Empa Quarterly

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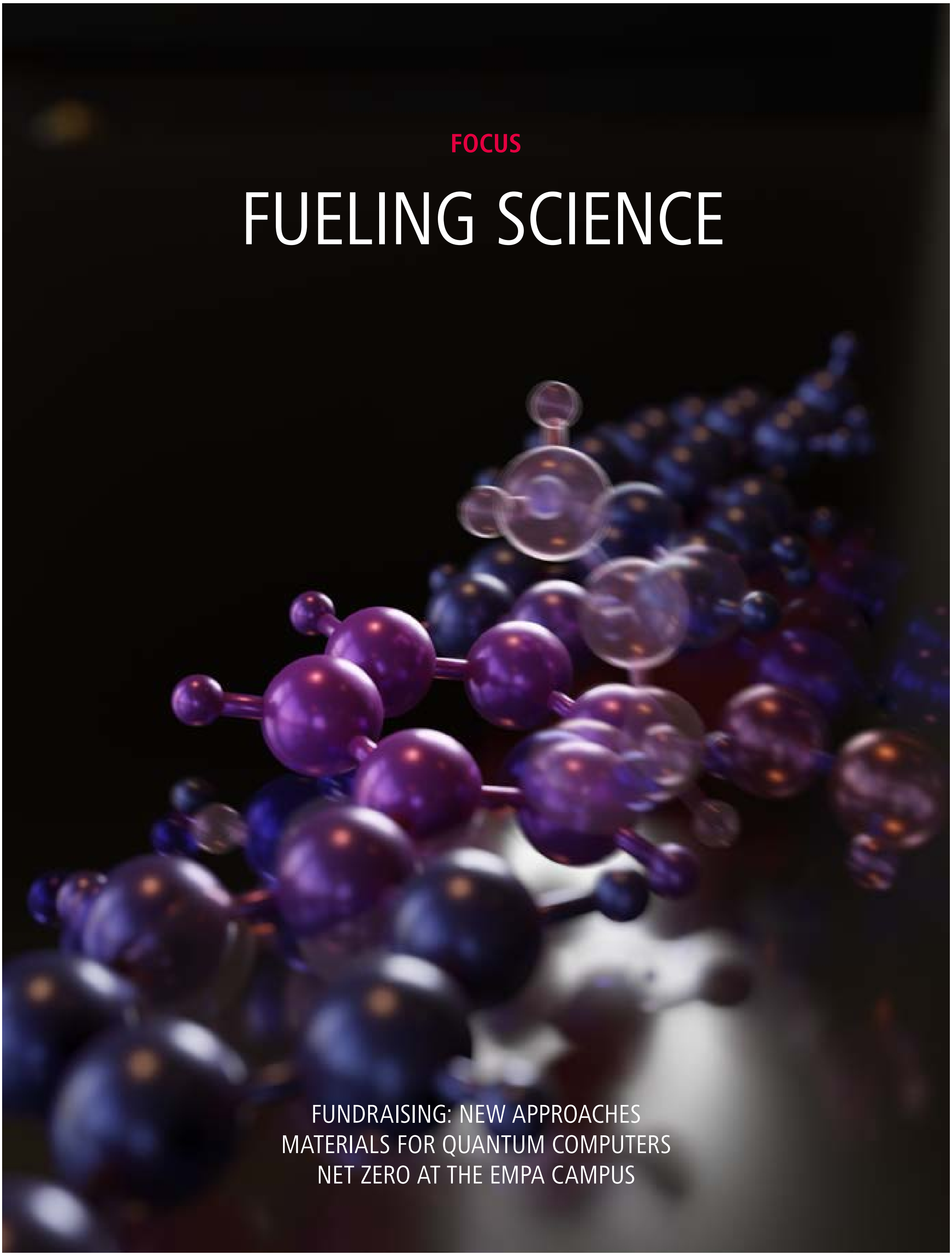


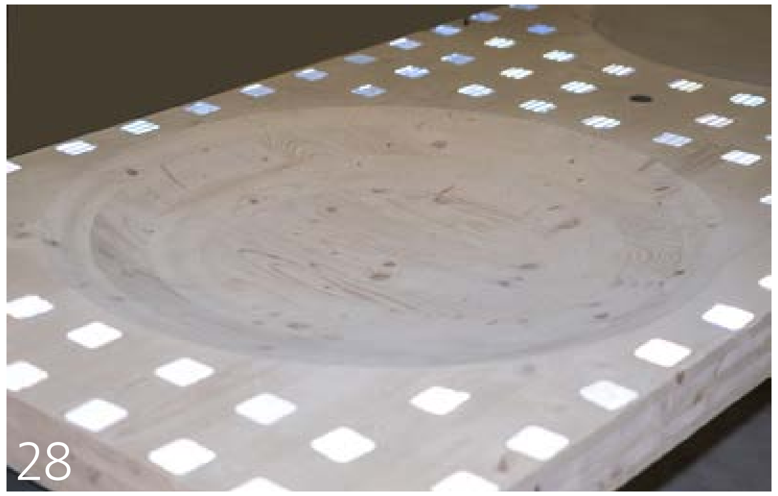
FOCUS

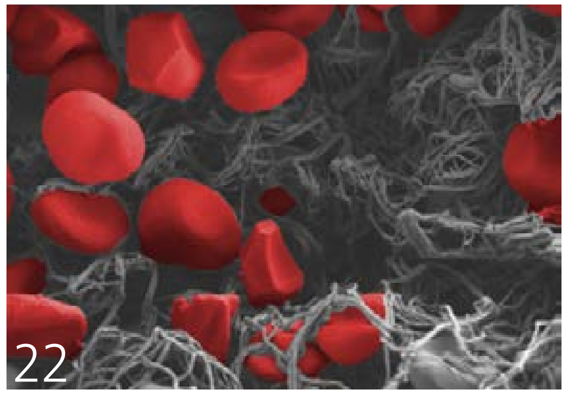
FUELING SCIENCE

FUNDRAISING: NEW APPROACHES
MATERIALS FOR QUANTUM COMPUTERS
NET ZERO AT THE EMPA CAMPUS

[CONTENT]

[FOCUS: RESEARCH FUNDING]





Photos: Empa (3), Nicolas Zonvi / Empa (1), Felix Wey / Werner Siemens-Stiftung (1)

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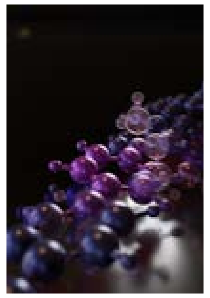

Empa's "nanotech@ surfaces" research group is investigating carbon structures that could be suitable for the architecture of quantum computers. These special molecules are studied on gold surfaces under the scanning tunneling microscope – and are often also synthesized there.
Image: Empa

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A NUMBERS GAME

Dear Readers,

What gave many of us our first sense of achievement at school, besides reading, – for some more, for others less – is also omnipresent at Empa: figures and numbers. Mathematical formulas and computer calculations are crucial to, say, understanding complex flow phenomena and developing novel aerogel materials to capture CO_2 from the atmosphere (p. 32).

In a similar vein, our new research initiative CO_2UNTdown (p. 8), which already has counting in its name, is about adding up CO_2 emissions against sinks. Its goal is to develop CO_2-negative processes. These are urgently needed if Switzerland wants to achieve the target of net zero by 2050 – because despite technological progress, we will not succeed in making all technical processes CO2-neutral. Actually, simple school mathematics: if I have debts (in the form of CO_2 emissions), I also need some kind of credit for a balanced account, i.e.,: CO_2-negative technologies.

Numbers are ultimately central to finance as well. In terms of research funding, we recently decided to break new ground and actively solicit support – because our researchers simply have too many good ideas and, despite solid basic funding, we cannot finance them all (from p. 12). In the meantime, our "Zukunftsfonds" has picked up speed, quite successfully, one could add. We will regularly report on our fundraising activities in future editions of Empa Quarterly.

Enjoy reading!

MICHAEL HAGMANN

Photo: Ladina Bischof / TaDA (https://tada-residency.ch)

FLORAL SPLENDOR FROM THE LAB

The New York and Istanbul based artist Sonia Li has created an artificial flower garden with her walk-through installation as the center of the compassion mandala,"Buddhaverse", which also features two technologies from Empa's Advanced Fibers lab: an artificial turf made of bicomponent fibers with a polyamide core and a recycled polymer film coated with a conductive nanometal layer in Empa's plasma coating facility. Lasers were used to cut floral motifs out of the film, which shimmer in a multicolored way in the installation's UV light. The conductivity of the nanocoating will be used to create a space with interactive multi-sensory experiences when the work is developed further, the artist said. Sonia Li was supported by the TaDA Textile and Design Alliance during the previous grant period. The temporary installation was showcased at the final exhibition at the end of her residency. TaDA promotes interdisciplinary works by artists from all over the world that combine contemporary art with textile innovation and tradition in Eastern Switzerland.

Further information:
www.empa.ch/web/s402/nanocoatings
www.sonialidesigns.com/

CHARCOAL COOLING BLANKET FOR FRUIT AND VEGGIE STORAGE

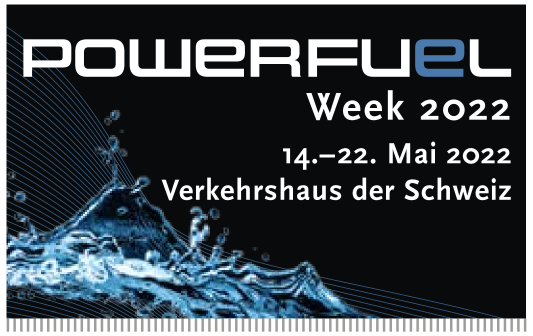
LOW-TECH SOLUTION
Last September, the team tested the cooling blanket for two days on the Empa campus. The "cold room" is around 1.5 meters long and 1.0 meter wide and contained apples in a crate.

In developing countries, storing agricultural produce is often difficult: heat and drought cause fruits and vegetables to spoil quickly – a problem especially for smallholder farmers who cannot afford refrigeration equipment or have no access to electricity. A "cooling blanket" from Empa's Laboratory for Biomimetic Membranes and Textiles in St. Gallen could provide a solution. It harnesses the cold produced when water evaporates – with the help of a low-cost material that is available everywhere: charcoal can absorb a lot of water thanks to its high porosity, enabling efficient evaporation. To use the charcoal, the researchers constructed their blanket with vertical tubes that are filled with pieces of charcoal. This creates self-supporting, malleable "walls" that are doused with water – and evaporation cools the space inside. In analyses in the lab, the temperature dropped by about five degrees in a moderately humid environment. In drier and warmer climates, the researchers say, it could drop by ten degrees or more. At the same time, the humidity inside rose significantly – a natural protection against wilting. With this experience, the researchers now want to develop a pilot plant and test it in Africa or Asia. At the same time, they are working on a business model that will make it easier for smallholder farmers to adopt and introduce the technology.

www.empa.ch/web/simbiosys/charcoal-cooling-blanket

Photo: Empa

Photos: Imperial College London, QuZ



SWITZERLAND'S FIRST HYDROGEN FORUM

With the first Powerfuel Week from 14 to 22 May 2022, a completely new event concept is being created at the Swiss Museum of Transport in Lucerne, with a conference, a trade fair and public events. At the same time, visitors to the Swiss Museum of Transport will experience hydrogen as an essential building block on the way to achieving climate targets. A series of lectures as part of the Powerfuel Conference from 16 to 18 May 2022 rounds off the program.

Learn more: www.powerfuel.ch

A DRONE THAT CAN CHANGE ITS SHAPE

HIGH-TECH SOLUTION
Mirko Kovac is head of the Materials and Technology Center of Robotics at Empa and director of the Aerial Robotics Laboratory at Imperial College London. Image: Imperial College London.

Mirko Kovac has been awarded one of the prestigious ERC Consolidator Grants under Horizon Europe, the EU's funding program for research and innovation. Kovac, who conducts research at both Empa and the Imperial College London, is developing metamorphic drones for use in areas with complex environmental conditions, such as the Arctic. "Aerial drones can already observe the environment from the air, but they cannot move underwater or on the water surface to collect valuable environmental data there," says Kovac,adding that while there are some bimodal air/water vehicles, none has yet been able to demonstrate a full operational cycle including energy-efficient locomotion in the air, in the water and on the water surface. With the ProteusDrone, the robotics expert now wants to solve this problem.

www.empa.ch/web/s604/proteus-drone

"CO_2 MUST BE FAIRLY PRICED"

Empa is working intensively on solutions to reach the climate targets and is starting on its own doorstep. The new research campus currently under construction – co-operate – will be geared to minimizing greenhouse gas emissions thanks to innovative technologies and with as little compensation as possible in the form of certificates. Empa is also launching a research initiative to develop CO_2-negative processes and bring them into use as fast as possible.

Interview: Norbert Raabe

Anyone visiting the Empa and Eawag campus these days will find a large construction site: The new research campus, co-operate, with the future laboratory building at its center is growing rapidly. But interesting views are also provided by installations below ground. In the coming winters, 144 geothermal probes extending to a depth of 100 meters will supply heat – an innovative technology which, as a pilot project, is also expected to provide new insights.

For Empa, however, this is just the beginning. Photovoltaics will be further expanded on campus; the proportion of biogas is to increase. Intelligent control of the electrical and thermal networks and automated building operations should further reduce the consumption of fossil fuels. The insights gained in the process, with the goal of a zero-emission operation, will later benefit many other building projects in Switzerland and abroad.

To achieve Switzerland's climate targets by 2050, it will not be enough to electrify cars, reduce emissions from industrial operations and optimize other areas – even then, large quantities of greenhouse gases will continue to be emitted, for example by the livestock industry in agriculture.

To achieve net zero thus requires technologies with a negative greenhouse gas balance. And to this end, processes for capturing and storing CO_2 from the atmosphere must become much more efficient. One hope for this is aerogels, which Empa researchers have been working on for years, and the possibility of converting CO_2 into building materials.

Ideas, hopes, challenges: Peter Richner, NEST co-founder and Empa's deputy CEO, explains the institute's focus on climate-neutral technologies in an interview.

Peter Richner, the new Empa and Eawag campus is taking shape. If you had one wish for its future, what would that be?

That would really be that our seasonal heat storage facility, which we have just built, indeed has the capacities we envision. This would enable us to save significant amounts of "leftover" heat from the summer for the winter to cover peak energy demand during the cold season.

By 2024, the Empa campus' CO_2 emissions are to be reduced by almost three quarters compared to 2006. To this end, biogas is to be used increasingly; photovoltaics are to be expanded ... – what else are you planning?

We are a very energy-intensive organization; there is always great potential for optimization. In order to save heating energy, for example, an experiment is currently underway in our administration building: We are trying to implement the technology of an Empa spin-off, viboo, which comes from our Urban Energy Systems lab. But I also have the feeling that we still have a large potential as far as research operations is concerned; there is rather little sensitivity there as to how much energy we actually consume in all our experiments.

What do you mean, specifically?

Photo: Felix Wey / Empa

AMBITIOUS PLANS
Peter Richner on the construction site of the future Empa campus – in front of the experimental building NEST, which will also serve as a test laboratory for climate-friendly construction in the future.

RECYCLING WITH STYLE
Peter Richner in front of a partition wall in NEST that was built with used reference books and magazines.

PETER RICHNER

CAREER After studying chemistry and completing his doctorate at ETH Zurich, Peter Richner conducted research on plasma mass spectrometry at Indiana University and joined Empa in 1990.
SCIENCE From 1995 he was responsible for the Corrosion/Surface Protection lab and became head of the Engineering Sciences department in 2002. He is also responsible for Empa's Research Focus Area Energy and is co-founder of the experimental building NEST, which was opened in 2016.

Do research facilities have to run 24/7? In the case of AC units, it's clear that the more precisely you set the target room climate – say, plus-minus 0.5 degrees Celsius and plus-minus 2 percent relative humidity – the more energy you need to keep it in this narrow range. So the question really is: Aren't there times and settings where we can live with larger fluctuations? That would immediately have a very positive impact on our energy consumption. I think these are things we haven't looked at enough yet.

So in the future, the Empa campus will be a "climate construction site" – with challenges that also apply to Switzerland as a whole. In cement production, greenhouse gas emissions are as unavoidable for the foreseeable future as they are in agriculture. Empa is now launching the Below Zero project over four years. What is it all about?

Of course, we have to reduce or prevent emissions. But it is also quite obvious that we will overshoot the CO_2 emission targets of international agreements that would allow us to limit global warming to 1.5 to 2 degrees – simply because we reacted far too late and too slowly to climate change. In other words, we need to develop technologies that will cause atmospheric CO_2 concentrations to drop. Collectively, these CO_2-negative technologies can be summarized under the label "Below Zero"; so we called our corresponding research initiative CO_2UNTdown.

And it is precisely the building sector that you see as the most effective lever.

Absolutely. The Swiss construction sector plays a central role with its material consumption and resource turnover, which are associated with high CO_2 emissions. Also in operation: We still have a lot of fossil heating systems. And we have to change these conditions. If construction doesn't get its act together, Switzerland won't either. That much is clear.

What are your favorites among the Below Zero technologies of the future?

There are basically two ways to deal with atmospheric CO_2: You can try to store it underground and hope that it will either remain there as a gas or be mineralized over time – there are certain rock formations that have the potential to do that. Or you say: No, I'm going to try to convert CO_2 into a material that I can use to replace other materials. And if you really want to use millions of tons of materials to achieve a real effect towards negative emissions, it can really only be in the construction sector. And within the construction sector, concrete is the most important material, then asphalt, and then maybe insulation materials – we have huge potential sinks for CO_2 here.

Photo: Felix Wey / Empa

CO_2-negative magnesium-based cements are already being investigated and developed at Empa …

This is a cement that can absorb CO_2 and thus become CO_2-negative on balance. But I also see great potential if we can replace aggregates for concrete or asphalt – that is, sand, gravel, crushed stones – for example, with carbon-based materials that basically originate from atmospheric CO_2. There is just one "little" catch: We first have to capture the gas efficiently from the atmosphere.

Empa has long been working with highly porous aerogels, which could also help with such technologies. What is the current status there?

We are at an early stage. Aerogels are suitable because, with their many pores, they have a very, very large specific surface area – similar to a sponge – that is needed to interact with the gas. And this surface has to be modified in such a way that CO_2 can first be absorbed, but also be desorbed again later on in high concentrations. By means of modeling, we are trying to find out what the pore structure must look like for this interaction to take place. And, of course, how we can chemically modify the surface so that when a molecule hits it, it sticks and reacts.

Skeptical voices keep expressing that net zero cannot be achieved by 2050 despite all efforts. How do you intend to accelerate the process of bringing new ideas into building practice?

First of all, we have to show that there are practicable solutions. And then, of course, the question of cost comes up very quickly: It's absolutely crucial that CO_2 emissions are priced in a transparent and fair way. As long as we have certain sectors in our economy that are allowed to emit CO_2 basically for free, it will be extremely difficult to establish CO_2-neutral solutions. We see this in Switzerland, too: Depending on whether the CO_2 emissions are from heating oil, from a diesel-powered vehicle or from kerosene in an airplane, they are taxed very differently – or even not at all. Policymakers must ensure a level playing field – because for our climate, it doesn't matter where the CO_2 molecule comes from.

Ambitious goals like Empa's therefore also require support. If you had one wish to politicians, what would it be?

A new CO_2 law is now in discussion, and opinions differ widely. There is a school of thought that says the first law was rejected because people don't want more taxes – so there should also be no additional taxes in the new draft. But then the question is: How should anything move at all? I am more inclined to a system that will tax every greenhouse gas molecule depending on its effect on the climate, regardless of its source. But this new CO_2 tax should be distributed back again to the people in the sense of an incentive tax – 100 percent; so the overall tax burden would not increase.

Based on what we know today, do you think Switzerland will achieve net zero by 2050?

If we want to, we certainly can. The only question is if we really want to – our will and determination is really all that matters. ■

BELOW ZERO

The vision "Below Zero" is at the heart of Empa's CO_2UNTdown research initiative. It aims to further focus and harness the expertise of researchers to combat climate change. An initial focus is on the development of novel materials, followed by their scaling-up and implementation to pilot and demonstration projects – on Empa's newly emerging campus, for example in the NEST experimental and demonstration building. After about two years, this will be done in cooperation with partners from industry, who will also be involved in the evaluation of new solutions – with a view to practical use in the construction industry.

DEVELOPING SWITZERLAND

The entire Swiss construction sector is as complex as its challenges for the future. A group of experts has launched an initiative for an overall view – for new impetus in research and practice.
https://www.empa.ch/web/empa/entwicklung-bauwerk-schweiz

Further information on the topic is available at:
www.empa.ch/web/empa/engineering-sciences

A GIANT LEAP FOR QUANTUM COMPUTING

RESEARCH ON A TIP
Artistic rendering of a triangulene quantum spin chain adsorbed on a gold surface and probed with the sharp tip of a scanning tunneling microscope. These tailor made carbon structures exhibit quantum effects that are stable and can be manipulated even at room temperature. That could be a silver bullet for building entirely new kinds of quantum computers.

Grafic: Empa

Twelve years of intense work are now bearing fruit – researchers at Empa have developed unique carbon materials with quite astonishing, hitherto unattained electronic and magnetic properties, which one day could be used to build quantum computers with novel architectures. A one million dollar grant from the Werner Siemens Foundation for the next ten years now gives this visionary project an unusually long research horizon, greatly increasing the prospects for success.

Text: Rainer Klose

An exceptionally large grant will allow a team of Empa researchers to work on an ambitious project over the next ten years: The Werner Siemens Foundation (WSS) is supporting Empa's CarboQuant project with 15 million Swiss francs. The project aims to lay the foundations for novel quantum technologies that may even operate at room temperature – in contrast to current technologies, most of which require cooling to near absolute zero. "With this project we are taking a big step into the unknown," says Oliver Gröning who coordinates the project. "Thanks to the partnership with the Werner Siemens Foundation, we can now move much further away from the safe shore of existing knowledge than would be possible in our 'normal' day-to-day research. We feel a little like Christopher Columbus and are now looking beyond the horizon for something completely new."

The expedition into the unknown now being undertaken by Empa researchers Pascal Ruffieux, Oliver Gröning and Gabriela Borin-Barin under the lead of Roman Fasel was preceded by twelve years of intensive research activity. The researchers from Empa's nanotech@surfaces laboratory, headed by Fasel, regularly published their work in renowned journals such as Nature, Science and Angewandte Chemie.

In 2010, the team succeeded in synthetizing graphene strips, so-called nanoribbons, from smaller precursor molecules for the first time. With their novel synthesis approach, the Empa team can now produce carbon nanomaterials with atomic precision, thereby precisely defining their quantum properties. Graphene is considered ▸

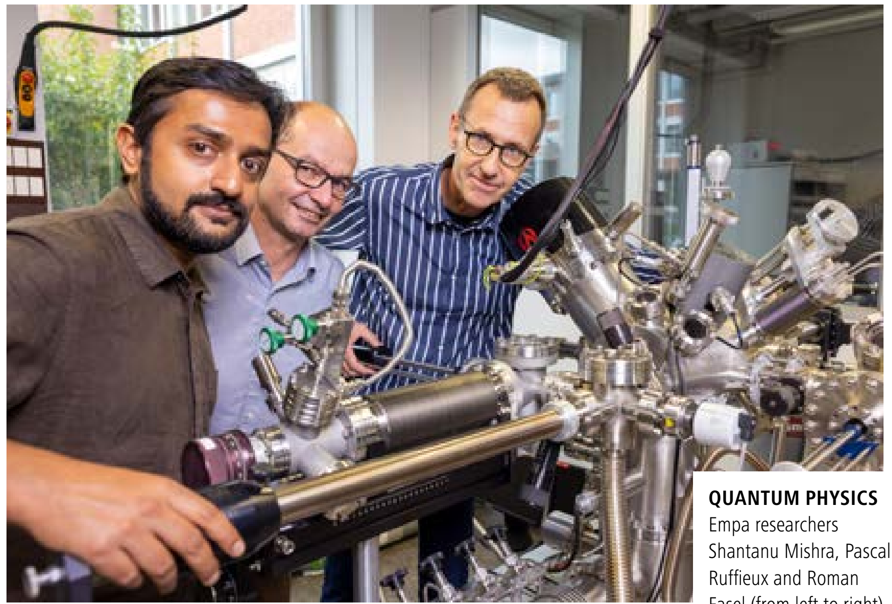
WERNER SIEMENS FOUNDATION

The Werner Siemens Foundation (WSS) was founded in 1923 in Schaffhausen by Charlotte von Buxhoeveden and Marie von Graevenitz, née Siemens, the daughters of Carl von Siemens, who together with his brother Werner von Siemens had founded the later Siemens Group. The two founders were later joined by other family members as benefactors. The Werner Siemens Foundation, which resides in Switzerland, promotes outstanding innovations and talented young people working in technology and the natural sciences.

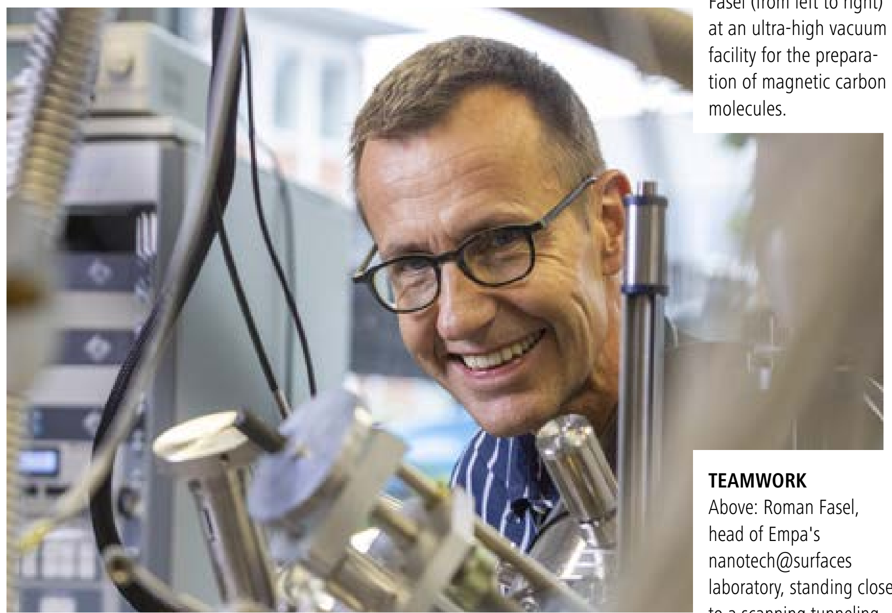
a possible building material for computers of the future; it is made of carbon and resembles the familiar graphite. The material is, however, just one atomic layer thin and promises faster, more powerful computer architectures than the semiconductor materials known today. Back in 2017, the research team, in collaboration with colleagues from the University of California, Berkeley, built the first transistor from graphene nanoribbons and published the result in Nature Communications.

A FIRST MILESTONE

But then the researchers realized an effect that had previously only been predicted theoretically and seemed even more interesting: Their tiny, tailor-made carbon nanomaterials exhibited properties of magnetism. In 2020, they first reported on the effect they had discovered in the journal Nature Nanotechnology – and followed up with a more refined paper in October 2021: Now, using their carbon nanomaterials, they had demonstrated for the first time a physical effect that the future Nobel Prize winner in physics F.D.M. Haldane had predicted nearly 40 years ago: spin fractionalization. This fractionalization only forms when many spins



QUANTUM PHYSICS
Empa researchers Shantanu Mishra, Pascal Ruffieux and Roman Fasel (from left to right) at an ultra-high vacuum facility for the preparation of magnetic carbon molecules.



TEAMWORK
Above: Roman Fasel, head of Empa's nanotech@surfaces laboratory, standing close to a scanning tunneling microscope in his lab. Below: Empa scientist Oliver Gröning is coordinating project CarboQuant.

Photos: Gian Vaitl / Empa (2), Felix Wey / Werner Siemens-Stiftung (1)

(i.e., fundamental quantum magnets) can be brought into a common, coherent quantum superposition. Empa researchers have achieved just that in their precisely synthesized molecular chains.

CarboQuant is intended to build on these special spin effects in graphene nanoribbons. Gröning says, "So far, we see spin states at very specific locations in the nanoribbons, which we can generate and detect. The next step will be to manipulate these spin states deliberately, for example, to reverse the spin at one end of the nanoribbon and thus elicit a corresponding reaction at the other end." This would give Empa researchers something very unique to work with: a quantum effect that is stable and can be manipulated even at room temperature or requiring just moderate cooling. That could be a silver bullet for building entirely new kinds of quantum computers.

0 AND 1 AT THE SAME TIME

But why is it that quantum computers can calculate faster than conventional computers? Classical computing machines calculate in bits. Each component can have one of two possible states: 0 or 1. In the quantum world, however, these states can be superimposed: 0 or 1 or both states at the same time are possible. That's why circuits in a quantum computer, known as qubits, can perform not just one computational operation after another, but multiple ones simultaneously. Gröning is already looking forward to the experiment: "If we manage to control the spin states in our nanoribbons, we can use them for quantum electronic devices."

While one part of the team continues to study spin effects in a high vacuum, other team members will focus on the everyday suitability of the graphene nanoribbons. "We have to get the components out of the protected environment of the high vacuum and prepare them in such a way that even in ambient air and at room temperature, they do not disintegrate. Only then can we equip the nanoribbons with contacts – which is the prerequisite for practical applications without the need of an elaborate infrastructure," Gröning says.

INTENSE LASER PULSES

The journey into this unknown, new world will in any case be very demanding. Already the initial phase – the entry ticket, if you wish –, the control and time-resolved measurement of spin states, requires a completely new set of equipment that the researchers will have to develop and build. "We need to combine the scanning tunneling microscope (STM), in which we synthesize the nanoribbons and look at their structure, with ultra-fast measurements of their electronic and magnetic properties," Gröning explains. That can be done by high-frequency electrical signals at high magnetic fields and by irradiation with very short, extremely intense laser pulses.

To achieve this, two new measurement systems are being set up at Empa, which will also play key roles in the team's other research projects and which are co-funded by the Swiss National Science Foundation (SNSF) and the European Research Council (ERC). "This shows that synergies always emerge from different projects," says Gröning, "but also that ambitious goals can only be achieved with the support of different players at multiple levels." The researchers estimate that it will take two to three years just to set up these new analytical instruments and to carry out the first test runs.

A VERY DISTINCT PROJECT

CarboQuant is a very special project thanks to its long-term and generous funding, says Oliver Gröning. The researchers at Empa's nanotech@surfaces lab now have extraordinarily great and long-term creative freedom on the way to their ambitious goal: a possible building material for next-generation quantum computers. "We don't yet see the island that might be out there. But we can guess it, and if there is something out there, we are confident that we will find it, thanks to the support of the Werner Siemens Foundation and our national and international research partners," says Gröning. ■

RESEARCHING FOR THE WORLD OF TOMORROW

Research projects such as CarboQuant promise enormous progress, but are always fraught with the possibility of failure. The Empa Zukunftsfonds aims to support such exceptionally risky and at the same time particularly promising projects by acquiring grants from foundations and donations from private individuals. If you are interested in supporting the Empa Zukunftsfonds, you can find more information at: https://www.empa.ch/web/zukunftsfonds

Further information on the topic is available at: www.empa.ch/web/s205

WE ARE LOOKING FOR PROJECTS IN THE "VALLEY OF DEATH"

DECISION Together with his colleagues on the board, Hubert Keiber determines the allocation of the grants.

Photo: Nicolas Zonvi / Empa

Hubert Keiber, Chairman of the Board of Trustees of the Werner Siemens Foundation, describes why the Board decided to award a 15 million Swiss francs grant to a team of Empa researchers.

Interview: Michael Hagmann

What was your first thought when you heard about the CarboQuant project?

The project came to me via our Scientific Advisory Board, which recommended it to me – or rather to the Foundation Board – as worthy of funding. When I received the application on my desk, I thought to myself – even before I had read it – "Well, graphene, there was a Nobel Prize for it; but what would you want to do that's new, since the topics are largely known and worked on. So what's so special about the project?" Well, the exciting thing about the project is that it's about the geometry of these new graphene materials, that you can "tune" their electrical and magnetic properties via the geometry of the graphene nanoribbons – and that goes far beyond what has been known so far. So it is the shape that determines the function, and not the chemistry – thus a completely new way of thinking. That really impressed me. That's why we invited Roman Fasel, Oliver and Pierangelo Gröning to give us a closer look at the project.

What do you primarily look for when you review a project?

We look first and foremost at the protagonists, at the team, and ask ourselves: Can they really implement the project, do we really trust them? How do they act during the presentation, is it a one-man show, does one person talk the whole time while the others just sit and listen, or do they interact? If they're more like lone wolves, then that's already a problem for us. We're looking for projects that are highly interdisciplinary – and that's rather difficult with a single person. In other words, team play is tremendously important for us. How do they function as a team, is the chemistry right between them? If not, then in extreme cases we would reject even a scientifically excellent project – and we have already done so in the past.

So with the CarboQuant team, the chemistry seems to have been right.

That was a presentation, as we imagine it. It wasn't just a case of one person calling the shots and the others chewing over what the boss said. They really passed the ball to each other. There were three individual minds, and everyone had their own independent opinion – and that's exactly what's needed in such an ambitious project. There has to be discussion and friction in order to make progress. That's what convinced us.

The purpose of the Werner Siemens Foundation is to support outstanding, innovative research projects with the aim of being able to use the resulting innovations on an industrial scale. For instance, you are funding a robot-guided laser scalpel for minimally invasive surgery or antiviral drugs. Where does CarboQuant or quantum physics fit in?

First of all, we have already rejected projects in the field of quantum computers in the past. Today, a lot of purely basic research is still being done in this field – and that is explicitly not our topic. However, we also do not fund projects according to the motto "faster, better, higher" – i.e. when it is "only" a matter of optimizing something that already exists. We are looking for projects that are in the so-called Valley of Death: The basic research has been done – in this case: Graphene exists and is well-known. And now someone has an idea of what could be done with it, such as building a prototype – for which he usually does not yet receive venture capital, but also no more funding for basic research, for example from the Swiss National Science Foundation. Many projects in this "in-between" area never get off the ground because they lack funding. This is exactly where we step in – and CarboQuant fits in perfectly. These very special graphene structures, whose electronic and magnetic properties can be adjusted via their geometry, their shape, could in the future enable computer chips on a completely different basis than is the case with today's quantum computers. However, quantum computers are just ONE possible application for these graphene structures; the quantum computer is the distant goal, so to speak. I am convinced that the findings and developments along the way will also lead to technological innovations in completely different areas.

HUBERT KEIBER

CAREER Hubert Keiber holds a doctorate in physics and held management positions at Siemens Switzerland, as well as Siemens subsidiaries in Russia and China, from 1983 to 2015. As Chairman of the Werner Siemens Foundation, he is chairman of the three-member foundation board.

Which ones, for example?

Microelectronic components and switching elements, for example. The fact that I can set different material properties via the geometry of the graphene was decisive for us – because this completely new approach makes it possible to develop different, i.e. non-silicon-based semiconductors for tomorrow's microelectronics.

15 million Swiss francs is an extraordinarily high amount of money for Empa for a single project – also for the Werner Siemens Foundation?

No, that is exactly the way we fund projects. That's why we fund "only" three to four projects per year, but these are funded with amounts in the range of five to 15 million francs, usually over ten years.

Since you can only spend each franc once, this funding approach involves certain risks. Why do you pursue this particular funding philosophy?

It's because of the way our foundation is organized – we have a very lean staff, and so we only have a limited capacity to review projects. If we were to work on and fund many small projects, we would need a completely different organization. Our philosophy is: small but efficient, if you wish – and by that I mean the project overhead. We don't want to spend money on overhead, the money should go to the research projects.

What "strings" are attached to the funding?

We request a progress report once a year – and then report on it ourselves in our annual report. That's all there is for the researchers to do. Once we decide to fund a project, we also take the risk that it could go wrong. On the one hand, the project may die because the basic idea is not feasible – fortunately, we have not yet experienced this, but it is conceivable, and it can happen. What would somehow be worse, however, is if the team were not able to implement the project – despite good ideas. Because in this case, we, the Board, would have made a mistake. In other words: High risk – high gain.

Quantum computers are regularly in the media – mostly in connection with tech giants like IBM, Microsoft or Google. Why are you supporting a small player like Empa in this "race"?

Because the team wants to think and design quantum computers in a completely new way, also on the material side. Today, you need 4 degrees Kelvin, i.e. temperatures close to absolute zero, to run a quantum computer with, say, 8 Qbits – and CarboQuant could make it possible to run such computers with chips that look like normal chips at much higher temperatures, possibly even at room temperature. And another point: In the area of quantum computing, as you rightly said, Europe is not really at the top of the game. With CarboQuant, Europe could make a contribution to this important field of research. ■

PROFESSIONAL
As a trained physicist and manager of many years', Hubert Keiber assesses the funding applications submitted.

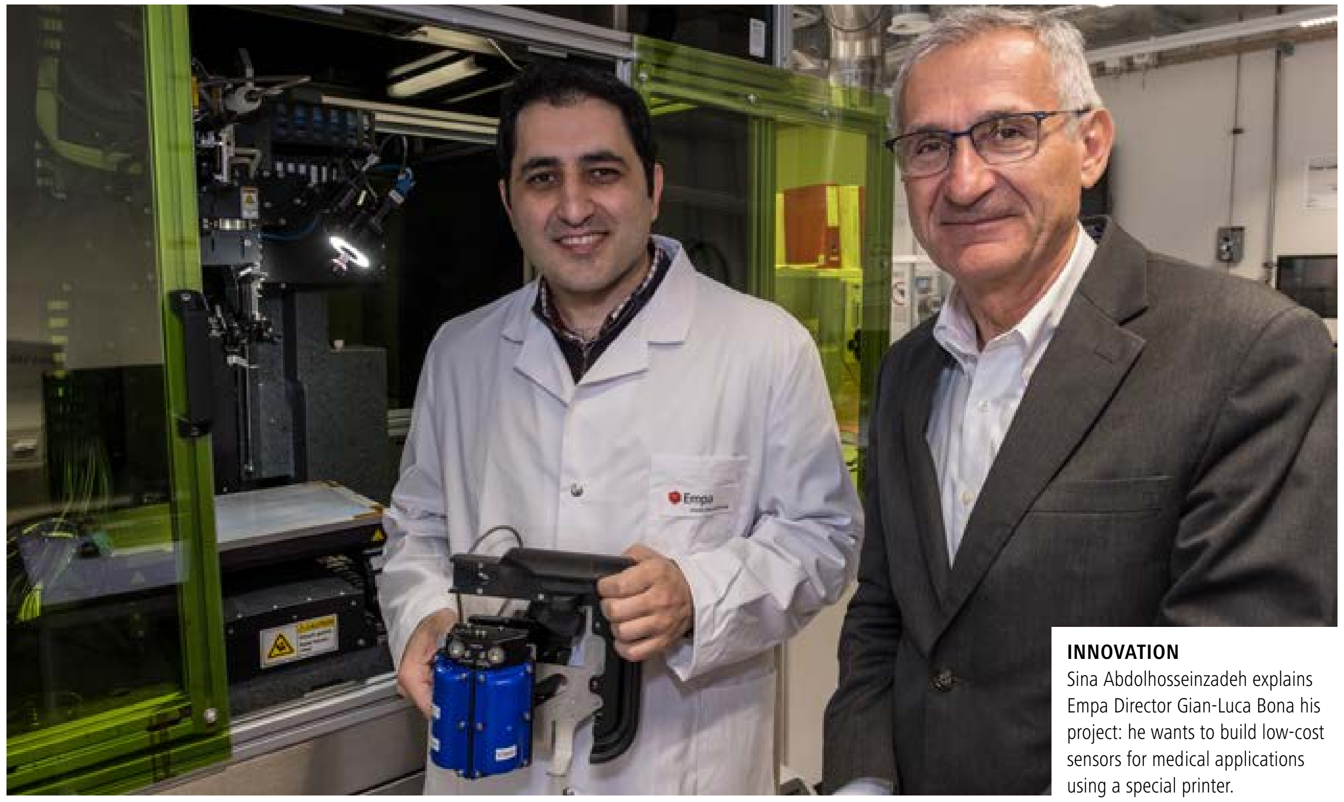
Photo: Nicolas Zonvi / Empa

Further information on the topic is available at:
www.wernersiemens-stiftung.ch/

NEW PATHS IN FUNDRAISING

Many potentially groundbreaking ideas are born in the minds of researchers at Empa – not all of them can be implemented, and for some there is simply no funding. The Empa Zukunftsfonds is intended to close this gap in the future; through professional fundraising, the Zukunftsfonds supports exciting research projects that have not yet received funding elsewhere, as well as particularly promising talents.

Text: Redaktion Empa



INNOVATION
Sina Abdolhosseinzadeh explains Empa Director Gian-Luca Bona his project: he wants to build low-cost sensors for medical applications using a special printer.

Photo: Empa

Empa is one of Switzerland's key drivers of innovation; application-oriented, practical, focused on the prime challenges of our time. In more than 400 ongoing research projects with several hundred partners from all over the world, Empa researchers are developing innovative materials, technologies and concepts to enable the energy transition, advance a circular economy or bring personalized medical applications into everyday practice.

To keep this innovation engine running, it needs to be kept lubricated – with scholarships, grants, donations and other types of financial support. After all, cutting-edge research does not come for free. Although Empa, as a research institute of the ETH Domain, is solidly funded by the federal government, there are always projects that are ahead of their time – in other words, that have enormous potential if they are successful, but cannot be financed by conventional means. ▶

Or, on the other hand, enormously talented young researchers whose further scientific careers are supported.

TIME FOR PROFESSIONAL FUNDRAISING

In order to have greater room for maneuver in cases such as these, Empa's Directorate decided some time ago to set up a professional fundraising: the Empa Zukunftsfonds. "We want to make it possible for private donors to support projects or "bright minds" in topics that are close to their hearts, such as sustainability or medicine – and thus help us directly shape our future in a livable and sustainable way," says Empa CEO Gian-Luca Bona. The Empa Zukunftsfonds offers various thematic funds that enable private donors to support a specific purpose: There are currently research funds for sustainability, health, energy and nanotechnology, as well as a fund for the promotion of young scientists.

EMPA FELLOWSHIPS FOR OUTSTANDING TALENTS

For the latter, the Empa Zukunftsfonds recently received a significant donation: Last November, the Board of Trustees of the Ria & Arthur Dietschweiler Foundation decided to fully fund a two-year Empa Young Scientist Fellowship at St. Gallen with 270,000 Swiss francs. The St. Gallen-based foundation was established in 1981 by the German-Swiss entrepreneurial couple Ria and Arthur Dietschweiler, and since then has supported charitable, pioneering projects in the fields of education, culture and social affairs.

The Empa Young Scientist Fellowship is a funding instrument for exceptionally talented young scientists. The fellow receives financial support to set up and carry out an independent research project over a period of two years. The duration of two years is deliberately kept short, as the Fellowship is intended as a kick-start for an international scientific career, and not as an entry into a career at Empa. The Fellowship is awarded through a competitive process to ensure that the applicants with the highest potential are selected.

LOW-COST SENSORS FOR MEDICINE

The selection process for the 2022 awardee has just started. So who will enjoy the Fellowship of the Ria & Arthur Dietschweiler Foundation is not yet known. However, a first Empa Young Scientist Fellowship has already been running since October 2021: Sina Abdolhosseinzadeh completed his PhD thesis last year and has since been working in Empa's Functional Polymers lab. His project: to develop intelligent and at the same time inexpensive sensors for medical technology.

Low-cost diagnostic instruments that can be produced in large numbers are an important prerequisite for an affordable healthcare system. While chemical sensors show promise for detecting a wide range of diseases, from cancer to viral infections, producing them cost-effectively is tricky. One industrial-scale production method for such devices would be printing. However, functional inks are currently in short supply; moreover, the construction of most conventional biosensors makes it impossible to use existing printing methods. In his research project, Abdolhosseinzadeh plans to build on the results of his PhD thesis and attempt to develop a universal sensor platform that solves these problems and is compatible with existing technology.

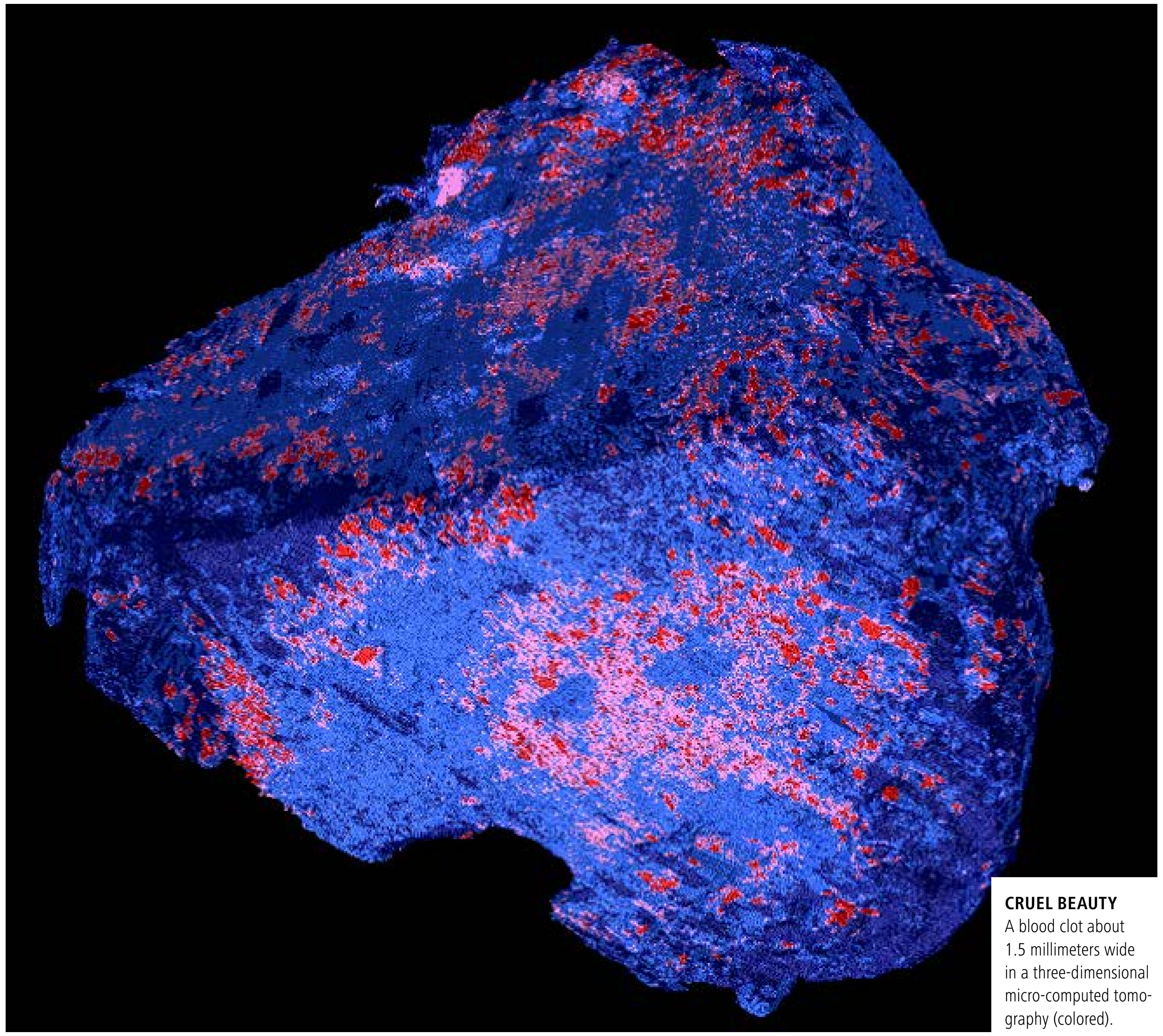
A PROMISING START

Gian-Luca Bona considers the funding that could already be raised an encouraging start – and hopes that these initial successes will soon be followed by others: "The support from the Ria & Arthur Dietschweiler Foundation, but also the grant from the Werner Siemens Foundation for our research in the field of novel architectures for quantum computers (see article on p.12) are an incentive for us to pursue this path further and, together with our sponsors, continue to launch groundbreaking innovations in future in order to be able to solve the urgent challenges facing our society." ■

THE EMPA ZUKUNFTSFONDS

The Empa Zukunftsfonds is Empa's fundraising and donation tool and currently comprises five thematic funds: four research funds for the areas of energy, health, sustainability and nanotechnology, and one fund for talent development. Each of these funds has a clearly defined application and award process. Empa prepares annual accounts for each fund and discloses them to donors; donations to the Empa Zukunftsfonds are tax-deductible. The Zukunftsfonds team consists of Gabriele Dobenecker and Martin Gubser. In recent years, Gubser has headed fundraising for the Swiss Paraplegic Foundation and the UZH Foundation, the University of Zurich's foundation. Gabriele Dobenecker has many years of experience in maintaining contacts with Empa's partners in industry and business. Further information: www.empa.ch/zukunftsfonds

Further information on the topic is available at: www.empa.ch/zukunftsfonds



CRUEL BEAUTY
A blood clot about 1.5 millimeters wide in a three-dimensional micro-computed tomography (colored).

METEORITE IMPACT IN THE BRAIN

A blood clot in the brain that blocks the supply of oxygen can cause an acute stroke. In this case, every minute counts. A team from Empa, the University Hospital in Geneva and the Hirslanden Clinic is currently developing a diagnostic procedure that can be used to start a tailored therapy in a timely manner.

Text: Andrea Six

Image: Empa

Images: Empa

There is no warning sign: from one moment to the next, entire brain areas are blocked. When a clot occludes a blood vessel, the oxygen supply to the brain is interrupted, and the affected person suffers an acute cerebral stroke. The life-threatening condition can manifest itself in many different ways: from muscle paralysis to loss of hearing or vision to unconsciousness. But one thing is certain: This is a medical emergency, and the time span until the vascular blockage is resolved must be as short as possible in order to save as many nerve cells as possible from dying. This is the only way to prevent permanent neurological damage.

Which treatment is best suited for this purpose is not always easy to determine in the required rush. Based on X-ray analysis and electron microscopy, a team from Empa, the Hirslanden Clinic and the University Hospital in Geneva is currently developing a method that should enable the optimal therapy to be identified in the shortest possible time. A first study has now been published in the current issue of the scientific journal Scientific Reports ((link paper)). This data should provide the basis for tailored treatment in the sense of personalized medicine.

SCREENING EACH CELL INDIVIDUALLY

The reason for this dilema: Not all blood clots are the same; depending on the type, different types of cells can clump together. Depending on whether red or white blood cells predominate, or on the proportion of fibrin fibers, the thrombus has completely different properties. In addition, thrombi differ greatly in shape. A 15-millimeter-long thrombus that does not completely fill a blood vessel has different mechanical properties than a clot that is only a few millimeters short but completely blocks a vessel and the blood supply to the brain areas behind it. The optimal treatment depends on these differences, whether it is dissolving the clot with drugs or using a so-called stent retriever, a kind of tiny fishing rod with which the thrombus in the blood vessel can be "fished out" and whose material can be selected differently depending on the thrombus.

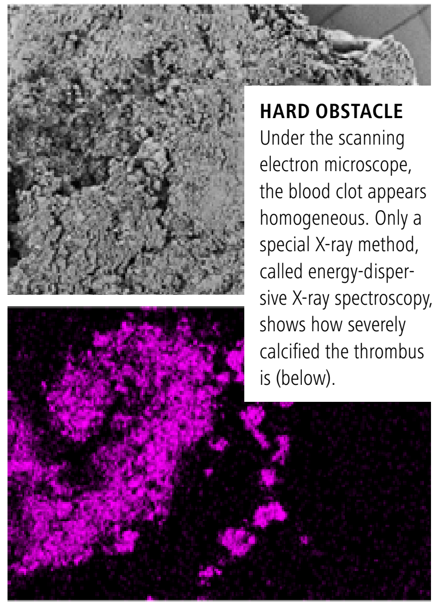
Radiology currently relies on conventional computed tomography scans to make the therapeutic decision. However, images of the patient's head provide little information about the details of a clot because objects made of similar materials are too difficult to distinguish from one another and to resolve spatially. Moreover, in everyday clinical practice the resolution of the images is limited to 200 micrometers.

This is different with laboratory methods, which the researchers used for their new study: The team, with the participation of Robert Zboray, Antonia Neels and Somayeh Saghamanesh from Empa's Center for X-Ray Analytics, had examined various blood clots taken from patients during neurosurgical procedures. For this purpose, different laboratory technologies were combined, resulting in virtual 3D images that revealed detailed and previously unknown properties of blood clots. "We used 3D micro-tomography to examine individual red blood cells down to the micrometer-range," says Empa researcher Zboray. Such tomography using phase-contrast techniques produces stronger contrast. Objects that are easy to penetrate, such as muscles, connective tissue or blood clots, can thus be visualized in particularly fine nuances and in their spatial spread.

CALCIFIED THROMBI

Other technologies such as scanning electron microscopy and X-ray diffraction and scattering methods provided additional information down to atomic levels. Here it was shown for the first time that a thrombus not only consists of blood cells and fibrin networks, but can even be interspersed with minerals such as hydroxyapatite, as is known from vessel walls in arterial calcification.

However, this detailed information on the peculiarities of a blood clot comes too late, when the thrombus has already been surgically removed. In addition, the newly acquired data cannot be compared with the conventional images and findings in the hospital. Digitalization in medicine, meanwhile, allows the data to be modeled in such a ▶



HARD OBSTACLE
Under the scanning electron microscope, the blood clot appears homogeneous. Only a special X-ray method, called energy-dispersive X-ray spectroscopy, shows how severely calcified the thrombus is (below).

TRAPPED IN A BLOOD CLOT
With the scanning electron microscope, red blood cells with a diameter of just a few micrometers can be clearly visualized.

way that an algorithm could read out the detailed information in the future. "To do this, we still need to study a large number of thrombi so that we can use machine learning to identify new features and image patterns regarding the composition of the clot, which can then be transferred to conventional hospital images to help distinguish different types of thrombi," Zboray said.

Eventually, the researchers hope that due to their findings conventional hospital images might be interpreted in a very short time – just as if the blood clot had been examined in an ultrafast virtual laboratory. This would pave the way for a more accurate and personalized therapy for stroke patients in a timely manner. ■

Further information on the topic is available at:
www.empa.ch/web/s499

GLOWING GLASS DROPLETS ON THE ISS

Together with researchers from Ulm and Neuchâtel, Empa will soon be studying material samples on the International Space Station ISS. The material in question are superhard and corrosion-resistant alloys of palladium, nickel, copper and phosphorus – also known as "metallic glasses". A high-tech company from La Chaux-de-Fonds, which produces materials for the watch industry, is also involved.

Text: Rainer Klose

It has the color of white gold, but it is hard like quartz glass and at the same time exhibits high elasticity. The smooth surface is free of crystalline structures and makes the material resistant to salts or acids. Individual pieces – for medical implants, for example – can be produced using 3D printing, while larger series – for watch cases, for example – are manufactured using injection molding. This is roughly how the material of dreams is described that scientists are currently researching. They are talking about "bulk metallic glass".

At Empa, Antonia Neels, head of Empa's Center for X-ray Analytics, has been working on this mysterious material for about 15 years. Her team investigates the internal structure of metallic glass using various X-ray methods, thereby discovering correlations with properties such as deformability or fracture behavior. Even for professionals in materials science, metallic glasses are a tough nut to crack: "The closer we look at the samples, the more questions arise," says Antonia Neels. This spurs the researchers' ambition all the more.

Photo: Airbus Defence and Space

WEIGHTLESS FOR SECONDS
Scientists at the University of Ulm during a melting test in the Zero-G-Airbus operated by Novespace.

TOGETHER INTO SPACE

In a few months, a sample of metallic glass will be studied in the microgravity of the International Space Station (ISS). A group of researchers with Empa participation has prepared the samples and registered them with the European Space Agency ESA for space flight. The special alloy is supplied by the PX Group company from La Chaux-de-Fonds, which produces materials for the watch industry and dental technology. The team also includes researchers Markus Mohr and Hans-Jörg Fecht from the Institute of Functional Nanosystems at the University of Ulm and Roland Logé from the Laboratory of Thermomechanical Metallurgy at EPFL in Neuchâtel.

The production of metallic glass is not entirely simple: Compared to window glass, the specially selected metal alloys must be cooled up to a hundred times faster so that the metal atoms do not form crystalline structures Only when the melt solidifies extremely quickly, it is able to form a glass. In industry, thin sheets of metallic glass are produced by pressing the melt between rapidly rotating copper drums. Researchers sometimes cast their samples in molds made of solid copper, which dissipates heat particularly well. But larger, solid workpieces made of metallic glass are not feasible using these methods.

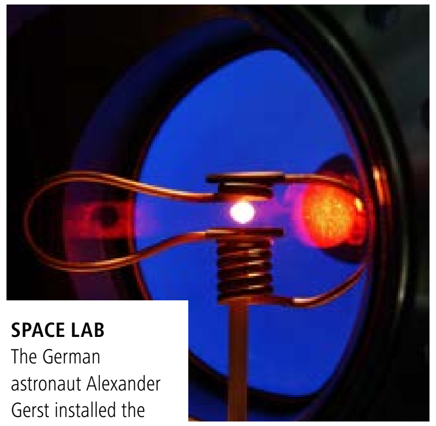
3D PRINTING HELPS

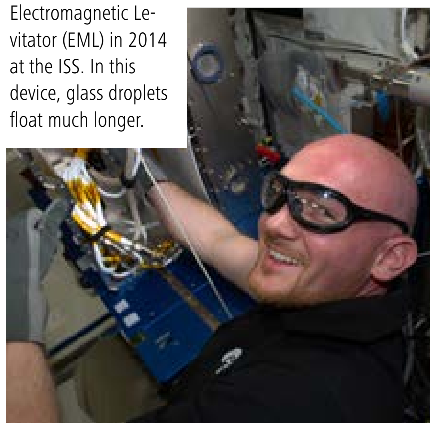
One possible way out of the dilemma is 3D printing using a process known as powder bed process. A fine powder of the desired alloy is heated for a few milliseconds with a laser. The metal grains fuse with their neighbors to form a kind of foil. Now a thin layer of powder is placed on top, the laser fuses the freshly applied powder with the underlying foil, and thus a three-dimensional workpiece is gradually created from many briefly heated powder grains. ▶

This method requires a fine dosage of the laser pulse. If the laser burns too weakly on the powder, the particles do not fuse together, and the workpiece remains porous. If the laser burns too strongly, it also melts the lower layers again. The multiple melting allows the atoms to rearrange themselves, forming crystals – and that's the end of metallic glass.

X-RAY METHODS AND THEIR EXTRAORDINARY DIVERSITY

At Empa's Center for X-ray Analytics, Antonia Neels' team has already analyzed several such samples from 3D printing experiments. Meanwhile, the results always raise new questions. "Some evidence suggests that the mechanical properties of the glasses do not deteriorate, but on the contrary actually improve, if the sample contains small crystalline fractions," says Neels. "Now we're looking into the question of how large this crystal fraction in the glass needs to be, and what kind of crystals need to form to increase, say, the pliability or impact strength of the glass at room temperature." To track crystal growth in an otherwise amorphous environment, Empa experts use a variety of X-ray methods. "With radiation of different wavelengths, we can learn about the structure of the crystalline portions, but also determine close-order phenomena of the atoms in the sample – in other words, determine the properties of the chemical bonds," Neels explains. In addition, X-ray imaging analysis, known as micro-CT, reveals details about density fluctuations in the sample. This indicates phase segregation and crystal formation. However, the density differences between the glassy and crystalline regions are extremely small. Detailed image processing is therefore needed to visualize the three-dimensional distribution of the crystalline portions.





SPACE LAB
The German astronaut Alexander Gerst installed the Electromagnetic Levitator (EML) in 2014 at the ISS. In this device, glass droplets float much longer.

PARABOLIC FLIGHT IN THE AIRBUS

But material samples from the 3D laser printer alone cannot completely solve the puzzle of metallic glasses. "We need to know at what temperatures these crystals form and how they grow – in order to use them to define stable manufacturing processes," explains X-ray specialist Neels. Important information is provided by thermo-physical parameters of the melt, such as viscosity and surface tension. Experiments on the ISS offer ideal conditions for these analyses. Preliminary experiments take place in parabolic flights.

As early as 2019, the first droplets of metallic glass have floated on an experimental basis. A specially converted Airbus A310 from the company Novespace flew a zero-gravity flight with a material sample. On board were scientists from Ulm and a small, metallic glass droplet from the PX Group company in La Chaux-de-Fonds. The metallic glass that the research group is studying consists of palladium, copper, nickel and phos-phorus. In the experiment called TEMPUS (crucible-free electromagnetic processing under zero gravity), the glass droplet was held in suspension by means of a magnetic field and heated up to 1500 degrees Celsius by induction. During the cooling phase, two short pulses of induction current caused the glowing droplet to oscillate. A camera recorded the experiment. After landing, the material sample was analyzed at Empa's Center for X-ray Analytics.

WHY THE ISS DELIVERS MORE RESULTS

The analysis of the video from the parabolic flight allows conclusions to be drawn about the viscosity and surface tension of the droplet – important data for better controlling the production of metallic glasses with specific properties. But the time of microgravity during the flight lasts only 20 seconds – too little for a detailed analysis. That can only be done on the ISS.

So now a sample of the same material has been registered for a flight in the European COLUMBUS module of the ISS. The ISS-EML electromagnetic levitation furnace has been installed there since 2014. In each case, 18 material samples fly along, are automatically exchanged and can be observed by researchers on Earth via video stream. The metallic glass from Switzerland will go into space with the next batch of samples.

NEW CASTING PROCESSES

The researchers plan to generate a computer simulation of the melt from the far more detailed data obtained during the space flight. This will bring all the answers together in a single model through a combination of experiments on Earth and in space: At what temperature is there what viscosity and surface tension? When do crystals of what

Photos: ESA

Photo: Empa

GROUND CREW
Empa researcher Antonia Neels is an expert for metallic glasses and will analyze samples from the ISS.

> "With X-rays of different wavelengths we can learn something about the structure of the crystalline parts."

composition, size and orientation form? How does this internal material structure influences the properties of the metallic glass? From all these parameters, the researchers want to develop a manufacturing method together with the industrial partner PX Group, in order to be able to produce the coveted material in a defined form. So there is still a lot for the materials researchers to do in the next few years. ■

Further information on the topic is available at:
www.empa.ch/web/s499

BLACK HOLES AS NOISE TRAPS

Anyone who lives in an old building with wooden floors knows the problem: even if the neighbors from above glide across the floor with graceful elegance, it sounds in your own apartment as if you were living under a bowling alley. Impact sound is a challenge even for the most modern wooden buildings. Scientists at Empa are tinkering with a solution.

Text: Noé Waldmann

Research is currently being completed at Empa on a world first in the sound insulation of wooden buildings. Using a physical theory from the 1990s and the tools of digitization, a research team has developed new floor elements made of solid wood panels that have so-called acoustic black holes. The brilliant idea came from Stefan Schoenwald, head of Empa's Building Acoustics Laboratory in Dübendorf. He has encountered the theory of acoustic black holes several times at conferences and in scientific publications since it was first published in 1987. According to the Russian author M.A. Mironov from the "Andreyev Acoustics Institute" in Moscow, a parabolic recess in a material can absorb vibrations like sound ▶

Photo: Strüby Konzept AG

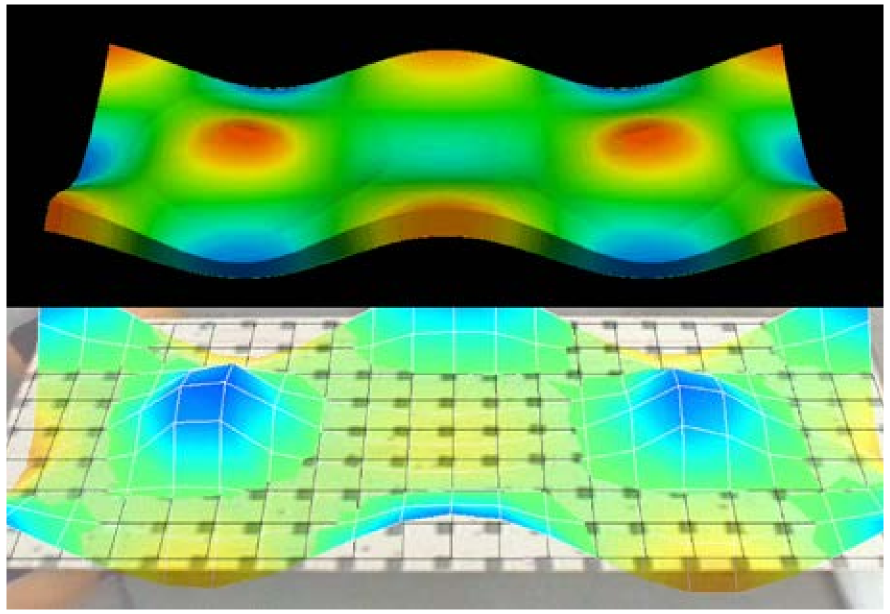
PRECISION
Alex Bellmont from Strüby AG in Seewen milled the mathematically calculated hollows into a plywood panel.

and allow them to resonate – in other words, swallow them. Acoustic black holes have already been used in cars and airplanes, where their sound-reducing effect has been confirmed.

However, manufacturing them with very thin, hard materials is not easy. Neither in wood construction nor in building acoustics have experiments with Mironov's recesses ever taken place. This is now being changed by laboratory manager Stefan Schoenwald together with his colleague Sven Vallely. The two researchers want to use novel cross-laminated timber panel elements to improve impact sound insulation in timber construction.

Just as there are sound waves in the air, there are sound waves in materials, so-called structure-borne sound waves. "When you hit a floor, it's like throwing a stone into a pond: Sound waves propagate in all directions in the material," Schoenwald explains. When a lenticular depression is milled out of the material according to a specific mathematical function, the sound waves travel into this area. In the process, the amplitudes keep amplifying, while the wavelengths of the oscillations decrease. "If you could make the plates infinitely thin in the area of these depressions, then the sound waves would actually run dead by themselves in these 'black holes,' so nothing would come out of the lens," Schoenwald said. However, it was questionable whether the sound-reducing effect would also occur with a limited depth of the recess – because "infinitely thin material thicknesses," as mathematical theory would demand, are not feasible in practice.

The idea to experiment with acoustic black holes in wooden structures came to Stefan Schoenwald while he was working. He asked his colleague Vallely to simulate and calculate the soundreducing effect on the computer.



INTELLIGENT NOISE INSULATION
Stefan Schoenwald and Sven Vallely verify whether the vibrations of the real wooden panel correspond to the calculations (coloured image below). The cavities are now filled with sand, which converts the vibrations into heat. A "footfall sound simulator" knocks on the panel with metal hammers.

Images: Empa

To get static concerns out of the way, Andrea Frangi, a timber construction expert at ETH Zurich, was asked for his assessment. Not only was his feedback promising, but so was the computer modeling of sound reduction. So Schoenwald commissioned a prototype and a normal control panel made of the same material from the wood construction company Strüby AG in Seewen. Using a CNC machine, wood construction specialist Alex Bellmont there milled the lenticular hollow out of a cross-laminated timber panel with dimensional accuracy. "An order like this isn't very difficult, but it's all the more exciting for it," says the machinist, "I've never made something that was then researched."

THE LATEST COMPUTING TECHNOLOGY MAKES IT POSSIBLE

The two plates – one with, one without acoustic black holes – were subjected to a vibration analysis at Empa. In this measurement, sound is conducted into the test body as a vibration over the entire relevant sound spectrum. A laser measures the vibration of the test panels in a grid pattern at several points. The measured values can then be used to calculate how the vibration moves through the plate – and whether the milled-out dents actually "capture" the sound and cause it to dissipate in the form of heat.

Ten years ago, such a series of experiments would not have been feasible. Even modeling the vibration of a small bandwidth range was a dissertation in terms of computational effort. Today, Schoenwald and Vallely calculate the entire acoustic spectrum in one afternoon and make the vibrations immediately visible as a visualization. The goal of the experiment is to examine whether the simulated results correspond to the measured values. After all, if the computer model corresponds to reality, all possible parameters can be changed on the computer almost free of charge, without having to make a new test plate each time. In this way, the sound reduction can be calculated for wooden elements all over the world without time-consuming experiments. This means that sound reduction can be optimized for wooden elements of all possible sizes and geometries without time-consuming experiments.

BETTER INSULATION PERFORMANCE WITH LESS WEIGHT

Result of the tests: The measured values agree very well with the model calculation. Stefan Schoenwald is very satisfied with a deviation of only about 5 percent. This deviation can be explained by the production of the boards and the natural variation of the wood, adds Vallely. The next tests with the test panels manufactured in Seewen will now follow: "We are currently working on the impact sound measurements, which we are carrying out in accordance with international standard specifications. The next step is to confirm the fire protection and structural properties," explains Schoenwald. These further tests are intended to ensure that the cross-laminated timber boards not only insulate sound at least at the standard market level, but also obtain all the necessary certifications for use in construction.

HOW IT WORKS

Stefan Schoenwald describes how the boards work like this. "When insulating impact sound, I have to keep three properties in mind at the same time: the mass of the component on the one hand, its stiffness and damping on the other. Stiffness and damping contradict each other – a soft component can be damped well, a stiff component less well." Schoenwald gives an example: "Classic solid wood ceilings are both light and stiff – so two unfavorable properties are combined here." One possible way out is to increase the mass of the component. In modern wooden houses, architects therefore install thick layers of gravel for weighting. That way, the wooden ceilings are less likely to vibrate if an adult walks across them or a child bounces around the home.

Schoenwald and Vallely are taking a different approach. "We make the wood ceilings extra soft in certain places so they can vibrate extra strongly there. At these points, we specifically dampen the vibration with a small amount of sand or gravel," explains Stefan Schoenwald. The same material, namely gravel, serves a completely different purpose here: "In our case, the gravel is not there for weighting. Instead, it is supposed to move and convert vibration into heat through its internal friction."

The result: a wooden ceiling with acoustic black holes is much lighter than a conventional ceiling and yet dampens impact sound much better. The structurally advantageous stiffness of the entire ceiling structure is retained.

ALL THAT'S MISSING IS AN INDUSTRIAL PARTNER

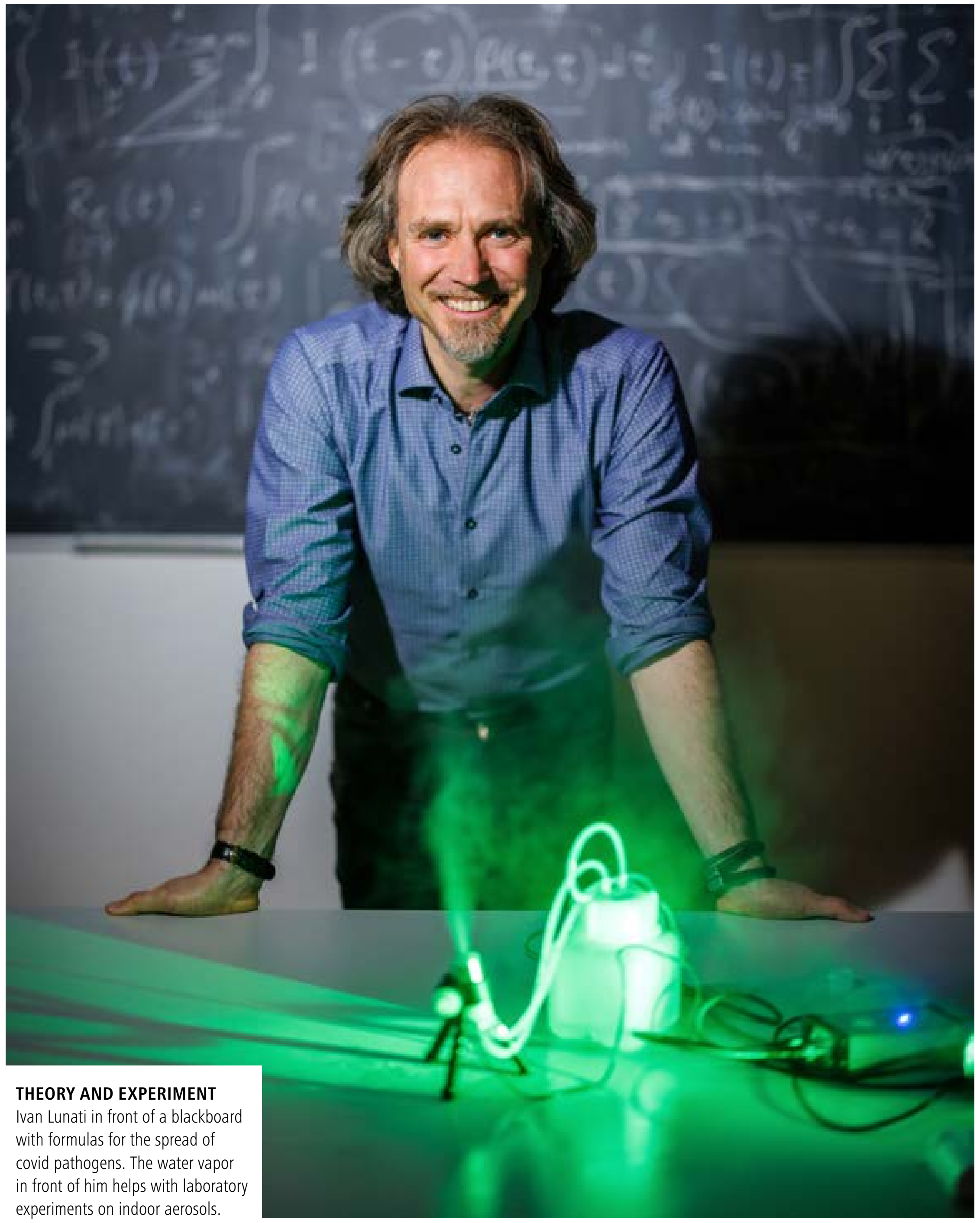
Now that the series of tests has been completed, the scientists still want to develop a method that automatically points out the best arrangement and shape of the acoustic black holes to the desired floor size and shape. This would make the method applicable to architects and civil engineers who want to apply the revolutionary damping method directly in newly built houses. The only thing missing now is an industrial partner interested in producing and distributing acoustic black holes for modern wooden buildings. ■

Further information on the topic is available at:
www.empa.ch/web/s509

DESCRIBING THE WORLD

While setting up his new lab at Empa, the Covid pandemic made Ivan Lunati's work quite a bit harder – and at the same time provided exciting questions for his research. In the future, Lunati will, together with his team, continue to address a wide range of topics – as a passionate theorist with a soft spot for practical applications.

Text: Norbert Raabe



THEORY AND EXPERIMENT
Ivan Lunati in front of a blackboard with formulas for the spread of covid pathogens. The water vapor in front of him helps with laboratory experiments on indoor aerosols.

Photo: Nicolas Zonvi / Empa

The two worlds, in which Ivan Lunati feels at home, can be seen on his office wall immediately to the left of the entry: photos of him hurtling downhill through the deep powder near Verbier. And right next to it, a whiteboard with notes, sketches, integrals, differentials ... – a "wall of ideas" because creative research work is easier for him when he's on the move.

The physicist, who heads one of Empa's scientific labs since February 2020, has enough tricky tasks. For example, the questions of where and how corona viruses spread – whether in cable cars and classrooms or throughout Switzerland and Germany. The results of this research triggered a massive response – and many media appearances with fellow researcher Hossein Gorji from his team. A topic that certainly facilitated the start of the new lab.

THE PANDEMIC AS A SOURCE OF IDEAS

But why Covid scenarios, of all things, which so many researchers have been jumping on since the beginning of the pandemic? Out of curiosity! Lunati studied the scientific literature on the spread of aerosols along with viruses and found quite a few open questions. "My life was so affected by masks and hygiene and distance rules," he said, "I wanted to understand why my world was suddenly upside down." And everyday work even more difficult: working from home and other measures certainly didn't make establishing the lab any easier, Lunati adds.

In the meantime, his team has taken shape: three senior researchers plus postdocs, students and experienced technicians are already staffing the lab, which also includes a water and a wind tunnel – large-scale infrastructure for experiments that can be used to explore complex flow phenomena.

For example, for Covid research. To better understand how droplets containing pathogens move and spread in the air, the team developed a "cough machine." As if from lungs, two piston tubes exhale compressed air from a "mouth" with relative humidity, temperature, and droplets as if from a human. Two cameras in the wind tunnel record how the droplets move about. Using tiny particles to visualize air movements, more accurate models can be developed of how viruses spread in real life.

This is uncharted territory for Lunati and his team, who have all the more experience in other areas. His longstanding research interest is porous media. And the question: How can we describe mathematically which substances move how in those media? A picture on the lab's homepage illustrates how tricky this is: What appears to be a tangle of colored worm tubes shows the shape of air penetrating a sandstone with tiny pores, the physicist explains with a point of his finger – displacing water that was there before.

Complex insights with practical value: Years ago, Lunati was already helping to make such knowledge useful for groundwater, radioactive waste storage, petroleum deposits or environmental problems. "Companies invest a lot in numerical methods," says the physicist, "you have to be able to describe how water, oil or gas moves in the underground reservoirs – from the smallest pore in the rock to the scale of kilometers." Such insights could also help in future climate protection efforts to safely store atmospheric CO_2 underground.

For the past 20 years or so, the physicist has been working on multiscale modeling, as this field is called, which research groups around the world are working on: simulations from the smallest to the largest – for example, from the quantum scale to atomic and molecular bonds to structures visible to the naked eye. Such models could also be useful for new materials. Take aerogels, for example: In future, these extremely porous materials will be used to filter CO_2 molecules from the atmosphere. When it comes to the question of how an aerogel has to be manipulated in detail for this purpose, Lunati's team cooperates with scientists in other Empa labs.

COMMUNICATE AND CONNECT

Porous media as a beacon of hope? Seemingly hard to convey to laypeople, but Lunati once brought it closer to children – at an open lab day at the University of Lausanne. Using the example of drinking water production, he recounts with a mischievous smile, "I played with sand, water and porous material, from a 3D printer. Simply to stimulate the children to engage with research."

Making complex things intelligible gives him palpable pleasure – and is by no means a contradiction to how he sees himself. "I'm a theoretical person," Lunati says, "theory is important to me." But that doesn't mean he neglects a practical view – on the contrary: "If I work on devising new models, they can later on be used by other people – in a wider variety of fields."

That's his vision for other topics as well. Take embodied machine learning, for example: Drones, which Empa experts are developing, could be equipped with sensors and novel algorithms to become intelligent by learning while interacting with their environment to collect data. Take the spread of corona viruses, for example: Instead of conventional computational models ►

IVAN LUNATI

CAREER Postdoctoral studies at ETH Zurich, Institute of Fluid Dynamics, Senior Scientist at ETH Lausanne, SNSF Professorship at the University of Lausanne, Institute of Earth Sciences. Since February 2020 Empa Head of Department

SCIENCE Physics studies at the University of Milan, PhD at ETH Zurich, research on porous media, fluid dynamics, multiscale modeling, data science and other fields with numerous publications. Member of numerous expert committees and panelist for funding agencies..

that simulate viral spread based on different populations, future models could even link single individuals.

Lunati reaches for a printout on the office desk: beneath a map of Switzerland, a circular network of countless black spots connected by pale strokes. "These dots could describe people and all the lines their contacts," he explains. Such a network does not emerge from classical statistics, but from intelligent data. Such methods could also reveal unknown interactions and could be used to refine conventional models.

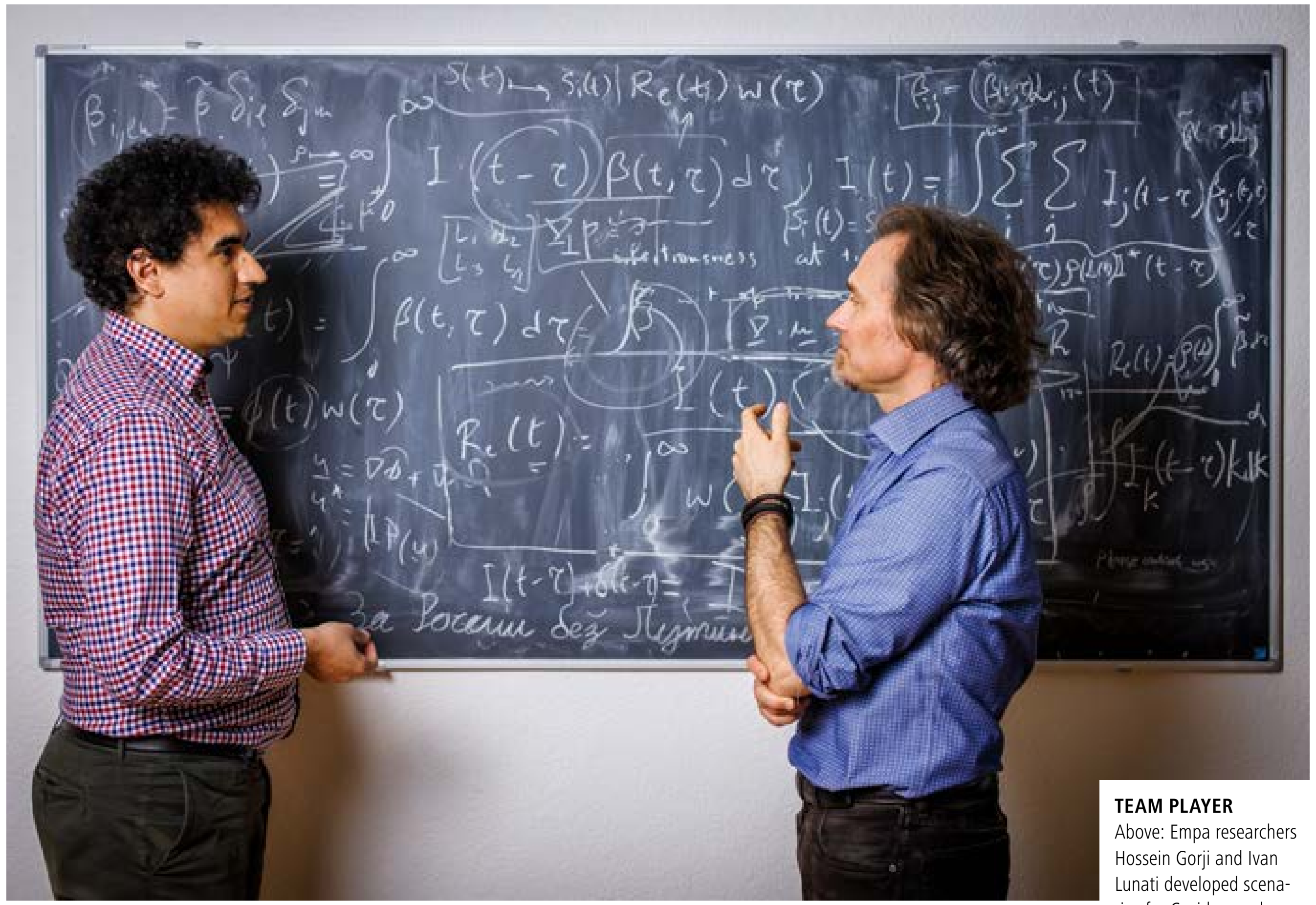
INTUITION AS A RESEARCHER'S VIRTUE

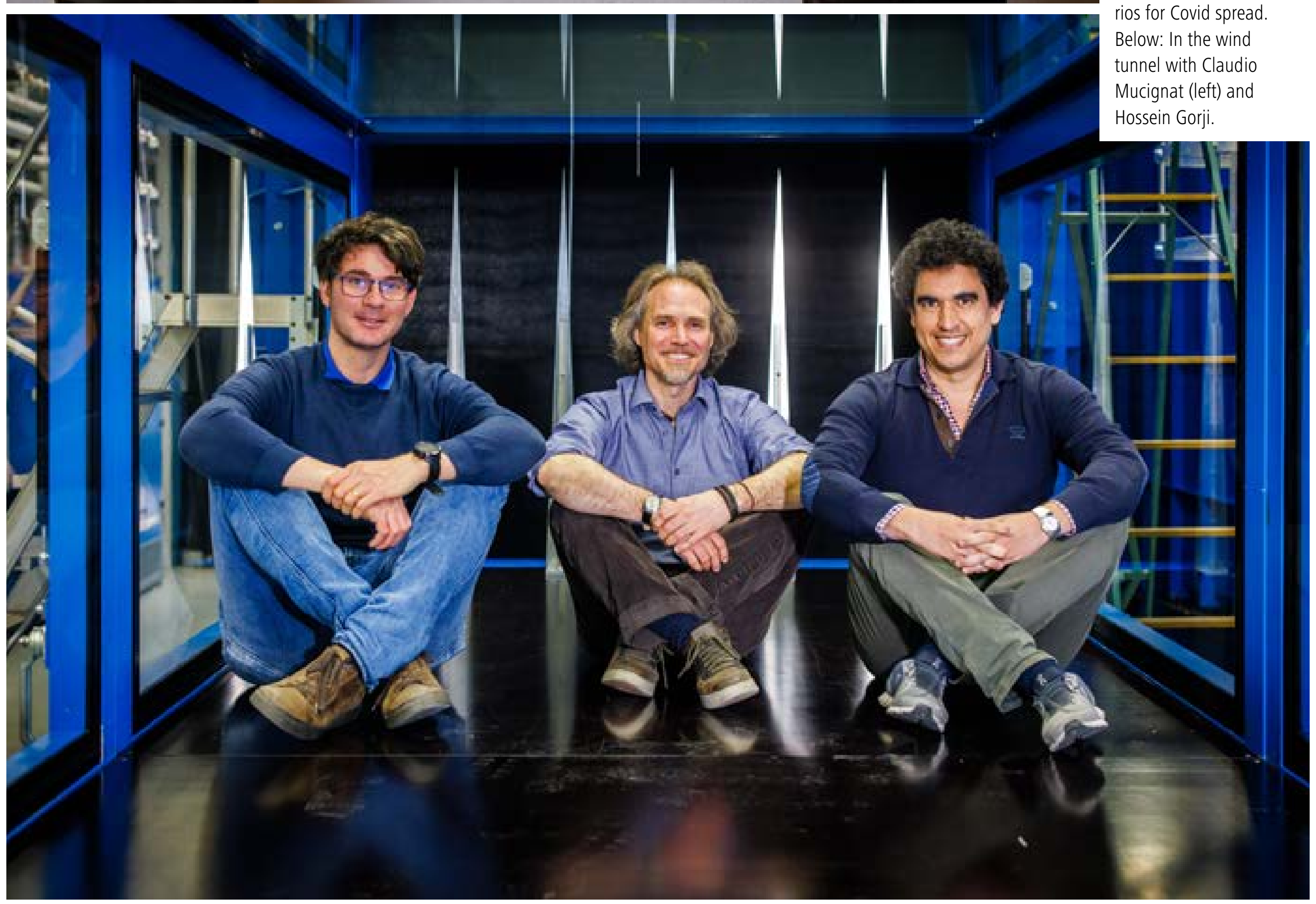
When Lunati talks about science, you can feel his enthusiasm for ideas ... – the whiteboard in his office will hardly ever be blank. Just like the classic blackboard in the bright hall his team uses for meetings and discussions, littered with mathematical formulas. Eventually, Lunati also wants to impart a way of thinking, a mindset: a certain intuition to simplify and not drown in masses of data – not just finding some formula, but a simple and, yes, also a beautiful solution to the problem at hand.

"In that sense, I'm an old-fashioned scientist," he admits, "I want to describe the world." Reduce the complexity – for solutions and ideas that can then be applied to a variety of questions. That's how he would like his lab to be: diverse, yet at the same time focused so that its research can be summed up in one sentence. And yes: His team should still grow. "On a hundred-meter sprint, we'd be at 50 meters now," he says, "but it's a marathon, really." ■

Further information on the topic is available at: www.empa.ch/web/s305

Photos: Nicolas Zonvi / Empa





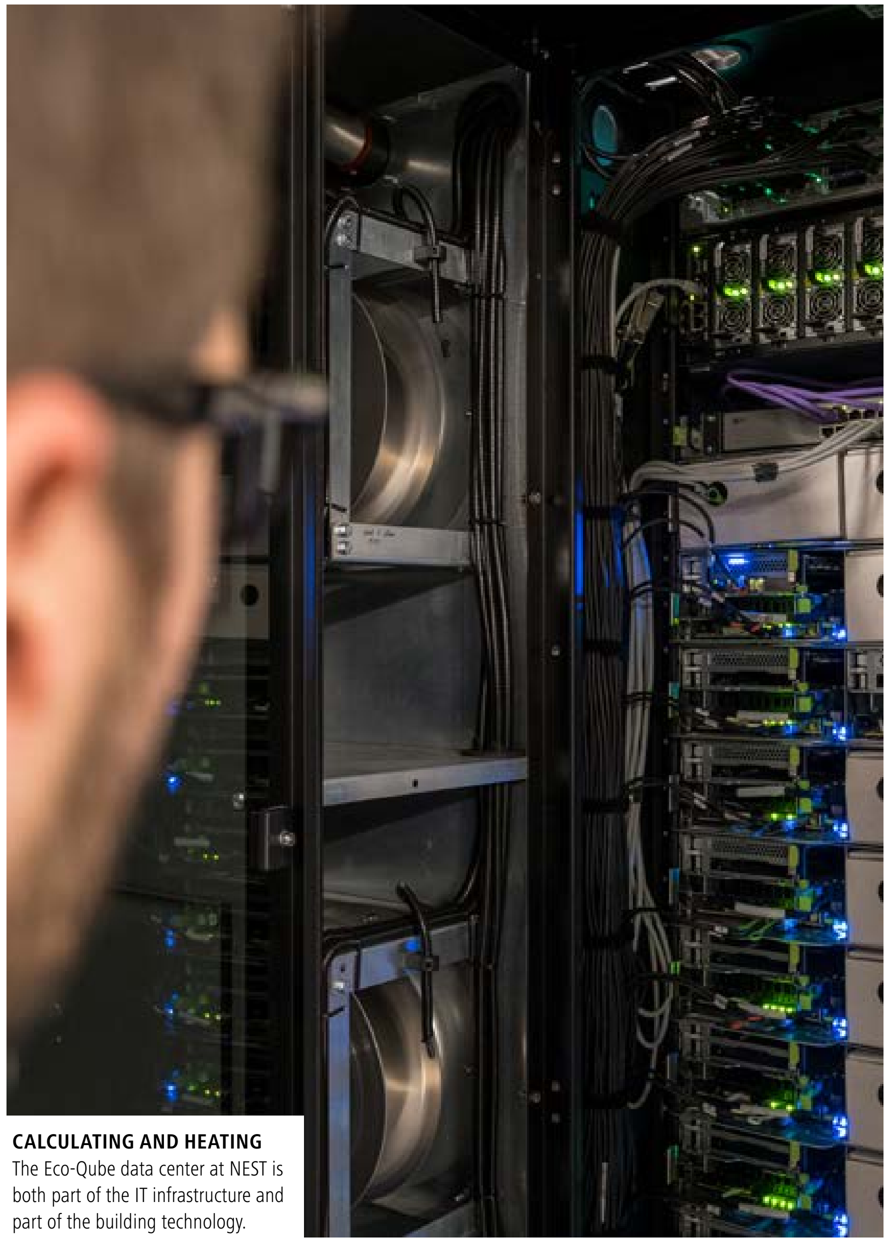
TEAM PLAYER
Above: Empa researchers Hossein Gorji and Ivan Lunati developed scenarios for Covid spread. Below: In the wind tunnel with Claudio Mucignat (left) and Hossein Gorji.

DATA PROCESSING PROVIDES HEAT

A newly installed data center in the NEST research building is not only used for data processing, but also helps to heat the entire building. The server system is part of the international EU research project ECO-Qube, which is investigating the integration of data centers into building systems and their energy-efficient operation.

Text: Stephan Kälin

"The trend toward the Internet of Things means we need to process data locally again – where the data comes from."



CALCULATING AND HEATING
The Eco-Qube data center at NEST is both part of the IT infrastructure and part of the building technology.

Photo: Empa

A click on the internet leaves traces behind. Not only in the web itself, but also in the form of a large ecological footprint. Because even though all our data is supposedly floating in the cloud, physical data centers are required to process and store it, and these consume huge amounts of energy – a significant proportion of which is used to cool the facilities due to the enormous amount of waste heat that is generated during computation. The big tech giants are now well aware of their responsibilities, investing generously in renewable energy and looking for ways to optimize the energy efficiency of their server farms. One of these paths, for example, leads to the Arctic Circle, where some of the largest data centers are currently located. The cold temperatures there help to reduce the amount of energy needed to cool the equipment.

With the latest digital trends such as artificial intelligence (AI), augmented reality (AR) and the Internet of Things (IoT), however, further challenges lie ahead: The volumes of data to be processed are increasing rapidly, and at the same time, reactions are required in real time – without delay. To achieve this, the processing of the data must move closer to the place where it was created. For instance, in the form of a micro data center in the neighborhood. In the best case, however, this local data center will not only be used for data processing, but – connected to the energy system – will also be used to heat the building. A field test with micro data centers in the NEST research building at Empa and at two other locations in Turkey and Netherlands aims to explore the potential of this idea.

INTELLIGENT COOLING

The project, called ECO-Qube, is supported by the EU's Horizon 2020 program and brings together research and industry partners from Switzerland, Turkey, Spain, Germany, Netherlands and Sweden. "Our goal is to reduce both the energy demand and CO_2 emissions of small data centers by one-fifth each," says Çağatay Yılmaz, Innovation Manager at Turkish IT solution provider Lande and ECO-Qube project leader. According to the Sustainable Digital Infrastructure Alliance, another project partner, conventional data centers often operate at only about 15 percent of their capacity. Despite this, the servers constantly need power and are cooled. To counter this problem, the cooling of the ECO-Qube data centers is made intelligent: Sensor data from the individual IT components are accumulated into Big Data structures and help to ensure that the heat distribution within the components is accurately recorded at all times. AI combines this data with airflow simulations so that cooling can be specifically targeted. At the same time, the computing loads in the three test data centers in Switzerland, Turkey and the Netherlands are distributed in such a way that all three facilities can be operated as energy-efficiently as possible.

REUSING WASTE HEAT

The three data centers will be integrated directly into the energy systems of their surrounding neighborhoods and are to be supplied with renewable energy whenever possible. In NEST, for example, the electricity for operating the data center is provided by the photovoltaic systems of the NEST units and Empa's mobility demonstrator, move, among others. The waste heat from the data center is fed into the existing medium- or low-temperature network. In winter, it thus directly feeds the building's heating system and, over the year, simultaneously serves as a source for a heat pump that provides domestic hot water.

"For us, it is interesting to consider the micro data center not just as an electrical consumer, but as a dynamic component in the overall system that we can use so that calculations take place when it makes sense ecologically. The coupling of the electrical and thermal world with the IT infrastructure and data processing offers great potential for optimization towards sustainable operation," says Philipp Heer, Head of the Energy Hub (ehub) at Empa.

The project will last about three years. After completion, the team hopes to be able to provide guidelines for planners and building operators to help them integrate data centers into buildings and neighborhoods in an energy-efficient manner. ■

Further information on the topic is available at: https://eco-qube.eu/

EMPA RESEARCHER TO HEAD THE EUROPEAN CERAMIC SOCIETY

Thomas Graule, head of Empa's High Performance Ceramics lab, has been elected president of the European Ceramic Society ECerS – the umbrella organization of 28 national associations that provides training for researchers, organizes international conferences and promotes the exchange of scientific publications in the field of ceramics research. ECerS also represents the interests of the European ceramics industry and provides a link between academic research and the application of ceramic materials.

https://ecers.org

COORDINATOR
Thomas Graule will assume the presidency of the ECerS from 2023 to 2025.

JOINING THE COMPUTER RESEARCH NETWORK MARVEL

COMPLEX SOLUTIONS
Daniele Passerone is an expert in computer simulations in the field of materials science.

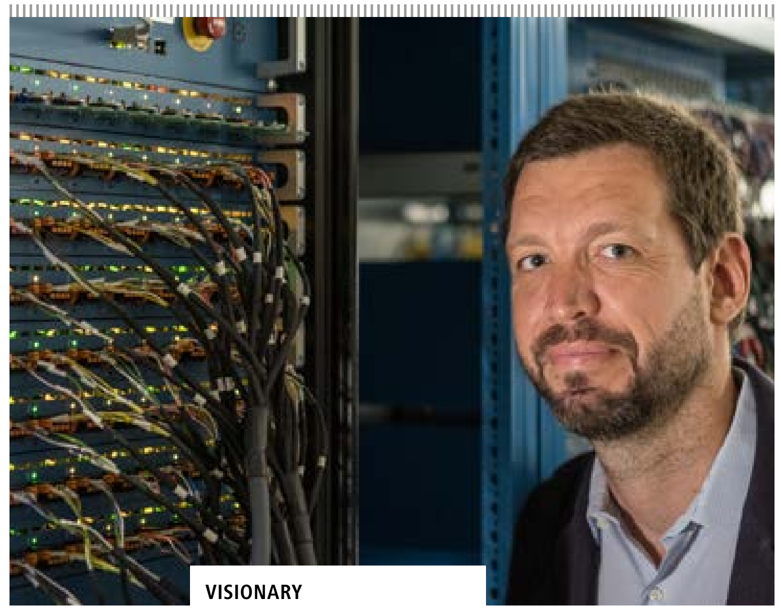
ETH Zurich has appointed Empa researcher Daniele Passerone as titular professor in March 2022. He has been conducting research at Empa since 2006, where he leads the Atomistic Simulations team at the nanotech@surfaces lab. The activities of Passerone's team range from modeling atomic, electronic and scanning tunneling microscopy via the thermodynamics of growth and the structural or electronic properties of clusters, materials and films to the study of surface-based nanostructures. Recently, Daniele Passerone's group has also joined the National Center of Competence in Research for the Development of Novel Materials Using Computers (NCCR MARVEL).

https://nccr-marvel.ch/research/ii/design-and-discovery/low-dimensional-materials

Photos: Empa

Photo: Empa

CIRCUBAT IMPROVES LIFE CYCLE ASSESSMENT OF E-MOBILITY



VISIONARY
Empa researcher Corsin Battaglia leads a subproject of the CircuBAT research project.

The CircuBAT research project aims to close the loop between production, application and recycling of lithium-ion batteries for mobility. To this end, seven Swiss research institutions and 24 companies are working together to find ways of optimizing the processes. Of the seven subprojects, three are led by Empa researchers. The Battery Cell Production subproject aims to make the manufacturing process more energy-efficient. By far the most energy-intensive step in the production of a lithium-ion battery cell is the drying of the battery electrode after coating. Dry electrode coating would eliminate this step, resulting in significant energy and cost savings. Corsin Battaglia is leading this subproject.

https://circubat.ch/

EVENTS

(IN GERMAN AND ENGLISH)

10. MAI 2022
Tropical Day: Imaging and Image Analysis XIII
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/imaging
Online

20. MAI 2022
Kurs: Elektrochemische Charakterisierung und Korrosion
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/korrosion
Empa, Dübendorf

29. JUNI 2022
Technology Briefing: Materials for CO_2UNTdown – Mit innovativen Materialien zur CO_2-Neutralität
Zielpublikum: Wirtschaft und Industrie
www.empa-akademie.ch/technology
Empa, Dübendorf

1. JULI 2022
Kurs: Hightech-Keramiken
Zielpublikum: Industrie und Forschung
www.empa-akademie.ch/ht-keramik
Empa, Dübendorf

13.–15. SEPTEMBER 2022
Biointerfaces International Conference (BIC) 2022
Zielpublikum: Industrie und Wissenschaft
www.biointerfaces.ch
ETH, Zürich

Details and further events at
www.empa-akademie.ch

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