Empa News

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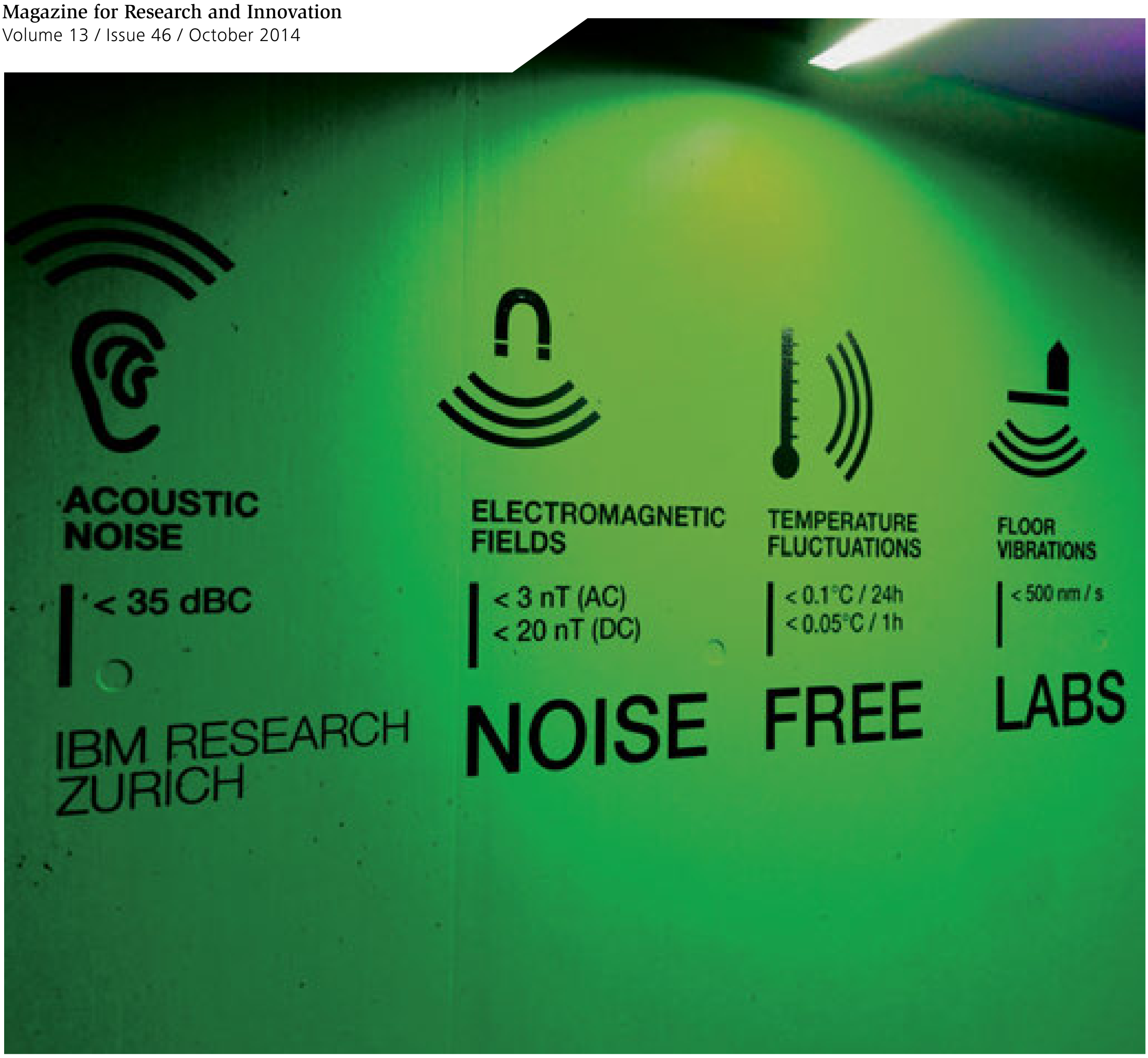


The great silence

EMPA
Materials Science & Technology

Scouring the atmosphere for pollutants

Comet hunt: Empa technology sniffs out clues

Ceramic brakes for compact cars

MICHAEL HAGMANN Head of Communications

A hole in the ozone layer – and in beer cans

Dear readers

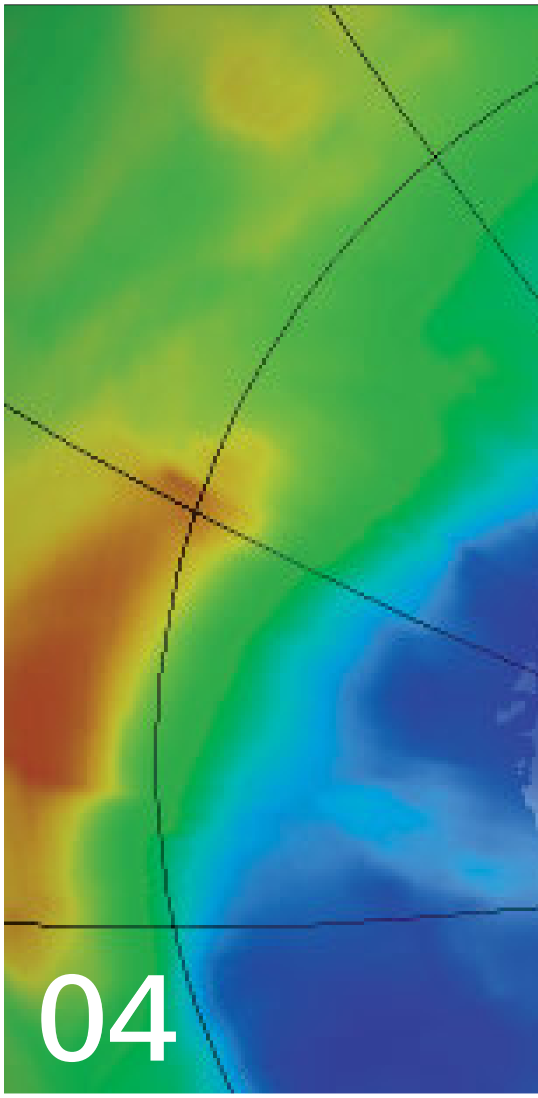
"Bad news is good news", as they say in the media industry. Because that's what sells. And we're no strangers to bad news when it comes to the environment: melting polar ice caps, pollutants in glacial ice, more and more endangered species, plastic waste in the oceans. The shape our planet is in, it would seem, is going from bad to worse.

However, there are also a few glimmers of hope: the hole in the ozone layer above the Antarctic is not getting any bigger at least and might even replenish itself over the next few decades, according to a recently published UN report, in which Empa researchers played an instrumental role. A success story that did not come about by chance but was made possible through a global treaty, the Montreal Protocol – yet another reminder of how crucial international collaboration and partnership are these days. What came up trumps for the hole in the ozone layer, however, is still hanging in the balance for climate change – cue the Kyoto Protocol. At any rate, the physicochemical relationships that influence our global climate are way more difficult to read than the action mechanisms of ozone killers.

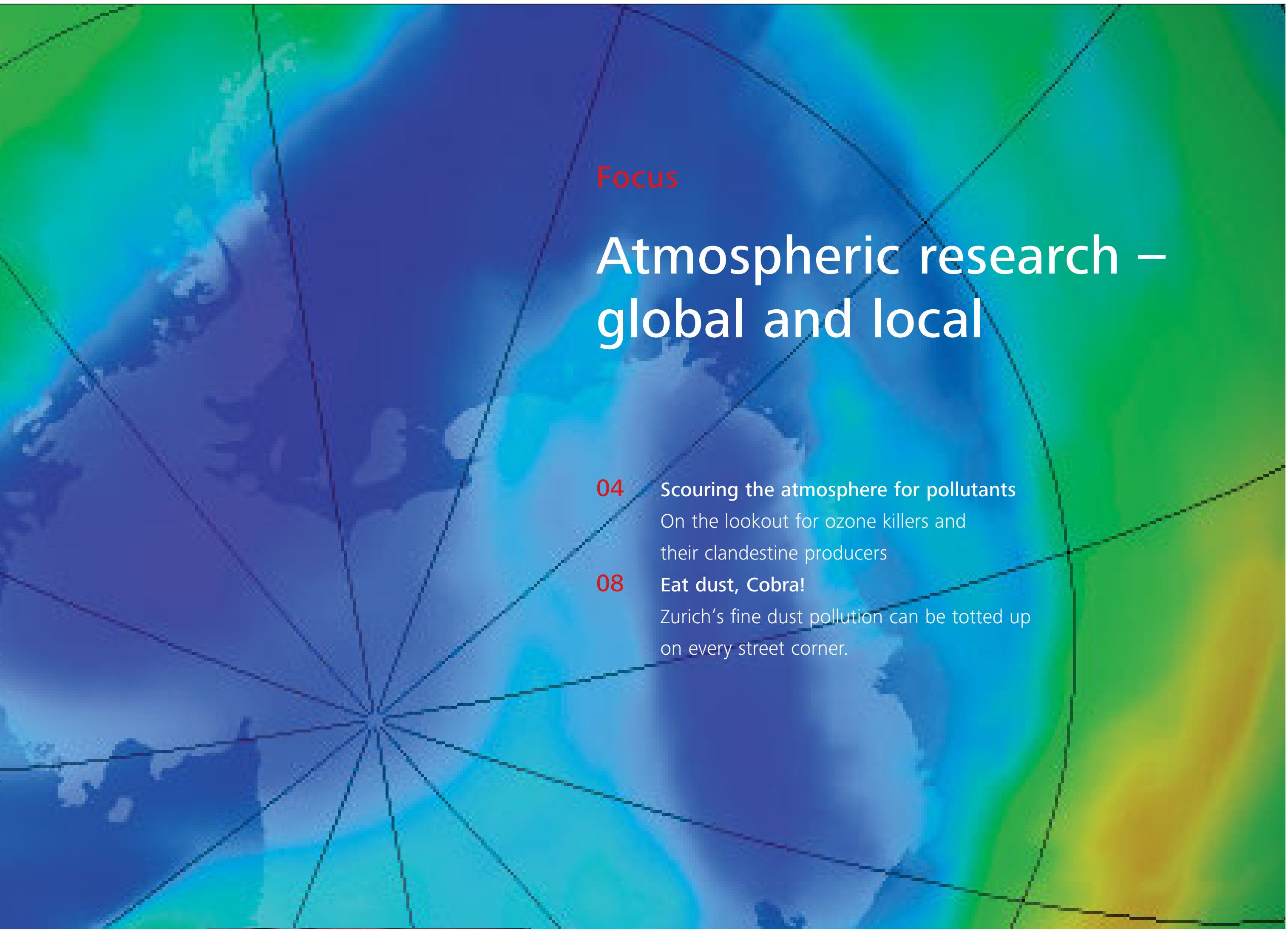
Ecology and the environment also take center stage for Empa researcher Bernd Nowack. The environmental scientist recently featured on an illustrious list: The world's most influential scientific minds by Thompson Reuters. Congratulations on this honor! Nowack is studying the impact of synthetic nanoparticles on the environment – and has a somewhat unusual (and aesthetically worthwhile) hobby: solarigraphy. Find out what this is all about and why perforated beer cans are important in the portrait on page 14.

Speaking of the environment: if you want to save on postage and paper for EmpaNews, our magazine is also available as an app for iPad and Android tablets. Info and downloads at www.empa.ch/app.

Enjoy reading!

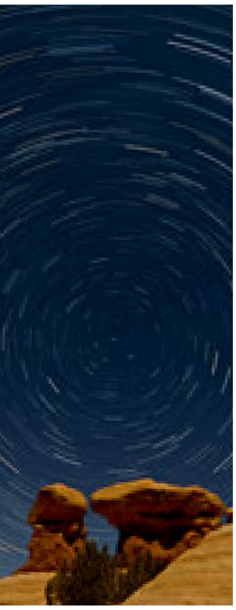


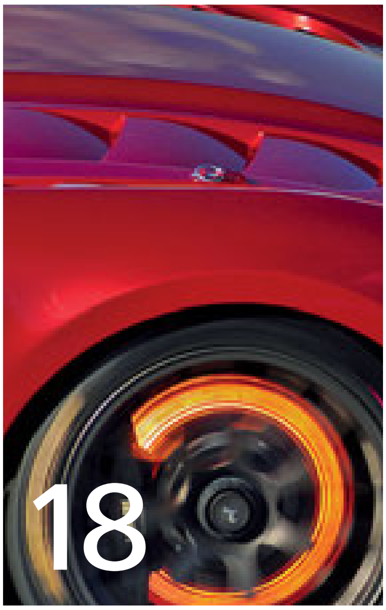
Cover
One of the six "noise-free labs" at the IBM Zurich Research Laboratory in Rüschlikon where Empa and IBM researchers have been operating a special microscope capable of displaying details that are smaller than the diameter of an atom since the summer of 2014. The microscope weighs 1.5 tons but needs absolute calm: even the gentle breeze from an AC unit is enough to distort the reading. ***Page 20.***



Focus

Atmospheric research – global and local





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Scouring the atmosphere for pollutants

CFCs are still harming the ozone layer; industrial gases with a high greenhouse potential heat up the atmosphere. The polluters don’t go undiscovered, though. Empa atmosphere scientists are tracking the trace gases with highly sensitive instruments and identify the sources of pollution with the help of meteorological data.

TEXT: Rainer Klose / PICTURES: iStockphoto, Empa, Nasa

Praying and hoping for improvements wouldn't have done any good. In 1987 the dwindling ozone layer could only be saved through an international agreement – the Montreal Protocol. 197 countries have since ratified the treaty and banned the worst ozone killers: greenhouse gases in spray cans and synthetic foams, cooling agents and fire extinguishing gases. The most recent model calculations show that the earth's protective shield is slowly starting to recover. By around 2050 the ozone layer above the southern hemisphere will probably be as thick as in 1980 – if we continue to be on our guard.

Stefan Reimann along with his team is monitoring which substances are particularly damaging for the ozone layer right now. The Empa scientist sits in a rather quiet room in the basement of the laboratory building on Empa's Dübendorf campus. The computer is his tool. This is where the data from the AGAGE network are collated – Advanced Global Atmospheric Gases Experiment. Around the world ultrasensitive scientific instruments literally keep their noses in the wind to identify trace gases that shouldn't be there. The Swiss nosy parker is located 3,580 meters above sea level at Jungfraujoch, the Irish one at Mace Head on the Atlantic coast and the Norwegian one at Ny-Ålesund on Spitzbergen.

Every two hours these devices "breathe" in two liters of air from their environs and draw it through an activated carbon filter cooled to -170 degrees Celsius. At the end of the measurement the filter is

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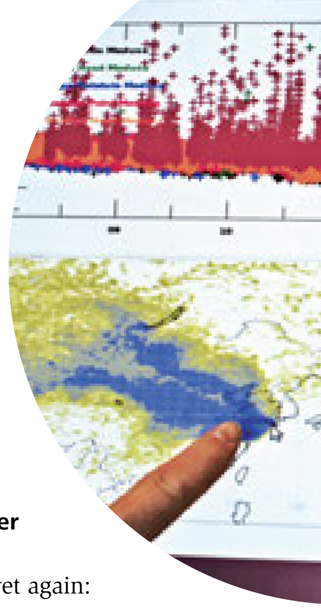
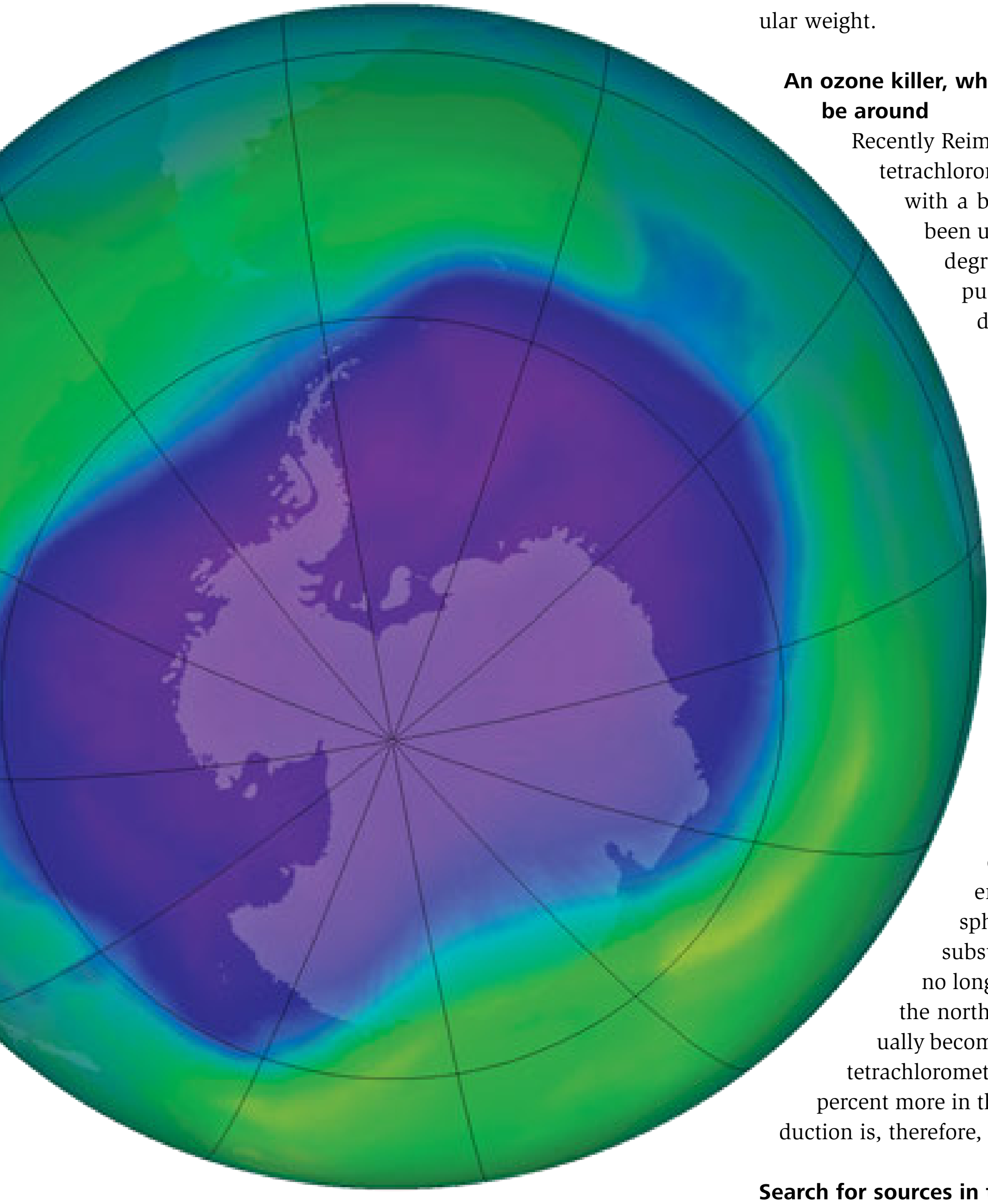


heated to more than 100 degrees and the captured chemical substances are placed in a GC-MS, a gas chromatograph with an attached mass spectrometer. There each individual substance can be identified thanks to its signature molecular weight.



An ozone killer, which should no longer be around

Recently Reimann was surprised yet again: tetrachloromethane, a sweet-smelling liquid with a boiling point of 77 degrees, which had been used in the past in fire extinguishers and as a degreasing agent in workshops and chemical purification (it is globally banned today), is disappearing far more slowly from the atmosphere than expected. Normally, the substance would gradually degrade in the atmosphere – the concentration should fall by about four percent every year. But this isn't happening as Reimann could see from his data. It is only falling by around one percent a year. This means that new tetrachloromethane is being emitted somewhere. The researchers estimate a volume of 39,000 tons a year. The substance may still be used by industry as an intermediate product for chemical syntheses – but small leaks in a few factories here and there still don't go far enough to explain such an emission level.

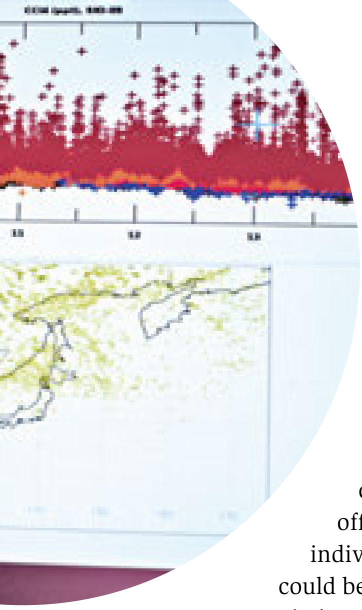
And another clue in Reimann's data points to ongoing tetrachloromethane emissions. "Around 90 percent of global emissions come from the northern hemisphere", explains the atmospheric chemist. If a substance – for instance after a global ban – were no longer to be emitted, then the concentrations in the northern and southern hemispheres would gradually become aligned. Reimann: "This is not the case for tetrachloromethane. We consistently measure one to two percent more in the north than in the south. In the north production is, therefore, continuing."

Search for sources in the atmosphere

Whenever high concentrations are measured at Jungfraujoch, the Empa researcher compares the noticeable peaks in his measurements with meteorological data. The air currents during the measurement reveal at which location the substance was blown into the air. "The source of tetrachloromethane is not in Europe", comments Reimann, "that's for sure". As the European measurement stations on their own are not capable of pinpointing any exact location in the rest of the world, the Empa scientist looked into the dataset from the AGAGE network. And in fact: one station in South Korea identified major peaks, which means some of the emissions are likely to come from Asia.

To ensure that politicians and the public also take note of the most recent findings about the condition and chemistry of the at-

Video
What would have happened if CFCs hadn't been banned in 1987? An animation by NASA provides the answer.



mosphere, Stefan Reimann and his international colleagues regularly publish articles in scientific journals and pass on the data to the Federal Office for the Environment (BAFU) and other national authorities. There the Empa observations are compared with estimates based on the official emission data reported by the individual countries. These findings could be included in the next round of negotiations about adjustments to the Montreal Protocol. Reimann also regularly writes reports for the World Meteorological Organization (WMO) in Geneva. His latest report is brand-new, dating back only to September 2014: Scientific Assessment of Ozone Depletion. In this report he warns about the growing indirect influence of climate gases such as laughing gas, methane and carbon dioxide on the ozone layer. Furthermore, increasing levels of fluorinated hydrocarbons (HFCs) are already beginning to reverse the progress of the Montreal Protocol in countering global warming. So the problem hasn't been solved for good.

Greenhouse gases from northern Italy

The researchers not only catch ozone killers but also classical greenhouse gases (regulated under the Kyoto Protocol) in their "dragnet operation". One particularly harmful greenhouse gas is HFC-23 (trifluoromethane). The substance is formed as a by-product during the manufacture of HCFC-22, which is used amongst other things to make Teflon. The manufacturers are obliged to report HFC-23 emissions. But it seems they only do this sporadically. Italy, for example, reported an annual emission of 2.6 tons for 2009 – the measurements at Jungfraujoch showed, however, that, during the period in question, between 26 and 56 tons were released into the atmosphere over northern Italy, to be more precise from just one factory. What makes this situation so critical: HFC-23 has a climate impact about 15,000-fold stronger than that of carbon dioxide (CO_2). In other words: in just one year this factory's emissions contribute the equivalent of 50,000 Italian mid-range cars that each travel 10,000 kilometers to global warming.

According to Reimann these measurements are – unfortunately – not yet being used to verify the Kyoto Protocol for imposing international limits on the greenhouse effect. The reason: his analytical method that compares trace gas measurements with weather data was only validated ten years ago. The Kyoto Protocol, however, was already negotiated in 1997 and entered into force in 2005 before the negotiators were familiar with today's skills of the "atmosphere detectives". And so it is left to each individual country to correctly report its emissions (or not) until the next climate summit. //

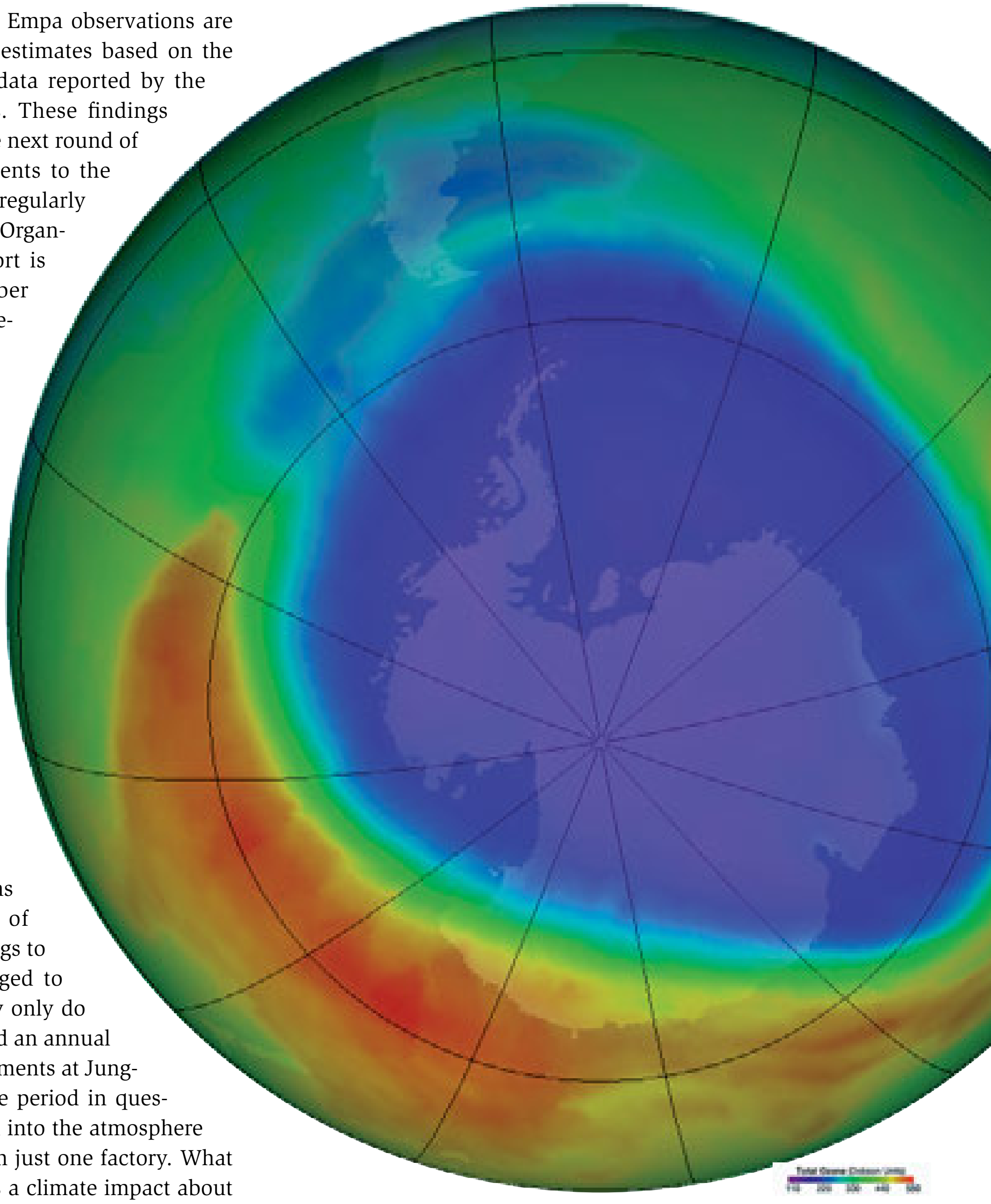


Photo left: On September 24, 2006, the hole in the ozone layer was at its biggest to date.

Photo right: The hole in the ozone layer over the Antarctic measured on September 18, 2014.
Source: http://ozonewatch.gsfc.nasa.gov/
(The Dobson Unit scale reveals the total amount of ozone from the Earth's surface into the empty cosmos.
Bluish-purple: lowest ozone levels; red: highest levels.)

Photo top: The ozone killer tetrachloromethane is still produced in large amounts in Asia. Thanks to the global AGAGE monitoring network, the region where the pollutant comes from can be identified.

1

Eat dust, Cobra!

Whilst some atmospheric researchers at Empa look at global effects, their colleagues investigate air quality in downtown Zurich. Special fine dust sensors mounted on Cobra trams travel around the city generating huge amounts of data. The researchers then use these data to determine pollution in the city.

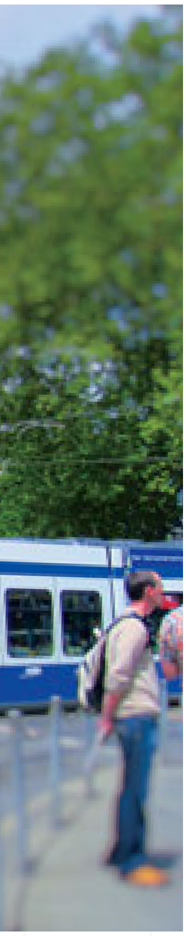
TEXT: Rainer Klose / PICTURES: VBZ, Empa

1
The roofs of ten Cobra trams from the Verkehrsbetriebe Zürich (VBZ) are fitted with fine dust gages operated by ETH Zurich. (Photomontage: Empa)

2
Empa researchers use the data from these fine dust readings to calculate a detailed air pollution map for the Zurich metropolitan area – down to a precision of 10 · 10 meters. The map shows pollution levels on a thursday morning in Winter 2014.

Urban air currents and the related spread of air pollutants are complex. Nevertheless, town planners, air quality experts and, last but not least, residents want to know in which quarters air quality is satisfactory and where pollutants accumulate. The biggest emission sources are known: cars and heating systems. Where buildings are less dense and air can circulate freely, pollutants are diluted more quickly. Where buildings are more compact the air rapidly becomes heavier.

So far, so good. However, anyone trying to determine the level of pollutants in every corner of the city has to resort to a model. Christoph Hüglin and Michael Müller have set themselves the goal of simulating pollution in urban areas on the computer. In future, a simulation tool is to be established, which will precisely describe the link between pollution and geographical and urban information and then calculate pollution at every location – even where measurements have never taken. The researchers use Zurich to examine and refine their computer model.



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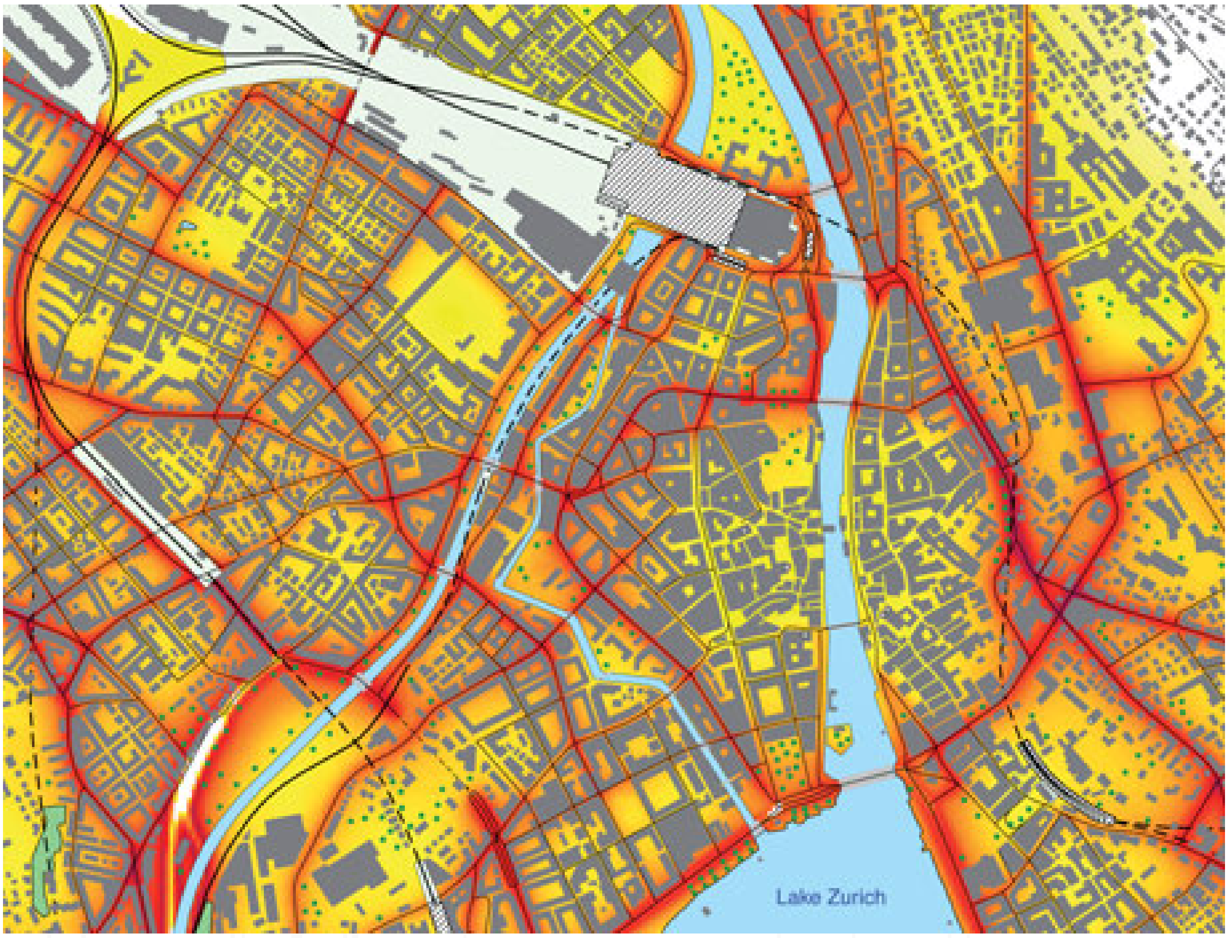


Zurich as a model

The Zurich municipal authorities supply the basic data: a three-dimensional urban model, the land register of residential heating systems, transport data. These parameters are supplemented by up-to-date fine dust measurements from various parts of the city. In this context, the Empa researchers draw on data from the OpenSense measurement network operated by scientists from ETH Zurich. Ten special sensors move around the city throughout the day, mounted on the roof of trams, and measure fine dust. Currently Hüglin and Müller are only using the fine dust measurements. But as soon as sufficiently reliable measurements are available for other airborne pollutants, these can likewise be calculated using mathematical models that generate pollution maps, say for nitrogen oxides or carbon monoxide, with a very high resolution of both time and space.

Two disciplines have joined forces in this project. Christoph Hüglin has been working for many years in air research and is very familiar with the pollutants' dispersal pathways. Michael Müller has a PhD in geomatics engineering and is an expert in the evaluation of GPS data and the modelling of spatial processes. A number of modelling problems have to be solved: Zurich's tram lines do not cover the entire city. What's more, the ten trams equipped with sensors have alternating schedules and are only out and about in an irregular manner. Hence, there is an abundance of data for tram hot spots like "Bahnhofsplatz" whereas the pollution on the slopes of the Züriberg is only documented sporadically by one "sensor tram line". There are not enough night measurements either. Nonetheless, the calculations already function quite well. The researchers can do without weather data as the weather conditions are reflected indirectly in the measurements themselves. "Rain, for instance, washes pollutants out of the air", says Hüglin. "The measurements are then much lower."

Urban walks furnish the evidence

But even the best model must stand up in reality and lend itself to examination. Are the measurements accurate at the edge of the forest, too? Is the pollutant gradient correctly predicted on the transition to the urban area? Additional measurements in the city will have to demonstrate this. And that's why geomatics engineer Müller was out and about in January with a measurement device in his rucksack. He did 16 city hikes in various districts along busy roads, through suburbs and along the edge of the forest.

The result: the project is progressing well. Already now the team can accurately calculate fine dust pollution in downtown Zurich to a precision of 10 x 10 meters and in a 30-minute window. Of course, there is still some room for improvement. "If we could look at up-to-date traffic data in our model, this would considerably improve accuracy", says Christoph Hüglin. And Michael Müller adds, "Additional sensors on the edge of the forest and in urban clean air districts would supply important information on background pollution."

Ultimately, the pollutant maps developed at Empa will be helpful not only for air quality experts and urban planners but also for health researchers and the interested public. //

To boldly go where no man has gone before

Rosetta has arrived. After a lengthy voyage through space to the comet 67P/Churyumov-Gerasimenko – affectionately nicknamed Tschuri by the researchers – the space orbiter has now reached its final destination. Also on board are highly complex Empa sensors made of metal ceramics, incorporated into two mass spectrometers.

TEXT: Cornelia Zogg / PICTURES: ESA

Over ten years ago, the space probe Rosetta embarked on its voyage into space with the aim of accompanying the comet for a year and, for the first time, setting a lander (Philae) down on its surface – a major undertaking and the pride and joy of the European Space Agency (ESA). A short while ago, the final brake maneuver was successfully completed, enabling the space probe to inspect and record the target comet 67P/Churyumov-Gerasimenko from all angles. Comets are regarded as primitive masses in our solar system and may have carried water or even simple building blocks for life to Earth. However, many fundamental questions concerning these giant lumps made of dust and ice remain open, which is where Rosetta comes in. The comet's first images from approximately 12,000 kilometers away reveal that Tschuri consists of two lumps that are connected via a "neck", making the comet look like a giant rubber duck.


Target comet "Tschuri"

Empa on board

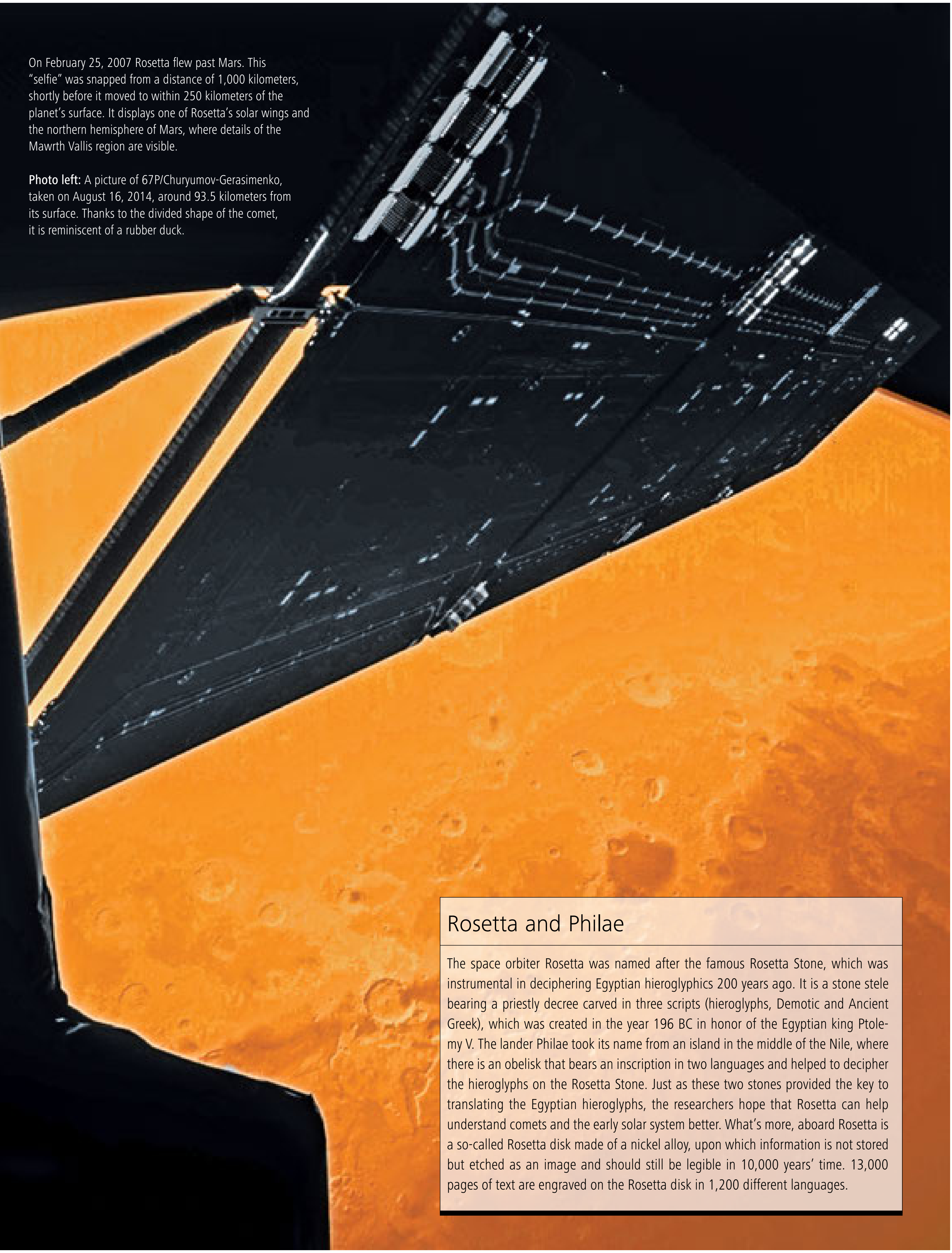
One of the numerous pieces of equipment on Rosetta was developed with Empa's help. The instrument group ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) was developed within a project lead by the University of Berne. It comprises two mass spectrometers, a pressure sensor (which also gages the temperature and velocity of the comet gas) and a data-processing unit. The Berne team brought in Empa, which assumed the development and production of the ion-optic sensors for the two spectrometers. Not only do these need to be light; they also have to withstand the harsh conditions in space.

After the cosmic rendezvous with the comet, ROSINA is supposed to analyze ions and neutral gas particles in the (extremely "thin") atmosphere and the ionosphere of 67P/Churyumov-Gerasimenko. After all, this enables conclusions to be drawn regarding the origin of our solar system. The mass spectrometer DFMS (double focusing mass spectrometer) has two different operating modes: a gas mode to measure neutral gas particles and the ion mode to analyze ionized particles. The time-of-flight mass spectrometer RTOF (reflectron time of flight) enhances the DFMS by increasing the sensitivity of the entire instrument. In the process, the mass is analyzed using the "time-of-flight" technique. The combination of an extremely high mass and temporal resolution enables snapshots of the entire mass range from one to 1,000 amu (atomic mass unit).

Successful process development

The ion-optic structural components for both mass spectrometers were developed and produced by a team lead by Empa engineer Hans Rudolf Elsener. One major challenge was to convert the astrophysicists' ideas and requirements into a multi-functional, "space-worthy" product that satisfied the highest demands: it needed to be ultra-light, mechanically robust, high-voltage-proof and extremely precise. Besides tweaking the design, Elsener developed various processes to combine different substances, such as metals and non-metals (ceramics). For instance, the individual parts were not screwed together, as is normally the case, but rather soldered in a vacuum furnace. In doing so, the materials were combined chemically with the aid of filler materials. This requires a wide range of coatings, all of which need to be tested beforehand. The parts to be joined are in a solid state – only the filler material is melted and either reacts with the coating or base material.

The methods and technologies developed at Empa were quite successful; no wonder then, that other space projects soon followed. Elsener and his team are currently developing a new ion-optic sensor for an even smaller, lighter mass spectrometer for the Russo-Indian moon mission LUNA. And the Empa engineers recently produced equally complex modules and sensors for the joint European and Japanese Mercury mission BepiColombo. //



On February 25, 2007 Rosetta flew past Mars. This "selfie" was snapped from a distance of 1,000 kilometers, shortly before it moved to within 250 kilometers of the planet's surface. It displays one of Rosetta's solar wings and the northern hemisphere of Mars, where details of the Mawrth Vallis region are visible.

Photo left: A picture of 67P/Churyumov-Gerasimenko, taken on August 16, 2014, around 93.5 kilometers from its surface. Thanks to the divided shape of the comet, it is reminiscent of a rubber duck.

Rosetta and Philae

The space orbiter Rosetta was named after the famous Rosetta Stone, which was instrumental in deciphering Egyptian hieroglyphics 200 years ago. It is a stone stele bearing a priestly decree carved in three scripts (hieroglyphs, Demotic and Ancient Greek), which was created in the year 196 BC in honor of the Egyptian king Ptolemy V. The lander Philae took its name from an island in the middle of the Nile, where there is an obelisk that bears an inscription in two languages and helped to decipher the hieroglyphs on the Rosetta Stone. Just as these two stones provided the key to translating the Egyptian hieroglyphs, the researchers hope that Rosetta can help understand comets and the early solar system better. What's more, aboard Rosetta is a so-called Rosetta disk made of a nickel alloy, upon which information is not stored but etched as an image and should still be legible in 10,000 years' time. 13,000 pages of text are engraved on the Rosetta disk in 1,200 different languages.

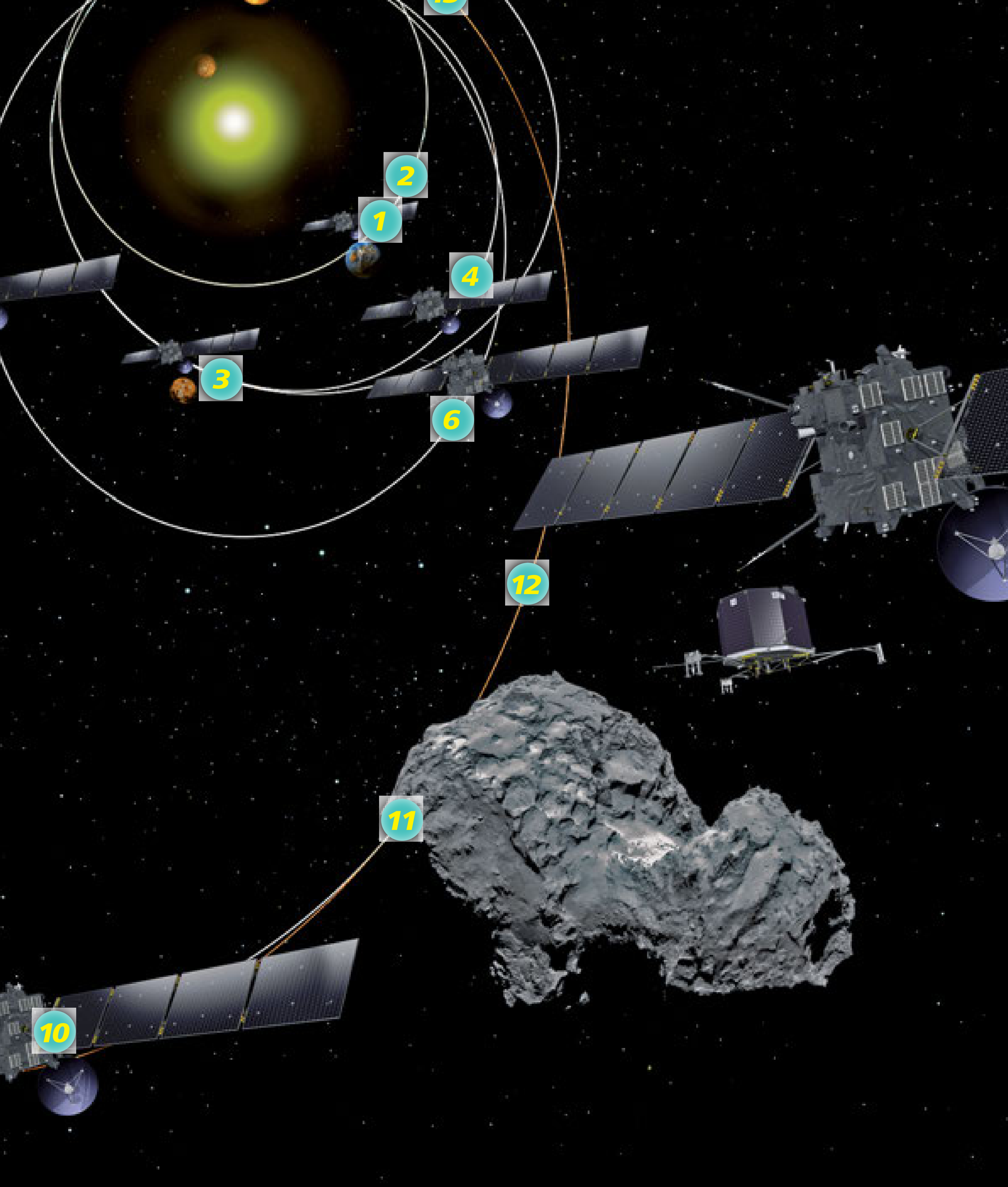
A cosmic trip to meet a comet

Rosetta is facing the final phase of a lengthy journey – and has still a way to go. The probe has reached the target comet "Tschuri" – short for "67P/Churyumov-Gerasimenko" – and has already identified a suitable place for its lander Philae to touch down. Rosetta and her comet are currently around 405 million kilometers from the Earth. Rosetta will now shadow the comet for at least another year.

1 *March 2004: Rosetta lifts off into space on board an Ariane-5 rocket*
2 *March 2005: first Earth gravitation thrust*
3 *February 2007: Mars gravitation thrust*
4 *November 2007: second Earth gravitation thrust*
5 *September 2008: flyby past asteroid "Steins"*
6 *November 2009: third Earth gravitation thrust*
7 *July 2010: flyby past asteroid "Lutetia"*
8 *June 2011: Rosetta enters hibernation*
9 *January 2014: Rosetta is awoken*
10 *May 2014: rendezvous maneuver with target comet*
11 *August 2014: arrival at target comet*
12 *November 2014: Philae's landing maneuver*
13 *August 2015: Rosetta and Tschuri fly past sun at an extremely close distance*
14 *December 2015: scheduled end to the mission*

Video
The probe Rosetta has been circling the comet since August 6. This is what its exact flight path looks like.

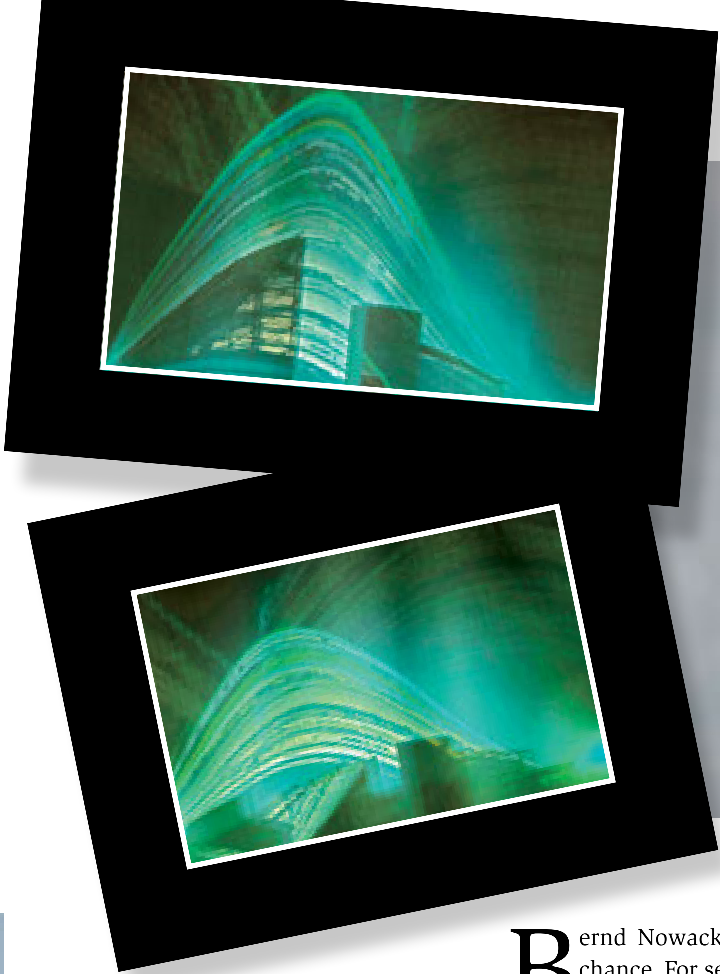
http://www.esa.int/spaceinvideos/Videos/2014/08/How_to_orbit_a_comet



Raider of the lost particles

Bernd Nowack was recently admitted by Thomson Reuters, a provider of scientific online databases, to the circle of the world's most influential scientists in the field of environmental sciences. The Empa researcher investigates the environmental aspects of nanoparticles. A visit to St. Gallen.

INTERVIEW: Martina Peter / PICTURES: Empa, Bernd Nowack



Bernd Nowack with his "camera" – a beer can that acts as a long-term pinhole camera on one of the Empa buildings in St. Gallen.

Solarigraphy: the solar path and the Empa buildings are visible on the photosensitive paper exposed over a period of six months.

«Seizing opportunities when they arise, that's what I'm all about.»

Bernd Nowack came to studying nanoparticles by chance. For seven years the environmental chemist was a senior scientist at ETH Zurich's Institute of Terrestrial Ecosystems. In 2006 he was appointed to the editorial board of the scientific journal "Environmental Pollution". The editor-in-chief happened to be looking for an article on the subject of "nanoparticles in the environment" for the journal's anniversary issue. On an impulse Nowack put his own name forward because, almost at that exact same time, he had accepted a new position at Empa where he was to investigate the environmental impact of nanotechnology.

No sooner said than done. The article marked Nowack's entry into the nano-sphere; up to now this has been his most highly cited article. Researchers who write about environmental exposure to nanoparticles can't get around it. Even now the article is still cited around 100 times a year, says Nowack not without pride, and oftentimes by authors from completely different disciplines.

As a scientist he mainly focuses today on the question of how nanomaterials are released from products and in what form, how material flows in the environment can be determined with the help of computational models, and what the related risks might be. He has published some 50-odd articles on this subject. All this secured Nowack a place on the current list of the world's most influential scientists (see box).

A man with many interests

"Seizing opportunities when they arise, that's what I'm all about", says Nowack. "I'm not so much interested in looking at a subject in any great depth." He can't imagine himself spending decades, like other scientists do, studying the details of an academic object. Nowack sees himself as the kind of researcher who finds out that there is such a thing as pi, that pi is approximately 3.1 and that

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you can actually do something useful with this knowledge. "It's then down to other scientists to identify the next million digits." He is fascinated by topics to which he and his team can make a substantial contribution. And then rapidly move on to the next one. "Here at Empa there are still so many questions to be answered about the relevance of new materials for the environment."

He already picked his course of study because it seemed highly diverse. In the new Environmental Sciences course introduced back then at ETH Zurich, he was able to take all the natural sciences that interested him in school. "In the 1980s we were all pretty concerned about "Waldsterben" (dying forests)", he recalls. "We were told that Switzerland would have become an acidic wasteland by the time we were grown up." Nowak didn't consider himself a die-hard treehugger. As a realist it was more important for him to understand the scientific aspects of the problem rather than campaigning to save the world. At that time there had been a major shake-up in the media, and scientists had contributed significantly to this. For instance, the regional forest damage in the Erzgebirge mountains in Eastern Germany, which had clearly been caused by the local industry in Saxony emitting huge amounts sulphur dioxide, had been declared a global calamity provoking a major public outcry.

Simple rather than spectacular – but relevant all the same

Nowack's principle is to simply do something and be bold about it. Sometimes he had the feeling that it almost took more courage to tackle the simple rather than the spectacular topics. It was a mystery to him why, for instance, scarcely anyone had taken a more detailed look at the release into suds of nanoparticles from textiles such as silver-coated, antibacterial socks. For years there were no scientific studies. Nowack, "It seems that everyone thought that the topic was too trite."

But the Empa researcher grasped its social relevance. People – and last but not least the legislator – did, in fact, want to know what was happening in their washing machines and whether the released nanoparticles could be "dangerous". As a scientist he had to come up with answers. With his team he had discovered some interesting aspects. Textiles with a nanocoating result in fewer nanoparticles in washing water than those coated with "normal" silver. This prompted him to look at how the chemical composition of detergents influences release. That's what he's working on right now.

Not causing a stir but introducing a certain degree of calm into the debate

In his studies Nowack doesn't normally uncover scandals. Quite the contrary, he can frequently sound the all-clear. Wouldn't he like just once to land a big coup and report an alarming result? "Everyone", he replies, "who works in the risk area would, of course, like to publish the fact that he has identified a serious problem." But for him his overriding task was to supply robust data and evaluations in order to be able to independently assess the situation. Nowack doesn't want to hush up anything when it comes to controversial topics, nor does he want to cause a stir; above all he wants to introduce calm. His heritage from the 1980s.

His success proves him right. As a researcher, he currently finds himself in the comfortable situation of being able to pick and choose his research projects. He receives

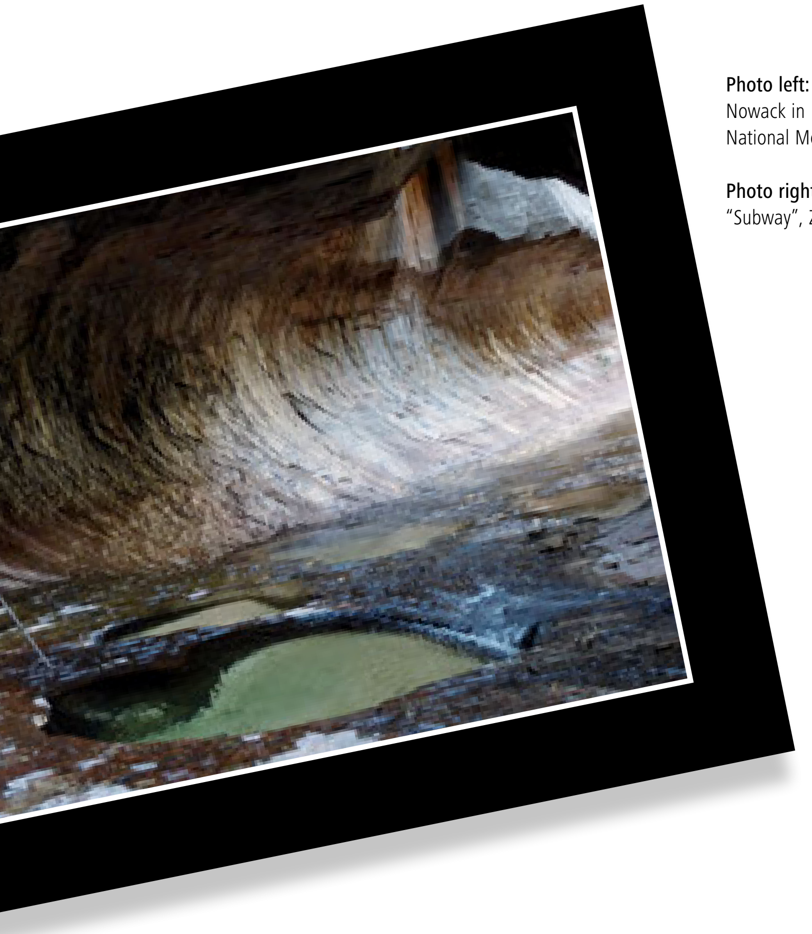


Photo left: Image of the starry sky, taken by Bernd Nowack in Devils Garden, Grand Staircase-Escalante National Monument, Utah, USA.

Photo right: Bernd Nowack taking a picture at the "Subway", Zion National Park, Utah, USA.

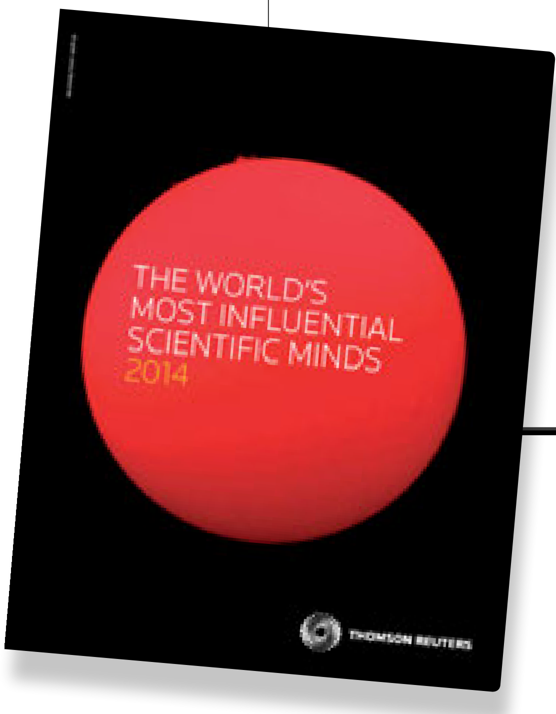
more inquiries for joint projects and expert reports than he can handle with his team. The most important element are his co-workers who take up ideas, steer a topic in a completely new direction or contribute knowledge that he himself doesn't have. Only in a team is it possible nowadays to engage in the full spectrum of research and to ven-ture, again and again, into new interesting areas.

Art from a beer can: solarigraphy

Nowack also enters new territory in his leisure hours. He devotes his time to solarigraphy, a very special type of photography. After the solstice in December, at the latest in January, he distributes beer can pinhole cameras in nature, on bridges and on roofs – for instance on Empa buildings in St. Gallen. They contain photographic paper, which is exposed through a tiny hole for six months and records the traces of the sun. In June when the sun reaches its peak Nowack "harvests" the cans. It is fascinating that six months elapsed between the composition of the image in situ and the finished image. "Chance is often my most important team mate", he says. Sometimes the cans have disappeared or are damaged or they produce crazy effects. Nowack scans the long-exposed films after development and converts the pics into positives using an image processing program. The colours are generated by coloured silver salts which appear yellowish or reddish in the negatives. He would like to write a scientific paper some-time soon on this subject, and reflect more on the link between art and science. In the widest sense this is about nanotechnology, too: in a chemical process nano-sized silver particles ensure that the light leaves behind traces on the photographic paper. This brings him full circle to his scientific work on silver. //

"The World's Most Influential Scientific Minds"

Bernd Nowack is head of Empa's Environmental Risk Assessment and Management Group (ERAM), a team that investigates new materials and the environment. Furthermore, at ETH Zurich Nowack shares his knowledge as an Adjunct Professor in the Department of Environmental Sciences. Recently Nowack has been named one of the 140 most influential scientists in the field of environmental sciences/ecology by the Thomson Reuters publishing house. Based on the Web of Science administered by Thomson Reuters, that encompasses several online citation databases, the publishing house identified all highly cited researchers between 2002 and 2012 in 21 scientific fields. How often a researcher is cited is the decisive yardstick for the influence of a scientific publication and the standing of its author amongst his peers. The list "The World's Most Influential Scientific Minds" includes a total of 3,200 scientists.



Collection of Bernd Nowack:
www.fotocommunity.de

Jakob Kübler is visibly proud that his pan-European research project has hit the home stretch. It took months and no less patience to get all the partners around one table: Empa is to develop a novel brake disk for mass-produced small cars under the direction of the Politecnico di Torino and in conjunction with Spanish brake manufacturer Fagor Ederlan, Liechtenstein soldering specialists Listemann AG and the Fiat research center C.R.F. The Swiss and Liechtenstein portion of the research project is funded by the Swiss Commission for Technology and Innovation (CTI). A prototype of the brake should be up and running by April of next year. While today's brake disks are produced from heavy, heat-resistant cast iron, the disks of the future, which the consortium is developing, should be made of light aluminum. This saves weight and thus fuel while improving the vehicle's handling as the unsprung masses in the chassis will be smaller.

However, aluminum is soft, which makes it unsuitable for powerful brake calipers. A ceramic layer is therefore required to protect the aluminum brake disks, which perform the friction work and channel off the generated heat. Empa is developing this crucial component, upon which the project can founder or set trends.

While ceramic brakes are nothing new, having long been used in sports and racing cars, they are expensive. For the Porsche 911, for instance, ceramic carbon brakes will add a whopping 12,000 Swiss francs to the price – almost the cost of a complete Fiat 500! Therefore, the technology hardly seems suitable for use in budget cars.

Several technical hurdles at once

Hence the consortium is on the lookout for another solution: the brake needs to be produced quickly and in large quantities, be affordable and last at least as long as its existing cast-iron counterparts. For ceramics specialist Kübler, this means clearing several technical hurdles in one fell swoop. "First of all, we had to find a low-priced ceramic material that is a good heat conductor and can also be processed easily," he explains. This rules out zirconium oxide as it insulates too strongly. And silicon carbide conducts heat well but breaks too easily, which leaves only one material: aluminum oxide. The material is in many ceramic components, from faucets to hip joints, and can be obtained inexpensively.

Kübler and his team used it to design a ceramic laminate – a ceramic plate that is around two millimeters thick and comprises up to 15 individual layers: silicon carbide is added to the aluminum oxide layers to increase the heat conductivity, along with a cover to regulate wear and tear, and an adherent layer to enable the ceramics to be soldered to the aluminum surface. Every layer is blended with water to make a sludge, which is then applied to a synthetic film. Finally, the layers are compressed, the synthetic material in-between burned out and the different layers joined and condensed at several hundred degrees. The electron microscope then reveals just how well the vertical interconnection process has worked.

The consortium decided to make small tiles, which are soldered to the brake disk side by side like bathroom tiles. The reason: when exposed to heat, aluminum expands three to four

High-end brakes for the Cinquecento?

An ambitious project is taking shape at Empa's Laboratory for High Performance Ceramics: ceramic brake disks for compact cars. Empa scientists have teamed up with partners from Italy, Spain and Liechtenstein to develop the automobile technology of tomorrow. The only thing is: can the high-tech solution also be realized with a reasonable price tag?

TEXT: Rainer Klose / PICTURE: iStockphoto

times more than ceramics. A single-piece ceramic brake pad would thus fall off the aluminum carrier due to stress cracks. However, the soldering process is also easier said than done with small tiles: as aluminum melts at roughly 700 degrees, the soldering has to be carried out at lower temperatures. Nonetheless, the solder mustn't go soft during an emergency stop; otherwise, the tiles will fall off just when they are needed most.

Therefore, a single ceramic mix is not enough. Kübler and his team keep having to check the feedback from the soldering specialists from Torino, optimize the mixture of ceramics further and provide new samples. And not only that; he already has to factor in the costs during the design phase: expensive techniques, say, in a vacuum or under shielding gas, have to be avoided as they would be unsuitable for mass production.

In the meantime, Listemann AG in Vaduz is developing the special joining technology to solder the tiles that is suitable for industry. The brake manufacturer Fagor Ederlan is designing the brake system out of aluminum and the necessary dimensions of the brake disk. The culmination of the project will be a prototype, which can then be put through its paces at brake testing rigs and subsequently incorporated into a test vehicle. If it passes, it will be used to develop a serial component over the next few years, which will give European cars a head start on the global market. //

I spy with my little eye…

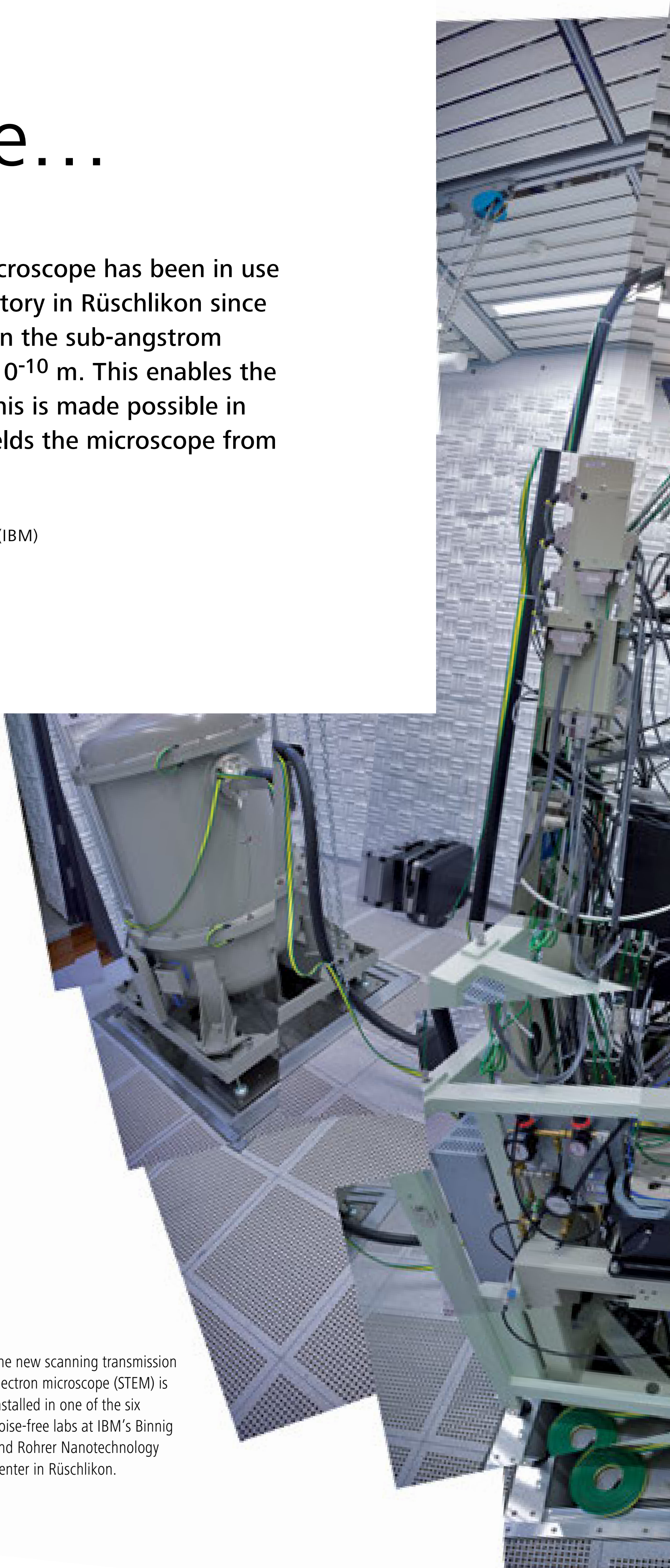
A unique transmission electron microscope has been in use at the IBM Zurich Research Laboratory in Rüschlikon since the summer, allowing resolutions in the sub-angstrom range, i.e. on a scale of less than 10^{-10} m. This enables the atomic structures to be studied. This is made possible in a special noise-free lab, which shields the microscope from any outside influences.

TEXT: Martina Peter / PICTURE: Urs Siegenthaler (IBM)

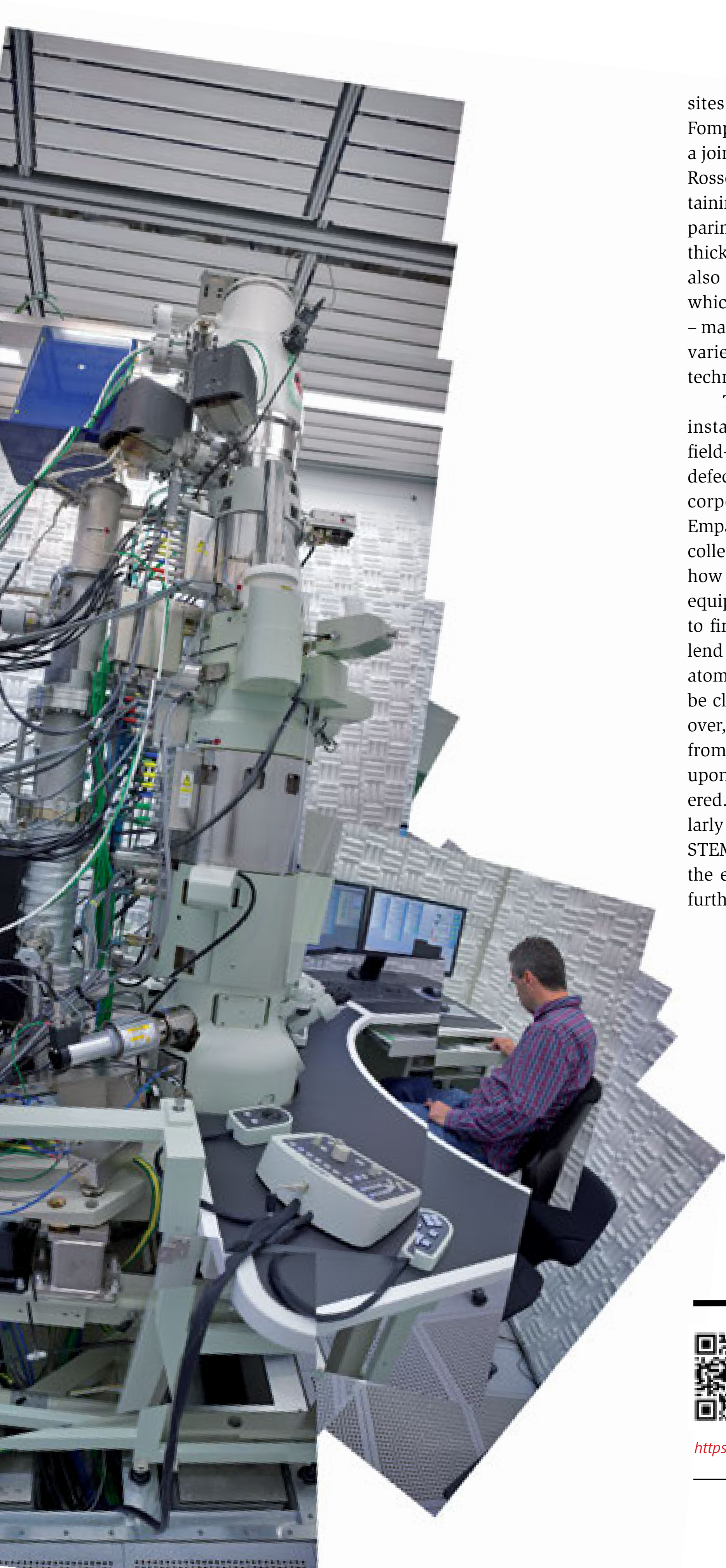
Eight meters underground, in the basement of the IBM Zurich Research Laboratory's Binnig and Rohrer Nanotechnology Center in Rüschlikon, a special-class microscope rests on a 40-ton foundation. It can display details that are smaller than the diameter of an atom. Despite weighing in at one and a half tons and towering three meters, however, the colossus is surprisingly sensitive: a draft created by the AC unit is enough to affect the readings, let alone the temperature fluctuations when the lab doors are opened or the noise from the nearby town or highway. All these influences need to be kept at an arm's length: in the noise-free labs, even electromagnetic fields are minimized through suitable constructional measures and clever shields and muffling.

The transmission electron microscope (TEM) works in a similar way to an optical microscope but uses an electron beam instead of light. The electrons penetrate the sample and interact with it before various lenses conduct them to detectors, which "translate" the electrons that are bent and scattered at different angles into an image. Because the TEM works in both a broad-beam and a grid mode (scanning TEM, STEM), not only can it display the structure of a sample; it can even chemically detect individual atoms.

The combination of a special lab and top-class electron microscopy makes readings possible at a precision that is unprecedented in Switzerland (and very rare worldwide). When it came to introducing the device, Rolf Erni, the head of Empa's Electron Microscopy Center, and his colleague Marta Rossell brought just the right prerequi-



The new scanning transmission electron microscope (STEM) is installed in one of the six noise-free labs at IBM's Binnig and Rohrer Nanotechnology Center in Rüschlikon.



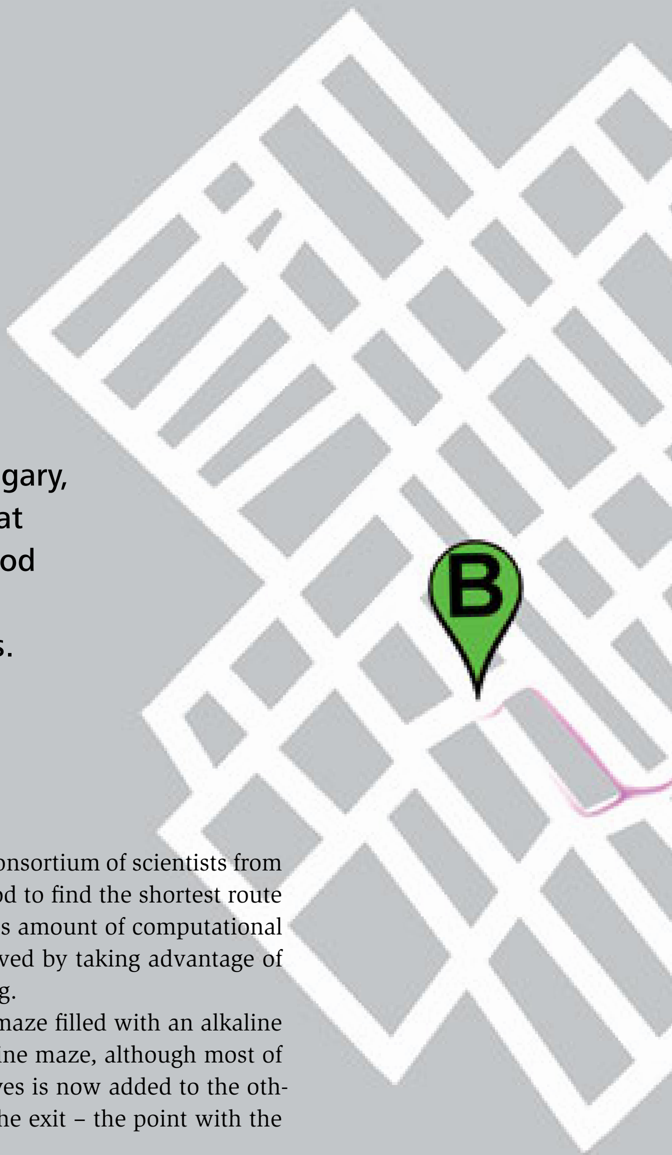
sites to the table. Together with IBM researcher Jean Fompeyrine, they developed the highly sensitive device in a joint-venture and now run it as a joint user lab. Erni and Rossell look back on many years of experience in maintaining maximum-resolution electron microscopy and preparing samples, which are merely ten to 100 nanometers thick. Thanks to her expertise, before long Rossell was also able to present unique images on the new STEM, which allow scientists a glimpse inside "their" materials – materials which could in future be channeled into a wide variety of applications, such as in electronics or novel technologies for energy conversion or storage.

The team headed by IBM researcher Heike Riel, for instance, wants to find out how nanowires in novel field-effect transistors settle on a substrate. She is studying defects in novel semiconductor structures, which are incorporated into the crystal lattice during production. Empa scientists, on the other hand, have teamed up with colleagues from the University of Barcelona to investigate how nanoparticles made of magnetite (Fe_3O_4) can best be equipped with palladium and platinum atoms. The aim is to find the composition and arrangement, at which they lend themselves to an optimum catalysis as individual atoms or clusters. As Fe_3O_4 is magnetic, the catalyst can be cleaned easily (and without filters) and reused. Moreover, Erni's colleague Yucheng Zhang and Empa scientists from Thun are examining different carbon nanotubes, upon which titanium dioxide molecules have been layered. The layers enable electrons to be "captured" particularly effectively in photovoltaic processes. Thanks to the STEM images, the researchers learn to understand how the efficiency of novel solar cells can be increased even further. //

First pictures made by the IBM microscope at flickr.

https://flic.kr/s/aHsk35pmK3

Satnav from the chemistry set



Empa researchers teamed up with colleagues from Hungary, Japan and Scotland to develop a chemical processor that displays the shortest way through a maze. As the method is faster than a navigation system, it could in future be particularly useful in transport planning and logistics.

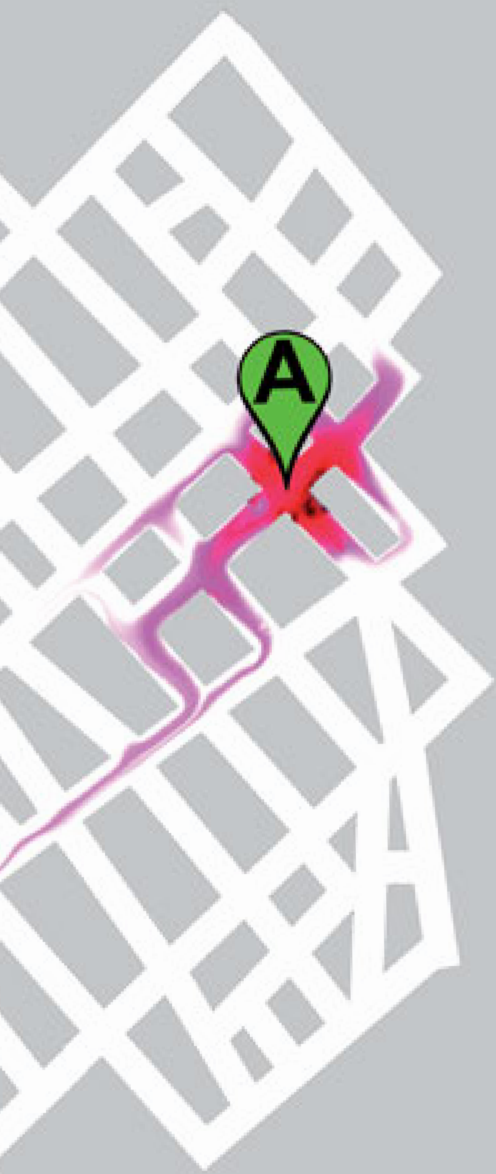
TEXT: Cornelia Zogg / PICTURE: Empa

You don't always need GPS, a map or a compass to find your way. A consortium of scientists from Empa, Hungary, Japan and Scotland have devised a chemical method to find the shortest route through a maze or even on a city map. What demands a tremendous amount of computational power from today's computer-based navigation systems can also be achieved by taking advantage of the laws of physical chemistry, i.e. practicing so-called chemical computing.

The trick works thus: a gel mixed with acid is applied at the exit of a maze filled with an alkaline solution. Within a short period of time, the acid spreads through the alkaline maze, although most of it remains close to the gel at the exit. If an alkaline solution mixed with dyes is now added to the other end of the maze, i.e. the entrance, it automatically "seeks" the way to the exit – the point with the highest acidity (the lowest pH).

This process is an example of the Marangoni effect (see box), which occurs because the acid distributed in the maze reacts with the newly added (dyed) alkaline solution. As a result, the latter is pushed to the source of the acidity at the exit, leaving a colored trail in its wake thanks to the dye. In doing so, the alkaline solution tends to opt for the shortest way. At the same time, however, it also takes alternative routes – albeit with a considerably lower probability and thus a weaker trace of color. "The advantage of this chemical computer over its electronic counterpart is that it finds all possible paths virtually in parallel. A computer successively calculates one possibility after another, which on average takes longer," explains Rita Tóth from Empa's Laboratory for High Performance Ceramics. Although methods to find such pathways using liquids already exist, the new technique is the first that works purely chemically and where a trail of color shows the path directly.

As the next step, the team is now looking to attempt larger and more complex mazes, the test object only being a few square centimeters in size. Nonetheless, the method has already passed a test "in the real world": in a somewhat larger maze based on a Budapest neighborhood, the alkaline "guiding" solution traced the shortest route to its target, a pizzeria. Eventually, the system could also be used in transport planning. And developer Tóth also envisages potential applications in brain research, psychology, network research or robotics. //



Marangoni effect

Liquids that don't mix lie on top of each other in "layers", so-called phases, between which there is a certain surface tension. If the surface tension between the two liquids varies, the liquids begin to flow towards the higher surface tension. This is referred to as the Marangoni effect. Differences in the surface tension can be triggered by local changes in temperature or the pH value, for instance.

50 years on and still making plenty of noise

A little over 50 years ago, the Laboratory of Acoustics/Noise Control saw the light of day. Its landmark birthday was given a fitting celebration on August 22. Since the lab's foundation, Empa has formed an interface between research and industry and is instrumental in many innovations in the field. Numerous developments by Empa "acousticians" have already taken hold on the market, including the world's first lightweight, translucent and sound-absorbing curtain. Likewise, the latest large-scale project at Empa – the building lab NEST – is, besides developing innovative ways of living and working, also set to clear up acoustic issues.
The lab was formed thanks to the dedication of the Liga gegen den Lärm (Swiss Anti-Noise League; now known as Lärmliga), which was already campaigning for eco-political matters at a time when environmental protection was still virtually unheard of. A document declaring noise a "legal problem" in Switzerland for the first time prompted politicians from all parties to take action. One initial step was the foundation of a corresponding research lab at Empa, which still does its bit to this day. The lab also played a key role in supporting the technical implementation of the Lärmschutzrecht (Noise Control Act).

Empa Innovation Award presented at ETIF 2014

This year's Innovation Award was presented at the last Empa Technology & Innovation Forum (ETIF). The prize went to a joint team from two labs, Structural Engineering and Joining Technologies & Corrosion, for the project Shape memory steel as a new pre-stressing material for the building industry – a successful collaboration between materials science and engineering, as Empa's Deputy Director Peter Richner pointed out. The project uses shape memory alloys (SMAs) to prestress large concrete support structures, an approach which had previously been far too expensive. The newly developed, iron-based SMA turned this on its head meeting all requirements for use in concrete structures such as phase transformation temperature and corrosion behavior.

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