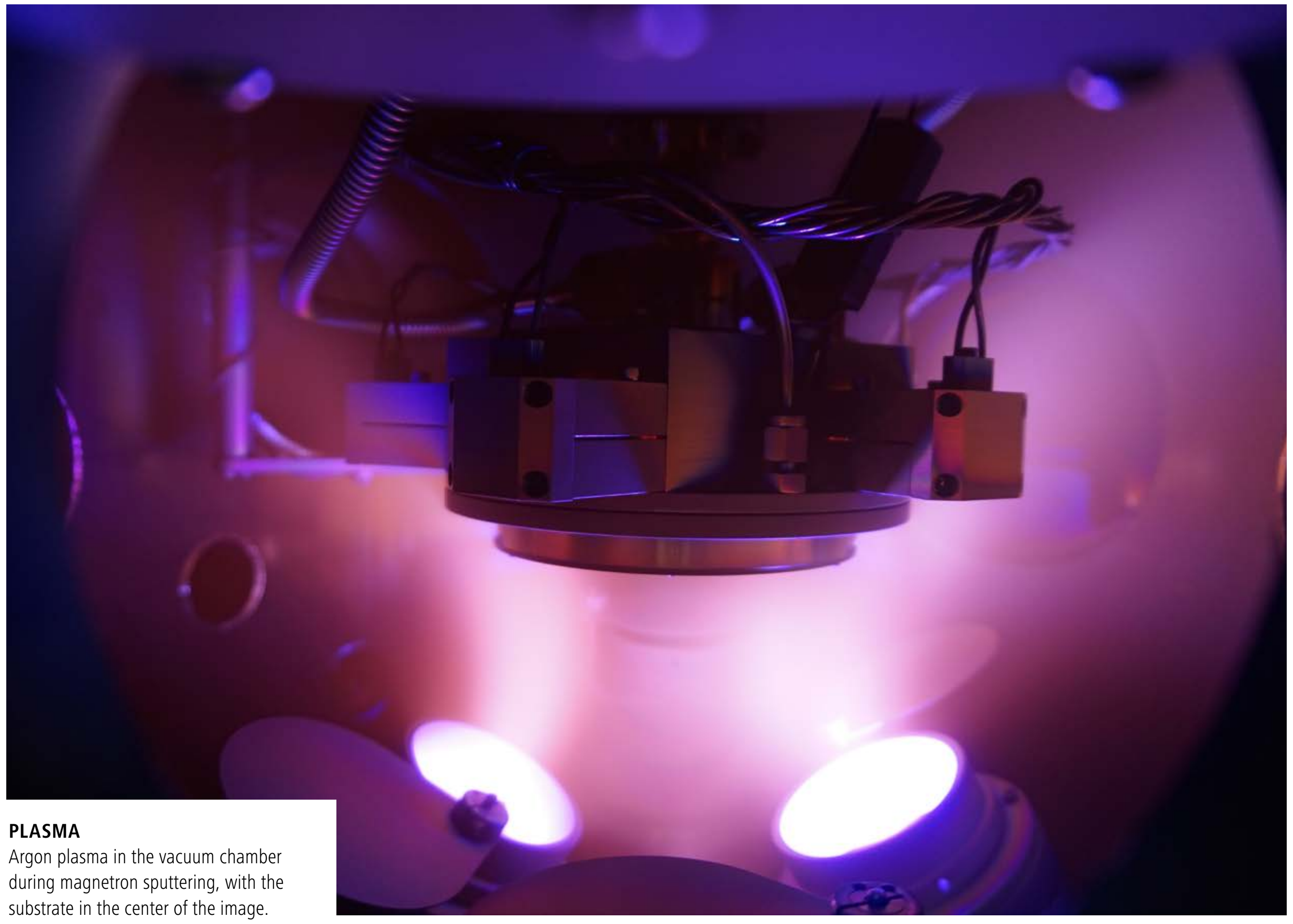


Photo: Empa

PLASMA
Argon plasma in the vacuum chamber during magnetron sputtering, with the substrate in the center of the image.

However, until now, this process was not viable for piezoelectric thin films. This is because applying a voltage to the substrate does not only accelerate the film-forming target ions, but also argon ions from the process gas. This argon bombardment must be avoided. "Several percent of argon can sometimes be incorporated in hard coatings," says Empa researcher Sebastian Siol. "Piezoelectric thin films often operate under high voltages. Here, such impurities could lead to a catastrophic electrical breakdown."

Nevertheless, Siol's team believed in the potential of HiPIMS for piezoelectric thin films. The high energy with which the ions fly towards the substrate is extremely advantageous. If the ion hits the substrate with sufficient energy, it remains mobile for a short time and can find an optimal position in the growing crystal lattice. But what can be done about the undesired argon inclusions?

During his doctoral thesis, Jyotish Patidar developed a clever solution. Not all ions arrive at the target at the same time. The majority of argon ions are located in the plasma in front of the target. This means that they often reach the substrate before the target ions, which first must be knocked out of the target and then have to cross the entire distance to the substrate. Patidar's innovation was in the timing: "If we apply the voltage to the substrate at exactly the right moment, we only accelerate the desired ions," Siol explains. The argon ions have already flown past at this point – and without the additional acceleration, they have too little energy to be incorporated in the growing film.

"ELECTRON SHOWER" AS A FLIGHT CONTROLLER

Using this trick, the researchers were able to produce high-quality piezoelectric thin films with HiPIMS for the first time – with a performance equivalent to or even better compared to conventional methods. Now came the next challenge: Depending on the specific application, thin films need to be produced on insulating substrates, such as glass or sapphire. However, if the substrate is non-conductive, no voltage can be applied to it. Although there is a method in industry to accelerate the ions anyway, this also often leads to argon inclusions in the layer.

This is where the Empa researchers achieved a breakthrough. To accelerate the ions onto the insulating substrate, they use the magnetron pulse itself – the short impulse that shoots the process gas ions onto the target. The plasma in the chamber contains not only ions, but also electrons. Each pulse from the magnetron automatically accelerates these negatively charged elemental particles onto the substrate. The tiny electrons reach the target much faster than the much larger ions.

Normally, this "electron shower" is not relevant for the HiPIMS process. However, when the electrons arrive at the substrate, for a fraction of a second, they give it a negative charge – enough to accelerate the ions. If the researchers trigger a subsequent magnetron pulse at exactly the right time interval, the electron shower accelerates the target ions that started their flight during the previous pulse. And of course, the timing can also be adjusted so that only the right ions end up in the thin film.

FROM CHIPS TO QUBITS

The results are impressive: "With our method, we were able to produce piezoelectric thin films on insulating substrates just as well as on conductive ones," summarizes Siol. The researchers have termed the process Synchronized Floating Potential HiPIMS, or SFP-HiPIMS for short. The big advantage: With SFP-HiPIMS, piezoelectric thin films can be produced in very high quality at low temperatures. This opens up new possibilities for the production of chips and electronic components, which often cannot withstand high temperatures. The technique for insulating substrates is particularly important for the semiconductor industry: "Many production tools in the semiconductor industry are designed in such a way that there is not even a possibility to apply an electrical voltage to the substrate," says Siol.

In the next step, he aims to work on the development of ferroelectric thin films with his team – another key technology in current and future electronics. Based on this success, the Empa researchers are also launching several collaborations with other research institutions to bring their thin films into applications ranging from photonics to quantum technologies. And finally, they want to further optimize the innovative process with the help of machine learning and high-throughput experiments. ■

A HOSTILE ENVIRONMENT

What happens to titanium implants once they are inside the human body? Why are they sometimes rejected or even break? Empa researcher Martina Cihova is exploring these questions at the interface between implants and human tissues and cells, where materials science meets medicine. She was recently awarded an Ambizione Grant from the Swiss National Science Foundation (SNSF) to support her research.

Text: Anna Ettlin

Photo: Empa

FOCUSING ON TITANIUM
Martina Cihova investigates how the body can attack the surface of titanium implants.

Thanks to advances in medicine, people today live longer than ever. Understandably, we also want to remain healthy and mobile well into old age. Implants and prosthetics can replace worn joints and teeth, relieve pain and greatly improve our quality of life. Modern medical implants are small marvels of biomaterials science and bioengineering. Yet, despite their sophistication, implants do occasionally fail, which can have serious consequences for patients.

Why do these failures occur – and why have they been occurring more frequently in recent years? Empa researcher Martina Cihova from the Joining Technology and Corrosion laboratory aims to find out. To do so, she is taking a close look at the behavior of implants inside the body. The scientist has received a four-year Ambizione Grant from the Swiss National Science Foundation for her research project.

Many commonly used implants – including artificial joints, dental implants and pacemakers – are made of titanium. This transition metal is lightweight and strong, highly durable inside the body, and particularly good in allowing bone tissue to attach to it. These favorable properties are due to a thin oxide layer that forms naturally on the surface of titanium when exposed to air. Ultimately, it is not the titanium itself, but this protective surface layer that comes into contact with the body. "As this native passive layer is less than ten nanometers thick, it often receives too little attention in medical technology and research," says Martina Cihova.

In addition, some manufacturers modify the oxide layer, for example, by thickening it to color-code implant types and sizes. Others roughen the surface of the implants to encourage bone integration – or laser-engrave the serial number to ensure traceability. Thanks to laser-based processes, even 3D printing of patient-specific implants is now possible. These are all useful applications, but: "Any treatment can change the titanium oxides on the implant surface," says Cihova, "and there has been far too little research into how these changes affect the interaction of the implant with the body and its corrosion resistance."

RESEARCH ON THE EDGE

With her project, the Empa researcher aims to close this knowledge gap. Her fascination with materials science began during her studies in bioengineering, which inspired her to shift focus and pursue a PhD in metallurgy to dive deeper into the world of materials. Today, she combines both fields of expertise, focusing on where metal, or metal oxides, and biology meet: the interface between implants and the human body.

"Such biointerfaces are incredibly complex, but also extremely fascinating," says the young researcher. "When we think of corrosion, we usually think of salty seawater, humid air, maybe a rusty bicycle – but not the human body." Yet our body can be a surprisingly aggressive environment to materials, especially when immune reactions take place. Immune cells release various substances that can, for instance, lower the pH value and attack the implant. So, what effect does the body's environment have on materials that we consider stable? This is the question at heart of biocorrosion research.

These processes are very complex on both the (electro)chemical and the biological level. In addition, not all titanium oxide is the same. Although its chemical composition, TiO_2, remains the same, titanium oxide can exist in three different crystalline forms or in an amorphous, "undefined" structural state. Each of these forms has different electronic and electrochemical properties, which may also affect how the material interacts with the body.

A STEPWISE APPROACH TO COMPLEXITY

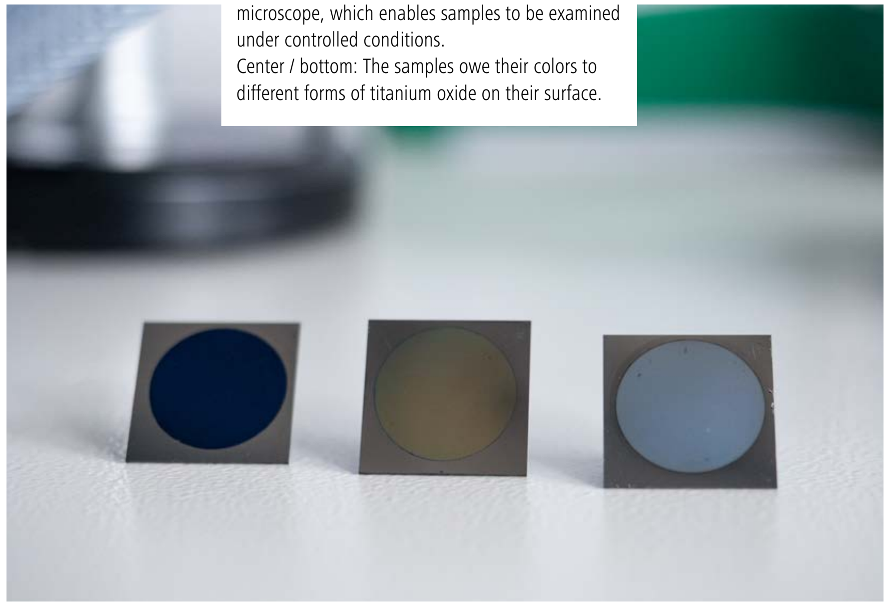
The surface treatment of implants can alter the crystalline structure of these oxides, either across the entire implant or only in selected areas. To understand how this local heterogeneity affects the already complex biointerface, Cihova and her team are taking a systematic step-by-step approach. In collaboration with experts for laser processing of metals at Empa in Thun, they create sample substrates with differently structured titanium oxide layers that vary systematically in their heterogeneity. These substrates are then exposed to increasingly complex body fluids to investigate the fundamental relationships between oxide structure, properties and reactivity.

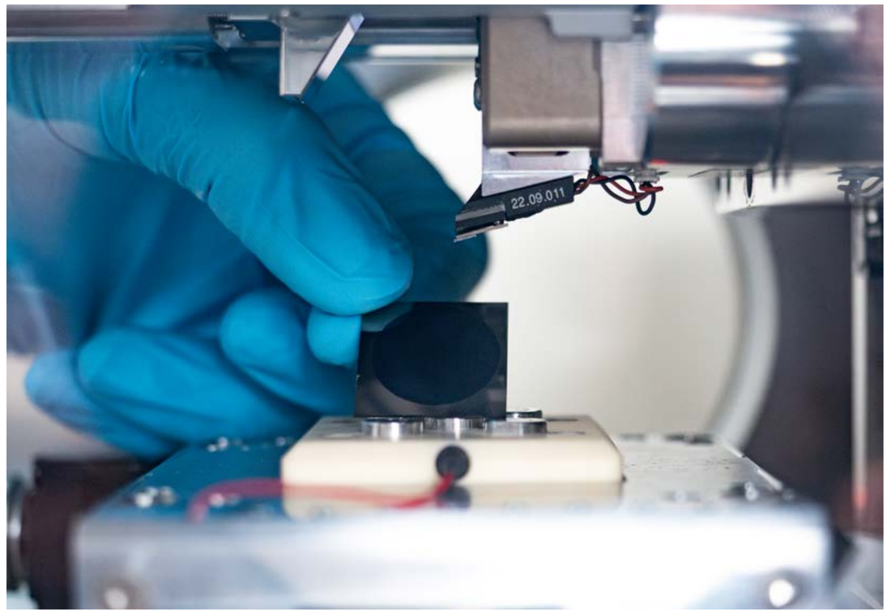
"We start with simulated physiological fluids that contain only water and ions," explains Cihova. The next step involves adding proteins such as fibrinogen, which is involved in immune responses and wound healing. Finally, the researchers plan to investigate how the biointerface behaves in contact with living macrophage cells – the body's police force. For this, they are collaborating with Empa researchers in St. Gallen. "I am very pleased that we were able to get colleagues from all three Empa sites on board for this project," says Cihova. "The complex questions we are addressing are inherently interdisciplinary, and tackling them requires expertise from across multiple fields."

At each stage of the study, the interfaces are thoroughly investigated using electrochemical methods paired with high-resolution electron and atomic force microscopy. "Seeing is understanding – even if that means zooming in to length scales much smaller than a human cell," says Cihova. "That is where crucial details can often be uncovered."

The Empa researcher hopes that the findings from the next few years will lead to safer, more reliable implants. And also "that we learn more about how to effectively harness the remarkable variety of oxide properties for specific biomedical applications." Following her Ambizione project in 2028, she plans to expand the new methods to other medical materials. Cihova is convinced that this field of research will become even more important in the future: "The behavior of metal oxides at biointerfaces is also key to their performance in the emerging fields of nanomedicine and implantable sensor technology." ■

Photos: Empa





OXIDE LAYERS IN THE SPOTLIGHT
Top: Martina Cihova at the scanning electron microscope, which enables samples to be examined under controlled conditions.
Center / bottom: The samples owe their colors to different forms of titanium oxide on their surface.

HIGH PERFORMANCE
Empa researcher Konstantin Egorov coats the stainless steel components with corrosion-resistant titanium oxide.

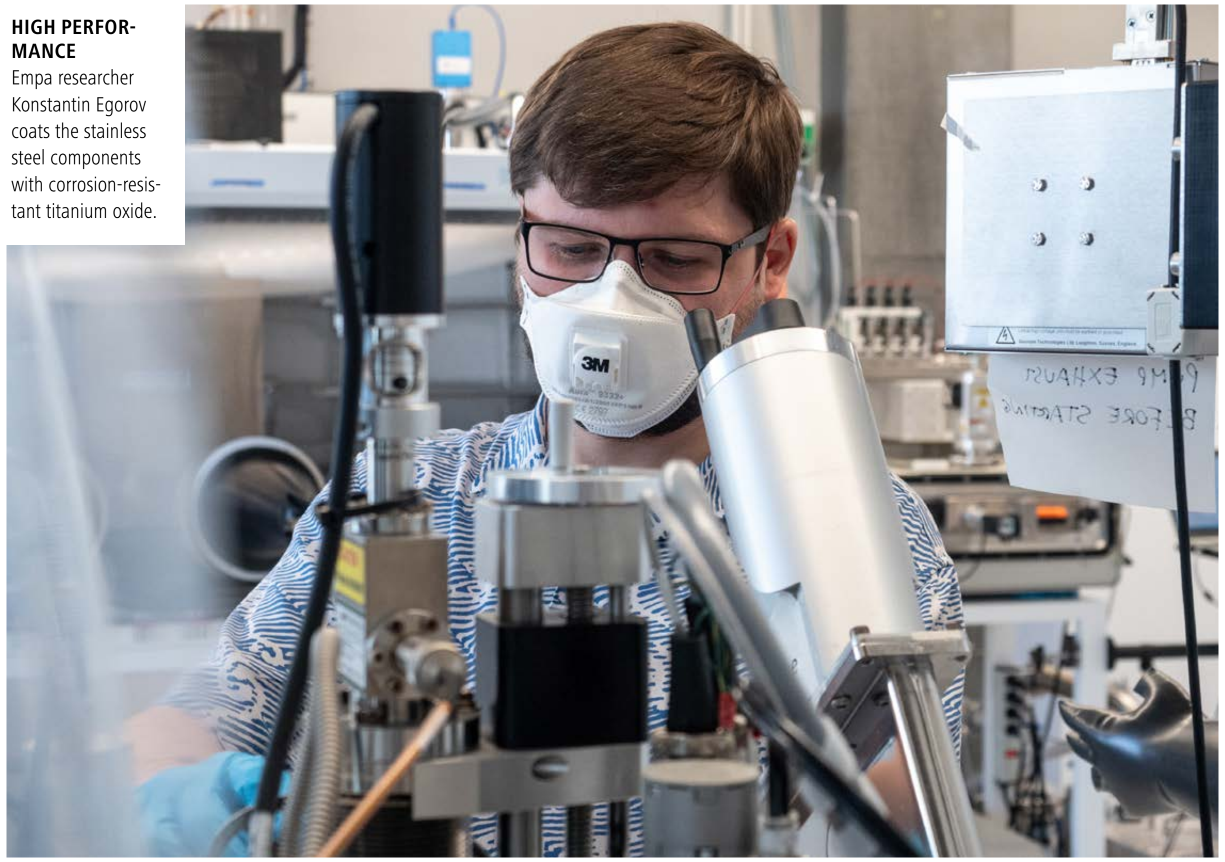


Photo: Empa

AFFORDABLE AT LAST

Green hydrogen – produced from water using renewable energy – is an important sustainable fuel and energy storage medium. However, its industrial production is significantly more expensive than the conventional production of hydrogen from fossil sources. Empa researchers and their partners are developing materials for water electrolysis that are not only efficient and more cost-effective but can also be scaled up to an industrial level.

Text: Anna Ettlin

Hydrogen can partially replace fossil fuels, which makes it a cornerstone of the energy transition. The idea is simple: electricity from renewable sources plus water equals hydrogen and oxygen. If the hydrogen is burned as fuel, it reacts with atmospheric oxygen to form water, and the cycle is complete – without any greenhouse gas emissions.

At least that's the ideal scenario. In reality, the production of "green" hydrogen using electrolysis faces strong competition. Over 90 percent of hydrogen is currently obtained from fossil sources, mainly from natural gas. The main reason for this is that the more sustainable hydrogen from electrolysis is around twice as expensive to produce.

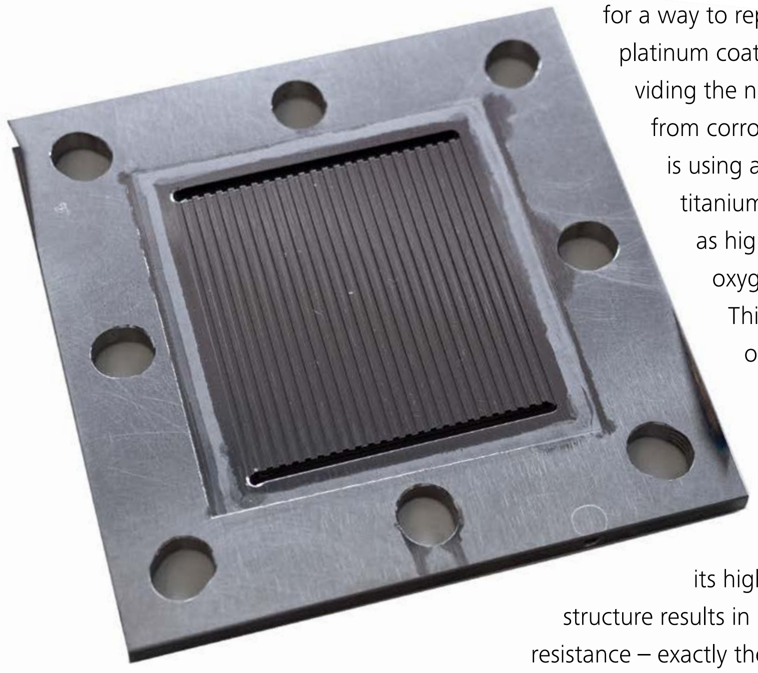
In a project supported by the Swiss National Science Foundation (SNSF) and the French Agence Nationale de la Recherche (ANR), Empa researchers from the Materials for Energy Conversion laboratory want to change this. The materials used in electrolysers are one of the cost drivers in electrolysis. Together with researchers from the French research institutes Institute of Corrosion in Brest and LEMTA in Nancy, Empa researchers are working on more affordable alternatives for two key components of electrolysis devices.

RESISTING CORROSION

The researchers are focusing on proton-exchange membrane water electrolysis, or PEMWE for short. PEMWE electrolysers are efficient and compatible with the energy fluctuations that can be expected from renewable sources. However, the environment inside the electrolyser is corrosive. In the core of the electrolyser, steel simply dissolves "like sugar in a cup of tea", says Empa researcher Konstantin Egorov. And even parts that do not come into contact with the highly acidic core corrode. Even minor quantities of metals dissolved in the ultra-pure water flowing into the device in order to be electrolyzed impair its performance and durability.

> "We want to develop something that the industry can actually use."

Components for transporting water and the resulting gases within the electrolyser are therefore made of titanium, which is both expensive and difficult to process. But even that is not enough: To prevent the titanium from oxidizing and reducing the effectiveness of the device, the components must be coated with the precious metal platinum, which further increases the costs.



DURABLE
The plate shows no trace of corrosion.

Photo: Empa

Material scientist Egorov is looking for a way to replace the costly platinum coating while still providing the necessary protection from corrosion. For this, he is using a special form of titanium oxide known as highly crystalline oxygen-deficient rutile. This oxide is missing oxygen atoms in certain places, which gives the material good conductivity while its highly crystalline structure results in high corrosion resistance – exactly the right prerequisites for PEMWE electrolysis.

The researchers are also replacing the titanium carrier material with steel. "Besides being more cost-effective, steel components are much easier to manufacture, which allows engineers to create more advanced designs that enhance cell performance", explains Egorov. Thanks to the robust coating, the corrosive environment should no longer be able to harm the material.

THINKING OF INDUSTRIAL PRODUCTION RIGHT FROM THE START

The first results show the high corrosion resistance of the innovative coating. "We were able to develop a method to coat the first component of the PEMWE electrolyser, the so-called bipolar plate, successfully with titanium oxide," says Egorov. The method the Empa scientist is using is called physical vapor deposition (PVD) and is widely used in industry. "It is important for us to develop something that industry can actually use," emphasizes the researcher.

The components that Egorov manufactures at Empa are subjected to thorough corrosion tests by his partners, first under lab conditions and then in a functioning electrolyser. The bipolar plate has already successfully passed the tests. Next, the researchers want to coat another key component with titanium oxide, the so-called porous transport layer.

"Coating porous materials poses many challenges," says Egorov. The pores must be coated evenly so that the underlying material does not corrode – but at the same time they must not become blocked. The coating expert is confident that this can be achieved. The project will run until 2026, after which the Empa researchers hope to bring in industrial partners to develop the innovative technology towards commercialization. ■

WHEN THE STRONGEST STEEL SUCCUMBS

Hydrogen damages steels. High-strength steels, particularly those used to construct bridges, high-rise buildings, and oil and gas infrastructure, are susceptible to embrittlement caused by atomic hydrogen coming from the environment. The complex mechanisms behind this are not yet fully understood. Native oxide films on steel can act as barriers to block hydrogen from entering the steel workpiece. Empa researchers want to investigate the interaction of hydrogen with the thin oxides on steel with unprecedented spatial and temporal resolution.

Text: Anna Ettlin

On the night of September 11, 2024, an approximately 100-meter-long section of the Carola Bridge in Dresden collapsed into the Elbe River. The culprit: cracks in the bridge's steel tension structure caused by hydrogen. The Carola Bridge is by no means the first building to be affected by hydrogen. Other well-known examples include the London skyscraper 122 Leadenhall Street, popularly known as the Cheesegrater, and the partial replacement of the Bay Bridge in San Francisco. In both cases, failure of steel bolts resulted in renovation costs running into millions.

The process is known as hydrogen embrittlement. Certain corrosion processes in the presence of water release atomic hydrogen – the smallest element in the periodic table – at the surface of steel components. Owing to its small size, hydrogen easily diffuses into the steel, promoting crack formation and propagation.

The fact that hydrogen attacks metals has been known since the 19th century. However, the complex mechanisms behind hydrogen embrittlement are still not fully understood – despite a plethora of studies. Empa researchers from the Joining Technology and Corrosion Laboratory are now investigating an aspect of hydrogen embrittlement that has received very little attention to date: the interaction of hydrogen with the so-called native oxide layer on steel.

PROTECTIVE ATMOSPHERE
Chiara Menegus works in a glovebox to eliminate environmental influences.

Photo: Empa

The native oxide layer, also known as the passivation layer, is a thin layer that forms naturally on the surface of the majority of metals and alloys. It is what gives stainless steels their corrosion resistance. The type and composition of this layer, which is only a few nanometers thick, differs from steel to steel. Some oxides are significantly more stable and resistant to hydrogen than others, thus shielding the steel from embrittlement. This is what Empa researchers Chiara Menegus and Claudia Cancellieri set out to investigate. They are focusing specifically on the interface between the metal and its oxide layer. "Hydrogen accumulates in regions where the material is disordered," explains doctoral student Menegus. "The metal-oxide interface is one such area."

ALL EYES ON THE INTERFACE

Studying hydrogen in steel is challenging. The light element cannot be directly tracked using most conventional analysis methods. And the experiments must take place in the absence of all other environmental factors such as oxygen and moisture – otherwise, complex interactions arise that can mask the influence of hydrogen. The final challenge is the interface itself: "It is difficult to examine a buried interface inside the material without destroying the sample," says Claudia Cancellieri, research group leader in the Joining Technologies and Corrosion Laboratory.

HAXPES

HAXPES, short for hard X-ray photoelectron spectroscopy, is an analysis method based on the photoelectric effect, for the discovery of which Albert Einstein was awarded the Nobel Prize in Physics in 1921. Electrons are "kicked out" of the material using X-rays, allowing conclusions to be drawn about the chemical nature of the sample. While conventional X-ray photoelectron spectroscopy is limited to the surface of the material, the "hard" version – HAXPES – probes much deeper into the sample thanks to high-energy X-rays and allows precise characterization of multi-layered structures and buried interfaces. HAXPES has applications in the development of microelectronic devices, solid-state batteries, and functional thin films as well as in catalysis and corrosion research. The only facility in Switzerland is located in Empa's Joining Technologies and Corrosion Laboratory in Dübendorf.

The researchers master these challenges with an innovative experimental setup. In the first year of her doctorate, Chiara Menegus developed an electrochemical cell in which the steel sample is mounted. Water is placed on one side of the sample and the inert noble gas argon on the other. By applying an electrical voltage, atomic hydrogen is generated from the water. The hydrogen diffuses through the thin sample until it reaches the oxide layer on the opposite side, where it interacts with the native oxide. "This allows us to isolate the interaction of atomic hydrogen with the native oxide from the uncontrolled environment," explains Menegus. All steps – from assembling the cell to analyzing the sample – take place in a protective atmosphere, inside a glovebox.

A SHIELD OR A PATHWAY?

To characterize the samples, the researchers use an analysis technique that is unique in Switzerland: hard X-ray photoelectron spectroscopy (HAXPES, see info box). This spectroscopy method uses high-energy X-rays to determine the type and chemical state of atoms in a material; not just on the top surface, but up to 20 nanometers deep – enough to detect the oxide layer, which is around five nanometers thick, and the interface with the steel underneath.

Although hydrogen itself cannot be directly detected with this method, the researchers have already been able to clearly demonstrate its effects on the oxide layer. "The first tests show that the hydrogen degrades the protective oxide layer," says Menegus. She now wants to investigate oxides on different iron-chromium alloys as well as some common steels. Later on, the researchers will collaborate with the Ion Beam Physics Lab at ETH Zurich to directly determine the hydrogen content in the samples in real time, using a complex particle accelerator method. "We hope to better understand the effect of hydrogen on the native oxide layers and find particularly resistant oxide forms," summarize Menegus and Cancellieri. Their findings could lead to the construction of more durable bridges – as well as to better infrastructure for the storage and transportation of green hydrogen. ■

LIGHT ON – BACTERIA DEAD

Just switch on the light: disinfecting surfaces could be as simple as that. To turn this idea into a weapon against antibiotic-resistant germs, Empa researchers are developing a coating whose germicidal effect can be activated by infrared light. The plastic coating is also skin-friendly and environmentally friendly. A first application is currently being implemented for dentistry.

Text: Andrea Six

Antibiotic-resistant bacteria and emerging viruses are a rapidly increasing threat to the global healthcare system. Around 5 million deaths each year are linked to antibiotic-resistant germs, and more than 20 million people died during the COVID-19 virus pandemic. Empa researchers are therefore working on new, urgently needed strategies to combat such pathogens. One of the goals is to prevent the spread of resistant pathogens and novel viruses with smart materials and technologies.

Surfaces that come into constant contact with infectious agents, such as door handles in hospitals or equipment and infrastructure in operating theaters, are a particularly suitable area of application for such materials. An interdisciplinary team from three Empa laboratories, together with the Czech Palacký University in Olomouc, has now developed an environmentally friendly and biocompatible metal-free surface coating that reliably kills germs. The highlight: The effect can be reactivated again and again by exposing it to light.

"The new material is designed to kill microorganisms locally and quickly," explains Giacomo Reina from Empa's Nanomaterials in Health Laboratory in St. Gallen. A basic matrix of polyvinyl alcohol, a biocompatible plastic that is also used in the food industry, was used for this purpose. Embedded in this matrix is specially synthesized graphenic acid, which is ideally suited as an antimicrobial coating due to its chemical properties. Its full potential can be exploited by using near-infrared light. As soon as the composite material is irradiated, it unfolds its dual strategy: Firstly, it absorbs the energy of the infrared light and converts it into germicidal heat. It also stimulates the formation of oxygen radicals, which cause additional damage to the pathogens.

Another advantage here is that this strategy is completely different from the mode of action of conventional antibiotics. The material thus offers continuous protection against a broad spectrum of microorganisms without contributing to the development of resistance. "Our laboratory experiments have clearly confirmed the effectiveness of the antimicrobial material against various bacteria and viruses," says the Empa researcher.

APPLICATION FOR DENTISTRY

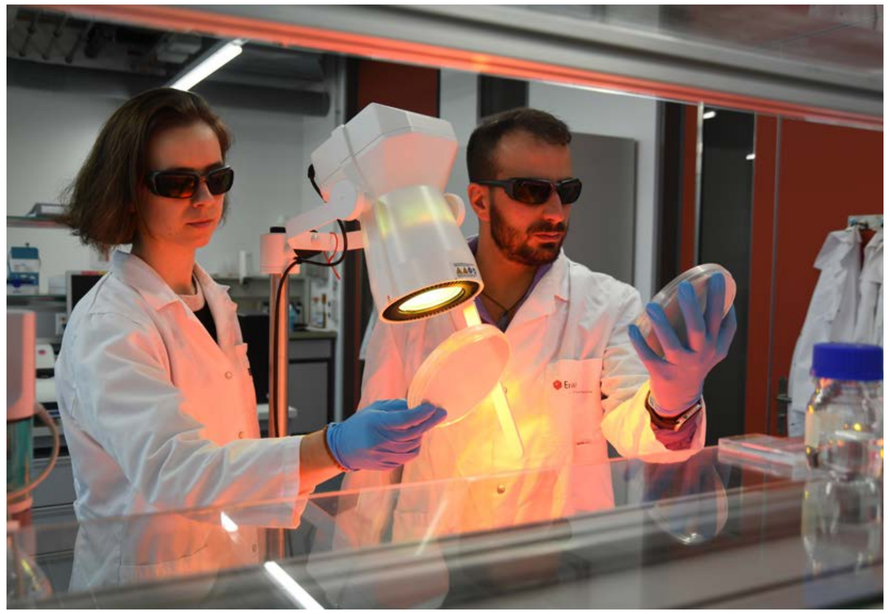
An initial application for the antimicrobial coating is currently being developed for dentistry. To this end, Empa researchers are working together with the Center

MICROBE HUNTERS
Empa researchers Paula Bürgisser and Giacomo Reina from the Nanomaterials in Health laboratory in St. Gallen.

Photo: Empa

ZUKUNFTSFONDS
Empa's Zukunftsfonds is looking for private donations for outstanding research projects and talents that are not (yet) supported elsewhere. If you would also like to make a contribution to the project, you can find our donation form here:

AGAINST ANTIBIOTIC RESISTANCE
Stable and safely embedded in a compatible polymer, graphenic acid is deadly for germs such as *Pophyromonas gingivalis* (center), a pathogen that causes severe periodontitis.



for Dental Medicine at the University of Zurich on a dental splint that kills microorganisms in the oral cavity.

The microbial flora in the mouth is a particularly unpleasant opponent in the fight against infectious agents: Complex communities of bacteria cavort in inaccessible niches, embedded in a self-produced mucous matrix. Antibiotics and disinfectants barely penetrate these resistant biofilms. This allows the germs to ruin teeth unhindered or even lead to extensive infections in the body. The interdisciplinary team led by Giacomo Reina is therefore working on a plastic splint into which nanomaterials such as graphenic acid can be stably integrated. As near-infrared light can penetrate the tissue several centimeters deep, the splint can be placed in the oral cavity and activated from the outside by a light source, over and over again.

The project can be started thanks to generous donations from the Eduard Aeberhardt Foundation and another foundation. Clinic Director Ronald Jung from the Center for Dental Medicine at the University of Zurich appreciates this interdisciplinary approach to materials science and clinical research. "Such new and innovative solutions will offer great added value for patients," says Jung. ■

Photos: Empa, Adobe Stock

WHERE SOUND WAVES GET LOST

Empa researchers have developed innovative sound absorbers made of mineral foams. Not only are they significantly thinner than conventional materials, they can also be designed specifically for different frequencies. They have now been tested for the first time in a driveway in the city of Zurich to dampen street noise.

Text: Manuel Martin

In the fight against noise, every centimeter counts in the construction sector. Traditional sound absorbers are usually made of bulky materials such as rock wool or melamine foam, however. In order to effectively dampen even low sound frequencies, thick layers of insulation materials are required – which costs space, restricts design and is often simply not even feasible in outdoor areas. Together with the company de Cavis, Empa researchers have therefore developed ultra-thin sound absorbers made of mineral gypsum or cement foams. These are just as effective as conventional absorbers, but around four times thinner. Further advantages: The foams can be tuned to specific frequency ranges and are easy to cut and install. Made from plaster or cement, they can be fireproof and recyclable, and do not release any harmful particles. Cement foams are also weatherproof and therefore suitable for outdoor use.

A LABYRINTH FOR SOUND WAVES

According to Empa researcher Bart Van Damme, the high sound absorption despite the low thickness is based on a patented design: "The varying pore structure of the mineral foams forces air particles to take a longer route to get into the material and out again. Despite the low thickness, this creates the impression of a much thicker absorber for the sound waves." The decisive factor here is having the largest possible pores with the thinnest possible pore walls. The researchers from Empa's Acoustics/Noise Control lab use several porous layers for the new type of sound absorber. They not only vary the thickness of the individual layers and the size of the pores but also provide them with tiny holes. While the foams, which have a pore content of over 90 percent, can be produced from plaster or cement using established processes, perforation is currently still done by hand.

The researchers also used a numerical model to simulate how air flows through the pores of the mineral foams at the smallest level. "We can thus simulate and even specifically influence the acoustic behavior of the entire material by varying pore size, perforation and layer structure," says Van Damme.

TAILOR-MADE INSTEAD OF BULKY

Traffic noise is typically in the range between 500 and 1000 hertz. Model calculations show that four coordinated layers of fine-pored mineral foam with a total thickness of around 5.5 centimeters are sufficient as insulation material for this frequency range. An initial prototype with a total area of twelve square meters has already been tested in a driveway together with the city of Zurich. In the preliminary simulation of the driveway, the researchers optimized the arrangement of the individual panels on the walls. Controlled measurements on site confirmed the predictions: The noise level dropped by up to 4 decibels thanks to the 72 panels. The effect was particularly noticeable for passing cars approaching or leaving the driveway, as the sound is reflected several times by the panels on the way into the courtyard.

A comparison with conventional rock wool showed that the new absorbers are more reliable at low frequencies and slightly less efficient at higher frequencies – but still reduce sound transmission in the area of peak absorption. "Even an installation as compact as the one in the driveway significantly reduces noise," concludes Van Damme.

PREDESTINED FOR SPECIAL APPLICATIONS

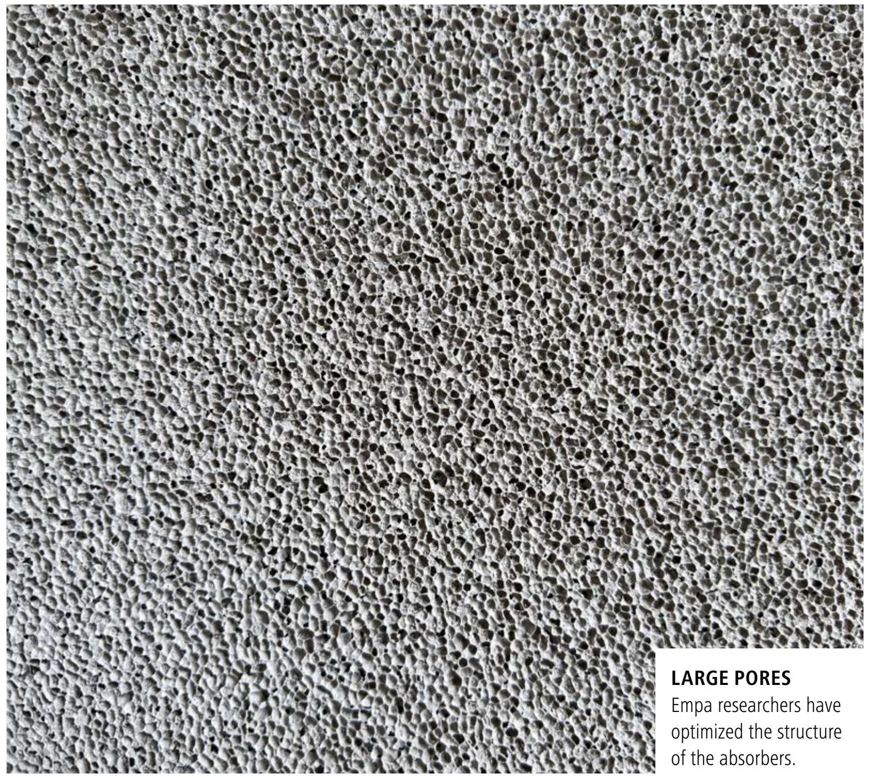
In future, the mineral sound absorbers could be retrofitted in driveways, under balconies or on façades in noisy streets. As with all open-pored absorbers, the prerequisite is protection from the weather and from dirt, for example with a perforated top layer. "Ideally, absorbers are already taken into account in the architectural design of new buildings," explains Van Damme. The elements can also be easily integrated into stairwells or large interior spaces such as offices, canteens or sports halls – also from a design perspective, as the porous mineral foam is made of the same material as the surfaces of the walls.

According to Bart Van Damme, the idea for the absorber originated several years ago. However, the breakthrough only came through the combination of material development and acoustic modeling as part of an Innosuisse project. Thanks to the modeling, the absorber can now be flexibly customized: Should it dampen particularly low tones, such as in large halls? Or should it be more effective in the mid-range, such as in traffic noise, offices or classrooms?

At the moment, production is still complex and partly done by hand. Together with a suitable industrial partner, the material is now to be further developed and produced on a larger scale. The potential is huge – especially for special applications where limited space, fire protection and design requirements have to be taken into account at the same time. ■

INDOORS AND OUT
The sound absorbers were tested in a driveway in Zurich.

Photo: Empa



LARGE PORES
Empa researchers have optimized the structure of the absorbers.

Photo: Empa

IT'S ALL IN THE WALL

In construction, wood is often hailed as a sustainable alternative to concrete. However, there is a gap in the structural analysis of timber frame buildings: walls with window openings are not taken into account for horizontal bracing because of a lack of data on their load-bearing behavior. A project by Empa, Bern University of Applied Sciences, and ETH Zurich, in collaboration with the Swiss Federal Office for the Environment (FOEN) and industry, aims to change this – using mathematical models and large-scale experiments.

Text: Anna Ettlin

The wood creaks and groans as the number on the screen continues to rise. At over 100 kilonewtons of horizontal load, there is a loud bang: One of the beams in the two-story house wall has split under the enormous pressure. Empa researcher Nadja Manser is satisfied: The experiment was a success. Over the next few days, the wooden wall in Empa's construction hall will be dismantled and replaced with a new wall, which will in turn be loaded to failure, monitored by numerous cameras and sensors.

These spectacular experiments mark the final phase of a four-year research project conducted by Empa, Bern University of Applied Sciences and ETH Zurich, supported by the Swiss Federal Office for the Environment (FOEN) as part of the "Aktionsplan Holz", and by several industry partners and associations. The goal: greater efficiency in timber frame construction thanks to improved structural calculations. "We are investigating the horizontal bracing of buildings with timber frame walls that contain window openings," explains Manser.

STRUCTURALLY SOUND AGAINST WIND AND EARTHQUAKES

Buildings must not only withstand vertical loads such as snow and their own weight, but also lateral loads such as wind pushing against the facade or earthquakes. During the planning process, civil engineers must calculate these horizontal loads in order to design sufficiently rigid and load-bearing

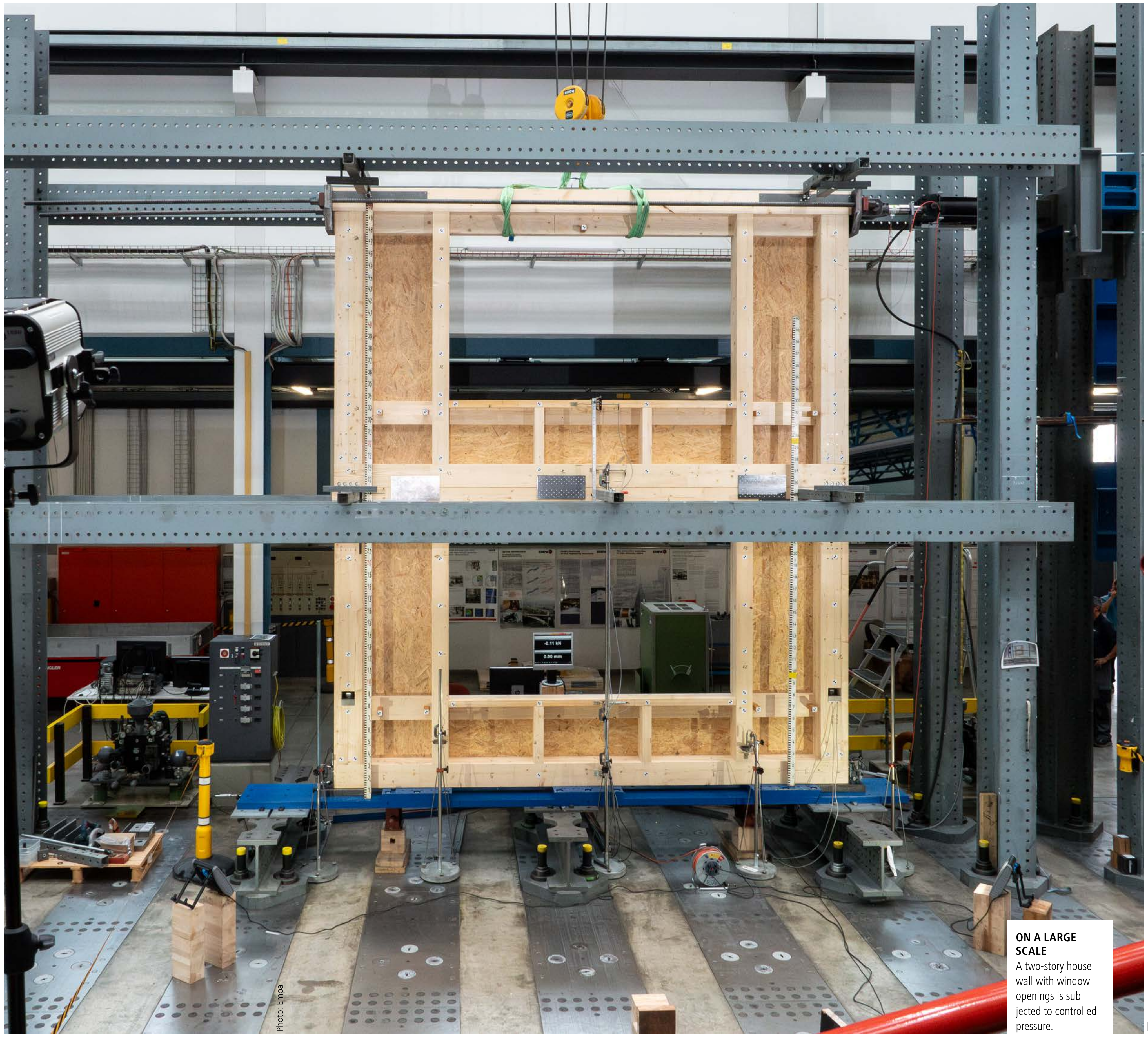
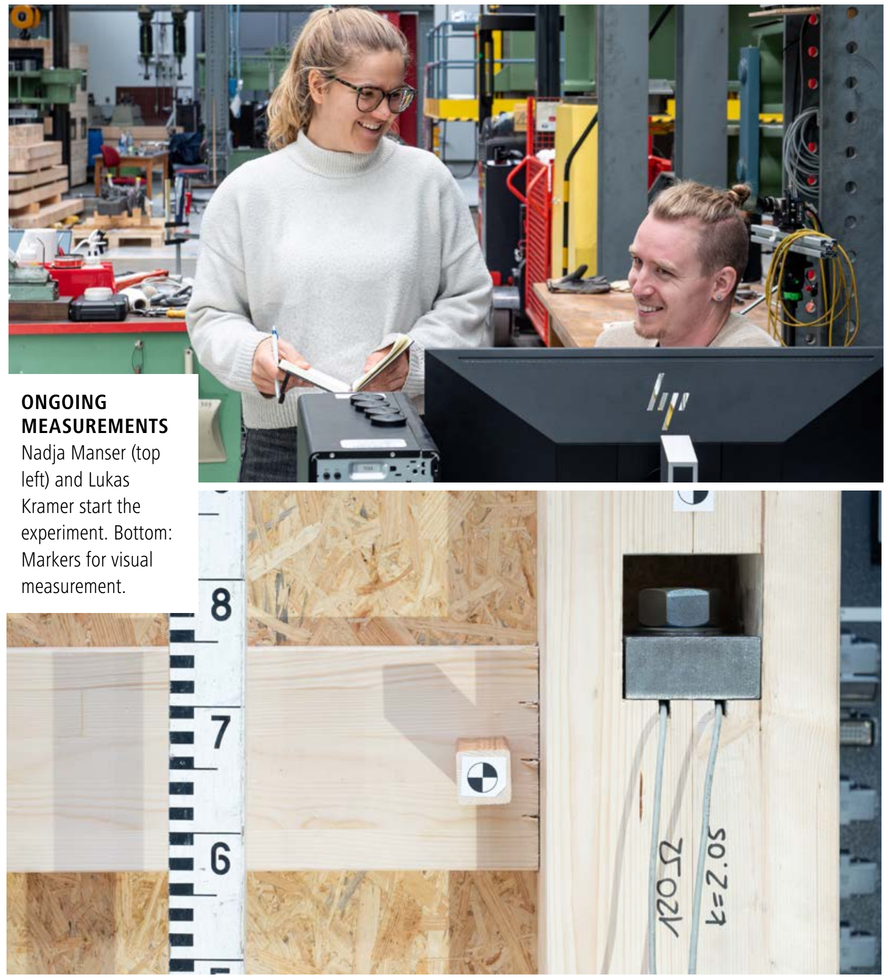


Photo: Empa

ON A LARGE SCALE
A two-story house wall with window openings is subjected to controlled pressure.



ONGOING MEASUREMENTS Nadja Manser (top left) and Lukas Kramer start the experiment. Bottom: Markers for visual measurement.

structures. However, there is a significant knowledge gap in timber frame construction: "Neither in Switzerland nor in other European countries are there currently any regulations governing how much horizontal load a timber frame wall can bear if it contains a window opening," says Nadja Manser. "As soon as a window is planned in the facade, the entire wall segment must be treated by the planning engineer as if it was air. That is simply not efficient."

In 2021, Manser, her team, and their project partners have set out to close the knowledge gap and allow walls with window openings to be considered in building stiffening. The experiments began on a small scale at the Bern University of Applied Sciences in Biel, first with individual planking panels as used in timber frame construction, then with small wall elements, and finally with single-story walls with window openings of various sizes.

PARTNER INSTITUTIONS

- Bern University of Applied Sciences – School of Architecture, Wood and Civil Engineering
- Empa, Structural Engineering Research Lab
- ETH Zurich, Institute of Structural Engineering (IBK)
- Federal Office for the Environment (FOEN) – Aktionsplan Holz
- Swiss Timber Engineers
- Holzbau Schweiz
- Ancotech AG

SAVING TIME AND MATERIALS

The researchers conducted the final large-scale tests in Empa's "Bauhalle": first, with two-story wooden walls, followed by long single-story walls with two window openings next to each other. The findings from these experiments are being incorporated into a new computer model that can be used to calculate the horizontal bracing of walls with window openings. Work on the model is not yet complete, but the initial results are promising: The contribution of walls with window openings to building stiffening is significant enough that fewer expensive and labor-intensive steel anchors will be required in future. "In certain buildings, it may even be possible to dispense with a concrete core, which is currently necessary in many wooden buildings in order to achieve the desired stiffness values," says Nadja Manser. This would save time and materials and enables more economical and sustainable timber buildings.

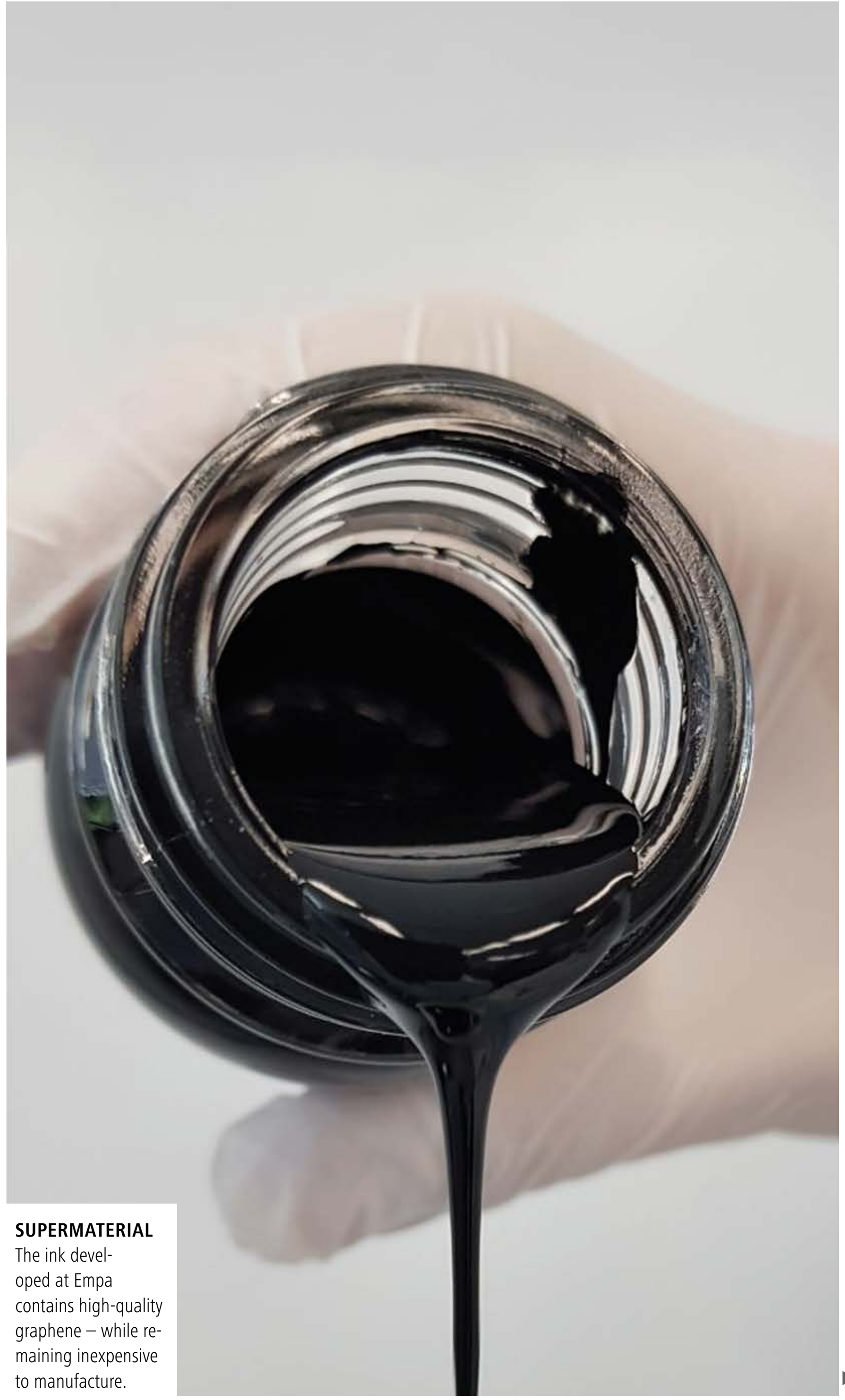
Before the new computational model can be used in industry, it will be further streamlined. "Currently, we have a complex research model with numerous parameters. The goal is to derive a simplified practical model that is less computationally intensive but still provides sufficiently accurate values," explains Manser. To this end, the researchers are working closely with their industry partners – as they have done throughout the project. "It wasn't always easy to reconcile the different demands of industry and research. But by doing so, this now means that our results can be put to practical use very quickly," says the researcher and civil engineer. ■

Photos: Empa

A BOOST FOR SUPERCAPS

Supercapacitors, or supercaps in short, are fast, powerful energy storage devices. They complement the relatively slow (dis-)charging batteries in numerous applications ranging from electric cars to industrial machines and wind turbines. A team of Empa researchers wants to develop better supercaps based on a printable graphene ink – and make them ready for large-scale commercial production.

Text: Anna Ettlin



SUPERMATERIAL The ink developed at Empa contains high-quality graphene – while remaining inexpensive to manufacture.

Photo: Empa

Supercapacitors are the nimble little siblings of batteries. Both technologies store electrical energy. Batteries have a high energy density but a low power density. In other words, they can store a lot of energy, but charging and discharging is rather slow. Supercapacitors are pretty much the opposite: They absorb and release energy at lightning speed but can only store a small amount of it.

"Batteries are like a large container with a narrow neck that can only fill up slowly. Supercapacitors are more like small cups with a wide opening. They fill up quickly, but have little volume," explains Empa researcher Sina Azad. The two technologies are often teamed up: In an electric car, supercaps quickly capture the braking energy and then pass it on to the slower batteries for storage. Supercaps can also be found in solar farms and wind turbines, as well as in industrial machines that sometimes need a lot of electricity quickly.

Azad, a postdoctoral researcher in Empa's Functional Polymers laboratory, and his team have set themselves the goal of improving these ubiquitous, fast storage devices by developing a new kind of electrode based on graphene. This two-dimensional form of carbon should allow the supercaps to achieve significantly higher energy densities.

"Record energy densities for supercapacitors have been described several times in the scientific literature," Azad acknowledges. The focus of his research project is not record-breaking, but scalability. Right from the start, the researchers are focusing on materials and processes that can be implemented not only in the laboratory but also on an industrial scale. For this reason. their project is being supported by Bridge, a joint funding program of the Swiss National Science Foundation (SNSF) and Innosuisse.

IT'S THE SURFACE THAT COUNTS

Similar to a battery, a supercapacitor consists of two electrodes surrounded by a liquid electrolyte. During charging and discharging, the electrolyte transports the ions – the charge carriers – from one electrode to the other. Unlike in a battery, however, no chemical reaction takes place. "Supercapacitors store energy electrostatically by depositing as many charged particles as possible on the surface of the electrode," says Jakob Heier, head of the Functional Thin Film Solution Processing research group in the Laboratory for Functional Polymers, to which Sina Azad belongs.

Hence, the larger the surface area of the electrode, the more ions can attach to it – and the higher the energy density of the supercapacitor. "Today, highly porous activated carbon is usually used as the electrode material of choice," says Empa researcher Vahid Charkesht. However, in contrast to graphene, activated carbon has a very low electrical conductivity, which impairs the storage capacity of the electrode.

Another disadvantage arises during the processing of the material. In industry, the electrodes are printed onto flexible films in a roll-to-roll process, then cut and rolled up into finished supercaps. To be able to print the powdered activated carbon onto a carrier material, it is mixed with binding agents and other additives that impair its porosity.

FROM INK TO PRODUCT

Printing graphene is not a given either. Pure graphene for industrial applications is usually obtained from graphite. Conventional production methods have a very low yield of pure graphene, which has to be separated from waste products at great expense. However, thanks to a previous research project, the Empa researchers have an ace up their sleeve: They developed a process with which high-quality graphene can be "exfoliated" from graphite both cost-effectively and efficiently, and processed into a gel-like printable ink.

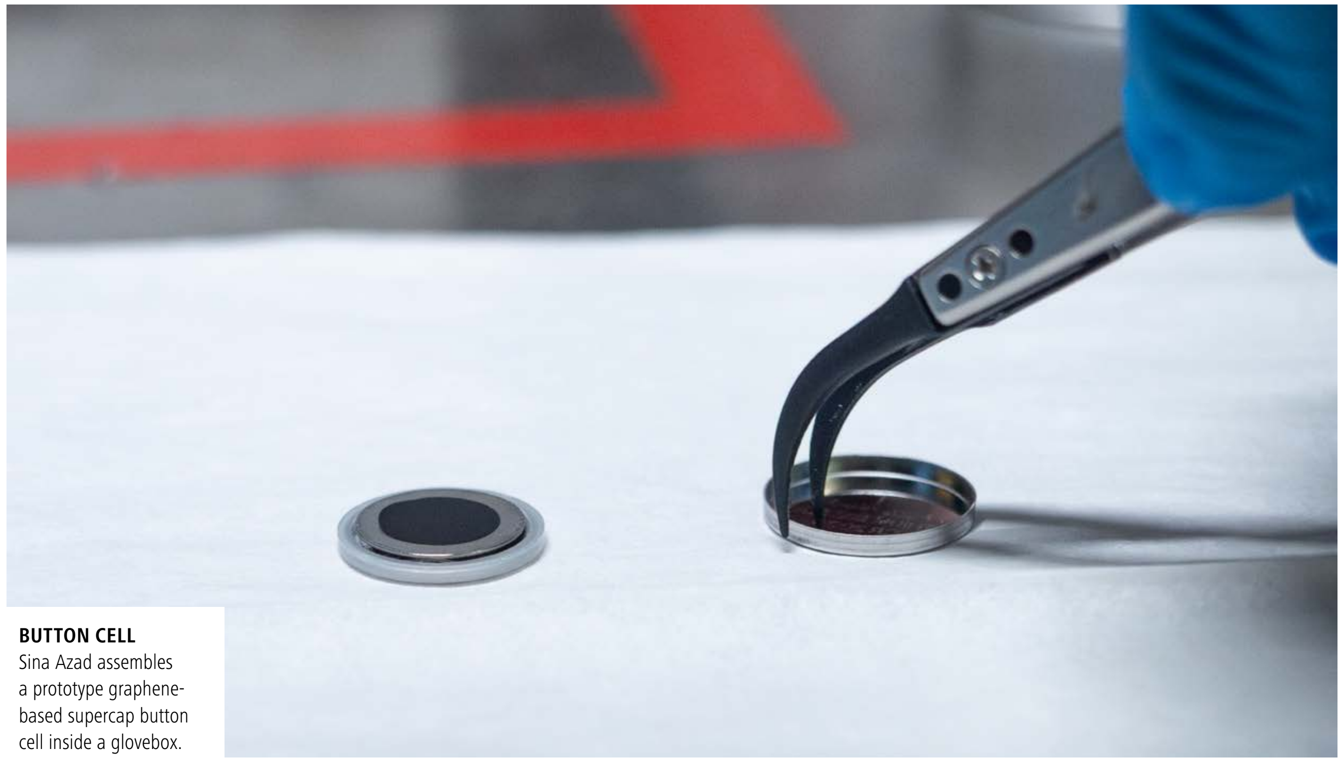
This graphene ink offers a decisive advantage in the production of supercapacitor electrodes. By cleverly mixing two different types of graphene, the researchers can selectively influence the size of the pores between the graphene layers. "If the pore size of the electrode is matched to the size of the ions in the electrolyte, the energy density of the supercapacitor increases dramatically," explains Azad. With activated carbon, controlling pore size is impossible.

With their high conductivity, precise pore size, large surface area and scalability, the new electrodes are likely to become a high-tech product. "At the end of the project, we want to bring our technology to market, either with industrial partners or with our own spin-off," says Jakob Heier.

However, there is still a lot to do – the project runs until 2028. The researchers not only want to develop the electrode technology, but also manufacture electrodes and install them in functional prototypes. The aim is to define the right process steps, find a suitable electrolyte and then precisely characterize the finished supercaps. "We want to develop a real, reliable product," summarizes Azad. ■

TEAMWORK
From left: Sina Azad, Vahid Charkesht, and Jakob Heier with a graphene electrode.

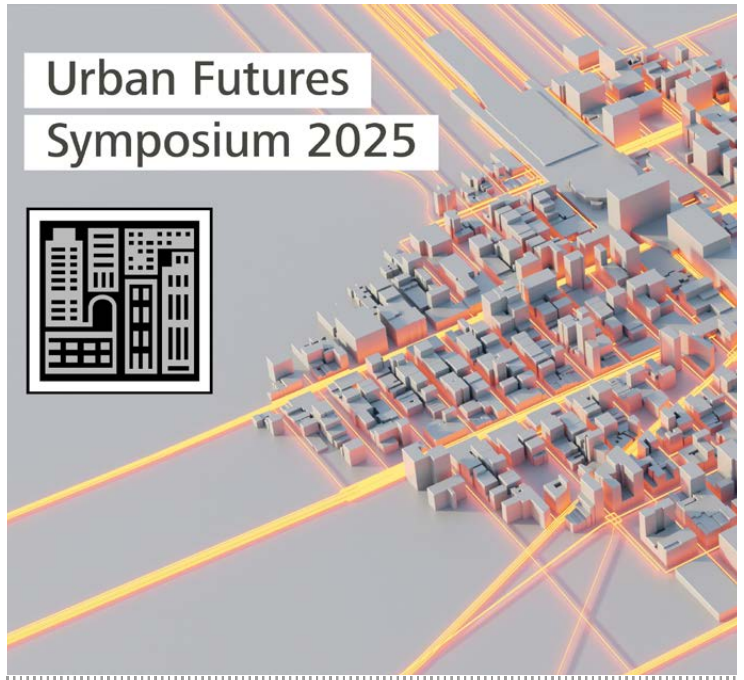
Photo: Empa



BUTTON CELL
Sina Azad assembles a prototype graphene-based supercap button cell inside a glovebox.

Photo: Empa

TEN YEARS OF INNOVATION IN URBAN ENERGY SYSTEMS



The Urban Futures Symposium brings together researchers, industry representatives, and policymakers to shape the future of urban landscapes. The event marks the 10th anniversary of Empa's Urban Energy Systems Laboratory and emphasizes interdisciplinary collaboration and knowledge transfer and exchange. The symposium will take place on September 1 and 2, 2025, at Empa in Dübendorf.

ADDITIVE MANUFACTURING OF METALS AND ALLOYS

From September 3 to 5, 2025, Empa and EPFL are jointly organizing the Alloys for Additive Manufacturing Symposium 2025 (AAMS 2025) on the EPFL campus in Neuchâtel. The symposium, which is aimed at experts from research and industry, is all about the additive manufacturing of metals and composite materials with metallic phases, whether from the experimental, theoretical, or computational side. A special focus will be placed on the optimization of existing and the design of novel alloys for additive manufacturing. Registration and further information on the program:

Graphics: Empa

ACHIEVING CIRCULARITY FOR BATTERIES

CircuBAT2025 will take place in Bern on November 13 and 14, 2025. The international conference on the topic of circular economy for lithium-ion batteries is the result of the Innosuisse flagship project of the same name, in which 11 Swiss research institutions, including Empa, and 24 industrial partners have jointly developed innovations for more sustainable lithium-ion batteries. At the conference, the project participants will present results from the seven sub-projects and showcase the latest technological advances and scientific developments in the industry.

Graphic: CircuBAT

EVENTS

(IN GERMAN AND ENGLISH)

25. – 27. AUGUST 2025
Swiss Remote Sensing Days 2025
Zielpublikum: Wissenschaft
www.empa.ch/web/swiss-remote-sensing
Empa, Dübendorf

03. – 05. SEPTEMBER 2025
Alloys for Additive Manufacturing Symposium
Zielpublikum: Industrie und Wirtschaft
alloysforam.org
EPFL, Neuchâtel

25. SEPTEMBER 2025
Tage der Technik 2025: Future Health
Zielpublikum: Industrie und Wirtschaft
www.tage-der-technik.ch
Empa, Dübendorf

28. OKTOBER 2025
Course: Laser Micromachining
Target group: engineer level required
www.empa-akademie.ch/laser
Empa, Dübendorf

17. NOVEMBER 2025
Course: Energy-autonomous embedded systems and the Internet-of-Things
Target group: development engineers, product managers, R&D managers
www.empa-akademie.ch/energy
Empa, Dübendorf

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